DCM® Module

DCM290y138x600A40

Isolated, Regulated DC Converter

Features

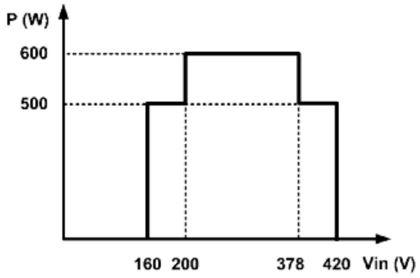
- Isolated, regulated DC-to-DC converter
- Up to 600 W, 43.5 A continuous
- 93% peak efficiency
- 1244 W/in^3 Power density
- Wide input range 160 – 420 Vdc
- Safety Extra Low Voltage (SELV) 13.8 V Nominal Output
- 4242 Vdc isolation
- ZVS high frequency (MHz) switching
  - Enables low-profile, high-density filtering
- Optimized for Array Operation
  - Up to 8 units – 4800 W
  - No power derating needed
  - Permit different line voltages
- Fully operational current limit
- OV, OC, UV, short circuit and thermal protection
- 4623 through-hole ChiP package
  - 1.878" x 0.898" x 0.286"
    (47.71 mm x 22.8 mm x 7.26 mm)

Typical Applications

- Transportation
- Industrial Systems
- Electric Vehicle (EV) / Hybrid Electric Vehicle (HEV)
- On-board Power

Product Ratings

Operating Input (V)			Output Power Max (W)	Output (V) set point 100% load, 25°C		
Min	**Nom**	**Max**		**Min**	**Nom**	**Max**
200	290	378	600	11.5	13.8	15.5
160		200	500			
378		420				

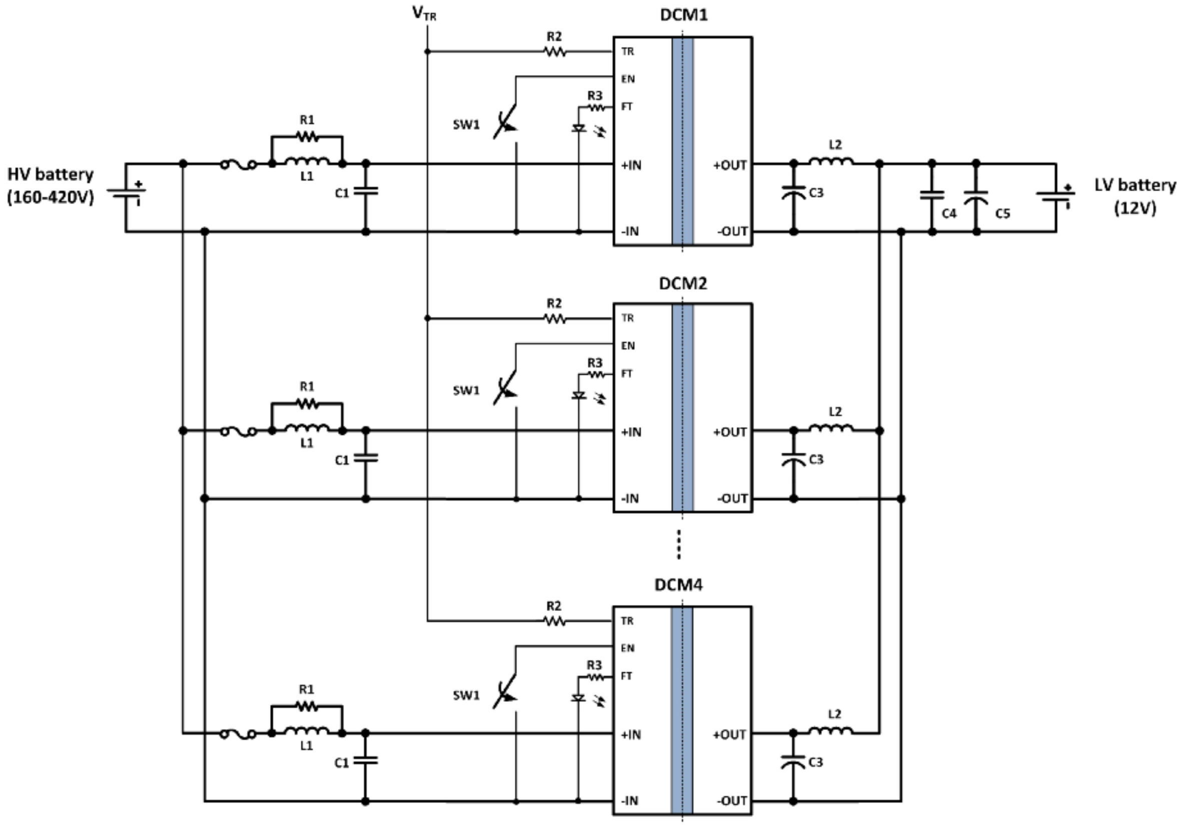


Product Description

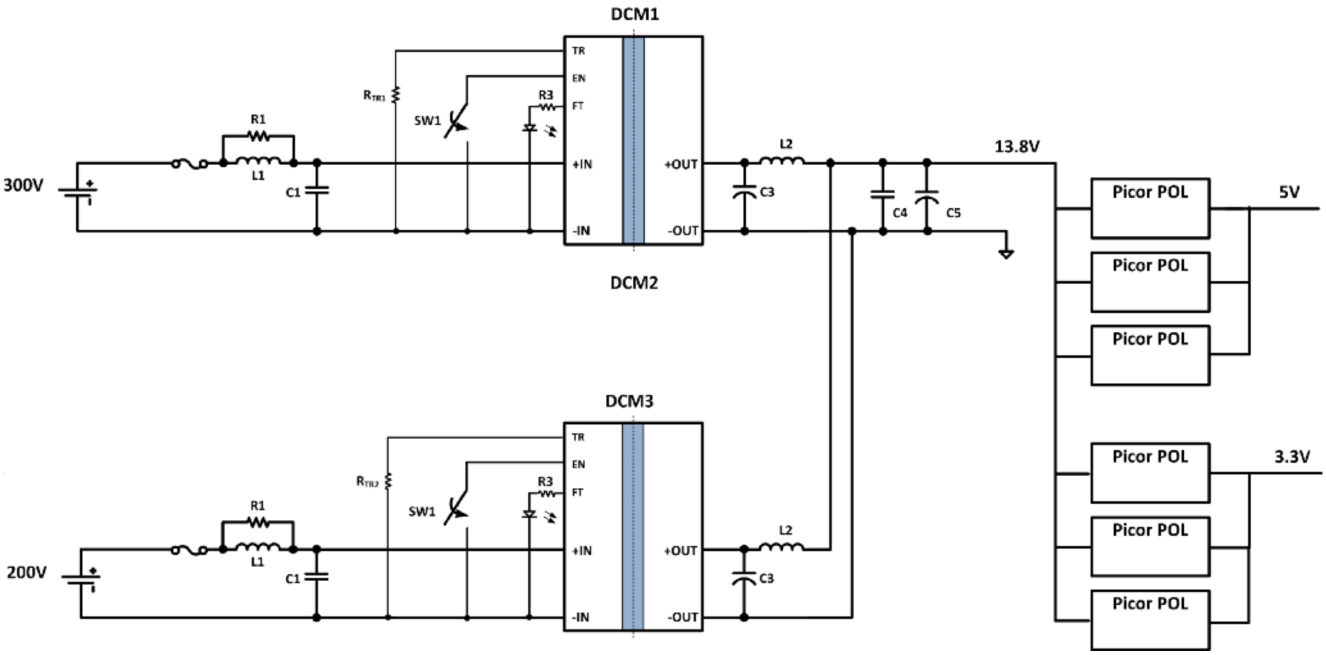
The DCM Isolated, Regulated DC Converter is a DC-to-DC converter, operating from an unregulated, wide range input to generate an isolated 13.8 Vdc output. With its high frequency zero voltage switching (ZVS) topology, the DCM converter consistently delivers high efficiency across the input line range. Modular DCM converters and downstream DC-DC products support efficient power distribution, providing superior power system performance and connectivity from a variety of unregulated power sources to the point-of-load.

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

Typical Application

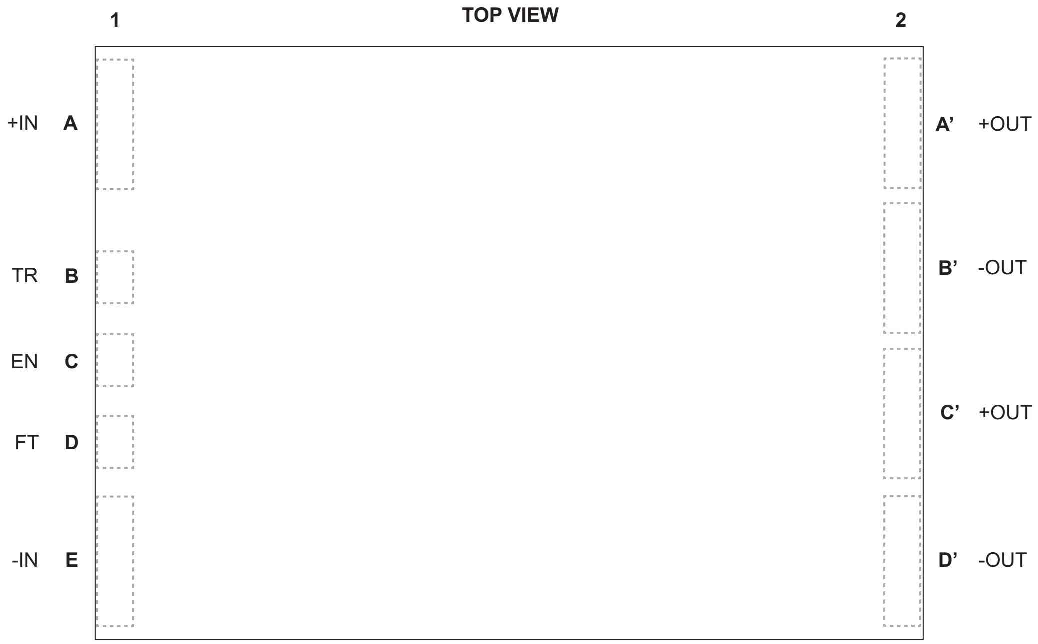


Typical Application 1: DCM290**y**138**x**600A40 for EV/HEV applications



Typical Application 2: DCM290**y**138**x**600A40 + Picor Point-of-Load

Pin Configuration



4623 ChiP Package

Pin Descriptions

Pin Number	Signal Name	Type	Function
A1	+IN	INPUT POWER	Positive input power terminal
E1	-IN	INPUT POWER RETURN	Negative input power terminal
B1	TR	INPUT	Enables and disables trim functionality. Adjusts output voltage when trim active.
C1	EN	INPUT	Enables and disables power supply
D1	FT	OUTPUT	Fault monitoring
A'2, C'2	+OUT	OUTPUT POWER	Positive output power terminal
B'2, D'2	-OUT	OUTPUT POWER RETURN	Negative output power terminal

Part Ordering Information

Device	Input Voltage Range	Package Type	Output Voltage x 10	Temperature Grade	Output Power	Revision	Version
DCM	290	y	138	x	600	A4	0
DCM = DCM	290 = 160 to 420 V	P = ChiP TH	138 = 13.8 V	T = -40 to 125°C	600 = 600 W	A4	Analog Control Interface Version

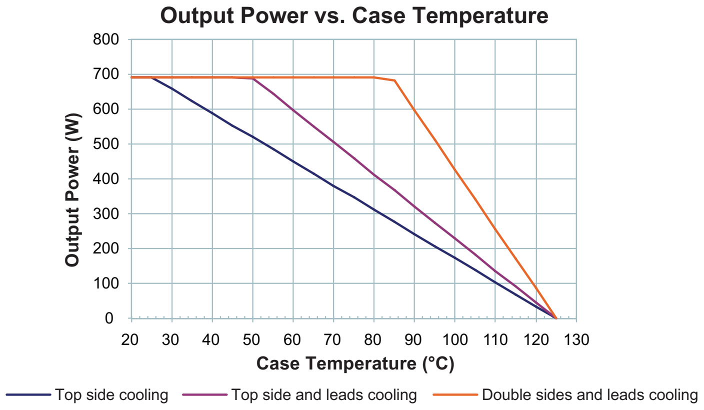
Standard Models

Part Number	V_{IN}	Package Type	V_{OUT}	Temperature	Power	Version
DCM290**P**138**T**600A40	160 to 420 V	ChiP TH	13.8 V (11.5 to 15.5 V)	T = -40 to 125°C	600 W	Analog Control Interface Version

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. Electrical specifications do not apply when operating beyond rated operating conditions.

