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 1258 W/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 0.37 in
95.59 x 35.54 x 9.40 mm

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 NBM 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, 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's 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.

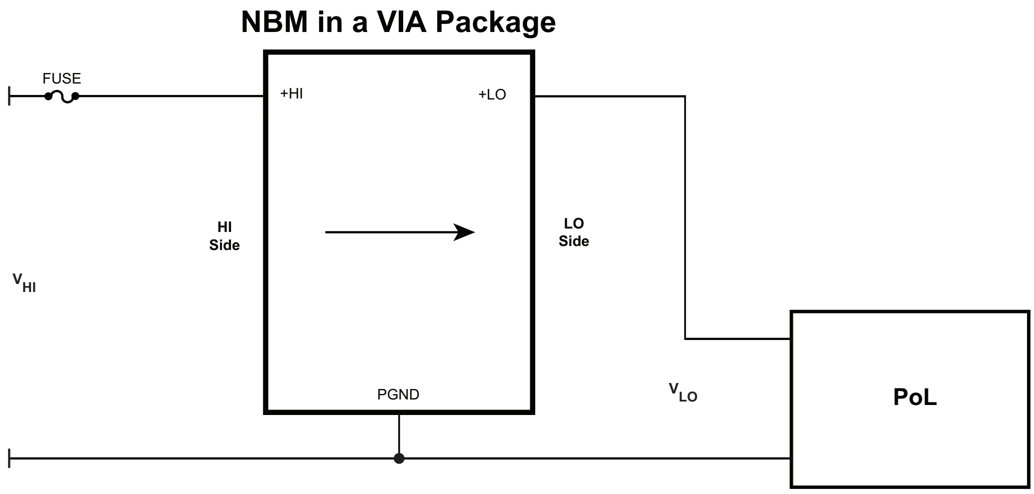
The NBM non-isolated topology allows start up and steady state operation in forward and reverse directions. It provides bidirectional protections. However if power train is disabled by any protection, and V_{LO} is present, then voltage equal to V_{LO} minus two diode drops will appear on high voltage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

Part Ordering Information

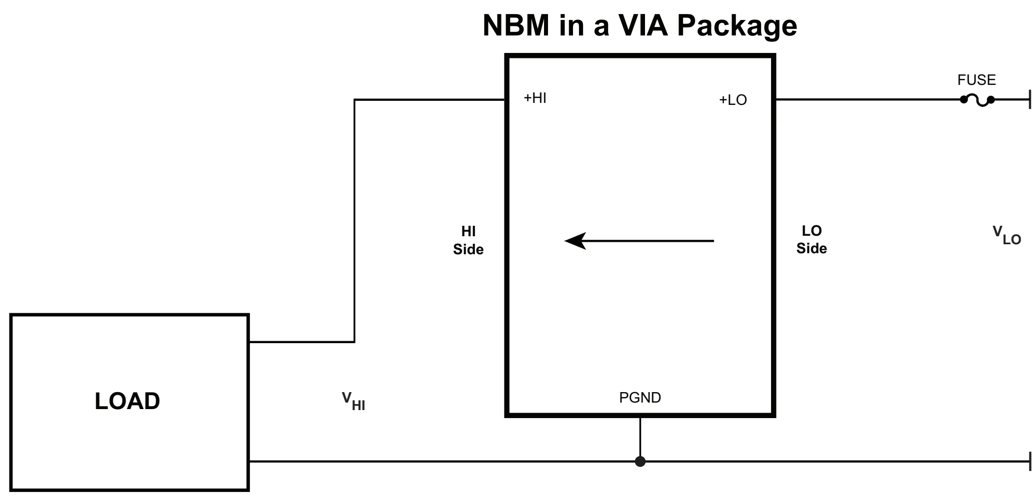
Product Function	Package Length	Package Width	Package Type	Max High Side Voltage	High Side Voltage Range Ratio	Max Low Side Voltage	Max Low Side Current	Product Grade (Case Temperature)	Option Field
NBM	38	14	x	46	C	15	A6	y	zz
NBM = Non-Isolated Bus Converter Module	Length in Inches x 10	Width in Inches x 10	B = Board VIA V = Chassis VIA	Internal Reference				C = -20 to 100°C[1] T = -40 to 100°C[1]	00 = Chassis/Always On 04 = Short Pin/Always On 08 = Long Pin/Always On

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

Typical Application

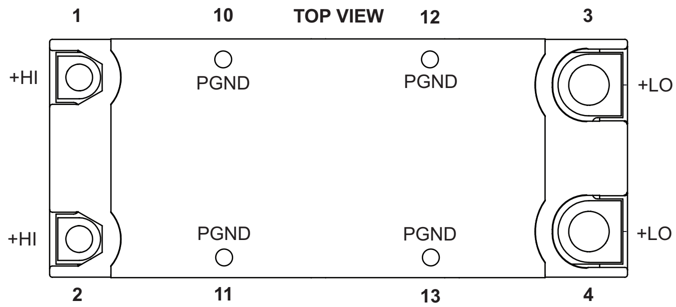


NBM3814x46C15A6yzz at point of load providing fixed ratio step-down DC-DC conversion to PoL devices. NBM is operating in forward direction.

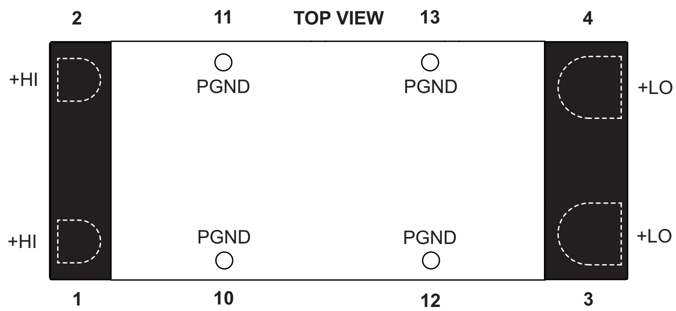


NBM3814x46C15A6yzz providing fixed ratio step-up DC-DC conversion. NBM is operating in reverse direction.

Pin Configuration



NBM in a 3814 VIA Package - Chassis (Lug) Mount



NBM in a 3814 VIA Package - Board (PCB) Mount

Pin Descriptions

Pin Number	Signal Name	Type	Function
1, 2	+HI	HIGH SIDE POWER	Positive auto-transformer power terminal - on high voltage side
3, 4	+LO	LOW SIDE POWER	Positive auto-transformer power terminal - on low voltage side
10, 11, 12, 13	PGND	POWER RETURN	Common negative auto-transformer 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
Dielectric Withstand*	See note below			
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}

