

### Intended Audience

This application note concerns application engineers and system engineers with technical background and contains useful information to help integrating both TEP 150UIR and TEP 200UIR 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 enlarge Hold-up time.

#### Active Inrush Current Limitation (see chapter «Active Inrush Current Limitation»)

Using capacitors in any circuit like input filter or hold-up will generate a huge charging current when starting up the application. This start-up current is called Inrush Current. If the energy is high enough, it will blow fuses or trigger protection features like over current protection (OCP) or short circuit protection (SCP). This causes the application to stop working after a very short period of time.

Mentioned series feature an Active Inrush Current Limitation for a softer start after powering up the application.

### 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 criterias 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 $V_{nom}$	$\leq 1000$ ms	B
0.6 to 1.4 $V_{nom}$	$\leq 100$ ms	A

Table 1: input voltage criteria

The following interruption and changer over criterias are defined in the EN 50155 standard:

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

Table 2: interruption criteria

Change over	Duration	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.		
C1	$\leq 100$ ms (0.6 x $U_{nom}$ )	A
C2	$\leq 30$ 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 does not to be added to the input circuit. Both the TEP 150UIR series and the TEP 200UIR series have a integrated diode internally in order to avoid a short circuit path that keeps the energy of the capacitor flowing into the power supply.

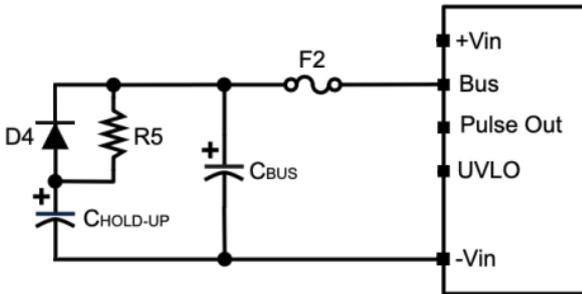


Figure 1: Recommended input circuit

Component	Specification
D4	200 V / 10 A / SBR10U200P5
R5	100 Ω / 5 W
F2	5 A / fast acting
C <sub>BUS</sub>	150 μF / 200 V / KXJ series
C <sub>HOLD-UP</sub>	See table below

Table 4: Recommended input circuit

- Notes:
- Fuse F2 ist not necessarily needed. The fuse can protect the module from short circuits caused by peripheral components connected to the BUS pin.
  - C<sub>BUS</sub> should always be installed and connected to the BUS pin for module's stability.

When a supply voltage interrupt 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.

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 voltages between 80 and 160 volts, which is helpful to reduce the needed total hold-up capacitance.

Other than the smaller TEP 40UIR series, TEP 60UIR series and TEP 100UIR series and due to their high power density, TEP 150UIR series and TEP 200UIR series can provide a fixed BUS voltage of up to 80 volts input voltage. This requires a higher voltage rating for C<sub>Hold-Up</sub>.

On higher input voltages the BUS voltage raises linearly with the actual input voltage. The use of a correct capacitor voltage rating has to be considered in the design phase.

