ON Semiconductor

Design Note – DN06025/D
Starting the CS51411

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
CS51411/12/ 13/14 NCV51411	Consumer/ industrial/ Automotive	Up to 40V	Various	Buck	no

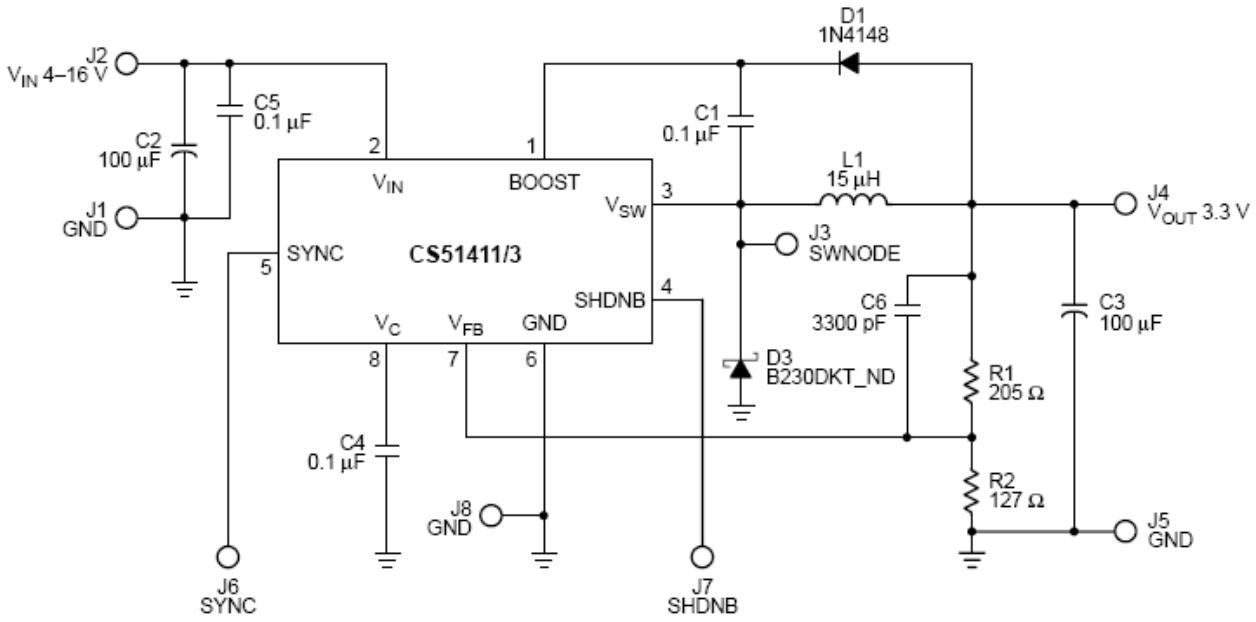

Figure 1 Basic evaluation board schematic.

Circuit Description

The CS5141X and NCV5141X series are general purpose PWM switching regulators that have a variety of applications usually in a buck topology. The internal NPN transistor can deliver up to 1.5A of output current while the input voltage ranges from 4.4 V to 40V. The internal power switch is biased by an external boost circuit to ensure that it is saturated and delivers maximum efficiency. It is this external boost circuit that we address in this design note.

Referring to Figure 1, this is the basic circuit used in the ON Semiconductor evaluation board and described in CS51411DEMO/D.

The charge pump circuit comprising C1 and D1 provides an addition "boost" voltage on the Boost pin to bias the internal power transistor. When the power switch is on, (ton) the voltage at pin 3 is effectively the input voltage and the output capacitor C3 is charged through the inductor L1 to the regulated output voltage determined by the ratio of R1 and R2. When the power switch turns off (toff) the voltage at pin 3 drops to a diode drop below ground. During this time, the charge pump capacitor C1 charges through diode D1 to the same potential as Vout. On the next cycle when the power switch again turns on, capacitor C1 is raised so that it is referenced to the input voltage and applies a voltage, Vout + Vin, to the boost pin, in other words, a standard charge pump circuit.

