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# BCM<sup>®</sup> Bus Converter

## BCM6123xD1E13A3yzz



### Isolated Fixed-Ratio DC-DC Converter

#### Features & Benefits

- Up to 125A continuous secondary current
- Up to 2208W/in<sup>3</sup> power density
- 97.4% peak efficiency
- 4,242V<sub>DC</sub> isolation
- Parallel operation for multi-kW arrays
- OV, OC, UV, short circuit and thermal protection
- BCM6123 through-hole ChiP package
  - 2.402 x 0.990 x 0.284in  
[61.00 x 25.14 x 7.21mm]
- PMBus™ management interface <sup>[a]</sup>

#### Typical Applications

- 380V<sub>DC</sub> Power Distribution
- High-End Computing Systems
- Automated Test Equipment
- Industrial Systems
- High-Density Power Supplies
- Communications Systems
- Transportation

Product Ratings	
$V_{PRI} = 384V (260 - 410V)$	$I_{SEC} = \text{up to } 125A$
$V_{SEC} = 12V (8.1 - 12.8V)$ (NO LOAD)	$K = 1/32$

#### Product Description

The BCM6123xD1E13A3yzz is a high-efficiency Bus Converter, operating from a 260 to 410V<sub>DC</sub> primary bus to deliver an isolated, ratiometric secondary voltage from 8.1 to 12.8V<sub>DC</sub>.

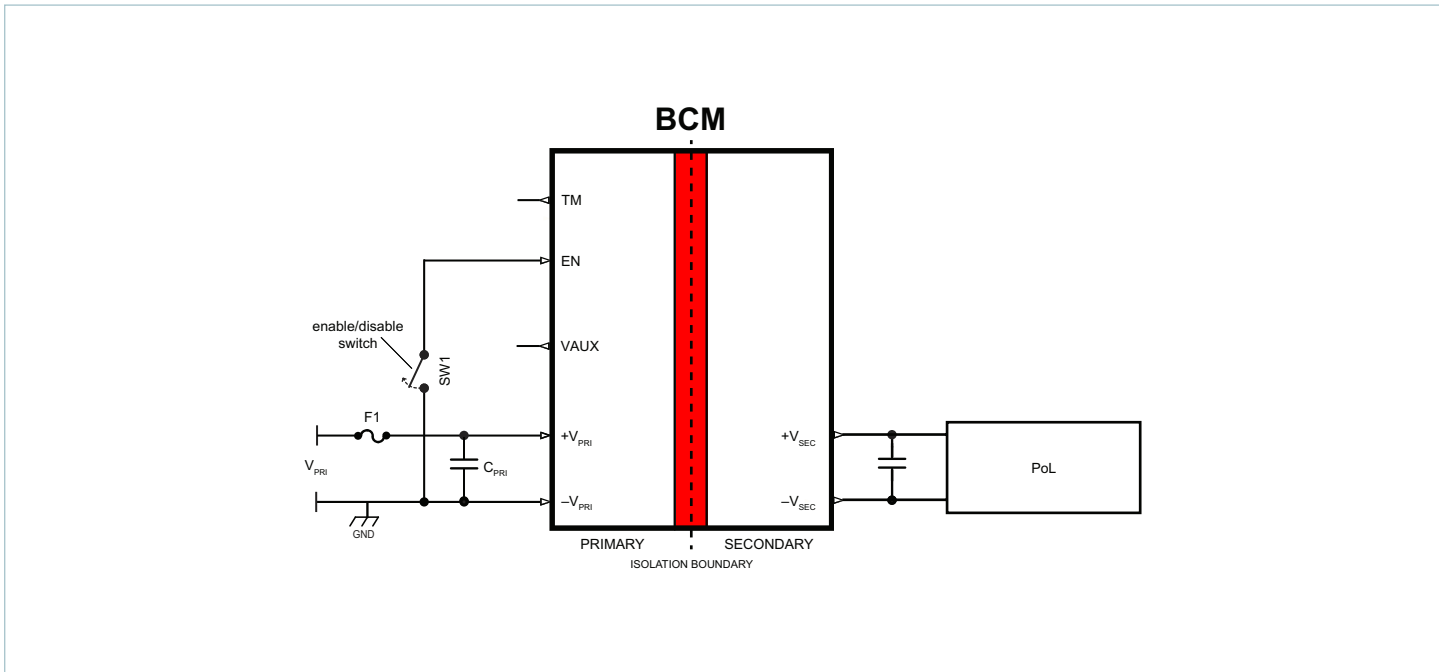
The BCM6123xD1E13A3yzz offers low noise, fast transient response, and industry leading efficiency and power density. In addition, it provides an AC impedance beyond the bandwidth of most downstream regulators, allowing input capacitance normally located at the input of a PoL regulator to be located at the primary side of the BCM. With a primary to secondary K factor of 1/32, that capacitance value can be reduced by a factor of 1024x, resulting in savings of board area, material and total system cost.

Leveraging the thermal and density benefits of Vicor ChiP packaging technology, the BCM offers flexible thermal management options with very low top and bottom side thermal impedances. Thermally-adept ChiP-based power components enable customers to achieve low cost power system solutions with previously unattainable system size, weight and efficiency attributes quickly and predictably.

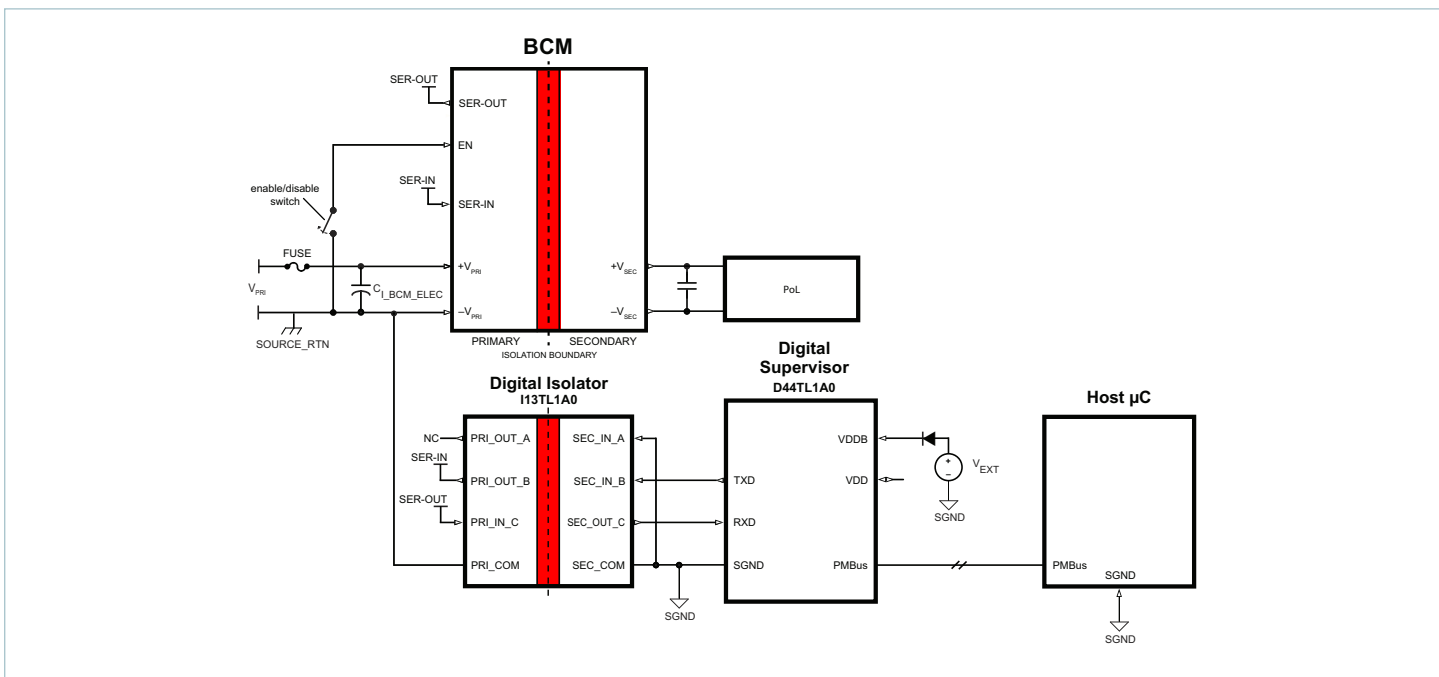
This product can operate in the reverse direction, at full rated current, after being previously started in the forward direction.

