Not Recommended For New Designs

NBM™ in a VIA™ Package Bus Converter

NBM3814x46C15A6yzz

Non-Isolated, Fixed-Ratio DC-DC Converter

Features & Benefits

- Up to 160A continuous low-voltage-side current
- Fixed transformation ratio (K) of 1/3
- Up to 1258W/in^3 power density
- 97.9% peak efficiency
- Bidirectional operation capability
- Integrated ceramic capacitance filtering
- Parallel operation for multi-kW arrays
- OV, OC, UV, short circuit and thermal protection
- 3814 package
- High MTBF
- Thermally enhanced VIA package

Typical Applications

- DC Power Distribution
- Information and Communication Technology (ICT) Equipment
- High-End Computing Systems
- Automated Test Equipment
- Industrial Systems
- High-Density Energy Systems
- Transportation

Size:
3.76 x 1.40 x 0.37in
[95.59 x 35.54 x 9.40mm]

Product Ratings	
V_{HI} = 42V (36 – 46V)	I_{LO} = up to 160A
V_{LO} = 14V (12 – 15.3V) (NO LOAD)	K = 1/3

Product Description

The NBM3814x46C15A6yzz in a VIA package is a high-efficiency Bus Converter, operating from a 36 to 46V_{DC} high-voltage bus to deliver a non-isolated 12 to 15.3V_{DC} unregulated, low voltage.

This unique, ultra-low-profile module incorporates DC-DC conversion and integrated filtering in a chassis- or PCB-mount form factor.

The NBM offers low noise, fast transient response and industry-leading efficiency and power density.

Leveraging the thermal and density benefits of Vicor VIA packaging technology, the NBM module offers flexible thermal management options with very low top and bottom side thermal impedances.

When combined with downstream Vicor DC-DC conversion components and regulators, the NBM allows the Power Design Engineer to employ a simple, low-profile design, which will differentiate the end system without compromising on cost or performance metrics.

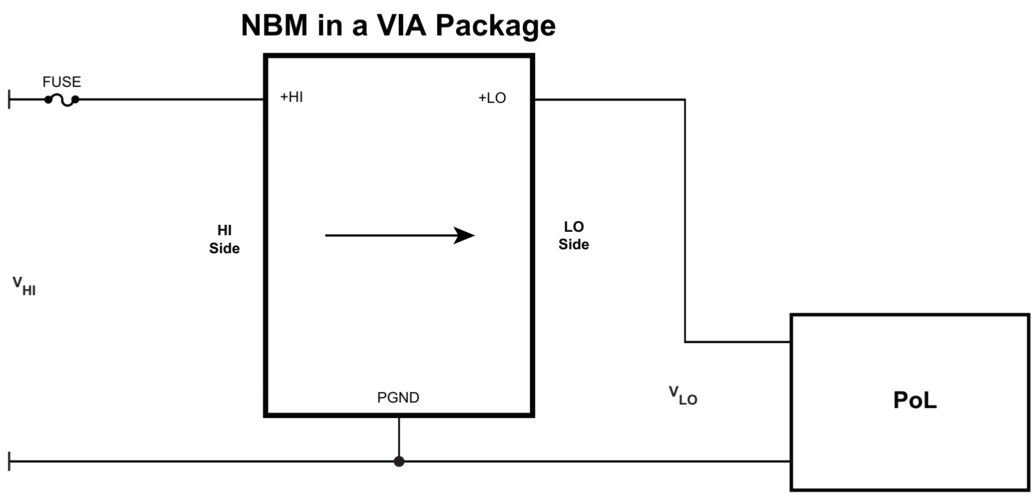
The NBM non-isolated topology allows start up and steady state operation in forward and reverse directions. It provides bidirectional protections. However if the powertrain is disabled by any protection and V_{LO} is present, then a voltage equal to V_{LO} minus two diode drops will appear on the high-voltage side.

Part Ordering Information

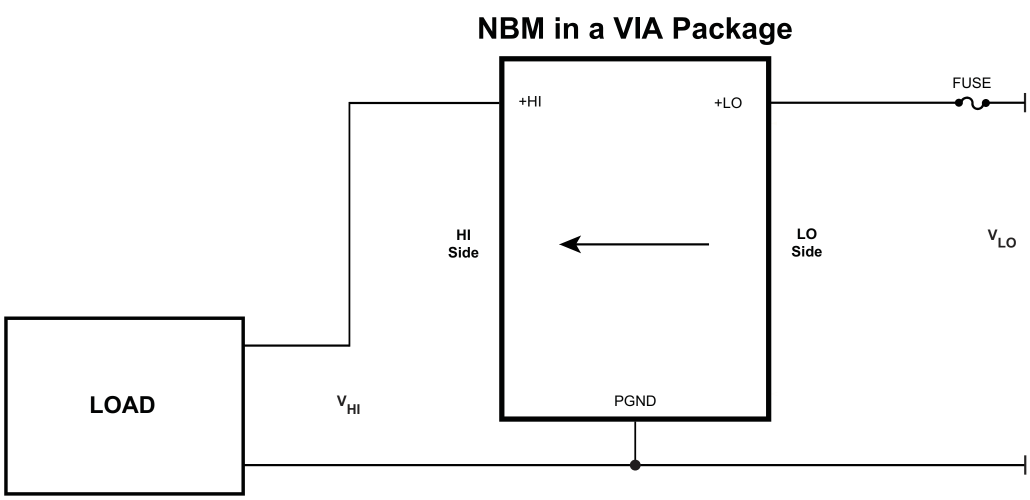
Product Function	Package Length	Package Width	Package Type	Max High-Side Voltage	High-Side Voltage Range Ratio	Max Low-Side Voltage	Max Low-Side Current	Product Grade (Case Temperature)	Option Field
NBM	38	14	x	46	C	15	A6	y	zz
NBM = Non-Isolated Bus Converter Module	Length in Inches x 10	Width in Inches x 10	**B** = Board VIA **V** = Chassis VIA	Internal Reference				**C** = –20 to 100°C [a] **T** = –40 to 100°C [a]	**00** = Chassis/Always On **04** = Short Pin/Always On **08** = Long Pin/Always On

[a] High-Temperature Current Derating may apply; See Figure 1, specified thermal operating area.

Typical Applications

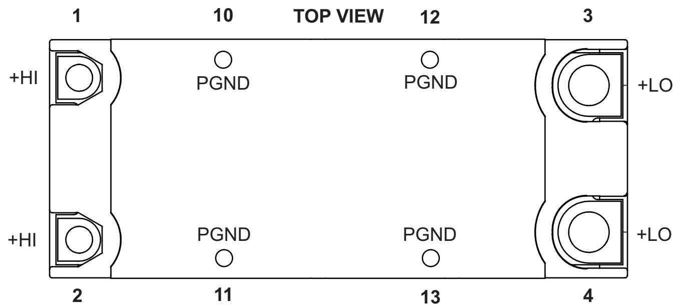


NBM3814x46C15A6yzz at point-of-load providing fixed ratio step-down DC–DC conversion to PoL devices. NBM is operating in forward direction.

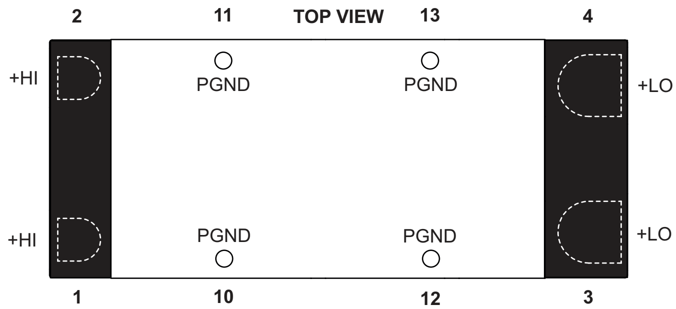


NBM3814x46C15A6yzz providing fixed ratio step-up DC-DC conversion. NBM is operating in reverse direction.

Pin Configuration



NBM3814 in a VIA Package - Chassis (Lug) Mount



NBM3814 in a VIA Package - Board (PCB) Mount

Pin Descriptions

Pin Number	Signal Name	Type	Function
1, 2	+HI	HIGH SIDE POWER	High-voltage-side positive power terminal
3, 4	+LO	LOW SIDE POWER	Low-voltage-side positive power terminal
10, 11, 12, 13	PGND	POWER RETURN	Common negative power terminal

Absolute Maximum Ratings

The absolute maximum ratings below are stress ratings only. Operation at or beyond these maximum ratings can cause permanent damage to the device.

Parameter	Comments	Min	Max	Unit
+HI to PGND		–1	60	V
HI_DC or LO_DC Slew Rate			1	V/µs
+LO to PGND		–1	20	V
Isolation Voltage / Dielectric Withstand [b]	High-voltage side to case	N/A		V_{DC}
	High-voltage side to low-voltage side	N/A		V_{DC}
	Low-voltage side to case	N/A		V_{DC}

[b] The PGND of the NBM in a VIA package is directly connected to the case. The NBM does not contain any insulation (isolation) from high-voltage side to low-voltage side

Electrical Specifications

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of $-40°C \le T_{CASE} \le 100°C$ (T-Grade); all other specifications are at T_{CASE} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
General Powertrain Specification – Forward Direction Operation (High-Voltage Side to Low-Voltage Side)						
HI-Side Voltage Range, (Continuous)	V_{HI_DC}		**36**		**46**	V
HI-Side Voltage Initialization Threshold	$V_{\mu C\_ACTIVE}$	HI-side voltage where internal controller is initialized, (powertrain inactive)			15	V
HI-Side Quiescent Current	I_{HI_Q}	Disabled, V_{HI_DC} = 42V		8		mA
		$T_{CASE} \le$ 100°C			12	
No-Load Power Dissipation	P_{HI_NL}	V_{HI_DC} = 42V, T_{CASE} = 25°C		12.5	19.5	W
		V_{HI_DC} = 42V	**5**		**28**	
		V_{HI_DC} = 36 – 46V, T_{CASE} = 25 °C			22	
		V_{HI_DC} = 36 – 46V			**31**	
HI-Side Inrush Current Peak	$I_{HI\_INR\_PK}$	V_{HI_DC} = 46V, C_{LO_EXT} = 3000µF, R_{LOAD_LO} = 20% of full-load current		30		A
		$T_{CASE} \le$ 100°C			75	
DC HI-Side Current	$I_{HI\_IN\_DC}$	At $I_{LO\_OUT\_DC}$ = 160A, $T_{CASE} \le$ 85°C			53.9	A
Transformation Ratio	K	High voltage to low voltage, K = V_{LO_DC} / V_{HI_DC}, at no load		1/3		V/V
LO-Side Current (Continuous)	$I_{LO\_OUT\_DC}$	$T_{CASE} \le$ 85°C			160	A
LO-Side Current (Pulsed)	$I_{LO\_OUT\_PULSE}$	10ms pulse, 25% duty cycle, $I_{LO\_OUT\_AVG} \le$ 50% rated $I_{LO\_OUT\_DC}$			176	A
Efficiency (Ambient)	η_{AMB}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A	96.8	97.6		%
		V_{HI_DC} = 36V to 46V, $I_{LO\_OUT\_DC}$ = 160A	96.5			
		V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 80A	97.3	97.8		
Efficiency (Hot)	η_{HOT}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A, T_{CASE} = 85°C	96.7	97.1		%
Efficiency (Over Load Range)	$\eta_{20\%}$	32A < $I_{LO\_OUT\_DC}$ < 160A	95			%
LO-Side Output Resistance	R_{LO_COLD}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A, T_{CASE} = –40°C	0.8	1.3	1.7	mΩ
	R_{LO_AMB}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A	0.9	1.7	2.1	
	R_{LO_HOT}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A, T_{CASE} = 85°C	1.5	2.1	2.4	
Switching Frequency	F_{SW}	LO-side voltage ripple frequency = 2x F_{SW}	**1.14**	1.20	**1.26**	MHz
LO-Side Voltage Ripple	$V_{LO\_OUT\_PP}$	C_{LO_EXT} = 0µF, $I_{LO\_OUT\_DC}$ = 160A, V_{HI_DC} = 42V, 20MHz BW		110		mV
		$T_{CASE} \le$ 100°C			205	