This works well is most cases but problems can arise when Vin and Vout are very close in value and there is only a light load on the output. Consider what happens in a case where Vin = 10V and Vout = 8V. Assuming no losses, the duty cycle, d= 0.8. The capacitor C1 is only charged during the off time so if the fsw is 260 kHz this allows only 0.7 microseconds each cycle to charge the capacitor. The result is that the capacitor does not charge fully and the startup behavior is erratic.

The same situation can also arise if the input voltage exhibits a slow rise time. The following oscilloscope shots show some of the common waveforms that you may see.

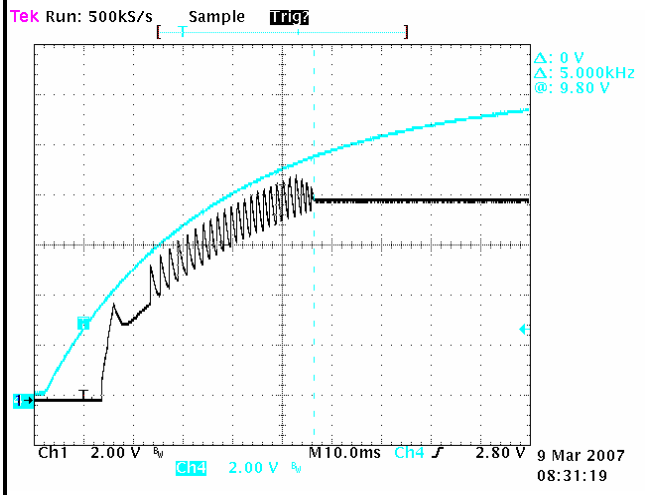

Figure 2 Turn on Waveforms
Channel 1 (Bk) Vout
Channel 2 (Bl) Vin.
In figure 1 the output appears to oscillate as the regulator starts.

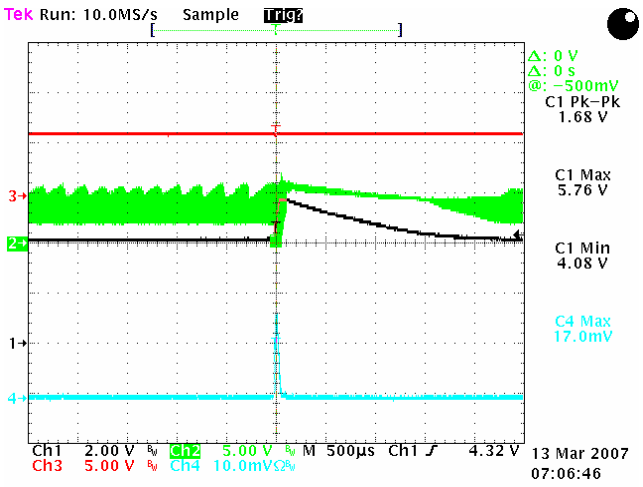

Figure 3 Expanded view of the output waveform
Ch1 : (Bk) Vout Ch2 : (Gn) Vsw
Ch3 : Vin Ch4 : Iout (200mA/div)

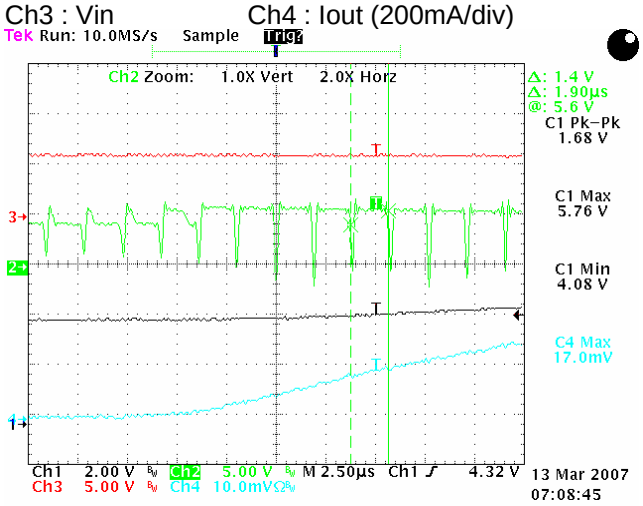

Figure 4 Switch node waveform expanded
The green trace shows the duty cycle during startup

Keep in mind that the boost capacitor only charges during the off time.

