

CBAM™ HUL-28 Module



Features

- High energy density
- User programmable hold-up trip voltage
- Trip status indicator
- Designed for use with Calex DC/DC Converters
- Small package design (1.45" x 2.28" x 0.50")
- Excellent MTBF
- Aluminum substrate technology
- All applicable materials used are a minimum of UL94V-0 rated. Designed to meet UL60950.
- Five year warranty
- Available with RoHS compliant construction, simply add "(RoHS)" after the part number: HUL-28 (RoHS)

Description

The HUL-28 is a hold-up module designed for use with Calex DC/DC converters to protect against brown-out and temporary power loss conditions and provide a clean, uninterrupted source of power for downstream circuitry. The HUL-28 is built in a small package with a user programmable hold-up trip voltage.

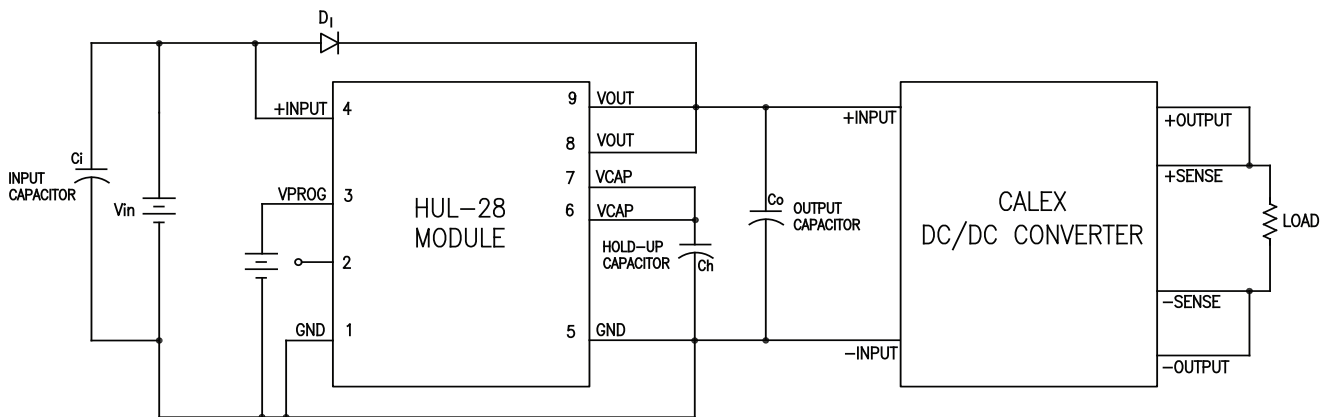


Figure 1. Recommended Application

Principles of Operation

The HUL-28 has two modes of operation: “stand-by” and “tripped”. During stand-by, the HUL-28 charges the hold-up capacitor to 45V and maintains that voltage. When tripped, the HUL-28 stops charging the hold-up capacitor and connects it to the V_{OUT} pins.

The mode of operation is determined by the value of the input voltage (+INPUT) in relation to the “trip voltage”. Tripped mode is entered when the input voltage drops below a preset trip voltage. Stand-by mode is entered when the input voltage rises 2.1V above the trip voltage. The trip voltage is set by the user via the V_{PROG} pin.

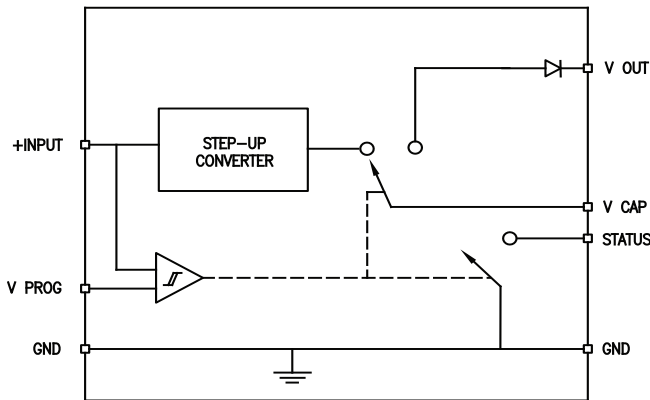


Figure 2. Internal Block Diagram

Thermal Considerations

In stand-by mode, the HUL-28 does not dissipate much heat and the baseplate temperature will typically be 5°C higher than ambient temperature in a still air environment. When the HUL-28 transitions from tripped to stand-by mode and vice versa, a large amount of power is dissipated in the HUL-28. If frequent transitions are expected, care should be taken to ensure the baseplate temperature does not exceed 100°C.

Caution

After shutting off power to the HUL-28, do not handle the circuit until the hold-up capacitor is discharged. With no load on the output, voltages in excess of 45V may be present on the V_{CAP} and V_{OUT} pins for a prolonged period of time.

Hold-up Time

Hold-up time is defined as the maximum time that the downstream circuitry can be powered solely from the hold-up capacitor. In this data sheet, hold-up time is defined as the time when the downstream circuitry is powered solely from the hold-up capacitor and the hold-up capacitor is charged to at least 10V. The following table illustrates the maximum hold-up time (ms) achievable with different capacitor configurations.