* 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 ≤ 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
General Powertrain High Voltage Side to Low Voltage Side Specification (Forward Direction)						
Hi Side Input Voltage range, continuous	V_{HI_DC}		**36**		**46**	V
V_{HI} µController	$V_{\mu C\_ACTIVE}$	V_{HI_DC} voltage where µC is initialized, (powertrain inactive)			15	V
HI to LO Input Quiescent Current	I_{HI_Q}	Disabled, V_{HI_DC} = 42V		8		mA
		T_{CASE} ≤ 100°C			12	
HI to LO 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} = 36V to 46V, T_{CASE} = 25 °C			22	
		V_{HI_DC} = 36V to 46V			**31**	
HI to LO 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} ≤ 100°C			75	
DC HI Side Input Current	$I_{HI\_IN\_DC}$	At $I_{LO\_OUT\_DC}$ = 160A, T_{CASE} ≤ 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 Output Current (continuous)	$I_{LO\_OUT\_DC}$	T_{CASE} ≤ 85°C			160	A
LO Side Output Current (pulsed)	$I_{LO\_OUT\_PULSE}$	10ms pulse, 25% Duty cycle, $I_{LO\_OUT\_AVG}$ ≤ 50% rated $I_{LO\_OUT\_DC}$			176	A
HI to LO 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		
HI to LO Efficiency (hot)	η_{HOT}	V_{HI_DC} = 42V, $I_{LO\_OUT\_DC}$ = 160A, T_{CASE} = 85°C	96.7	97.1		%
HI to LO Efficiency (over load range)	$\eta_{20\%}$	32A < $I_{LO\_OUT\_DC}$ < 160A	95			%
HI to LO 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}	Frequency of the LO Side Voltage Ripple = 2x F_{SW}	**1.14**	1.20	**1.26**	MHz
LO Side Output 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} ≤ 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 ≤ 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
General Powertrain High Voltage Side to Low Voltage Side Specification (Forward Direction) 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
Effective LO Side Output Capacitance (External)	$C_{LO\_OUT\_EXT}$	Excessive capacitance may drive module into SC protection			**3000**	µF
Effective LO Side Output Capacitance (External)	$C_{LO\_OUT\_AEXT}$	$C_{LO\_OUT\_AEXT}$ Max = N * 0.5 * $C_{LO\_OUT\_EXT\ MAX}$, where N = the number of units in parallel				
Protection High Voltage Side to Low Voltage Side (Forward Direction)						
Auto Restart Time	$t_{AUTO\_RESTART}$	Startup 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 Startup Delay	$t_{HI\_UVLO+\_DELAY}$	From $V_{HI\_DC} = V_{HI\_UVLO+}$ to powertrain active, (i.e One time Startup delay form application of V_{HI_DC} to V_{LO_DC})		30		ms
HI Side Soft-Start Time	$t_{HI\_SOFT\text{-}START}$	From powertrain active. Fast Current limit protection disabled during Soft-Start		1		ms
LO Side Output Overcurrent Trip Threshold	$I_{LO\_OUT\_OCP}$		**177**	200	**240**	A
LO Side Output Overcurrent Response Time Constant	$t_{LO\_OUT\_OCP}$	Effective internal RC filter		4		ms
LO Side Output Short Circuit Protection Trip Threshold	$I_{LO\_OUT\_SCP}$		**240**			A
LO Side Output 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	$t_{UTP\_RESTART}$	Startup 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 ≤ 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
General Powertrain Low Voltage Side to High Voltage Side Specification (Reverse Direction)						
LO Side Input Voltage range, continuous	V_{LO_DC}		**12**		**15.3**	V
LO to HI 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} = 12V to 15.3V, T_{CASE} = 25°C			22	
		V_{LO_DC} = 12V to 15.3V			**31**	
DC LO Side Input Current	$I_{LO\_IN\_DC}$	At I_{HI_DC} = 53.3A, T_{CASE} ≤ 85°C			**162**	A
HI Side Output Current (continuous)	$I_{HI\_OUT\_DC}$	T_{CASE} ≤ 85°C			**53.3**	A
HI Side Output Current (pulsed)	$I_{HI\_OUT\_PULSE}$	10ms pulse, 25% Duty cycle, $I_{HI\_OUT\_AVG}$ ≤ 50% rated $I_{HI\_OUT\_DC}$			**58.7**	A
LO to HI 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		
LO to HI Efficiency (hot)	η_{HOT}	V_{LO_DC} = 14V, $I_{HI\_OUT\_DC}$ = 53.3A, T_{CASE} = 85°C	96.3	96.9		%
LO to HI Efficiency (over load range)	$\eta_{20\%}$	10.66A < $I_{HI\_OUT\_DC}$ < 53.3A	**94.6**			%
LO to HI 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 Output 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} ≤ 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
Protection Low Voltage Side to High Voltage Side (Reverse Direction)						
Effective HI Side Output Capacitance (External)	$C_{HI\_OUT\_EXT}$	Excessive capacitance may drive module into SC 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 Output 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 Output 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	**810**			A
HI Side Short Circuit Protection Response Time	t_{HI_SCP}			1		µs

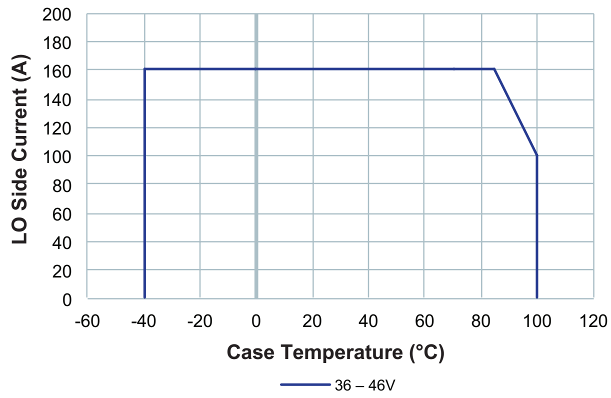


Figure 1 *— Specified thermal operating area*

1. The NBM in a VIA Package is cooled through bottom case (bottom housing).
2. The thermal rating of the NBM in a VIA Package is based on typical measured device efficiency.
3. The case temperature in the graph is the measured temperature of the bottom housing, such that operating internal junction temperature of the NBM in a VIA Package does not exceed 125°C.

