

Intended Audience

This application note concerns application engineers and system engineers with technical background and contains useful information to help integrating THN 10UIR, THN 15UIR, and THN 20UIR 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, whether 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 U_{nom})	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.

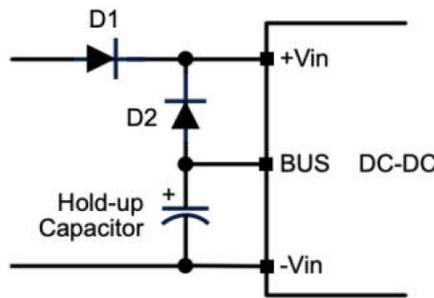


Figure 1: recommended input circuit

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.

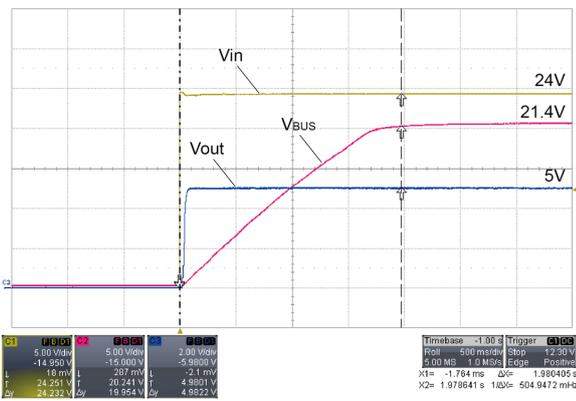


Figure 2: Start-up characteristic
 $V_{in} = 24\text{ V} / \text{Full load} / C_{hold-up} = 11'000\ \mu\text{F}$

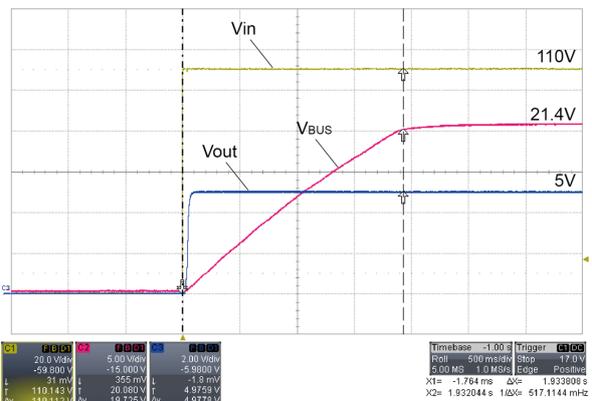


Figure 3: Start-up characteristic
 $V_{in} = 110\text{ V} / \text{Full load} / C_{hold-up} = 11'000\ \mu\text{F}$

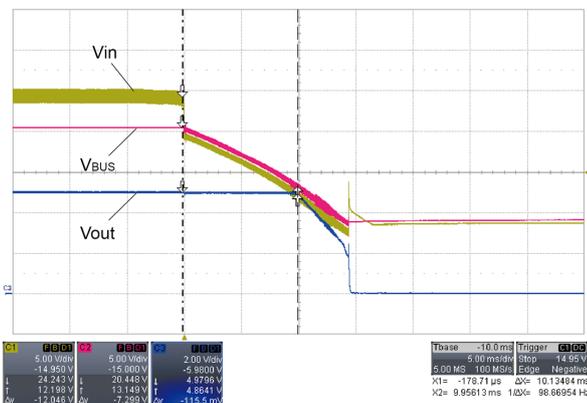


Figure 4: Hold-up characteristic after supply interruption
 $V_{in} = 24\text{ V}; \text{Full load}; C_{hold-up} = 11'000\ \mu\text{F}$

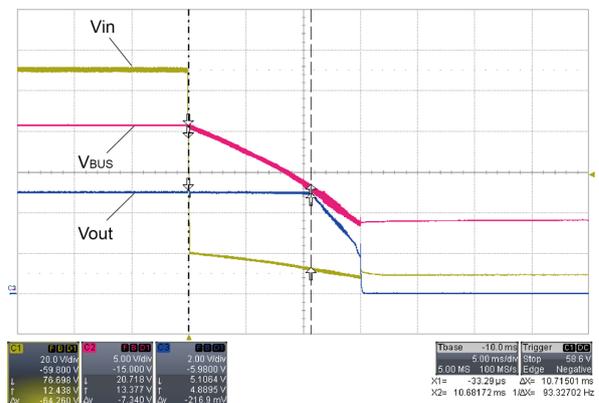


Figure 5: Hold-up characteristic after supply interruption
 $V_{in} = 110\text{ V}; \text{Full load}; C_{hold-up} = 11'000\ \mu\text{F}$

Formula to calculate hold-up capacitor

Calculation

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

For 36 Vin model (THN xx-36xxUIR):

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

For 72 Vin models (THN xx-72xxUIR):

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

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

Pre-calculated values for hold-up capacitor for every model are listed on the following pages.