Solutions
Given that the problem is a lack of charge on the bootstrap capacitor there are a number of possible solutions:

1. Hold off the controller until the input voltage has stabilized.

This is a practical solution and is relatively easy since the CS51411 has an enable pin. We can simply add an external resistor divider on the enable pin to establish the UVLO point. For a more accurate and faster turn on we can add an inexpensive part such as the NCP300 Voltage detector or similar as shown in figure 5.

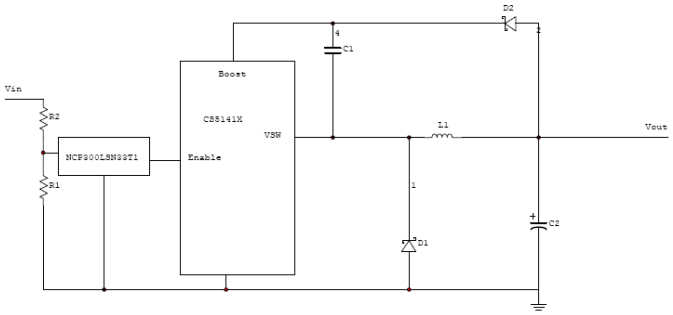

Figure 5 Using a voltage detector for accurate turn-on voltage.

We can also provide some immunity from line glitches by adding a capacitor and diode between R1 and R2 to provide some hold up time.

2. Remove the bootstrap during startup and reconnect it when Vin has stabilized. This results in the following waveforms.

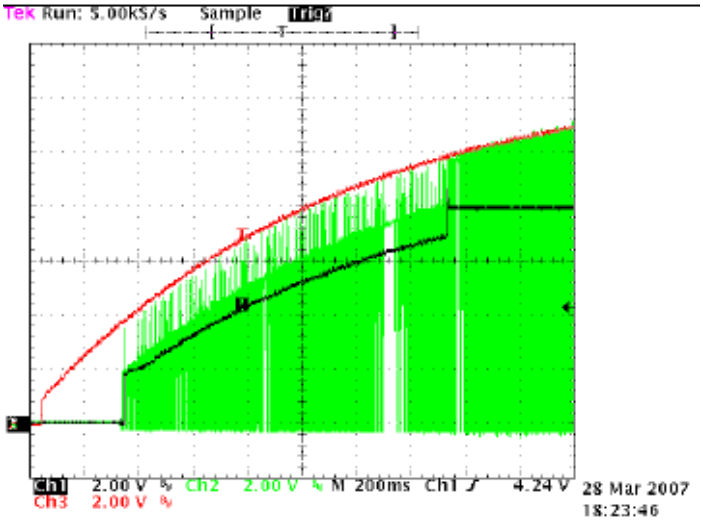

Figure 6 Expanded view of the output waveform
I load = 0.3A
Ch1 : (Bk) Vout Ch2 : (Gn) Vsw
Ch3 : (Red)Vin

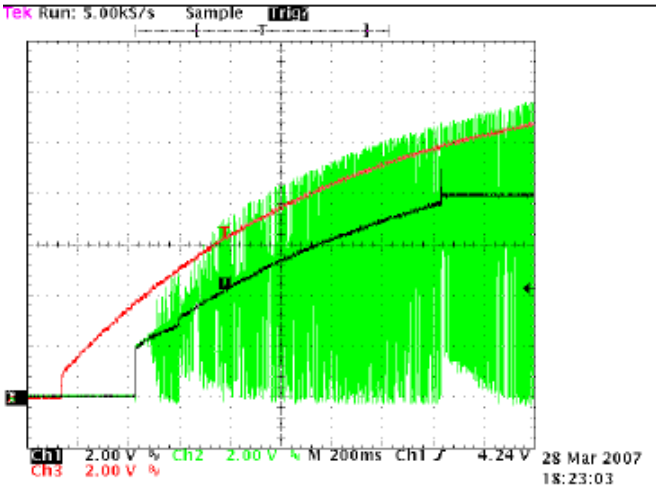

Figure 7 Expanded view of the output waveform
I load = 0.029A
Ch1 : (Bk) Vout Ch2 : (Gn) Vsw
Ch3 : (Red)Vin

