Analysis and Solution of the LM5122 Bypass Function Loss

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Summary

The LM5122 is a synchronous boost controller that supports wide inputs from 4.5V to 65V, with wide adoption in manufacturing, automotive electronics and beyond. Bypass function may loss under certain conditions in application. This article addresses this issue, describes the reasons for the Bypass function loss, and provides solutions.

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1 LM5122 features

The LM5122 is a multi-phase capable synchronous boost controller intended for high-efficiency synchronous boost applications. Based on peak current mode control, it internally provides feed forward and cycle by cycle limit and simplify compensation. The LM5122 is equipped with input undervoltage lockout, and programmable soft-start which can remotely control necessary time series and ON-OFF signals. An internal charge pump enables the high-side switch in Bypass operation when the input voltage is equal to or higher than the selected output.

A typical application circuit for LM5122 is shown below.
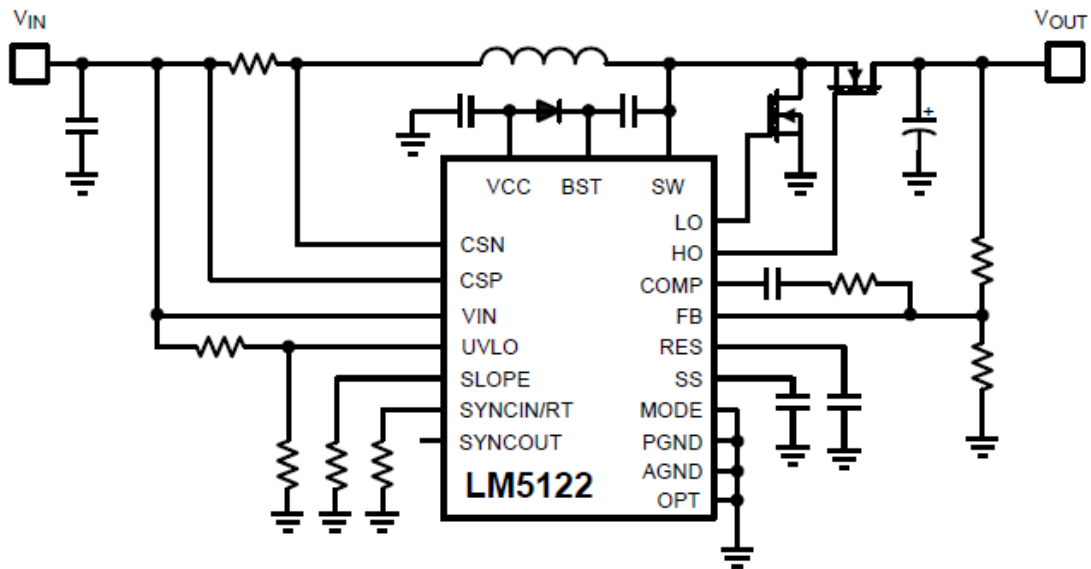
Figure 1. A typical application circuit for LM5122

2 LM5122 Bypass function loss and reasons

2.1 LM5122 normal Bypass waveform

As described in the data sheet, the LM5122 will operate in the Bypass mode if the input voltage is above the enable threshold and is forced into PWM mode, when the input voltage is equal to or higher than the output voltage. This mode enables the high-side switch, thus effectively improving system efficiency.

Figure 2 shows a typical operating waveform in the Bypass mode. CH1 is the output voltage (VO); CH2 is the high-side output voltage (HO); CH3 is the soft-start pin (SS). Test settings: The input voltage sets to 40V; the fixed output voltage sets to 28V. As can be seen from the figure below, when the input voltage is lower than the output, the LM5122 operates in the PWM mode, and the high-side switch is controlled by pulse-width modulation (PWM); when the input voltage rises above the selected 28V, an internal charge pump charges the high-side switch, which enables the Bypass mode. It can be verified that the LM5122 can achieve the Bypass function well within the recommended operating voltage range (4.5V~65V) when it is switched on and off only by the input voltage.
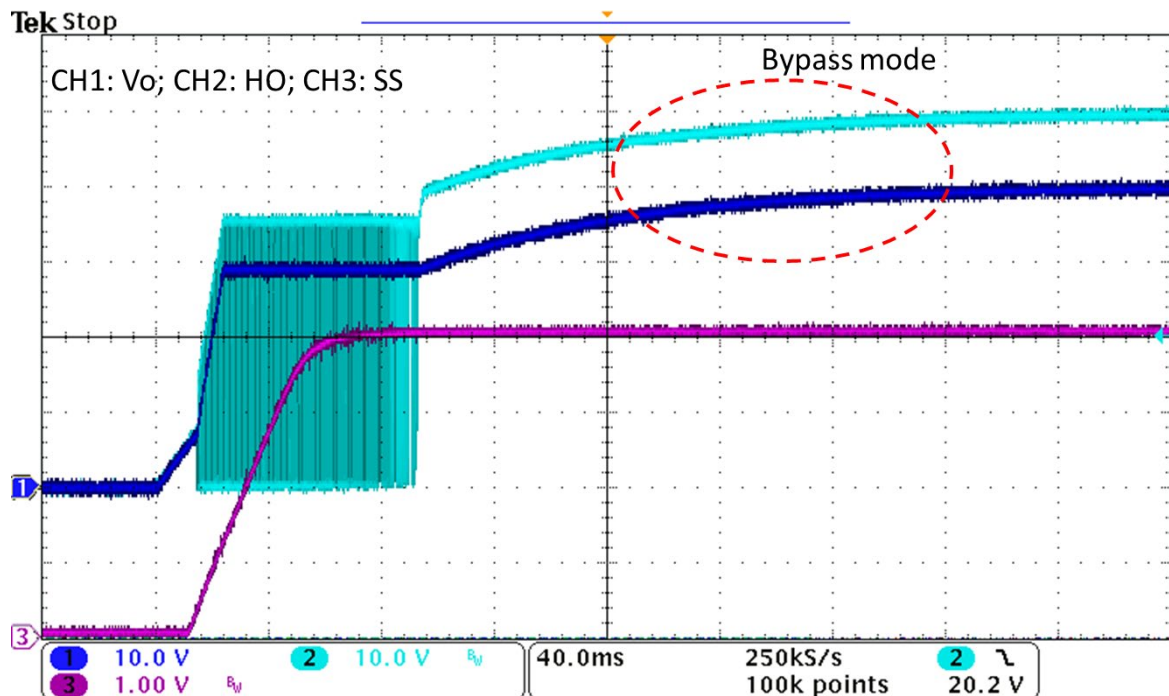

