TRACO POWER

Enhanced Hold-Up & Inrush Current Limitation   TEP 40UIR & TEP 60UIR & TEP 100UIR Series

Intended Audience

This application note concerns application engineers and system engineers with technical background and contains useful information to help integrating TEP 40UIR, TEP 60UIR and TEP 100UIR 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 inputs 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.
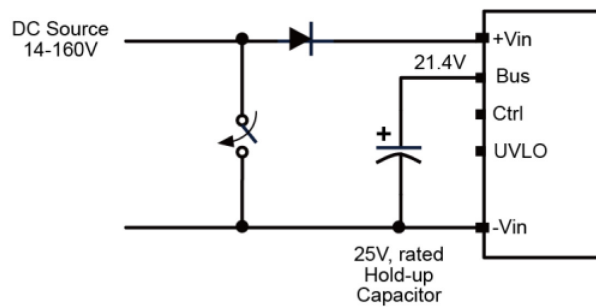

Figure 1: recommended input circuit

When a 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.
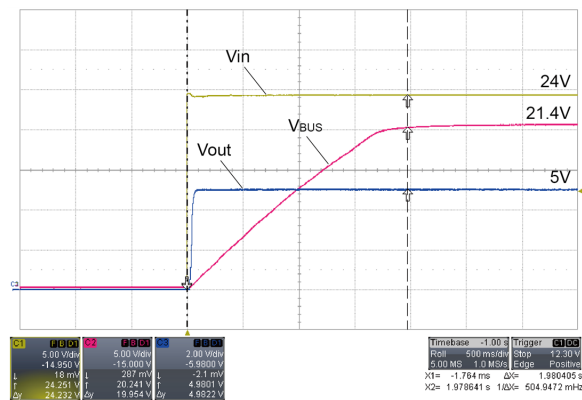

Figure 2: Start-up characteristic
V_{in} = 24 V / Full load / $C_{hold-up}$ = 11'000 μF

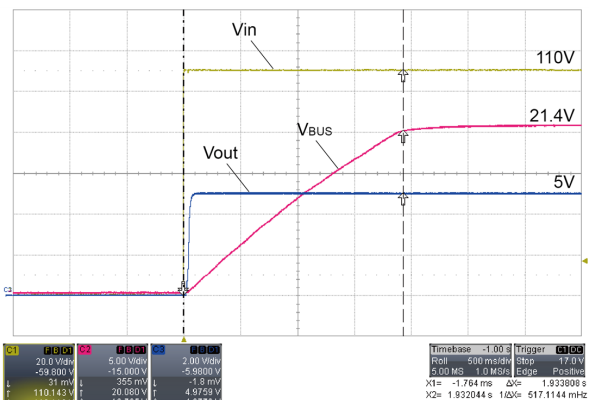*Figure 3: Start-up characteristic*
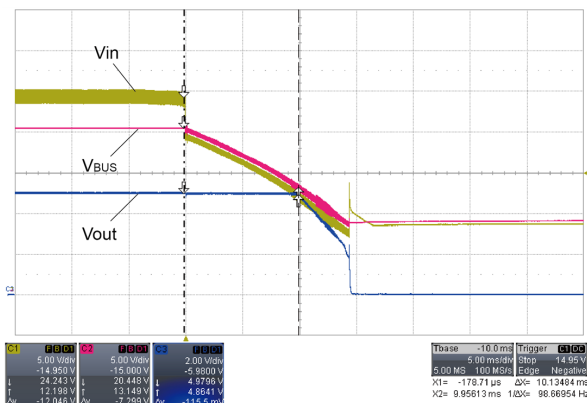V_{in} = 110 V / Full load / $C_{hold-up}$ = 11'000 μF

