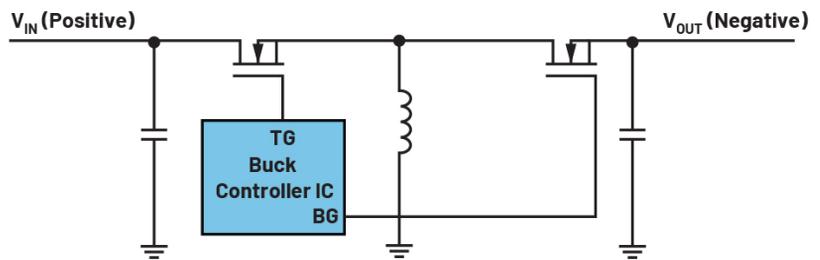


Why You Need Level Shifting in Buck-Boost Circuits

Inverting buck-boost circuits are commonly used to generate negative supply voltages from positive voltages. However, additional level-shifting circuits may be necessary if the power supply is controlled or supervised by the main application circuit.

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 that has an inverting buck-boost circuit, communications pins may be needed in the system design. If they are required, it's essential for designers to remember adequate level shifting so that synchronization and enable signals can be utilized.



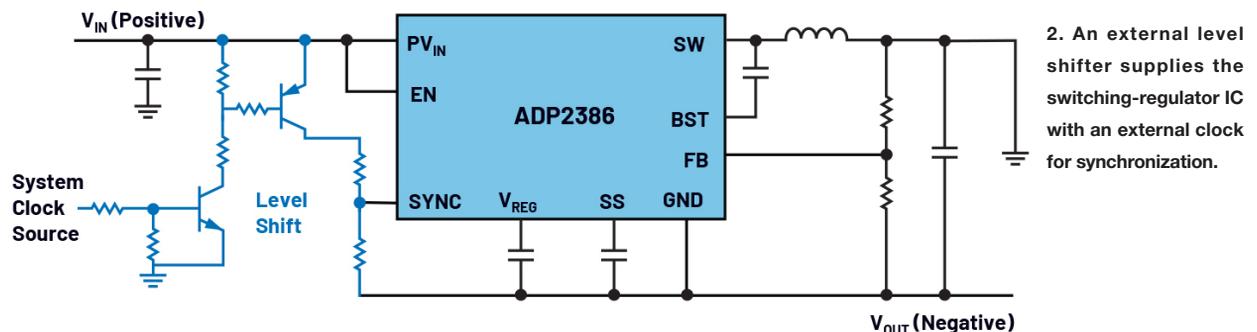
1. Shown is an inverting buck-boost topology for generating a negative voltage with a step-down (buck) switching regulator.

availability of possible switching-regulator building blocks is therefore large. *Figure 1* shows the inverting topology with all of the necessary components.

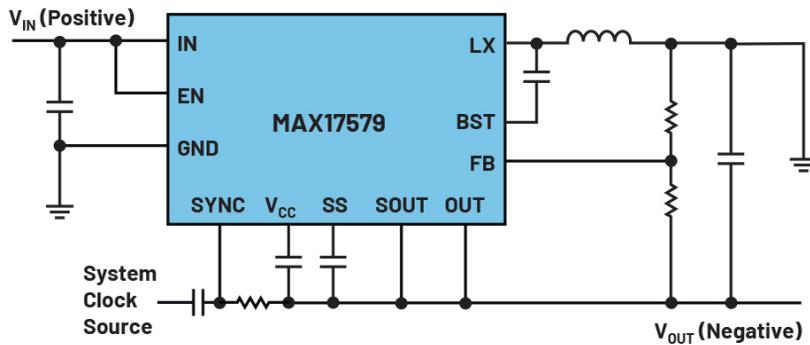
What to Consider When Designing Level-Shift Circuits

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

A buck-boost circuit with an [ADP2386](#) buck regulator is depicted in *Figure 2*. 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



2. An external level shifter supplies the switching-regulator IC with an external clock for synchronization.



3. The MAX17579, designed as an inverting buck-boost regulator, integrates level shifting.

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) isn't connected to the system ground.

As a result, these two grounds aren't 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. Consequently, the communication lines and connections from the system to the IC and vice versa need level shifting to guarantee safe communication and prevent damage. The relevant signals are typically 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.

Eliminating External Level-Shifting Circuitry

One way to avoid this external circuitry is to use a switching-regulator IC that's designed specifically for inverting voltages. For example, Analog Devices offers a family of such ICs that are variations of buck-regulator ICs. They're designed to facilitate communication between the system, i.e., the entire electronic circuitry, and the inverting switching-regulator IC. External level shifting as shown in Figure 2 isn't needed.

Figure 3 shows the MAX17579 switching-regulator IC, which generates a negative voltage from a positive voltage. As can be seen, 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.

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, Ariz., 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.