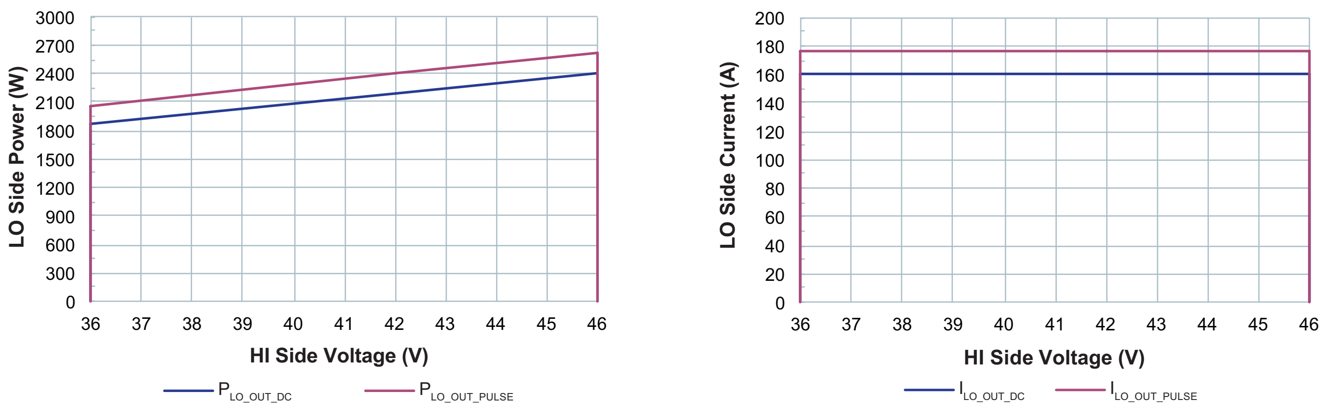


Figure 2 *— Specified electrical operating area using rated R_{LO_HOT}*

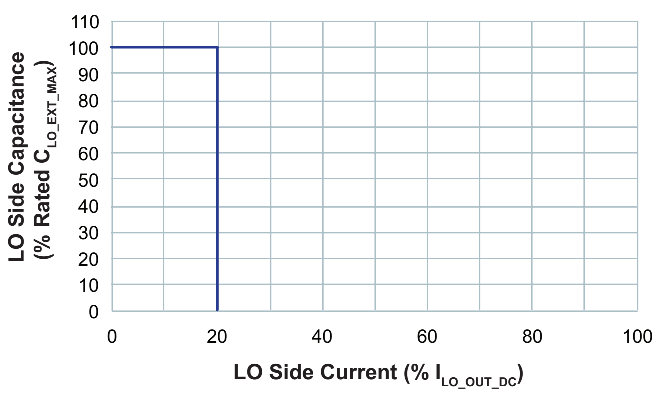
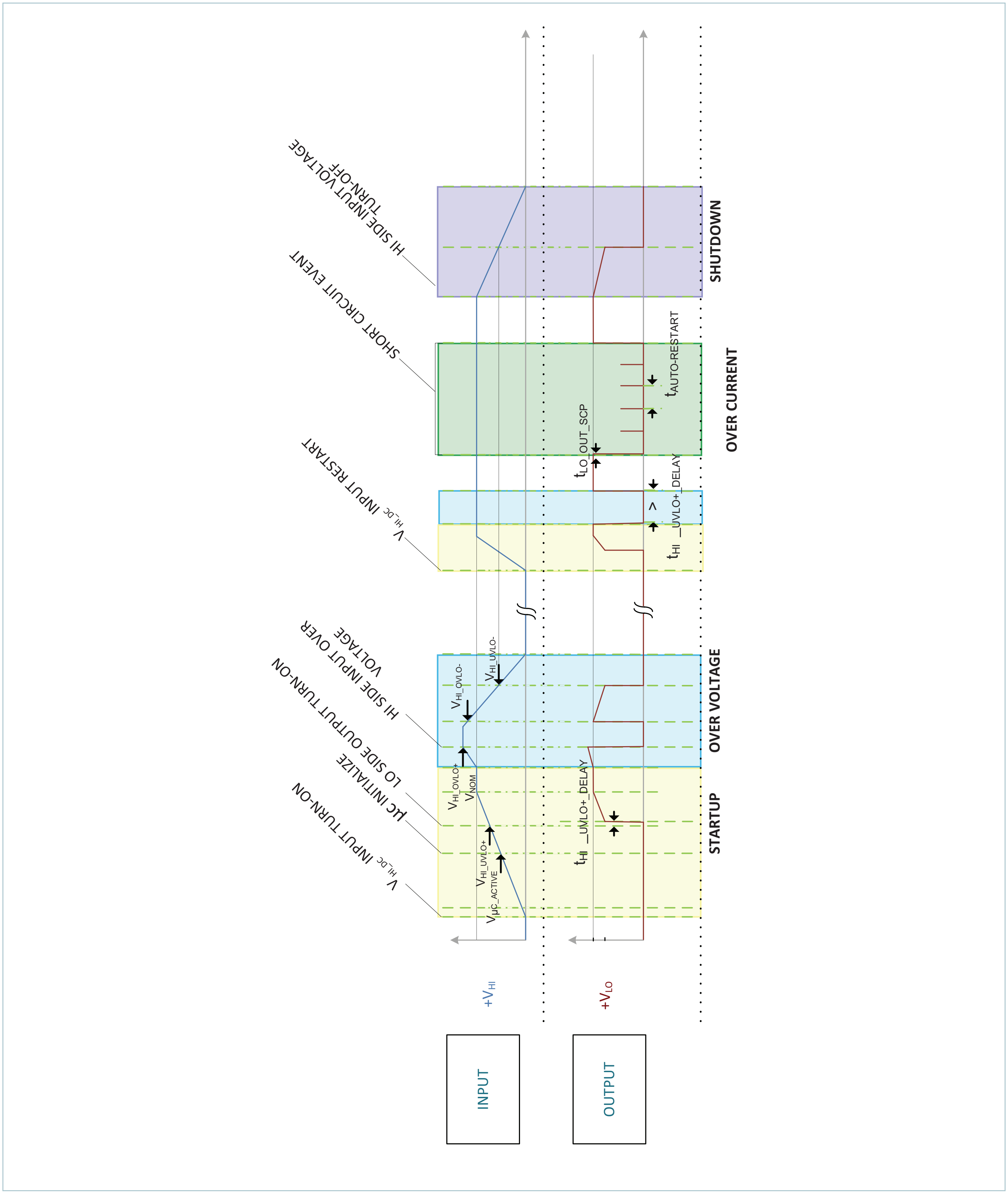
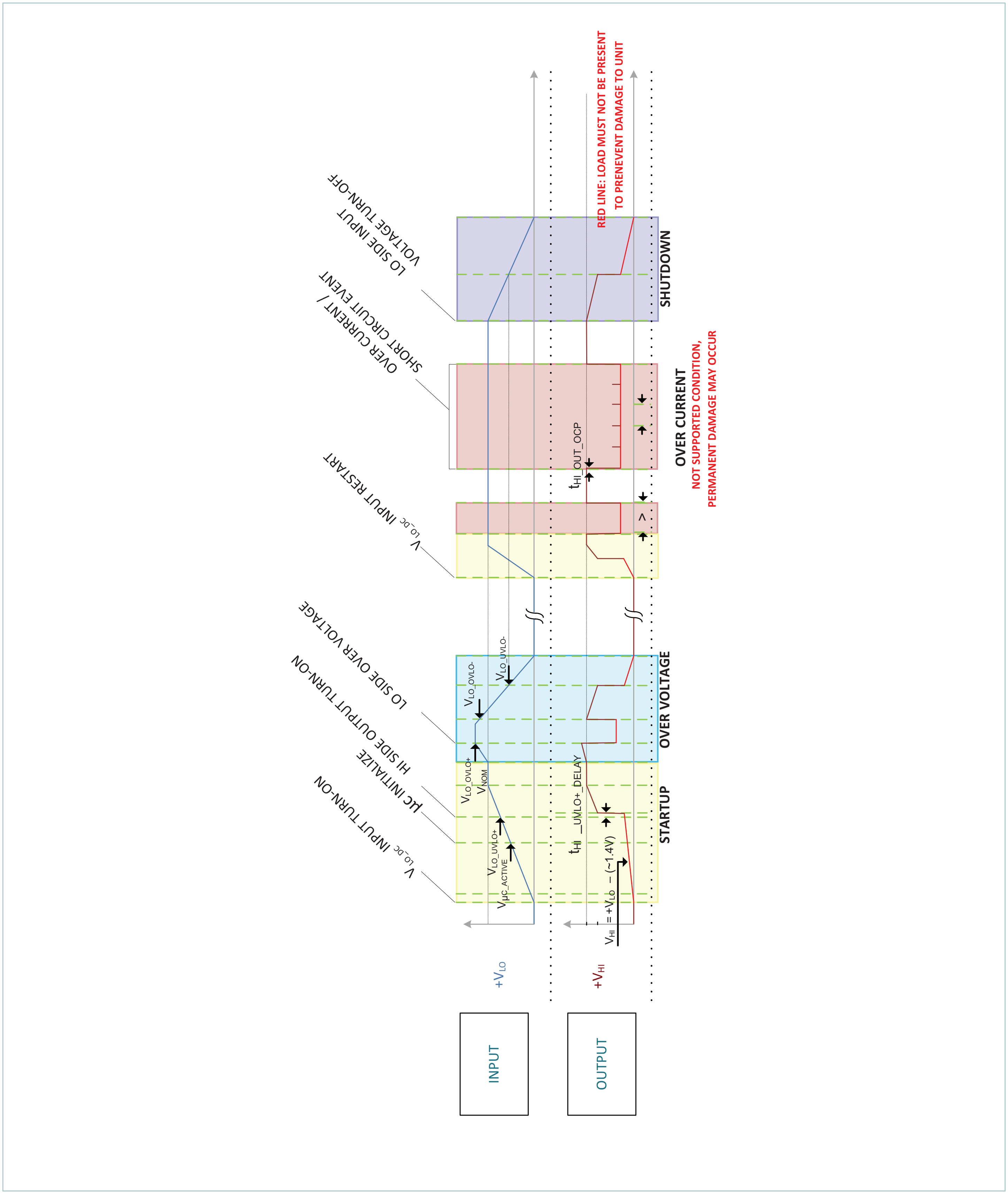