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of $-40°C \leq T_{CASE} \leq 100°C$ (T-Grade); all other specifications are at $T_{CASE} = 25°C$ unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
General Powertrain Specification – Forward Direction Operation (High-Voltage Side to Low-Voltage Side), Cont.						
Effective HI-side Capacitance (Internal)	C_{HI_INT}	Effective value at $42V_{HI\_DC}$		16.8		µF
Effective LO-Side Capacitance (Internal)	C_{LO_INT}	Effective value at $14V_{LO\_DC}$		140		µF
Rated LO-Side Capacitance (External)	$C_{LO\_OUT\_EXT}$	Excessive capacitance may drive module into short circuit protection			**3000**	µF
Rated LO-Side Capacitance (External), Parallel Array Operation	$C_{LO\_OUT\_AEXT}$	$C_{LO\_OUT\_AEXT}$ Max = N • 0.5 • $C_{LO\_OUT\_EXT\ MAX}$, where N = the number of units in parallel				
Powertrain Protection Specification – Forward Direction Operation (High-Voltage Side to Low-Voltage Side)						
Auto Restart Time	$t_{AUTO\_RESTART}$	Start up into a persistent fault condition. Non-latching fault detection given $V_{HI\_DC} > V_{HI\_UVLO+}$	**940**		**1010**	ms
HI-Side Overvoltage Lockout Threshold	V_{HI_OVLO+}		**48**	50	**52**	V
HI-Side Overvoltage Recovery Threshold	V_{HI_OVLO-}		**46**	48	**50**	V
HI-Side Overvoltage Lockout Hysteresis	$V_{HI\_OVLO\_HYST}$			2		V
HI-Side Overvoltage Lockout Response Time	t_{HI_OVLO}			30		µs
HI-Side Undervoltage Lockout Threshold	V_{HI_UVLO-}		**28**	30	**32**	V
HI-Side Undervoltage Recovery Threshold	V_{HI_UVLO+}		**30**	32	**34**	V
HI-Side Undervoltage Lockout Hysteresis	$V_{HI\_UVLO\_HYST}$			2		V
HI-Side Undervoltage Lockout Response Time	t_{HI_UVLO}			100		µs
HI-Side Undervoltage Start-Up Delay	$t_{HI\_UVLO+\_DELAY}$	From $V_{HI\_DC} = V_{HI\_UVLO+}$ to powertrain active (i.e., one-time start-up delay from application of V_{HI_DC} to V_{LO_DC})		30		ms
HI-Side Soft-Start Time	$t_{HI\_SOFT-START}$	From powertrain active. Fast current limit protection disabled during soft start		1		ms
LO-Side Overcurrent Trip Threshold	$I_{LO\_OUT\_OCP}$		**177**	200	**240**	A
LO-Side Overcurrent Response Time Constant	$t_{LO\_OUT\_OCP}$	Effective internal RC filter		4		ms
LO-Side Short Circuit Protection Trip Threshold	$I_{LO\_OUT\_SCP}$		**240**			A
LO-Side Short Circuit Protection Response Time	$t_{LO\_OUT\_SCP}$			1		µs
Overtemperature Shutdown Threshold	t_{OTP+}	Temperature sensor located inside controller IC	**125**			°C
Overtemperature Recovery Threshold	t_{OTP-}		105	110	115	°C
Undertemperature Shutdown Threshold	t_{UTP}	Temperature sensor located inside controller IC; Protection not available for M-Grade units.			–45	°C
Undertemperature Restart Time	$t_{UTP\_RESTART}$	Start up into a persistent fault condition. Non-latching fault detection given $V_{HI\_DC} > V_{HI\_UVLO+}$		3		s

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of $-40°C \leq T_{CASE} \leq 100°C$ (T-Grade); all other specifications are at $T_{CASE} = 25°C$ unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
General Powertrain Specification – Reverse Direction Operation (Low-Voltage Side to High-Voltage Side)						
LO-Side Voltage Range, (Continuous)	V_{LO_DC}		**12**		**15.3**	V
No-Load Power Dissipation	P_{LO_NL}	V_{LO_DC} = 14V, T_{CASE} = 25°C		12.5	20	W
		V_{LO_DC} = 14V	**5**		**29**	
		V_{LO_DC} = 12 – 15.3V, T_{CASE} = 25°C			22	
		V_{LO_DC} = 12 – 15.3V			**31**	
DC LO-Side Current	$I_{LO\_IN\_DC}$	At I_{HI_DC} = 53.3A, $T_{CASE} \leq$ 85°C			**162**	A
HI-Side Current (Continuous)	$I_{HI\_OUT\_DC}$	$T_{CASE} \leq$ 85°C			**53.3**	A
HI-Side Current (Pulsed)	$I_{HI\_OUT\_PULSE}$	10ms pulse, 25% duty cycle, $I_{HI\_OUT\_AVG} \leq$ 50% rated $I_{HI\_OUT\_DC}$			**58.7**	A
Efficiency (Ambient)	η_{AMB}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A	96.4	97.2		%
		V_{LO_DC} = 12V to 15.3V, $I_{HI\_OUT\_DC}$= 53.3A	96.1			
		V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 26.7A	97.3	97.8		
Efficiency (Hot)	η_{HOT}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A, T_{CASE} = 85°C	96.3	96.9		%
Efficiency (Over Load Range)	$\eta_{20\%}$	10.66A < $I_{HI\_OUT\_DC}$ < 53.3A	**94.6**			%
HI-Side Output Resistance	R_{HI_COLD}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A, T_{CASE} = –40°C	10	16	20	mΩ
	R_{HI_AMB}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A	12	20	24	
	R_{HI_HOT}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A, T_{CASE} = 85°C	16	23	26	
HI-Side Voltage Ripple	$V_{HI\_OUT\_PP}$	$C_{HI\_OUT\_EXT}$ = 0µF, $I_{HI\_OUT\_DC}$ = 53.3A, V_{LO_DC} = 14V, 20MHz BW		330		mV
		$T_{CASE} \leq$ 100°C			**615**	

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of –40°C ≤ T_{CASE} ≤100°C (T-Grade); all other specifications are at T_{CASE} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Powertrain Protection Specification – Reverse Direction Operation (Low-Voltage Side to High-Voltage Side)						
Rated HI-Side Capacitance (External)	$C_{HI\_OUT\_EXT}$	Excessive capacitance may drive module into short circuit protection when starting from low-voltage side to high-voltage side			**300**	µF
LO-Side Overvoltage Lockout Threshold	V_{LO_OVLO+}		**16**	16.7	**17.4**	V
LO-Side Overvoltage Recovery Threshold	V_{HI_OVLO-}		**15.3**	16	**16.7**	V
LO-Side Overvoltage Lockout Response Time	t_{HI_OVLO}			30		µs
LO-Side Undervoltage Lockout Threshold	V_{LO_UVLO-}		**9.3**	10	**10.7**	V
LO-Side Undervoltage Recovery Threshold	V_{HI_UVLO+-}		**10**	10.7	**11.4**	V
LO-Side Undervoltage Lockout Response Time	t_{LO_UVLO}			100		µs
HI-Side Overcurrent Trip Threshold	$I_{HI\_OUT\_OCP}$	Powertrain is stopped but current can flow from LO Side to HI-Side through MOSFET body diodes	**56**	66.7	**80**	A
HI-Side Overcurrent Response Time Constant	$t_{HI\_OUT\_OCP}$	Effective internal RC filter		4		ms
HI-Side Short Circuit Protection Trip Threshold	I_{HI_SCP}	Powertrain is stopped but current can flow from LO Side to HI Side through MOSFET body diodes	**80**			A
HI-Side Short Circuit Protection Response Time	t_{HI_SCP}			1		µs

Operating Area

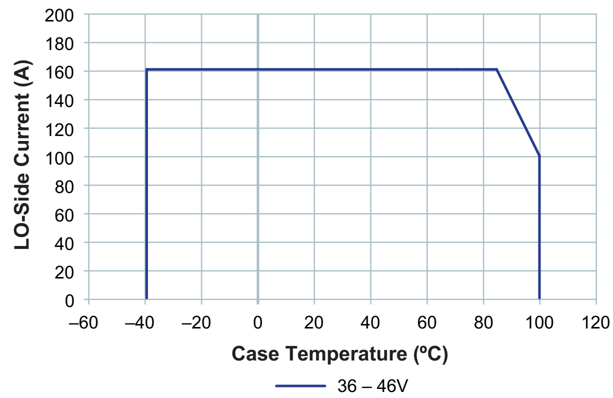


***Figure 1 —** Specified thermal operating area*

1. The NBM in a VIA package is cooled through the non-pin-side case.
2. The thermal rating is based on typical measured device efficiency.
3. The case temperature in the graph is the measured temperature of the non-pin-side housing, such that the internal operating temperature does not exceed 125°C.