<sup>[a]</sup> When used with D44TL1A0 and I13TL1A0

Typical Applications

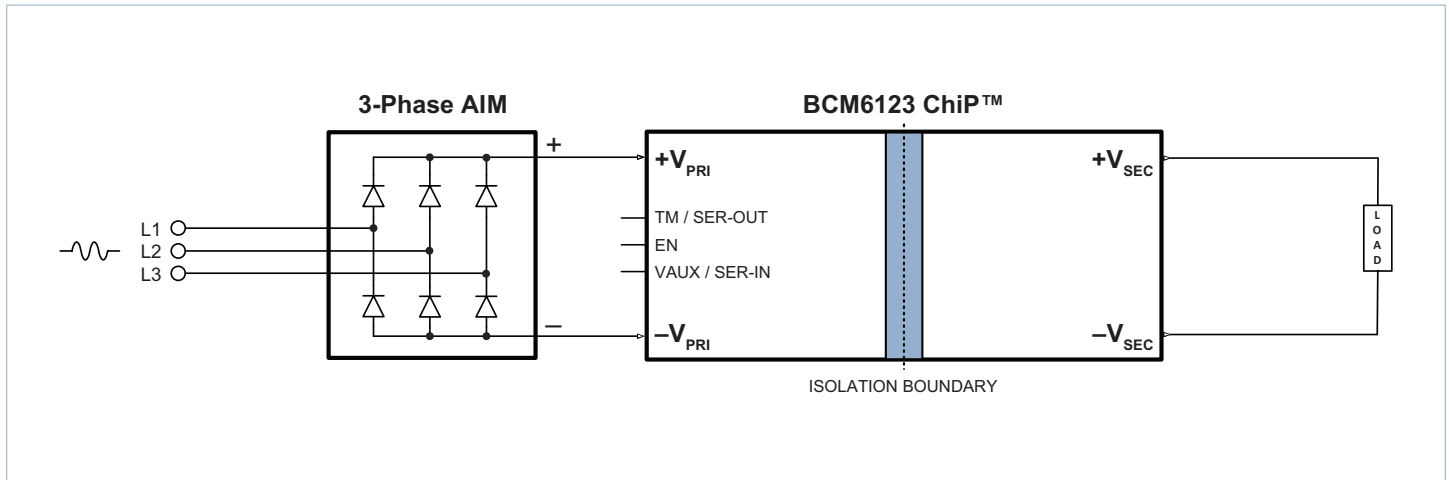


BCM6123xD1E13A3y00 at point-of-load



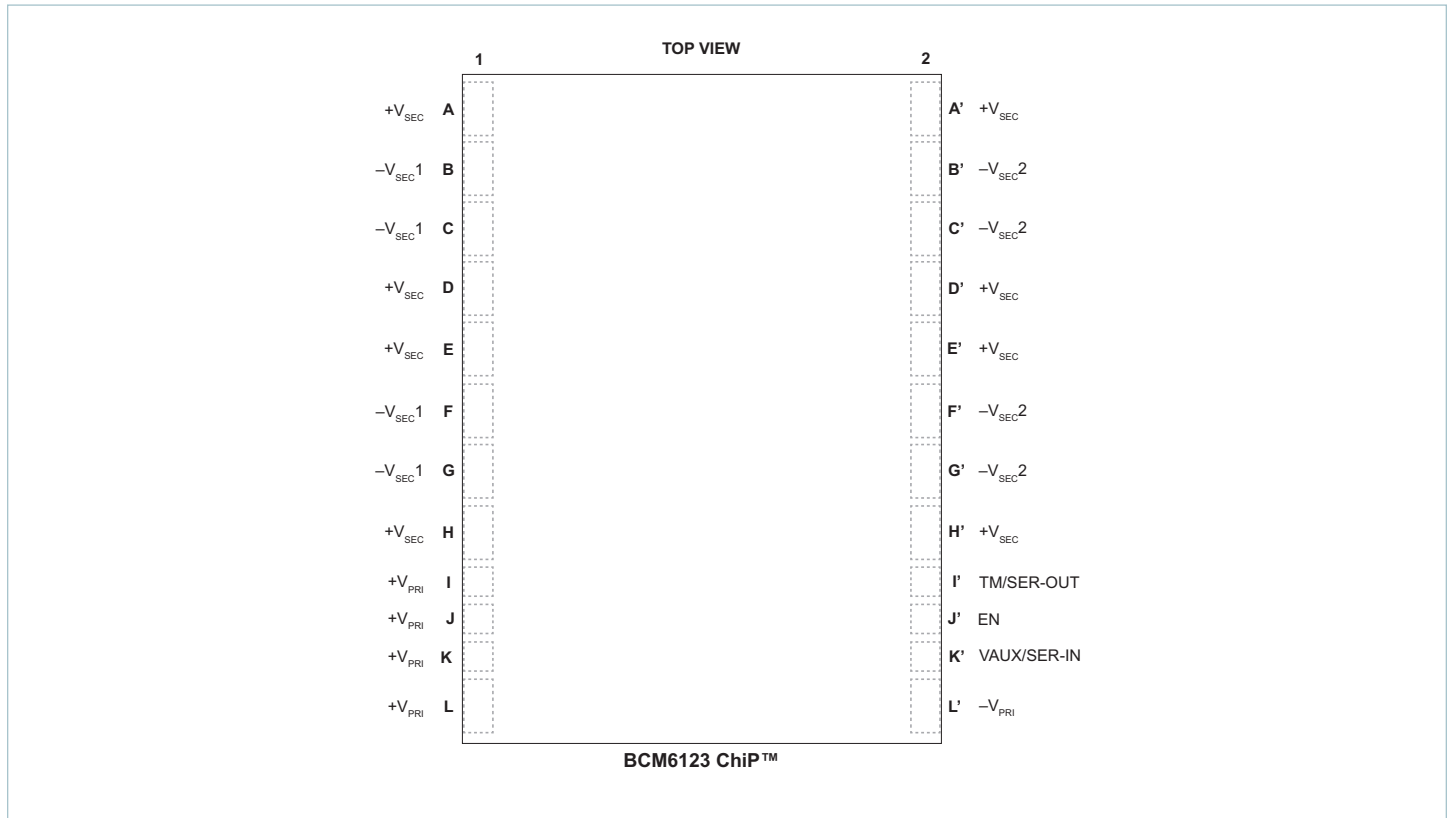
BCM6123xD1E13A3y01 at point-of-load

Typical Applications (Cont.)



3-phase AC to point-of-load (3-phase AIM™ + BCM6123xD1E13A3yzz)

Pin Configuration



Pin Descriptions

Power Pins			
Pin Number	Signal Name	Type	Function
I1, J1, K1, L1	+V <sub>PRI</sub>	PRIMARY POWER	Positive primary transformer power terminal
L'2	-V <sub>PRI</sub>	PRIMARY POWER RETURN	Negative primary transformer power terminal
A1, D1, E1, H1, A'2, D'2, E'2, H'2	+V <sub>SEC</sub>	SECONDARY POWER	Positive secondary transformer power terminal
B1, C1, F1, G1 B'2, C'2, F'2, G'2	-V <sub>SEC</sub> [b]	SECONDARY POWER RETURN	Negative secondary transformer power terminal
Analog Control Signal Pins			
Pin Number	Signal Name	Type	Function
I'2	TM	OUTPUT	Temperature Monitor; primary side referenced signals
J'2	EN	INPUT	Enables and disables power supply; primary side referenced signals
K'2	VAUX	OUTPUT	Auxiliary Voltage Source; primary side referenced signals
PMBus™ Control Signal Pins			
Pin Number	Signal Name	Type	Function
I'2	SER-OUT	OUTPUT	UART transmit pin; Primary side referenced signals
J'2	EN	INPUT	Enables and disables power supply; Primary side referenced signals
K'2	SER-IN	INPUT	UART receive pin; Primary side referenced signals

[b] For proper operation an external low impedance connection must be made between listed -V<sub>SEC</sub>1 and -V<sub>SEC</sub>2 terminals.

## Part Ordering Information

Product Function	Package Size	Package Mounting	Max Primary Input Voltage	Range Identifier	Max Secondary Voltage	Secondary Output Current	Temperature Grade	Option
BCM	6123	x	D1	E	13	A3	y	zz
Bus Converter Module	61 = L 23 = W	T = TH	410V	260 – 410V	13V No Load	125A	T = –40 to 125°C M = –55 to 125°C	<b>00</b> = Analog Ctrl <b>01</b> = PMBus Ctrl <b>OR</b> = Reversible Analog Ctrl <b>OP</b> = Reversible PMBus Ctrl

All products shipped in JEDEC standard high profile (0.400" thick) trays (JEDEC Publication 95, Design Guide 4.10).

## Standard Models

Product Function	Package Size	Package Mounting	Max Primary Input Voltage	Range Identifier	Max Secondary Voltage	Secondary Output Current	Temperature Grade	Option
BCM	6123	T	D1	E	13	A3	T	00
BCM	6123	T	D1	E	13	A3	T	01
BCM	6123	T	D1	E	13	A3	T	OR
BCM	6123	T	D1	E	13	A3	T	OP

## 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
+V <sub>PRI_DC</sub> to –V <sub>PRI_DC</sub>		–1	480	V
V <sub>PRI_DC</sub> or V <sub>SEC_DC</sub> Slew Rate (Operational)			1	V/μs
+V <sub>SEC_DC</sub> to –V <sub>SEC_DC</sub>		–1	15	V
TM/SER-OUT to –V <sub>PRI_DC</sub>		–0.3	4.6	V
EN to –V <sub>PRI_DC</sub>			5.5	V
VAUX/SER-IN to –V <sub>PRI_DC</sub>			4.6	V

Electrical Specifications

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade). All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>General Powertrain PRIMARY to SECONDARY Specification (Forward Direction)</b>						
Primary Input Voltage Range (Continuous)	$V_{\text{PRI\_DC}}$		<b>260</b>		<b>410</b>	V
$V_{\text{PRI}}$ $\mu$ Controller	$V_{\mu\text{C\_ACTIVE}}$	$V_{\text{PRI\_DC}}$ voltage where $\mu\text{C}$ is initialized, (i.e., VAUX = Low, powertrain inactive)			130	V
PRI to SEC Input Quiescent Current	$I_{\text{PRI\_Q}}$	Disabled, EN Low, $V_{\text{PRI\_DC}} = 384\text{V}$ $T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$		2	4	mA
PRI to SEC No-Load Power Dissipation	$P_{\text{PRI\_NL}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$		11	17	W
		$V_{\text{PRI\_DC}} = 384\text{V}$	<b>5.9</b>		<b>25</b>	
		$V_{\text{PRI\_DC}} = 260 - 410\text{V}$ , $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$			19	
		$V_{\text{PRI\_DC}} = 260 - 410\text{V}$			<b>27</b>	
PRI to SEC Inrush Current Peak	$I_{\text{PRI\_INR\_PK}}$	$V_{\text{PRI\_DC}} = 410\text{V}$ , $C_{\text{SEC\_EXT}} = 1000\mu\text{F}$ , $R_{\text{LOAD\_SEC}} = 50\%$ of full-load current $T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$		10		A
					15	
DC Primary Input Current	$I_{\text{PRI\_IN\_DC}}$	At $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$ , $T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$			4.1	A
Transformation Ratio	K	Primary to secondary, $K = V_{\text{SEC\_DC}} / V_{\text{PRI\_DC}}$ , at no load		1/32		V/V
Secondary Output Current (Continuous)	$I_{\text{SEC\_OUT\_DC}}$				125	A
Secondary Output Current (Pulsed)	$I_{\text{SEC\_OUT\_PULSE}}$	10ms pulse, 25% duty cycle, $I_{\text{SEC\_OUT\_AVG}} \leq 50\%$ of rated $I_{\text{SEC\_OUT\_DC}}$			167	A
Secondary Output Power (Continuous)	$P_{\text{SEC\_OUT\_DC}}$	Specified at $V_{\text{PRI\_DC}} = 410\text{V}$			1500	W
Secondary Output Power (Pulsed)	$P_{\text{SEC\_OUT\_PULSE}}$	Specified at $V_{\text{PRI\_DC}} = 410\text{V}$ ; 10ms pulse, 25% duty cycle, $P_{\text{SEC\_AVG}} \leq 50\%$ of rated $P_{\text{SEC\_OUT\_DC}}$			2000	W
PRI to SEC Efficiency (Ambient)	$\eta_{\text{AMB}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$	96.2	97		%
		$V_{\text{PRI\_DC}} = 260 - 410\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$	95.2			
		$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 62.5\text{A}$	96.5	97.4		
PRI to SEC Efficiency (Hot)	$\eta_{\text{HOT}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$	95.8	97		%
PRI to SEC Efficiency (Over Load Range)	$\eta_{20\%}$	$25\text{A} < I_{\text{SEC\_OUT\_DC}} < 125\text{A}$	<b>90</b>			%
PRI to SEC Output Resistance	$R_{\text{SEC\_COLD}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$ , $T_{\text{INTERNAL}} = -40^{\circ}\text{C}$	1.10	1.50	1.80	m $\Omega$
	$R_{\text{SEC\_AMB}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$	1.50	1.85	2.30	
	$R_{\text{SEC\_HOT}}$	$V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$ , $T_{\text{INTERNAL}} = 100^{\circ}\text{C}$	2.2	2.45	2.70	
Switching Frequency	$F_{\text{SW}}$	Frequency of the output voltage ripple = $2x F_{\text{SW}}$	<b>0.95</b>	1.00	<b>1.05</b>	MHz
Secondary Output Voltage Ripple	$V_{\text{SEC\_OUT\_PP}}$	$C_{\text{SEC\_EXT}} = 0\mu\text{F}$ , $I_{\text{SEC\_OUT\_DC}} = 125\text{A}$ , $V_{\text{PRI\_DC}} = 384\text{V}$ , 20MHz BW $T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$		195		mV
					250	
Primary Input Leads Inductance (Parasitic)	$L_{\text{PRI\_IN\_LEADS}}$	Frequency 2.5MHz (double switching frequency), simulated lead model		7		nH
Secondary Output Leads Inductance (Parasitic)	$L_{\text{SEC\_OUT\_LEADS}}$	Frequency 2.5MHz (double switching frequency), simulated lead model		0.64		nH
Primary Input Series Inductance (Internal)	$L_{\text{IN\_INT}}$	Reduces the need for input decoupling inductance in BCM arrays		0.56		$\mu\text{H}$

