Powering drones with a wide V_{IN} DC/DC converter

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TEXAS INSTRUMENTS

Drone applications require high cell count battery packs to support longer flying distances and flight times. As an example, consider a 14-series (14s) Li-ion battery pack architecture where the working voltage is 50 V to 60 V. When designing a DC/DC power supply for such a system, one of the challenges is how to select the maximum input voltage rating. A large voltage excursion can occur at the node designated V_M in Figure 1.

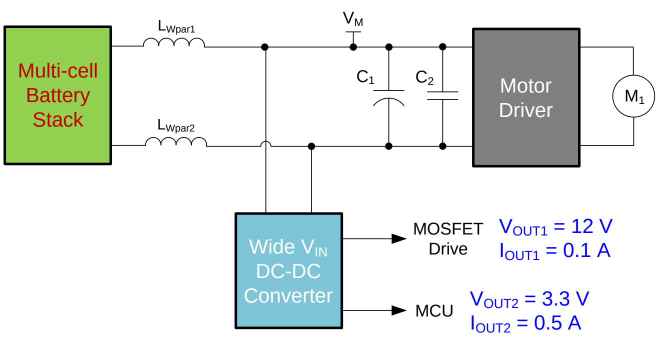

Figure 1. Drone system block diagram

To understand the modes of operation of a motor driver, consider the schematic diagram of Figure 2. The battery stack powers a brushed-DC (BDC) motor, M_1, through the forward current path designated as loop 1, and electric power converts to the rotational kinetic energy of the motor during this period.

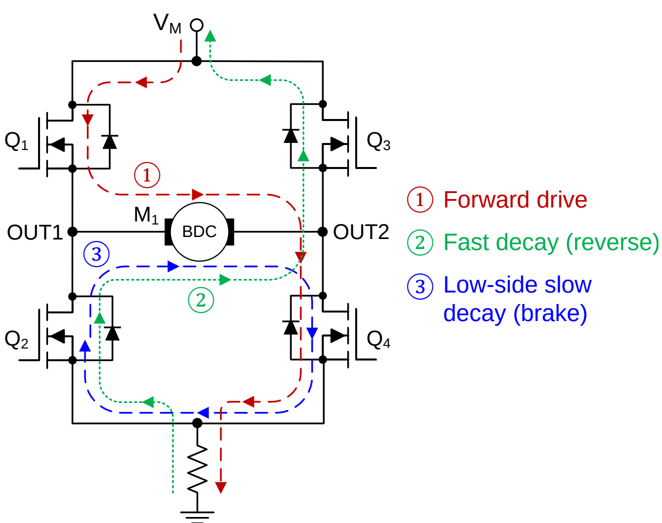

Figure 2. BDC motor H-bridge driver forward current paths

Conversely, when the motor decelerates or changes its direction of rotation, it acts as a generator and the resultant back EMF returns energy to the input through the driver using current loop 2. Although this regenerative behavior may be considered advantageous in terms of improving overall system efficiency, it can result in a large reverse current and consequent voltage overshoot at the supply input.

To manage this voltage excursion and ensure the system runs safely, system designers can use an electrolytic bulk capacitor for C_1 to absorb the energy or, alternatively, to add a TVS diode to clamp the voltage to a safe range. Consider the Rubycon 2200-µF, 63-V electrolytic capacitor for example. With a diameter and height of 18 mm and 33 mm, respectively, the capacitor is too large for most drone implementations where footprint and profile are important constraints. More important is that the E-cap, with its finite, rated lifetime, represents an acknowledged limitation in terms of system reliability and robustness. A TVS diode also entails space, cost, and reliability concerns for the whole system and can be difficult to select because its clamping voltage varies with current.

Choosing a Power Solution

Another option is to use a DC/DC power converter IC solution. The choice hinges initially on input voltage and output current specifications. However, solutions specifically with a wide input voltage range (wide V_{IN}) and high line transient immunity offer outsized voltage rating and operating margin to accommodate the peak voltage transient during the regenerative action of the drone motor.

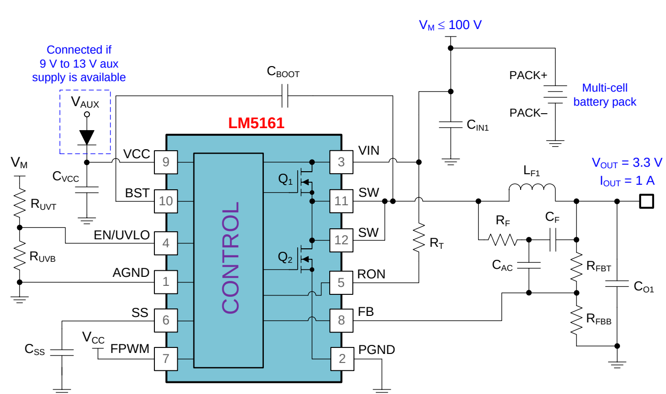

Figure 3. LM5161 synchronous buck converter

Selecting a converter with a wide V_{IN} range, such as the LM5161, a 100-V, 1-A synchronous buck converter, shown in Figure 3, lets designers eliminate the bulk capacitor or TVS protection, saving time, cost, and board space. If an auxiliary rail between 9 V and 13 V is available to supply VCC bias power as indicated in Figure 3, the quiescent current of the LM5161 input reduces to 325 µA at 50-V input, to uphold battery life during standby operating conditions.

