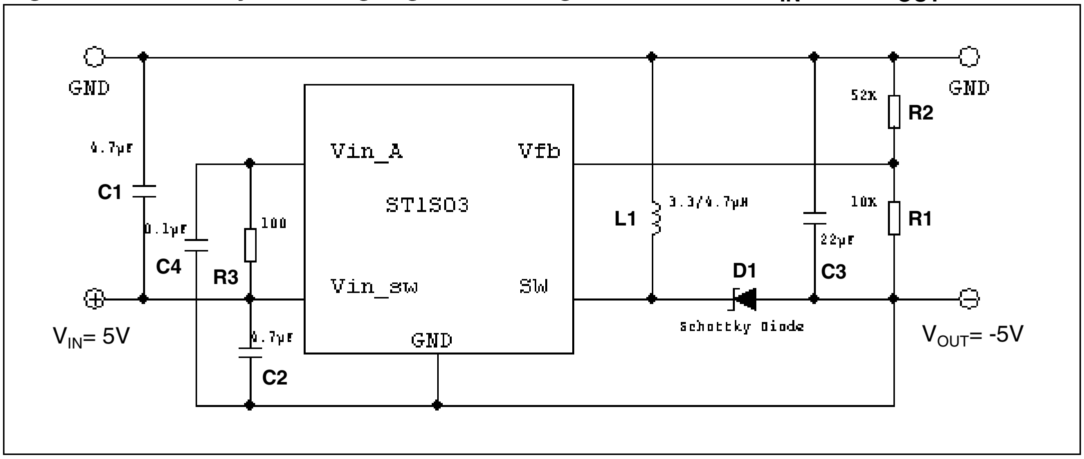
Positive to negative buck-boost converter using ST1S03 asynchronous switching regulator

Abstract

The ST1S03 is a 1.5 A, 1.5 MHz adjustable step-down switching regulator housed in a DFN6 package with internal power switch.

The device is a complete 1.5 A switching regulator with internal compensation that eliminates the need for additional components. In this document the design of a polarity inverting converter is discussed.

Figure 1. Polarity-inverting regulator using the ST1S03, 5 V_{IN} to - 5 V_{OUT}, 500 mA



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1 Principle of operation

The polarity-inverting converter uses the basic principle of energy storage in the inductor L during the ON time of the operating period (*Figure 2*), and then transfers the energy via the freewheeling diode D to the output during the OFF time (*Figure 3*).