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade). All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>General Powertrain PRIMARY to SECONDARY Specification (Forward Direction) Cont.</b>						
Effective Primary Capacitance (Internal)	$C_{\text{PRI\_INT}}$	Effective value at $384V_{\text{PRI\_DC}}$		0.37		$\mu\text{F}$
Effective Secondary Capacitance (Internal)	$C_{\text{SEC\_INT}}$	Effective value at $12V_{\text{SEC\_DC}}$		208		$\mu\text{F}$
Rated Secondary Output Capacitance (External)	$C_{\text{SEC\_OUT\_EXT}}$	Excessive capacitance may drive module into short-circuit protection			<b>1000</b>	$\mu\text{F}$
Rated Secondary Output Capacitance (External), Parallel Array Operation	$C_{\text{SEC\_OUT\_AEXT}}$	$C_{\text{SEC\_OUT\_AEXT Max}} = N \cdot 0.5 \cdot C_{\text{SEC\_OUT\_EXT Max}}$ , where N = the number of units in parallel				
<b>Powertrain Protection PRIMARY to SECONDARY (Forward Direction)</b>						
Auto Restart Time	$t_{\text{AUTO\_RESTART}}$	Start up into a persistent fault condition. Non-latching fault detection given $V_{\text{PRI\_DC}} > V_{\text{PRI\_UVLO+}}$	<b>292.5</b>		<b>357.5</b>	ms
Primary Overvoltage Lockout Threshold	$V_{\text{PRI\_OVLO+}}$		<b>420</b>	434.5	<b>450</b>	V
Primary Overvoltage Recovery Threshold	$V_{\text{PRI\_OVLO-}}$		<b>410</b>	424	<b>440</b>	V
Primary Overvoltage Lockout Hysteresis	$V_{\text{PRI\_OVLO\_HYST}}$			10.5		V
Primary Overvoltage Lockout Response Time	$t_{\text{PRI\_OVLO}}$			100		$\mu\text{s}$
Secondary Soft-Start Time	$t_{\text{SEC\_SOFT-START}}$	From powertrain active; fast current limit protection disabled during soft start		1		ms
Secondary Output Overcurrent Trip Threshold	$I_{\text{SEC\_OUT\_OCP}}$		<b>145</b>	170	<b>210</b>	A
Secondary Output Overcurrent Response Time Constant	$t_{\text{SEC\_OUT\_OCP}}$	Effective internal RC filter		3		ms
Secondary Output Short-Circuit Protection Trip Threshold	$I_{\text{SEC\_OUT\_SCP}}$		<b>187</b>			A
Secondary Output Short-Circuit Protection Response Time	$t_{\text{SEC\_OUT\_SCP}}$			1		$\mu\text{s}$
Overtemperature Shut-Down Threshold	$t_{\text{OTP+}}$	Temperature sensor located inside controller IC	<b>125</b>			$^{\circ}\text{C}$



Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>Powertrain Supervisory Limits PRIMARY to SECONDARY (Forward Direction)</b>						
Primary Overvoltage Lockout Threshold	$V_{\text{PRI\_OVLO+}}$		<b>420</b>	434.5	<b>450</b>	V
Primary Overvoltage Recovery Threshold	$V_{\text{PRI\_OVLO-}}$		<b>410</b>	424	<b>440</b>	V
Primary Overvoltage Lockout Hysteresis	$V_{\text{PRI\_OVLO\_HYST}}$			10.5		V
Primary Overvoltage Lockout Response Time	$t_{\text{PRI\_OVLO}}$			100		$\mu\text{s}$
Primary Undervoltage Lockout Threshold	$V_{\text{PRI\_UVLO-}}$		<b>195</b>	221	<b>250</b>	V
Primary Undervoltage Recovery Threshold	$V_{\text{PRI\_UVLO+}}$		<b>225</b>	243	<b>255</b>	V
Primary Undervoltage Lockout Hysteresis	$V_{\text{PRI\_UVLO\_HYST}}$			15		V
Primary Undervoltage Lockout Response Time	$t_{\text{PRI\_UVLO}}$			100		$\mu\text{s}$
Primary-to-Secondary Start-Up Delay	$t_{\text{PRI\_TO\_SEC\_DELAY}}$	From $V_{\text{PRI\_DC}} = V_{\text{PRI\_UVLO+}}$ to powertrain active, EN floating (i.e., one-time start-up delay from application of $V_{\text{PRI\_DC}}$ to $V_{\text{SEC\_DC}}$ )		20		ms
Secondary Output Overcurrent Trip Threshold	$I_{\text{SEC\_OUT\_OCP}}$		<b>145</b>	170	<b>210</b>	A
Secondary Output Overcurrent Response Time Constant	$t_{\text{SEC\_OUT\_OCP}}$	Effective internal RC filter		3		ms
Overtemperature Shut-Down Threshold	$t_{\text{OTP+}}$	Temperature sensor located inside controller IC	<b>125</b>			$^{\circ}\text{C}$
Overtemperature Recovery Threshold	$t_{\text{OTP-}}$		105	110	115	$^{\circ}\text{C}$
Undertemperature Shut-Down Threshold	$t_{\text{UTP}}$	Temperature sensor located inside controller IC; Protection not available for M-Grade units.			-45	$^{\circ}\text{C}$
Undertemperature Restart Time	$t_{\text{UTP\_RESTART}}$	Start up into a persistent fault condition. Non-latching fault detection given $V_{\text{PRI\_DC}} > V_{\text{PRI\_UVLO+}}$		3		s

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>General Powertrain SECONDARY to PRIMARY Specification (Reverse Direction)</b>						
Secondary Input Voltage Range (Continuous)	$V_{\text{SEC\_DC}}$		<b>8.1</b>		<b>12.8</b>	V
SEC to PRI No-Load Power Dissipation	$P_{\text{SEC\_NL}}$	$V_{\text{SEC\_DC}} = 12\text{V}, T_{\text{INTERNAL}} = 25^{\circ}\text{C}$		11	17	W
		$V_{\text{SEC\_DC}} = 12\text{V}$	<b>5.9</b>		<b>25</b>	
		$V_{\text{SEC\_DC}} = 8.1 - 12.8\text{V}, T_{\text{INTERNAL}} = 25^{\circ}\text{C}$			19	
		$V_{\text{SEC\_DC}} = 8.1 - 12.8\text{V}$			<b>20</b>	
DC Secondary Input Current	$I_{\text{SEC\_IN\_DC}}$	At $I_{\text{PRI\_DC}} = 3.9\text{A}, T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$			<b>127</b>	A
Primary Output Power (Continuous)	$P_{\text{PRI\_OUT\_DC}}$	Specified at $V_{\text{SEC\_DC}} = 12.8\text{V}$			<b>1500</b>	W
Primary Output Power (Pulsed)	$P_{\text{PRI\_OUT\_PULSE}}$	Specified at $V_{\text{SEC\_DC}} = 12.8\text{V}$ ; 10ms pulse, 25% duty cycle, $P_{\text{PRI\_AVG}} \leq 50\%$ of rated $P_{\text{PRI\_OUT\_DC}}$			<b>2000</b>	W
Primary Output Current (Continuous)	$I_{\text{PRI\_OUT\_DC}}$				<b>3.9</b>	A
Primary Output Current (Pulsed)	$I_{\text{PRI\_OUT\_PULSE}}$	10ms pulse, 25% duty cycle, $I_{\text{PRI\_OUT\_AVG}} \leq 50\%$ of rated $I_{\text{PRI\_OUT\_DC}}$			<b>5.2</b>	A
SEC to PRI Efficiency (Ambient)	$\eta_{\text{AMB}}$	$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}$	96.2	97		%
		$V_{\text{SEC\_DC}} = 8.1 - 12.8\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}$	95.2			
		$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 1.95\text{A}$	96.5	97.4		
SEC to PRI Efficiency (Hot)	$\eta_{\text{HOT}}$	$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}$	96.2	97		%
SEC to PRI Efficiency (Over Load Range)	$\eta_{20\%}$	$0.78\text{A} < I_{\text{PRI\_OUT\_DC}} < 3.9\text{A}$	<b>90</b>			%
SEC to PRI Output Resistance	$R_{\text{PRI\_COLD}}$	$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}, T_{\text{INTERNAL}} = -40^{\circ}\text{C}$	2100	2400	2700	m $\Omega$
	$R_{\text{PRI\_AMB}}$	$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}$	2500	2700	2900	
	$R_{\text{PRI\_HOT}}$	$V_{\text{SEC\_DC}} = 12\text{V}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}, T_{\text{INTERNAL}} = 100^{\circ}\text{C}$	2900	3150	3400	
Primary Output Voltage Ripple	$V_{\text{PRI\_OUT\_PP}}$	$C_{\text{PRI\_OUT\_EXT}} = 0\mu\text{F}, I_{\text{PRI\_OUT\_DC}} = 3.9\text{A}, V_{\text{SEC\_DC}} = 12\text{V}, 20\text{MHz BW}$		6250		mV
		$T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$			<b>9600</b>	

Electrical Specifications (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>Protection SECONDARY to PRIMARY (Reverse Direction)</b>						
Secondary Overvoltage Lockout Threshold	$V_{\text{SEC\_OVLO+}}$	Module latched shut down with $V_{\text{PRI\_DC}} < V_{\text{PRI\_UVLO-R}}$	<b>13.1</b>	13.6	<b>14.1</b>	V
Secondary Overvoltage Lockout Response Time	$t_{\text{PRI\_OVLO}}$			100		$\mu\text{s}$
Secondary Undervoltage Lockout Threshold	$V_{\text{SEC\_UVLO-}}$	Module latched shut down with $V_{\text{PRI\_DC}} < V_{\text{PRI\_UVLO-R}}$	<b>3.4</b>	3.75	<b>4.1</b>	V
Secondary Undervoltage Lockout Response Time	$t_{\text{SEC\_UVLO}}$			100		$\mu\text{s}$
Primary Undervoltage Lockout Threshold	$V_{\text{PRI\_UVLO-R}}$	Applies only to reversible products in forward and in reverse direction; $I_{\text{PRI\_DC}} \leq 20\%$ while $V_{\text{PRI\_UVLO-R}} < V_{\text{PRI\_DC}} < V_{\text{PRI\_MIN}}$	<b>110</b>	120	<b>130</b>	V
Primary Undervoltage Recovery Threshold	$V_{\text{PRI\_UVLO+R}}$	Applies only to reversible products in forward and in reverse direction	<b>120</b>	130	<b>150</b>	V
Primary Undervoltage Lockout Hysteresis	$V_{\text{PRI\_UVLO\_HYST\_R}}$	Applies only to reversible products in forward and in reverse direction		10		V
Primary Output Overcurrent Trip Threshold	$I_{\text{PRI\_OUT\_OCP}}$	Module latched shut down with $V_{\text{PRI\_DC}} < V_{\text{PRI\_UVLO-R}}$	<b>4.2</b>	5.3	<b>6.6</b>	A
Primary Output Overcurrent Response Time Constant	$t_{\text{PRI\_OUT\_OCP}}$	Effective internal RC filter		3		ms
Primary Short Circuit Protection Trip Threshold	$I_{\text{PRI\_SCP}}$	Module latched shut down with $V_{\text{PRI\_DC}} < V_{\text{PRI\_UVLO-R}}$	<b>5.8</b>			A
Primary Short Circuit Protection Response Time	$t_{\text{PRI\_SCP}}$			1		$\mu\text{s}$