Figure 2.   Normal Bypass waveform

2.2 LM5122 Bypass function loss

In practice, the input voltage is often not always varied to switch on and off due to time series or system control aspects. The input undervoltage lockout (UVLO) and programmable soft-start (SS) of the LM5122 can receive external signals to achieve switch control (UVLO pin is recommended for practical applications). When the voltage of the UVLO pin drops below 1.2V, the LM5122 will turn off the PWM signal. In practice, it is found that the Bypass function may be lost if the external signal controls the UVLO pin for switching on and off, when the input voltage is higher than the output, as shown in Figure 3. CH1 is the output voltage (VO); CH2 is the high-side output voltage (HO); CH3 is the soft-start pin (SS). Test settings: The input voltage sets to 40V; the fixed output voltage sets to 28V. It is clear in the figure below that after the soft-start HO is the same with the output voltage, the high-side switch is not enabled, neither is the Bypass function.
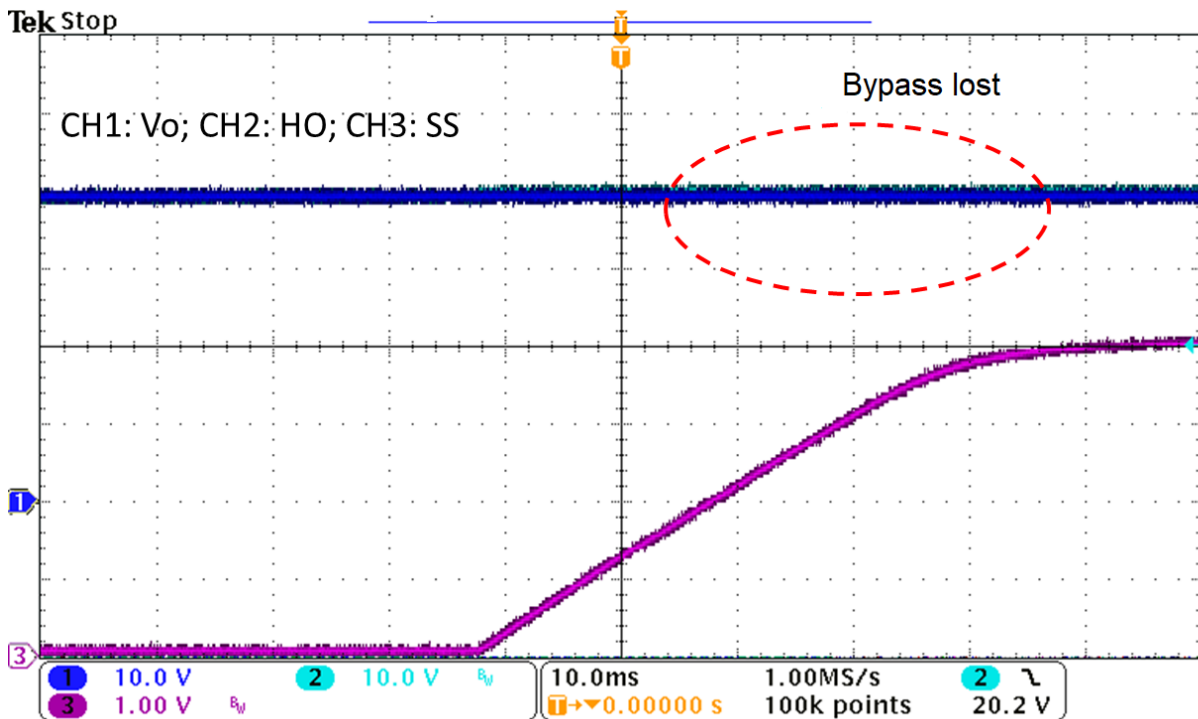

Figure 3.   Waveform of Bypass loss

2.3 LM5122 Bypass function loss and reasons

The LM5122 incorporates an internal "Forced Diode Emulation" logic circuit, as shown in Figure 4.
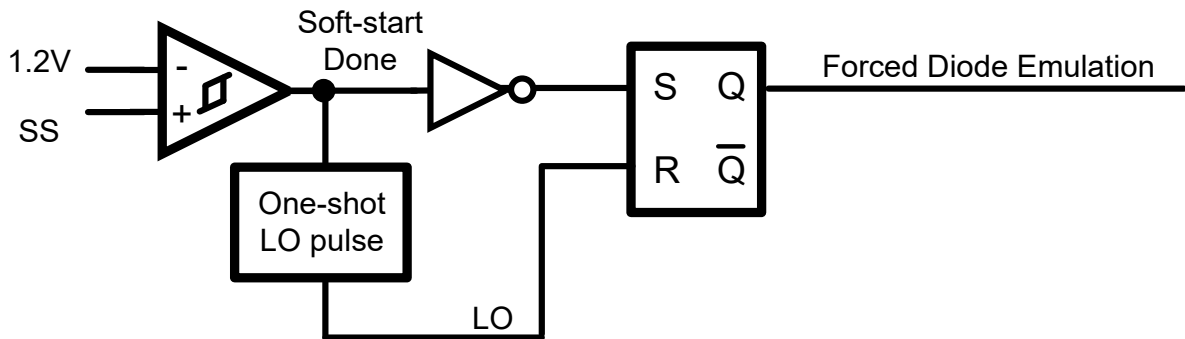