This gives a slight overshoot on the output, when the bootstrap circuit is connected back into the circuit. This may be acceptable for many applications. Reconnecting the bootstrap circuit can be accomplished by a load switch configuration such as that shown in figure 8.

The disadvantage is that there is some additional current drain from the input source to keep the transistor active during operation.

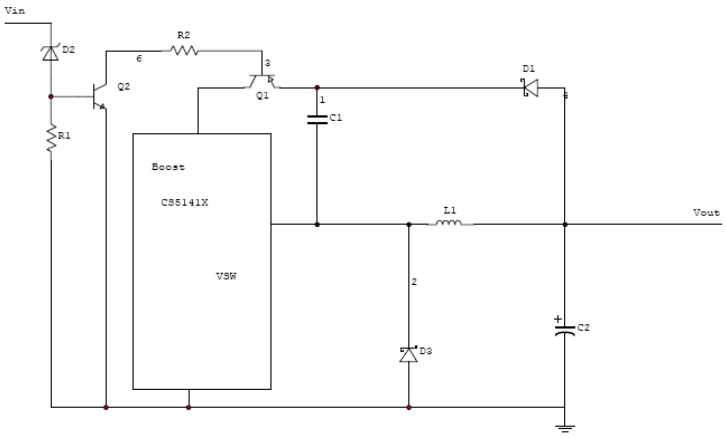

Figure 8 A few additional components, Q1, Q2, D2 R1 and R2, provides a load switch that can connect the boost circuit when Vin reaches a preset value.

3. Connect a larger load on the output during startup and remove it once the input voltage in at its nominal level or after a preset time. In the circuit in figure 9 the time constant established by the values of R1 and C3 determines how long the additional load resistor R2 remains connected to the output. On initial power up capacitor C3 is discharged and Q1 is on. As C3 charges, Q1 switches off and remove the additional load on the output. An additional diode connected across R1 will ensure fast discharge for C3 should the input voltage get grounded. The time constant of R1 and C3 must be matched to the rise time of the input supply.

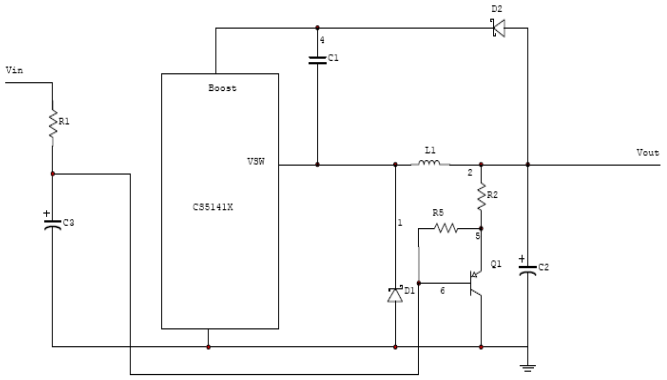

Figure 9 Expanded view of the output waveform
I load = 0.029A
This gives a startup waveform as shown in Figure 10. The disadvantage is that the circuit must be somewhat over designed to allow for the extra load current requirement that will need to exist for some time after startup.