Operating Area

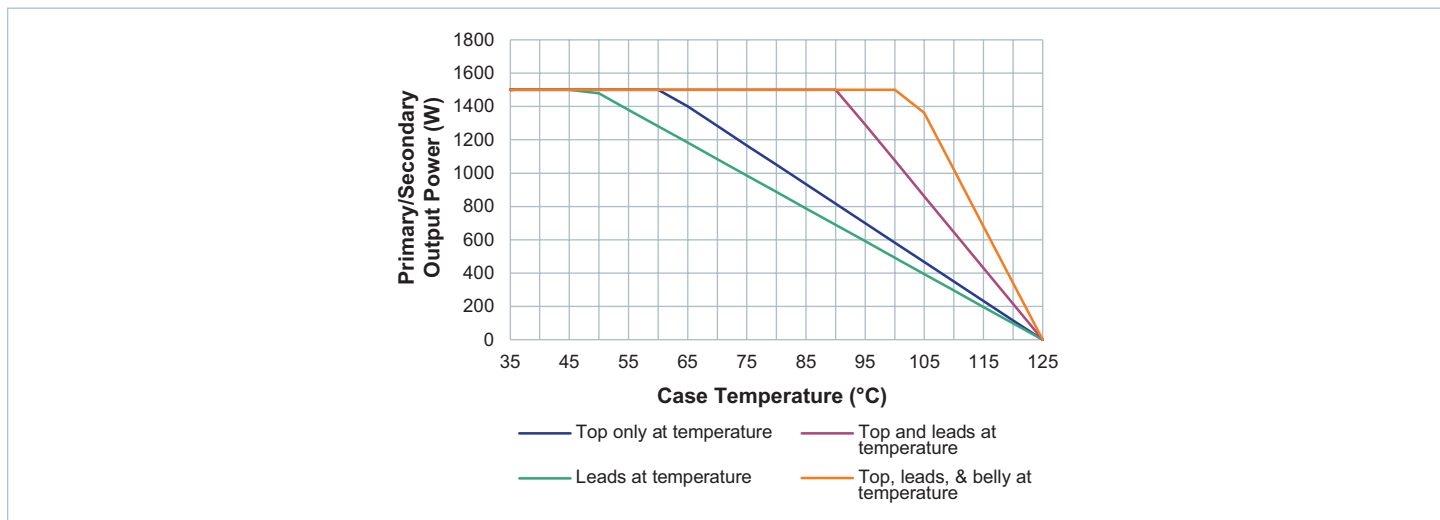


Figure 1 — Specified thermal operating area

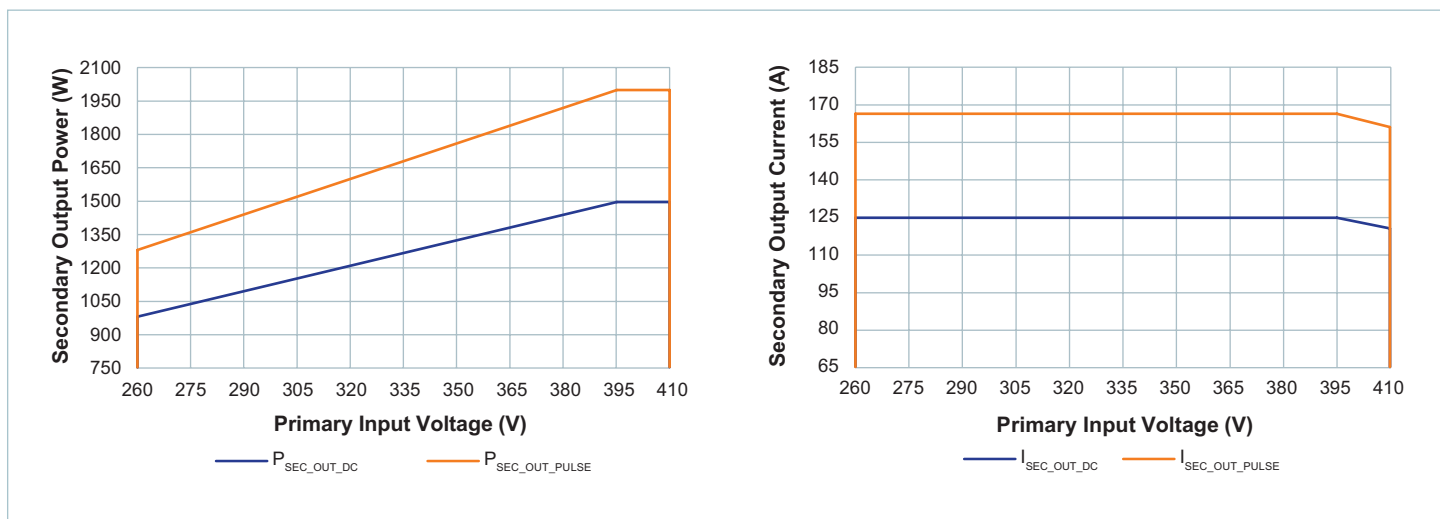


Figure 2 — Specified electrical operating area using rated  $R_{SEC\_HOT}$

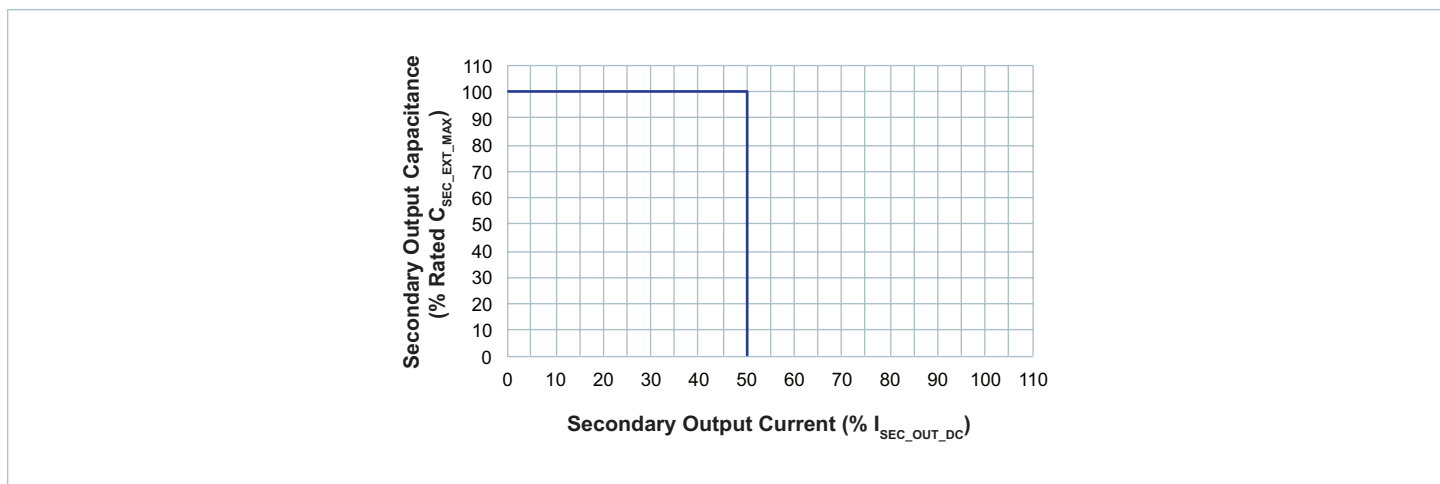


Figure 3 — Specified primary start up into load current and external capacitance

### Analog Control Signal Characteristics

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Temperature Monitor									
<ul style="list-style-type: none"> <li>The TM pin is a standard analog I/O configured as an output from an internal <math>\mu\text{C}</math>.</li> <li>The TM pin monitors the internal temperature of the controller IC within an accuracy of <math>\pm 5^{\circ}\text{C}</math>.</li> <li><math>\mu\text{C}</math> 250kHz PWM output internally pulled high to 3.3V.</li> </ul>									
Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit	
DIGITAL OUTPUT	Start Up	Powertrain Active to TM Time	$t_{\text{TM}}$			<b>100</b>		$\mu\text{s}$	
		TM Duty Cycle	$\text{TM}_{\text{PWM}}$		<b>18.18</b>		<b>68.18</b>	%	
	Regular Operation	TM Current	$I_{\text{TM}}$					<b>4</b>	mA
		<b>Recommended external filtering</b>							
		TM Capacitance (External)	$C_{\text{TM\_EXT}}$	Recommended External filtering			0.01		$\mu\text{F}$
		TM Resistance (External)	$R_{\text{TM\_EXT}}$	Recommended External filtering			1		k $\Omega$
		<b>Specifications using recommended filter</b>							
		TM Gain	$A_{\text{TM}}$				10		mV / $^{\circ}\text{C}$
		TM Voltage Reference	$V_{\text{TM\_AMB}}$	Internal temperature = $27^{\circ}\text{C}$			1.27		V
		TM Voltage Ripple	$V_{\text{TM\_PP}}$	$R_{\text{TM\_EXT}} = 1\text{k}\Omega$ , $C_{\text{TM\_EXT}} = 0.01\mu\text{F}$ , $V_{\text{PRI\_DC}} = 384\text{V}$ , $I_{\text{SEC\_DC}} = 125\text{A}$ $T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$				28	
							40		

Enable / Disable Control									
<ul style="list-style-type: none"> <li>The EN pin is a standard analog I/O configured as an input to an internal <math>\mu\text{C}</math>.</li> <li>It is internally pulled high to 3.3V.</li> <li>When held low, the BCM internal bias will be disabled and the powertrain will be inactive.</li> <li>In an array of BCMs, EN pins should be interconnected to synchronize start up.</li> </ul>									
Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit	
ANALOG INPUT	Start Up	EN to Powertrain Active Time	$t_{\text{EN\_START}}$	$V_{\text{PRI\_DC}} > V_{\text{PRI\_UVLO+}}$ , EN held low both conditions satisfied for $T > t_{\text{PRI\_UVLO+\_DELAY}}$		<b>250</b>		$\mu\text{s}$	
		EN Voltage Threshold	$V_{\text{EN\_TH}}$		<b>2.3</b>			V	
	Regular Operation	EN Resistance (Internal)	$R_{\text{EN\_INT}}$	Internal pull-up resistor			1.5		k $\Omega$
		EN Disable Threshold	$V_{\text{EN\_DISABLE\_TH}}$					<b>1</b>	V

Analog Control Signal Characteristics (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Auxiliary Voltage Source									
Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit	
ANALOG OUTPUT	Start Up	Powertrain Active to VAUX Time	$t_{\text{VAUX}}$	Powertrain active to VAUX High		<b>2</b>		ms	
	Regular Operation	VAUX Voltage	$V_{\text{VAUX}}$			<b>2.8</b>		<b>3.3</b>	V
		VAUX Available Current	$I_{\text{VAUX}}$					<b>4</b>	mA
		VAUX Voltage Ripple	$V_{\text{VAUX\_PP}}$		$T_{\text{INTERNAL}} \leq 100^{\circ}\text{C}$		50		mV
								<b>100</b>	
		VAUX Capacitance (External)	$C_{\text{VAUX\_EXT}}$					0.01	$\mu\text{F}$
	VAUX Resistance (External)	$R_{\text{VAUX\_EXT}}$	$V_{\text{PRI\_DC}} < V_{\mu\text{C\_ACTIVE}}$		1.5			k $\Omega$	
Fault	VAUX Fault Response Time	$t_{\text{VAUX\_FR}}$		From fault to $V_{\text{VAUX}} = 2.8\text{V}$ , $C_{\text{VAUX}} = 0\text{pF}$		10		$\mu\text{s}$	

PMBus™ Control Signal Characteristics

Specifications apply over all line, load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