Figure 4.   "Forced Diode Emulation" function module

Under normal operating conditions, the soft-start is completed after the SS voltage rises to 1.2V. The comparator sends a high-level signal, the Set input of the R/S flip-flop circuit goes low, and "One-Shot LO pulse" generator sends a high-level pulse to the Reset of the R/S flip-flop circuit. This is when Q of the R/S flip-flop circuit goes low and turns on the Bypass function. The ideal trigger waveform is shown in the Good diagram of Figure 5.

In practice, the SS pin will be coupled to switching noise. When the noise coupling is loud enough to exceed the threshold of the internal comparator, the comparator may be triggered again and send out a Glitch pulse, cutting off the "Force Diode Emulation" signal. This is when the Bypass function is lost. Please refer to the Bad diagram in Figure 5 for detailed waveforms.

As shown in the above working principle, there will be better noise immunity if the hysteresis of the comparator can be increased. The implementation of a solution circuit is introduced in the following chapter.
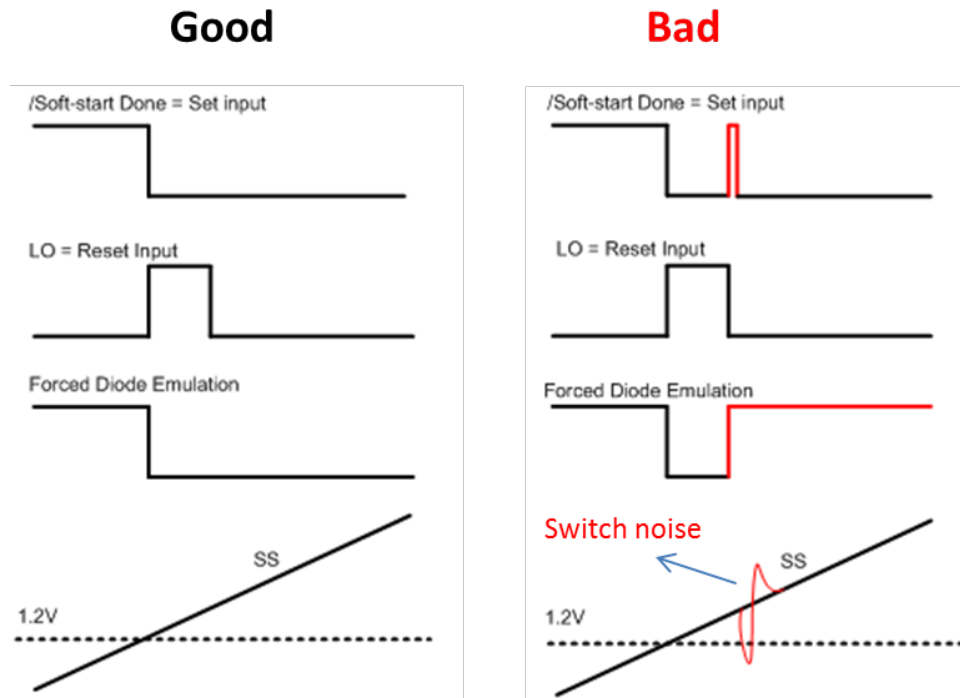
Figure 5.   "Forced Diode Emulation" triggers waveform