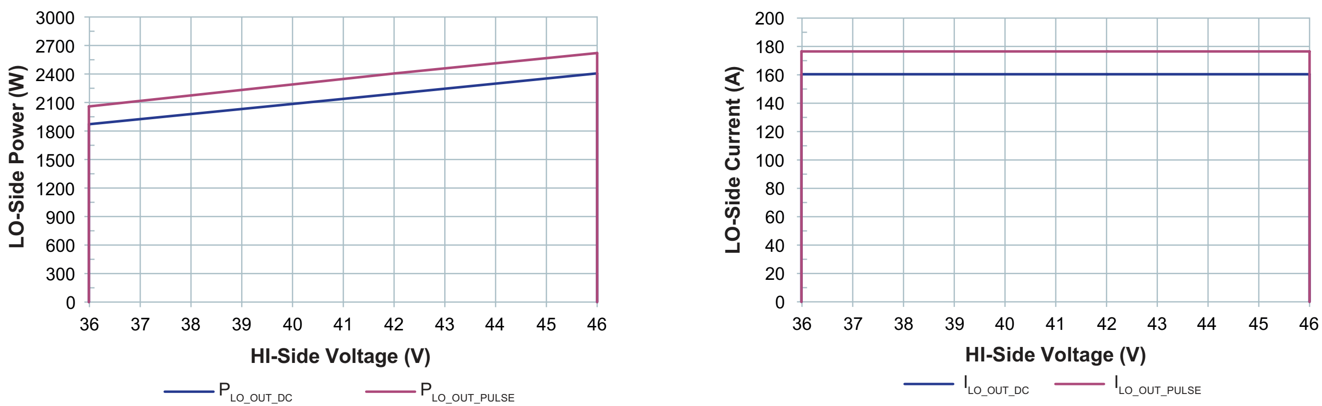


***Figure 2 —** Specified electrical operating area using rated R_{LO_HOT}*

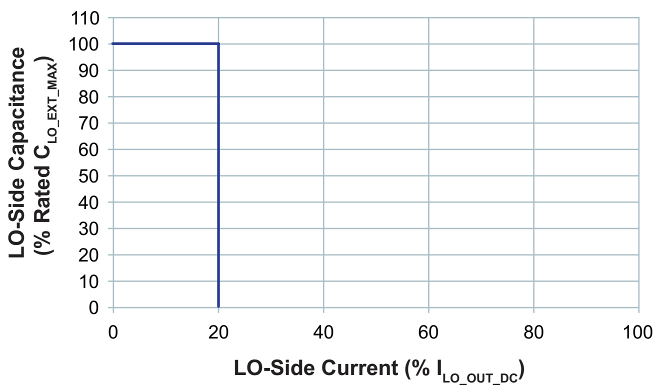
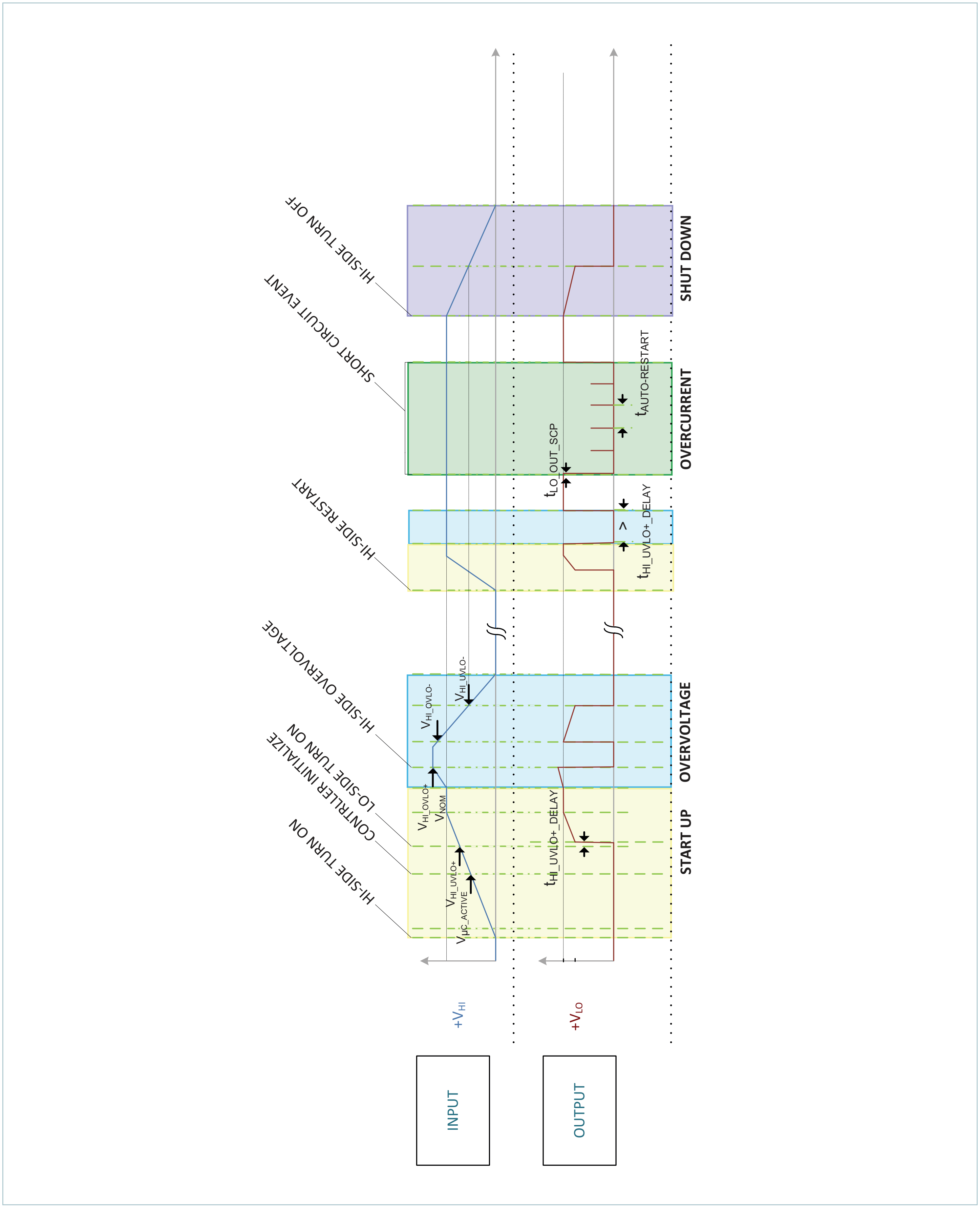
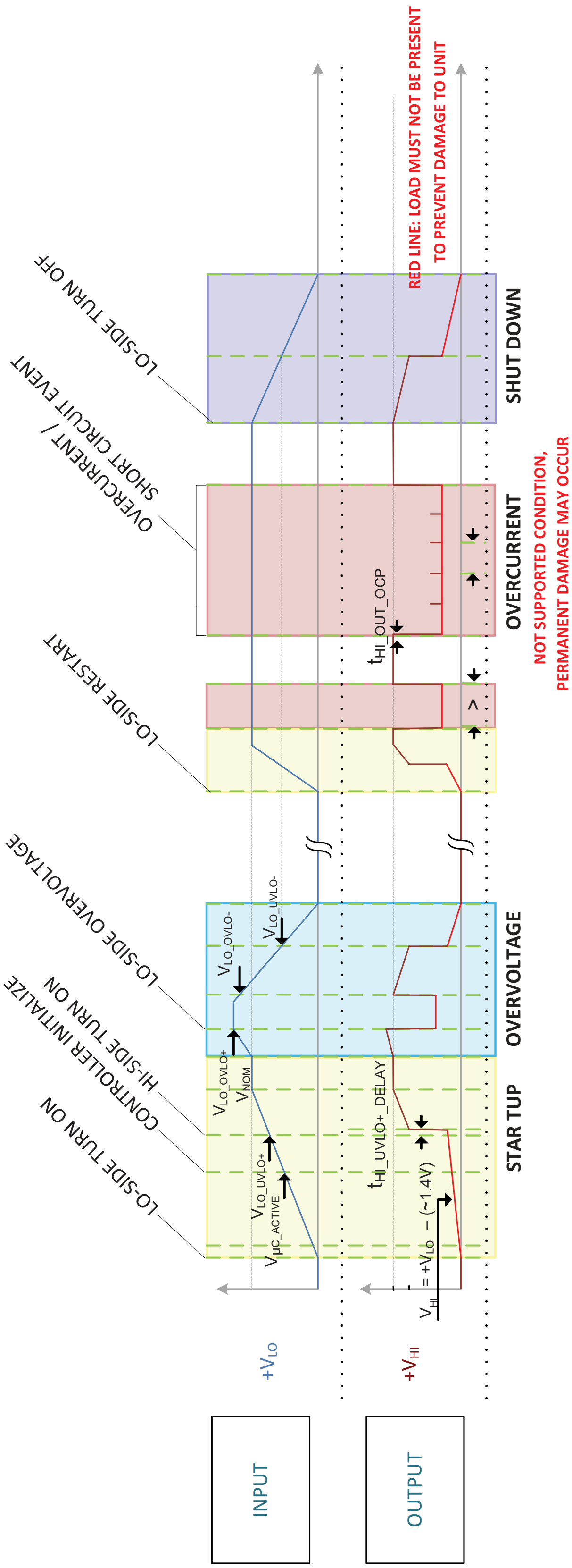


***Figure 3 —** Specified HI-side start up into load current and external capacitance*

Timing Diagram (Forward Direction)



Timing Diagram (Reverse Direction)



Application Characteristics

Temperature controlled via pin-side side cold plate, unless otherwise noted. All data presented in this section are collected from units processing power in the forward direction (high-voltage side to low-voltage side). See associated figures for general trend data.

