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MIL-COTS PRM™ Regulator

for MIL-STD 704E/F Applications

MPRM48NH480M250A00

High Efficiency Converter

Features

- Optimized for operation with MIL-COTS BCM® in 270 VDC Applications
- MIL-STD-704E/F compliant when used with MBCM270x450M270A00
- 48.0 V nominal input non-isolated ZVS buck-boost regulator
- Input Transient operation between 30.0 V and 60.0 V
- 20.0 V to 55.0 V adjustable output range
- 250 W output power in 0.57 in^2 footprint
- 96.7% typical efficiency, at full load
- 1676 W/in^3 (102 W/cm^3) Power Density
- 5.29 MHrs MTBF (MIL-HDBK-217 Plus Parts Count)
- Pin selectable operating mode
  - Adaptive Loop
  - Remote Sense / Slave
- Half VI Chip® Package
  - 22.0mm x 16.5mm x 6.73mm

Typical Applications

- High Voltage 270 V Aircraft Distributed Power
- High Density Power Supplies
- Communication Systems

Product Ratings	
V_{IN} = 38.0 V to 55.0 V (30.0 V to 60.0 V for up to 150 ms)	P_{OUT} = 250 W
V_{OUT} = 48.0 V (20.0 V to 55.0 V Trim)	I_{OUT} = 5.21 A

Product Description

The VI Chip® PRM™ Regulator is a high efficiency converter, operating from a 38.0 to 55.0 Vdc input to generate a regulated 20.0 to 55.0 Vdc output. The ZVS buck-boost topology enables high switching frequency (~1.03 MHz) operation with high conversion efficiency. High switching frequency reduces the size of reactive components enabling power density up to 1676 W/in^3.

The Half VI Chip package is compatible with standard pick-and-place and surface mount assembly processes with a planar thermal interface area and superior thermal conductivity.

The MPRM48NH480M250A00 is optimized for operation with MIL-COTs BCMs in MIL-STD-704 E/F 270 VDC systems. In a 270 VDC system, the upstream BCM provides an interface and isolation between the high voltage DC bus and the PRM, converting the input down by a fixed ratio.

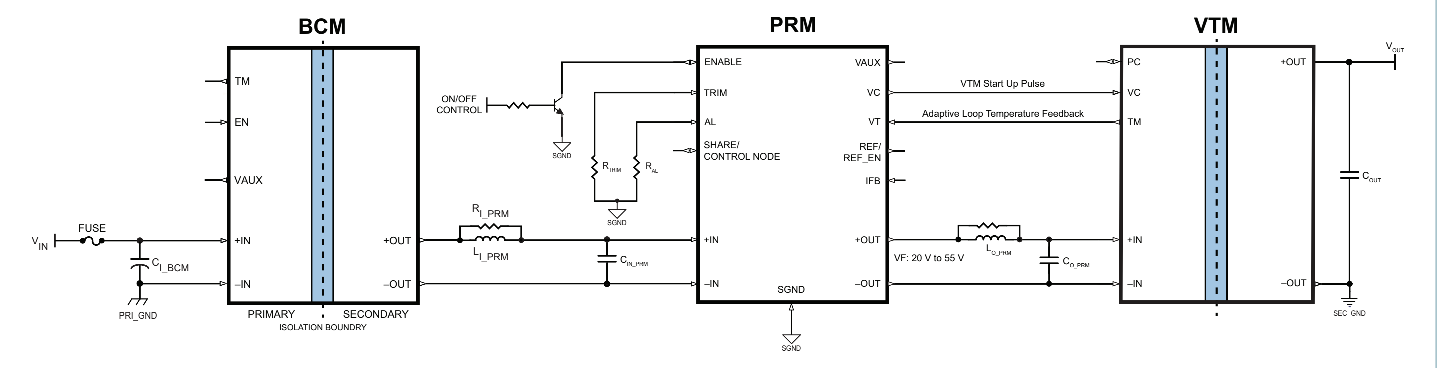
The downstream PRM and VTM™ current multiplier minimize distribution and conversion losses in a high power solution, providing an isolated, regulated output voltage.

The MPRM48NH480M250A00 has two selectable modes of regulation depending on the application requirements.