3   Solution for the LM5122 Bypass loss

3.1   Solution for the LM5122 Bypass loss

It is observed in Figure 5 that the low-side switch output sends a narrow pulse after the soft-start. The hysteresis can be improved if the pulse is coupled to the SS pin through an external capacitor to accelerate the charging rate of the soft-start capacitor. To achieve this, we have designed the circuit shown in Figure 6 and performed basic simulations with TINA. As can be seen from the simulation waveform Figure 7, the LO pulse generates a jump on the SS, which improves the hysteresis of the internal comparator.
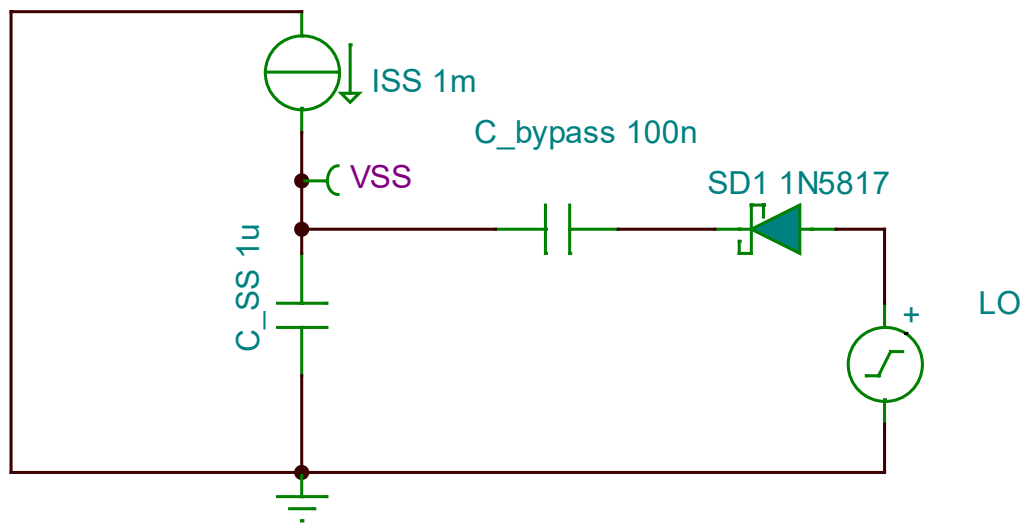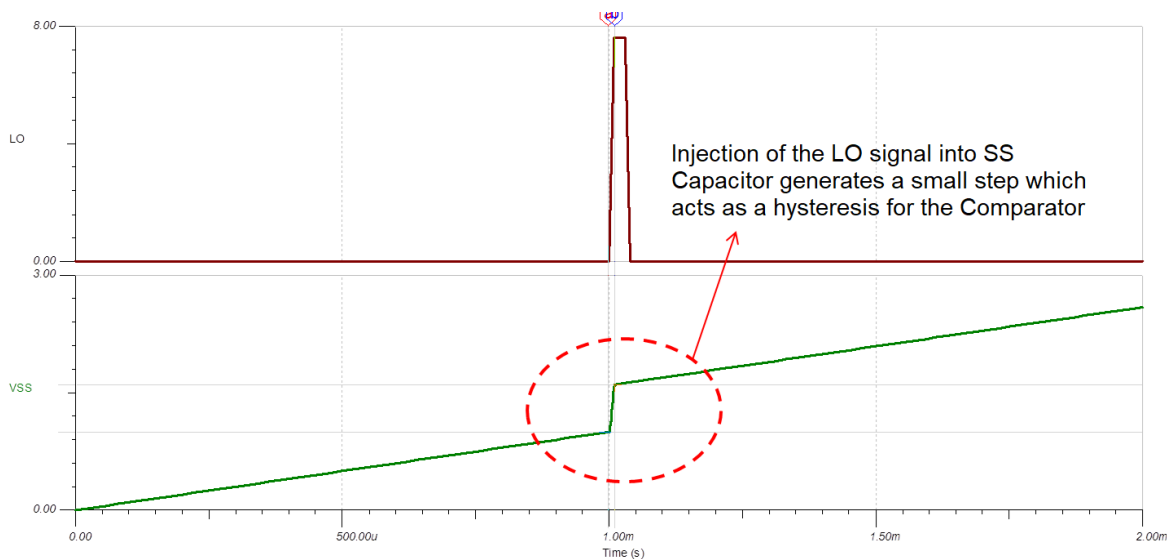
Figure 6.   Coupling capacitor circuit

Injection of the LO signal into SS Capacitor generates a small step which acts as a hysteresis for the Comparator

Figure 7.   TINA simulation waveform

The parameters in Figure 6 are set to test whether the circuit we designed will achieve the desired goal. In fact, a 10uA current source is used to charge the soft stat capacitor. C_SS and C_bypass should be chosen so that no glitch occurs when starting in Bypass mode, while startup in Boost operation is still possible without observing high inrush currents or OCP trigger. Generally, it is recommended to select the smallest possible C_SS capacitance, that is still within the specifications of the application requirements. Then add the C_bypass capacitance as 5% - 20% of the C_SS capacitance. On the EVM, we set the expected output voltage to 28V and selected both a 0.1uF C_SS capacitor and a 3.9nF C_bypass capacitor, with a Schottky diode for SD1. The bypass function can be perfectly implemented within the recommended application range in the Datasheet. The test waveforms are shown in Figures 8 and 9.
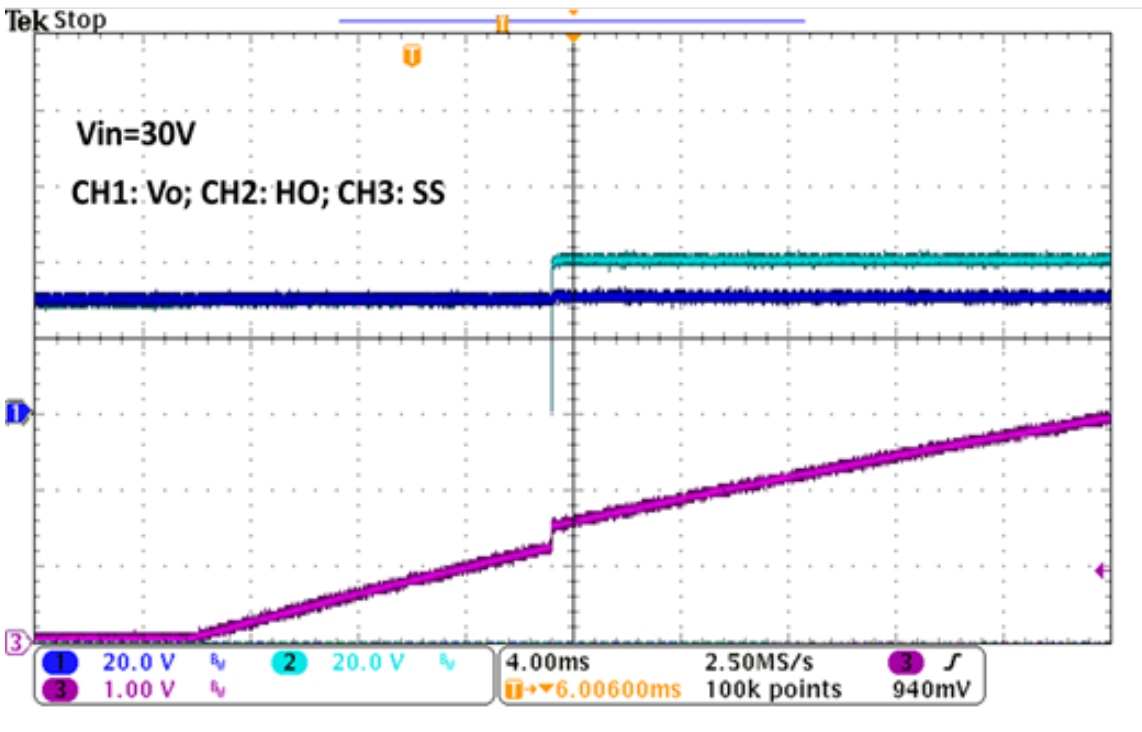