Parameter	Comments	Min	Max	Unit
Input Voltage (+IN to –IN)	550 V for 100 ms	-0.5	550	V
Input Voltage Slew Rate		-1	1	V/µs
TR to - IN		-0.3	3.5	V
EN to -IN		-0.3	3.5	V
FT to -IN		-0.3	3.5	V
			5	mA
Output Voltage (+Out to –Out)		-0.5	25	V
Dielectric withstand (input to output)	Basic insulation 1 min.		4242	Vdc
Temperature				
Operating Internal		-40	125	°C
Storage		-40	125	°C
Output Current			51	A



Electrical Specifications

Specifications apply over all line, trim and load conditions, internal temperature T_{INT} = 25°C, unless otherwise noted. **Boldface** specifications apply over the temperature range of -40°C < T_{INT} < 125°C.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Power Input Specification						
Input voltage range, continuous operation	V_{IN}	Module will only startup if input voltage is inside the range of $V_{IN\text{-}FULL\text{-}POWER}$. After startup, Module can then operate in the entire V_{IN} range	**160**	**290**	**420**	V
Full power input voltage range, continuous operation	$V_{IN\text{-}FULL\text{-}POWER}$		**200**	**290**	**378**	V
Inrush current (peak)	I_{INRP}	With maximum $C_{OUT\text{-}EXT}$, full resistive load, over V_{IN} and trim			**7.5**	A
Input capacitance (internal)	$C_{IN\text{-}INT}$	Effective value at nominal input voltage		0.8		µF
Input capacitance (internal) ESR	R_{Cin}	At 1 MHz		10		mΩ
Input capacitance (external)	$C_{IN\text{-}EXT}$	Effective value at nominal input voltage	**0.68**			µF
No Load Specification						
Input power – disabled	P_Q	Nominal line, see Fig. 2		1	1.5	W
		Worst case line, see Fig. 2			**2**	W
Input power – enabled with no load	P_{NL}	Nominal line, see Fig. 3		2	3	W
		Worst case line, see Fig. 3			**8.5**	W
Power Output Specification						
Output voltage set point	V_{OUT}	V_{IN} = 290 V, trim inactive, at 100% Load, T_{INT} = 25°C	13.66	13.8	13.94	V
Output voltage trim range	$V_{OUT\text{-}TRIMMING}$	At full rated load current. Trim V_{OUT} higher than $V_{OUT\text{-}TRIMMING}$ could possibly cause output OVP	**11.5**		**15.5**	V
Output voltage load regulation	$\%V_{OUT\text{-}LOAD}$	Linear load line, over 5% to 100% Load, relative to Vo_0A, which is the virtual no load output voltage without considering the additional Vout; see Fig. 5 and Sec. Design Guidelines	-4.00	-5.00	-6.00	%
Output voltage load regulation	$V_{OUT\text{-}LL}$	0% to 5% Load, additional V_{OUT} relative to calculated 5% load-line point; see Fig. 5 and Sec. Design Guidelines	**0.0**		**2.3**	V
Output voltage temperature coefficient	$\%V_{OUT\text{-}TEMP}$	Nominal, linear temperature coefficient, relative to T_{INT} = 25 °C. See Fig. 4 and Sec. Design Guidelines		**-1.84**		mV/°C
V_{OUT} accuracy	$\%V_{OUT\text{-}ACCURACY}$	The total output voltage setpoint accuracy from the calculated ideal Vout based on load, temp and trim			**2.00**	%
Rated output power	P_{OUT}	Continuous, V_{OUT} ≥ 13.8 V, 200 V ≤ V_{IN} ≤ 378 V			**600**	W
Rated output current	I_{OUT}	Continuous, V_{OUT} ≤ 13.8 V, 200 V ≤ V_{IN} ≤ 378 V			**43.5**	A
Derated output power	$P_{OUT\text{-}DERATED}$	Continuous, V_{OUT} ≥ 13.8 V, 160 V < V_{IN} < 200 V or 378 V < V_{IN} < 420 V			**500**	W
Derated output current	$I_{OUT\text{-}DERATED}$	Continuous, V_{OUT} ≤ 13.8 V, 160 V < V_{IN} < 200 V or 378 V < V_{IN} < 420 V			**36.2**	A
Output current limit	$I_{OUT\text{-}LM}$	Of I_{OUT} max. Fully operational current limit	100	105	117	%
Current limit delay	$t_{IOUT\text{-}LIM}$	The module will power limit in a fast transient event		1		ms
Efficiency	η	Full Load, Nominal Line, trim inactive	92.8	93.5		%
		Full Load, over line and temperature, trim inactive	**92.0**			%
		50% Load, over line, temperature and trim	**90.0**			%
Output voltage ripple	$V_{OUT\text{-}PP}$	Over all operating steady-state line, load and trim conditions, 20 MHz BW, with minimum $C_{OUT\text{-}EXT}$		750		mV

Electrical Specifications (cont.)

Specifications apply over all line, trim and load conditions, internal temperature T_{INT} = 25°C, unless otherwise noted. **Boldface** specifications apply over the temperature range of -40°C < T_{INT} < 125°C.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Power Output Specifications (Cont.)						
Output capacitance (internal)	$C_{OUT\text{-}INT}$	Effective value at nominal output voltage		72		µF
Output capacitance (internal) ESR	R_{Cout}	At 1MHz		2.0		mΩ
Output capacitance (external)	$C_{OUT\text{-}EXT}$	Electrolytic Capacitor preferred. Excludes component tolerances and temperature coefficient	**1000**		**10000**	µF
Output capacitance, ESR (ext.)	$C_{OUT\text{-}EXT\text{-}ESR}$	At 10 kHz, 25°C, excludes component tolerances	**10**		**100**	mΩ
Initialization delay	t_{INIT}	After input voltage first exceeds $V_{IN\text{-}UVLO+}$		25	**40**	ms
Output turn-on delay	t_{ON}	From rising edge EN, with V_{IN} pre-applied. See timing diagram		500		µs
Output turn-off delay	t_{OFF}	From falling edge EN. See timing diagram			**200**	µs
Start-up setpoint aquisition time	t_{SS}	Full load (soft-start ramp time) with minimum $C_{OUT\text{-}EXT}$	36	38	40	ms
Monotonic soft-start threshold voltage	$V_{OUT\text{-}MONOTONIC}$	At startup, the DCM output voltage rise becomes monotonic once it crosses $V_{OUT\text{-}MONOTONIC}$, standalone or as a member in an array			**10.5**	V
Minimum required disabled duration	$t_{OFF\text{-}MIN}$	This refers to the minimum time a module needs to be in the disabled state before it will attempt to start via EN			**2**	ms
Minimum required disabled duration for predictable restart	$t_{OFF\text{-}MIN\text{-}NICE\text{-}RESTART}$	This refers to the minimum time a module needs to be in the disabled state before it is guaranteed to exhibit monotonic soft-start and have predictable startup timing			**100**	ms
Voltage deviation (transient)	$\%V_{OUT\text{-}TRANS}$	C_{OUT_EXT} = min; (10 ↔ 90% load step), excluding load line. Load transient slew rate up to full load current per millisecond		<10		%
Recovery time	t_{TRANS}			<0.5		ms
Powertrain Protections						
V_{IN} undervoltage Turn-OFF	$V_{IN\text{-}UVLO-}$		**130**		**155**	V
V_{IN} undervoltage Turn-ON	$V_{IN\text{-}UVLO+}$	See Timing diagram			**200**	V
V_{IN} overvoltage Turn-OFF	$V_{IN\text{-}OVLO+}$				**450**	V
V_{IN} overvoltage Turn-ON	$V_{IN\text{-}OVLO-}$	See Timing diagram	**380**			V
Output overvoltage threshold	$V_{OUTOVP1}$	From 25% to 100% load. Latched shutdown; primary sensed output voltage only	**17.17**			V
Output overvoltage threshold	$V_{OUTOVP2}$	From 0% to 25% load. Latched shutdown; primary sensed output voltage only	**18**			V
Minimum current limited V_{OUT}	$V_{OUT\text{-}UVP}$	Over all operating steady-state line and trim conditions			**6**	V
Overtemperature threshold (internal)	$T_{INT\text{-}OTP}$	In order to have an effective over temperature protection, keep case bottom temperature no more than case top temperature			**125**	°C
Power limit	P_{LIM}	See Fig.1, SOA			**880**	W
V_{IN} overvoltage to cessation of powertrain switching	t_{OVLO_SW}	Independant of fault logic		**1**		µs
V_{IN} overvoltage response time	t_{OVLO}	For fault logic only			**200**	µs
V_{IN} undervoltage response time	t_{UVLO}				**100**	ms
Short circuit response time	t_{SC}	Powertrain on, operational state			**200**	µs
Short circuit, or temperature fault recovery time	t_{FAULT}	See Timing diagram		1		s

Signal Specifications

Specifications apply over all line, trim and load conditions, internal temperature $T_{INT} = 25°C$, unless otherwise noted. **Boldface** specifications apply over the temperature range of $-40°C < T_{INT} < 125°C$.

Enable: EN

- The EN pin enables and disables the DCM converter; when held low the unit will be disabled.
- The EN pin has an internal pull-up to VCC and is referenced to the -IN pin of the converter.

SIGNAL TYPE	STATE	ATTRIBUTE	SYMBOL	CONDITIONS / NOTES	MIN	TYP	MAX	UNIT
DIGITAL INPUT	Any	EN enable threshold	$V_{ENABLE\text{-}EN}$				**2.31**	V
		EN disable threshold	$V_{ENABLE\text{-}DIS}$		**0.99**			V
		Internally generated V_{CC}	V_{CC}		**3.21**	3.30	**3.39**	V
		EN Internal Pull up resistance to V_{CC}	$R_{ENABLE\text{-}INT}$	Pull up to V_{CC}	**9.5**	10.0	**10.5**	kΩ

Trim: TR

- The TR pin enables and disables trim functionality when V_{IN} is applied to the DCM converter.
  TR pin voltage is sampled right before soft start stage during DCM startup.
- If TR is not floating at power up and has a voltage less than TR trim enable threshold, trim is active.
- If trim is active, the TR pin provides dynamic trim control with at least 30Hz of -3dB control bandwidth over the output voltage of the DCM converter.
- The TR pin has an internal pull-up to V_{CC} and is referenced to the -IN pin of the converter.