Figure 3 *— Specified HI side start-up into load current and external capacitance*

NBM™ Forward Direction Timing Diagram



NBM™ Reverse Direction Timing Diagram



Application Characteristics

Product is mounted and temperature controlled via top side cold plate, unless otherwise noted. All data presented in this section are collected data from high voltage side sourced units processing power in forward direction.See associated figures for general trend data.

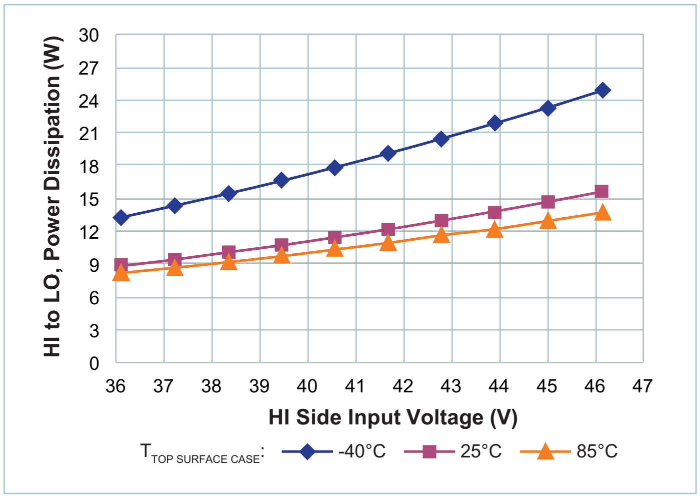


Figure 4 — *No load power dissipation vs. V_{HI_DC}*

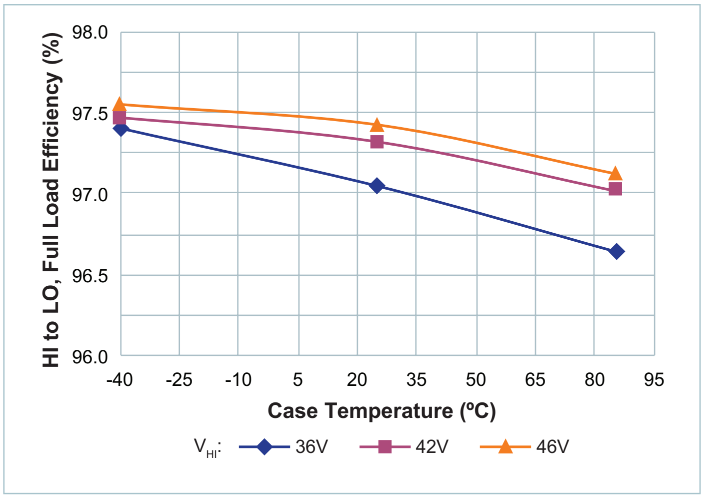


Figure 5 — *Full load efficiency vs. temperature; V_{HI_DC}*

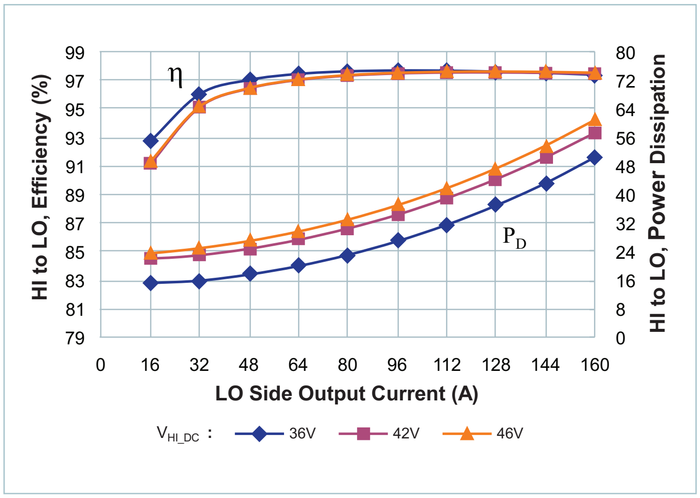


Figure 6 — *Efficiency and power dissipation at T_{CASE} = -40°C*

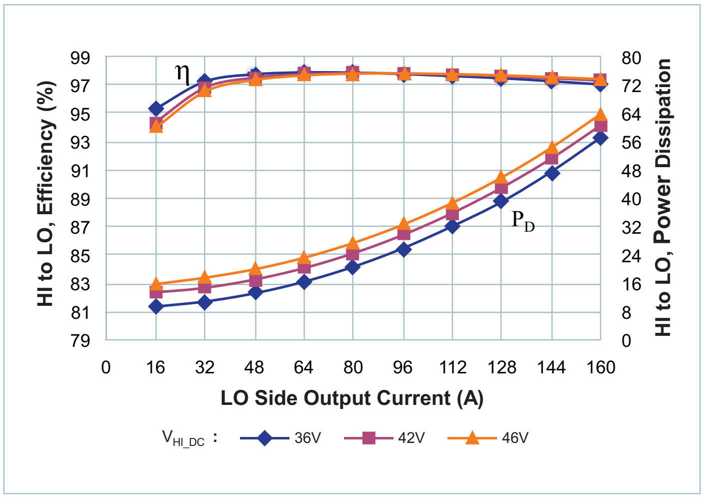


Figure 7 — *Efficiency and power dissipation at T_{CASE} = 25°C*

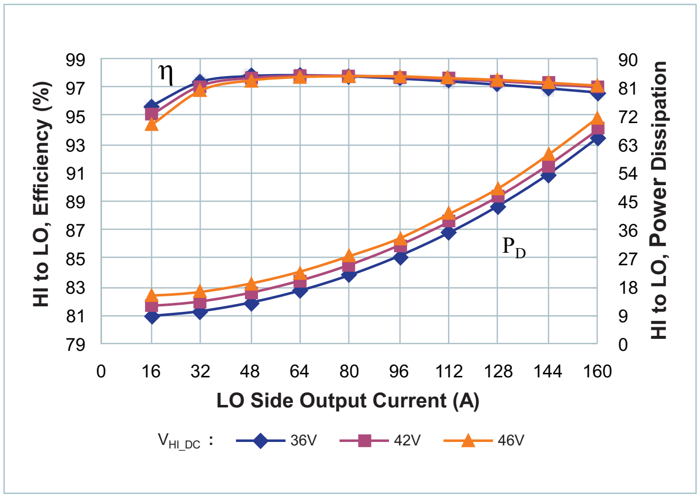


Figure 8 — *Efficiency and power dissipation at T_{CASE} = 85°C*