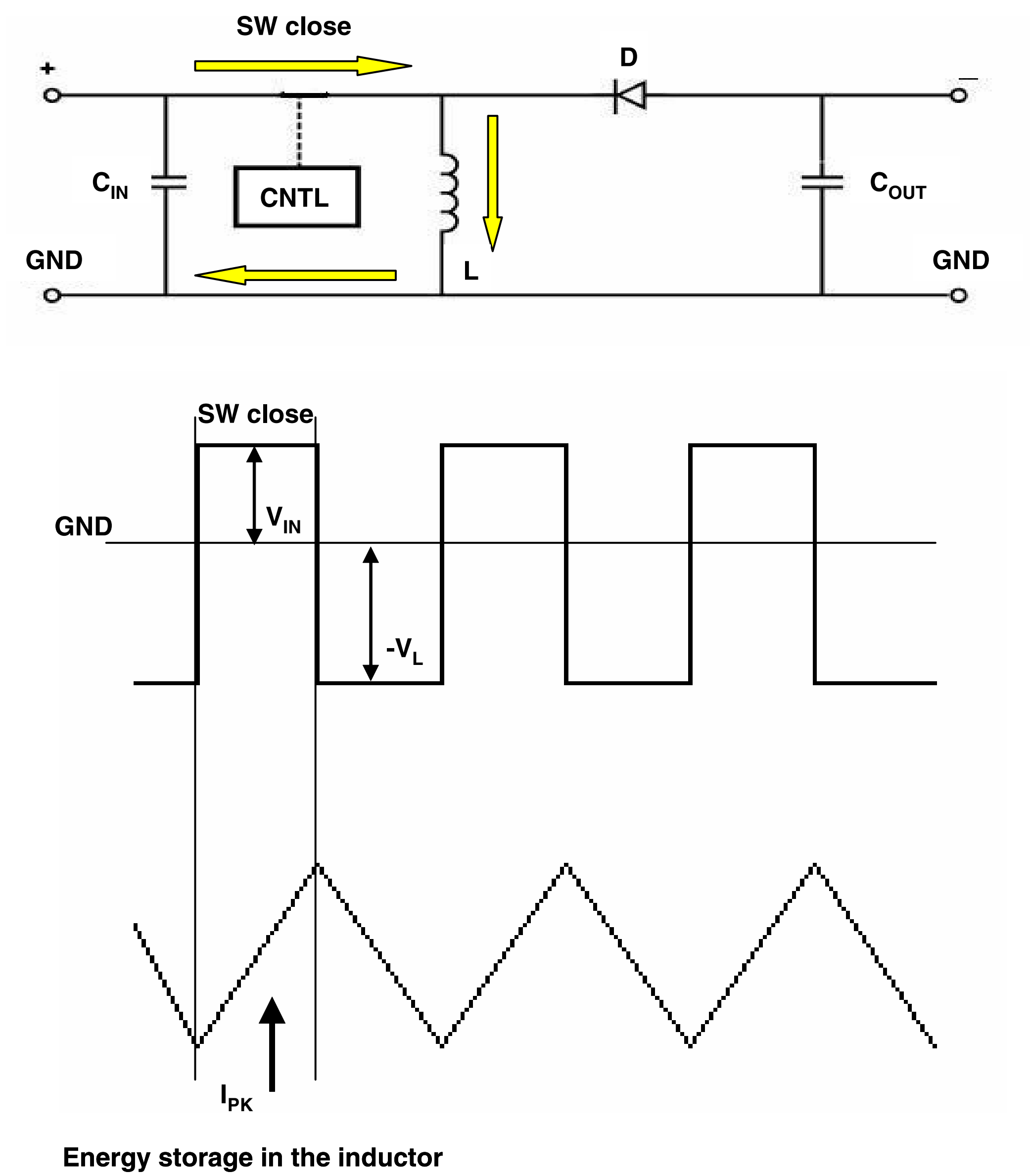
When the switch turns ON, the diode is reverse-biased and current flows only in the inductor.

When the switch is turned OFF, the reverses its polarity, thus the freewheeling diode is forward-biased, and the energy stored in the inductance is transferred to the load as well as the capacitor.

The output voltage across the capacitor becomes negative because the inductor current is negative with respect to ground.