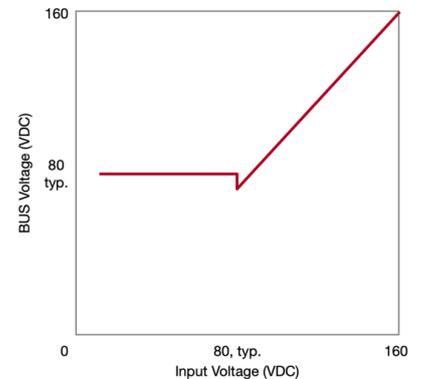


Figure 2: BUS voltage curve

### Example: Interruption S2

TEP 200-7211UIR, 72 Vin, Full load, C<sub>HOLD-UP</sub> = 3'000 μF

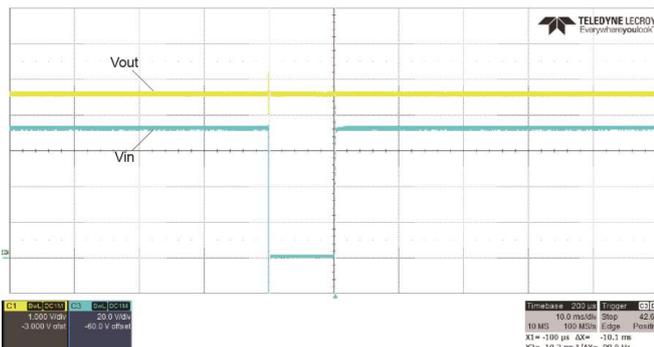


Figure 3: interruption S2

### Example: Change-over C2

TEP 200-7211UIR, 72 Vin, Full load, C<sub>HOLD-UP</sub> = 8'800 μF

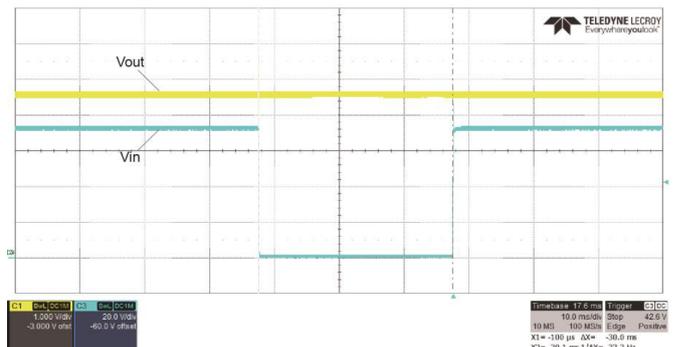


Figure 4: change-over C2

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

Interruption Change-over	Model	Nominal Input Voltage			Model	Nominal Input Voltage		
		24 V, 36 V, 48 V, 72 V	96 V	110 V		24 to 72 V	96 V	110 V
<b>Capacitor voltage rating</b>		100 V	160 V		100 V	160 V		
<b>S2 (10 ms)</b>	TEP 150-7211UIR	2'400 $\mu\text{F}$	800 $\mu\text{F}$	500 $\mu\text{F}$	TEP 200-7211UIR	3'000 $\mu\text{F}$	1'100 $\mu\text{F}$	640 $\mu\text{F}$
	TEP 150-7212UIR	1'800 $\mu\text{F}$			TEP 200-7212UIR	2'400 $\mu\text{F}$		
	TEP 150-7213UIR	2'400 $\mu\text{F}$			TEP 200-7213UIR	3'000 $\mu\text{F}$		
	TEP 150-7215UIR	1800 $\mu\text{F}$			TEP 200-7215UIR	2'400 $\mu\text{F}$		
	TEP 150-7216UIR	2'400 $\mu\text{F}$			TEP 200-7216UIR	3'000 $\mu\text{F}$		
	TEP 150-7218UIR				TEP 200-7218UIR			
	TEP 150-72153UIR	1'800 $\mu\text{F}$			TEP 200-72153UIR	2'400 $\mu\text{F}$		
<b>S3 (20 ms)</b>	TEP 150-7211UIR	4'800 $\mu\text{F}$	1'600 $\mu\text{F}$	1'000 $\mu\text{F}$	TEP 200-7211UIR	6'000 $\mu\text{F}$	2'200 $\mu\text{F}$	1'300 $\mu\text{F}$
	TEP 150-7212UIR	3'600 $\mu\text{F}$			TEP 200-7212UIR	4'800 $\mu\text{F}$		
	TEP 150-7213UIR	4'800 $\mu\text{F}$			TEP 200-7213UIR	6'000 $\mu\text{F}$		
	TEP 150-7215UIR	3'600 $\mu\text{F}$			TEP 200-7215UIR	4'800 $\mu\text{F}$		
	TEP 150-7216UIR	4'800 $\mu\text{F}$			TEP 200-7216UIR	6'000 $\mu\text{F}$		
	TEP 150-7218UIR				TEP 200-7218UIR			
	TEP 150-72153UIR	3'600 $\mu\text{F}$			TEP 200-72153UIR	4'800 $\mu\text{F}$		
<b>C1 0.6 x U<sub>nom</sub> 100 ms</b>	TEP 150-xxxxUIR	$C_{\text{HOLD-UP}}$ not required			TEP 200-xxxxUIR	$C_{\text{HOLD-UP}}$ not required		
<b>C2 (30 ms)</b>	TEP 150-7211UIR	6'800 $\mu\text{F}$	2'400 $\mu\text{F}$	1'500 $\mu\text{F}$	TEP 200-7211UIR	8'800 $\mu\text{F}$	3'300 $\mu\text{F}$	1'900 $\mu\text{F}$
	TEP 150-7212UIR	4'900 $\mu\text{F}$			TEP 200-7212UIR	6'800 $\mu\text{F}$		
	TEP 150-7213UIR	6'800 $\mu\text{F}$			TEP 200-7213UIR	8'800 $\mu\text{F}$		
	TEP 150-7215UIR	4'900 $\mu\text{F}$			TEP 200-7215UIR	6'800 $\mu\text{F}$		
	TEP 150-7216UIR	6'800 $\mu\text{F}$			TEP 200-7216UIR	8'800 $\mu\text{F}$		
	TEP 150-7218UIR				TEP 200-7218UIR			
	TEP 150-72153UIR	4'900 $\mu\text{F}$			TEP 200-72153UIR	6'800 $\mu\text{F}$		

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

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.

