IoT calls for a new approach to backup circuitry design

Two backup options are compared and new backup circuitry is proposed to meet a 15ms holdup time for a 12V/60W flyback converter with a 9V to 60V wide input range.

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In telecommunication applications, network devices often need input status data so that they can send out dying last-gasp messages to users in the event of a power interruption. These network devices rely on temporary energy storage such as capacitor banks, which enables graceful shutdowns and the generation of these messages. The backup (holdup) circuity is designed to last from 10 to 20ms in order to perform these tasks. This extended period is called the holdup time.

Power supply designers are likely to have two questions about the holdup circuitry, especially for a wide input DC/DC converter. The first is should the holdup capacitor be placed on the input side or output side.

Traditionally, the power supply has a bulky output capacitor bank. The output capacitor holds up the output voltage and slowly decays, thus extending operation time before total system shutdown. The holdup energy, Ecap is quadratically proportional to the capacitor voltage, V as shown in the equation:

$$Ecap = {}^{1}CcapV^{2}$$

where, Ccap is the capacitance.

Since the output voltage is slowly decaying, it requires a downstream system with a wide input voltage tolerance. If the input range is limited, the energy utilisation is poor. In the following equation, the energy utilisation rate (EU%), is defined as a percentage of energy used over the energy stored:

$$EU\% = \frac{E_{MAX} - E_{MIN}}{E_{MAX}} = \frac{V^2_{O(MAX)} - V^2_{O(MIN)}}{V^2_{O(MAX)}}$$

The second question is: for a wide input range is a two-stage or single-stage approach preferrable?

Where to place the holdup capacitor

Consider a 60V input, 12V/60W flyback converter as an example, with a design holdup time of 30ms.

In a typical 12V system operating with a minimum 8V input, the utilisation on the capacitor bank would be 55%. For sensitive equipment with a tight voltage tolerance, such as 10%, the utilisation rate would be just 19%.

It is also possible to use high voltage capacitors on the input side. If the input voltage is allowed to discharge from 60V to 9V, the energy utilisation rate improves to 97.8%.

A high voltage capacitor has higher energy density than a low voltage capacitor. For example, a 1,200µF, 80V aluminium capacitor is the same size as a 6,800µF, 16V aluminium capacitor, but its energy density is 4.4 times higher than the low voltage capacitor.

There are two designs to consider. The first design uses a simple and straightforward approach, with holdup capacitors on the output side. This requires seven 6,800µF, 16V, 16 x 40mm output capacitors, which occupy more than half the available board space. The holdup time is an estimated 32ms with a full 60W load.

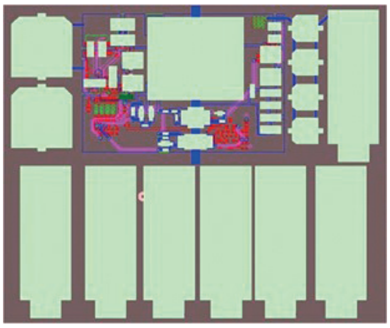

Figure 1: The holdup solution with the capacitor located on the output side.

The second design uses one high voltage, 1,200µF, 80V, 16 x 40mm input capacitor as the energy source. This single input capacitor provides a 32ms holdup time at a full load, assuming 90% system efficiency. The system efficiency reduces the available holdup time, since the flyback converter processes the input-side energy.

The first design (shown in Figure 1) measures 116.84 x 93.98mm (4.6 x 3.7 inches) which is twice as big as the second design, shown in Figure 2. The holdup time is 32ms for both designs. This comparison shows that placing the high voltage capacitor on the input side results in the use of fewer capacitors and that the input-side holdup design halves holdup capacitor bank size - and cost.

Comparing approaches

If the converter has a wide input range, such as 9V to 60V, the stored energy and energy utilisation rate will drop significantly as the input voltage level drops. At the minimum 9V input, the high voltage input capacitor offers virtually zero holdup capability.

One quick remedy is to add a boost converter in the front end (Figure 3). The boost converter steps up the wide input to 60V or higher. There are drawbacks to this two-stage approach, however. It lowers system efficiency and adds extra cost.

An alternative is to use an auxiliary

Figure 2: The input-side holdup design option measures 116.84 x 47mm.

