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Hold-Up Modules Reduce Capacitance Requirements For High-Rel Power Supplies

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When a power supply designer needs to comply with military standards, he may need to take into account the transparency or hold-up requirement. The transparency requirement is the minimum amount of time during which input power can go away but the equipment is expected to remain operational. This power interruption duration can range from 50 ms all the way to 1000 ms for the DO-160 or Mil Std 704 standards, for example.

The simplest way to achieve such a hold-up function, is to connect the input bus to a huge tank capacitor that will store energy during normal operation, and restore it during power interruption. Of course, the actual capacitor(s) required to achieve the required hold-up time can be quite large and occupy a significant amount of space in the power system design. What's more, some additional circuitry will be needed to manage the high inrush currents that result from having such a high input capacitance.

Integrated hold-up modules offer a space saving alternative. By boosting the voltage used to charge the hold-up capacitor, these modules allow more energy to be stored in the capacitor for a given capacitance value. The end result is that long hold-up times can be achieved using relatively low values of capacitance. Consequently the space required for the hold-up capacitor(s) is greatly reduced while the module itself occupies a very small footprint.

This article will discuss hold-up requirements as they are typically encountered in military/aerospace applications using 28-V input dc-dc converters operating at different power levels. The capacitance values needed to meet a common hold-up specification using typical hold-up circuitry will be compared with capacitance values required when integrated hold-up modules are employed. The design space required with each approach will also be compared.

Calculating Hold-Up Capacitance

For a given value of hold-up time, the necessary capacitance value is given by the following formula:

$$\text{Total Capacitance} = 2 \times P \times \Delta t / (\eta \times (V_1^2 - V_2^2))$$

where :

P = power at the load

Δt =hold-up time required

η = converter efficiency

V1 = charged capacitor voltage before power drop out

V2 = final input voltage before power supply shut down.

As an example, achieving 200-ms transparency on a 28-V input bus, a 25-W dc-dc converter with 9- to 36-V input voltage range requires a capacitor value as high as 25,000 µF rated at 50 V. Not only will this capacitor be very big, but it will also result in very high inrush current to charge it, unless some additional circuit comes into play to limit it.

Fig. 1 shows an example of a typical hold-up circuit.

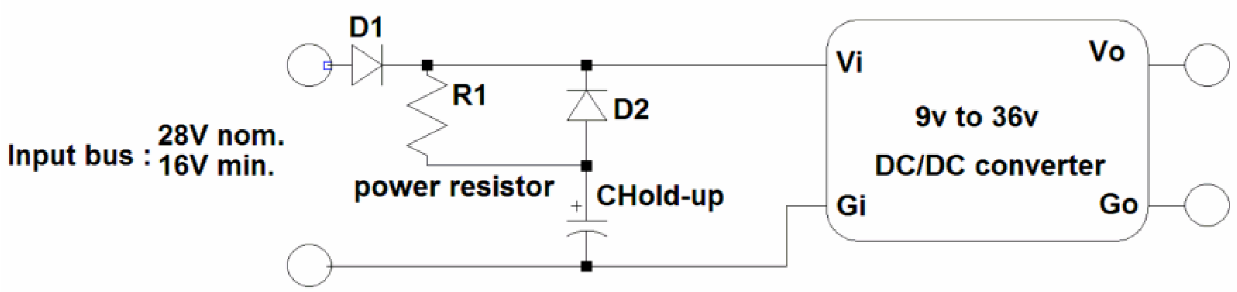

Fig. 1. Typical hold-up circuitry for a 28-V nominal input dc-dc converter.

Table 1 shows the dropout voltage V1 – V2 under different conditions of capacitor charge voltage (such as in normal operation, emergency operation or low transient on the input bus), before the input drops to 9 V, the shutdown voltage of the dc-dc converter.

Table 1. Dropout voltage as a function of input bus level.

Input bus level before dropout:	Hold-up voltage capability
28 V (normal)	19 V (28 V to 9 V)
16 V (emergency)	7 V (16 V to 9 V)
9 V (low transient)	No hold-up capability

To help reduce size, inrush current and monitor the state of charge, an integrated high-voltage module increases the voltage to which the hold-up capacitor is charged, thus increasing the stored energy for a given capacitance value. In other words, for a given level of energy storage, increasing the voltage to which the hold-up cap is charged reduces the needed capacitor value, and consequently reduces the capacitor size too.