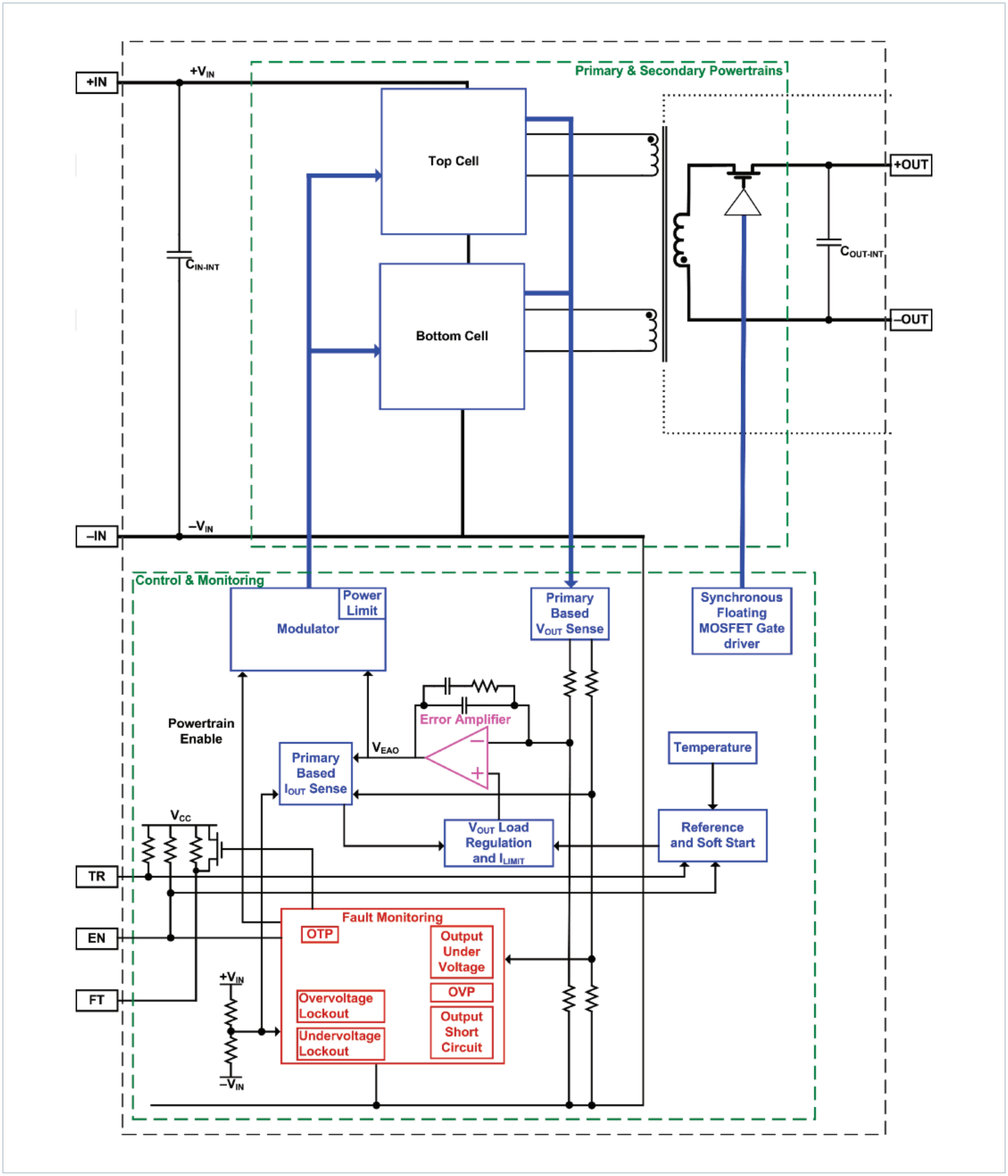
SIGNAL TYPE	STATE	ATTRIBUTE	SYMBOL	CONDITIONS / NOTES	MIN	TYP	MAX	UNIT
DIGITAL INPUT	Startup	TR trim enable threshold	$V_{TRIM\text{-}EN}$				3.15	V
		TR trim disable threshold	$V_{TRIM\text{-}DIS}$		3.20			V
ANALOG INPUT	Operational with Trim enabled	Internally generated V_{CC}	V_{CC}		**3.21**	3.30	**3.39**	V
		TR pin analog range	$V_{TRIM\text{-}RANGE}$	Trim V_{OUT} higher than output voltage trim range $V_{OUT\text{-}TRIMMING}$ could possibly cause output OVP	0.5	1.9	2.8	V
		V_{OUT} referred TR pin resolution	$V_{OUT\text{-}RES}$	With $V_{CC} = 3.3$ V		28.0		mV
		TR internal pull up resistance to V_{CC}	$R_{TRIIM\text{-}INT}$		**9.5**	10.0	**10.5**	kΩ

Fault: FT

- The FT pin is a Fault flag pin.
- When the module is enabled and no fault is present, the FT pin does not have current drive capability.
- Whenever the powertrain stops (due to a fault protection or disabling the module by pulling EN low), the FT pin output Vcc and provides current to drive an external ciruit.
- When module starts up, the FT pin is pulled high to V_{CC} during microcontroller initialization and will remain high until soft start process starts.

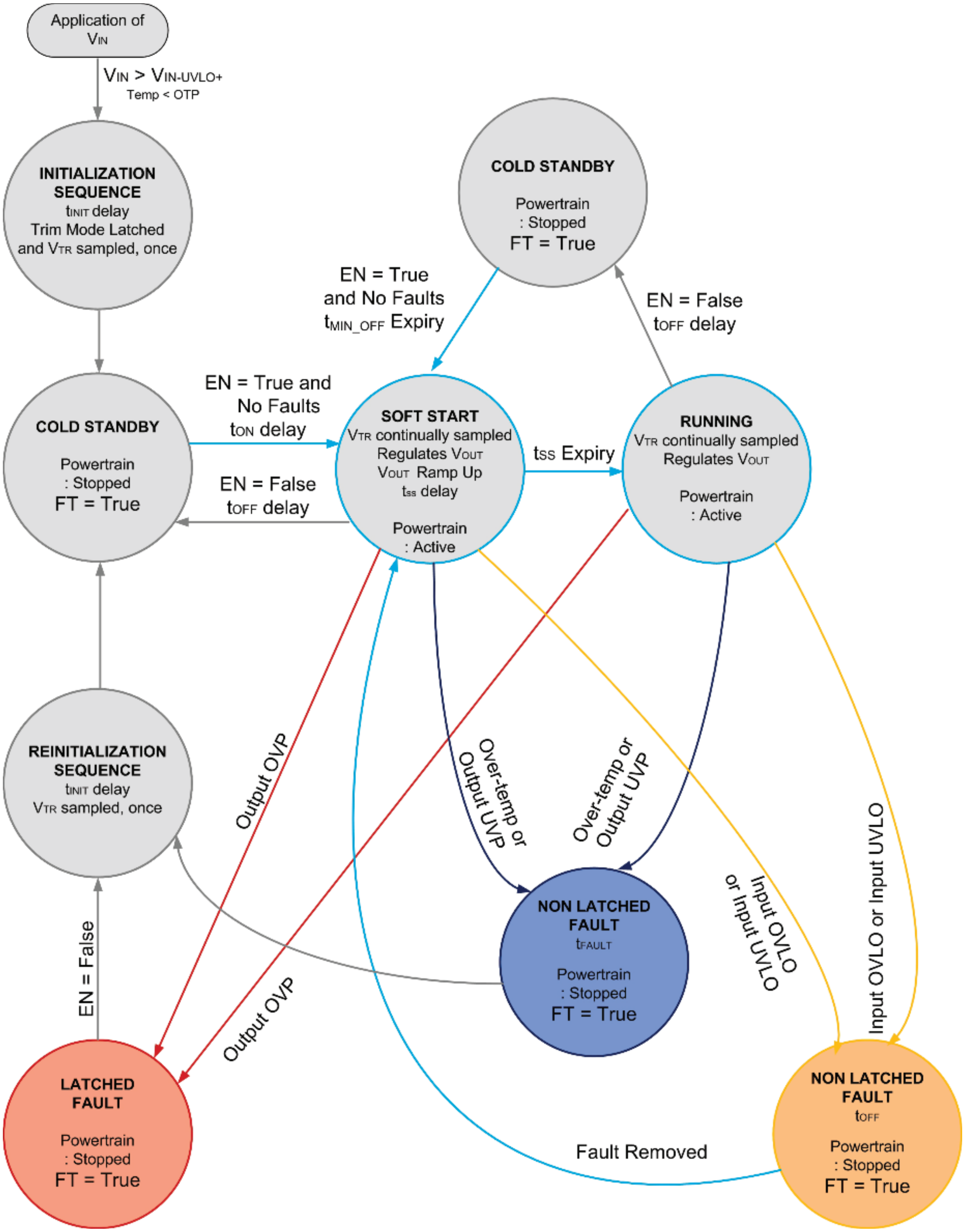
SIGNAL TYPE	STATE	ATTRIBUTE	SYMBOL	CONDITIONS / NOTES	MIN	TYP	MAX	UNIT
DIGITAL OUTPUT	FT Inactive	Internally generated V_{CC}			**3.21**	3.30	**3.39**	V
		FT internal pull up resistance to V_{CC}	$R_{FAULT\text{-}INACTIVE}$		**474**	499	**524**	kΩ
	FT Active	FT Voltage	$V_{FAULT\text{-}ACTIVE}$	At load = 5 mA	**3.21**			V
		FT current drive capability	$I_{FAULT\text{-}ACTIVE}$	Over-current FT drive beyond its capability may cause module damage			**5.00**	mA
		FT response time	$t_{RESPONSE\text{-}FAULT}$	After Fault detected		200.0		µs
			$t_{RESPONSE\text{-}ENABLE}$	After EN being pulled low		200.0		µs
			$t_{RESPONSE\text{-}INACTIVE1}$	After the module returns to no fault state, the time for FT to become inactive, for input UVLO and OVLO			1	ms
			$t_{RESPONSE\text{-}INACTIVE2}$	After the module returns to no fault state, the time for FT to become inactive, for other (slower recovery) fault types			51	ms

Functional Block Diagram



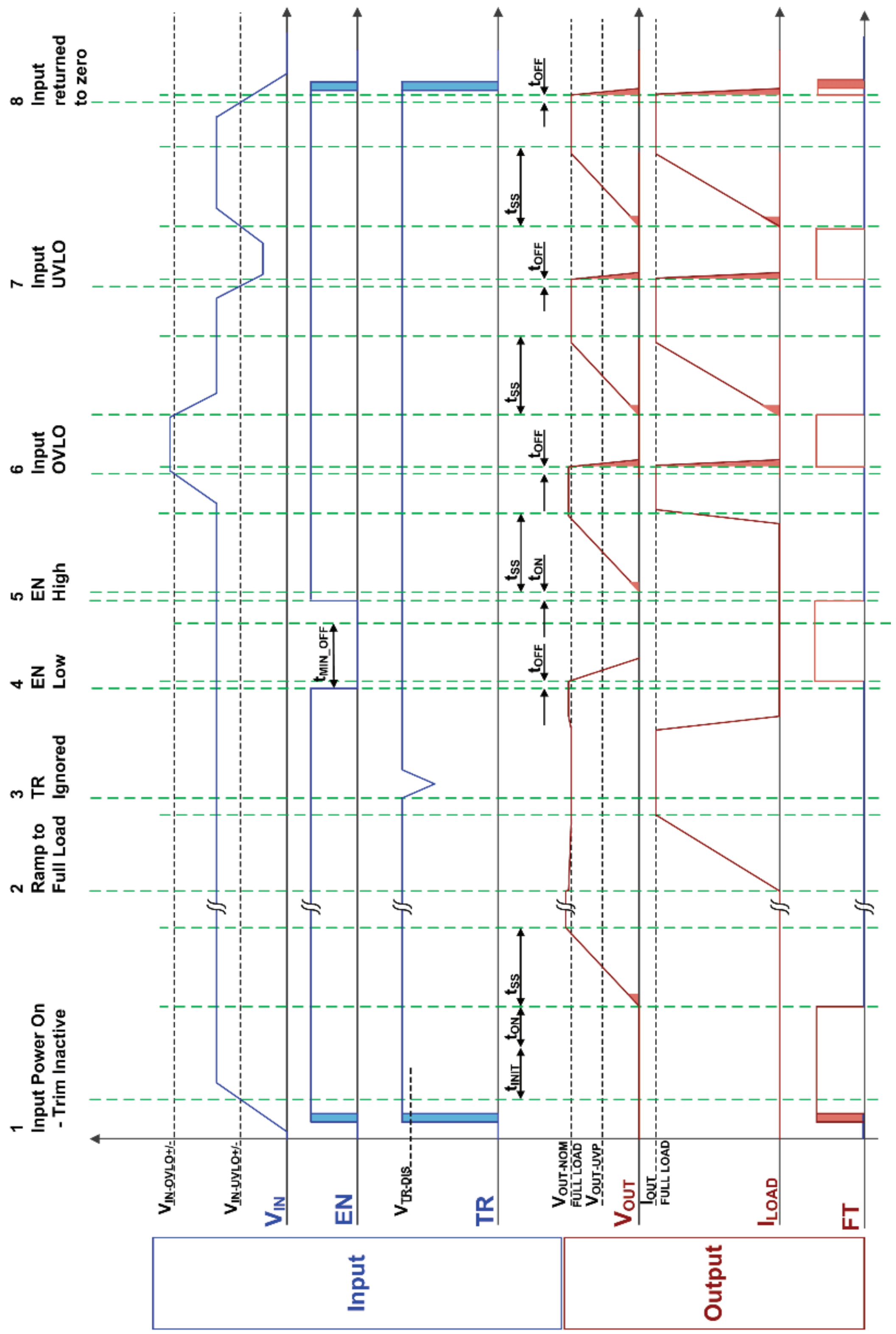
High Level Functional State Diagram

Conditions that cause state transitions are shown along arrows. Sub-sequence activities listed inside the state bubbles.



