

RAQ Issue 213: Generating Negative Voltages—Why You Need Level Shifting in Buck-Boost Circuits

Frederik Dostal, Field Applications Engineer

Question:

Why is level shifting required?



Answer:

Inverting buck-boost circuits are commonly used for generating negative supply voltages from positive voltages. The most important step is ensuring that the negative voltages are generated correctly. However, additional level shifting circuits may be necessary if the power supply is controlled or supervised by the main application circuit. It has a reference to ground, while the GND pin of the inverting buck-boost power circuit is connected to the created negative voltage.

Introduction

The magnitude of the negative voltage generated by inverting buck-boost circuits can be higher or lower than that of the available positive voltage. For example,

–8 V or even –14 V can be generated from +12 V. When working with a switching regulator IC with an inverting buck-boost circuit, communications pins may be needed in the system design. If they are, it is essential for designers to remember adequate level shifting so that synchronization and enable signals can be utilized.

What to Consider When Designing Level Shift Circuits

The inverting buck-boost topology is one of the basic switching regulator topologies, requiring just one inductor, two capacitors, and two MOSFETs as switches. The switches can be driven with any buck regulator or controller. The availability of possible switching regulator building blocks is therefore large. Figure 1 shows the inverting topology with all the necessary components.

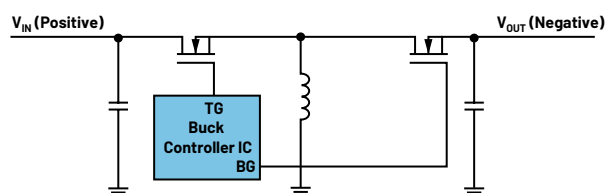


Figure 1. An inverting buck-boost topology for generating a negative voltage with a step-down (buck) switching regulator.

Figure 2 shows a buck-boost circuit with an **ADP2386** buck regulator. If a buck regulator IC is used for the inverting circuit, the ground connection of the IC is at the generated negative voltage. The original output voltage from the buck regulator is connected to the system ground. The buck regulator in the inverting topology references its own ground to the set negative voltage because the output voltage is connected to the system ground. The reference ground for the IC (GND in Figure 2) is not connected to the system ground. As a result, these two

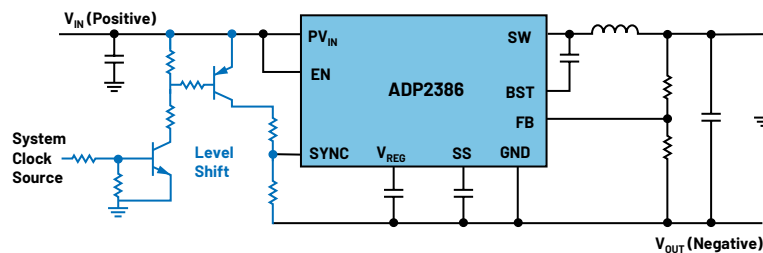


Figure 2. External level shifter for supplying the switching regulator IC with an external clock for synchronization.

grounds are not at the same potential. The switching regulator IC ground becomes the generated negative voltage. All pins on the switching regulator IC are now referenced to the generated negative voltage, rather than to the system ground. As a result, the communication lines and connections from the system to the IC and vice versa need level shifting to guarantee safe communication and prevent damage. Typically, the relevant signals are SYNC, PGOOD, TRACKING, MODE, EN, UVLO, and RESET. Figure 2 shows a possible level shift circuit with two bipolar transistors and seven resistors (in blue) for one signal. This circuit requires a certain amount of space and adds complexity to the circuitry as well as costs. Such a level shifter would have to be implemented separately for all signals previously mentioned. It is especially complicated when a switching regulator IC uses a digital bus such as the Power Management Bus (PMBus®). Then, the entire bus connection has to be operated with level shifting or galvanic isolation.

One way to avoid this external circuitry is to use a switching regulator IC that has been designed specifically for inverting voltages. Analog Devices offers a family of switching regulator ICs that are variations of buck regulator ICs. They are designed to facilitate communication between the system, that is, the entire electronic circuitry, and the inverting switching regulator IC. External level shifting as shown in Figure 2 is not needed.

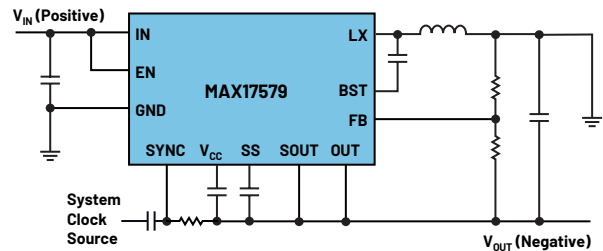


Figure 3. A MAX17579 designed as an inverting buck-boost regulator and with level shifting already integrated.

Figure 3 shows the MAX17579 switching regulator IC, which generates a negative voltage from a positive voltage. As can be seen in Figure 3, the circuit is much more compact than the one in Figure 2.

Simulation tools such as LTspice® or the EE-SIM® design and evaluation environment can provide a better understanding of the regulation behavior and the potential differences in an inverting topology. Level shift circuits can be designed and optimized with these tools. ICs like the MAX17579 can also easily be simulated with the EE-SIM design tool.



About the Author

Frederik Dostal is a power management expert with more than 20 years of experience in this industry. After his studies of microelectronics at the University of Erlangen, Germany, he joined National Semiconductor in 2001, where he worked as a field applications engineer, gaining a lot of experience in implementing power management solutions in customer projects. During his time at National, he also spent four years in Phoenix, Arizona (U.S.A.), working on switch-mode power supplies as an applications engineer. In 2009, he joined Analog Devices, where since then he held a variety of positions working for the product line and European technical support, and currently brings in his broad design and application knowledge as a power management expert. Frederik works in the ADI office in Munich, Germany.