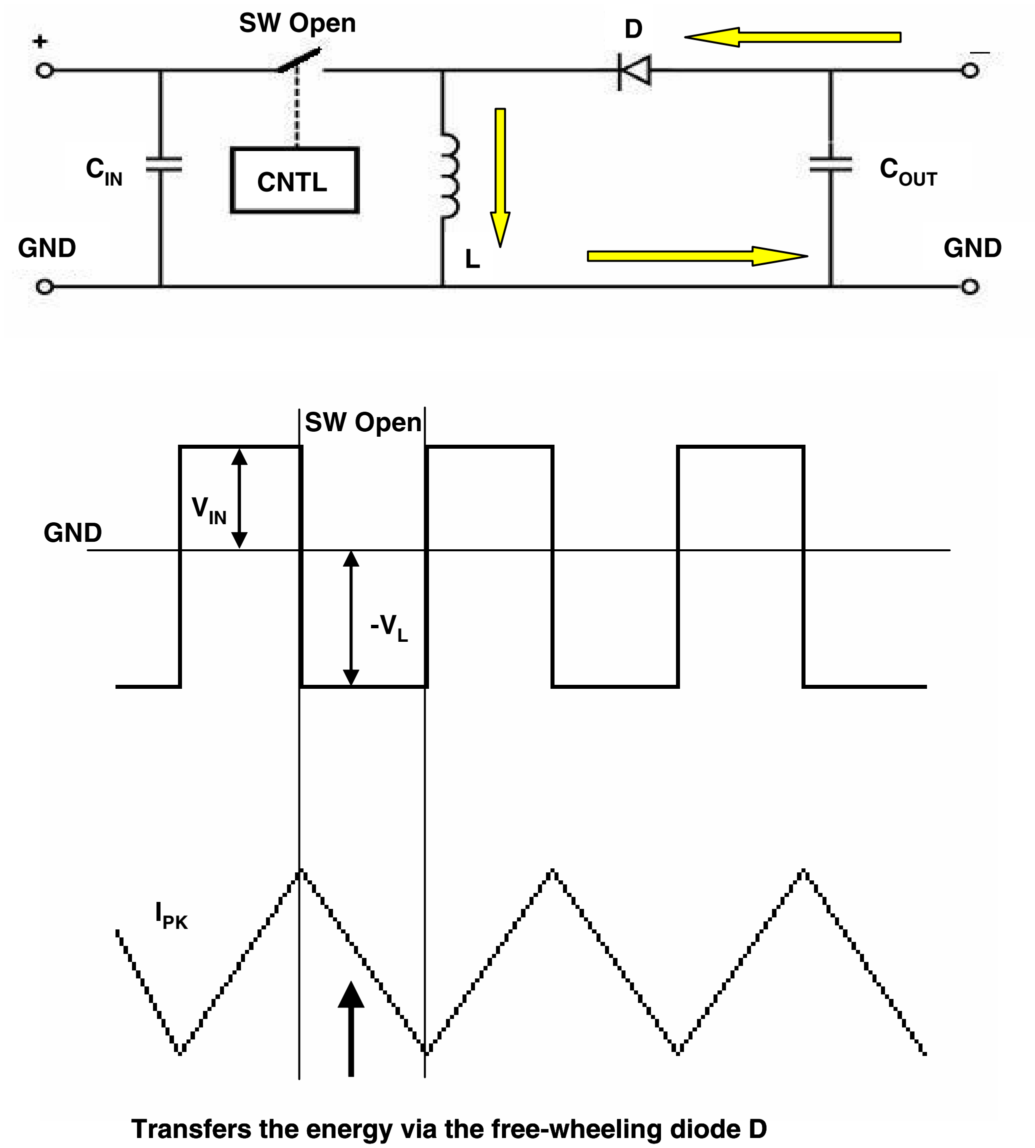
This circuit is also known as a buck-boost converter because this type of converter can step-up and step-down the magnitude of the input voltage.

Figure 2. Basic configuration of a polarity-inverting converter (buck-boost) [(1)]



1. Energy is stored in inductor L during the ON time of the operating period.

Figure 3. Basic configuration of a polarity-inverting converter (buck-boost) (1)