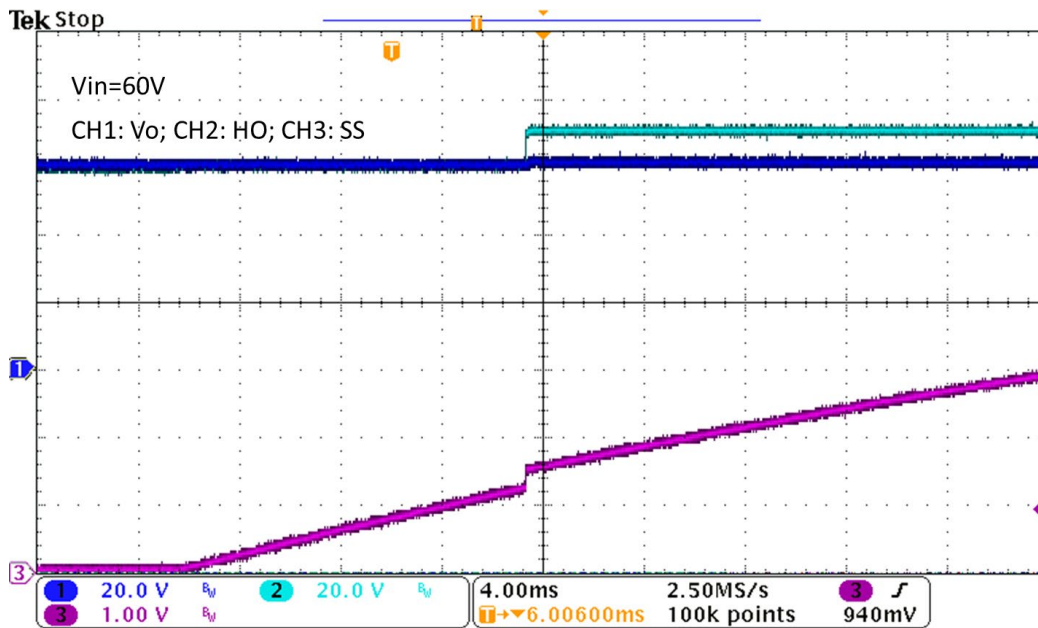Figure 8.   Bypass waveform at 30V input

Figure 9.   Bypass waveform at 60V input

3.2 Risks of coupling capacitors

The coupling capacitor can improve the immunity of the internal comparator and turn on the Bypass function, however, in the PWM mode, when the input is lower than the selected output, the jump generated by the SS coupling capacitor can lead to the loss of soft-start. The amount of loss is associated with how big the jump is. The test waveforms are shown in Figure 10. For applications that are starting up in both Boost mode and Bypass mode operation, additional modification may be required to achieve a smooth startup in both cases.
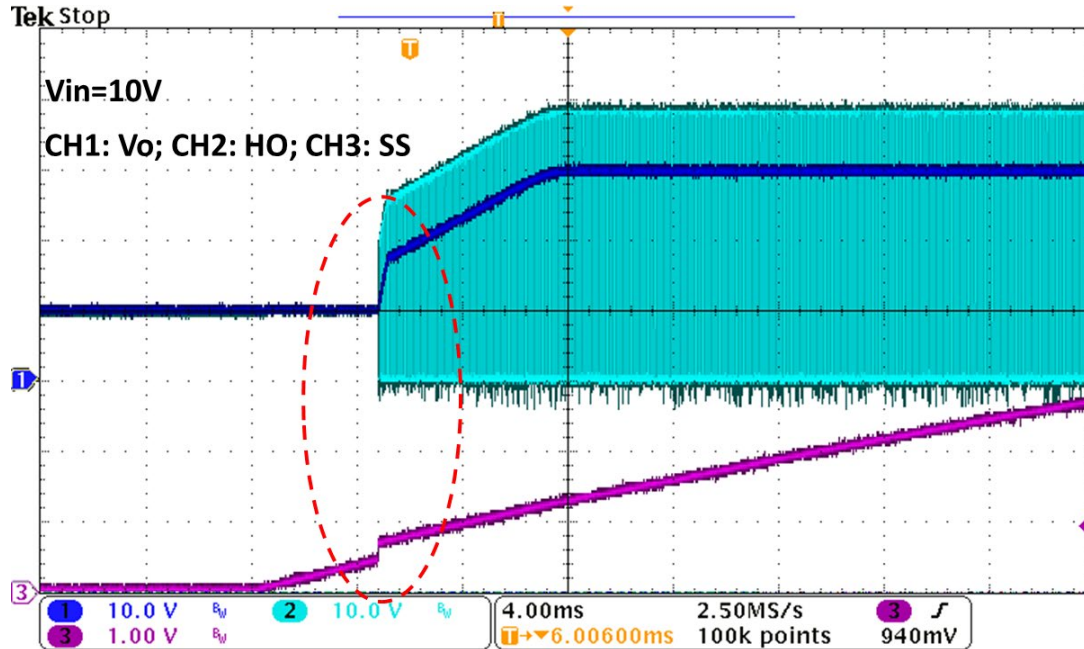
Figure 10.   Waveform for soft-start loss caused by the coupling capacitor

