

Cost reduction through Traco Power's latest DC/DC converters with ULTRA-wide input voltage range

“Cost and board-space savings using Traco Power’s new 12:1 ULTRA-wide input voltage range DC/DC converters with extended holdup feature”

1 Executive Summary

Traco Power’s new line of 12:1 ultra-wide input voltage range DC/DC converters feature a dedicated holdup capacitor connection (“Bus pin”). This new feature allows the application engineer to save up to 93% on external capacitor costs while reducing their volume by up to 93%. By lowering the number of design-channels from three to one, the engineering, certification, testing, assembly, retooling, stocking, maintenance, and support effort is reduced to a minimum when compared to a conventional solution.

To demonstrate the attractiveness of the design, a case study is performed based on a real-world application: a passenger information system for use on (light) rail vehicles. The application fulfills the requirement to ride through 20ms long supply voltage interruptions, which may commonly occur in battery-powered systems. The study shows that Traco Power’s new line of 12:1 ultra-wide input voltage range of DC/DC converters with extended holdup feature compares favorably to conventional 12:1 ultra-wide input voltage range DC/DC converters as well as to state-of-the-art DC/DC converters with a 4:1 wide input voltage range.

2 Introduction

The EN 50155 standard [1] establishes important requirements for the operation, design, and testing of electronic equipment on rail vehicles. Thanks to its comprehensive consideration of “harsh” environmental conditions, the EN 50155 is often considered for design of ruggedized industrial applications. This includes continued operation during an interruption of the supply voltage for a duration of up to $T_h = 20 \text{ ms}$.

During the interruption, the input may be shorted. Power needs to be supplied from an (external) hold-up capacitor bank. The design of the holdup circuit and the dimensioning of the capacitor bank are important parts of the overall application design process.

3 Case Study: Design for Extended Holdup Time

In this case study, an original equipment manufacturer (OEM) develops a DC power supply for a cost-effective, highly compact, and lightweight passenger information system for use on (light) rail vehicles. The power supply operates at a peak power of $P_{nom} = 40 \text{ W}$, which is sufficient to supply a small screen, a field computer and networking peripherals such as industrial ethernet and/or IEEE 802.11 wireless communication.

3.1 Key Requirements of the DC power supply

Table 1 lists the most important electrical requirements of the DC power supply. The nominal input voltages include the industry standard 24 V, 48 V, 96 V and 110 V battery system voltages.

To reduce time-to-market and save on engineering, manufacturing and maintenance costs, the OEM has opted for a solution with one single power supply that accepts all input voltages

- Scenario A presents the reference design leading to the most favorable solution. The chosen Traco Power TEP 40UIR converter supports continuous operation at a nominal power over 40W over the whole input voltage range. Thanks to its dedicated holdup capacitor connection, the volume and costs of the required external capacitor bank are minimal.

In this case study, two alternative scenarios are analysed as well:

- Scenario B uses a comparable 12:1 ultra-wide input voltage range product from a competitor. However, the solution does not feature a dedicated low-voltage holdup capacitor circuit.
- Scenario C presents a reference design based on a state-of-the-art 4:1 wide input voltage range DC/DC converter, which does not feature a dedicated holdup capacitor connection. This design effectively results in a total of three different design channels with three different holdup circuits and ultimately three assembly channels.

3.2 Dimensioning of the holdup capacitor bank

The ability of the DC power supply to ride through short interruptions of the supply voltage depends on the correct design of the holdup circuit and the appropriate dimensioning of the capacitor bank. In the following, the design and dimensioning are discussed for all three scenarios.

3.2.1 Scenario A:

Figure 1 shows how the holdup capacitor bank is connected to the dedicated holdup circuit of the DC/DC converter using the extended holdup feature (“Bus pin”). During normal operation, the holdup capacitor is charged through an internal circuit of the DC/DC converter. In case of a supply voltage interruption, this circuit automatically switches the power over from the input clamps to the external holdup capacitor. A diode D_1 prevents the DC/DC converter from taking damage during an accidental reversal of the supply voltage. It also prevents discharging the hold-up capacitor bank into the main power source.

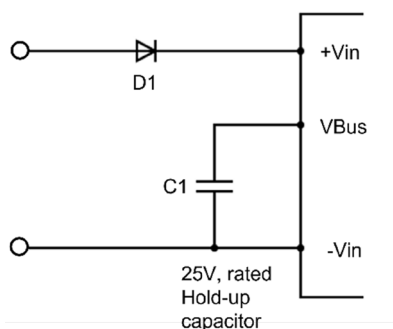


Figure 1: Simplified circuit diagram of the holdup circuit when using a DC/DC converter with a dedicated holdup capacitor connection (“Bus pin”).