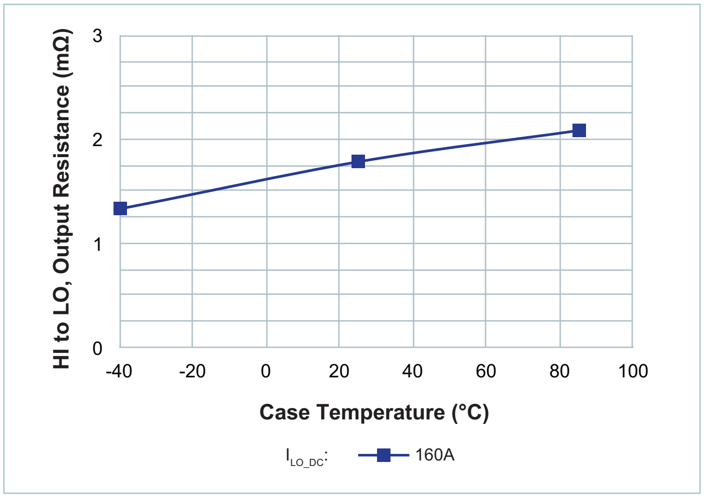


Figure 9 — *R_{LO} vs. temperature; Nominal V_{HI_DC}*
I_{LO_DC} = 160A at T_{CASE} = 85°C

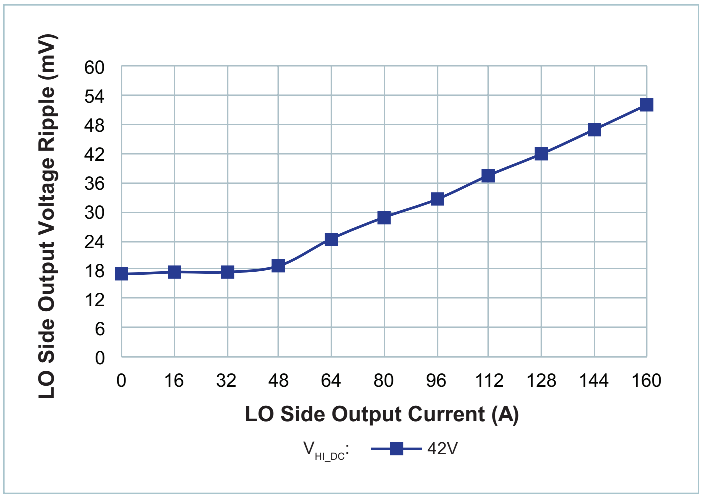


Figure 10 — $V_{LO\_OUT\_PP}$ vs. I_{LO_DC} ; No external $C_{LO\_OUT\_EXT.}$ Board mounted module, scope setting : 20MHz analog BW

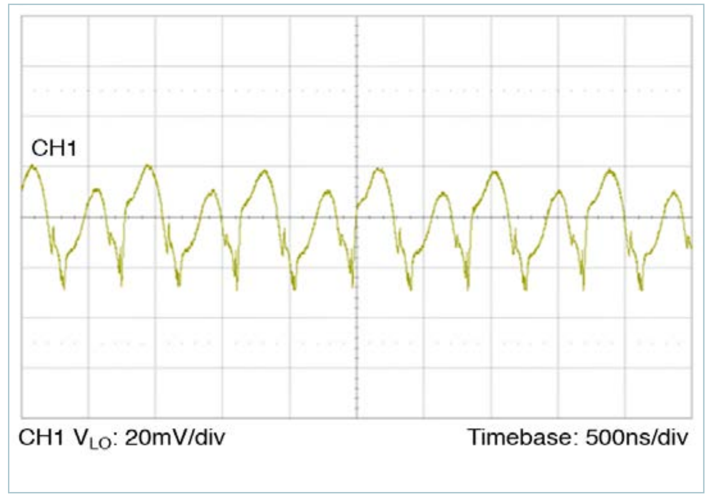


Figure 11 — Full load ripple, 300µF $C_{HI\_IN\_EXT}$; No external $C_{LO\_OUT\_EXT.}$ Board mounted module, scope setting : 20MHz analog BW

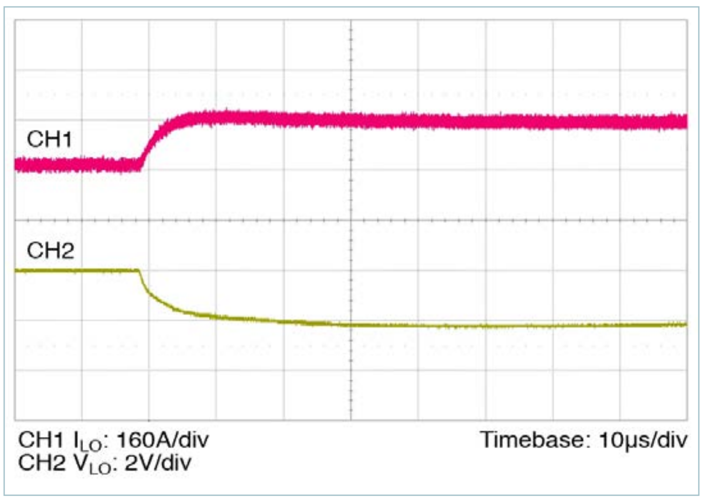


Figure 12 — 0A– 160A transient response: $C_{HI\_IN\_EXT}$ = 300µF, no external $C_{LO\_OUT\_EXT}$

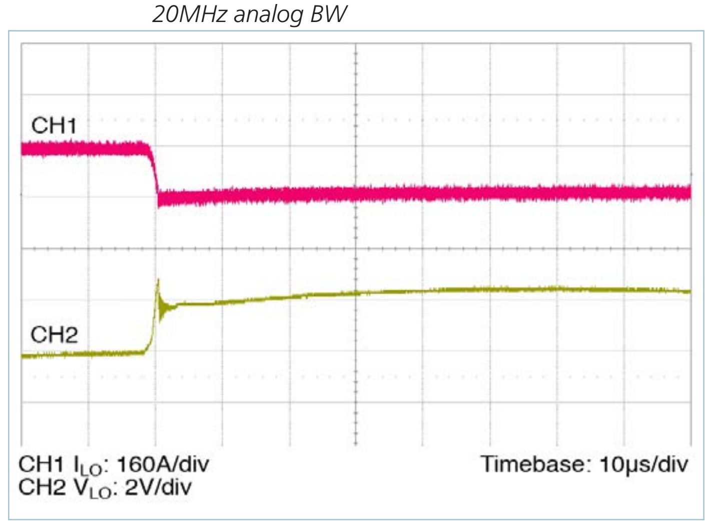


Figure 13 — 160A – 0A transient response: $C_{HI\_IN\_EXT}$ = 300µF, no external $C_{LO\_OUT\_EXT}$

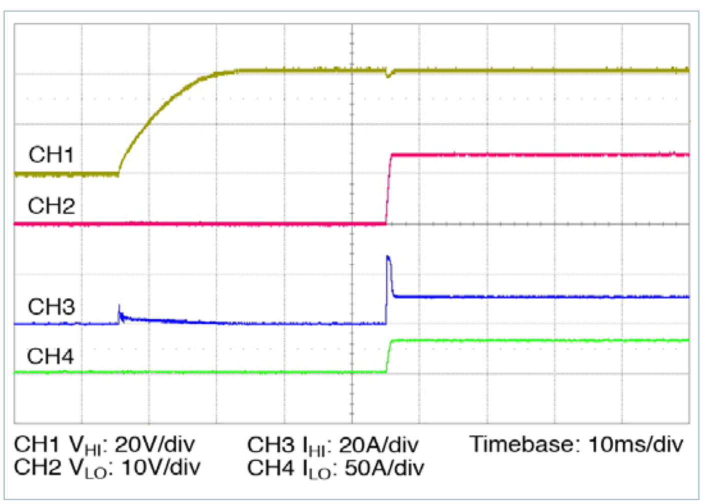


Figure 14 — Forward start up from application of V_{HI_DC} = 42V, 20% I_{LO_DC}, 100% $C_{LO\_OUT\_EXT}$

