

Configure Low Cost Buck Converter for Boost Operation

Buck converters are inherently different from boost converters in that the power switch is referenced to the output voltage (Buck mode) rather than ground (Boost mode). The Semtech SC1101 low cost, Buck controller has a floating output drive section allowing it to be configured as a Boost or Buck controller. The circuit shown in figure 1 configures the SC1101 for a +5 to +/-12V conversion with +/-500 mA output current.

Some pin connections are changed to use the SC1101 for step-up applications. The BST pin, which is normally connected to a high side drive supply in a buck converter, is now connected to the Vcc pin to drive the ground referenced MOSFET. Also, the low side of the current sense resistor, CS-, is connected to PGND pin. The feedback voltage will also need to reflect the new ratio of output to the 1.25V internal reference. In the schematic shown, the output is calculated as follows:

$$V_{out} = 1.25 \times (1 + R1 \div R5)$$

The sense resistor, R4, serves two purposes. First, it assures current limiting in the event of an overload or short circuit condition. It also guarantees proper start up upon application of power with full load by limiting the maximum duty cycle. With the output capacitors fully discharged, application of a full load demands high peak inductor currents to both charge the output capacitor and to supply the load current. However, if the duty cycle exceeds a maximum limit, the inductor will not have sufficient time to discharge and will saturate. By limiting the peak the inductor/switch current and thus the duty cycle, the output capacitors will be allowed to charge in several cycles upon start-up without inductor saturation. In this application, a .012 ohm resistor performs peak current limiting while allowing the required output current of +/- 500ma to be delivered. A 1K/100pf capacitor is added to filter the leading edge spike. In other cases a voltage divider may be used to tailor the current sense requirements to the 70mv internal comparator threshold.

While most boost converters require external frequency compensation components, the SC1101 voltage mode converter requires no additional parts in Boost mode. It is required that the output capacitor be selected with attention paid to the RHPZ (Right Half Plane Zero) introduced in all Boost (and Flyback) converters. From a practical view, at RHPZ frequency, the loop gain starts increasing at a 20db/decade rate but the loop phase decreases by -45 degrees (in a normal, Left Half Plane Zero, the loop phase will increase by +45 degrees). This imposes the restriction that the gain be rolled off to 0db before encountering the RHPZ. The RHPZ frequency is calculated as follows:

$$F_z(s) = 1 - (sL \div R) \times (V_o^2 \div V_i^2)$$

Where R is primarily the effective output load resistor:

$$R = V_{out} \div I_{out}$$

The double pole introduced by the output inductor and the output capacitor is used for rolling off the gain and is calculated as follows:

$$W_o = (1 - D) \div \sqrt{LC}$$

Where D is the converter duty cycle and is calculated as follows:

$$D = 1 - (V_i \div V_o)$$

L is the output inductor and C is the output capacitor.

The output filter double pole is counteracted by the output capacitor zero, which occurs at a frequency F_z :

$$Wz = 2\pi \times F_z = 1 \div (R_{esr} \times C_{out})$$

Where R_{esr} is the Equivalent Series Resistance of the output capacitor.

The output inductor, capacitor and the capacitor's ESR must be selected so that the double pole occurs first and then the output capacitor zero and then the RHPZ. This assures that the loop gain crosses 0db at a slope that is first order (20db/decade) and that the instability inherently associated with the RHPZ is circumvented by crossing 0db before the RHPZ frequency occurs. Fortunately, the high gain-bandwidth of the SC1101 error amplifier simplifies the component selection. In the application noted here, increasing the output capacitor to a value greater than 330uf alleviates the problem.

The output charge pump voltage inverter has been added to obtain -12V at .5 Amps as well. The +12V is rectified using a Fast Silicon rectifier, rather than a Schottky diode. This is done to balance the voltage drops in the -12V rectifier circuits (2 Schottky drops) with the +12V rectifier drop. Since this application is power limited by the current sense resistor, the current drawn from the -12V supply may be traded off for current on +12V. If the -12V is not used, the +12V can deliver 1 Amp and D1, D2, C1 and C2 may be eliminated. To improve efficiency, D4 may then be a Schottky diode. The controller provides separate grounds for power drive reference (PGND) and analog circuitry common (GND). These two grounds must be connected at the controller. Other voltages and currents may be achieved by modifying the feedback resistor and the power components.

With dual output (+/- 12V, 500 ma), the circuit efficiency was measured to be 91% at $V_{in}=5.0V$ and 93% at $V_{in}=5.5V$. For applications exceeding 50 deg C ambient, a slightly larger core may be used.