UART SER-IN / SER-OUT Pins									
Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit	
GENERAL I/O	Regular Operation	Baud Rate	$BR_{\text{UART}}$	Rate		<b>750</b>		Kbit/s	
		<b>SER-IN Pin</b>							
DIGITAL INPUT	Regular Operation	SER-IN Input Voltage Range	$V_{\text{SER-IN_IH}}$		2.3			V	
			$V_{\text{SER-IN_IL}}$				1	V	
		SER-IN Rise Time	$t_{\text{SER-IN_RISE}}$	10 – 90%		400		ns	
		SER-IN Fall Time	$t_{\text{SER-IN_FALL}}$	10 – 90%		25		ns	
		SER-IN $R_{\text{PULLUP}}$	$R_{\text{SER-IN_PLP}}$	Pull up to 3.3V		1.5		k $\Omega$	
		SER-IN External Capacitance	$C_{\text{SER-IN_EXT}}$				400	pF	
DIGITAL OUTPUT	Regular Operation	<b>SER-OUT Pin</b>							
		SER-OUT Output Voltage Range	$V_{\text{SER-OUT_OH}}$	$0\text{mA} \geq I_{\text{OH}} \geq -4\text{mA}$	2.8			V	
			$V_{\text{SER-OUT_OL}}$	$0\text{mA} \leq I_{\text{OL}} \leq 4\text{mA}$			0.5	V	
		SER-OUT Rise Time	$t_{\text{SER-OUT_RISE}}$	10 – 90%		55		ns	
		SER-OUT Fall Time	$t_{\text{SER-OUT_FALL}}$	10 – 90%		45		ns	
		SER-OUT Source Current	$I_{\text{SER-OUT}}$	$V_{\text{SER-OUT}} = 2.8\text{V}$			6	mA	
		SER-OUT Output Impedance	$Z_{\text{SER-OUT}}$				<b>120</b>	$\Omega$	

Enable / Disable Control								
Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
ANALOG INPUT	Start Up	EN to Powertrain Active Time	$t_{\text{EN\_START}}$	$V_{\text{PRL\_DC}} > V_{\text{PRL\_UVLO+}}$ EN held low both conditions satisfied for $t > t_{\text{PRL\_UVLO+\_DELAY}}$		<b>250</b>		$\mu\text{s}$
	Regular Operation	EN Voltage Threshold	$V_{\text{ENABLE}}$		<b>2.3</b>		V	
		EN Resistance (Internal)	$R_{\text{EN\_INT}}$	Internal pull-up resistor		1.5		k $\Omega$
		EN Disable Threshold	$V_{\text{EN\_DISABLE\_TH}}$				1	V

**PMBus™ Reported Characteristics**

Specifications apply over all line, load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Monitored Telemetry					
<ul style="list-style-type: none"> <li>The BCM communication version is not intended to be used without a Digital Supervisor.</li> <li>The current telemetry is only available in forward operation. The input and output current reported value is not supported in reverse operation.</li> </ul>					
Attribute	Digital Supervisor PMBus Read Command	Accuracy (Rated Range)	Functional Reporting Range	Update Rate	Reported Units
Input Voltage	(88h) READ_VIN	$\pm 5\%$ (LL – HL)	130 – 450V	100 $\mu\text{s}$	$V_{\text{ACTUAL}} = V_{\text{REPORTED}} \times 10^{-1}$
Input Current	(89h) READ_IIN	$\pm 20\%$ (10 – 20% of FL) $\pm 5\%$ (20 – 133% of FL)	0 – 5.9A	100 $\mu\text{s}$	$I_{\text{ACTUAL}} = I_{\text{REPORTED}} \times 10^{-3}$
Output Voltage <sup>[b]</sup>	(8Bh) READ_VOUT	$\pm 5\%$ (LL – HL)	4.25 – 14V	100 $\mu\text{s}$	$V_{\text{ACTUAL}} = V_{\text{REPORTED}} \times 10^{-1}$
Output Current	(8Ch) READ_IOUT	$\pm 20\%$ (10 – 20% of FL) $\pm 5\%$ (20 – 133% of FL)	0 – 190A	100 $\mu\text{s}$	$I_{\text{ACTUAL}} = I_{\text{REPORTED}} \times 10^{-2}$
Output Resistance	(D4h) READ_ROUT	$\pm 5\%$ (50 – 100% of FL) at NL $\pm 10\%$ (50 – 100% of FL) (LL – HL)	1 – 3m $\Omega$	100ms	$R_{\text{ACTUAL}} = R_{\text{REPORTED}} \times 10^{-5}$
Temperature <sup>[c]</sup>	(8Dh) READ_TEMPERATURE_1	$\pm 7^{\circ}\text{C}$ (Full Range)	-55 to 130 $^{\circ}\text{C}$	100ms	$T_{\text{ACTUAL}} = T_{\text{REPORTED}}$

<sup>[c]</sup> Default READ Output Voltage returned when unit is disabled = -300V.

<sup>[d]</sup> Default READ Temperature returned when unit is disabled = -273 $^{\circ}\text{C}$ .

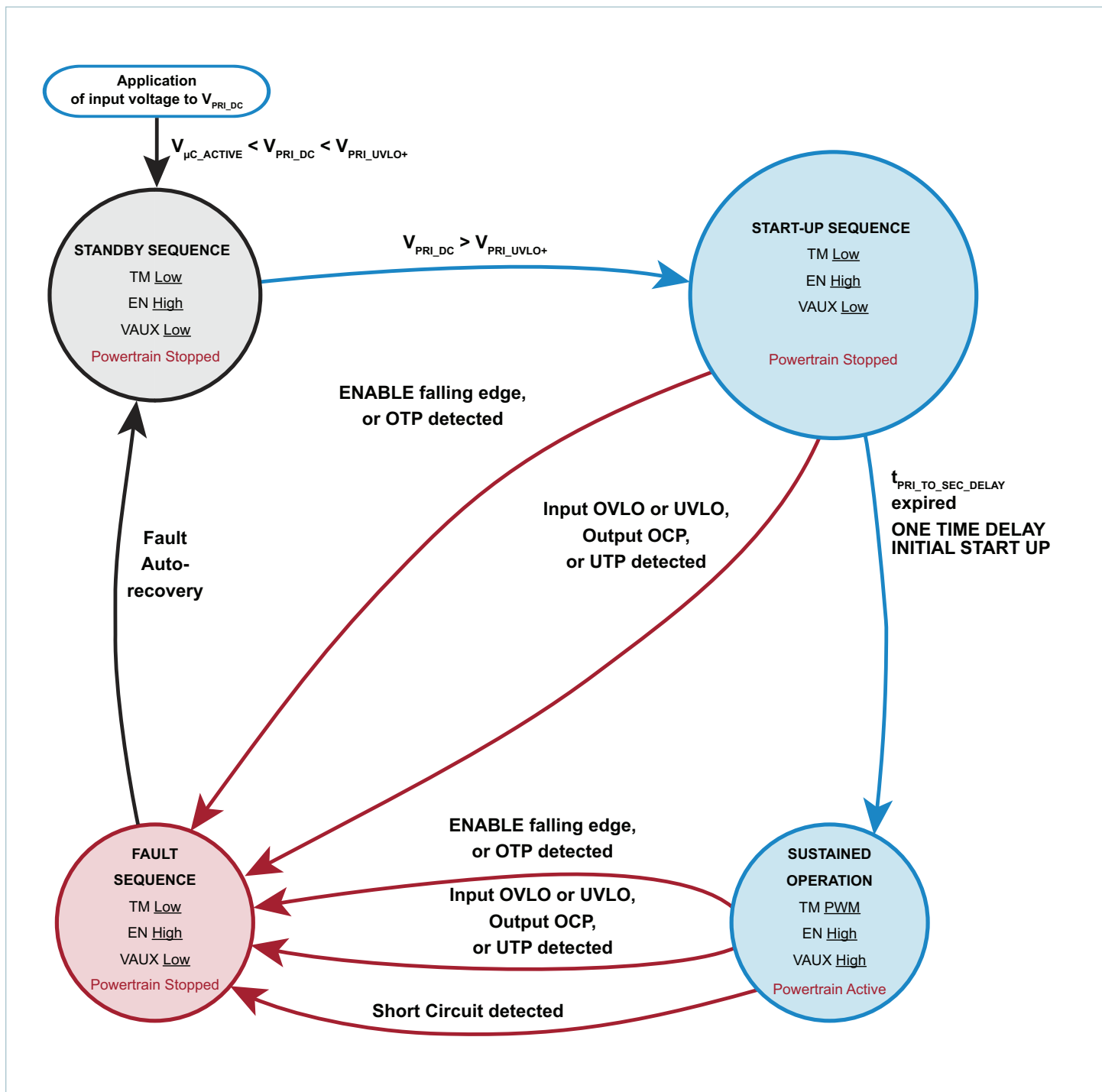
Variable Parameter					
<ul style="list-style-type: none"> <li>Factory setting of all below Thresholds and Warning limits are 100% of listed protection values.</li> <li>Variables can be written only when module is disabled either EN pulled low or <math>V_{\text{IN}} &lt; V_{\text{IN\_UVLO}}</math>.</li> <li>Module must remain in a disabled mode for 3ms after any changes to the below variables allowing ample time to commit changes to EEPROM.</li> </ul>					
Attribute	Digital Supervisor PMBus Command <sup>[d]</sup>	Conditions / Notes	Accuracy (Rated Range)	Functional Reporting Range	Default Value
Input / Output Overvoltage Protection Limit	(55h) VIN_OV_FAULT_LIMIT	$V_{\text{IN\_UVLO}}$ is automatically 3% lower than this set point	$\pm 5\%$ (LL – HL)	130 – 435V	100%
Input / Output Overvoltage Warning Limit	(57h) VIN_OV_WARN_LIMIT		$\pm 5\%$ (LL – HL)	130 – 435V	100%
Input / Output Undervoltage Protection Limit	(D7h) DISABLE_FAULTS	Can only be disabled to a preset default value	$\pm 5\%$ (LL – HL)	130 – 260V	100%
Input Overcurrent Protection Limit	(5Bh) IIN_OC_FAULT_LIMIT		$\pm 20\%$ (10 – 20% of FL) $\pm 5\%$ (20 – 133% of FL)	0 – 5.25A	100%
Input Overcurrent Warning Limit	(5Dh) IIN_OC_WARN_LIMIT		$\pm 20\%$ (10 – 20% of FL) $\pm 5\%$ (20 – 133% of FL)	0 – 5.25A	100%
Overtemperature Protection Limit	(4Fh) OT_FAULT_LIMIT		$\pm 7^{\circ}\text{C}$ (Full Range)	0 – 125 $^{\circ}\text{C}$	100%
Overtemperature Warning Limit	(51h) OT_WARN_LIMIT		$\pm 7^{\circ}\text{C}$ (Full Range)	0 – 125 $^{\circ}\text{C}$	100%
Turn-On Delay	(60h) TON_DELAY	Additional time delay to the undervoltage start-up delay	$\pm 50\mu\text{s}$	0 – 100ms	0ms

<sup>[e]</sup> Refer to Digital Supervisor datasheet for complete list of supported commands.