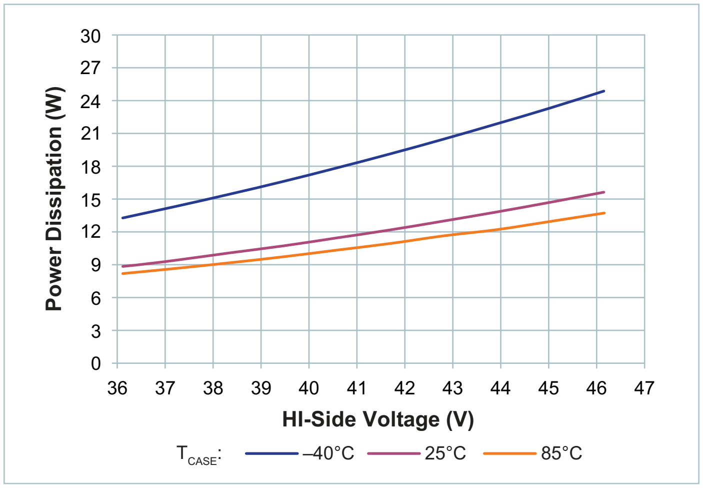


Figure 4 *— No-load power dissipation vs.* V_{HI_DC}

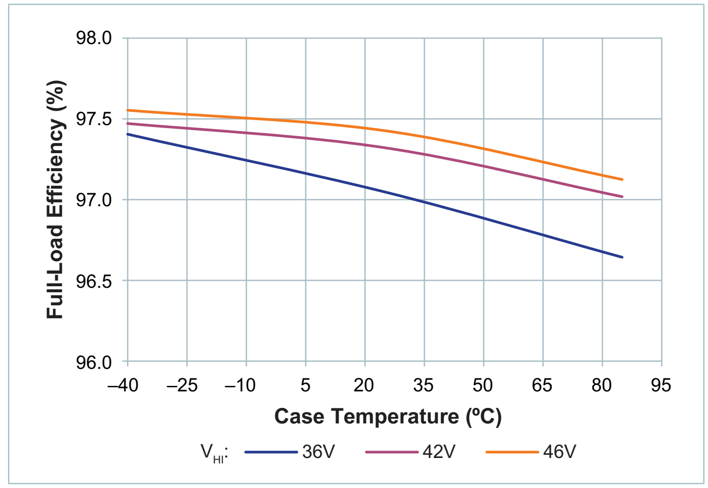


Figure 5 *— Full-load efficiency vs. temperature*

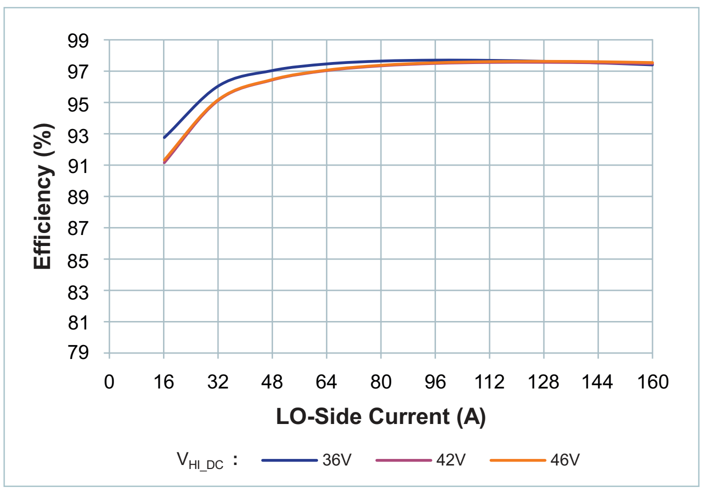


Figure 6 *— Efficiency at* T_{CASE} *= –40°C*

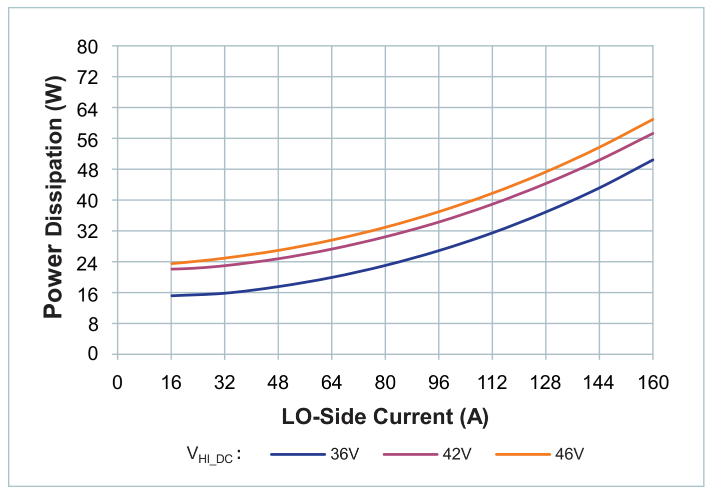


Figure 7 *— Power dissipation at* T_{CASE} *= –40°C*

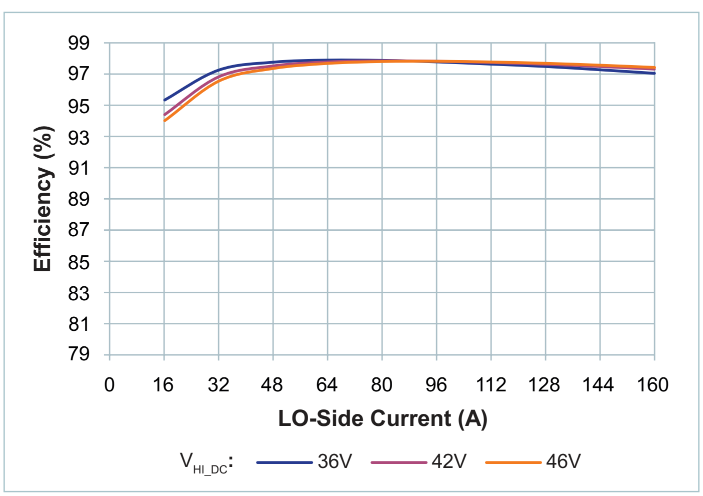


Figure 8 *— Efficiency at* T_{CASE} *= 25°C*

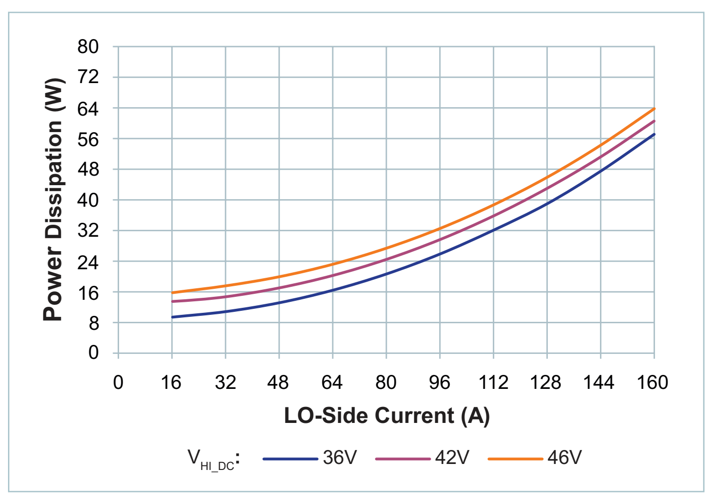


Figure 9 *— Power dissipation at* T_{CASE} *= 25°C*

Application Characteristics (Cont.)

Temperature controlled via pin-side side cold plate, unless otherwise noted. All data presented in this section are collected from units processing power in the forward direction (high-voltage side to low-voltage side). See associated figures for general trend data.

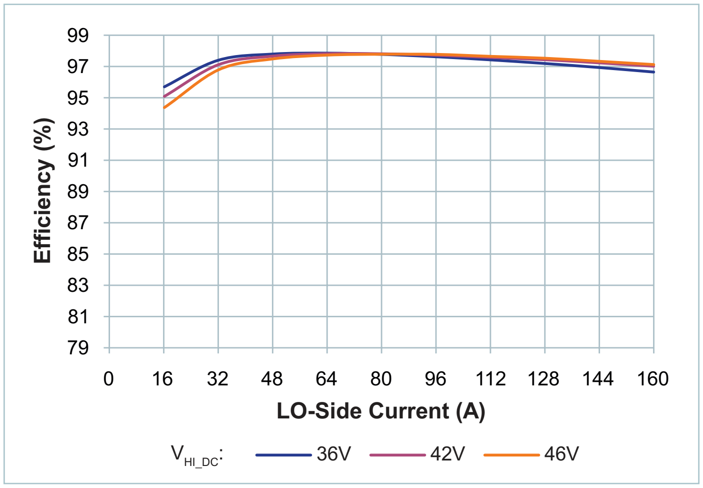


Figure 10 ***—*** *Efficiency at T_{CASE} = 85°C*

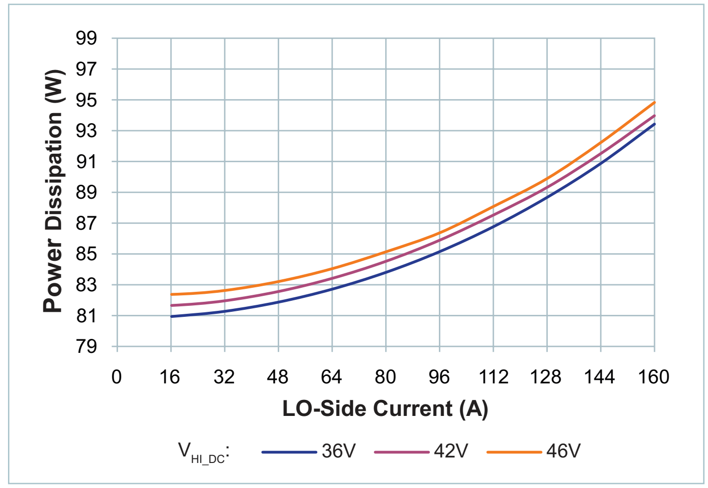


Figure 11 ***—*** *Power dissipation at T_{CASE} = 85°C*

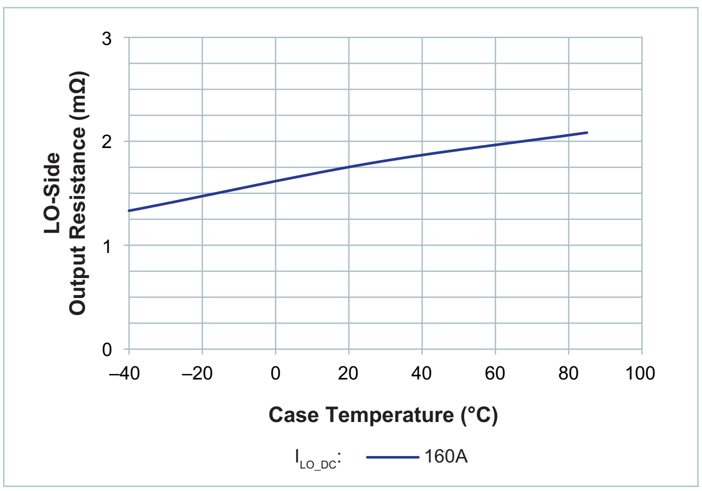


Figure 12 ***—*** *R_{LO} vs. temperature; nominal V_{HI_DC}*
I_{LO_DC} = 160A at T_{CASE} = 85°C

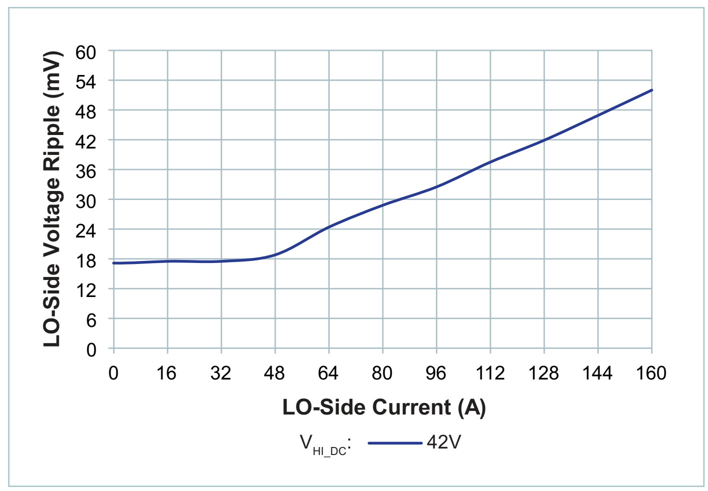


Figure 13 ***—*** *$V_{LO\_OUT\_PP}$ vs. I_{LO_DC} ; no external $C_{LO\_OUT\_EXT}$.*
Board-mounted module, scope setting:
20MHz analog BW

Application Characteristics (Cont.)