		Power (W)		
		60	120	180
Capacitance (mF)	10	160ms	80ms	53ms
	20	321ms	160ms	107ms
	30	481ms	241ms	160ms
	40	642ms	321ms	214ms
	50	802ms	401ms	267ms

CBAM™ HUL-28 Module

Input Parameters				
Input Voltage	MIN (3) TYP MAX	15.5 28 36		VDC
Input Current, hold-up capacitor charged	TYP	25		mARMS
Input Current while charging hold-up capacitor	MIN MAX	20 350		mA
Input Overvoltage, 100ms	MAX	50		VDC
Switching Frequency	TYP	310		kHz
Reflected Ripple	TYP	40		mA P-P
Recommended Input Fuse		Note (2)		
Output Parameters				
Hold-up Cap voltage (pin 6 and pin 7)	MIN TYP MAX	44 45 46		VDC
Hold-up Cap Charge Rate (0-45V)	TYP	278		$\frac{s}{F}$
Hold-up Capacitor (Ch)	MAX	50,000		μF
Response Time (4)	TYP	5		μs
V _{CAP} to V _{OUT} Voltage Drop	MIN	0.6		VDC
Hold-up Output Power	MAX	200		W
V _{OUT} Voltage	MIN MAX	9.0 45.5		VDC
Output Capacitance (5)	T _C ≤ 80°C	MAX	350	μF
	T _C ≤ 100°C	MAX	170	
Control Parameters				
Trip Voltage	V _{PROG} = 0V	MIN TYP MAX	21.4 22 22.5	VDC
	V _{PROG} Open	MIN TYP MAX	17.5 18 18.5	VDC
	V _{PROG} = 5V	MIN TYP MAX	13 13.5 14	VDC
Trip Voltage Hysteresis	TYP	2.1		VDC
V _{PROG} Voltage	MIN MAX	0 5		VDC
Input Impedance	TYP	24		k Ω
Status Pin Voltage	MAX	50		VDC
Status Pin Current	MAX	2		mA

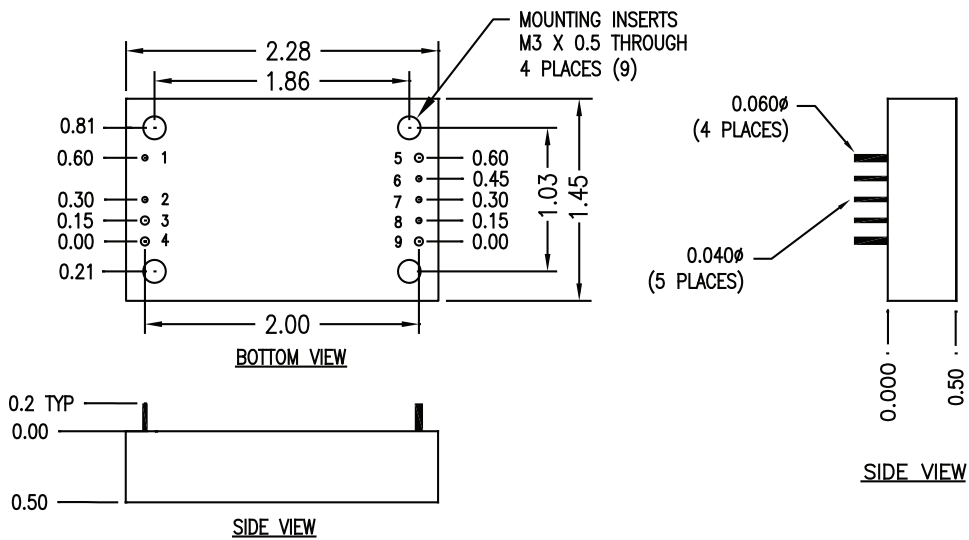
Notes:

- All parameters measured at T_c=25°C, V_{in}=28VDC, unless otherwise noted. Refer to the CALEX Application Notes for the definition of terms, measurement circuits, and other information.
- Refer to the CALEX Application Notes for information on fusing.
- Minimum operating voltage is affected by the value of the trip voltage.
- The response time is defined as the time from when the input voltage drops to the trip voltage to the moment when the output voltage "V_{OUT}" starts rising.
- This capacitance includes all input capacitance on the downstream circuitry: internal capacitance and C_o.
- Isolation is measured by applying a DC voltage between pins and baseplate.
- The case thermal impedance is defined as the case temperature rise over ambient per package watt dissipated.
- Thermal impedance is tested with the module mounted vertically and facing another printed circuit board 1/2 inch away.
- Torque fasteners into threaded mounting inserts at 12 in. oz. or less. Greater torque may result in damage to unit and void the warranty.
- Calex CBAM™ modules are designed to withstand most solder/wash processes. Careful attention should be used when assessing the applicability in your specific manufacturing process. The CBAM™ modules are not hermetically sealed.
- MTBF is calculated based on MIL-HDBK-217F under the following conditions:
 Reliability prediction method = Part Stress Analysis
 Baseplate temperature = 40°C
 Environment = Ground, Benign
- Available with RoHS and Non-RoHS construction, contact factory for details.
 RoHS Compliance means conformity to EU Directive 2002/95/EC of 27 January 2003, on the restriction of the use of certain hazardous substances in electrical and electronic equipment, lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls, and polybrominated diphenyl ethers are not present in quantities exceeding the following maximum concentrations in any homogeneous material, except for applicable exemptions.
 0.1% (by weight of homogeneous material) lead, mercury, hexavalent chromium, polybrominated biphenyls, polybrominated diphenyl ethers, or 0.01% (by weight of homogeneous material) cadmium.
 The RoHS marking is as follows.



