Intended Audience

This application note concerns application engineers and system engineers with technical background and contains useful information to help integrating TEN 30UIR and TEN 40UIR converters into the final application.

Introduction

The following features are described in this application note.

Enhanced Hold-Up function (see chapter «Enhanced Hold-Up function»)
The mentioned series contain an additional power hold-up function. The BUS pin is an additional feature providing a fixed voltage for charging capacitors. In general, to meet the conditions described in EN 50155, a sufficient number of aluminum electrolytic capacitors is needed to provide enough energy to extend Hold-up time. Different from the common way of hold-up functions, wether in a 24 V system or a 110 V system, the BUS pin always provides 21.4 V, which can be used with 25 V rated capacitors instead of high-priced 200 V rated capacitors

Inrush Current Limitation (see chapter «Inrush Current Limitation»)
The use of a Hold-Up capacitor helps reducing high inrush currents. No extra components will be needed. Inrush current limitation works self-sufficient as soon as Enhanced Hold-Up function is in use.

Background

When it comes to electronic equipment for rolling stock, EN 50155 is the most widely followed standard and is the gateway for power products to enter railway applications. It describes the conditions of input voltage, ambient temperature, isolation, interruption...etc. Compared with the general industrial application, the conditions are stricter in order to ensure the safety of public transportation and passengers. With the development of various industrial technologies and the requirements of miniaturization, it is a challenge for power modules and other electronic devices to meet high reliability and also meet requirements of regulations in harsh environment.

The following input voltage criteria are defined in the EN 50155 standard:

Voltage Range	Duration	Criteria
0.7 to 1.25 V_{nom}	continuous	A
1.25 to 1.4 V_{nom}	≤ 1000 ms	B
0.6 to 1.4 V_{nom}	≤ 100 ms	A

Table 1: input voltage criteria

The following interruption and change-over criteria are defined in the EN 50155 standard:

Due to a short circuit in the DC transmission line, the input voltage will drop to zero in a short time.		
Interruption	**Duration**	**Criteria**
S1		No performance criterion is requested but the equipment shall continue to operate as specified after the voltage interruption
S2	≤ 10 ms	A
S3	≤ 20 ms	A

Table 2: interruption criteria

The supply break is an open circuit and not a short circuit (“high impedance” condition). Due to switching from one source to another input voltage will drop.		
Change over	**Duration**	**Criteria**
C1	≤ 100 ms (0.6 x Unom)	A
C2	≤ 30 ms	B

Table 3: change-over criteria

Enhanced Hold-Up function

Recommended Input circuit

It is recommended to apply the circuit as follows. A series diode should be added to the input circuit to prevent stored Hold-up energy from flowing back to the DC Source in the event of a short circuit in the source path.

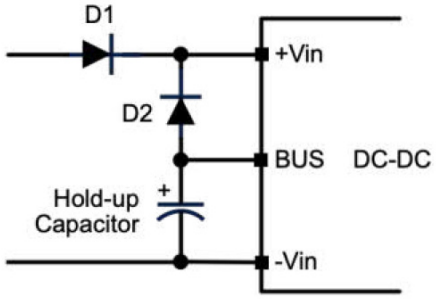

Figure 1: recommended input circuit

When an supply voltage interruption occurs, the input voltage will drop to the BUS voltage, and then the capacitors start discharging and provide energy to the power module. For best hold-up results UVLO should not be used. It has to be noted that the interval time of repeating interruptions is 10 seconds.
It has to be noted that the voltage of 21.4 V at the BUS pin is provided only if input voltage is 24 VDC or higher. If the input voltage is lower, enhanced hold-up function can not be guaranteed.

Calculation

The required capacitance of the hold-up capacitor can be calculated by using the following formulas:

For 36 Vin model (TEN 30-36xxUIR)**:**

$$C_{Hold\text{-}up} = 0.0077 \times P_{in} \times t$$

For 72 Vin models (TEN 30-72xxUIR)**:**

$$C_{Hold\text{-}up} = 0.0096 \times P_{in} \times t$$

$C_{Hold\text{-}up}$	Total capacitance of the hold-up capacitor [F]
P_{in}	max. Input power [W]
t	max. Hold-up time [s]

Recommended capacitance for $C_{HOLD\text{-}UP}$

Interruption Change-over	Model	Nominal Input Voltage 36 V	Model	Nominal Input Voltage 72 V
Capacitor voltage rating		25 V		25 V
S2 (10 ms)	TEN 30-3611UIR	2'567 µF	TEN 30-7211UIR	3'200 µF
	TEN 30-3612UIR		TEN 30-7212UIR	
	TEN 30-3613UIR		TEN 30-7213UIR	
	TEN 30-3615UIR		TEN 30-7215UIR	
	TEN 30-3622UIR		TEN 30-7222UIR	
	TEN 30-3623UIR		TEN 30-7223UIR	
S3 (20 ms)	TEN 30-3611UIR	5'133 µF	TEN 30-7211UIR	6'400 µF
	TEN 30-3612UIR		TEN 30-7212UIR	
	TEN 30-3613UIR		TEN 30-7213UIR	
	TEN 30-3615UIR		TEN 30-7215UIR	
	TEN 30-3622UIR		TEN 30-7222UIR	
	TEN 30-3623UIR		TEN 30-7223UIR	
C1 0.6 x Unom 100 ms	TEN 30-36xxUIR	$C_{HOLD\text{-}UP}$ not required	TEN 30-72xxUIR	$C_{HOLD\text{-}UP}$ not required
C2 (30 ms)	TEN 30-3611UIR	7'700 µF	TEN 30-7211UIR	9'600 µF
	TEN 30-3612UIR		TEN 30-7212UIR	
	TEN 30-3613UIR		TEN 30-7213UIR	
	TEN 30-3615UIR		TEN 30-7215UIR	
	TEN 30-3622UIR		TEN 30-7222UIR	
	TEN 30-3623UIR		TEN 30-7223UIR	

Table 4: Recommended capacitance for $C_{HOLD\text{-}UP}$ at full load, depending on TEN 30UIR model and nominal input voltage

Note: Max. hold-up capacitance must not exceed 9'900 µF. If a higher hold-up capacitance is needed anyway please contact TRACO POWER.