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

## Active 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.

The Pulse pin from TEP 150UIR series and TEP 200UIR series provides a 12 V / 1 kHz square wave signal which can be used on the inrush current limit circuit. By connecting the Active Inrush Current Limitation circuitry to the Pulse pin, the inrush current is limited effectively.

### Active Inrush Current Limitation Circuit:

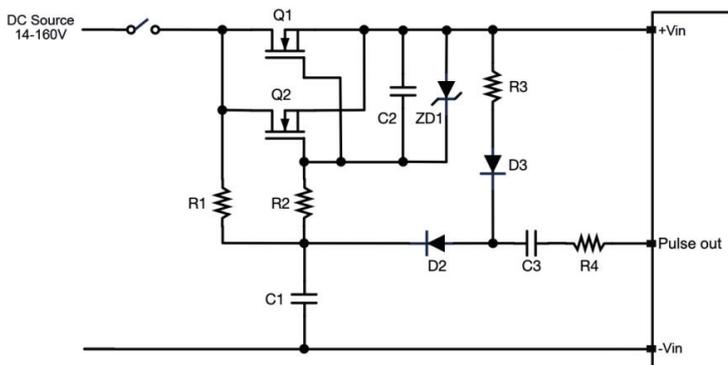


Figure 5: inrush current limitation circuit

Component	Specification
R1	560 kΩ / 1206
R2	6.8 Ω / 0805
R3	100 Ω / 0805
R4	51 Ω / 0805
D2, D2	BAV3004W / SOD323
C1	10 nF / 250 V / 1206 MLCC
C2	10 nF / 50 V / 0805 MLCC
C3	47 nF / 50 V / 0805 MLCC
Q1, Q2	FDB2710-D / 250 V / 50 A / TO263
Z2	PTZ15B / SMA

Table 6: inrush current limitation circuit

Inrush current: 120 A  
72 Vin, Full load

Inrush current: 24.5 A  
72 Vin, with Active Inrush Current Limitation

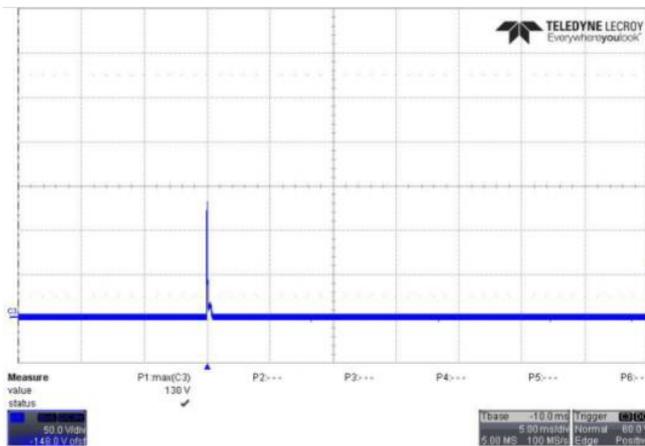


Figure 6: inrush current without inrush current limitation

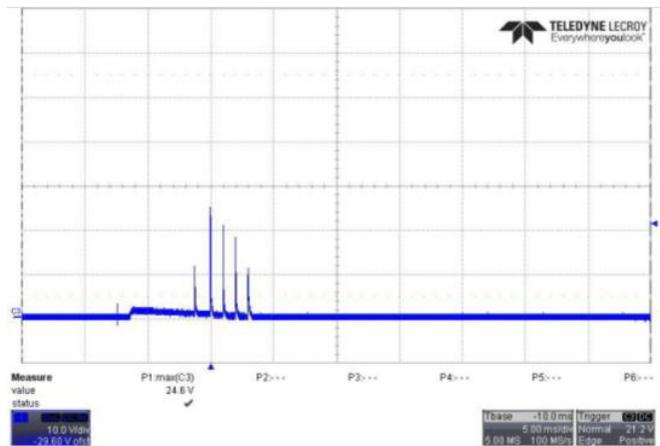


Figure 7: inrush current with inrush current limitation

## Conclusion

With the possibility to connect capacitors at the BUS pin instead of connecting them at the input line, it is possible, on lower input voltages until 80 VDC, to use cost-optimized and better supplyable low voltage capacitors.

By using the Active Inrush Current Limitation very high inrush currents will be avoided. Possible malfunctions on the supply circuitry will be reduced.