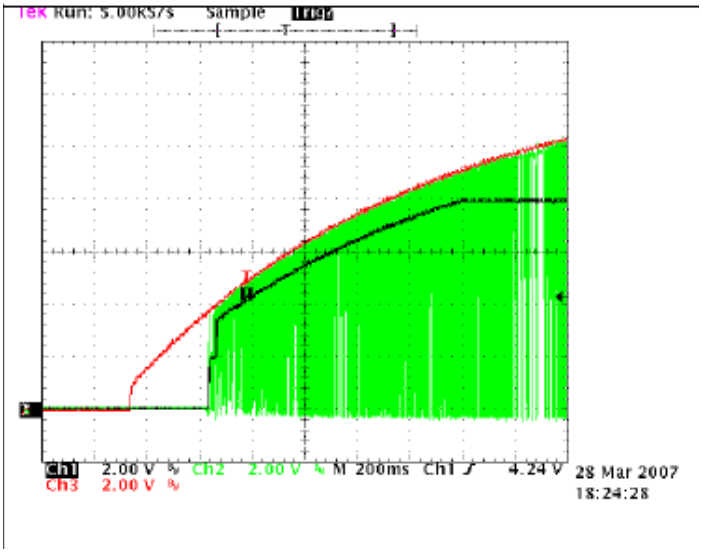

Figure 10 Startup waveform with artificial load of 100mA at startup
Ch1 : (Bk) Vout Ch2 : (Gn) Vsw
Ch3 : (Red)Vin

4. Use an additional transistor to increase the boost capacitor charging current. This can be accomplished with a couple of extra components (Q1 and D3) as shown in figure 11.

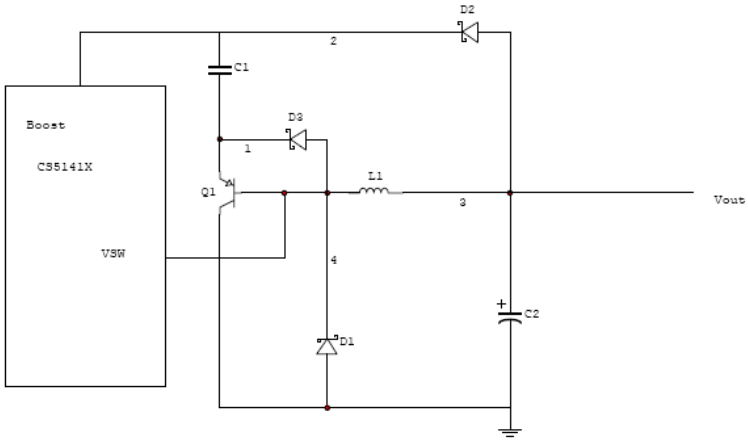

Figure 11 Current Boost Circuit

During the off time when Vsw goes low, Q1 is turned on and the boost capacitor C1 is charged via the transistor at a high current from the output. During the on-time, the additional diode D3, completes the current path through the output switch and C1.

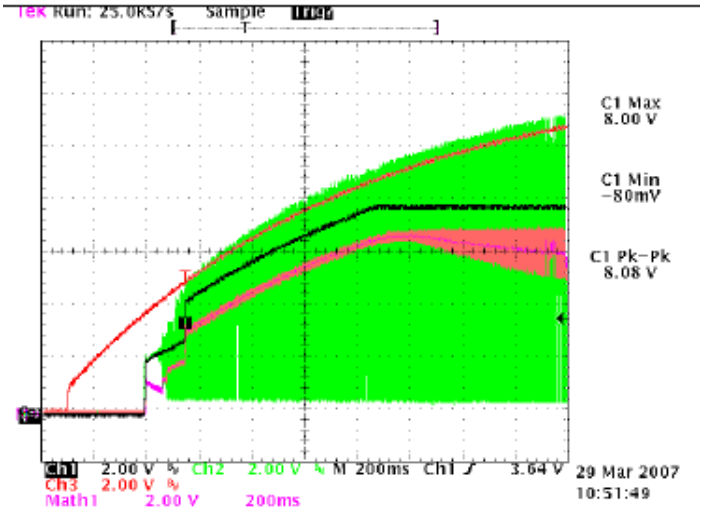

Figure 12 Startup waveform with current Boost Circuit
Ch1 : (Bk) Vout Ch2 : (Gn) Q1 emitter
Ch3 : (Red)Vin Ch 4 : V boost - V Q1 emitter.

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