High-Level Functional State Diagram



Application Characteristics

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

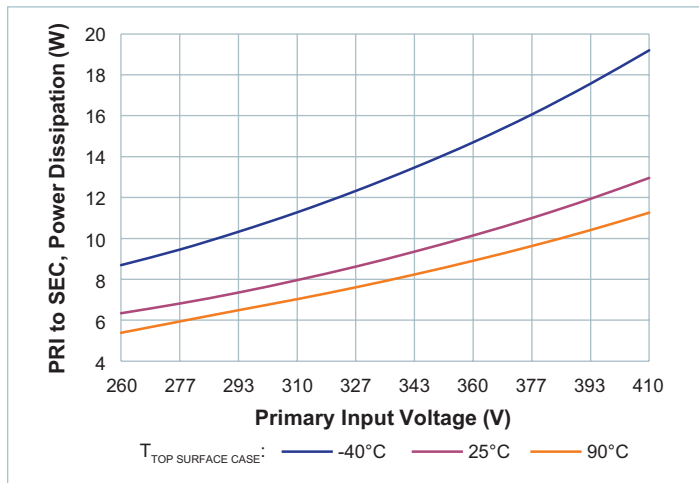


Figure 4 — No-load power dissipation vs.  $V_{PRI\_DC}$

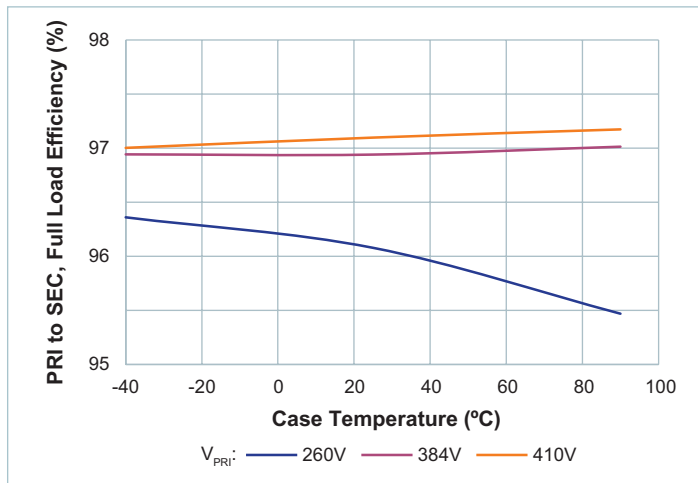


Figure 5 — Full-load efficiency vs. temperature;  $V_{PRI\_DC}$

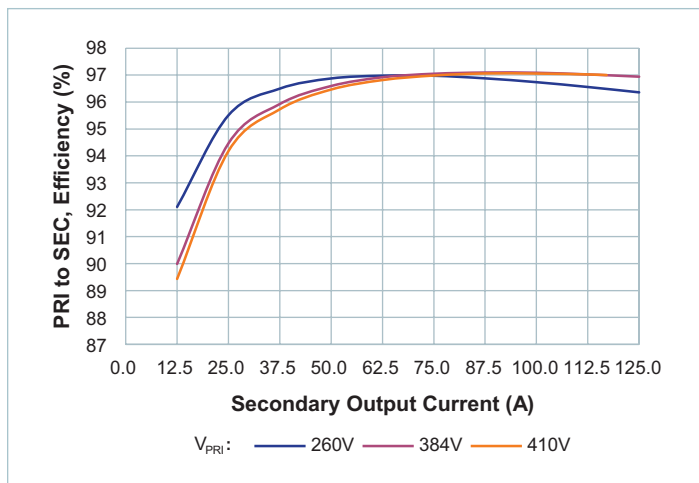


Figure 6 — Efficiency at  $T_{CASE} = -40^{\circ}C$

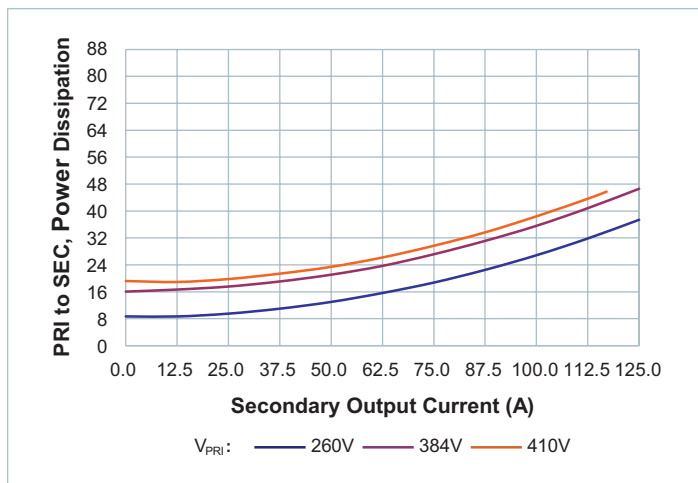


Figure 7 — Power dissipation at  $T_{CASE} = -40^{\circ}C$

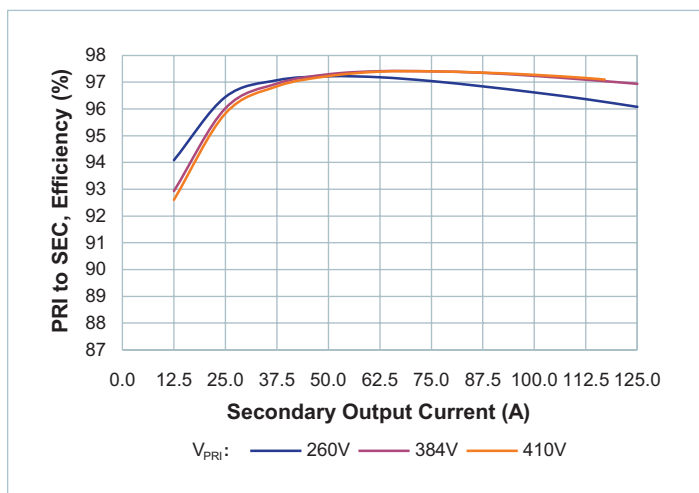


Figure 8 — Efficiency at  $T_{CASE} = 25^{\circ}C$

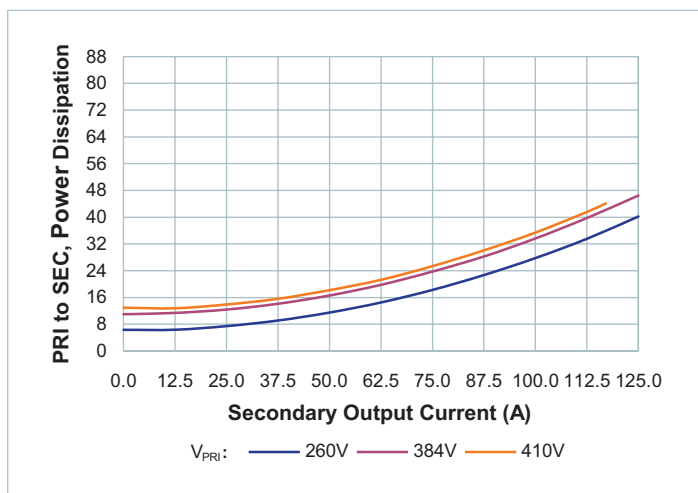


Figure 9 — Power dissipation at  $T_{CASE} = 25^{\circ}C$

Application Characteristics (Cont.)

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

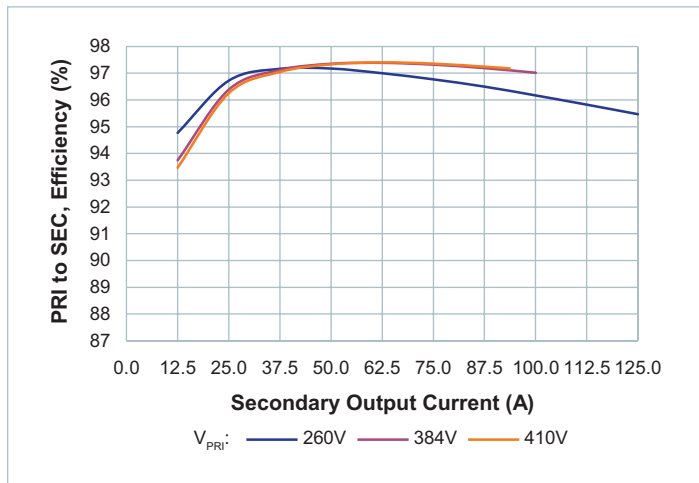


Figure 10 — Efficiency at  $T_{CASE} = 90^{\circ}C$

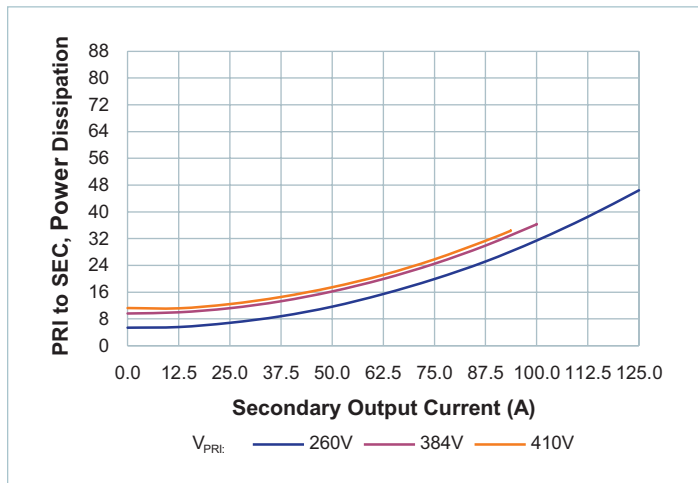


Figure 11 — Power dissipation at  $T_{CASE} = 90^{\circ}C$

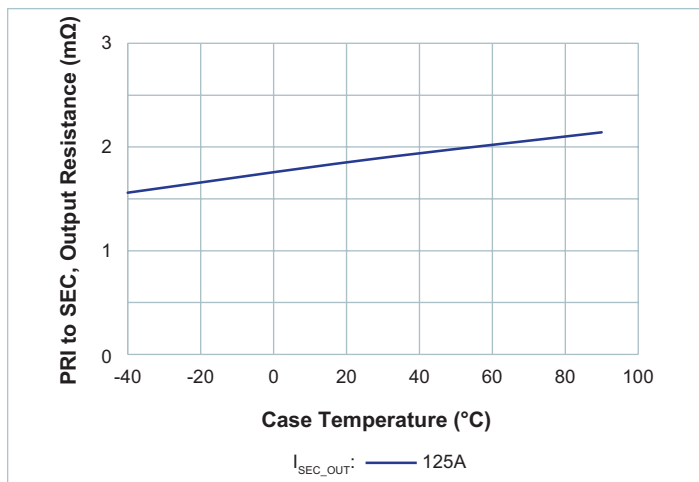


Figure 12 —  $R_{SEC}$  vs. temperature; nominal  $V_{PRI\_DC}$   
 $I_{SEC\_DC} = 100A$  at  $T_{CASE} = 90^{\circ}C$

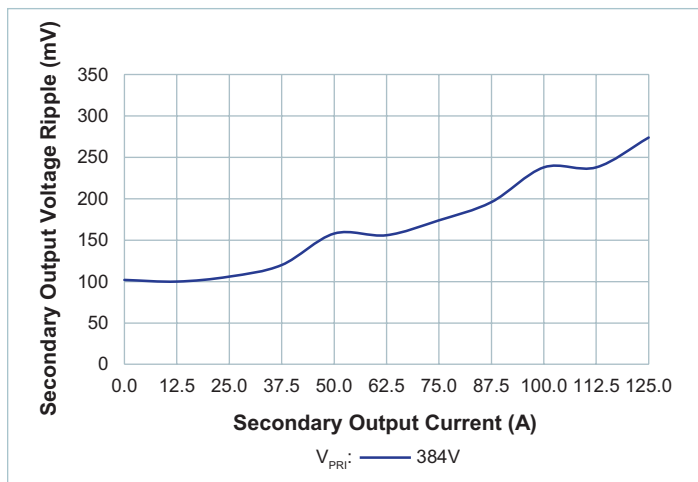


Figure 13 —  $V_{SEC\_OUT\_PP}$  vs.  $I_{SEC\_DC}$ ; no external  $C_{SEC\_OUT\_EXT}$ .  
Board-mounted module, scope setting:  
20MHz analog BW