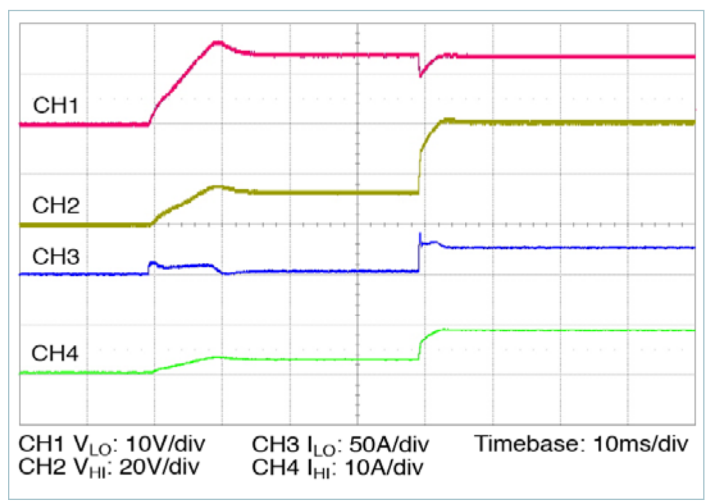


Figure 15 — Reverse start up from application of V_{LO_DC} = 14V, 20% I_{HI_DC}, 100% $C_{HI\_OUT\_EXT}$

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 heatsink		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		Palladium	0.8		6	µin
		Soft Gold	0.12		2	
Thermal						
Operating junction temperature	$T_{INTERNAL}$	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 top side	R_{JC_TOP}	Estimated thermal resistance to maximum temperature internal component from isothermal top		1.39		°C/W
Thermal Resistance Coupling between top case and bottom case	R_{HOU}	Estimated thermal resistance of thermal coupling between the top and bottom case surfaces		0.51		°C/W
Thermal resistance bottom side	R_{JC_BOT}	Estimated thermal resistance to maximum temperature internal component from isothermal bottom		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 < 2 kV)	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						
		CE Marked for Low Voltage Directive and RoHS Recast Directive, as applicable				

NBM in a VIA Package

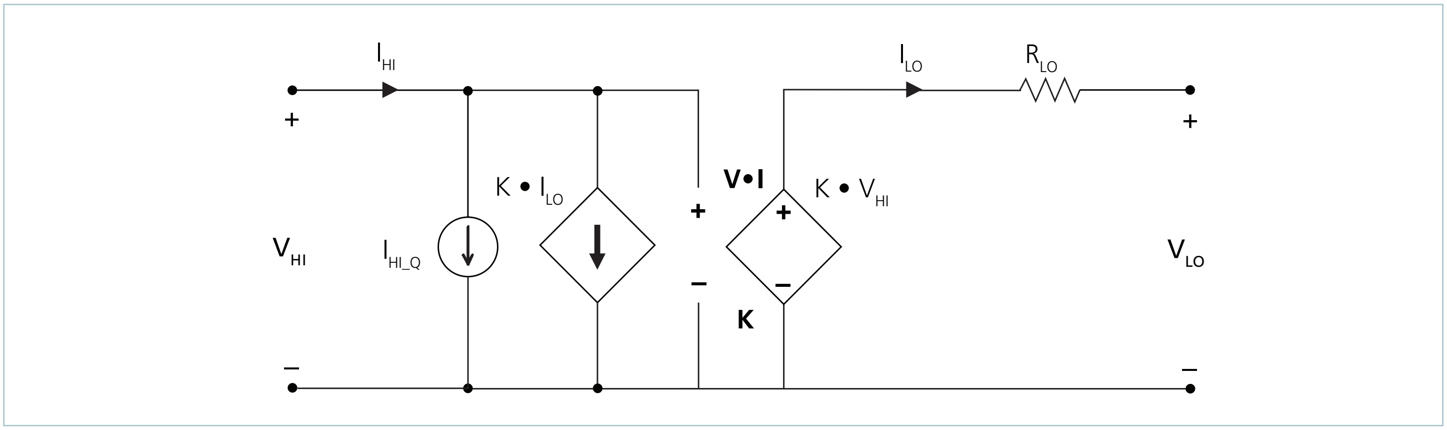


***Figure 16** — NBM DC model (Forward direction)*

The NBM in a VIA package uses a high frequency resonant tank to move energy from high voltage side to low voltage side and vice versa. The resonant LC tank, operated at high frequency, is amplitude modulated as a function of HI side voltage and 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 preceeding model.

At no load:

$$V_{LO} = V_{HI} \bullet K \qquad (1)$$

K represents the "turns ratio" of the NBM.
Rearranging Eq (1):

$$K = \frac{V_{LO}}{V_{HI}} \qquad (2)$$

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

$$V_{LO} = V_{HI} \bullet K - I_{LO} \bullet R_{LO} \qquad (3)$$

and I_{LO} is represented by:

$$I_{LO} = \frac{I_{HI} - I_{HI\_Q}}{K} \qquad (4)$$

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 control, gate drive circuitry, and core losses. The use of DC voltage transformation provides additional interesting attributes. Assuming that $R_{LO} = 0\Omega$ and $I_{HI\_Q} = 0A$, Eq. (3) now becomes Eq. (1) and is essentially load independent, resistor R is now placed in series
with V_{HI}.

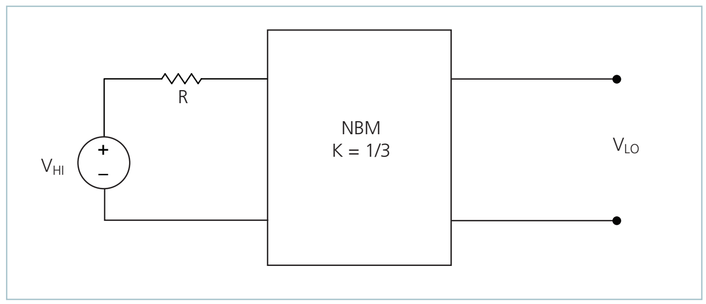


***Figure 17** — K = 1/3 NBM with series HI side resistor*

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

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

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

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

This is similar in form to Eq. (3), where R_{LO} is used to represent the characteristic impedance of the NBM™. However, in this case a real 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 should 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 18.