Temperature controlled via pin-side side cold plate, unless otherwise noted. All data presented in this section are collected from units processing power in the forward direction (high-voltage side to low-voltage side). See associated figures for general trend data.

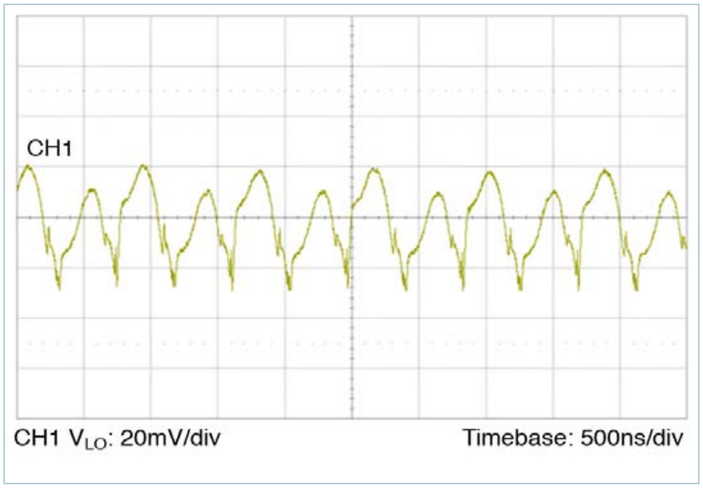


Figure 14 — *Full-load LO-side voltage ripple, 300µF $C_{HI\_IN\_EXT}$; no external $C_{LO\_OUT\_EXT}$. Board-mounted module, scope setting: 20MHz analog BW*

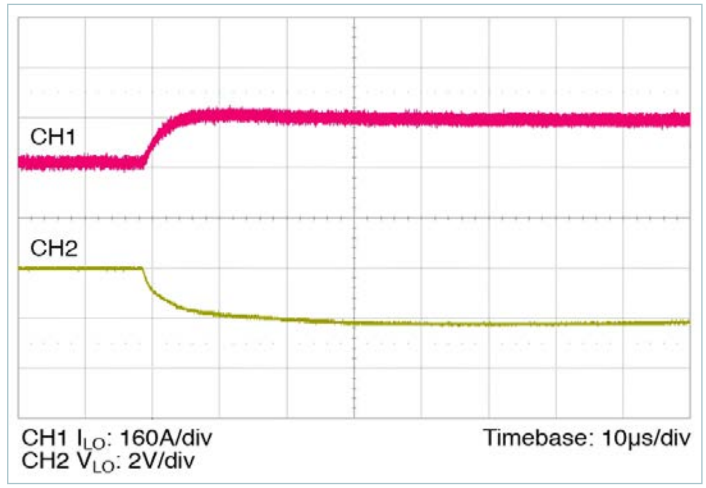


Figure 15 — *0 – 160A transient response: $C_{HI\_IN\_EXT}$ = 300µF, no external $C_{LO\_OUT\_EXT}$*

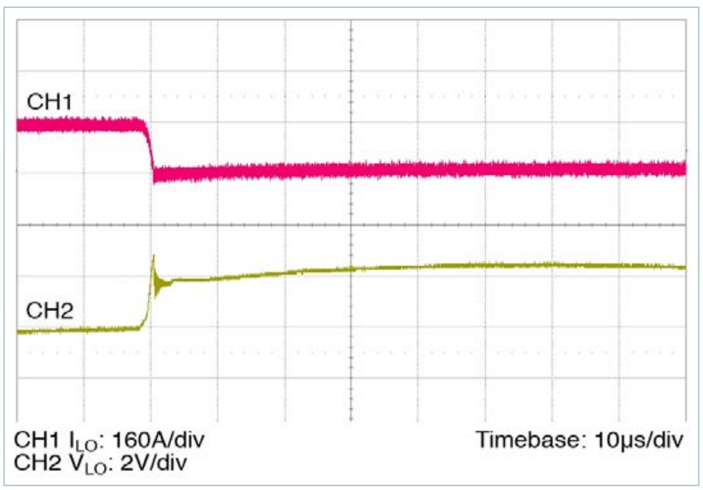


Figure 16 — *160 – 0A transient response: $C_{HI\_IN\_EXT}$ = 300µF, no external $C_{LO\_OUT\_EXT}$*

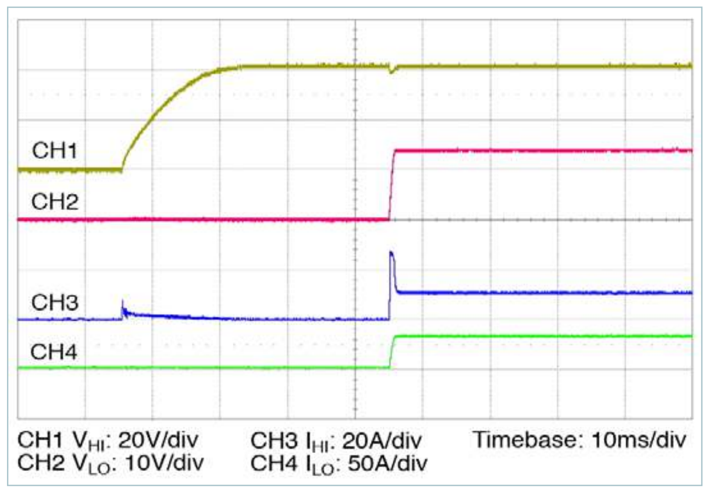


Figure 17 — *Forward start up from application of V_{HI_DC} = 42V, 20% I_{LO_DC}, 100% $C_{LO\_OUT\_EXT}$*

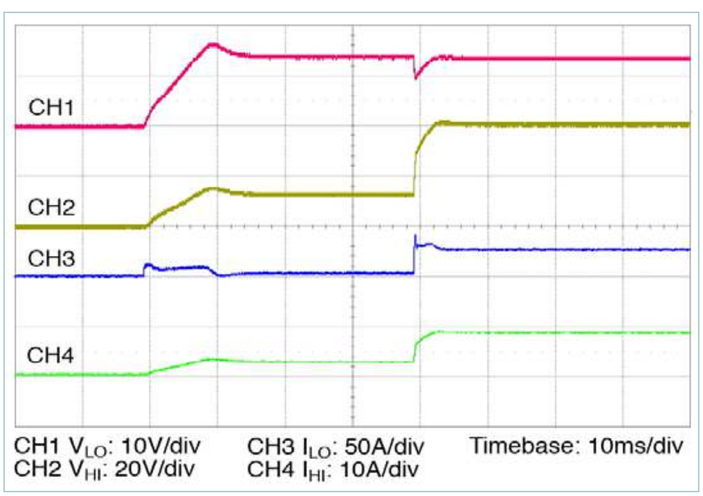


Figure 18 — *Reverse start up from application of V_{LO_DC} = 14V, 20% I_{HI_DC}, 100% $C_{HI\_OUT\_EXT}$*

General Characteristics

Specifications apply over all line, load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of –40°C ≤ T_{CASE} ≤100°C (T-Grade); all other specifications are at T_{CASE} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Mechanical						
Length	L	Lug (Chassis) Mount	95.34 [3.75]	95.59 [3.76]	95.84 [3.77]	mm [in]
Length	L	PCB (Board) Mount	95.34 [3.75]	95.59 [3.76]	95.84 [3.77]	mm [in]
Width	W		35.29 [1.39]	35.54 [1.40]	35.79 [1.41]	mm [in]
Height	H		9.019 [0.355]	9.40 [0.37]	9.781 [0.385]	mm [in]
Volume	Vol	Without heat sink		31.93 [1.95]		cm^3 [in^3]
Weight	W			130.4 [4.6]		g [oz]
Pin Material		C145 copper, 1/2 hard				
Underplate		Low-stress ductile Nickel	50		100	µin
Pin Finish (Gold)		Palladium	0.8		6	µin
		Soft Gold	0.12		2	
Pin Finish (Tin)		Whisker-resistant matte Tin	200		400	µin
Thermal						
Operating Internal Temperature	T_{INT}	NBM3814x46C15A6yzz (T-Grade)	–40		125	°C
		NBM3814x46C15A6yzz (C-Grade)	–20		125	
Operating Case Temperature	T_{CASE}	NBM3814x46C15A6yzz (T-Grade), derating applied, see safe thermal operating area	–40		100	
		NBM3814x46C15A6yzz (C-Grade), derating applied, see safe thermal operating area	–20		100	
Thermal Resistance Pin Side	$\theta_{INT\_PIN\_SIDE}$	Estimated thermal resistance to maximum temperature internal component from isothermal pin/ terminal-side housing		1.4		°C/W
Thermal Resistance Housing	θ_{HOU}	Estimated thermal resistance of thermal coupling between the pin-side and non-pin-side case surfaces		0.51		°C/W
Thermal Resistance Non-Pin Side	$\theta_{INT\_NON\_PIN\_SIDE}$	Estimated thermal resistance to maximum temperature internal component from isothermal non-pin/ non-terminal housing		0.83		°C/W
Thermal Capacity				52		Ws/°C
Assembly						
Storage Temperature	T_{ST}	NBM3814x46C15A6yzz (T-Grade)	–40		125	°C
		NBM3814x46C15A6yzz (C-Grade)	–40		125	°C
ESD Withstand	ESD_{HBM}	Human Body Model, "ESDA / JEDEC JDS-001-2012" Class I-C (1kV to <2kV)	1000			
	ESD_{CDM}	Charge Device Model, "JESD 22-C101-E" Class II (200V to <500V)	200			

General Characteristics (Cont.)