CBAM™ HUL-28 Module

Isolation			
Baseplate to Input (6)	MIN	700	VDC
Enviromental			
Baseplate Operating Temp Range	MIN	-40	°C
	MAX	100	
Storage Temperature Range	MIN	-40	°C
	MAX	120	
Case Thermal Impedance (7), (8)	TYP	13	°C/Watt
MTBF MIL-STD-217F (11)	TYP	365,308	h
General			
Unit Weight	TYP	55	g
Case Dimension		1.45" x 2.28" x 0.50"	
Torque on Mounting Inserts (9)	MAX	12 in. oz	



Pin	Diameter	Name
1	0.040"	GND
2	0.040"	STATUS
3	0.060"	VPROG
4	0.060"	+INPUT
5	0.060"	GND
6	0.040"	VCAP
7	0.040"	VCAP
8	0.040"	VOUT
9	0.060"	VOUT

Mechanical tolerances unless otherwise noted:
 X.XX dimensions: ±0.020 inches
 X.XXX dimensions: ±0.005 inches

HUL-28 Application Section

Hold-up Time

Hold-up time, as defined earlier, depends on downstream circuitry power draw, power loss in the HUL-28, the size of the hold-up capacitor, and the initial voltage of the hold-up capacitor.

Generally, for a C farad capacitor charged to V volts, the amount of energy available to provide hold-up is:

$$E = \frac{1}{2} \cdot C \cdot V^2 - \frac{1}{2} \cdot C \cdot 10^2$$

Therefore, a load drawing P watts will be supplied for t seconds:

$$t = \frac{E}{P} = \frac{1}{2} \cdot \frac{C}{P} \cdot (V^2 - 10^2)$$

Assuming full 45V charge in the hold-up capacitor, constant power draw, and *no loss in the HUL-28*, the hold-up time can be estimated by:

$$t_h = \frac{1}{2} \cdot \frac{C}{P} \cdot (45^2 - 10^2)$$

where t_h is the hold-up time in seconds. Figure A1 allows for a quick estimate of hold-up time based on hold-up capacitance at three levels of power draw. In the case of a 84% efficient converter delivering 100W, the power drawn from the HUL-28 would be 119W.

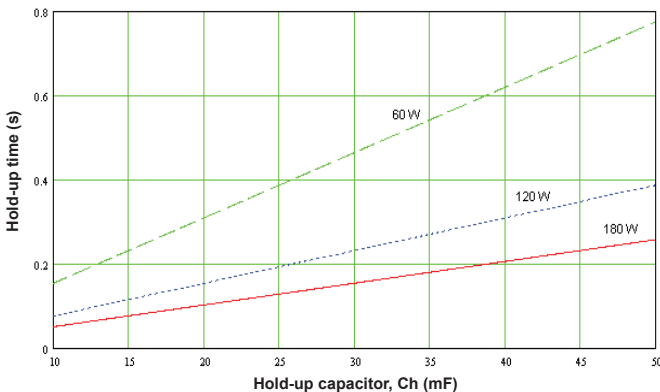


Figure A1. Hold-up time as a function of capacitance and power draw

Note that this hold-up time can only be achieved after the hold-up capacitor has been fully charged. Therefore the hold-up time is reduced or non-existent whenever the hold-up capacitor is not charged to 45V. *This condition is present immediately after start-up and immediately after recovering from a brown-out.* Power loss due to the voltage drop from V_{CAP} to V_{OUT} will slightly reduce this theoretical hold-up time.

Advantages of the HUL-28 in attaining the desired hold-up time

The “bulk capacitance” method (figure A2) can be used to provide hold-up without using the HUL-28. However, for any desired hold-up time, less capacitance will be required with the HUL-28. Furthermore, for the same hold-up time, the HUL-28 draws significantly lower inrush current.

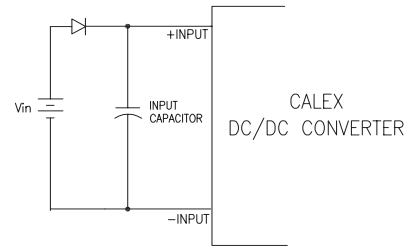


Figure A2.

For any given combination of capacitance and power draw, figure A3 shows how the HUL-28 improves hold-up time over the bulk capacitor solution. Equivalently, for any desired hold-up time at a given load, figure A3 shows how many times more hold-up capacitance is required without the HUL-28.