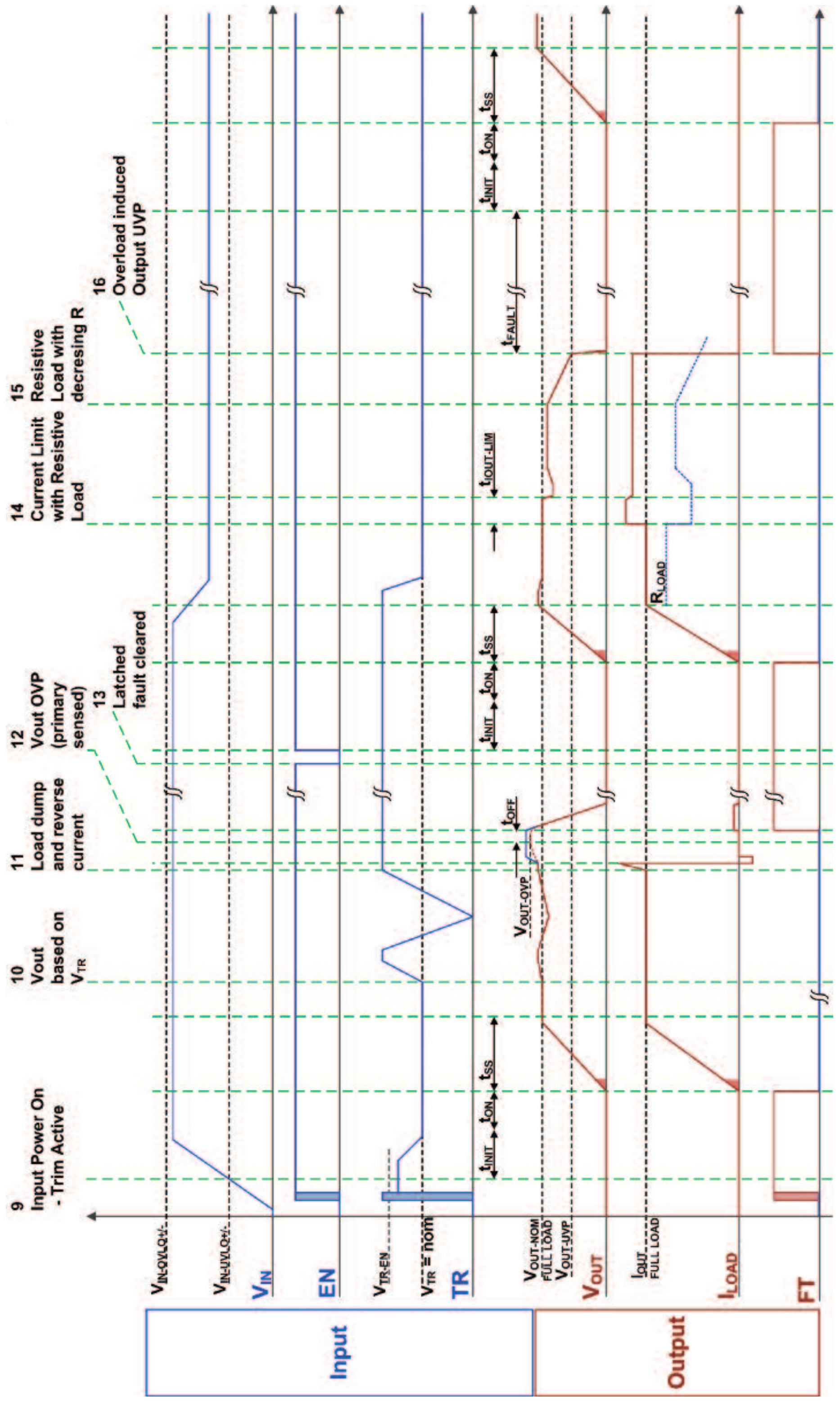
Timing Diagrams

Module Inputs are shown in blue; Module Outputs are shown in brown.



Timing Diagrams (Cont.)

Module Inputs are shown in blue; Module Outputs are shown in brown.



Typical Performance Characteristics

The following figures present typical performance at $T_C = 25°C$, unless otherwise noted. See associated figures for general trend data.

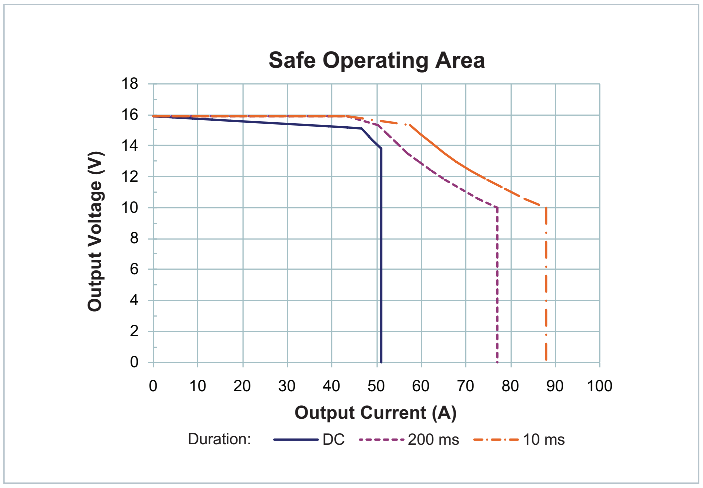


Figure 1 *— Output Safe Operating Area*

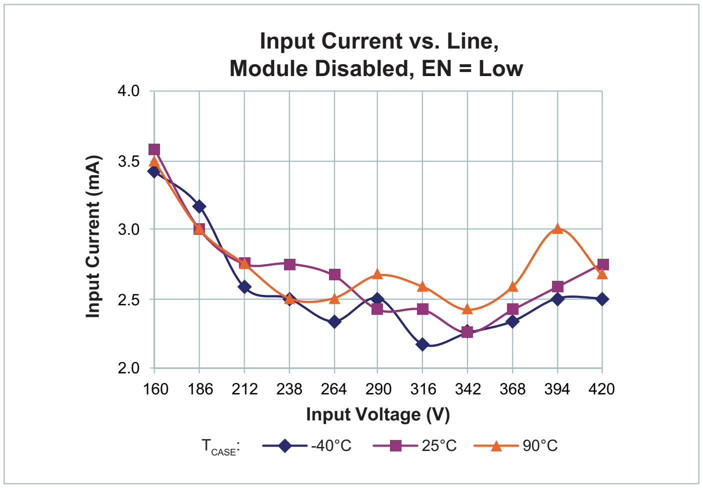


Figure 2 *— Disabled current consumption vs.* V_{IN}

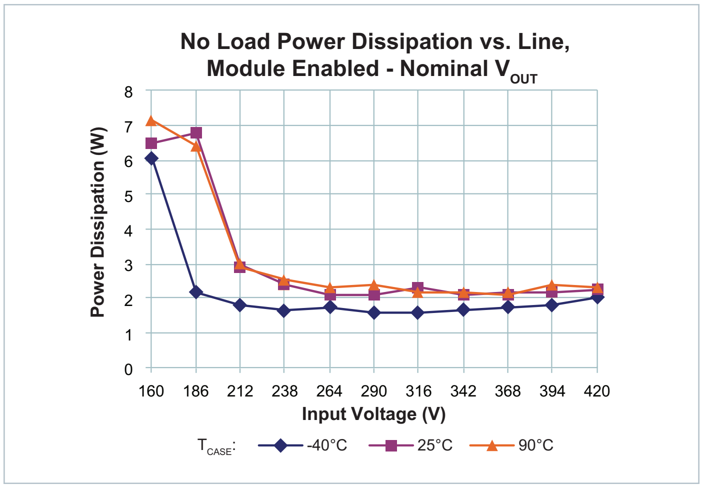


Figure 3 *— No load power dissipation vs.* V_{IN}*, at nominal trim*

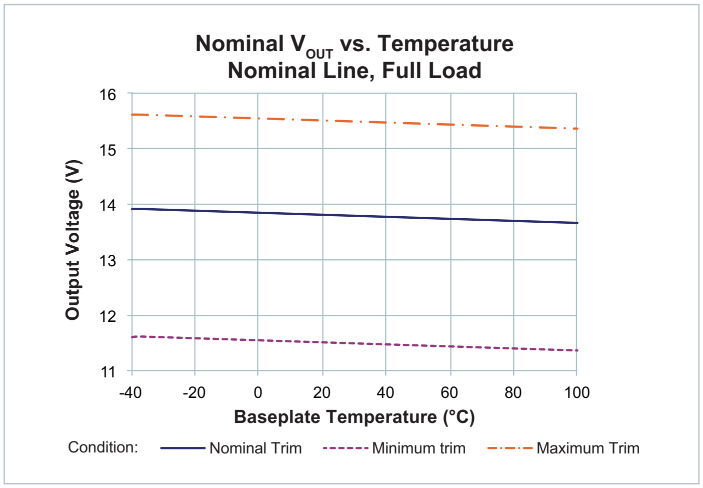


Figure 4 *—* V_{OUT} *vs. operating temperature trend, at full load and nominal line*

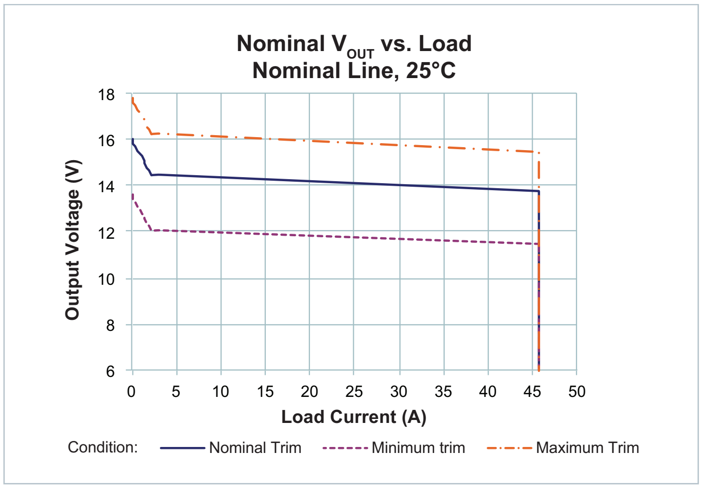


Figure 5 *—* V_{OUT} *vs. load current trend, at room temperature and nominal line*

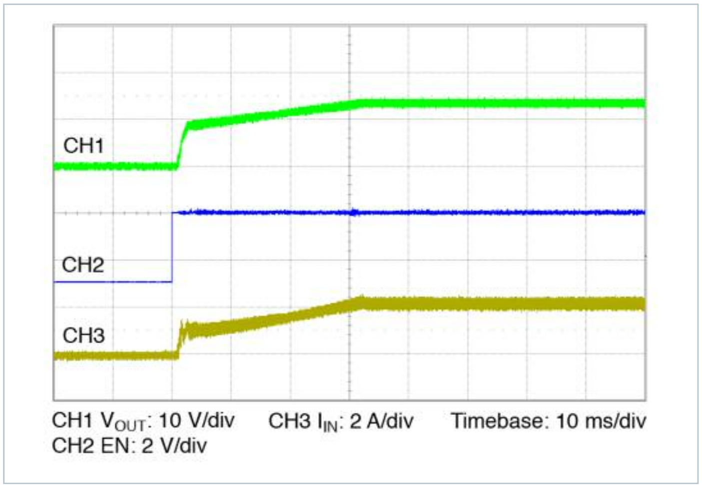


Figure 6 *— Initial startup from EN pin, with soft-start ramp.* $V_{IN} = 290\ V$, $C_{OUT\_EXT} = 10000\ \mu F$, $R_{LOAD} = 0.317\ \Omega$

Typical Performance Characteristics (cont.)

The following figures present typical performance at T_C = 25°C, unless otherwise noted. See associated figures for general trend data.