Recommended capacitance for $C_{\text{HOLD-UP}}$ (for THN 10UIR series)

Interruption Change-over	Model	Nominal Input Voltage		Model	Nominal Input Voltage	
		36 V			72 V	
Capacitor voltage rating		25 V		25 V		
S2 (10 ms)	THN 10-3610UIR	906 μF		THN 10-7210UIR	1'116 μF	
	THN 10-3611UIR	895 μF		THN 10-7211UIR	1'091 μF	
	THN 10-3612UIR	875 μF		THN 10-7212UIR		
	THN 10-3613UIR			THN 10-7213UIR	1'079 μF	
	THN 10-3615UIR			THN 10-7215UIR	1'103 μF	
	THN 10-3621UIR	928 μF		THN 10-7221UIR	1'143 μF	
	THN 10-3622UIR	885 μF		THN 10-7222UIR	1'103 μF	
	THN 10-3623UIR			THN 10-7223UIR	1'091 μF	
S3 (20 ms)	THN 10-3610UIR	1'812 μF		THN 10-7210UIR	2'233 μF	
	THN 10-3611UIR	1'791 μF		THN 10-7211UIR	2'182 μF	
	THN 10-3612UIR	1'750 μF		THN 10-7212UIR		
	THN 10-3613UIR			THN 10-7213UIR	2'157 μF	
	THN 10-3615UIR			THN 10-7215UIR	2'207 μF	
	THN 10-3621UIR	1'855 μF		THN 10-7221UIR	2'286 μF	
	THN 10-3622UIR	1'770 μF		THN 10-7222UIR	2'207 μF	
	THN 10-3623UIR			THN 10-7223UIR	2'182 μF	
C1 0.6 x U_{nom} 100 ms	THN 10-36xxUIR	$C_{\text{HOLD-UP}}$ not required		THN 10-72xxUIR	$C_{\text{HOLD-UP}}$ not required	
C2 (30 ms)	THN 10-3610UIR	2'718 μF		THN 10-7210UIR	3'349 μF	
	THN 10-3611UIR	2'686 μF		THN 10-7211UIR	3'273 μF	
	THN 10-3612UIR	2'625 μF		THN 10-7212UIR		
	THN 10-3613UIR			THN 10-7213UIR	3'236 μF	
	THN 10-3615UIR			THN 10-7215UIR	3'310 μF	
	THN 10-3621UIR	2'783 μF		THN 10-7221UIR	3'429 μF	
	THN 10-3622UIR	2'655 μF		THN 10-7222UIR	3'310 μF	
	THN 10-3623UIR			THN 10-7223UIR	3'273 μF	

Table 4: Recommended capacitance for $C_{\text{HOLD-UP}}$ at full load, depending on THN 10UIR model and nominal input voltage

Note: Max. hold-up capacitance must not exceed 3'300 μF . If a higher hold-up capacitance is needed anyway please contact TRACO POWER.

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

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

Recommended capacitance for $C_{\text{HOLD-UP}}$ (for THN 15UIR series)