A hold-up module such as GAIA Converter's HUGD-50 embeds a charger that charges the hold-up capacitor to the maximum input voltage that the dc-dc converter will sustain. In the case of a 28-V input converter, that voltage will typically be a constant 38 V.

In addition, the hold-up module features an active inrush current limitation and all necessary circuitry to manage the interruptions automatically, hold-up mode switching and monitoring (Fig 2.)

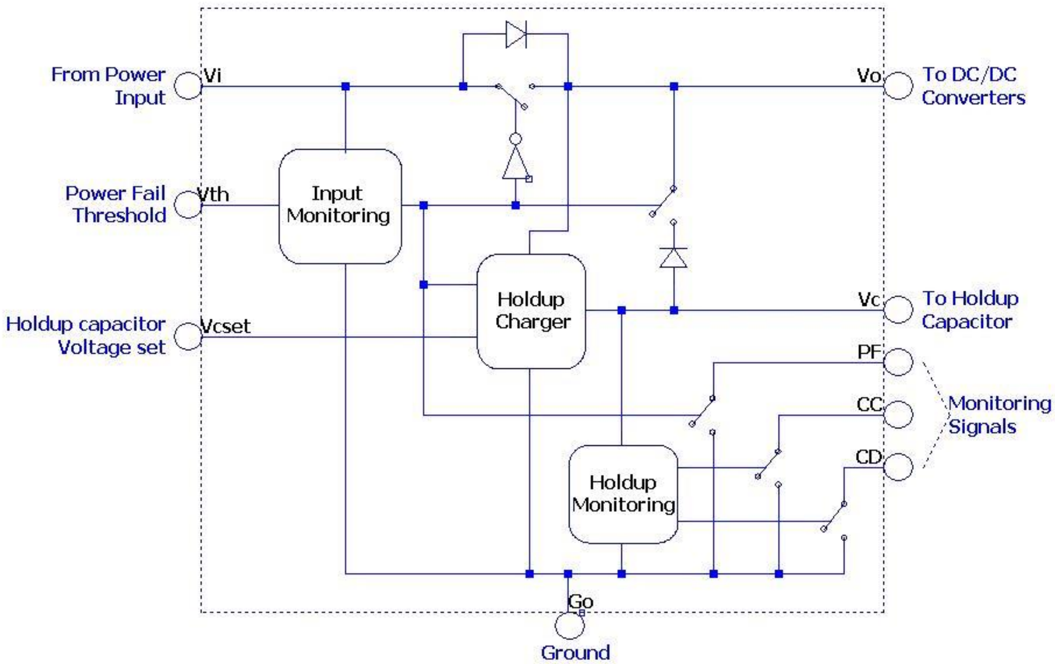

Fig. 2. Block diagram of Gaia Converter's integrated hold-up module reveals the charger and monitoring functions contained in the module.

Table 2 presents the key hold-up parameters associated with a typical example of a 25-W dc-dc converter power supply requiring 200-ms hold-up time from a charged capacitor voltage before power drops out at a 24-V input.

Table 2. Capacitance requirements for a 28-V input, 25-W dc-dc converter with 200-ms hold-up time with and without an integrated holdup module.

Application requiring 200-ms holdup	Capacitor value (μF)	Converter (cubic inches)	Typical hold-up cap volume (cubic inches)	Hold-up module volume (cubic inches)	Inrush current (A)*	Total volume (cubic inches)
9-V to 36-V 25-W dc-dc with basic hold-up capacitor	25,000	2	4.9	0	45	6.9
9-V to 36-V 25-W dc-dc with hold-up module	9,000	2	1.6	0.52	1	4.12
			Capacitor volume saved 67%		Inrush current reduction 98%	Total volume saved = 40%.

On top of significantly reducing the overall function size and inrush current, reducing the capacitor value also dramatically increases the power system's reliability. As shown above, the higher the hold-up capacitor voltage is, the smaller the physical size of the capacitor for a given hold-up time. Exploiting this higher-voltage principle together with the ever-wider input voltage ranges available with high-end dc-dc converters will help reduce hold-up size even more dramatically.