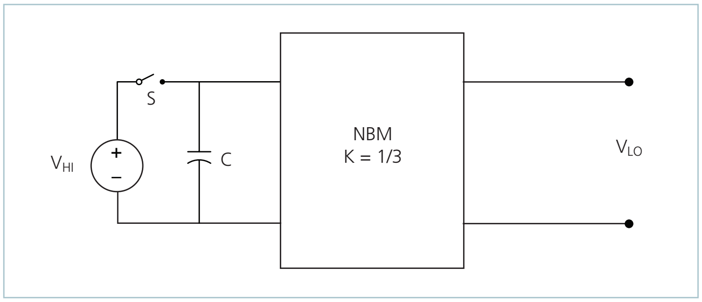


***Figure 18** — NBM with HI side capacitor*

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

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

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,

$$I_C = I_{LO} \bullet K \tag{8}$$

substituting Eq. (1) and (8) into Eq. (7) reveals:

$$I_{LO} = \frac{C}{K^2} \bullet \frac{dV_{LO}}{dt} \tag{9}$$

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 18, 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, the benefits are not useful 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 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 (R_{LO}): refers to the power loss across the NBM module modeled as pure resistive impedance.

$$P_{DISSIPATED} = P_{HI\_NL} + P_{R_{LO}} \tag{10}$$

Therefore,

$$P_{LO\_OUT} = P_{HI\_IN} - P_{DISSIPATED} = P_{HI\_IN} - P_{HI\_NL} - P_{R_{LO}} \tag{11}$$

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

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

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

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

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 HI side and LO 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 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 Eq. (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 top surface, the bottom 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 VIA, as can be seen from specified thermal operating area in Figure 1. Since the VIA has a maximum internal temperature rating, it is necessary to estimate this internal temperature based on a system-level thermal solution. To 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 19 shows the "thermal circuit" for the VIA module.

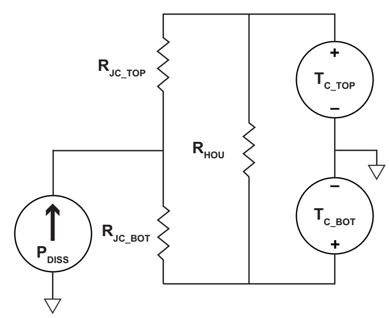


Figure 19 *— Double sided cooling VIA thermal model*

In this case, the internal power dissipation is P_{DISS}, R_{JC_TOP} and R_{JC_BOT} are thermal resistance characteristics of the VIA module and the top and bottom surface temperatures are represented as T_{C_TOP}, and T_{C_BOT}. It is interesting to notice that the package itself provides a high degree of thermal coupling between the top and bottom case surfaces (represented in the model by the resistor R_{HOU}). This feature enables two main options regarding thermal designs:

- Single side cooling: the model of Figure 19 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 bottom side cooling only is shown in Figure 20.

In this case, R_{JC} can be derived as following:

$$R_{JC} = \frac{(R_{JC\_TOP} + R_{HOU}) \bullet R_{JC\_BOT}}{R_{JC\_TOP} + R_{HOU} + R_{JC\_BOT}} \qquad (14)$$

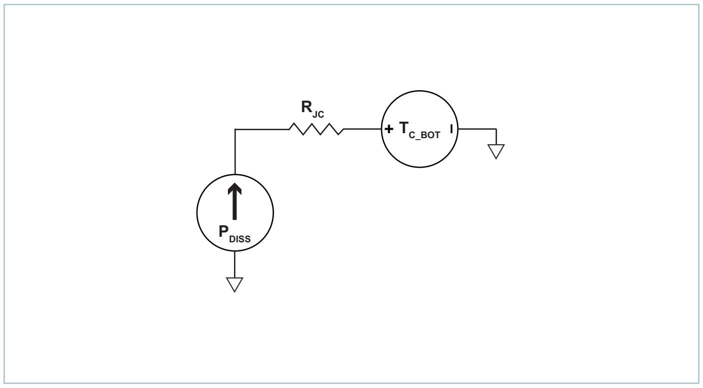


***Figure 20** — Single-sided cooling VIA thermal model*

- Double side cooling: while this option might bring limited advantage 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, like for example heatsinks with independent airflows or a combination of chassis/air cooling.

Current Sharing

The performance of the NBM in a VIA package 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.

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 VIA modules.
- Provide as symmetric a PCB/Wiring layout as possible among VIA™ 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 in a VIA package products is recommended at system level to provide thermal protection in case of catastrophic failure.

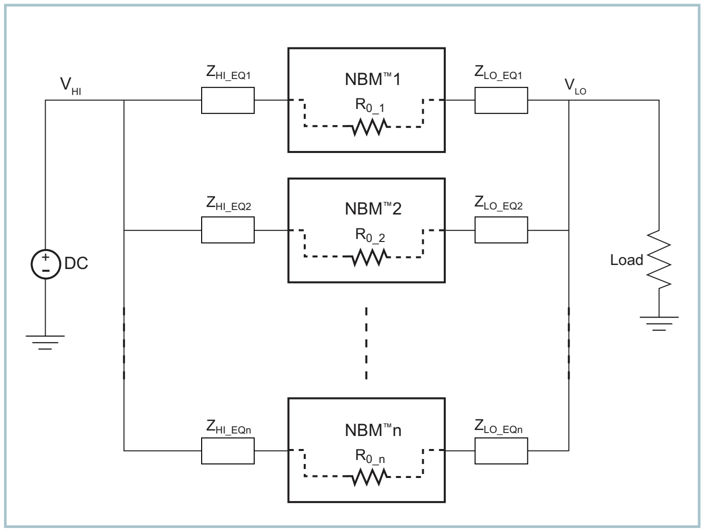


***Figure 21** — NBM module array*

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)

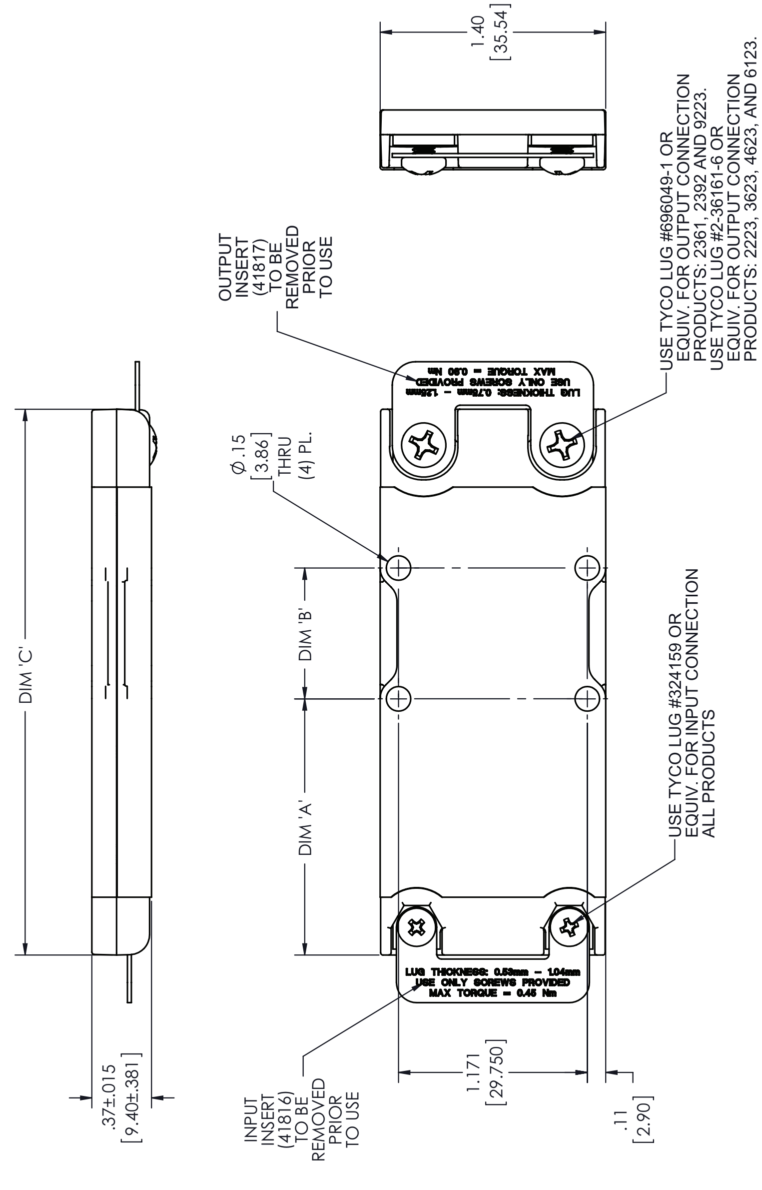
Startup and Reverse Operation

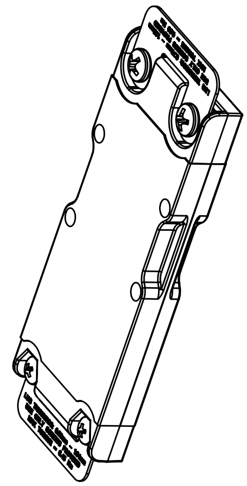
The NBM3814x46C15A6yzz is capable of startup in forward and reverse direction once the applied voltage is greater than the undervoltage lockout threshold.