Specifications apply over all line, load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of –40°C ≤ T_{CASE} ≤100°C (T-Grade); all other specifications are at T_{CASE} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Safety						
Isolation Capacitance	C_{HI_LO}	Unpowered unit	N/A	N/A	N/A	pF
Isolation Resistance	R_{HI_LO}	At $500V_{DC}$	0			MΩ
MTBF		MIL-HDBK-217Plus Parts Count - 25°C Ground Benign, Stationary, Indoors / Computer		2.2		MHrs
		Telcordia Issue 2 - Method I Case III; 25°C Ground Benign, Controlled		3.6		MHrs
Agency Approvals / Standards		cTÜVus EN 60950-1				
		cURus UL60950-1				
		CE Marked for Low Voltage Directive and RoHS Recast Directive, as applicable				

NBM in a VIA Package

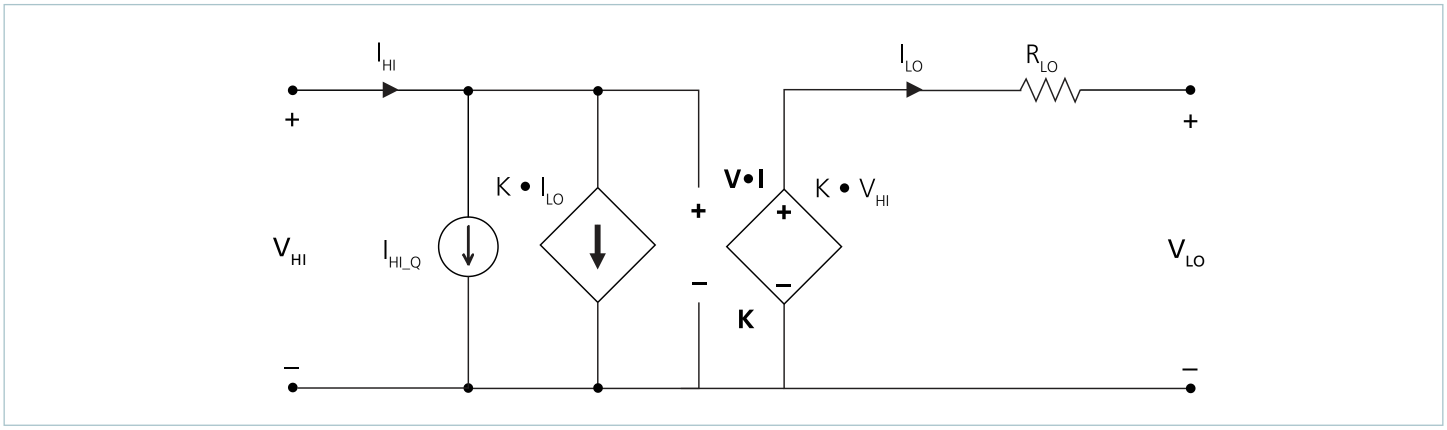


Figure 19 *— NBM DC model (Forward direction)*

The NBM uses a high frequency resonant tank to move energy from the high-voltage side to the low-voltage side and vice versa. The resonant LC tank, operated at high frequency, is amplitude modulated as a function of the HI-side voltage and the LO-side current. A small amount of capacitance embedded in the high-voltage-side and low-voltage-side stages of the module is sufficient for full functionality and is key to achieving high power density.

The NBM3814x46C15A6yzz can be simplified into the model shown in Figure 19.

At no load:

$$V_{LO} = V_{HI} \bullet K \tag{1}$$

K represents the "turns ratio" of the NBM.
Rearranging Equation 1:

$$K = \frac{V_{LO}}{V_{HI}} \tag{2}$$

In the presence of a load, V_{LO} is represented by:

$$V_{LO} = V_{HI} \bullet K - I_{LO} \bullet R_{LO} \tag{3}$$

and I_{LO} is represented by:

$$I_{LO} = \frac{I_{HI} - I_{HI\_Q}}{K} \tag{4}$$

R_{LO} represents the impedance of the NBM and is a function of the R_{DS_ON} of the HI-side and LO-side MOSFETs, PC board resistance of HI-side and LO-side boards and the winding resistance of the power auto-transformer. I_{HI_Q} represents the HI-side quiescent current of the NBM controller, gate drive circuitry, and core losses.

The effective DC voltage transformer action provides additional interesting attributes. Assuming that $R_{LO} = 0\Omega$ and $I_{HI\_Q} = 0A$, Equation 3 now becomes Equation 1 and is essentially load independent, resistor R is now placed in series with V_{HI}.

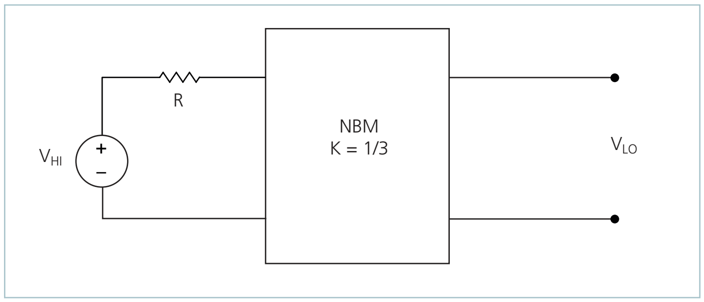


Figure 20 *— K = 1/3 NBM with series HI-side resistor*

The relationship between V_{HI} and V_{LO} becomes:

$$V_{LO} = \left(V_{HI} - I_{HI} \bullet R\right) \bullet K \tag{5}$$

Substituting the simplified version of Equation 4 (I_{HI_Q} is assumed = 0A) into Equation 5 yields:

$$V_{LO} = V_{HI} \bullet K - I_{LO} \bullet R \bullet K^2 \tag{6}$$

This is similar in form to Equation 3, where R_{LO} is used to represent the characteristic impedance of the NBM. However, in this case a real resistor, R, on the high-voltage side of the NBM is effectively scaled by K^2 with respect to the low-voltage side.

Assuming that R = 1Ω, the effective R as seen from the low-voltage side is 111mΩ, with K = 1/3.

A similar exercise can be performed with the additon of a capacitor or shunt impedance at the high-voltage side of the NBM. A switch in series with V_{HI} is added to the circuit. This is depicted in Figure 21.

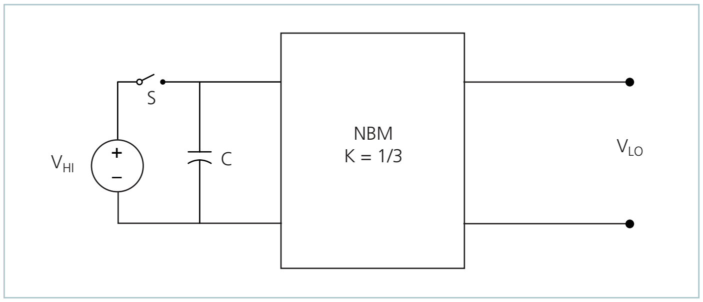


***Figure 21** — NBM with HI-side capacitor*

A change in V_{HI} with the switch closed would result in a change in capacitor current according to the following equation:

$$I_C(t) = C \frac{dV_{HI}}{dt} \qquad (7)$$

Assume that with the capacitor charged to V_{HI}, the switch is opened and the capacitor is discharged through the idealized NBM. In this case,

$$I_C = I_{LO} \bullet K \qquad (8)$$

substituting Equation 1 and 8 into Equation 7 reveals:

$$I_{LO}(t) = \frac{C}{K^2} \bullet \frac{dV_{LO}}{dt} \qquad (9)$$

The equation in terms of the LO side has yielded a K^2 scaling factor for C, specified in the denominator of the equation.

A K factor less than unity results in an effectively larger capacitance on the low-voltage side when expressed in terms of the high side. With a K = 1/3 as shown in Figure 21, C = 1µF would appear as C = 9µF when viewed from the low-voltage side.

Low impedance is a key requirement for powering a high-current, low-voltage load efficiently. A switching regulation stage should have minimal impedance while simultaneously providing appropriate filtering for any switched current. The use of a NBM between the regulation stage and the point-of-load provides a dual benefit of scaling down series impedance leading back to the source and scaling up shunt capacitance or energy storage as a function of its K factor squared. However, these benefits are not achieved if the series impedance of the NBM is too high. The impedance of the NBM must be low, i.e., well beyond the crossover frequency of the system.

A solution for keeping the impedance of the NBM low involves switching at a high frequency. This enables the use of small magnetic components because magnetizing currents remain low. Small magnetics mean small path lengths for turns. Use of low loss core material at high frequencies also reduces core losses.

The two main terms of power loss in the NBM module are:

- No-load power dissipation (P_{HI_NL}): defined as the power used to power up the module with an enabled powertrain at no load.
- Resistive loss ($P_{R_{LO}}$): refers to the power loss across the NBM module modeled as pure resistive impedance.

$$P_{DISSIPATED} = P_{HI\_NL} + P_{R_{LO}} \qquad (10)$$

Therefore,

$$P_{LO\_OUT} = P_{HI\_IN} - P_{DISSIPATED} = P_{HI\_IN} - P_{HI\_NL} - P_{R_{LO}} \qquad (11)$$

The above relations can be combined to calculate the overall module efficiency:

$$\eta = \frac{P_{LO\_OUT}}{P_{HI\_IN}} = \frac{P_{HI\_IN} - P_{HI\_NL} - P_{R_{LO}}}{P_{HI\_IN}} \qquad (12)$$

$$= \frac{V_{HI} \bullet I_{HI} - P_{HI\_NL} - (I_{LO})^2 \bullet R_{LO}}{V_{HI} \bullet I_{HI}}$$

$$= 1 - \left(\frac{P_{HI\_NL} + (I_{LO})^2 \bullet R_{LO}}{V_{HI} \bullet I_{HI}}\right)$$

Filter Design

A major advantage of NBM systems versus conventional PWM converters is that the auto-transformer based NBM does not require external filtering to function properly. The resonant LC tank, operated at extreme high frequency, is amplitude modulated as a function of HI-side voltage and LO-side current and efficiently transfers charge through the auto-transformer. A small amount of capacitance embedded in the high-voltage-side and low-voltage-side stages of the module is sufficient for full functionality and is key to achieving power density.

This paradigm shift requires system design to carefully evaluate external filters in order to:

- *Guarantee low source impedance:*

  To take full advantage of the NBM module's dynamic response, the impedance presented to its HI-side terminals must be low from DC to approximately 5MHz. The connection of the bus converter module to its power source should be implemented with minimal distribution inductance. If the interconnect inductance exceeds 100nH, the HI side should be bypassed with a RC damper to retain low source impedance and stable operation. With an interconnect inductance of 200nH, the RC damper may be as high as 1µF in series with 0.3Ω. A single electrolytic or equivalent low-Q capacitor may be used in place of the series RC bypass.

- *Further reduce HI-side and/or LO-side voltage ripple without sacrificing dynamic response:*

  Given the wide bandwidth of the module, the source response is generally the limiting factor in the overall system response. Anomalies in the response of the HI-side source will appear at the LO side of the module multiplied by its K factor.

- *Protect the module from overvoltage transients imposed by the system that would exceed maximum ratings and induce stresses:*

  The module high/low-side voltage ranges shall not be exceeded. An internal overvoltage lockout function prevents operation outside of the normal operating HI-side range. Even when disabled, the powertrain is exposed to the applied voltage and the power MOSFETs must withstand it.

Total load capacitance of the NBM module shall not exceed the specified maximum. Owing to the wide bandwidth and small LO-side impedance of the module, low-frequency bypass capacitance and significant energy storage may be more densely and efficiently provided by adding capacitance at the HI side of the module. At frequencies <500kHz the module appears as an impedance of R_{LO} between the source and load.

Within this frequency range, capacitance at the HI side appears as effective capacitance on the LO side per the relationship defined in Equation 13.

$$C_{LO\_EXT} = \frac{C_{HI\_EXT}}{K^2} \qquad (13)$$

This enables a reduction in the size and number of capacitors used in a typical system.