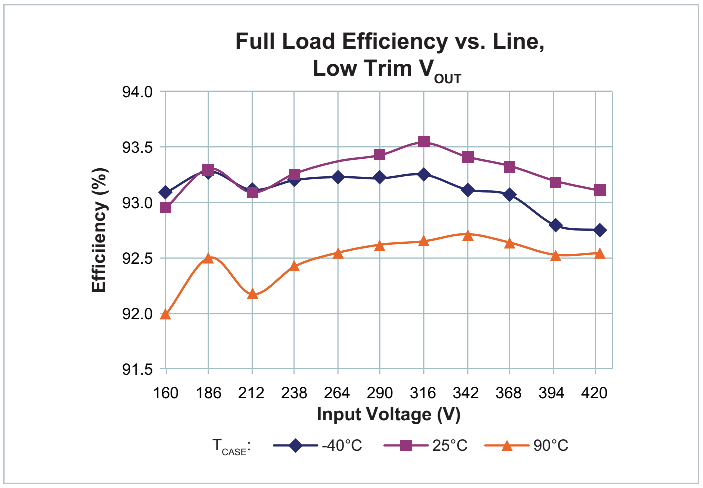


Figure 7 — *Full Load Efficiency vs. V_{IN}, V_{OUT} = 11.5 V*

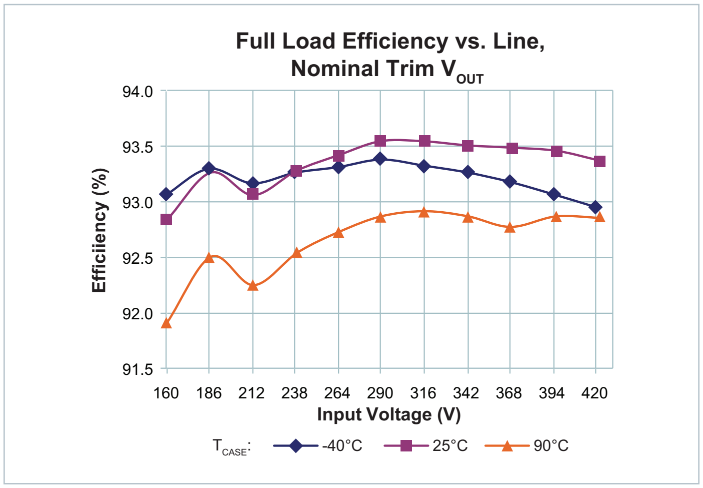


Figure 8 — *Full Load Efficiency vs. V_{IN}, V_{OUT} = 13.8 V*

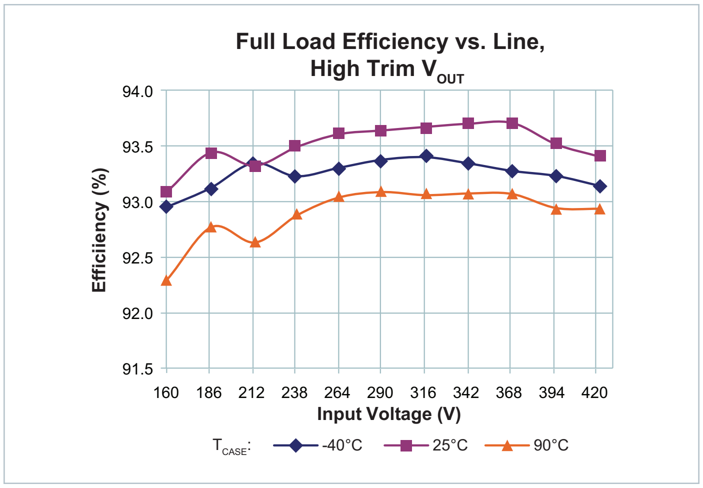


Figure 9 — *Full Load Efficiency vs. V_{IN}, V_{OUT} = 15.5 V*

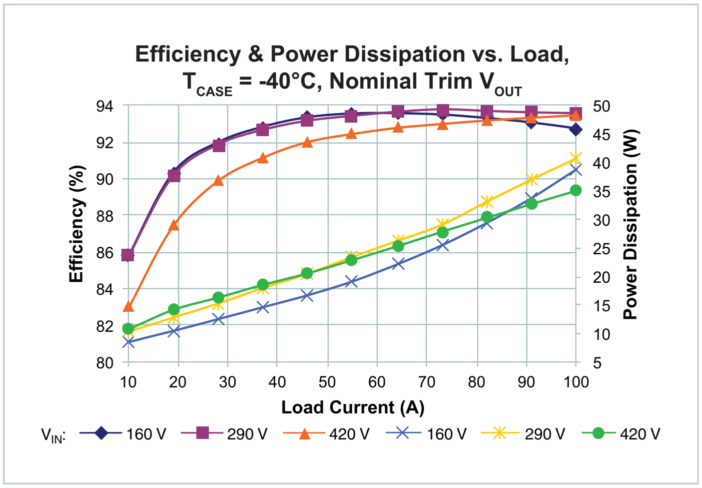


Figure 10 — *V_{IN} to V_{OUT} efficiency and power dissipation vs. V_{IN} to I_{OUT}, T_{CASE} = -40°C*

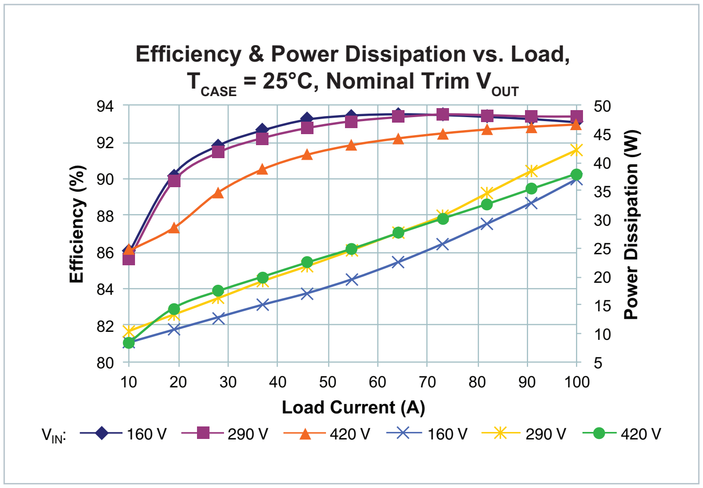


Figure 11 — *V_{IN} to V_{OUT} efficiency and power dissipation vs. V_{IN} to I_{OUT}, T_{CASE} = 25°C*

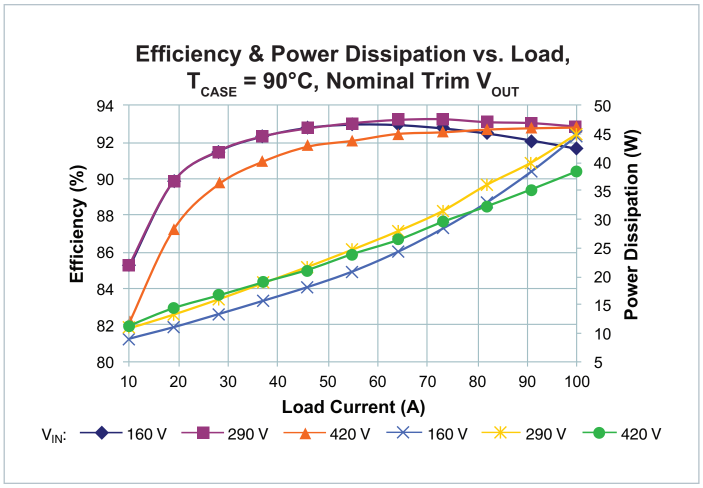


Figure 12 — *V_{IN} to V_{OUT} efficiency and power dissipation vs. V_{IN} to I_{OUT}, T_{CASE} = 90°C*

Typical Performance Characteristics (cont.)

The following figures present typical performance at T_C = 25°C, unless otherwise noted. See associated figures for general trend data.

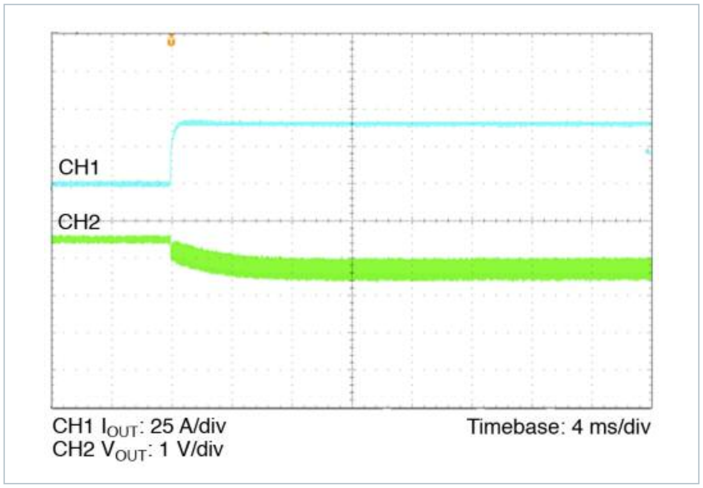


Figure 13 — *10% to 100% load transient response, V_{IN} = 290 V, nominal trim, C_{OUT_EXT} = 1000 µF*

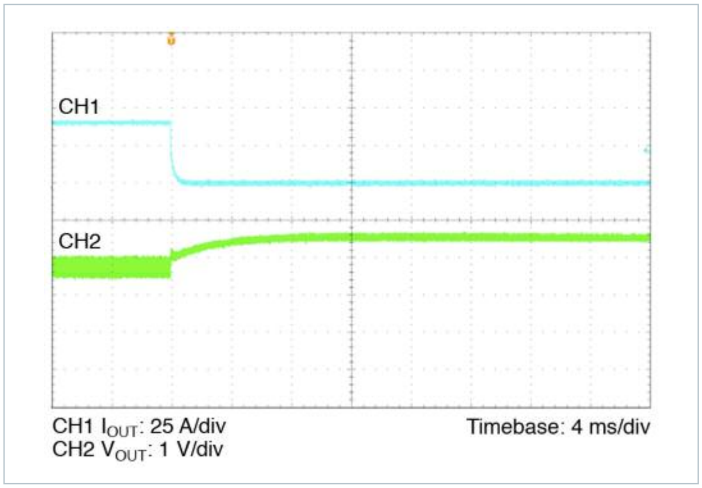


Figure 16 — *100% to 10% load transient response, V_{IN} = 290 V, nominal trim, C_{OUT_EXT} = 1000 µF*

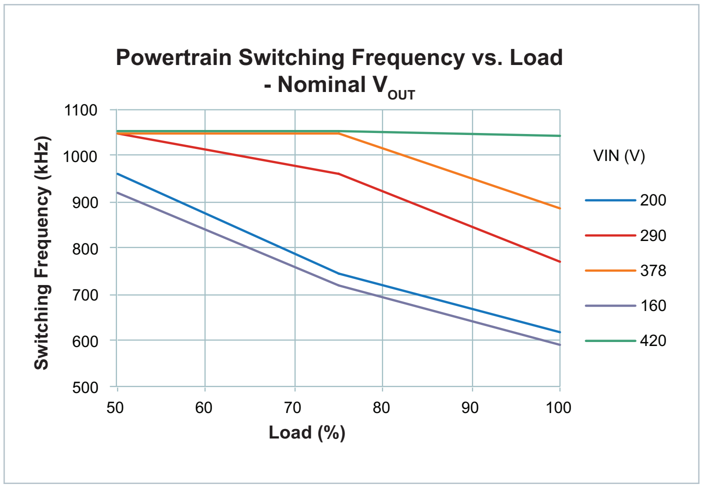


Figure 14 — *Powertrain switching frequency vs. load, at nominal trim*

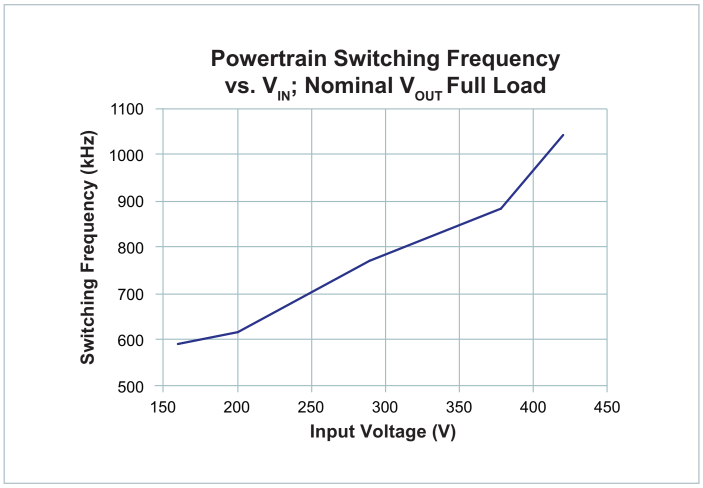


Figure 17 — *Powertrain switching frequency vs. V_{IN}, at nominal trim, full load*