Consider another integrated hold-up module—the new HUGD-300. This module is not only 300-W rated but also able to deliver a user-programmable 30-V to 80-V voltage to the hold-up capacitor in order to multiply by almost four the stored energy for a given capacitance. On top of the charger, switching and monitoring functions, the module also features a reverse-polarity function to help designers comply with several standards such as Mil-STD-704 and Mil-STD-1275 (Fig. 3.)

This complete set of functions makes it possible to preserve a constant and maximized hold-up capability regardless of the actual input bus voltage, as long as it remains within the hold-up module range.

Fig. 3. The HUGD-300, which measures 1 in. x 1.58 in. x 0.5 in., delivers a user-programmable 30-V to 80-V voltage to the hold-up capacitor of a dc-dc converter to increase the stored energy for a given value of capacitance.

Fig 4. shows the placement of an integrated hold-up module such as the HUGD50 or HUGD300 and the associated hold-up capacitor on the input of a 28-V nominal dc-dc converter. Then table 3 lists the hold-up voltage capability, expressed as the drop out voltage V1 - V2 under different conditions of capacitor charge voltage (such as in normal operation, emergency operation or low transient input bus) before the input bus drops down to 9 V. When the input bus drops to 9 V, the dc-dc converter will shut down.

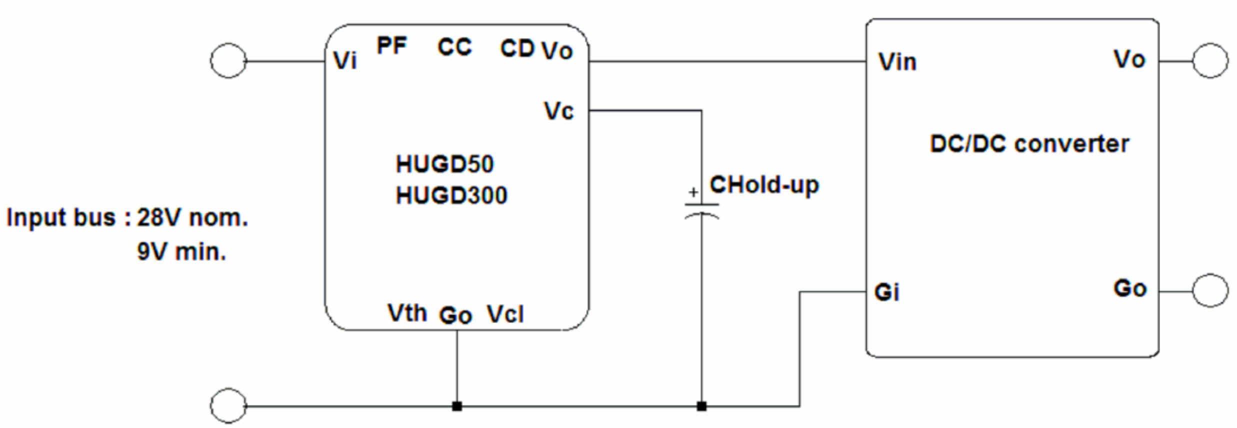

Fig. 4. Installed on the input of a dc-dc converter, an integrated hold-up module such as the HUGD50 or HUGD300 charges the hold-up capacitor to a much-higher value than the typical hold-up circuitry.

Table 3. Hold-up voltage capability of a 28-V input dc-dc converter with and without high-voltage hold up capability.

	Basic hold-up	High-voltage hold-up
Input bus level before dropout	Hold-up voltage capability	Hold-up voltage capability with 60-V setting
28 V (normal)	19 V (28 V – 9 V)	51 V (60 V – 9 V)
16 V (emergency)	7 V (16 V – 9 V)	51 V (60 V – 9 V)
9 V (low transient)	No possible hold-up	51 V (60 V – 9 V)

Table 4 shows a typical example of a 200-W dc-dc converter requiring 200-ms hold-up time, using a 9 to 60-V input voltage range dc-dc converter, such as a member of GAIA's 200-W series. In this case, the converter shuts down when the input bus level drops to 16 V.

Table 4. Converter volume for 200-W dc-dc converter with 200-ms hold-up time with and without integrated hold-up module.