Thermal Considerations

The VIA package provides effective conduction cooling from either of the two module surfaces. Heat may be removed from the pin-side surface, the non-pin-side surface or both. The extent to which these two surfaces are cooled is a key component for determining the maximum power that can be processed by a NBM, as can be seen from the specified thermal operating area in Figure 1. Since the NBM has a maximum internal temperature rating, it is necessary to estimate this temperature based on a system-level thermal solution. For this purpose, it is helpful to simplify the thermal solution into a roughly equivalent circuit where power dissipation is modeled as a current source, isothermal surface temperatures are represented as voltage sources and the thermal resistances are represented as resistors. Figure 22 shows the "thermal circuit" for the NBM in a VIA package.

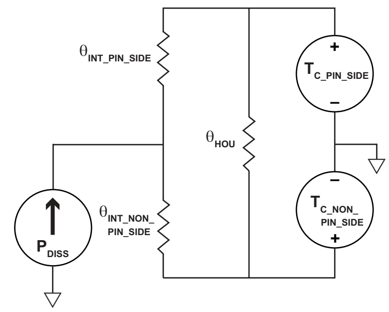


***Figure 22** — Double-sided cooling thermal model*

In this case, the internal power dissipation is P_{DISS}, $\theta_{INT\_PIN\_SIDE}$ and $\theta_{INT\_NON\_PIN\_SIDE}$ are the thermal resistance characteristics of the NBM and the pin-side and non-pin-side surface temperatures are represented as $T_{C\_PIN\_SIDE}$ and $T_{C\_NON\_PIN\_SIDE}$. It is interesting to note that the package itself provides a high degree of thermal coupling between the pin-side and non-pin-side case surfaces (represented in the model by the resistor θ_{HOU}). This feature enables two main options regarding thermal designs:

- Single-side cooling: the model of Figure 22 can be simplified by calculating the parallel resistor network and using one simple thermal resistance number and the internal power dissipation curves; an example for non-pin-side cooling only is shown in Figure 23.

In this case, θ_{INT} can be derived as follows:

$$\theta_{INT} = \frac{(\theta_{INT\_PIN\_SIDE} + \theta_{HOU}) \bullet \theta_{INT\_NON\_PIN\_SIDE}}{\theta_{INT\_PIN\_SIDE} + \theta_{HOU} + \theta_{INT\_NON\_PIN\_SIDE}} \qquad (14)$$

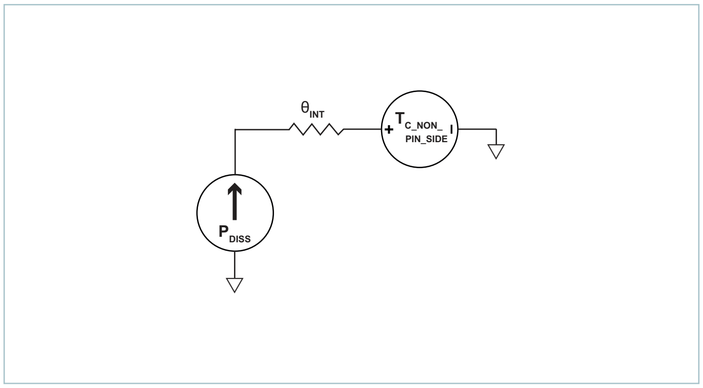


Figure 23 *— Single-sided cooling thermal model*

- Double-side cooling: while this option might bring limitedadvantage to the module internal components (given the surface-to-surface coupling provided), it might be appealing in cases where the external thermal system requires allocating power to two different elements, such as heat sinks with independent airflows or a combination of chassis/air cooling.

Current Sharing

The performance of the NBM is based on efficient transfer of energy through an auto-transformer without the need of closed loop control. For this reason, the transfer characteristic can be approximated by an ideal auto-transformer with a positive temperature coefficient series resistance.

This type of characteristic is close to the impedance characteristic of a DC power distribution system both in dynamic (AC) behavior and for steady state (DC) operation.

When multiple NBM modules of a given part number are connected in an array, they will inherently share the load current according to the equivalent impedance divider that the system implements from the power source to the point-of-load. Ensuring equal current sharing among modules requires that NBM array impedances be matched.

Some general recommendations to achieve matched array impedances include:

- Dedicate common copper planes/wires within the PCB/Chassis to deliver and return the current to the modules.
- Provide as symmetric a PCB/Wiring layout as possible among modules

For further details see:
[AN:016 Using BCM Bus Converters in High Power Arrays.]

Fuse Selection

In order to provide flexibility in configuring power systems, NBM in a VIA package modules are not internally fused. Input line fusing of NBM products is recommended at the system level to provide thermal protection in case of catastrophic failure.

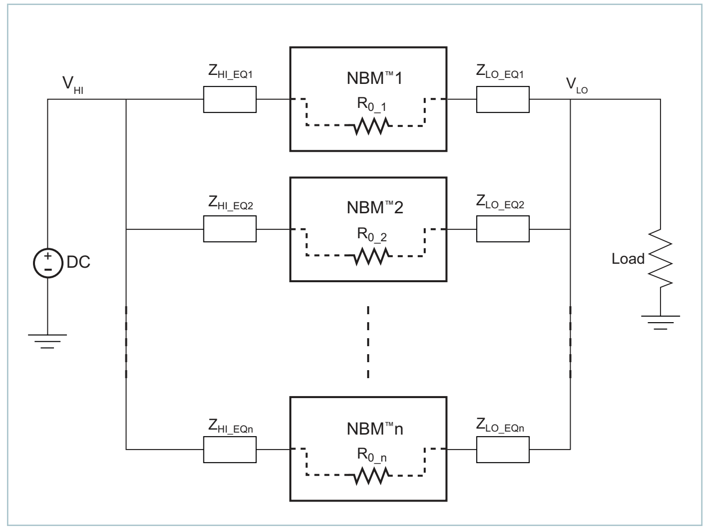


Figure 24 *— NBM module array*

The fuse shall be selected by closely matching system requirements with the following characteristics:

- Current rating
  (usually greater than maximum current of NBM module)
- Maximum voltage rating
  (usually greater than the maximum possible input voltage)
- Ambient temperature
- Nominal melting I^2t
- Recommend fuse: ≤60A Littelfuse TLS Series (HI side)

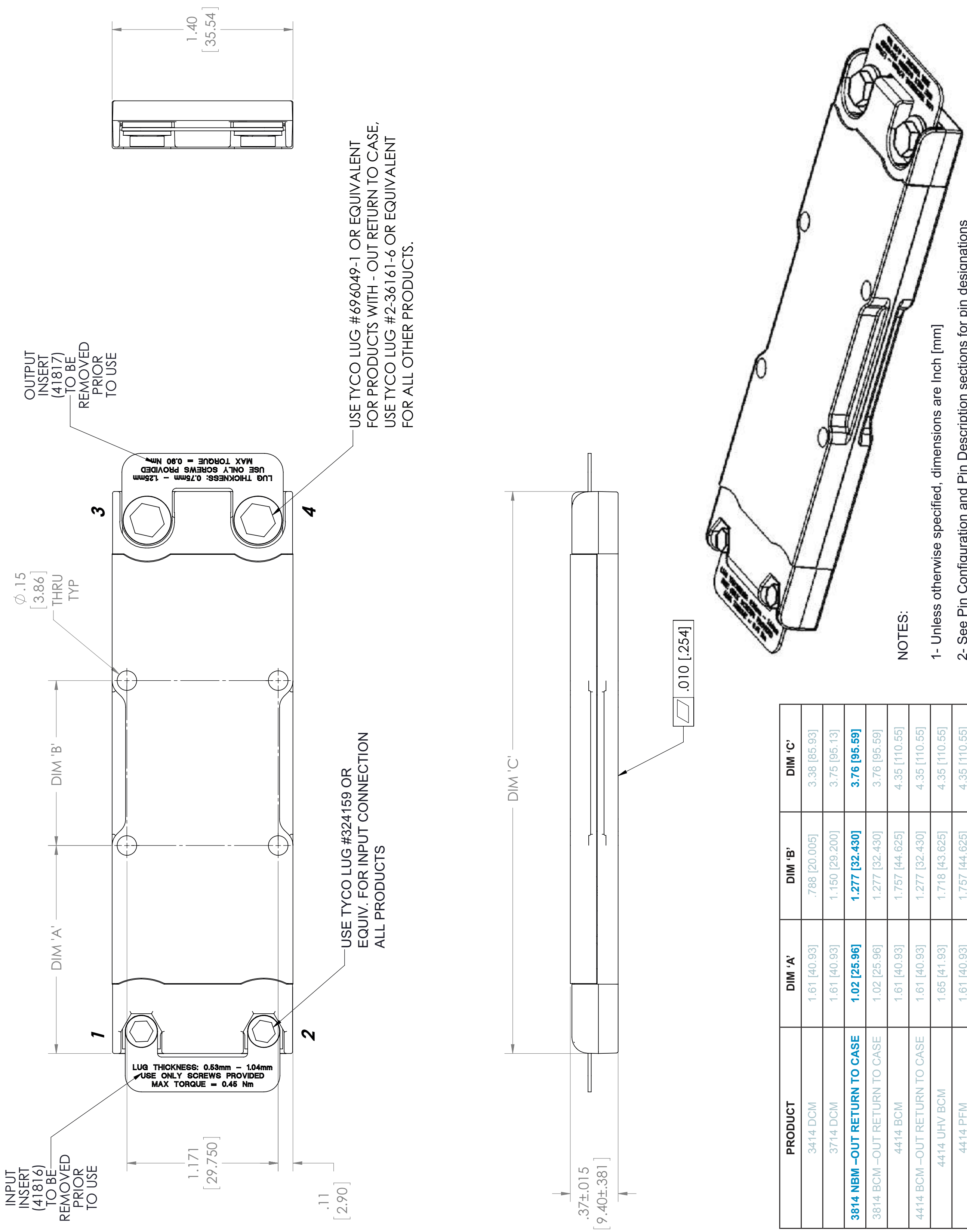
Start Up and Reverse Operation

The NBM3814x46C15A6yzz is capable of start up in forward and reverse direction once the applied voltage is greater than the undervoltage lockout threshold.

The non-isolated bus converter modules are capable of reverse power operation. Once the unit is enabled, energy can be transferred from low-voltage side back to the high-voltage side whenever the low-side voltage exceeds V_{HI} • K. The module will continue operation in this fashion for as long as no faults occur.

Start-up loading must be no greater than 20% of rated max current respectively in the forward or reverse direction. A load must not be present on the $+V_{HI}$ pin if the powertrain is not actively switching. High-voltage-side MOSFET body diode conduction will occur if the unit stops switching while a load is present on +HI and $+V_{LO}$ voltage is two diodes drop higher than $+V_{HI}$. Remove +HI load prior to disabling the module using +LO power or prior to faults.