Moreover, the LM5161 converter offers a large degree of flexibility in terms of platform design. Not only does the converter support a nonisolated output, but it can also deliver one or more isolated outputs using a Fly-Buck™ circuit design (see Figure 4) if needed in the drone system, to break a ground loop or to decouple different voltage domains.

Fly-Buck Topology

In general, a Fly-Buck converter represents an easy way to provide galvanically-isolated positive or negative voltage rails while keeping cost and complexity to a minimum. And, at the same time, the converter meets a diversity of challenges tied to the wide input voltage range, multiple outputs, small solution size, reliability, and electromagnetic interference (EMI).

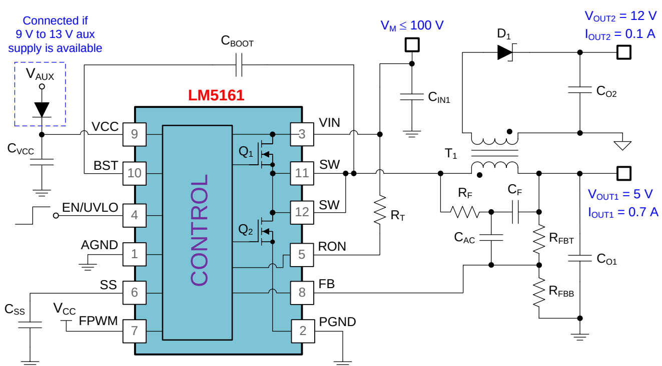

Figure 4. LM5161 Fly-Buck converter

Built from the synchronous buck regulator which has specific features to facilitate Fly-Buck functionality (including a current limit hiccup off-timer, negative primary-side current limit, and forced-PWM operation), the Fly-Buck stage has neither loop compensation nor feedback opto-coupler components. A compensated error amplifier is not needed, and a constant on-time (COT) control approach gives nearly-instantaneous response for excellent line and load transient dynamics. Feedback regulation is from the primary side through a standard resistor divider.

The Fly-Buck is ideal for auxiliary and bias rails, floating supplies for digital isolators, and bipolar supplies for powering high-precision op-amps and data converters in the drone system.

To customize for additional outputs, add a transformer secondary winding with the requisite number of turns, a rectifier diode, and an output capacitor.

Fly-Buck-Boost Topology

Related to the Fly-Buck, the Fly-Buck-Boost is another useful circuit for drone applications, especially if low input voltage operation or a negative-polarity output is required. Figure 5 shows the LM5017, a 100-V, 0.6-A synchronous buck converter configured to provide nonisolated ±12-V rails.

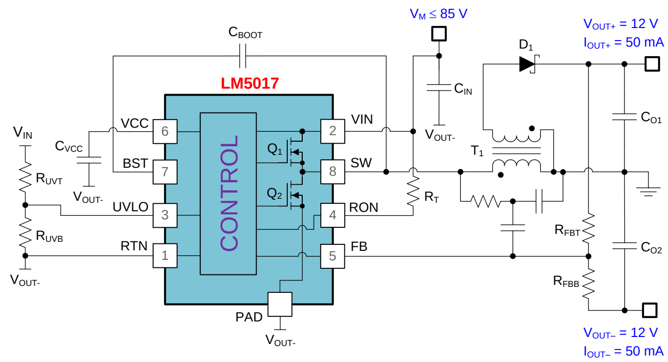

Figure 5. LM5017 Fly-Buck-Boost converter

In Figure 5, the GND of the LM5017 device is referenced to $V_{OUT–}$, and the feedback loop regulates the total of V_{OUT+} and $V_{OUT–}$, for balanced and symmetric startup and transient response behavior. Using an off-the-shelf unity turns ratio coupled inductor yields good load regulation performance and a low overall bill of materials cost. Moreover, the absence of a switch (SW) node voltage spike related to leakage inductance reduces EMI filtering requirements.

Table 1. Alternate converter recommendations

Device	V_{IN} Range, Rated I_{OUT}	Performance Feature	Package
LM5164	6 V to 100 V, 1 A	Wide V_{IN}, low I_Q	SO-8
LM5018	7.5 V to 100 V, 0.3 A	Buck and Fly-Buck capable	WSON-8, SO-8
LM5019	7.5 V to 100 V, 0.1 A	Buck and Fly-Buck capable	WSON-8, SO-8
LM5160A	4.5 V to 65 V, 2 A	Buck and Fly-Buck capable	WSON-12
LM5180	4.5 V to 65 V, 1.5 A (I_{SW-MAX})	PSR flyback	WSON-8
LM5166	3.5 V to 65 V, 0.5 A	Low EMI, low I_Q	VSON-10
LM5165	3.5 V to 65 V, 0.15 A	Low EMI, low I_Q	VSON-10, VSSOP-10

Table 2. Related TI application notes

SNVA802	Improving RF power amplifier efficiency in 5G radio systems using an adjustable DC/DC buck regulator
SNVA803	Improving EMI for free with PCB layout

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