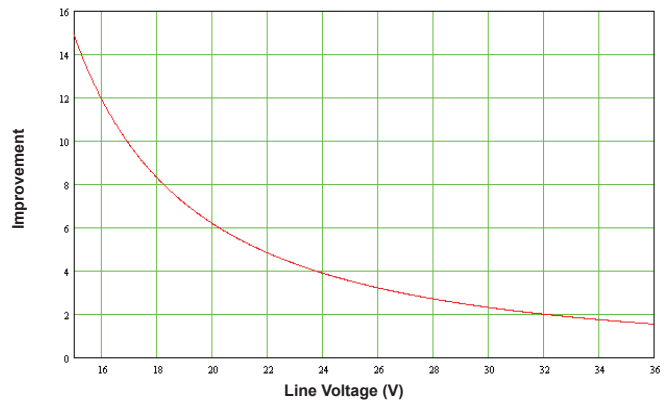


Figure A3. Improvement in hold-up time for a given combination of capacitance and power draw

Consider a Calex 24S15.10HEW converter operating from a 28V bus. 100ms hold-up time is desired. The converter is supplying a 7A, 15V load. at 86% efficiency, the converter is drawing 122W. From figure A1, it is estimated that 12.5mF of capacitance is required if using the HUL-28. If hold-up is provided by the circuit shown in figure A2, the hold-up capacitor only charges to the line voltage (28V). From figure A3, 2.8 times more capacitance, that is 35mF, would be required. If during normal operation, the line voltage is allowed to drop to 16V, 12 times more capacitance (150mF) would be required. With the HUL-28, hold-up time is not affected by line voltage.

Trip Voltage Set-point

There are three ways to set the trip voltage for the HUL-28.

- I. Connect a voltage source (0 to 5V) to V_{PROG} to obtain any trip voltage between 13.5V and 22V. The trip voltage may be computed as:

$$V_{TRIP} = 21.9 - 1.69V_{PROG}$$

Alternately it can be estimated from figure A4.

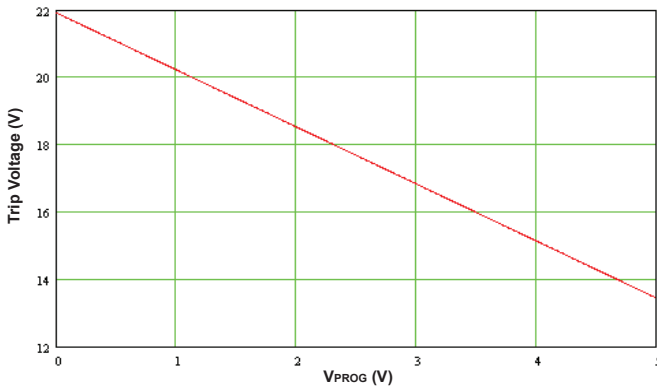


Figure A4. Trip voltage as a function of V_{PROG}

- II. For 18V trip voltage, leave V_{PROG} open. Hysteresis is reduced to 1.6V.
- III. External resistor method. This method allows the trip voltage to be set to any value between 13.5V and 22V, without using a separate voltage source. However, using this method, the hysteresis is reduced to as low as 1V, therefore stand-by mode may be entered whenever the line voltage rises as low as 1V above the trip voltage.
 - a. For a trip voltage smaller than 18V, connect a resistor between V_{PROG} and +INPUT as shown in figure A5. The trip voltage can be estimated from figure A6.
 - b. For a trip voltage greater than 18V, connect a resistor between V_{PROG} and GND as shown in figure A7. The trip voltage can be estimated from figure A8.

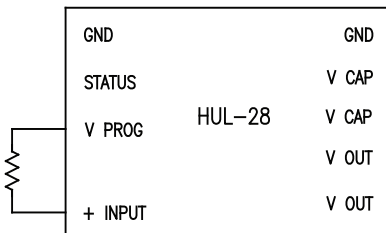


Figure A5. External resistor method for obtaining a trip voltage smaller than 18V

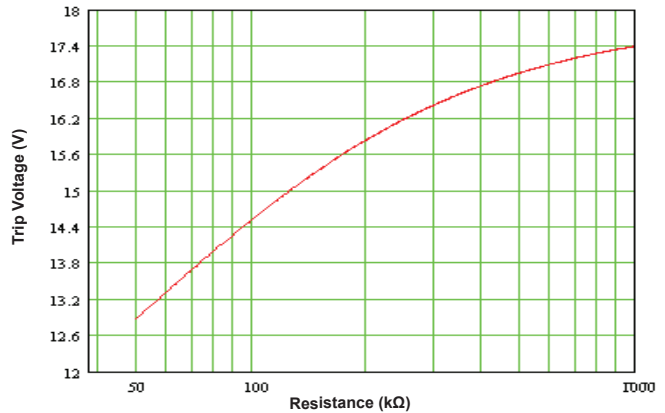


Figure A6. Trip voltage as a function of resistance connected between V_{PROG} and +INPUT