The minimum holdup capacitance is calculated according to the following formula [2]:

$$C_1 = C_{h,\min} = 1.5 \cdot \frac{1}{\eta_{wc}} \cdot \frac{2P_{\text{nom}} \cdot T_{\text{hold}}}{V_{h,\text{nom}}^2 - V_{\text{UVLO}}^2} \cdot$$

In the above, η_{wc} denotes the power conversion efficiency of the DC/DC converter at full load. A factor of 1.5 is included to account for component tolerances and other non-idealities. The variable V_{UVLO} denotes the lowest input voltage at which the converter is able to operate normally. The voltage $V_{h,\text{nom}}$ is the charge voltage of the holdup capacitance during normal operation. Thanks to the extended holdup feature, this voltage is constant for all nominal input voltages during normal operation [2]:

$$V_{h,\text{nom}} = 21.4V.$$

This allows the application designer to choose cost-effective low-voltage capacitors for the holdup energy storage with a rated voltage of

$$V_{C1,\text{rated}} = 25V,$$

as recommended in [2]. Notice how this voltage is only slightly above $V_{C1,\text{nom}}$ which underlines the effectiveness of the design. The holdup time can be reached even if an interruption occurs at the lowest nominal voltage, as required by the EN 50155 [1].

3.2.2 Scenario B:

Figure 2 shows a simplified circuit diagram of the holdup capacitor connection for use with a DC/DC converter that does not feature a dedicated holdup circuit. During normal operation, the holdup capacitor C_1 is charged via an external resistor R_1 . In case of a supply voltage interruption, the holdup capacitor supplies the stored energy to the DC/DC converter via the diode D_2 . The diode D_1 prevents the converter from taking damage in case of an accidental reversal of the input voltage.

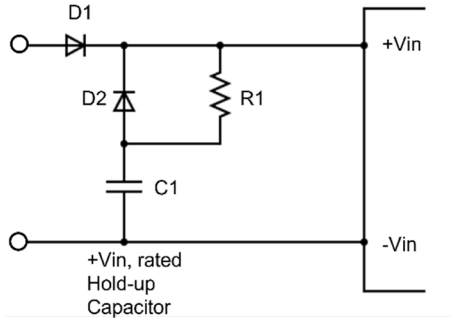


Figure 2: Simplified circuit diagram illustrating the connection of the holdup capacitor bank for the case that the DC/DC converter does not feature a dedicated holdup circuit.

The selection of R_1 presents a trade-off between limiting the inrush current and minimizing the (re-)charge time of the capacitor bank. The minimum holdup capacitance is calculated according to the following formula [3]:

$$C_2 = C_{h,\min} = 1.5 \cdot \frac{1}{\eta_{wc}} \cdot \frac{2P_{\text{nom}} \cdot T_{\text{hold}}}{V_{h,\text{nom}}^2 - V_{\text{UVLO}}^2}$$

In the above, η_{wc} again denotes the worst-case power conversion efficiency of the DC/DC converter at full load. A factor of 1.5 is included to account for component tolerances and other non-idealities. The variable V_{UVLO} denotes the lowest input voltage at which the converter can operate normally. Due to the lack of a dedicated holdup circuit, the holdup capacitor voltage follows the input voltage, which results in

$$V_{h,\text{nom}} = V_{\text{nom},\min} = 24\text{V}.$$

The capacitor bank must be designed for the maximum (transient) input voltage of

$$V_{h,\text{rated}} \geq V_{\text{in},\max} = 154\text{V}$$

The above presents a significant drawback of the conventional design. To ensure a safe operation, a voltage of $V_{h,\text{rated}} = 200\text{V}$ has been chosen.

3.2.3 Scenario C:

Since DC/DC converters with a 12:1 ultra-wide input voltage range are still relatively new on the market,

a comparison is made with a state-of-the-art design using a DC/DC converter with a 4:1 wide input voltage range. Due to the limited input voltage range, three different design channels are required resulting in three different assembly variants (one for each nominal system voltage).

As the principal design methodology for the holdup circuits is virtually identical to the design methodology outlined in Scenario B, it is not repeated herein. For a calculation of the holdup capacitance and the rated voltage using the state-of-the-art solution, refer to section 3.2.2 instead.