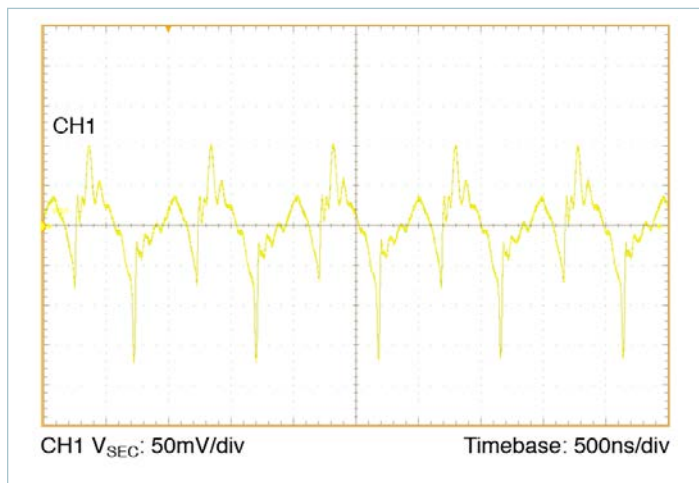
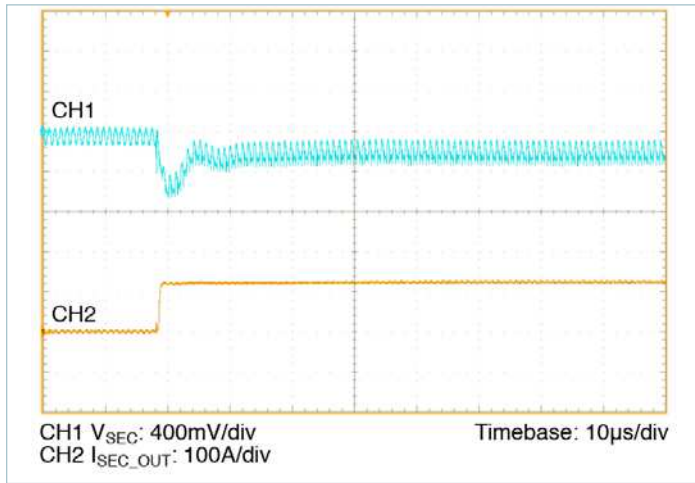


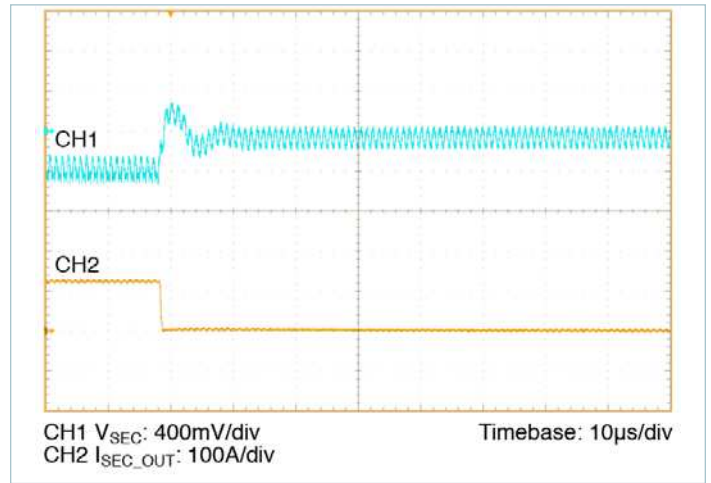
Figure 14 — Full-load secondary voltage,  $10\mu F C_{PRI\_IN\_EXT}$ ;  
no external  $C_{SEC\_OUT\_EXT}$ . Board-mounted module,  
scope setting: 20MHz analog BW

Application Characteristics (Cont.)

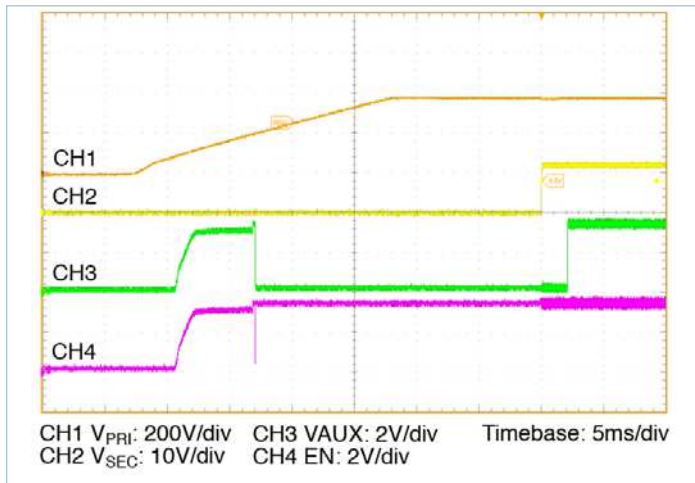
Temperature controlled via top-side cold plate, unless otherwise noted. All data presented in this section are collected from units processing power in the forward direction (primary side to secondary side). See associated figures for general trend data.



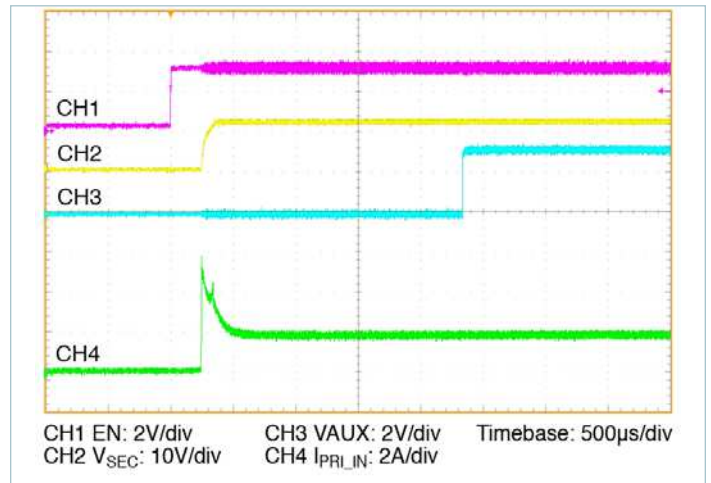
**Figure 15** — 0 – 125A transient response:  
 $C_{PRI\_IN\_EXT} = 10\mu F$ , no external  $C_{SEC\_OUT\_EXT}$



**Figure 16** — 125 – 0A transient response:  
 $C_{PRI\_IN\_EXT} = 10\mu F$ , no external  $C_{SEC\_OUT\_EXT}$



**Figure 17** — Start up from application of  $V_{PRI\_DC} = 384V$ ,  
 $50\% I_{SEC\_OUT\_DG}$   $100\% C_{SEC\_OUT\_EXT}$



**Figure 18** — Start up from application of EN with pre-applied  
 $V_{PRI\_DC} = 384V$ ,  $50\% I_{SEC\_OUT\_DG}$   $100\% C_{SEC\_OUT\_EXT}$

General Characteristics

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>Mechanical</b>						
Length	L		60.87 [2.396]	61.00 [2.402]	61.13 [2.407]	mm [in]
Width	W		24.76 [0.975]	25.14 [0.990]	25.52 [1.005]	mm [in]
Height	H		7.11 [0.280]	7.21 [0.284]	7.31 [0.288]	mm [in]
Volume	Vol	Without heatsink		11.06 [0.675]		cm <sup>3</sup> [in <sup>3</sup> ]
Weight	W			41 [1.45]		g [oz]
Lead Finish		Nickel	0.51		2.03	μm
		Palladium	0.02		0.15	
		Gold	0.003		0.051	
<b>Thermal</b>						
Operating Temperature	T <sub>INTERNAL</sub>	BCM6123xD1E13A3yzz (T-Grade)	-40		125	°C
		BCM6123xD1E13A3yzz (M-Grade)	-55		125	°C
Thermal Resistance Top Side	θ <sub>INT-TOP</sub>	Estimated thermal resistance to maximum temperature internal component from isothermal top		1.1		°C/W
Thermal Resistance Leads	θ <sub>INT-LEADS</sub>	Estimated thermal resistance to maximum temperature internal component from isothermal leads		1.4		°C/W
Thermal Resistance Bottom Side	θ <sub>INT-BOTTOM</sub>	Estimated thermal resistance to maximum temperature internal component from isothermal bottom		1.1		°C/W
Thermal Capacity				34		Ws/°C
<b>Assembly</b>						
Storage Temperature		BCM6123xD1E13A3yzz (T-Grade)	-55		125	°C
		BCM6123xD1E13A3yzz (M-Grade)	-65		125	°C
ESD Withstand	ESD <sub>HBM</sub>	Human Body Model, "ESDA / JEDEC JDS-001-2012" Class I-C (1kV to < 2kV)				
	ESD <sub>CDM</sub>	Charge Device Model, "JESD 22-C101-E" Class II (200V to < 500V)				

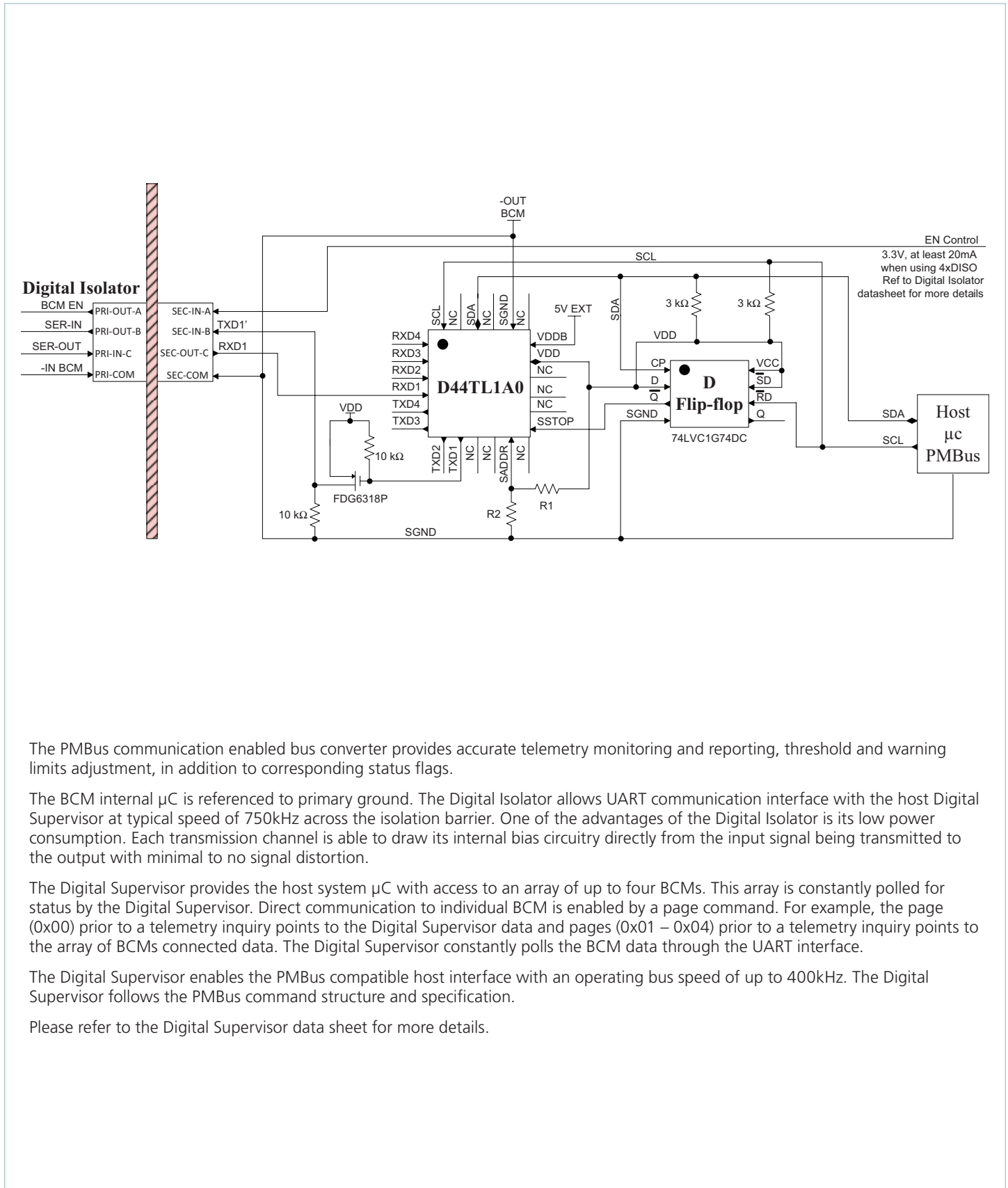
General Characteristics (Cont.)