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.

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

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





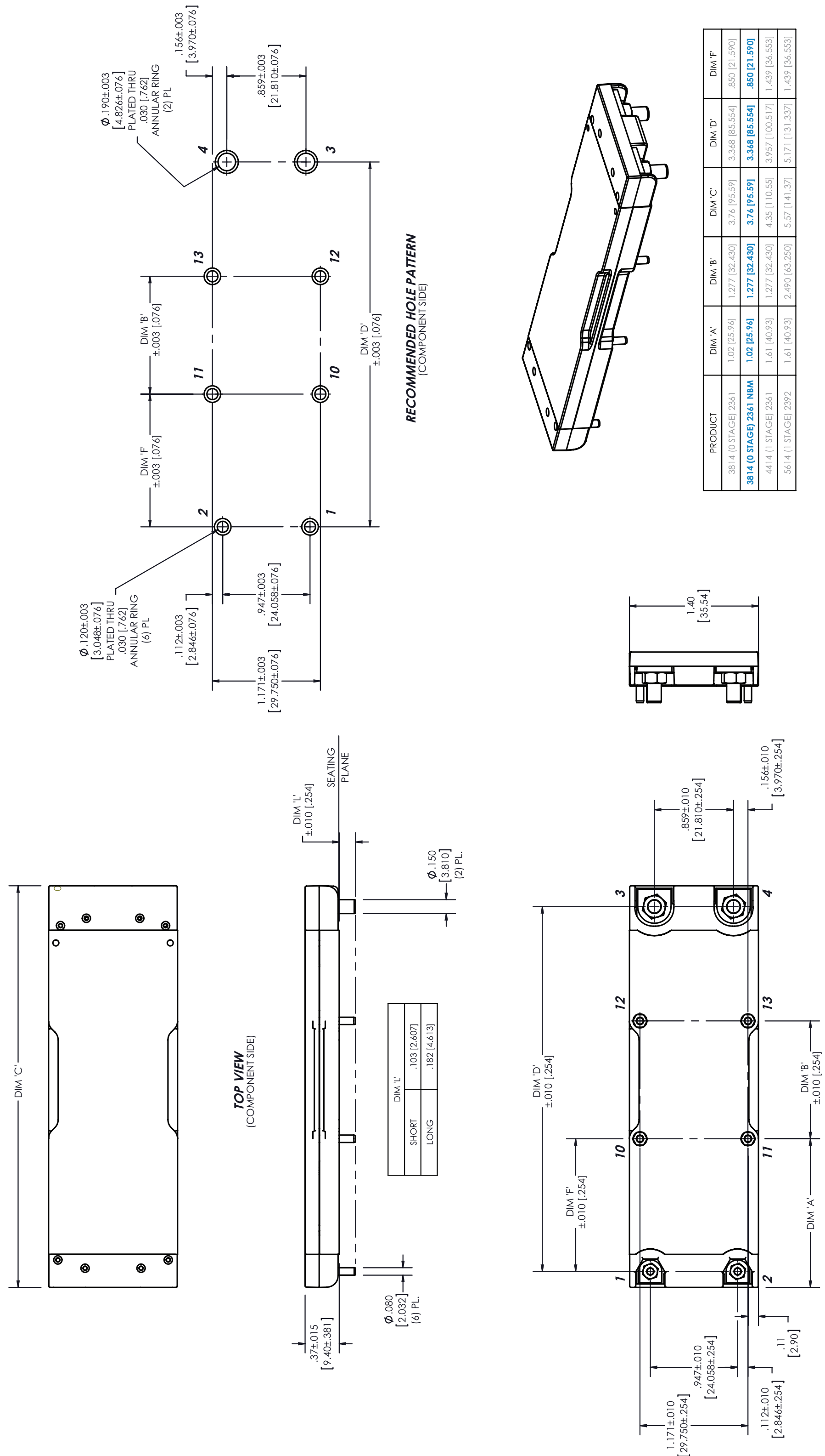
PRODUCT	DIM 'A'	DIM 'B'	DIM 'C'
2214 (0 STAGE) 2223	1.02 [25.96]	NA	2.25 [57.11]
2814 (1 STAGE) 2223	1.61 [40.93]	NA	2.84 [72.05]
2814 (0 STAGE) 3623	1.02 [25.96]	.789 [20.033]	2.80 [70.99]
3414 (1 STAGE) 3623	1.61 [40.93]	.789 [20.033]	3.38 [85.93]
3714 (1 STAGE) 4623	1.61 [40.93]	1.150 [29.200]	3.75 [95.12]
3814 (0 STAGE) 2361	1.02 [25.96]	1.277 [32.430]	3.76 [95.59]
3814 (0 STAGE) 2361 NBM	**1.02 [25.96]**	**1.277 [32.430]**	**3.76 [95.59]**
4414 (1 STAGE) 2361	1.61 [40.93]	1.277 [32.430]	4.35 [110.55]
4414 (1 STAGE) 6123	1.61 [40.93]	1.757 [44.625]	4.35 [110.55]
5614 (1 STAGE) 2392	1.61 [40.93]	2.490 [63.250]	5.57 [141.37]
5614 (1 STAGE) 9223	1.61 [40.93]	2.970 [75.445]	5.57 [141.37]

NOTES:

1- RoHS COMPLIANT PER CST-0001 LATEST REVISION.

2- SEE PRODUCT DATA SHEET FOR PIN DESIGNATIONS.

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



PRODUCT	DIM 'A'	DIM 'B'	DIM 'C'	DIM 'D'	DIM 'F'
3814 (0 STAGE) 2361	1.02 [25.96]	1.277 [32.430]	3.76 [95.59]	3.368 [85.554]	.850 [21.590]
3814 (0 STAGE) 2361 NBM	**1.02 [25.96]**	**1.277 [32.430]**	**3.76 [95.59]**	**3.368 [85.554]**	**.850 [21.590]**
4414 (1 STAGE) 2361	1.61 [40.93]	1.277 [32.430]	4.35 [110.55]	3.957 [100.517]	1.439 [36.553]
5614 (1 STAGE) 2392	1.61 [40.93]	2.490 [63.250]	5.57 [141.37]	5.171 [131.337]	1.439 [36.553]

NOTES:
1- RoHS COMPLIANT PER CST-0001 LATEST REVISION.
2- SEE PRODUCT DATA SHEET FOR PIN DESIGNATIONS.

Revision History

Revision	Date	Description	Page Number(s)
1.0	03/3/16	Initial release	n/a
1.1	05/2/16	New Power Pin Nomenclature	All

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