4   Reconstruct soft-start

In some applications where the board noise is high due to layout limitations, it is difficult to determine the right parameters to balance the two. The above coupling circuit can be considered to be reserved exclusively for the Bypass function. In this case, you can reduce the C_SS and increase the C_Bypass, that is, increasing the SS jump for increased immunity. The soft-start function can be achieved as follows: When the internal soft-start finishes, the external R/C circuit slowly raises the COMP pin.
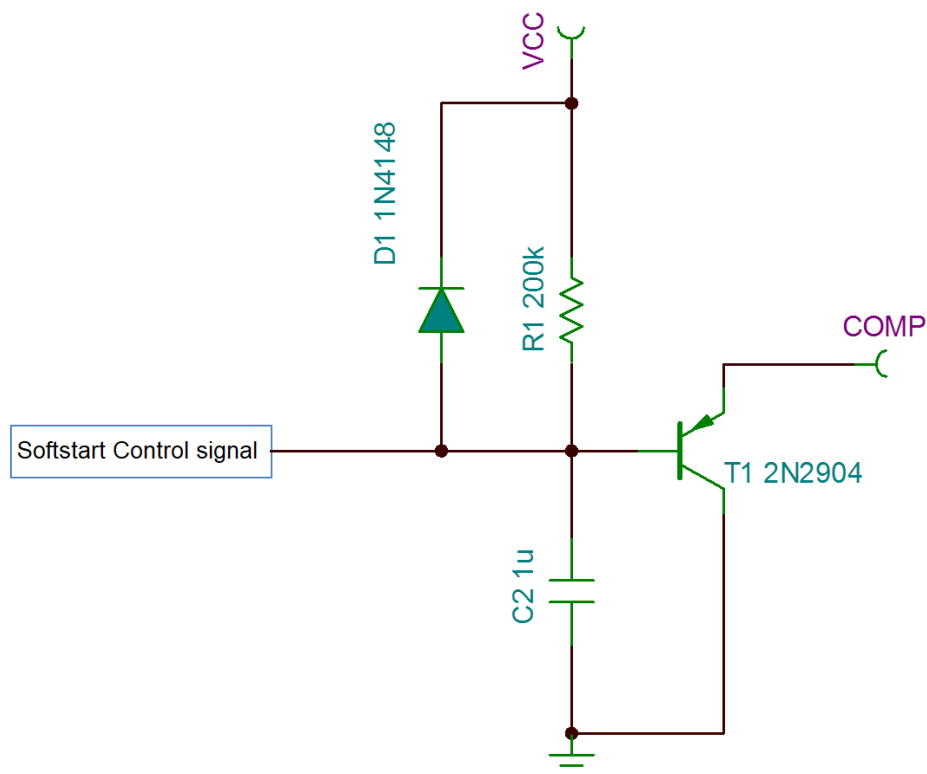
Figure 11.   Rebuild soft-start with COMP pin

We now implement and test the above coupling circuit and rebuild soft-start circuit on the LM5122EVM for a Bypass solution.

Figure 12 shows the associated test waveforms with an input voltage set at 10V and an output voltage set at 28V. The waveform diagram shows that after the circuit soft-start, there is about 6V driving voltage on the high-side switch VGS (HO-VO), and the Bypass starts to work; then when the COMP pin is slowly raised under the control of the external circuit, the PWM signal starts to appear and there is a good soft-start for the voltage output (VO).
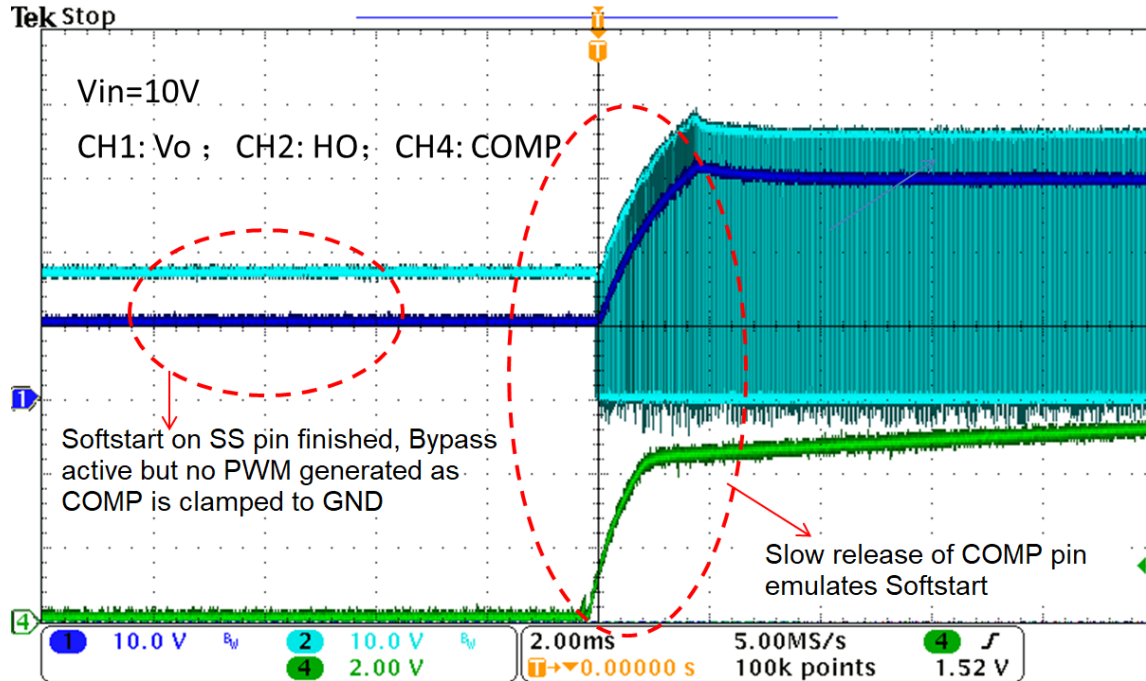
Figure 12. Bypass and reconstructed soft-start waveforms at 10V input