4 Results

Figure 1 shows the principal results of this study. For all three scenarios, the total capacitor design energy, the total capacitor costs, the number of capacitors and the total volume of the holdup capacitor bank are visualized per application.

Thanks to its dedicated holdup capacitor connection, the Traco Power TEP 40UIR converter (scenario A) leads to an overall 93% reduction of external holdup capacitor volume and an overall 93% reduction of the holdup capacitor costs compared to a design based on a conventional 12:1 ultra-wide input voltage range DC/DC converter without a dedicated holdup circuit (Scenario B).

The benefits of the reference design (scenario A) become even more apparent, when compared to a state-of-the-art solution based on a 4:1 wide input voltage range DC/DC converter (scenario C). Using the Traco Power TEP 40UIR, a reduction of capacitor volume by up to 36% and a total reduction of capacitors costs by up to 25% can be achieved while at the same time reducing the number of assembly variants from three to just one.

In other words: using Traco Power's new line of 12:1 ultra-wide input voltage range DC/DC converters with extended holdup feature ("Bus pin"), a single power supply design can cover multiple industry standard battery system voltages (24V, 48V, 96V and 110V) while reducing costs, weight, and size of the application.

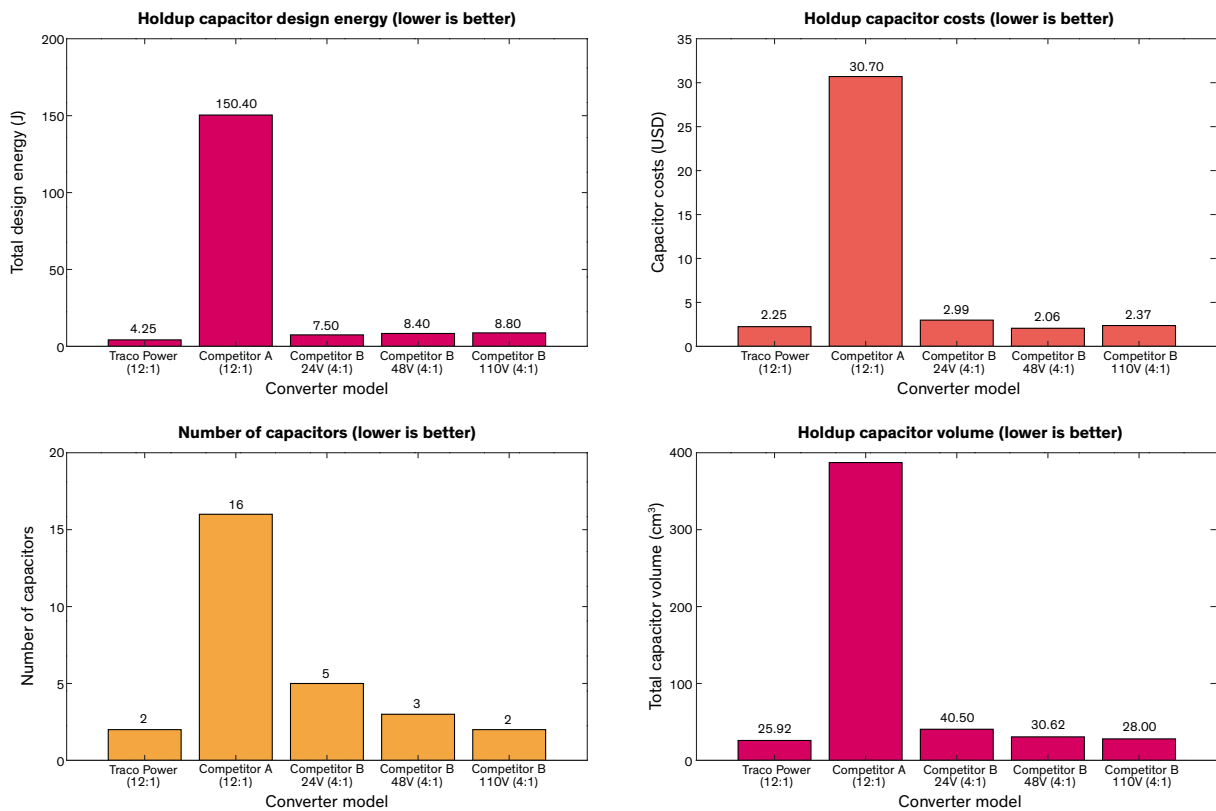


Figure 3: Comparison of the design energy, capacitor costs, number of capacitors and volume for all three scenarios

4.1 Assumptions & constraints

The case study discussed in this whitepaper is considered a real-world application. While the requirements and design decisions have been simplified to make the discussion of the principal results as comprehensive as possible, they accurately reflect the core engineering challenges of designing for continued operation during short interruptions of the DC supply voltages.