Figure 4: Hold-up characteristic after supply interruption
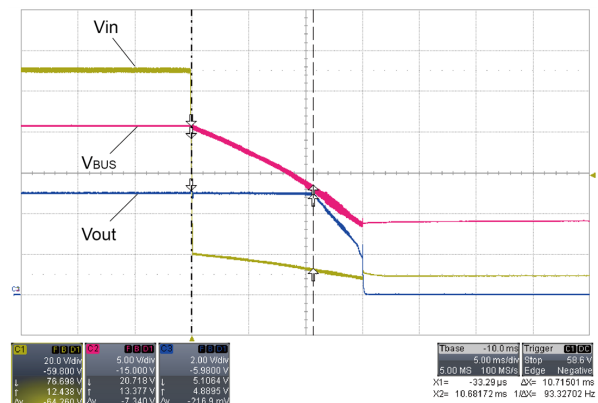V_{in} = 24 V; Full load; $C_{hold-up}$ = 11'000 μF

Figure 5: Hold-up characteristic after supply interruption
V_{in} = 110 V; Full load; $C_{hold-up}$ = 11'000 μF

Calculation

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

For 36 Vin model (TEP xx-36xxUIR)**:**

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

For 72 Vin models (TEP xx-72xxUIR)**:**

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

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

Recommended capacitance for $C_{HOLD-UP}$

Interruption Change-over	Model	Nominal Input Voltage 36 V	Model	Nominal Input Voltage 110 V
Capacitor voltage rating		25 V		25 V
S2 (10 ms)	TEP 40-3611UIR	3'500 µF	TEP 40-7211UIR	4'400 µF
	TEP 40-3612UIR	3'400 µF	TEP 40-7212UIR	4'300 µF
	TEP 40-3613UIR		TEP 40-7213UIR	
	TEP 40-3615UIR	3'500 µF	TEP 40-7215UIR	4'300 µF
	TEP 40-3618UIR	3'400 µF	TEP 40-7218UIR	
S3 (20 ms)	TEP 40-3611UIR	7'000 µF	TEP 40-7211UIR	8'700 µF
	TEP 40-3612UIR	6'800 µF	TEP 40-7212UIR	8'500 µF
	TEP 40-3613UIR		TEP 40-7213UIR	
	TEP 40-3615UIR	6'900 µF	TEP 40-7215UIR	8'600 µF
	TEP 40-3618UIR	6'800 µF	TEP 40-7218UIR	8'500 µF
C1 0.6 x Unom 100 ms	TEP 40-xxxxUIR	$C_{HOLD-UP}$ not required	TEP 40-xxxxUIR	$C_{HOLD-UP}$ not required
C2 (30 ms)	TEP 40-3611UIR	10'400 µF	TEP 40-7211UIR	13'000 µF
	TEP 40-3612UIR	10'200 µF	TEP 40-7212UIR	12'700 µF
	TEP 40-3613UIR		TEP 40-7213UIR	
	TEP 40-3615UIR	10'300 µF	TEP 40-7215UIR	12'800 µF
	TEP 40-3618UIR	10'200 µF	TEP 40-7218UIR	

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

It is furthermore possible to use a lower capacitance for $C_{HOLD-UP}$ 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.

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

Interruption Change-over	Model	Nominal Input Voltage 36 V	Model	Nominal Input Voltage 110 V
Capacitor voltage rating		25 V		25 V
S2 (10 ms)	TEP 60-3611UIR	5'200 µF	TEP 60-7211UIR	6'500 µF
	TEP 60-3612UIR		TEP 60-7212UIR	
	TEP 60-3613UIR	5'200 µF	TEP 60-7213UIR	
	TEP 60-3615UIR		TEP 60-7215UIR	6'400 µF
	TEP 60-3618UIR	5'100 µF	TEP 60-7218UIR	
S3 (20 ms)	TEP 60-3611UIR	10'400 µF	TEP 60-7211UIR	13'000 µF
	TEP 60-3612UIR		TEP 60-7212UIR	
	TEP 60-3613UIR	10'300 µF	TEP 60-7213UIR	
	TEP 60-3615UIR		TEP 60-7215UIR	12'800 µF
	TEP 60-3618UIR	10'200 µF	TEP 60-7218UIR	
C1 0.6 x Unom 100 ms	TEP 60-xxxxUIR	$C_{HOLD-UP}$ not required	TEP 60-xxxxUIR	$C_{HOLD-UP}$ not required
C2 (30 ms)	TEP 60-3611UIR	15'600 µF	TEP 60-7211UIR	19'500 µF
	TEP 60-3612UIR		TEP 60-7212UIR	
	TEP 60-3613UIR	15'400 µF	TEP 60-7213UIR	
	TEP 60-3615UIR		TEP 60-7215UIR	19'200 µF
	TEP 60-3618UIR	15'300 µF	TEP 60-7218UIR	