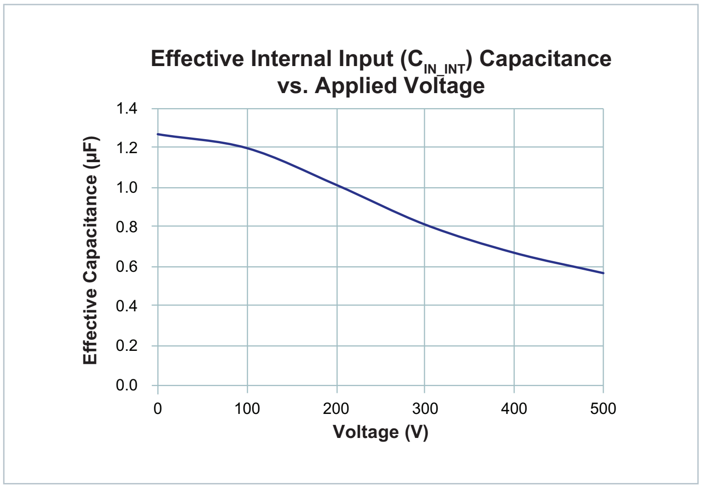


Figure 15 — *Effective internal input capacitance vs. applied voltage*

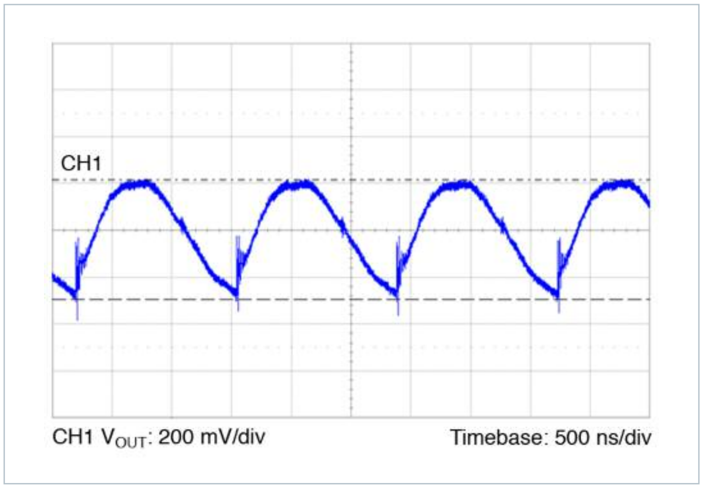


Figure 18 — *Typical output voltage ripple, V_{IN} = 290 V, V_{OUT} = 13.8 V, C_{OUT_EXT} = 1000 µF, R_{LOAD} = 0.317 Ω*

General Characteristics

Specifications apply over all line, trim and load conditions, internal temperature T_{INT} = 25°C, unless otherwise noted. **Boldface** specifications apply over the temperature range of -40°C < T_{INT} < 125°C.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Mechanical						
Length	L		47.33/ [1.863]	47.71/ [1.878]	48.09/ [1.893]	mm/[in]
Width	W		22.67/ [0.893]	22.8/ [0.898]	22.93/ [0.903]	mm/[in]
Height	H		7.21/ [0.284]	7.26/ [0.286]	7.31/ [0.288]	mm/[in]
Volume	Vol	No heat sink		7.90/ [0.48]		cm^3/$[in^3]$
Weight	W			29.2 / [1.03]		g/[oz]
Lead finish		Nickel	0.51		2.03	µm
		Palladium	0.02		0.15	
		Gold	0.003		0.05	
Thermal						
Operating internal temperature	T_{INT}		-40		125	°C
Thermal resistance top side	$\Phi_{INT\text{-}TOP}$	Estimated thermal resistance to maximum temperature internal component from isothermal top		1.80		°C/W
Thermal resistance leads	$\Phi_{INT\text{-}LEADS}$	Estimated thermal resistance to maximum temperature internal component from isothermal leads		5.54		°C/W
Thermal resistance bottom side	$\Phi_{INT\text{-}BOTTOM}$	Estimated thermal resistance to maximum temperature internal component from isothermal bottom		1.58		°C/W
Thermal capacity				TBD		Ws/°C
Assembly						
Peak Compressive Force Applied to Case (Z-axis)		Supported by leads only			6	lbs
					5.4	lbs /in^2
Storage temperature	T_{ST}		-40		125	°C
ESD rating	HSM	Method per Human Body Model Test ESDA/JEDEC JDS-001-2012	CLASS 1C			V
	CDM	Charged Device Model JESD22-C101E	CLASS 2			
Soldering						
Peak temperature top case					135	s
Peak temperature gradient (Top CASE - Lead)		Temp Gradient is measured at the time the lead is in solder and reaches its maximum temp of 257°C			141	°C/s
Peak temperature gradient (Top CASE - Lead) interconnect		Temp Gradient is measured at the moment that the lead top (interconnect) reaches its maximum temp of 199°C. At that time, temp of top of the ChiP is 117°C			82	°C/s

General Characteristics (Cont.)

Specifications apply over all line, trim and load conditions, internal temperature T_{INT} = 25°C, unless otherwise noted. **Boldface** specifications apply over the temperature range of -40°C < T_{INT} < 125°C.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Reliability and General Agency Approvals						
Isolation voltage (hipot)	V_{HIPOT}		4,242			V_{DC}
MTBF		MIL-HDBK-217 Plus Parts Count - 25°C Ground Benign, Stationary, Indoors / Computer		3.53		MHrs
		Telcordia Issue 2 - Method I Case 3; 25°C Ground Benigh, Controlled		3.90		MHrs
Agency approvals/standards		$_{C}UR_{US}$, $_{C}TUV_{US}$, 60950-1				
		CE Marked for Low Voltage Directive and RoHS Recast Directive, as applicable.				

Pin Functions

+IN, -IN

Input power pins. -IN is the reference for all control pins, and therefore a Kelvin connection is recommended to reduce effects of voltage drop due to -IN currents.

+OUT, -OUT

Output power pins.

EN (Enable)

This pin enables and disables the DCM converter; when held low the unit will be disabled. It is referenced to the -IN pin of the converter. The EN pin has an internal pull-up to V_{CC} through a 10 kΩ resistor.

- Output enable: When EN is allowed to pull up above the enable threshold, the module will be enabled. If leaving EN floating, it is pulled up to V_{CC} and the module will be enabled.
- Output disable: EN may be pulled down externally in order to disable the module.

TR (Trim)

The TR pin is used to select the trim mode and to trim the output voltage of the DCM converter. The TR pin has an internal pull-up to V_{CC} through a 10 kΩ resistor.

The DCM will latch trim behavior at application of V_{IN}, and persist in that same behavior until loss of input voltage.

- At application of V_{IN}, if TR is sampled at above $V_{TRIM\text{-}DIS}$, the module will latch in a non-trim mode, and will ignore the TR input for as long as V_{IN} is present.
- At application of V_{IN}, if TR is sampled at below $V_{TRIM\text{-}EN}$, the TR will serve as an input to control real time output voltage trim. It will persist in this behavior until V_{IN} is no longer present.

If trim is active, the TR pin provides dynamic trim control at a typical 30 Hz of -3dB bandwidth over the output voltage. V_{OUT} set point under full load and room temperature can be calculated using the equation below:

$$V_{OUT} = 10.00 + (6.48 \bullet V_{TR}/V_{CC})$$

FT (Fault)

The FT pin provides a Fault signal.

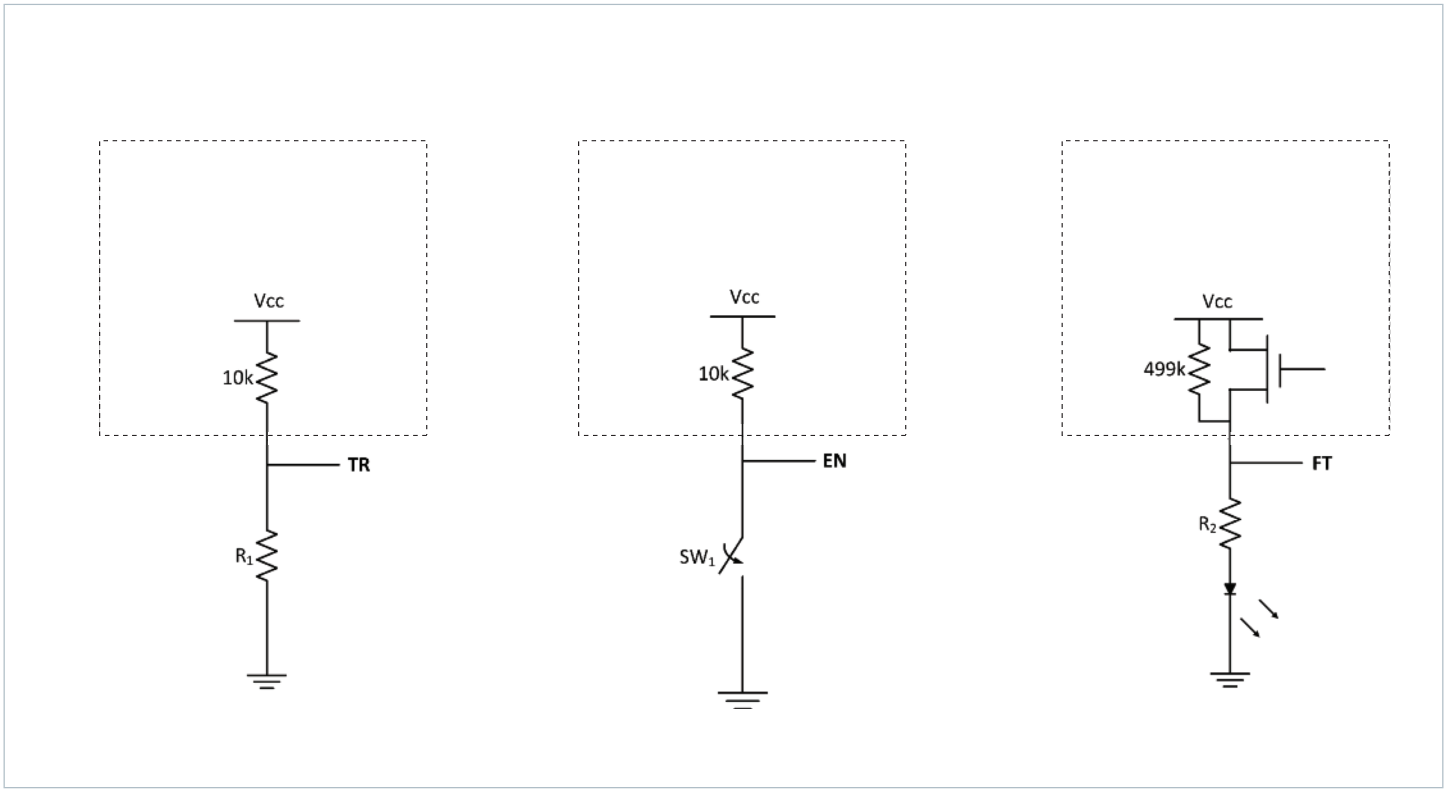
Anytime the module is enabled and has not recognized a fault, the FT pin is inactive.

Whenever the powertrain stops (due to a fault protection or disabling the module by pulling EN low), the FT pin becomes active and provides current to drive an external circuit.

The FT pin becomes active momentarily when the module starts up.

When active, FT pin drives to V_{CC}, with up to 5 mA of external loading. Module may be damaged from an over-current FT drive, thus a resistor in series for current limiting is recommended.

Typical External Circuits for Signal Pins (TR, EN, FT)



Design Guidelines

Building Blocks and System Design

The DCM converter input accepts the full 160 to 420 V range, and its isolation permits generation of a common 13.8 Vdc output bus voltage from a multitude of DCMs operating off of different positive input voltages.

The DCM converter provides a regulated output voltage around defined nominal load line and temperature coefficients. The load line and temperature coefficients enable configuration of an array of DCM converters which share the output load with no wires or communication bus between modules. Downstream (constant power) regulators may be used to provide tighter voltage regulation, if required.

The DCM290P138T600A40 may be used in standalone applications where the output power requirements are up to 600 W. However, it is easily deployed as arrays of modules to increase power handling capacity. Arrays of up to eight units have been qualified for 4800 W capacity. Application of DCM converters in an array requires no derating of the maximum available power versus what is specified for a single module.