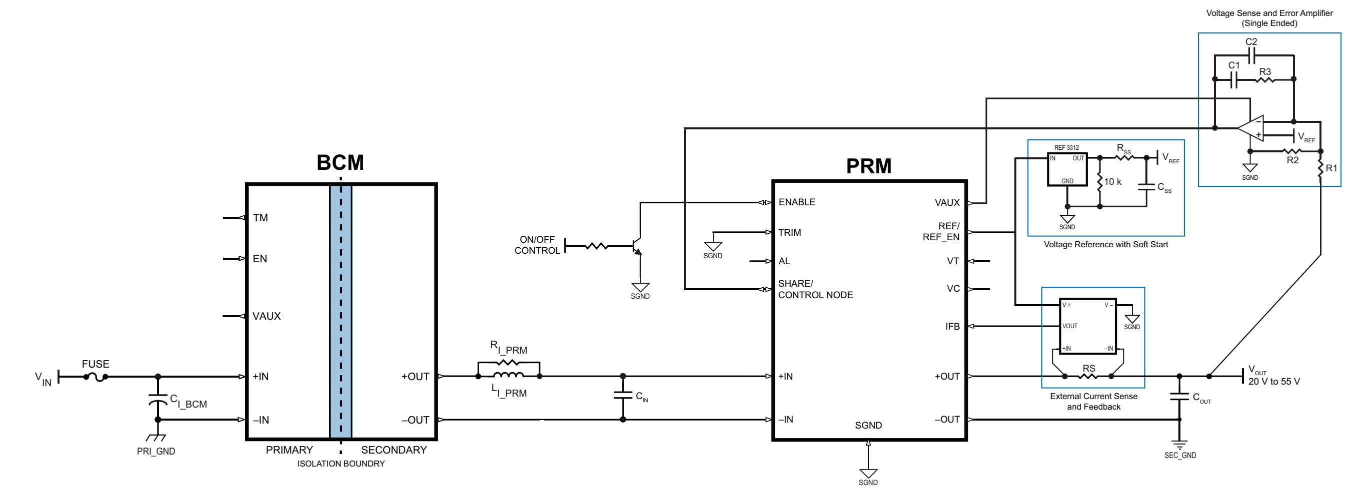
In Adaptive Loop Operation, the MPRM48NH480M250A00 utilizes a unique feed-forward scheme that enables precise regulation of an isolated POL voltage without the need for remote sensing and voltage feedback.

In Remote Sense Operation, the internal regulation circuitry is disabled, and an external control loop and current sensor maintain regulation. This affords flexibility in the design of both voltage and current compensation loops to optimize performance in the end application.

Typical Applications

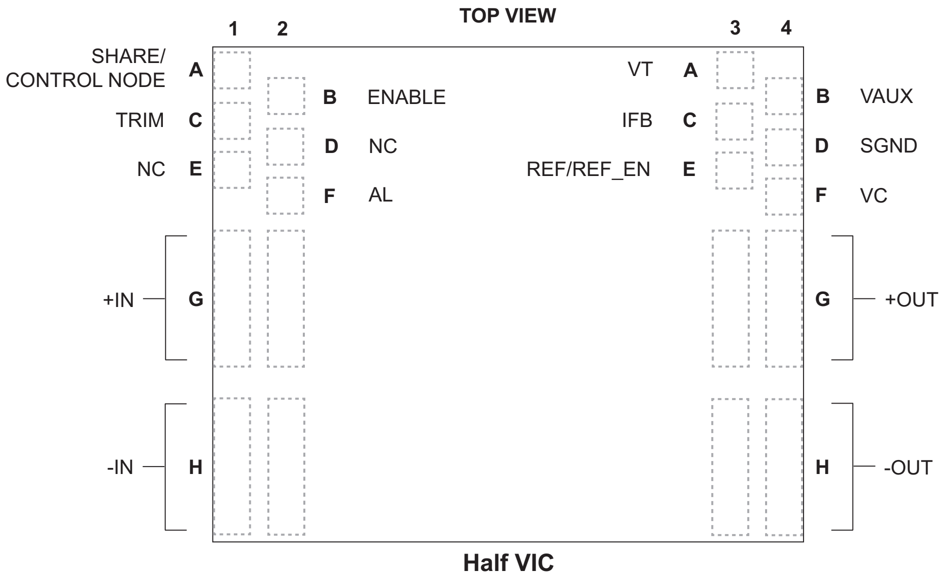


Typical Application: MBCM270**x**450M270A00 + MPRM48NH480M250A00 + VTM Adaptive loop Configuration



Typical Application: MBCM270**x**450M270A00 + MPRM48NH480M250A00 Remote Sense Configuration