5 Perfect implementation of the Bypass and the soft-start

From the internal block diagram of the LM5122 (Figure 13), we can see that there is a 1.2V bias from the output of the op amp to the PWM comparator. In other words, there is no PWM output before the COMP pin rises to 1.2V. In addition, if the SS capacity is small enough, such as 100pF, then the voltage rise rate on the SS will be fast enough to quickly cross the "Forced Diode Emulation" threshold, which can also effectively prevent noise interference. Based on the two point above, an alternative circuit implementation is introduced in Figure 14. This circuit combines both solutions for avoiding the glitch at the SS pin and still providing a smooth ramp up of the output voltage, thus both startup in Bypass mode and Boost mode is possible. The previous circuits from Figure 6 and Figure 11 are not required for this approach.
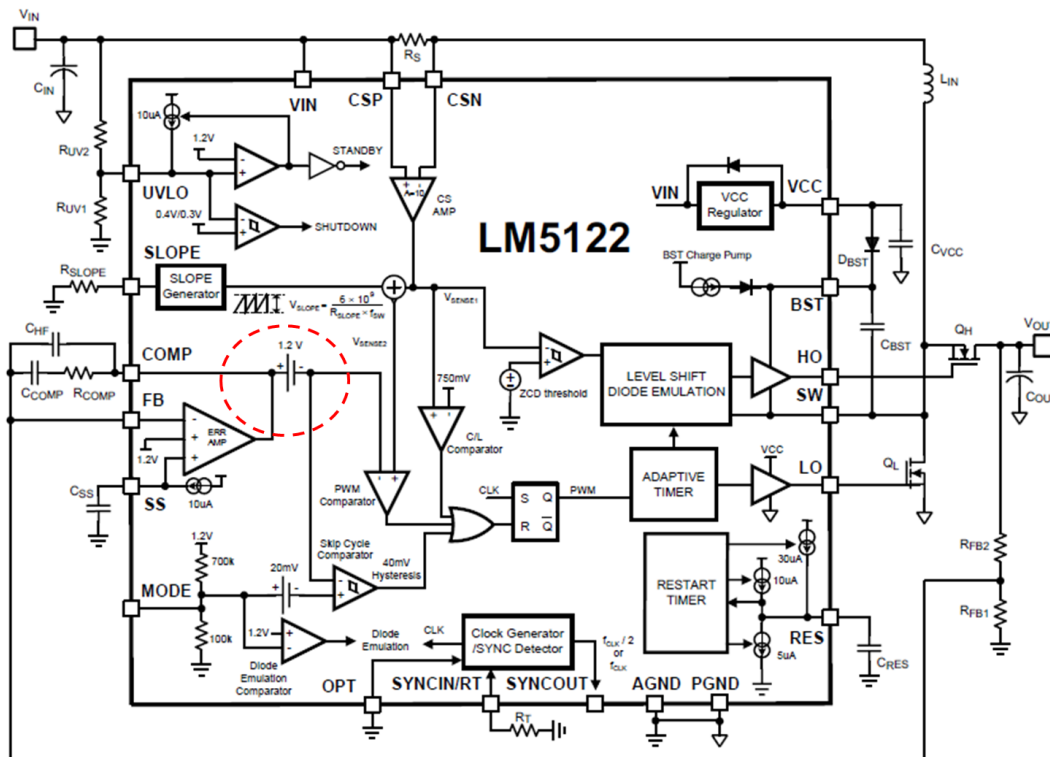
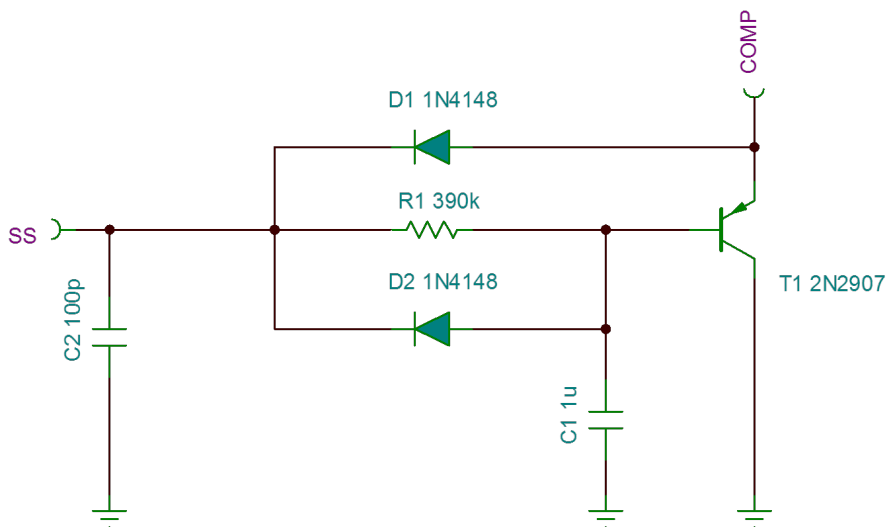Figure 13.   Bias between LM5122 voltage error amplifier and PWM comparator