Soft Start

When the DCM starts after application of input votlage, it will go through a soft start sequence. **Notice the module will only startup if input voltage is inside the range of $V_{IN\text{-}FULL\text{-}POWER}$.** After startup, Module can then operate in the entire V_{IN} range.

This soft start sequence permits initial startup into a completely discharged load capacitance. The soft start sequence ramps the output voltage by modulating the internal error amplifier reference. This causes the output voltage to approximate a piecewise linear ramp. The output ramp finishes when the voltage reaches either the nominal output voltage, or the trimmed output voltage in cases where trim mode is active.

A DCM recovering from any fault condition or disabled through EN does not assume that the output capacitance has remained charged. Just as with its initial startup sequence when V_{IN} is first applied, it will again execute the soft start ramp.

Trim Mode and Output Trim Control

When the input voltage is initially applied to a DCM, and after T_{INIT} elapses, the trim pin voltage V_{TR} is sampled. The TR pin has an internal pull up resistor to V_{CC}, so unless external circuitry pulls the pin voltage lower, it will float up to V_{CC}. If the sampled trim pin voltage is higher than $V_{TRIM\text{-}DIS}$, then the DCM will disable trimming as long as the V_{IN} remains applied. In this case, for all subsequent operation the output voltage will be programmed to the nominal. This affords applications that only need the nominal V_{OUT} and maximum output voltage accuracy, as there are no additional error tolerances from on board trim components.

If at initial application of V_{IN}, the TR pin voltage is lower than $V_{TRIM\text{-}EN}$, then the DCM will activate trim mode, and it will remain in this mode for as long as V_{IN} is applied.

V_{OUT} set point under full load and room temperature can be calculated using the equation below:

$$V_{OUT} = 10.00 + (6.48 \bullet V_{TR}/V_{CC}) \qquad (1)$$

Note that while the soft-start routine described above does re-arm after the unit self-protects from a fault condition, the trim mode is not changed when a DCM recovers from any fault condition or being disabled.

If V_{TR} is driven above the point where the trimmed Vout reaches the maximum trimmed Vout range, then the V_{OUT} will hold at the maximum of the trim range, and not wrap around or return to nominal V_{OUT}.

Module performance is guaranteed through output voltage trim range $V_{OUT\text{-}TRIMRNG}$. Trim V_{OUT} higher than output voltage trim range $V_{OUT\text{-}TRIMRNG}$ could possibly cause output OVP.

Nominal Output Voltage Load Line

Throughout this document, programmed output voltage, either the specified nominal output voltage if trim is inactive, or the trimmed output voltage if trim is active, is specified at full load, and at room temperature. The actual output voltage of the DCM is given by the programmed output voltage, with modification based on load and temperature. The nominal output voltage is 13.8 V, and the actual output voltage will match this at full load and room temperature.

The largest modification in actual output voltage compared to the programmed output is due to the 0.73 V nominal load line (5.26% relative to full load V_{OUT}). As the load is reduced, the internal error amplifier reference, and by extension the output, rises in response. This load line is the primary enabler of the wireless current sharing amongst an array of DCMs.

When load is from 0% to 5% load, there is an additional ΔV added to the output voltage, which is related to Burst Mode, which is to be introduced later.

For a given programmed output voltage, the actual output voltage versus load current at for nominal trim, nominal line, and room temperature is given by the following equation:

$$V_{OUT} = 13.8 + 0.73 + \Delta V - 0.73 \bullet I_{OUT} / 43.5 \qquad (2)$$

ΔV can be up to 2.3 V, when load is from 0% to 5% load.

Use 0 V for ΔV when load is from 5% to 100% load.

The load line impact on the output voltage is absolute, and is not scaled by the trim voltage.

Nominal Output Voltage Temperature Coefficient

There is an additional additive term in the actual output voltage relative to that programmed, which is based on the temperature of the module. This term permits improved thermal balancing among modules in an array, especially when the factory nominal trim point is utilized (time mode inactive). This term is much smaller than the load line described above, representing only a 0.138 V change every 75°C over the entire rated temperature range. Regulation coefficient is relative to 25°C T_{INT} (effective internal temperature).

For nominal trim, nominal line, and full load, the output voltage relates to the temperature according to the following equation:

$$V_{OUT} = 13.8 - 0.138 \bullet (T_{INT} - 25)/75 \qquad (3)$$

where T_{INT} is in °C.

The impact of temperature coefficient on the output voltage is absolute, and does not scale by trim or load.

Overall Output Voltage Transfer Function

Taking trim (equation 1), load line (equation 2) and temperature coefficient (equation 3) into account, the general equation relating the DC V_{OUT} at nominal line to programmed trim (when active), load, and temperature is given by:

$$V_{OUT} = 10.00 + (6.48 \bullet Vtr/Vcc) + 0.73 + \Delta V - 0.73 \bullet I_{OUT}/43.5 - 0.138 \bullet (T_{INT} - 25)/75 \qquad (4)$$

Output Current Limit

The DCM features a fully operational current limit which effectively keeps the module operating inside the Safe Operating Area (SOA) for all valid trim and load profiles. The current limit approximates a "brick wall" limit, where the output current is prevented from exceeding the current limit threshold by reducing the output voltage via the internal error amplifier reference. Output Overload protection threshold is typically 105% of maximum output current, and can vary from 100% to 117% of maximum output current.

When the output current exceeds the current limit threshold, current limit action is postponed by 1ms, which permits the DCM to momentarily deliver higher peak output currents to the load. Peak output power during this time is still constrained by the internal Power Limit of the module. The fast Power Limit and relatively slow Current Limit work together to keep the module inside the SOA. Delaying entry into current limit also permits the DCM to minimize droop voltage for load steps.

Sustained operation in current limit is permitted, and no derating of output power is required in an array.

Some applications may benefit from well matched current distribution, in which case fine tuning sharing via the trim pins permits control over sharing. The DCM does not require this for proper operation, due to the power limit and current limit behaviors described here.

Current limit can reduce the output voltage to as little as the UVP threshold ($V_{OUT-UVP}$). Below this minimum output voltage compliance level, further loading will cause the module to shut down due to the output undervoltage fault protection.

Line Impedance and Output Stability Requirements

Connect a high-quality, low-noise power supply to the +IN and –IN terminals. The interconnect cables can be up to 1 m long each way, and up to 0.1 m apart between each other. Additional capacitance may have to be added between +IN and –IN to make up for impedances in the interconnect cables as well as deficiencies in the source.

Significant source impedance can bring system stability issue for a regulated DC-DC converter and needs to be avoided or compensated. Additional information can be found in the filter design application note:
www.vicorpower.com/documents/application_notes/vichip_appnote23.pdf

If that input cables has to be longer or more separated between each other than recommended, please refer to this input filter design tool to ensure input stability:
http://app2.vicorpower.com/filterDesign/intiFilter.do.

Also make sure input voltage slew rate dVin/dt is less than 1 V/us, otherwise a pre-charge circuit is required in the input side to control the charging slew rate.

For the DCM, output voltage stability is guaranteed as long as hold up capacitance $C_{OUT-EXE}$ falls within the specified ranges.

Input Fuse Selection

DCM is not internally fused in order to provide flexibility in configuring power systems. Input line fusing is recommended at system level, in order to provide thermal protection in case of catastrophic failure. The fuse shall be selected by closely matching system requirements with the following characteristics:

- Current rating (usually greater than the DCM converter's maximum current)
- Maximum voltage rating (usually greater than the maximum possible input voltage)
- Ambient temperature
- Breaking capacity per application requirements
- Nominal melting I^2t

Fault Handling

Input Undervoltage Fault Protection (UVLO)

The converter's input voltage is monitored to detect an input under voltage condition. If the converter is not already running, then it will ignore enable commands until the input voltage is greater than $V_{IN-UVLO+}$. If the converter is running and the input voltage falls below $V_{IN-UVLO-}$, the converter recognizes a fault condition, the powetrain stops switching, and the output voltage of the unit falls.

UVLO faults which are shorter than t_{UVLO} may not be detected by the fault sequence logic, in which case the converter may not respond.

After a UVLO fault is detected by the fault sequence logic and the converter shuts down as a result, it will wait for the input voltage to rise above $V_{IN-UVLO+}$. Provided the converter is still enabled, the powertrain will again enter the soft start sequence.

Input Overvoltage Fault Protection (OVLO)

The converter's input voltage is monitored to detect an input over voltage condition. When the input voltage is more than the $V_{IN-OVLO+}$, a fault is detected, the powetrain immediately stops switching, and the output voltage of the converter falls.

After an OVLO fault occurs, the converter will wait for the input voltage to fall below $V_{IN-OVLO-}$. Provided the converter is still enabled, the powertrain will again enter the soft start sequence.

The powertrain controller itself also monitors the input voltage. Transient OVLO events which have not yet been detected by the fault sequence logic may first be detected by the controller, if the input slew rate is sufficiently large. In this case, powertrain switching will immediately stop. If the input voltage falls back in range before the fault sequence logic detects the out of range condition, the powertrain will resume switching and the fault logic will not interrupt operation Regardless of whether the powertrain is running at the time or not, if the input voltage does not recover from OVLO before t_{OVLO}, the converter fault logic will detect the fault.

Output Undervoltage Fault Protection (UVP)

The converter determines that an output overload or short circuit condition exists by measuring its primary sensed output voltage. In general, whenever the powertrain is switching and the primary-sensed output voltage falls below $V_{OUT-UVP}$ threshold, a short circuit fault will be registered. Once an output undervoltage condition is detected, the powertrain immediately stops switching, and the output voltage of the converter falls. The converter remains disabled for a time t_{FAULT}. Once recovered and provided the converter is still enabled, the powertrain will again enter the soft start sequence after t_{INIT} and t_{ON}.

Temperature Fault Protections (OTP)

The fault logic monitors the internal temperature of the converter. If the measured temperature goes higher than $T_{INT-OTP}$, a temperature fault is registered. As with the under voltage fault protection, once a temperature fault is registered, the powertrain immediately stops switching, the output voltage of the converter falls, and the converter remains disabled for a time t_{FAULT}. Then, the converter waits for the internal temperature to return to below $T_{INT-OTP}$ before recovering. Once recovered, provided the converter is still enabled, the DCM will again enter the soft start sequence after t_{INIT} and t_{ON}.

Output Overvoltage Fault Protection (OVP)

The converter monitors the primary sensed output voltage during switching to detect output OVP. If the primary sensed output voltage exceeds $V_{OUT-OVP}$, a fault is latched, the logic disables the powertrain, and the output voltage of the converter falls.

This type of fault is latched, and the converter will not operate until the latch is cleared. Clearing the fault latch is achieved by either disabling the converter via the EN pin, or else by removing the input power such that the input voltage goes down.

External Output Capacitance

The DCM converter requires an external capacitor on the output for proper operation and for good transient load regulation. An external capacitor of 1000 uF to 10,000 uF per DCM is required.

Burst Mode

Under light loading conditions, the DCM converter may operate in burst mode depending on the line voltage. Burst mode occurs whenever the internal power consumption of the converter combined with the external output load is less than is provided by the minimum power transfer per switching cycle. To prevent the output voltage from rising in this case, the powertrain is switched off and on repeatedly, to effectively lower the average switching frequency, and permit operation with no external load. During the time when the power train is off, the module internal consumption is significantly reduced, and so there is a notable reduction in no-load input power in burst mode.

Thermal Design

Based on the safe thermal operating area shown in page 5, the full rated power of the DCM290P138T600A40 can be processed provided that the top, bottom, and leads are all held below 80°C. This has included the extra margin that module may operate inside the current limit and provide more power than the rated 600 W. These curves highlight the benefits of dual sided thermal management, but also demonstrate the flexibility of the Vicor ChiP platform for customers who are limited to cooling only the top or the bottom surface.

Due to the OTP sensor is placed in the top side, in order to have an effective over temperature protection, keep case bottom temperature no more than case top temperature.

The ChiP package provides a high degree of flexibility in that it presents three pathways to remove heat from internal power dissipating components. Heat may be removed from the top surface, the bottom surface and the leads. The extent to which these three surfaces are cooled is a key component for determining the maximum power that is available from a ChiP, as can be seen from Figure 19.

Since the ChiP has a maximum internal temperature rating, it is necessary to estimate this internal temperature based on a real thermal solution. Given that there are three pathways to remove heat from the ChiP, 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 a VI Chip® DCM module 4623 in an application where the top, bottom, and leads are cooled. In this case, the DCM power dissipation is PD_{TOTAL} and the three surface temperatures are represented as T_{CASE_TOP}, T_{CASE_BOTTOM}, and T_{LEADS}. This thermal system can now be very easily analyzed using a SPICE simulator with simple resistors, voltage sources, and a current source.