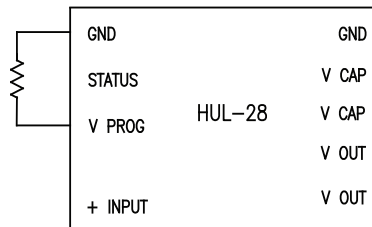


Figure A7. External resistor method for obtaining a trip voltage greater than 18V

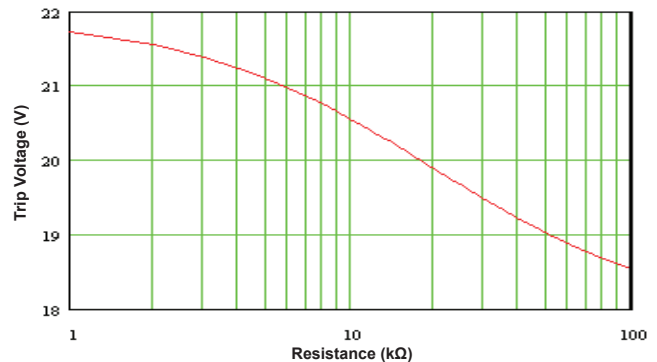


Figure A8. Trip voltage as a function of resistance connected between V_{PROG} and GND

Follow these steps to pick a trip voltage:

1. Decide on the lowest acceptable voltage for the downstream circuitry.
2. Compute or measure the change in voltage on the positive input of the downstream circuitry during the 5μs HUL-28 response time. This depends on downstream circuitry input capacitance (both internal and external), power draw, and trip voltage.
3. To obtain the trip voltage, add the two values above and the forward voltage drop of the input diode D_1 .

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Status Pin

Pin 2, STATUS, allows external circuitry to monitor the state of the HUL-28 as shown in the table below. This pin is connected to the open drain of a FET, therefore a pull-up resistor to the logic high voltage is required for normal operation.

Status Pin	HUL-28 Status
logic low	Tripped
logic high	Stand-by

Figure A9 shows an arrangement where a TTL compatible signal is generated at the STATUS pin. V_{PROG} is open, therefore the trip voltage is 18V. The voltage on +INPUT is ramped down then up. Figure A10 shows the behavior of the STATUS pin. Note that the HUL-28 returns to stand-by mode only after +INPUT rises about 2V above the trip voltage.

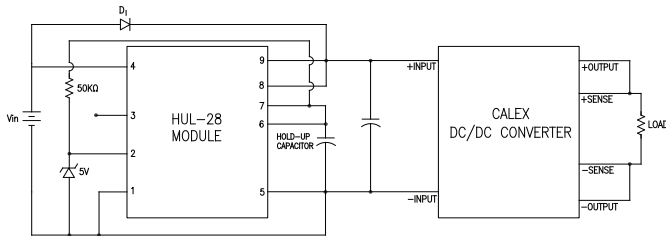


Figure A9. STATUS pin configured for TTL operation

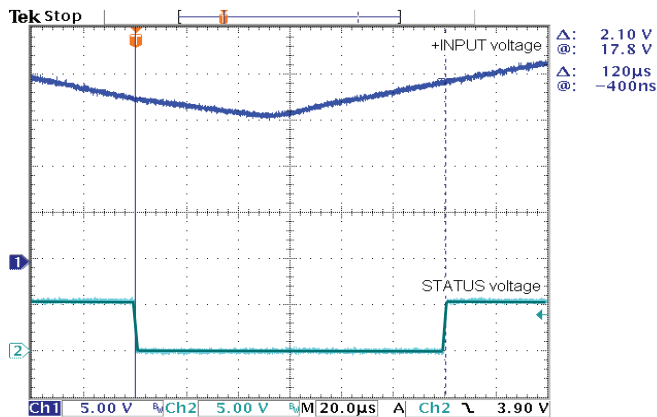


Figure A10. STATUS pin operation. ch1: +INPUT voltage, ch2: STATUS voltage

Ground Connection

There are two GND pins (1 and 5) on the HUL-28. Avoid running current through the module from one pin to the other. The correct configuration is shown in figure A11. Some incorrect configurations are presented in figures A12a and A12b.