Specifications apply over all line and load conditions, unless otherwise noted; **boldface** specifications apply over the temperature range of  $-40^{\circ}\text{C} \leq T_{\text{INTERNAL}} \leq 125^{\circ}\text{C}$  (T-Grade); All other specifications are at  $T_{\text{INTERNAL}} = 25^{\circ}\text{C}$  unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
<b>Soldering</b> <sup>[e]</sup>						
Peak Temperature Top Case					135	°C
<b>Safety</b>						
Isolation voltage / Dielectric test	V <sub>HIPO</sub> T	PRIMARY to SECONDARY	<b>4,242</b>			V <sub>DC</sub>
		PRIMARY to CASE	<b>2,121</b>			
		SECONDARY to CASE	<b>2,121</b>			
Isolation Capacitance	C <sub>PRI_SEC</sub>	Unpowered Unit	<b>620</b>	780	<b>940</b>	pF
Insulation Resistance	R <sub>PRI_SEC</sub>	At 500V <sub>DC</sub>	<b>10</b>			MΩ
MTBF		MIL-HDBK-217Plus Parts Count - 25°C Ground Benign, Stationary, Indoors / Computer		2.31		MHrs
		Telcordia Issue 2 - Method I Case III; 25°C Ground Benign, Controlled		3.41		MHrs
Agency Approvals / Standards		cTÜVus EN 60950-1				
		cURus UL 60950-1				
		CE Marked for Low Voltage Directive and RoHS Recast Directive, as applicable				
<b>Previous Part Numbers</b>						
		BCM384x120y1K5ACz				
		BCM384x120y1K5AC1				

<sup>[f]</sup> Product is not intended for reflow solder attach.

PMBus™ System Diagram



The PMBus communication enabled bus converter provides accurate telemetry monitoring and reporting, threshold and warning limits adjustment, in addition to corresponding status flags.

The BCM internal  $\mu$ C is referenced to primary ground. The Digital Isolator allows UART communication interface with the host Digital Supervisor at typical speed of 750kHz across the isolation barrier. One of the advantages of the Digital Isolator is its low power consumption. Each transmission channel is able to draw its internal bias circuitry directly from the input signal being transmitted to the output with minimal to no signal distortion.

The Digital Supervisor provides the host system  $\mu$ C with access to an array of up to four BCMs. This array is constantly polled for status by the Digital Supervisor. Direct communication to individual BCM is enabled by a page command. For example, the page (0x00) prior to a telemetry inquiry points to the Digital Supervisor data and pages (0x01 – 0x04) prior to a telemetry inquiry points to the array of BCMs connected data. The Digital Supervisor constantly polls the BCM data through the UART interface.

The Digital Supervisor enables the PMBus compatible host interface with an operating bus speed of up to 400kHz. The Digital Supervisor follows the PMBus command structure and specification.

Please refer to the Digital Supervisor data sheet for more details.



BCM in a ChiP™

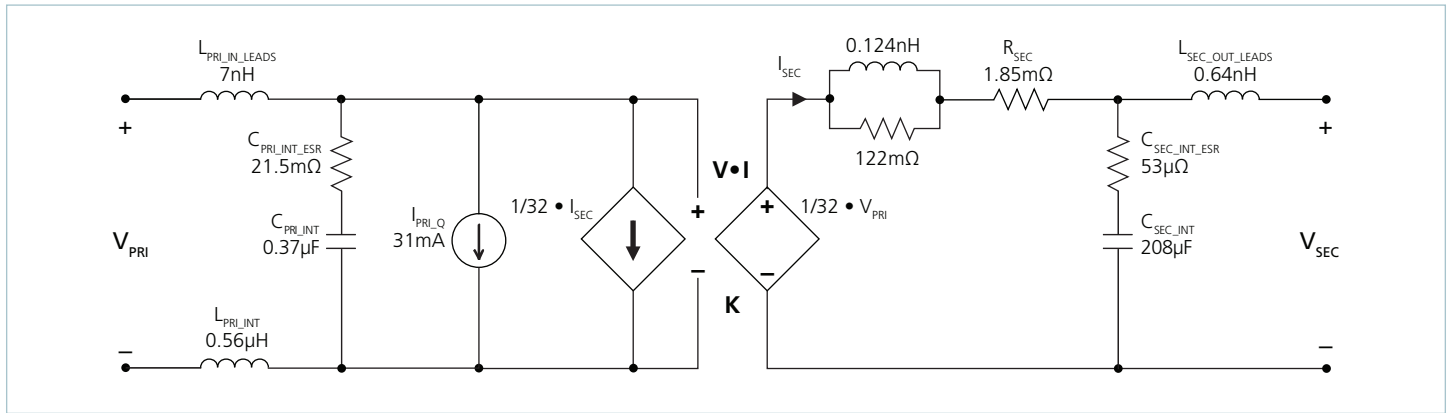


Figure 19 — BCM AC model

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

The BCM6123xD1E13A3yzz can be simplified into the model shown in Figure 19.

At no load:

$$V_{SEC} = V_{PRI} \cdot K \tag{1}$$

K represents the “turns ratio” of the BCM.

Rearranging Equation 1:

$$K = \frac{V_{SEC}}{V_{PRI}} \tag{2}$$

In the presence of a load, V\_SEC is represented by:

$$V_{SEC} = V_{PRI} \cdot K - I_{SEC} \cdot R_{SEC} \tag{3}$$

and I\_SEC is represented by:

$$I_{SEC} = \frac{I_{PRI} - I_{PRI\_Q}}{K} \tag{4}$$

R\_SEC represents the impedance of the BCM, and is a function of the R\_DS\_ON of the primary and secondary MOSFETs and the winding resistance of the power transformer. I\_PRI\_Q represents the quiescent current of the BCM controller, gate drive circuitry and core losses.

The effective DC voltage transformer action provides additional interesting attributes. Assuming that R\_SEC = 0Ω and I\_PRI\_Q = 0A, Equation 3 now becomes Equation 1 and is essentially load independent, resistor R is now placed in series with V\_PRI.

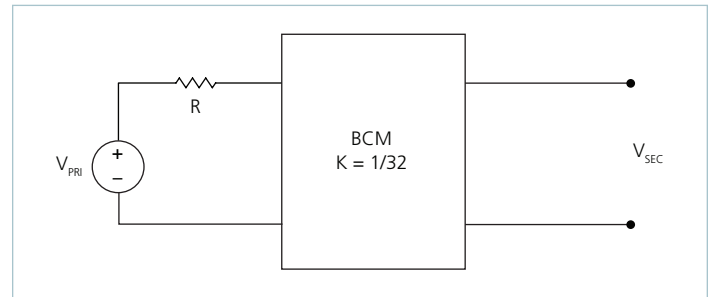


Figure 20 — K = 1/32 BCM with series primary resistor

The relationship between V\_PRI and V\_SEC becomes:

$$V_{SEC} = (V_{PRI} - I_{PRI} \cdot R) \cdot K \tag{5}$$

Substituting the simplified version of Equation 4 (I\_PRI\_Q is assumed = 0A) into Equation 5 yields:

$$V_{SEC} = V_{PRI} \cdot K - I_{SEC} \cdot R \cdot K^2 \tag{6}$$

This is similar in form to Equation 3, where R\_SEC is used to represent the characteristic impedance of the BCM. However, in this case a real resistor, R on the primary side of the BCM is effectively scaled by K^2 with respect to the secondary.

Assuming that R = 1Ω, the effective R as seen from the secondary side is 1mΩ, with K = 1/32.

A similar exercise can be performed with the addition of a capacitor or shunt impedance at the primary of the BCM. A switch in series with  $V_{PRI}$  is added to the circuit. This is depicted in Figure 21.

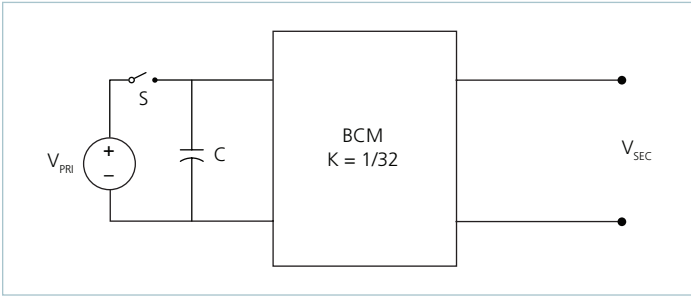


Figure 21 — BCM with primary capacitor

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

$$I_C(t) = C \frac{dV_{PRI}}{dt} \quad (7)$$

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

$$I_C = I_{SEC} \cdot K \quad (8)$$

substituting Equation 1 and 8 into Equation 7 reveals:

$$I_{SEC}(t) = \frac{C}{K^2} \cdot \frac{dV_{SEC}}{dt} \quad (9)$$

The equation in terms of the secondary 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 secondary when expressed in terms of the primary. With  $K = 1/32$  as shown in Figure 21,  $C = 1\mu\text{F}$  would appear as  $C = 1024\mu\text{F}$  when viewed from the secondary.

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 BCM 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 BCM is too high. The impedance of the BCM must be low, i.e., well beyond the crossover frequency of the system.

A solution for keeping the impedance of the BCM 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 BCM are:

- No load power dissipation ( $P_{PRI\_NL}$ ): defined as the power used to power up the module with an enabled powertrain at no load.
- Resistive loss ( $P_{R\_SEC}$ ): refers to the power loss across the BCM modeled as pure resistive impedance.

$$P_{DISSIPATED} = P_{PRI\_NL} + P_{R\_SEC} \quad (10)$$

Therefore,

$$P_{SEC\_OUT} = P_{PRI\_IN} - P_{DISSIPATED} = P_{PRI\_IN} - P_{PRI\_NL} - P_{R\_SEC} \quad (11)$$

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

$$\eta = \frac{P_{SEC\_OUT}}{P_{PRI\_IN}} = \frac{P_{PRI\_IN} - P_{PRI\_NL} - P_{R\_SEC}}{P_{PRI\_IN}} \quad (12)$$

$$= \frac{V_{PRI} \cdot I_{PRI} - P_{PRI\_NL} - (I_{SEC})^2 \cdot R_{SEC}}{V_{PRI} \cdot I_{PRI}}$$

$$= 1 - \left( \frac{P_{PRI\_NL} + (I_{SEC})^2 \cdot R_{SEC}}{V_{PRI} \cdot I_{PRI}} \right)$$