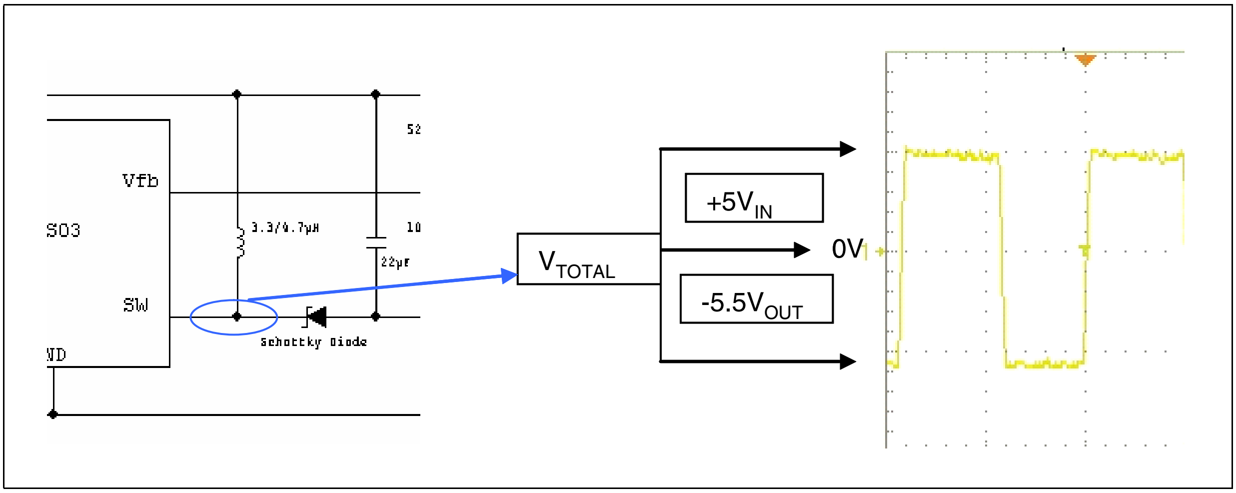


1. Energy is transferred via freewheeling diode D to the output during the OFF time of the operating period with polarity inverted referred to GND.

2 Design considerations

Figure 1 shows the typical configuration of a polarity inverting regulator using the ST1S03. Note that the ground is connected to the negative output and the feedback is referred to GND, so the device is supplied by V_{IN} plus the magnitude of V_{OUT} (i.e. for 5 V_{IN} and -5 V_{OUT}, the total V_{IN} for device is 10 V). For this reason, the AMR of device cannot be exceeded. For example, 12 V_{IN} and -12 V_{OUT} for a 24 V total it not possible due to the 18 V AMR (see *Figure 4*).

Figure 4. Total voltage of inductor



The output voltage is programmed by connecting feedback resistors from GND to $-V_{OUT}$ (close the output capacitor to have best performance in terms of stability).

Small capacitor C2 is connected from the input to the negative output in order to provide more phase margin to stabilize the regulator loop. R3 and C4 form a simple R-C filter on the analog input, which helps to reduce noise on the supply voltage, as well as improve stability.

Figure 5. Typical waveform of the switching regulator, 5 V_{IN}, - 5.5 V_{OUT}, no load

Figure 6. Typical waveform of the switching regulator, 5 V_{IN}, - 5.5 V_{OUT}, 500 mA I_{OUT}

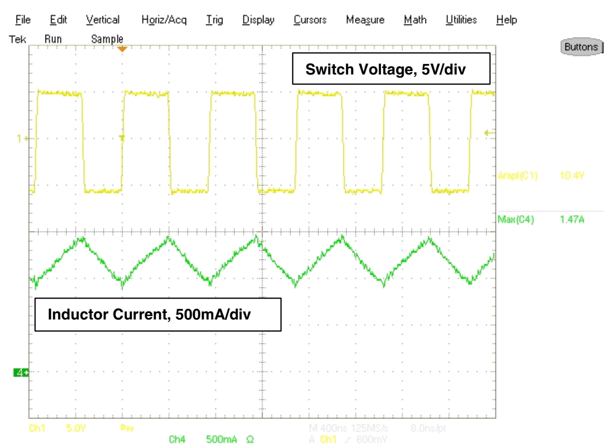


Figure 5 and *Figure 6* show the typical waveforms of the switching regulator.

The following figures show how the application functions well in step-down mode 12 V_{IN} -> -5 V_{OUT} (*Figure 7*) and in step-up mode 3.3 V_{IN} -> -5 V_{OUT} (*Figure 8*).