Application requiring 200-ms hold-up	Cap value (mF)	Converter (cubic inches)	Typical hold-up cap volume (cubic inches)	Hold-up module volume (cubic inches)	Total volume (cubic inches)
9-60 V 200-W dc-dc with basic hold-up cap. 16 V	530	2.8	153	0	155.8
9-60 V 200-W dc-dc with hold-up module	25	2.8	4.27	0.85	7.92
				Volume saved	95%

For such high-power applications, the amount of capacitance usually makes the hold-up function not practical altogether because of its prohibitive size, inrush current, cost and reliability.

With higher voltages and integrated switching hold-up modules such as the HUGD-300, this hold-up capability now becomes feasible at just a fraction of all these critical parameters.

A typical architecture for a mil/aero application is shown here in Fig. 5.

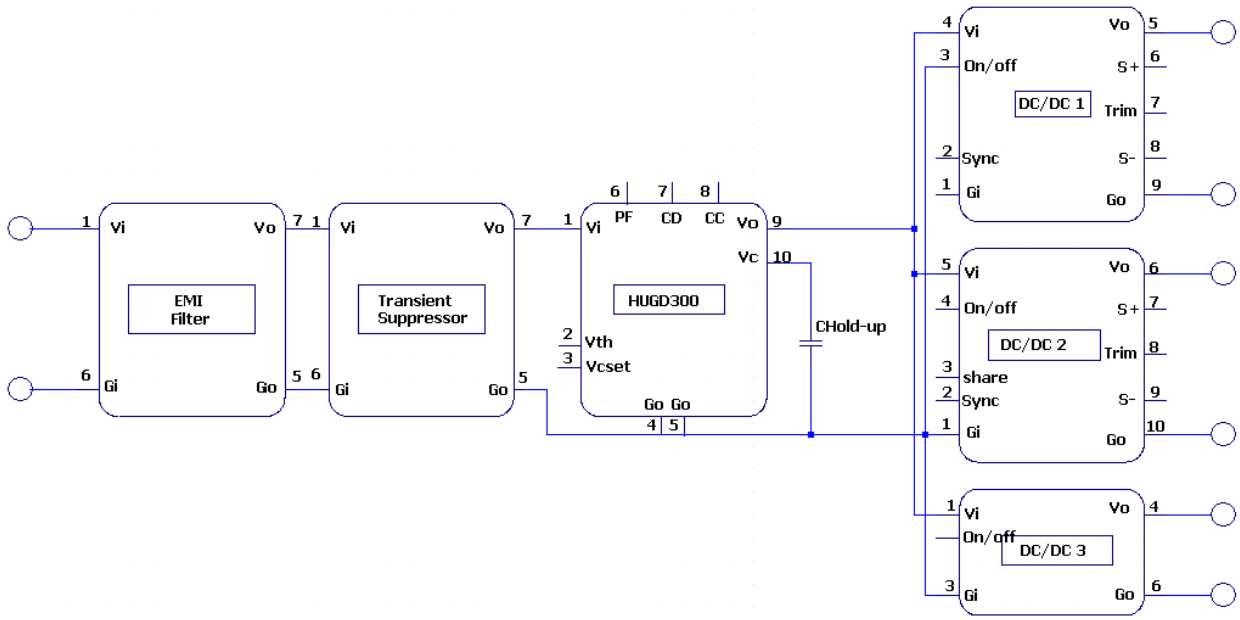

Fig. 5. Typical 28-V input distributed power architecture for a military/aerospace application.

The first two functions shown on the left are EMI filtering and transient protection (such as would be provided by Gaia's FGDS and LGDS modules, respectively). Then the hold-up function comes into play, right before power is fed to the dc-dc converters. It is important to note that the HUGD-50 or 300 hold-up module is completely transparent during normal operation and doesn't affect system stability or EMI performance, even during hold-up mode.

More details regarding such architectures can be found on Gaia Converter's website. In particular, see the application note "Modular Power Architecture Up to 300 W for Avionics/Military Applications."

About The Author

Christophe Massenet has spent the last 16 years in various electrical engineering positions, designing and managing aerospace and telecom programs with multiple power supply, RF, mechanical and thermal constraints. As the head of Gaia Converter's USA operations, he brings engineers local application, technical and logistic support. Christophe holds masters degrees in electrical engineering and business administration.

For further reading on dc-dc converters, see the How2Power Design Guide, select the Advanced Search option, go to Search by Design Guide Category and select "DC-DC converters" in the Power Supply Function category.