Pin Configuration



Pin Descriptions

Pin Number	Signal Name	Type	Function
A1	SHARE (Adaptive Loop / Slave Operation)	BIDIR	Parallel sharing control bus for master-slave configuration.
	CONTROL NODE (Remote Sense Operation)	INPUT	Modulator control node input. Driven by external error amplifier in Remote Sense Operation.
A3	VT (Adaptive Loop Operation)	INPUT	VTM TM input for temperature compensation. Leave disconnected for Remote Sense Operation.
B2	ENABLE	BIDIR	Enables power supply when allowed to float high. 5 V during normal operation.
B4	VAUX	OUTPUT	9 V auxiliary bias voltage.
C1	TRIM	INPUT	Selects operating mode. Adjusts output voltage in Adaptive Loop Operation.
C3	IFB (Remote Sense Operation)	INPUT	Current sense input for current limit and overcurrent protection in Remote Sense Operation. Leave disconnected for Adaptive Loop Operation.
D2	NC	n/a	Do not connect this pin.
D4	SGND	INPUT	Signal ground, reference for analog controls. Kelvin connected internally to –IN and –OUT.
E1	NC	n/a	Do not connect this pin.
E3	REF (Adaptive Loop Operation)	OUTPUT	Reference voltage for internal error amplifier in Adaptive Loop Operation.
	REF_EN (Remote Sense Operation)	OUTPUT	Powers and enables external control circuit voltage reference in Remote Sense Operation.
F2	AL (Adaptive Loop Operation)	INPUT	Adaptive loop gain control. Sets the magnitude of the Adaptive Loop load line in Adaptive Loop Operation. Leave disconnected for Remote Sense Operation.
F4	VC	OUTPUT	Bias voltage to power VTM module during start up
G1,G2	+IN	INPUT POWER	Positive input power terminal
G3,G4	+OUT	OUTPUT POWER	Positive output power terminal
H1,H2	-IN	INPUT POWER RETURN	Negative input power terminal. Connected internally to -OUT.
H3,H4	-OUT	OUTPUT POWER RETURN	Negative output power terminal. Connected internally to -IN.

Part Ordering Information

Device	Input Voltage Range	Package Type	Output Voltage x 10	Temperature Grade	Output Power	Revision	Version
MPRM	48N	H	480	M	250	A	00
MPRM = MIL-COTS PRM	48N = 38.0 V - 55.0 V	H = Half VIC SMD	480 = 48.0 V	M = -55 to 125°C	250 = 250 W	A	00 = AL / RS

Standard Models

Part Number	V_{IN}	Package Type	V_{OUT}	Temperature	Power	Version
MPRM48NH480M250A00	38.0 V - 55.0 V	Half VIC SMD	48.0 V (20.0 V to 55.0 V)	-55 to 125°C	250 W	AL / RS (Pin Selectable)

Absolute Maximum Ratings

The ABSOLUTE MAXIMUM ratings below are stress ratings only. Operation at or beyond these maximum ratings can cause permanent damage to device. Electrical specifications do not apply when operating beyond rated operating conditions. Operating beyond rated operating conditions for extended period of time may affect device reliability. All voltages are specified relative to SGND unless otherwise noted. Positive pin current represents current flowing out of the pin.

Parameter	Comments	Min	Max	Unit
SHARE / CONTROL NODE		-0.3	10.5	V
			+/-10	mA
ENABLE		-0.3	5.5	V
			+/-10	mA
+IN TO –IN	Continuous, non-operating	-1	80	V
	100 ms, non-Operating		100	V
VAUX		-0.5	10.5	V
			+/-100	mA
SGND			+/-100	mA
IFB		-0.5	5.7	V
REF / REF_EN		-0.3	3.6	V
	Remote Sense Operation (REF _EN)		10	mA
	Adaptive Loop Operation (REF)		3.4	mA
TRIM		-0.3	3.6	V
AL		-0.3	3.6	V
VT		-0.3	4.8	V
VC TO -OUT		-0.5	18	V
			+/-1.8	A
+OUT to -OUT		-1	62	V
Output Current			7.3	A
Internal Operating Temperature	M Grade	-55	125	°C
Storage Temperature	M Grade	-65	125	°C