Interruption Change-over	Model	Nominal Input Voltage	Model	Nominal Input Voltage
		36 V		72 V
Capacitor voltage rating		25 V	25 V	
S2 (10 ms)	THN 15-3611UIR	1'328 μF	THN 15-7211UIR	1'655 μF
	THN 15-3612UIR	1'313 μF	THN 15-7212UIR	1'636 μF
	THN 15-3613UIR		THN 15-7213UIR	1'655 μF
	THN 15-3615UIR			
	THN 15-3622UIR	1'328 μF	THN 15-7222UIR	3'310 μF
	THN 15-3623UIR	1'313 μF	THN 15-7223UIR	
S3 (20 ms)	THN 15-3611UIR	2'655 μF	THN 15-7211UIR	
	THN 15-3612UIR	2'625 μF	THN 15-7212UIR	3'273 μF
	THN 15-3613UIR		THN 15-7213UIR	3'310 μF
	THN 15-3615UIR			
	THN 15-3622UIR	2'655 μF	THN 15-7222UIR	C _{HOLD-UP} not required
	THN 15-3623UIR	2'625 μF	THN 15-7223UIR	
C1 0.6 x Unom 100 ms	THN 15-36xxUIR	C _{HOLD-UP} not required	THN 15-72xxUIR	
	C2 (30 ms)	THN 15-3611UIR	3'983 μF	THN 15-7211UIR
THN 15-3612UIR		3'938 μF	THN 15-7212UIR	4'909 μF
THN 15-3613UIR			THN 15-7213UIR	4'966 μF
THN 15-3615UIR				
THN 15-3622UIR		3'983 μF	THN 15-7222UIR	C _{HOLD-UP} not required
THN 15-3623UIR		3'938 μF	THN 15-7223UIR	

Table 4: Recommended capacitance for $C_{\text{HOLD-UP}}$ at full load, depending on THN 15UIR model and nominal input voltage

Note: Max. hold-up capacitance must not exceed 7'000 μF . If a higher hold-up capacitance is needed anyway please contact TRACO POWER.

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

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

Recommended capacitance for $C_{\text{HOLD-UP}}$ (for THN 20UIR series)

Interruption Change-over	Model	Nominal Input Voltage		Model	Nominal Input Voltage	
		36 V			72 V	
Capacitor voltage rating		25 V		25 V		
S2 (10 ms)	THN 20-3611UIR	1'770 μF		THN 20-7211UIR	2'207 μF	
	THN 20-3612UIR	1'750 μF		THN 20-7212UIR	2'182 μF	
	THN 20-3613UIR					
	THN 20-3615UIR					
	THN 20-3622UIR					
	THN 20-3623UIR					
S3 (20 ms)	THN 20-3611UIR	3'540 μF		THN 20-7211UIR	4'414 μF	
	THN 20-3612UIR	3'500 μF		THN 20-7212UIR	4'364 μF	
	THN 20-3613UIR					
	THN 20-3615UIR					
	THN 20-3622UIR					
	THN 20-3623UIR					
C1 0.6 x U_{nom} 100 ms	THN 20-36xxUIR	$C_{\text{HOLD-UP}}$ not required		THN 20-72xxUIR	$C_{\text{HOLD-UP}}$ not required	
C2 (30 ms)	THN 20-3611UIR	5'310 μF		THN 20-7211UIR	6'621 μF	
	THN 20-3612UIR	5'250 μF		THN 20-7212UIR	6'545 μF	
	THN 20-3613UIR					
	THN 20-3615UIR					
	THN 20-3622UIR					
	THN 20-3623UIR					

Table 5: Recommended capacitance for $C_{\text{HOLD-UP}}$ at full load, depending on THN 20UIR model and nominal input voltage

Note: Max. hold-up capacitance must not exceed 7'000 μF . If a higher hold-up capacitance is needed anyway please contact TRACO POWER.

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

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

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.

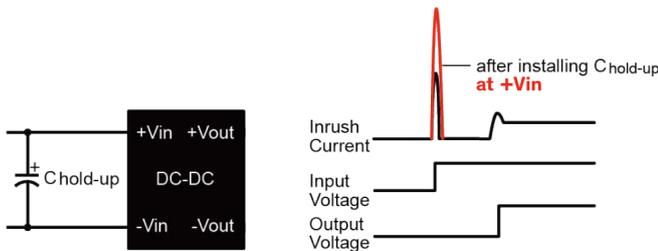


Figure 6: Capacitor at the input terminal between + Vin and - Vin

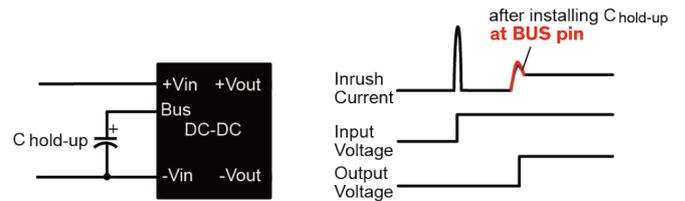


Figure 7: Capacitor between BUS and - Vin

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.