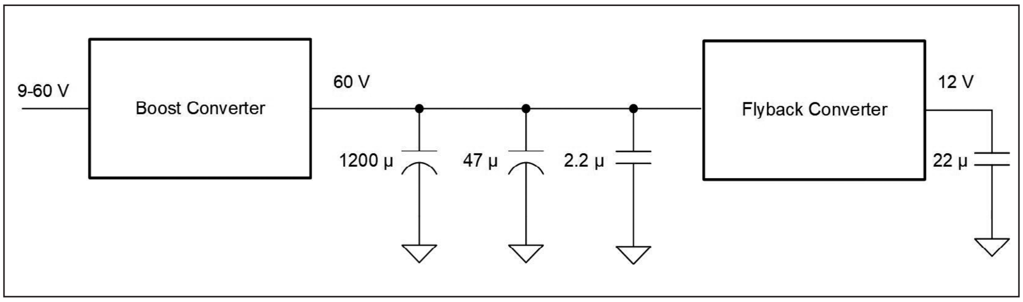

Figure 3: The traditional two-stage holdup solution.

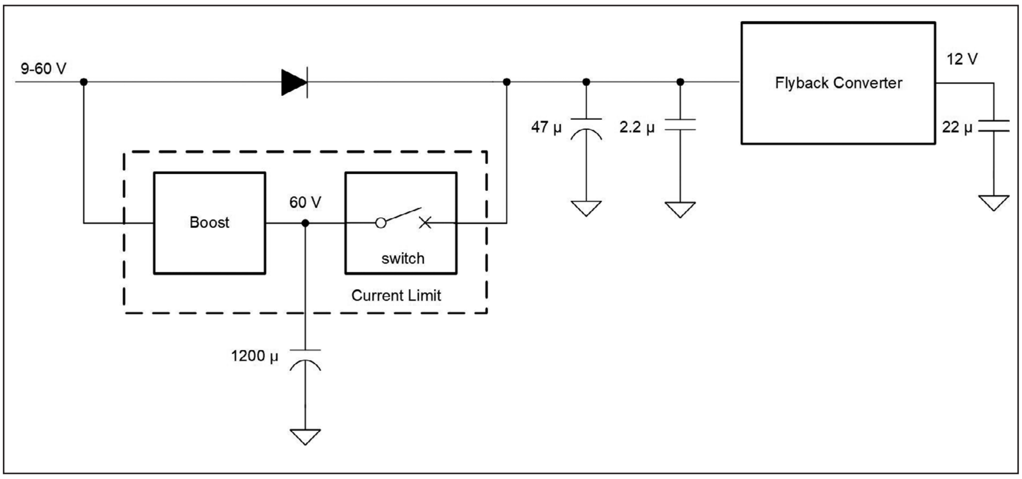

Figure 4: A proposed single-stage holdup solution maintains high efficiency.

boost converter to charge the high voltage capacitor to 60V and switch in the capacitor when the holdup circuitry detects a power interruption. Figure 4 shows this proposed high voltage holdup solution. The boost converter is not in the main power path, and therefore does not affect system efficiency.

The converter size is small given the low power level, which is just enough to charge the high voltage capacitor. The diode in Figure 4 could be a hot swap device or an ORing device, which is commonly available for telecommunication applications.

The energy transfer switch also needs special attention. It has to be fast acting; otherwise, the design needs a large amount of fixed input capacitance. It also has to limit power. During energy transfer, the flyback converter may drop to minimal operation levels while the holdup capacitor is fully charged, creating a large differential voltage across the switch. At the same time, a large amount of current is injected into the flyback input, generating tremendous electrical stress on the switch. Figure 5 illustrates a scalable current source with on/off control.

This energy transfer switch has a fast acting delay of less than 2.5µs. It also has an adjustable current limit set by the current-sense resistor. Connecting multiple current sources in parallel extends the power level. When the control FET (field effect transistor) gate is high, it pulls the main FET gate down, turning off the main transfer switch.

Figure 6 illustrates the verification of this concept in an IoT application. The flyback converter has a wide input range from 9V to 60V and the output is 12V/5A. There is only one holdup capacitor. The boost converter is small and three current sources are connected in parallel, placed on the back of the board, to relieve the device stress.