Figure 7. Step-down mode, 12 V_{IN}, - 5.5 V_{OUT}, 500 mA I_{OUT}

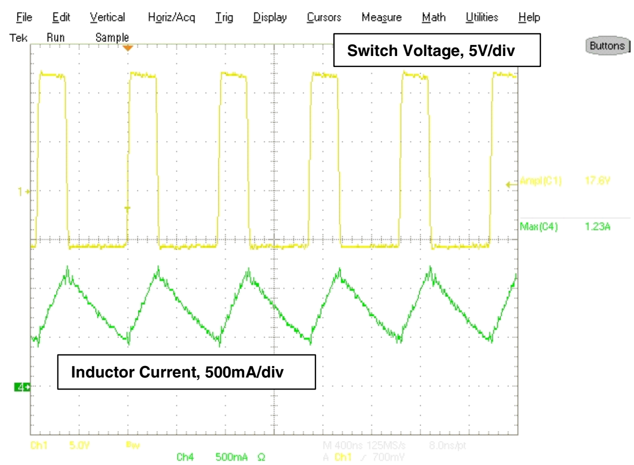


Figure 8. Step-up mode, 3.3 V_{IN}, - 5.5 V_{OUT}, 500 mA I_{OUT}

3 PCB layout guidelines

A recommended printed circuit board (PCB) layout for the ST1S03 inverting regulator is shown in *Figure 9*. It is very important to place the input capacitor as close as possible to the input pin of the regulator. In order to achieve the best performance, special care must be taken to ensure proper grounding. A good practice is to always use a separate ground plane, or at a minimum a single point ground structure.

High switching currents may cause voltage drops in the PCB metal trace, and long metal traces and component leads cause unwanted parasitic inductance as well, especially at switching frequencies of 1.5 MHz. This parasitic inductance is very often the main source of EMI problems and high voltage spikes at input and output lines. Therefore, place the inductor, freewheeling diode, and especially the input capacitor as close as possible to the device. Use big lines for the metal traces to these components. Wire the feedback circuit away from the inductor to avoid flux intersection. The use of a ground ring guard is recommended. Use shielded cores for better EMI performance. Capacitors with low ESR are recommended the for inputs and outputs.