Table 5: Recommended capacitance for $C_{HOLD-UP}$ at full load, depending on TEP 60UIR model and nominal input voltage

Interruption Change-over	Model	Nominal Input Voltage 36 V	Model	Nominal Input Voltage 110 V
Capacitor voltage rating		25 V		25 V
S2 (10 ms)	TEP 100-3611UIR	8'800 µF	TEP 100-7211UIR	11'000 µF
	TEP 100-3612UIR		TEP 100-7212UIR	
	TEP 100-3613UIR	8'700 µF	TEP 100-7213UIR	
	TEP 100-3615UIR	8'800 µF	TEP 100-7215UIR	
	TEP 100-3618UIR	8'600 µF	TEP 100-7218UIR	10'800 µF
S3 (20 ms)	TEP 100-3611UIR	17'500 µF	TEP 100-7211UIR	21'900 µF
	TEP 100-3612UIR		TEP 100-7212UIR	
	TEP 100-3613UIR	17'400 µF	TEP 100-7213UIR	
	TEP 100-3615UIR	17'500 µF	TEP 100-7215UIR	
	TEP 100-3618UIR	17'200 µF	TEP 100-7218UIR	21'600 µF
C1 0.6 x Unom 100 ms	TEP 100-xxxxUIR	$C_{HOLD-UP}$ not required	TEP 100-xxxxUIR	$C_{HOLD-UP}$ not required
C2 (30 ms)	TEP 100-3611UIR	26'300 µF	TEP 100-7211UIR	32'800 µF
	TEP 100-3612UIR		TEP 100-7212UIR	
	TEP 100-3613UIR	26'000 µF	TEP 100-7213UIR	
	TEP 100-3615UIR	26'300 µF	TEP 100-7215UIR	
	TEP 100-3618UIR	25'700 µF	TEP 100-7218UIR	32'400 µF

Table 6: Recommended capacitance for $C_{HOLD-UP}$ at full load, depending on TEP 100UIR model and nominal input voltage

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.
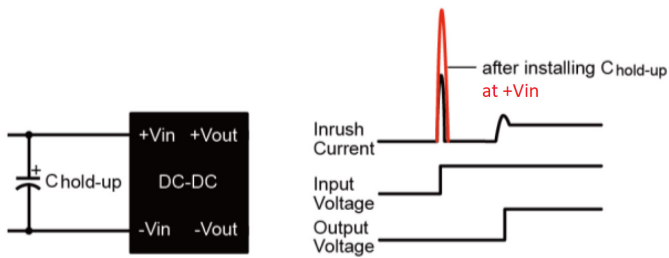

Figure 6: Capacitor at the input terminal between + Vin and - Vin
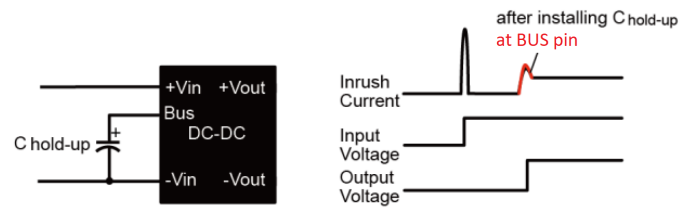

Figure 7: Capacitor between BUS and - Vin

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.