Electrical Specifications

Specifications apply over all line and load conditions, and trim from 20.0 V to 55.0 V, unless otherwise noted; **Boldface** specifications apply over the temperature range of -55°C < T_{INT} < 125°C; All other specifications are at T_{INT} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Power Input Specification						
Input Voltage Range	V_{IN}	Continuous, operating	**38.0**	48.0	**55.0**	V
Input Voltage Range Transient	V_{IN_TRANS}	Derated current or power supported, 150 ms max, 10% duty cycle max. See Figure 42.	**30.0**		**60.0**	V
V_{IN} Slew Rate	dV_{IN}/dt	0 ≤ V_{IN} ≤ 55.0 V	**0.001**		**1000**	V/ms
Initialization Voltage	V_{INIT}	Internal micro controller initialization voltage		10		V
Initialization Delay	t_{INIT}	From V_{IN} first crossing V_{INIT}	**5.0**	7.0	**9.0**	ms
No Load Power Dissipation	P_{NL}	ENABLE HIGH, V_{IN} = 48.0 V		2.4	**3.5**	W
Input Quiescent Current	I_{QC}	ENABLE LOW, V_{IN} = 48.0 V		14.5	**20.0**	mA
Input Current	I_{IN_DC}	I_{OUT} = 5.21 A, V_{IN} = 48.0 V, V_{OUT} = 48.0 V		5.4	**5.5**	A
Input Capacitance (Internal)	C_{IN_INT}	Effective value, V_{IN} = 48.0 V (see Fig. 13)		2		µF
Input Capacitance (Internal) ESR	R_{CIN}	Effective value, V_{IN} = 48.0 V		3.0		mΩ
Power Output Specification						
Rated Output Current	I_{OUT}	Standalone and Master Operation, see Figure 1, SOA			**5.21**	A
Rated Output Power	P_{OUT}	Standalone and Master Operation, see Figure 1, SOA			**250**	W
Switching Frequency	F_{SW}	V_{IN} = 48.0 V V_{OUT} = 48.0 V, I_{OUT} = 2.60 A, T_{INT} = 25°C	0.94	1.03	1.07	MHz
		Over line, load, trim and temperature, exclusive of burst mode	**0.70**		**1.07**	MHz
Output Turn-ON Delay	t_{ON}	From V_{IN} first crossing $V_{IN\_UVLO+\_SUPV}$ to ENABLE high; t_{INIT} expired		20		µs
		From ENABLE pin release to ENABLE high, V_{IN} applied, t_{OFF} expired		20		µs
Start up Sequence Timeout	$t_{STARTUP\_SEQ}$	From ENABLE high to start up sequence complete		17		ms
Efficiency Ambient	η_{AMB}	V_{IN} = 48.0 V, V_{OUT} = 48.0 V, I_{OUT} = 5.21 A, T_{INT} = 25°C	95.7	96.7		%
		V_{IN} = 48.0 V, V_{OUT} = 48.0 V, I_{OUT} = 2.60 A, T_{INT} = 25°C	94.5	95.7		%
		V_{IN} = 38.0 V to 55.0 V, V_{OUT} = 48.0 V, I_{OUT} = 5.21 A, T_{INT} = 25°C	95.1			%
		V_{IN} = 38.0 V to 55.0 V, I_{OUT} = 5.21 A, T_{INT} = 25°C, over trim	92.0			%
Efficiency Hot	η_{HOT}	V_{IN} = 48.0 V, V_{OUT} = 48.0 V, I_{OUT} = 5.21 A, T_{INT} = 100°C	95.5	96.5		%
		V_{IN} = 48.0 V, V_{OUT} = 48.0 V, I_{OUT} = 2.60 A, T_{INT} = 100°C	94.5	95.8		%
		V_{IN} = 38.0 V to 55.0 V , V_{OUT} = 48.0 V, I_{OUT} = 5.21 A, T_{INT} = 100°C	94.8			%
		V_{IN} = 38.0 V to 55.0 V , I_{OUT} = 5.21 A, T_{INT} = 100°C, over trim	91.3			%
Efficiency Over Temperature	η	>50% load and V_{OUT} = 48.0 V; over temperature	**94.0**			%
		>50% load; over temperature and trim	**89.2**			%
Output Discharge current	I_{OD}	Average Value		0.5		mA
Output Voltage Ripple	V_{OUT_PP}	V_{IN} = 48.0 V, V_{OUT} = 48.0 V, I_{OUT} = 5.21 A, C_{OUT_EXT} = 0 F, 20 MHz BW		1110	**1665**	mV
Output Inductance (Parasitic)	L_{OUT_PAR}	Frequency @ 1.03 MHz, Simulated J-Lead model		2.5		nH
Output Capacitance (Internal)	C_{OUT_INT}	Effective value, V_{OUT} = 48.0 V (see Fig.13)		2		µF
Output Capacitance (Internal) ESR	R_{COUT}	Effective value, V_{OUT} = 48.0 V		3.0		mΩ

Electrical Specifications (cont.)