Figure 9. PCB layout - top side

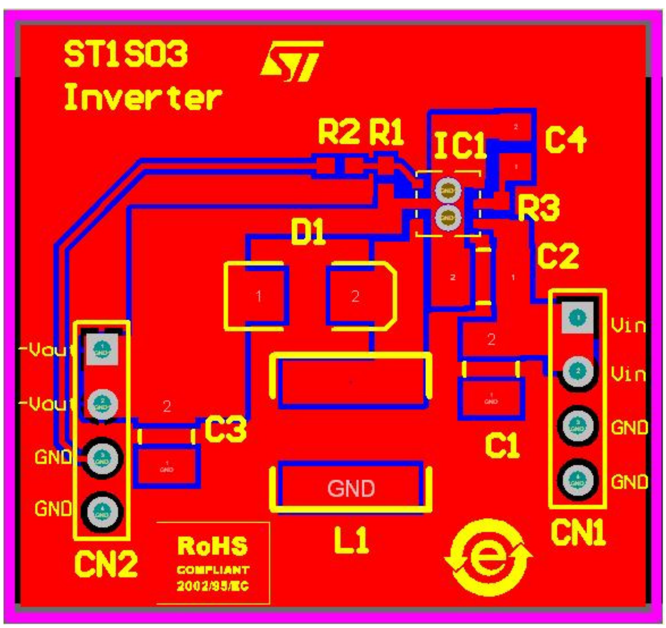


Figure 10. PCB layout - bottom side

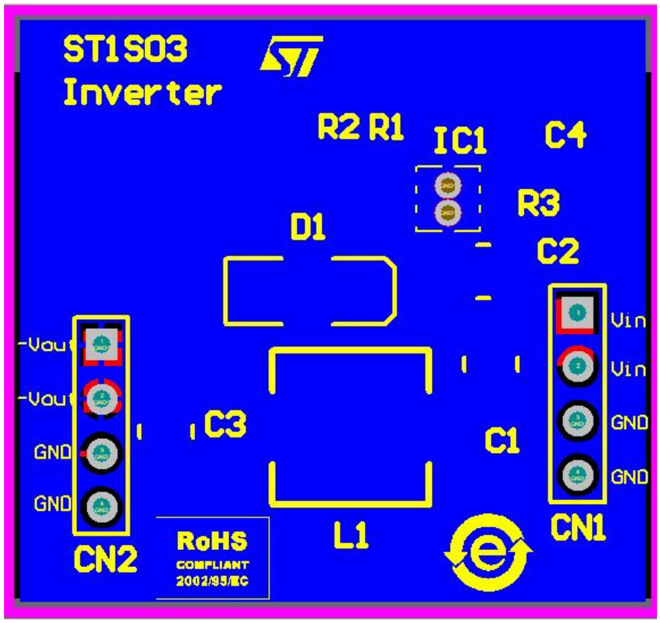


Table 1. Component list

Reference	Value	Description	Manufacturer
R1	10 kΩ	Resistor	
R2	52 kΩ	Resistor	
R3	100 Ω	Resistor	
C1	4.7 µF	Ceramic X5R or X7R	
C2	4.7 µF	Ceramic X5R or X7R	
C3	22 µF	Ceramic X5R or X7R	
C4	0.1 µF	Ceramic X5R or X7R	
D1	2 A (0.3 V or less) Schottky diode	STPS2L25	STMicroelectronics
L1	4.7 µH	DR734R7	Coiltronics
IC1	ST1S03	IC	STMicroelectronics
CN1	4 pins	Strip line male c.s.	
CN2	4 pins	Strip line male c.s.	

In polarity-inverting mode the ST1S03 is capable of supplying more output current, as shown in *Figure 11* and *Figure 12*.

With a 12 V input voltage (*Figure 12*), the ST1S03 should be able to provide up to 1.3 A of output current with good stability and performance. It is important not to exceed the maximum switching current limitation of 2.5 A that flows in the inductor. Choosing a good inductor, in terms of current capability and low series resistance, can help to improve efficiency.

Figure 11. Polarity-inverting mode, 5 V_{IN}, - 5.5 V_{OUT}, 950 mA I_{OUT}

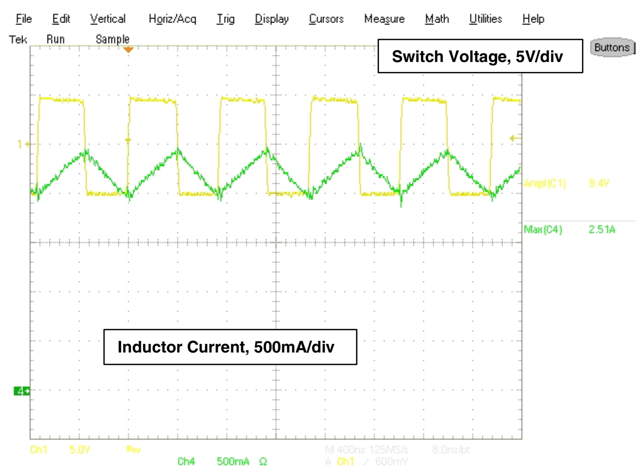
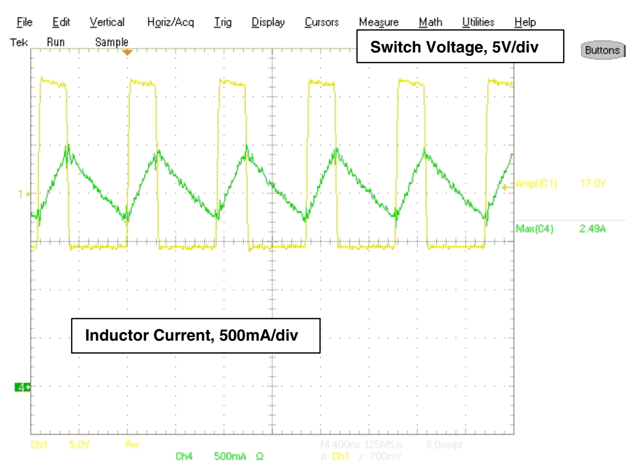


Figure 12. Polarity-inverting mode, 12 V_{IN}, - 5.5 V_{OUT}, 1.3 A I_{OUT}



4 Revision history

Table 2. Document revision history

Date	Revision	Changes
26-Feb-2009	1	Initial release.

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