The worst-case test condition is when the input voltage is 9V. The small boost converter charges the holdup capacitor up to 60V. The power interruption detection circuitry sets the threshold at 8V. When the input voltage drops below 8V after a power interruption, the energy transfer switch turns on, thus transferring the energy from the holdup capacitor to the main flyback input capacitor. The result is that the

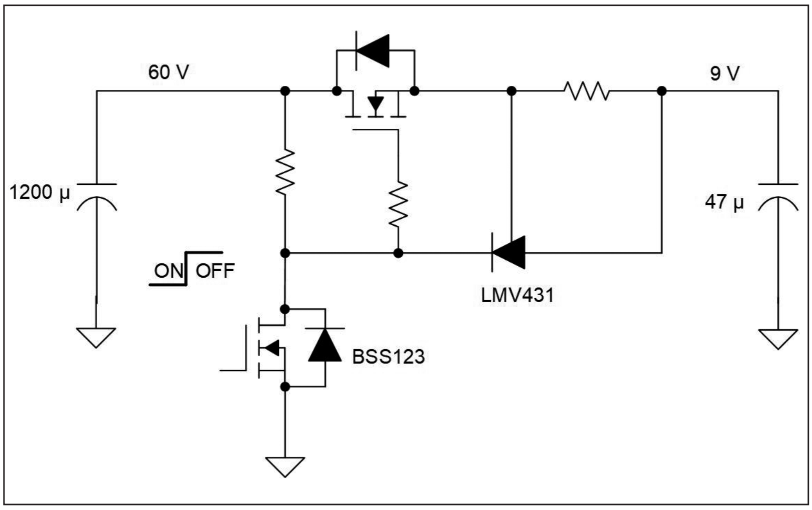

Figure 5. A scalable current source with on/off control.

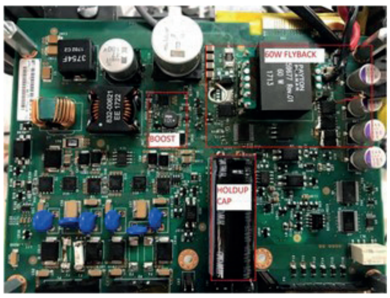

Figure 6. An IoT system example using a 60W flyback converter, holdup capacitor and a small boost converter.

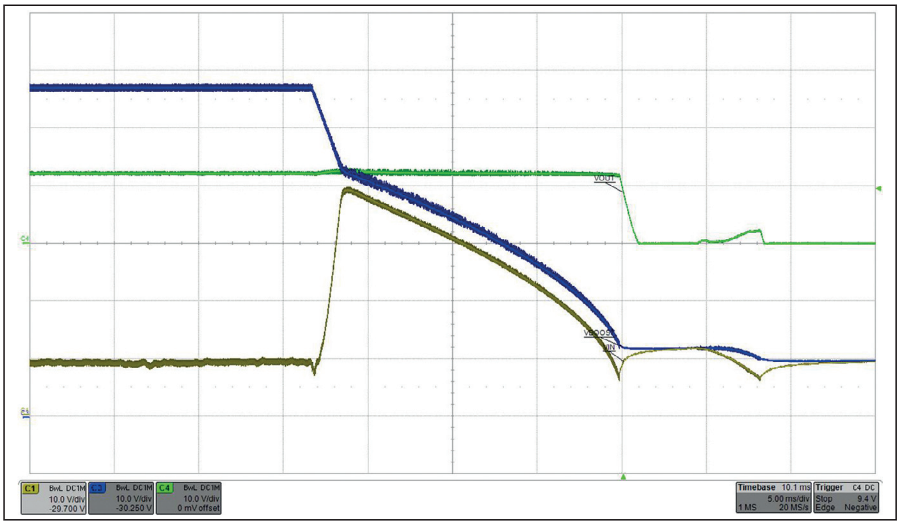

Figure 7. **Test data shows the energy transfer: holdup capacitor voltage (blue), flyback input voltage (olive green) and flyback output voltage (light green).**

holdup time is extended by 17ms.

The test data in Figure 7 shows that the flyback voltage rose from 9V to 40V during the energy transfer and the holdup capacitor voltage dropped from 58V to 43V. Both voltages depleted to supply the flyback converter for 17ms.

Conclusion

To meet the increasing holdup time requirement using a capacitor bank, two major considerations are energy density and the energy utilisation. An input-side holdup solution saves 50% board space compared to an easy-to-implement output-side holdup design, by taking advantage of the energy density and utilisation rate of a high voltage capacitor.

A backup circuitry designed to minimise insertion losses uses a small auxiliary boost converter to pump up the high voltage capacitor and a fast acting, current limiting switch to relieve stress during power dump. This proposed "pump-and-dump" solution maintains system efficiency, while the conventional two-stage solution takes a 5% efficiency hit because of the additional boost converter stage. The implementation of this backup circuitry in a 60W IoT application achieves a 17ms holdup time with a single 1,200μF holdup capacitor. This option is suitable for a wide input DC/DC converter where efficiency, space and cost are top design priorities. It also reduces the costly and bulky capacitor banks and significantly extends the holdup time of the energy storage capacitor.