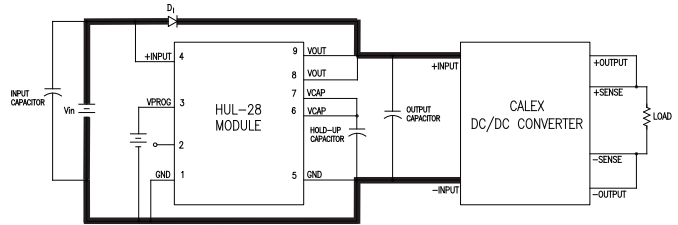


Figure A11. HUL-28 properly configured to avoid high currents through the module

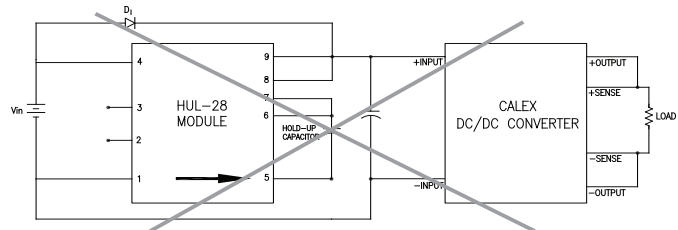


Figure A12a. Incorrect configuration: Hold-up current through HUL-28

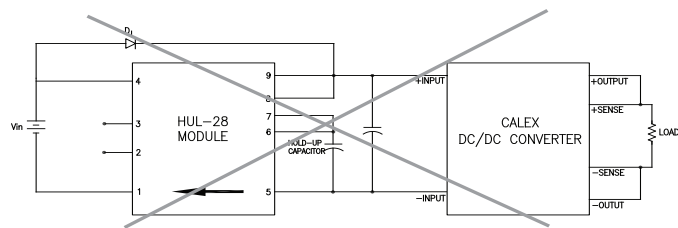


Figure A12b. Incorrect configuration: Converter current through HUL-28

Hysteresis and Lack of Brown-out Protection

Once the HUL-28 trips, the hold-up capacitor will not be recharged until the input voltage rises 2.1V above the trip voltage. If, after the HUL-28 is tripped, the input voltage recovers but does not rise at least 2.1V over the trip voltage, the HUL-28 will not provide any protection from any subsequent brown-out.

Consider the following scenario: The trip voltage is 18V. The line voltage (28V) drops out for 500ms. Uninterrupted power is provided by the HUL-28. The line recovers, but only to 19V. The HUL-28 remains in tripped mode, as the line voltage does not rise above 20V. Another 400ms brown-out occurs after which the line voltage fully recovers to 28V. Since the hold-up capacitor is only partially charged the HUL-28 can not keep the load running. This is illustrated in figure A13. The same experiment is repeated after setting V_{PROG} to 3.5V for a trip voltage of 16V. The results are shown in figure A14.

To avoid this problem, set the trip voltage 2.1V lower than the lowest permissible value for the line voltage.

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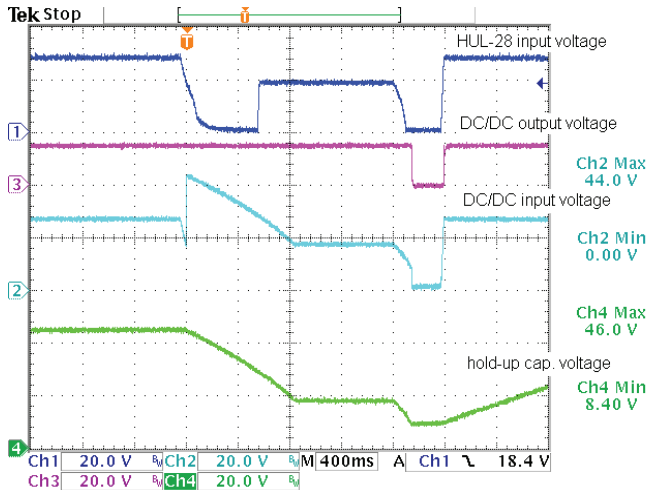


Figure A13. HUL-28 does not provide protection due to high trip voltage.

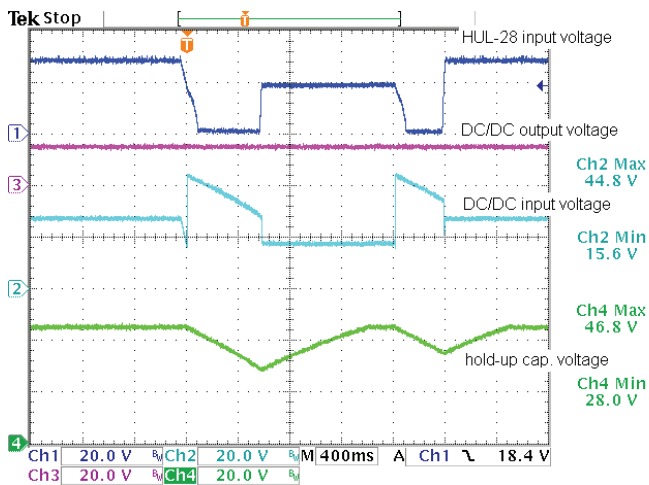


Figure A14. Lower trip voltage allows the HUL-28 to provide protection.

Layout Issues

+INPUT connection.

Connect +INPUT directly to the anode of the input diode, Di. This will provide the best measurement of the input voltage.

Stray Inductance on Output.

Care must be taken to reduce stray inductance that may be present between the hold-up capacitors, the HUL-28, and the downstream circuitry. When HUL-28 trips, the voltage on Vout will suffer a step rise as large as 35V. This will be accompanied by a 35A inrush current into the output capacitance. Inductance present in the path of this current will cause a large voltage spike and/or ringing on Vout.