NBM in VIA Package Chassis (Lug) Mount Package Mechanical Drawing



PRODUCT	DIM 'A'	DIM 'B'	DIM 'C'
3414 DCM	1.61 [40.93]	.788 [20.005]	3.38 [85.93]
3714 DCM	1.61 [40.93]	1.150 [29.200]	3.75 [95.13]
3814 NBM –OUT RETURN TO CASE	**1.02 [25.96]**	**1.277 [32.430]**	**3.76 [95.59]**
3814 BCM –OUT RETURN TO CASE	1.02 [25.96]	1.277 [32.430]	3.76 [95.59]
4414 BCM	1.61 [40.93]	1.757 [44.625]	4.35 [110.55]
4414 BCM –OUT RETURN TO CASE	1.61 [40.93]	1.277 [32.430]	4.35 [110.55]
4414 UHV BCM	1.65 [41.93]	1.718 [43.625]	4.35 [110.55]
4414 PFM	1.61 [40.93]	1.757 [44.625]	4.35 [110.55]
4414 PFM 3kV	1.61 [40.93]	1.658 [42.110]	4.35 [110.55]
4914 PFM	2.17 [55.12]	1.757 [44.625]	4.91 [124.75]

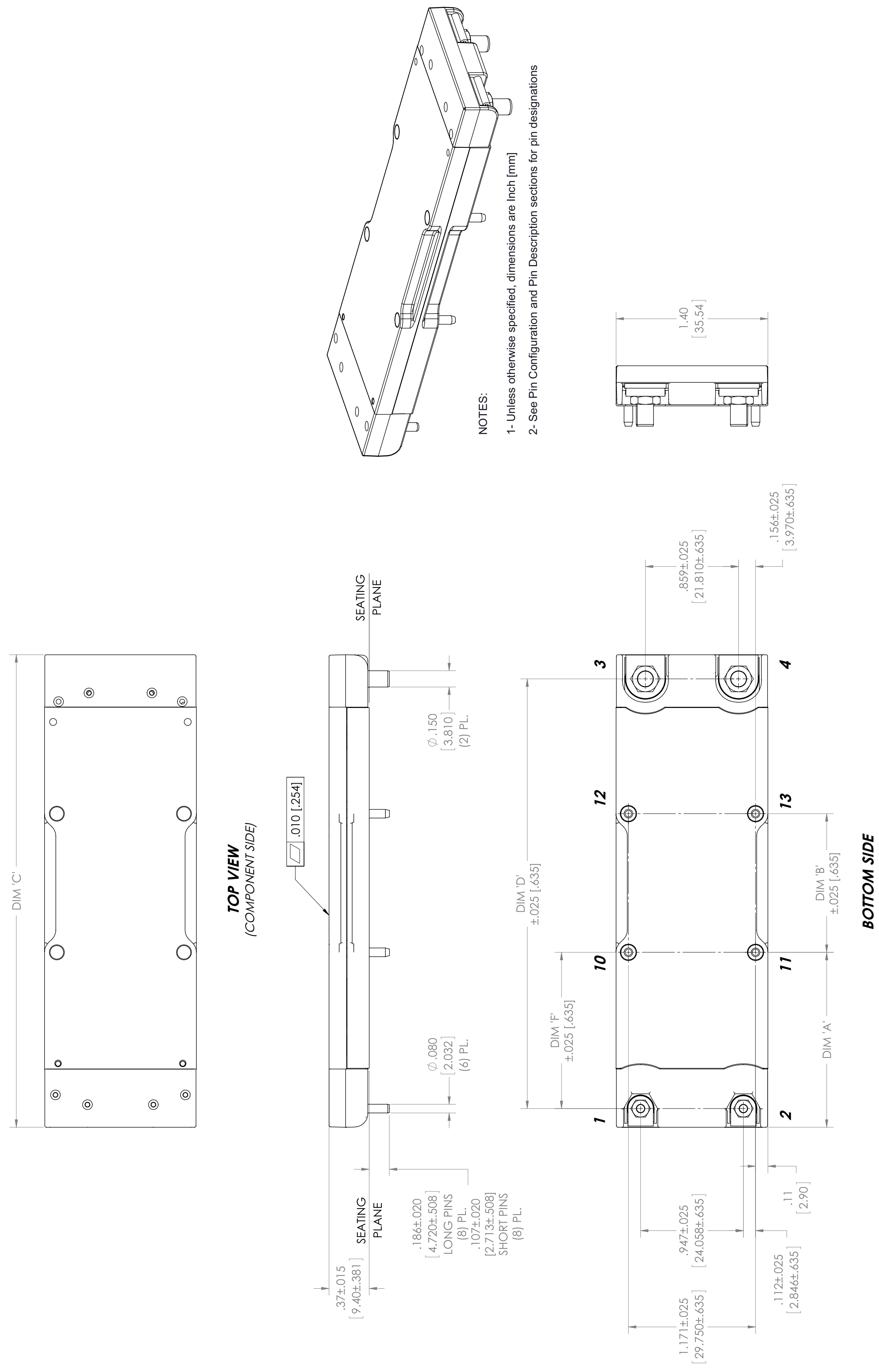
NOTES:

1- Unless otherwise specified, dimensions are Inch [mm]

2- See Pin Configuration and Pin Description sections for pin designations

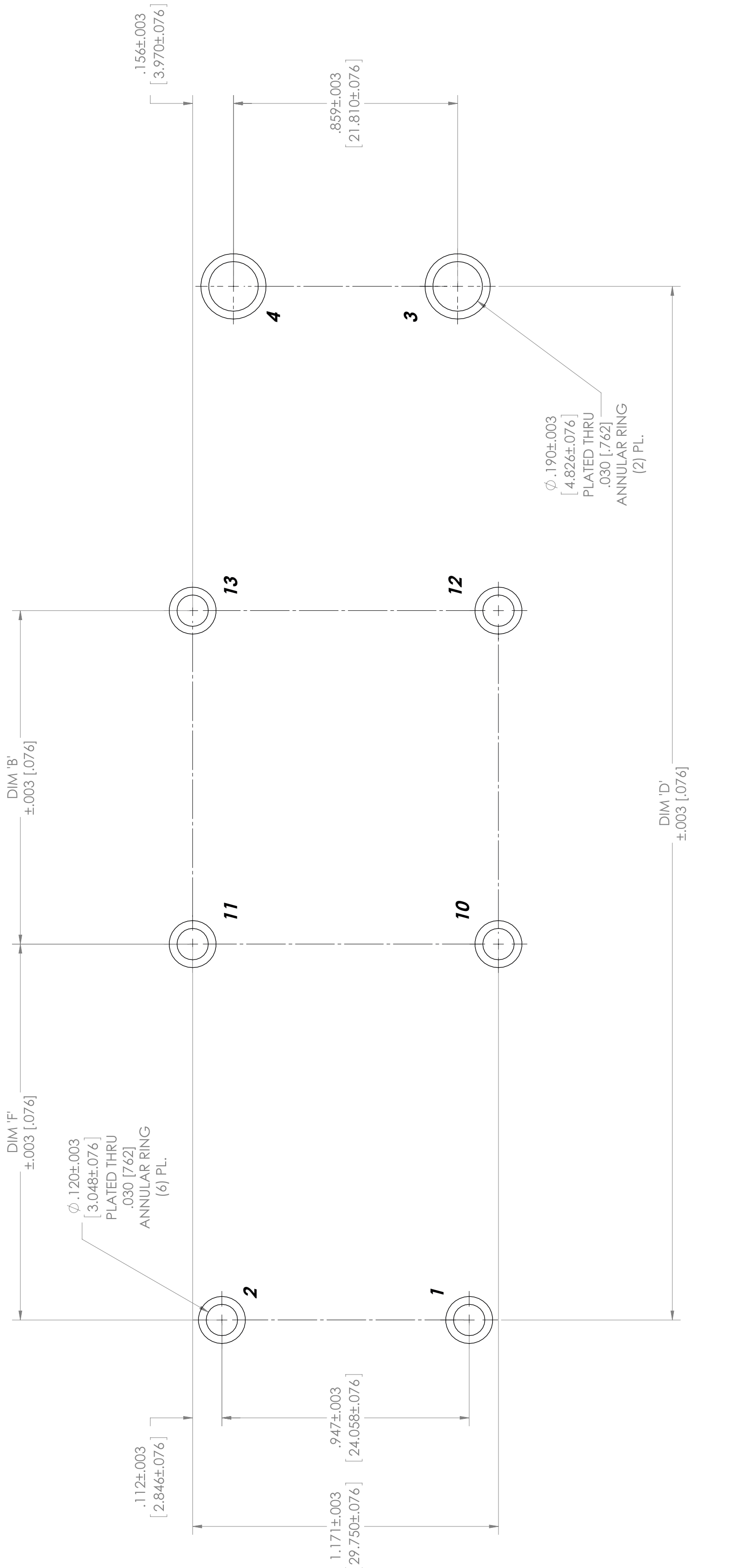
NBM in VIA Package PCB (Board) Mount Package Mechanical Drawing

PRODUCT	DIM 'A'	DIM 'B'	DIM 'C'	DIM 'D'	DIM 'F'
3814 NBM –OUT RETURN TO CASE	**1.02 [25.96]**	**1.277 [32.430]**	**3.76 [95.59]**	**3.368 [85.554]**	**.850 [21.590]**
3814 BCM –OUT RETURN TO CASE	1.02 [25.96]	1.277 [32.430]	3.76 [95.59]	3.368 [85.554]	.850 [21.590]
4414 BCM –OUT RETURN TO CASE	1.61 [40.93]	1.277 [32.430]	4.35 [110.55]	3.957 [100.517]	1.439 [36.554]



NBM in VIA Package PCB (Board) Mount Package Recommended Hole Pattern

PRODUCT	DIM 'A'	DIM 'B'	DIM 'C'	DIM 'D'	DIM 'F'
3814 NBM –OUT RETURN TO CASE	**1.02 [25.96]**	**1.277 [32.430]**	**3.76 [95.59]**	**3.368 [85.554]**	**.850 [21.590]**
3814 BCM –OUT RETURN TO CASE	1.02 [25.96]	1.277 [32.430]	3.76 [95.59]	3.368 [85.554]	.850 [21.590]
4414 BCM –OUT RETURN TO CASE	1.61 [40.93]	1.277 [32.430]	4.35 [110.55]	3.957 [100.517]	1.439 [36.554]



RECOMMENED HOLE PATTERN
(COMPONEBT SIDE)

NOTES:
1- Unless otherwise specified, dimensions are Inch [mm]
2- See Pin Configuration and Pin Description sections for pin designations

Revision History

Revision	Date	Description	Page Number(s)
1.0	03/03/16	Initial release	n/a
1.1	05/02/16	New Power Pin Nomenclature	All
1.2	04/11/17	Content improvements Package drawings update	All 21 – 23
1.3	09/21/17	Updated short circuit protection trip threshold	8
1.4	01/24/18	Updated mechanical drawings	21 – 23
1.5	02/06/18	Updated agency approvals	1, 16
1.6	08/17/18	Updated mechanical drawings	22 – 23

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