The results of the simulation would provide an estimate of heat flow through the various pathways as well as internal temperature.

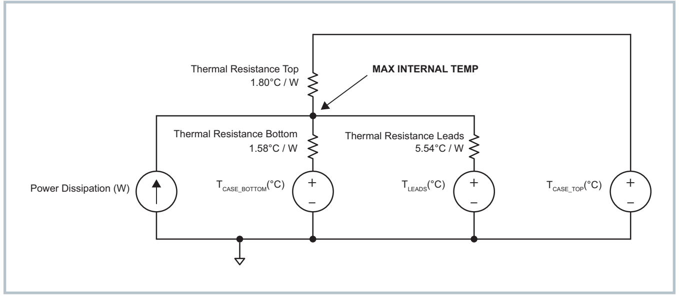


***Figure 19** — Double side cooling and leads thermal model*

Alternatively, equations can be written around this circuit and analyzed algebraically:

$$T_{INT} - PD_1 \bullet 1.80 = T_{CASE\_TOP}$$
$$T_{INT} - PD_2 \bullet 1.58 = T_{CASE\_BOTTOM}$$
$$T_{INT} - PD_3 \bullet 5.54 = T_{LEADS}$$
$$PD_{TOTAL} = PD_1 + PD_2 + PD_3$$

Where T_{INT} represents the internal temperature and PD_1, PD_2, and PD_3 represent the heat flow through the top side, bottom side, and leads respectively.

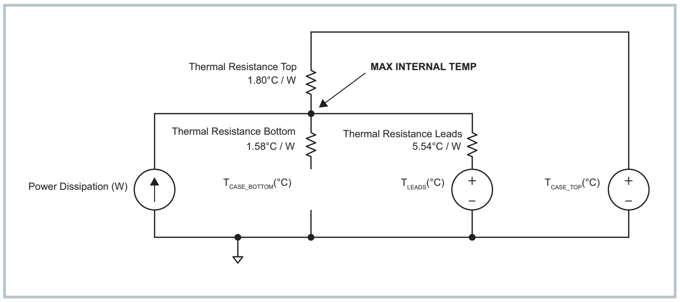


***Figure 20** — One side cooling and leads thermal model*

Figure 20 shows a scenario where there is no bottom side cooling. In this case, the heat flow path to the bottom is left open and the equations now simplify to:

$$T_{INT} – PD_1 • 1.80 = T_{CASE\_TOP}$$
$$T_{INT} – PD_3 • 5.54 = T_{LEADS}$$
$$PD_{TOTAL} = PD_1 + PD_3$$

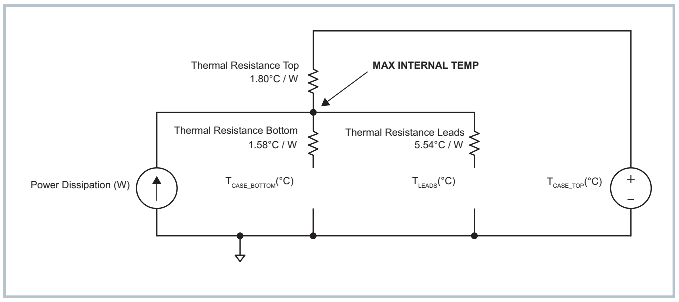


***Figure 21** — One side cooling thermal model*

Figure 21 shows a scenario where there is no bottom side and leads cooling. In this case, the heat flow path to the bottom is left open and the equations now simplify to:

$$T_{INT} – PD_1 • 1.80 = T_{CASE\_TOP}$$
$$PD_{TOTAL} = PD_1$$

Please note that Vicor has a suite of online tools, including a simulator and thermal estimator which greatly simplify the task of determining whether or not a DCM thermal configuration is valid for a given condition. These tools can be found at: www.vicorpower.com/powerbench.

Array Operation

A decoupling network is needed to facilitate paralleling:

- An output inductor needs to be added before the output of the DCMs connecting together, this is to decouple the output of DCMs;
- An individual input filter needs to be added before the input of the DCMs connecting together, this is to limit ripple current from each DCM and also limit the beat frequency input current ripple as they connects together.

If signal pins (TR, EN, FT) are not used, they can be left floating, and DCM will work in the nominal output condition.

When common mode noise in the input side is not a concern, TR and EN can be driven and FT received using the –IN as a reference.

An example of DCM paralleling circuit is shown below:

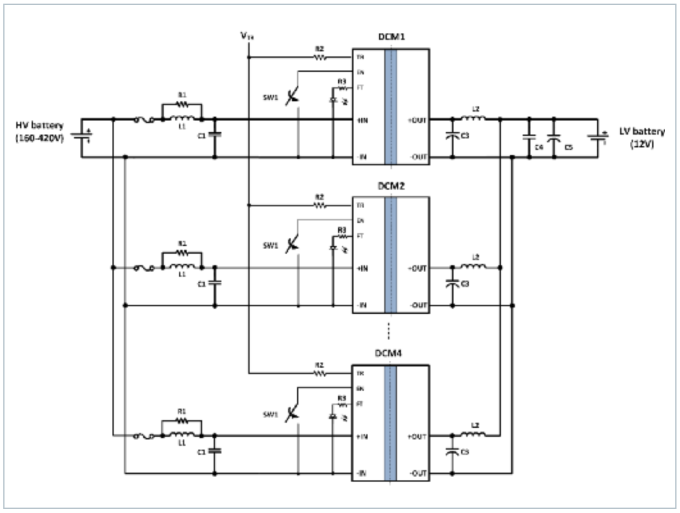


***Figure 22** — DCM paralleling configuration circuit 1*

Recommended values to start with:
L1: L1 = 1 uH, minimized DCR;
R1: 1 Ohm;
C1: Ceramic capacitors in parallel, C1 = 2 uF;
L2: L2 ≥ 0.15 uH;
C3: electrolytic or tantalum capacitor, 1000 uF ≤ C3 ≤10000 uF;
C4, C5: additional ceramic /electrolytic capacitors, if needed for output ripple filtering;
R3: current limit resistor for fault pin, a resistor of at least 1 k is recommended;

In order to help sensitive signal circuits immunized from potential noise interruption, additional components are recommended:
R2: 301 Ohm, facilitate noise attenuation for TR pin;
FB1, C2: FB1 is a ferrite bead with an impedance of at least 10Ohm at 100MHz. **C2** can be a ceramic capacitor of 0.1uF. Facilitate noise attenuation for EN pin.

When common mode noise rejection in the input side is needed, common modes choke can be added in the input side of each DCM. An example of DCM paralleling circuit is shown below:

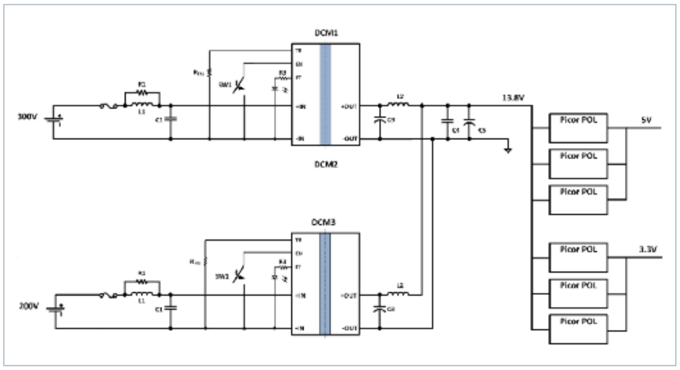
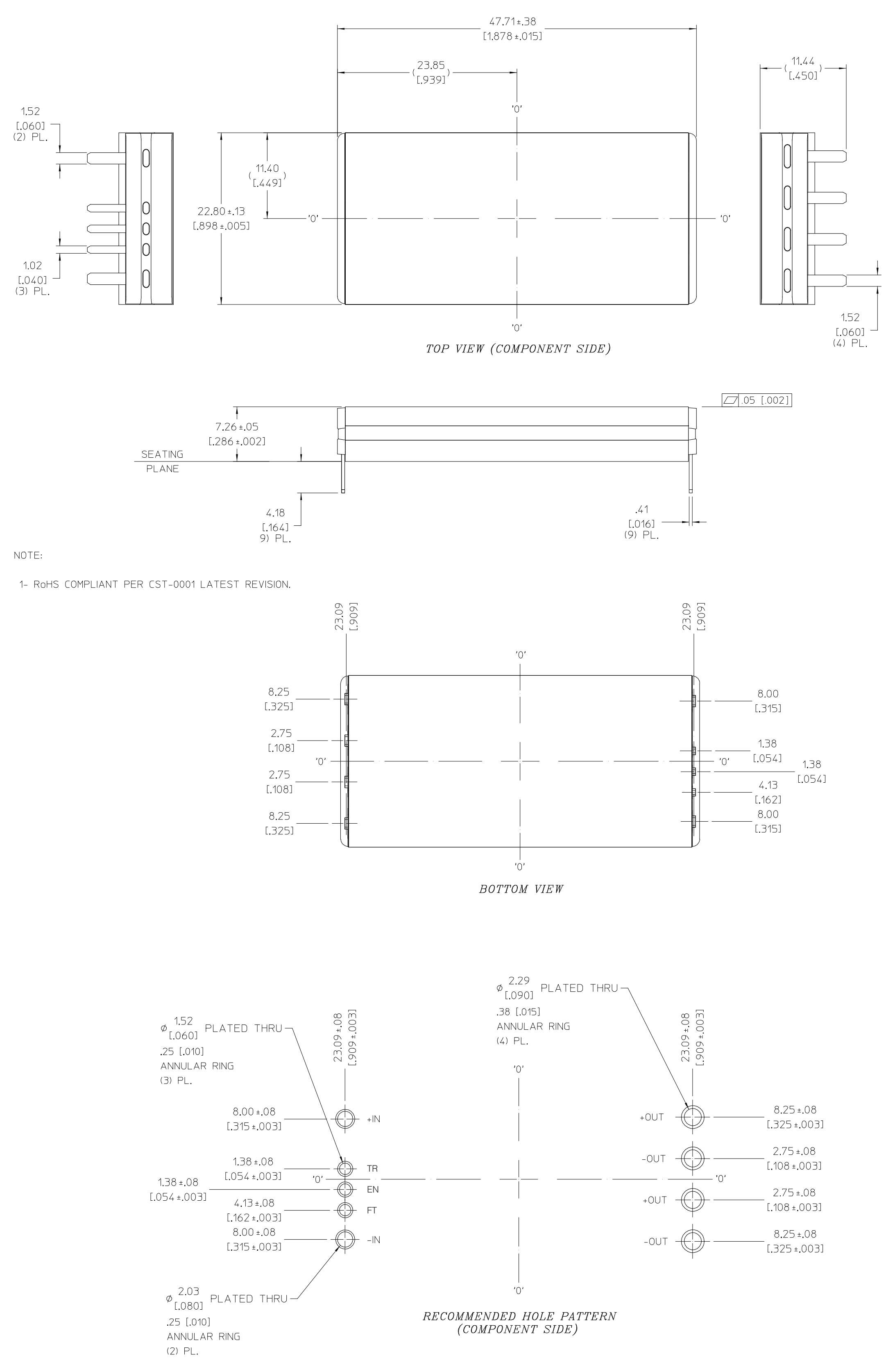


***Figure 23** — DCM paralleling configuration circuit 2*

Notice that each group of control pins need to be individually driven and isolated from the other groups control pins . If they share the same ground, the common mode chokes will malfunction and cause problems to the circuit.

DCM Module Product Outline Drawing Recommended PCB Footprint and Pinout



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Vicor will repair or replace defective products in accordance with its own best judgment. For service under this warranty, the buyer must contact Vicor to obtain a Return Material Authorization (RMA) number and shipping instructions. Products returned without prior authorization will be returned to the buyer. The buyer will pay all charges incurred in returning the product to the factory. Vicor will pay all reshipment charges if the product was defective within the terms of this warranty.

Life Support Policy

VICOR'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF VICOR CORPORATION. As used herein, life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness. Per Vicor Terms and Conditions of Sale, the user of Vicor products and components in life support applications assumes all risks of such use and indemnifies Vicor against all liability and damages.

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