HUL-28 Input Capacitance

Ci and Co shown in figure 1 are optional and are not required for the proper operation of the HUL-28. Co may be used if downstream circuitry requires external capacitance. If the required input capacitance is greater than the limit set by the HUL-28 output capacitance, Ci may be used in parallel with Co to attain the desired capacitance. When the HUL-28 is used with Calex HEW series converters, 220µF for Ci and 40µF for Co are recommended. Depending on operating conditions and converter model, other values may be required.

Measurements

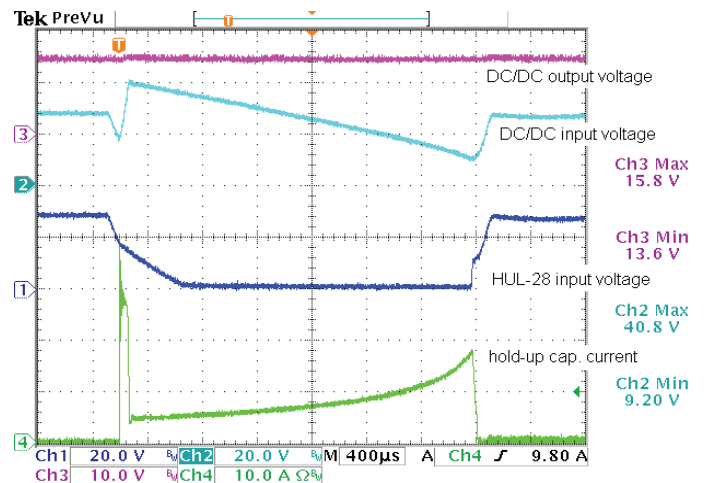


Figure A15. Brown-out event

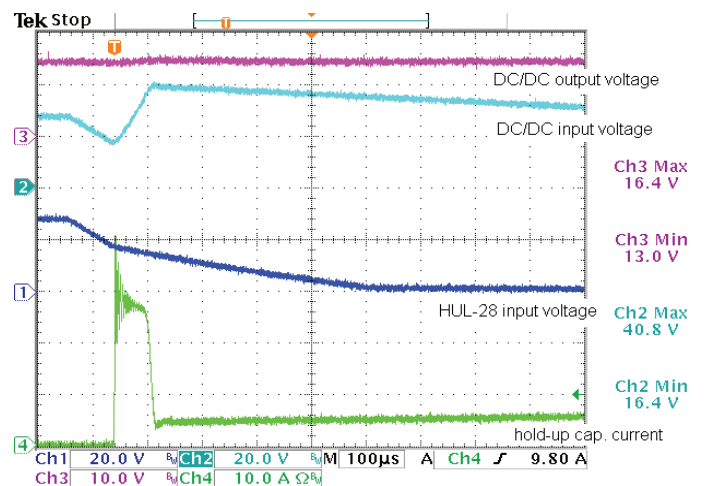


Figure A16. Start of brown-out event in figure A15

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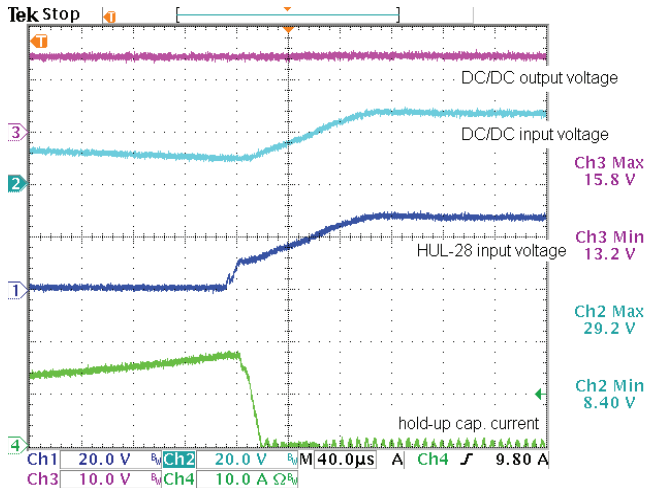


Figure A17. End of brown-out event in figure A15

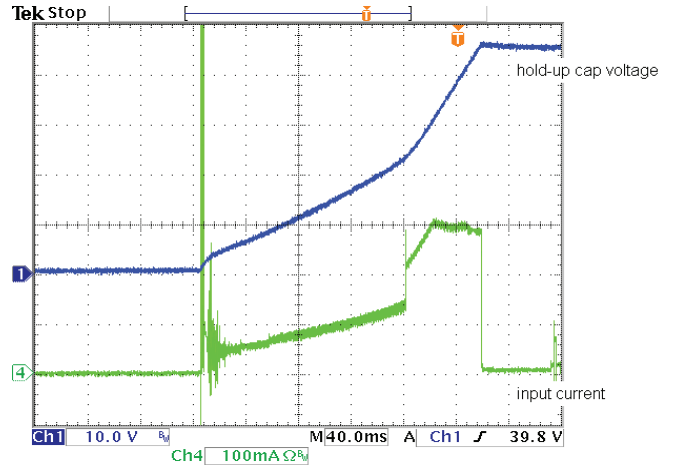


Figure A20. HUL-28 input current (ch4) with respect to hold-up capacitor voltage (ch1) at +INPUT = 36V