It is furthermore possible to use a lower capacitance for $C_{HOLD\text{-}UP}$ when actual output load is not full load. The required capacitance can be calculated by building the ratio between actual delivering output power and full load output power.

$$C_{HOLD\text{-}UP\_lower} = (\text{Actual Output Power} / \text{Full Load Output Power}) \times \text{Recommended } C_{HOLD\text{-}UP}$$

Calculation

The required capacitance of the hold-up capacitor can be calculated by using the following formulas:

For 36 Vin model (TEN 40-36xxUIR)**:**

$$C_{Hold\text{-}up} = 0.0077 \times P_{in} \times t$$

For 72 Vin models (TEN 40-72xxUIR)**:**

$$C_{Hold\text{-}up} = 0.0096 \times P_{in} \times t$$

$C_{Hold\text{-}up}$	Total capacitance of the hold-up capacitor [F]
P_{in}	max. Input power [W]
t	max. Hold-up time [s]

Recommended capacitance for $C_{HOLD\text{-}UP}$

Interruption Change-over	Model	Nominal Input Voltage 36 V	Model	Nominal Input Voltage 72 V
Capacitor voltage rating		25 V		25 V
S2 (10 ms)	TEN 40-3611UIR	3'422 µF	TEN 40-7211UIR	4'267 µF
	TEN 40-3612UIR		TEN 40-7212UIR	
	TEN 40-3613UIR		TEN 40-7213UIR	
	TEN 40-3615UIR		TEN 40-7215UIR	
	Optional model with dual 12 Vout		TEN 40-7222UIR	
	Optional model with dual 15 Vout		TEN 40-7223UIR	
S3 (20 ms)	TEN 40-3611UIR	6'844 µF	TEN 40-7211UIR	8'533 µF
	TEN 40-3612UIR		TEN 40-7212UIR	
	TEN 40-3613UIR		TEN 40-7213UIR	
	TEN 40-3615UIR		TEN 40-7215UIR	
	Optional model with dual 12 Vout		TEN 40-7222UIR	
	Optional model with dual 15 Vout		TEN 40-7223UIR	
C1 0.6 x Unom 100 ms	TEN 40-36xxUIR	$C_{HOLD\text{-}UP}$ not required	TEN 40-72xxUIR	$C_{HOLD\text{-}UP}$ not required
C2 (30 ms)	TEN 40-3611UIR	10'267 µF	TEN 40-7211UIR	12'800 µF
	TEN 40-3612UIR		TEN 40-7212UIR	
	TEN 40-3613UIR		TEN 40-7213UIR	
	TEN 40-3615UIR		TEN 40-7215UIR	
	Optional model with dual 12 Vout		TEN 40-7222UIR	
	Optional model with dual 15 Vout		TEN 40-7223UIR	

Table 4: Recommended capacitance for $C_{HOLD\text{-}UP}$ at full load, depending on TEN 40UIR model and nominal input voltage

Note: Max. hold-up capacitance must not exceed 13'000 µF. If a higher hold-up capacitance is needed anyway please contact TRACO POWER.

It is furthermore possible to use a lower capacitance for $C_{HOLD\text{-}UP}$ when actual output load is not full load. The required capacitance can be calculated by building the ratio between actual delivering output power and full load output power.

$$C_{HOLD\text{-}UP\_lower} = (\text{Actual Output Power} / \text{Full Load Output Power}) \times \text{Recommended } C_{HOLD\text{-}UP}$$

Inrush Current Limitation

Inrush current is one important characteristic that engineers must consider. When the input voltage begins to supply, the hold-up capacitors at the input terminal will cause a high inrush current, which often blows a fuse or causes error operation to other devices.
By connecting capacitors to the BUS pin, the inrush current is limited effectively via the internal charging path that reduces the need of extra external components.

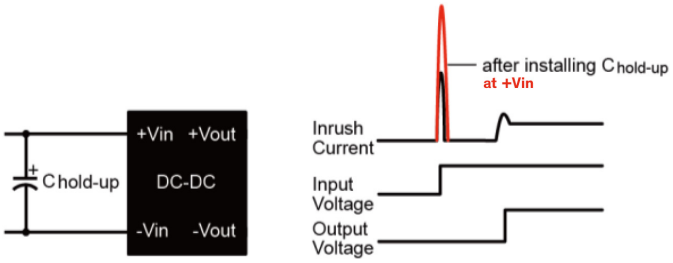

Figure 6: Capacitor at the input terminal between + Vin and - Vin

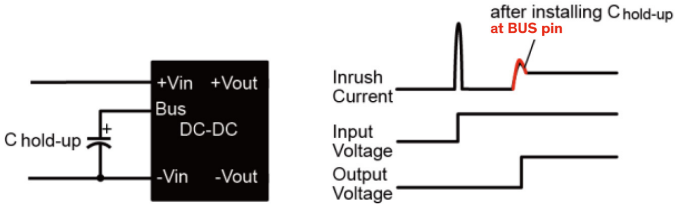

Figure 7: Capacitor between BUS and - Vin

Conclusion

With the possibility to connect capacitors at the BUS pin instead of connecting them at the input line it is possible to:
- To use cost-optimized and better available low voltage capacitors. For for high input voltage applications as well.
- To prevent very high inrush currents due to the hold-up capacitance.