Figure 14.   Circuit that perfectly implements the Bypass and the soft-start

We have conducted a detailed test on the circuit in Figure 14 of the LM5122EVM, and the test results have validated the feasibility of the design. The waveforms are shown in Figures 15 and 16.
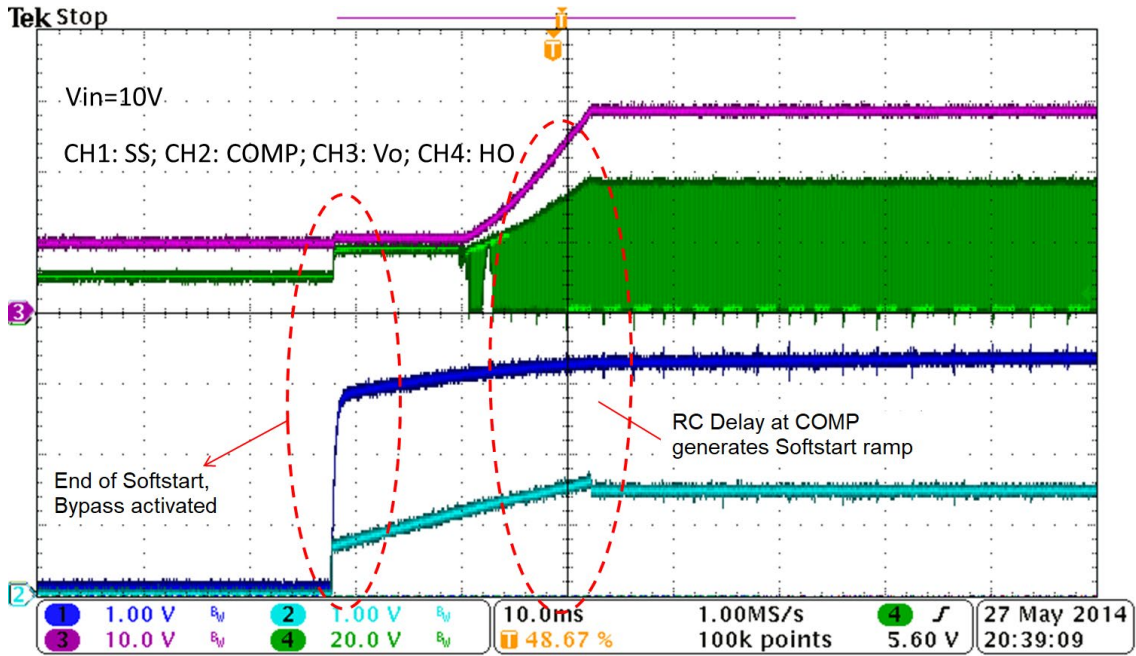

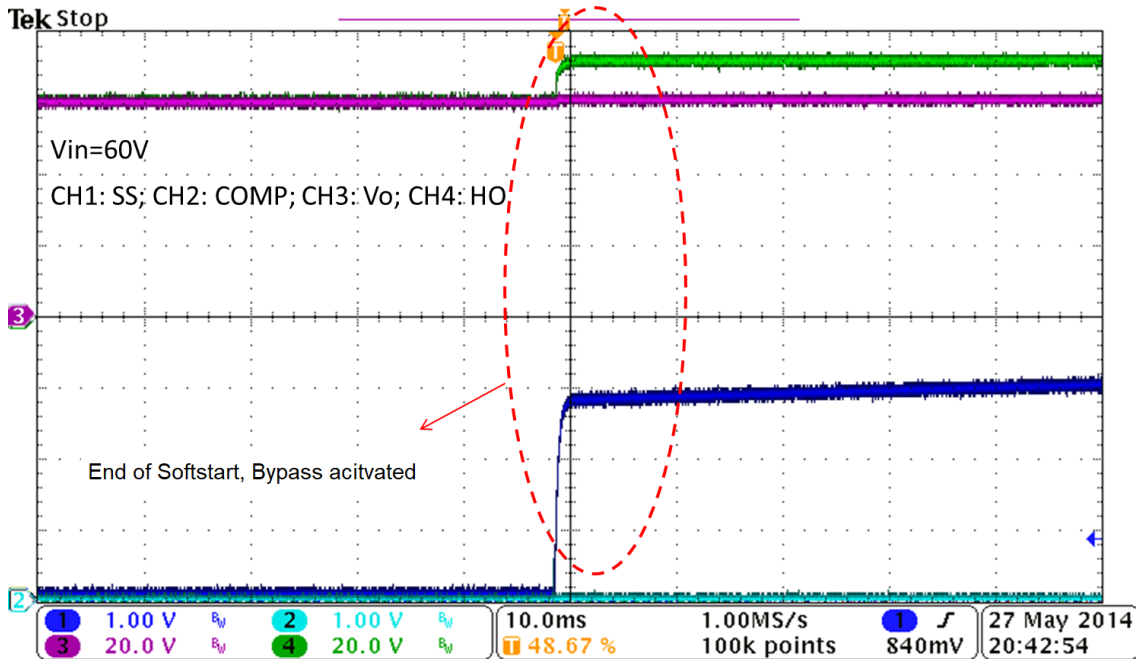**Figure 15. Perfect start waveform at 10V input**

Figure 16. Perfect start waveform at 60V input

6   Conclusion

When the circuit noise is too high, the "Force Diode Emulation" comparator inside the LM5122 will be easily disturbed, resulting in the loss of the Bypass function. This problem can be effectively solved by adding coupling capacity and circuits such as external soft-start.

7   References

1.   LM5122 datasheet, Texas Instruments Inc., 2013

2.   LM5122EVM-1PH Evaluation Module User's Guide, Texas Instruments Inc., 2013

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