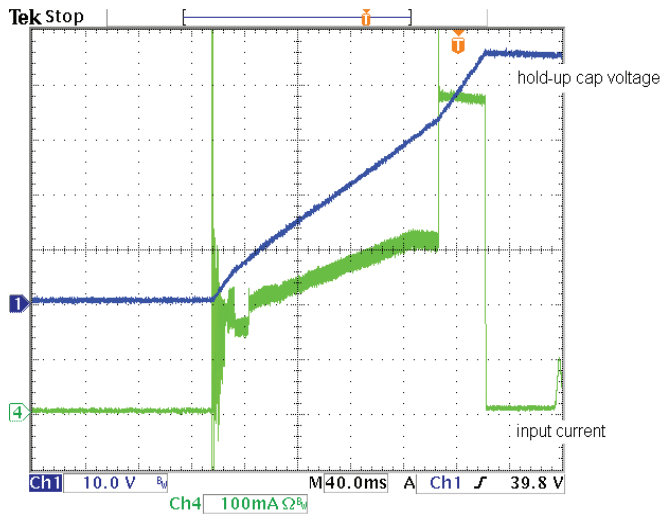


Figure A18. HUL-28 input current (ch4) with respect to hold-up capacitor voltage (ch1) at +INPUT = 15.5V

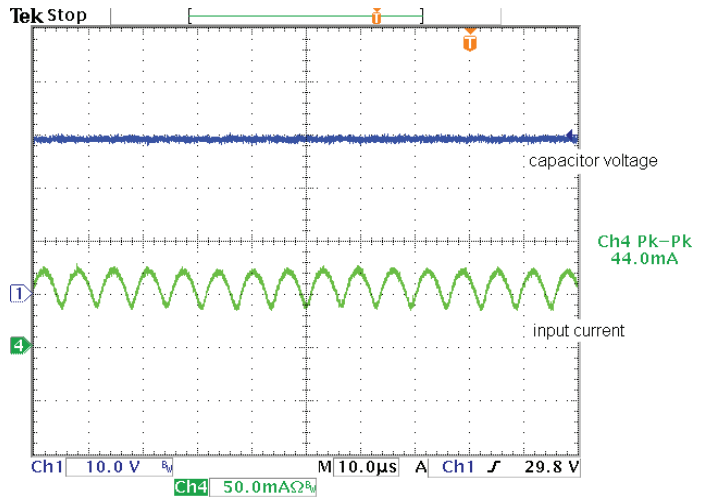


Figure A21. Typical input current ripple (ch4) while hold-up capacitor is charging (ch1)

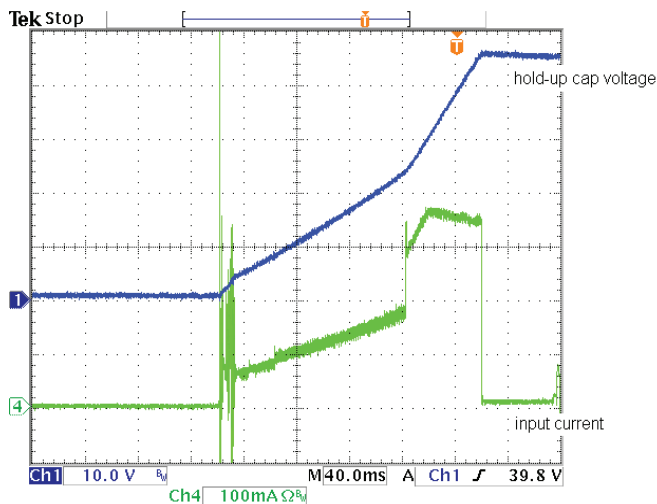


Figure A19. HUL-28 input current (ch4) with respect to hold-up capacitor voltage (ch1) at +INPUT = 28V

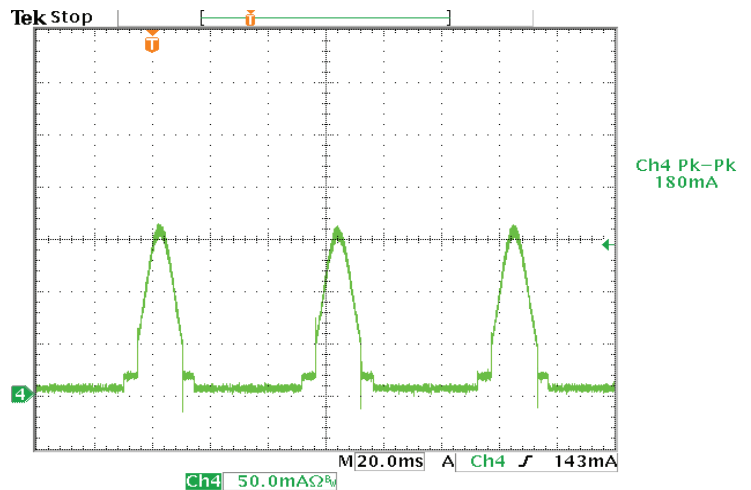


Figure A22. Typical input ripple when HUL-28 is in stand-by mode