Nevertheless, it is worth noting that this whitepaper presents theoretical considerations based on ideal operating conditions and ideal component characteristics. Additional application requirements may be contractually committed or technically required (such as input filters and thermal considerations) and must be assessed separately.

Compliance guidelines and (technical) regulations may have an impact on the design and dimensioning and thereby the result of this study and shall always be taken into consideration by the application engineer. It is strongly advised that tolerances, aging, and environmental conditions are sufficiently respected in the design process and that proper risk management is in place. Different circuit variants (e.g., with active changeover of the input voltage) require different design methodologies.

A detailed discussion of additional requirements such as the ones discussed above would have gone far beyond the scope of this whitepaper and have thus been omitted for the sake of brevity.

		Scenario A	Scenario B	Scenario C		
Application		Passenger information system				
Design channels		Single		Multiple		
Holdup connection		Dedicated	With input			
Power converter		TEP 40UIR	Competitor A	Competitor B		
Output power	P_{nom}	40W	40W	40W	40W	40W
Lowest nominal input voltage	$V_{nom,min}$	24V	24V	24V	48V	96V
Highest nominal input voltage	$V_{nom,max}$	110V	110V	24V	48V	110V
Maximum (transient) input voltage	$V_{in,max}$	154V	154V	34V	67V	154V
Output voltage	$V_{out,nom}$	24V	24V	24V	24V	24V
Duration of interruption	T_{holdup}	20 ms	20 ms	20 ms	20 ms	20 ms

Table 1: Key requirements of the power circuit for a passenger information system for light (rail) vehicles.

		Scenario A	Scenario B	Scenario C		
Worst-case power-conversion efficiency	η_{wc}	90%				
Minimum required holdup capacitance	$C_{h,min}$	10'641 μ F	7'234 μ F	5'349 μ F	1'335 μ F	0.358 μ F
Maximum UVLO threshold	V_{UVLO}	14.4V	14.4V	8.8V	17.5V	42V
Capacitor rated voltage	$V_{h, rated}$	25V	200V	50V	100V	200V
Capacitor		Nichicon UPW1E682 MHD	Nichicon UPW2C471 MRD	Nichicon UPW1H12 2MHD6	Nichicon UPW2A5 61MHD	Nichicon UPW2C2 21MRD6
Number of capacitors in parallel		2	16	5	3	2
Cost per capacitor		1.12 \$	1.91 \$	0.60 \$	0.69 \$	1.19 \$
Total capacitor volume (box)		26 cm^3	387 cm^3	41 cm^3	31 cm^3	28 cm^3
Total capacitor costs		2.25 \$	30.70 \$	2.99 \$	2.06 \$	2.37 \$

Table 2: Dimensioning and design of the capacitor bank used to ride through supply voltage interruptions.

5 Conclusion

This whitepaper has discussed how the extended holdup feature (“Bus pin”) of Traco Power’s newest 12:1 ultra-wide input voltage DC/DC converters can significantly reduce the cost and volume of the passive components in a typical application. A reference DC power supply design has been made for use in a passenger information system for light (rail) vehicles. When using the Traco Power TEP 40UIR DC/DC converter, the application engineer can save up to 93% on holdup capacitor costs and reduce the volume of

the holdup capacitors by up to 93% compared to a solution based on a competitor product without a dedicated holdup circuit.

The benefit of Traco Power’s new line of 12:1 ultra-wide input voltage range DC/DC converters become even more apparent when comparing them to state-of-the art products with a 4:1 wide input voltage range. Using the TEP 40UIR, the application engineer can not only save up to 25% on holdup capacitor

costs and up to 36% on holdup capacitor volume, but at the same time safely connect to multiple battery system voltages with a single design. This way, the application engineer reduces engineering, certification, testing, assembly, retooling, stocking, maintenance, and support costs as well.

6 References

- [1] EN 50155- Railway applications – Rolling stock – Electronic equipment
- [2] Traco Bus Pin AN
- [3] General Holdup Application Note

7 Disclaimer

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