Specifications apply over all line and load conditions, and trim from 20.0 V to 55.0 V, unless otherwise noted; **Boldface** specifications apply over the temperature range of -55°C < T_{INT} < 125°C; All other specifications are at T_{INT} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Power Output Specifications: Adaptive Loop Operation						
Output Voltage Setpoint	V_{OUT_SET}	No load, trim Inactive, Adaptive Loop load line inactive	**47.00**	48.00	**49.00**	V
Output Voltage Trim Range	V_{OUT}		**20.0**		**55.0**	V
Output Voltage Rise Time	t_{RISE_VOUT}	From soft start initiated to output voltage settled	**1.7**	1.8	**1.9**	ms
Output Voltage Load Regulation	$V_{OUT\_REG\_LOAD}$	Adaptive loop load line inactive		0.02	**0.2**	%
Output Voltage Line Regulation	$V_{OUT\_REG\_LINE}$	Adaptive loop load line inactive		0.02	**0.2**	%
Total Regulation Error	$V_{OUT\_REG\_TOTAL}$	PRM output voltage, Adaptive Loop load line inactive			**0.2**	%
Total AL Regulation Error	$V_{OUT\_REG\_AL}$	VTM output voltage, total Adaptive Loop regulation, V_{OUT} = 48.0 V, trim inactive		1	**3**	%
		VTM output voltage, total Adaptive Loop regulation, trim active, exclusive of external resistor tolerances			**5**	%
Line Frequency Ripple Rejection	$PSRR_{120HZ}$	120Hz, C_{OUT_EXT} = 0 F, I_{OUT} = 2.60 A		60		dB
Output Current Limit	I_{LIMIT}	V_{IN} = 48.0 V, V_{OUT} = 48.0 V, T_{INT} = 25°C, constant current limit after supervisory limit detection time t_{LIM_SUPV}	5.7	6.5	7.3	A
		Over line, load, trim and temperature	**5.3**		**7.75**	A
Load Capacitance (Electrolytic)	C_{LOAD_ALEL}	0.1 Ω ≤ ESR ≤ 1 Ω, See Figure 32, total capacitance (C_{LOAD_ALEL} + C_{LOAD_CER}) ≤ 47 µF			**47**	µF
Load Capacitance (Ceramic)	C_{LOAD_CER}	2 mΩ ≤ ESR ≤ 200 mΩ, See Figure 32			**25**	µF
Load Transient Voltage Deviation	V_{TRANS}	10% ↔ 100% load step, 10 A/µsec, 0 µF C_{OUT}, deviation from initial setpoint			**4.8**	V
Load Transient Recovery Time	t_{TRANS}	10% ↔ 100% load step, 10 A/µsec, 0 µF C_{OUT}, Recovery to 90% of final value, Adaptive Loop load line inactive		100		µs
		10% ↔ 100% load step, 10 A/µsec, 0 µF C_{OUT}, Recovery to 90% of final value, Adaptive Loop load line active, V_{AL} = 0.96 V		500		µs
Power Output Specifications: Slave Operation with AL Master						
Rated Current Within an Array	I_{OUT_ARRAY}	Slave Operation within an array, up to 5°C case temperature differential, master-slave configuration			**4.2**	A
		Slave Operation within an array, up to 30°C case temperature differential, master-slave configuration			**3.6**	A
Rated Power Within an Array	P_{OUT_ARRAY}	Slave Operation within an array, up to 5°C case temperature differential, master-slave configuration			**200**	W
		Slave Operation within an array, up to 30°C case temperature differential, master-slave configuration			**175**	W
Current Sharing Difference (Master to Slave)	$I_{OUT\_SHARE\_MS}$	Equal input, and output voltage at full load; V_{IN} = 48.0 V, V_{OUT} = 48.0 V			**15**	%
		Equal input and output voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°C and ≤ 5°C part-part temp. mismatch			15	%
		Equal input, and output voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°C and ≤ 30°C part-part temp. mismatch			20	%

Electrical Specifications (cont.)

Specifications apply over all line and load conditions, and trim from 20.0 V to 55.0 V, unless otherwise noted; **Boldface** specifications apply over the temperature range of -55°C < T_{INT} < 125°C; All other specifications are at T_{INT} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Powertrain Protections						
Input Undervoltage Turn-ON	V_{IN_UVLO+}			24.5	**26.0**	V
Input Undervoltage Turn-OFF	V_{IN_UVLO-}	Instantaneous powertrain shutdown, detected after t_{BLANK}	**22.0**	22.7		V
Input Undervoltage Hysteresis	V_{UVLO_HYST}	(V_{IN_UVLO+}) - (V_{IN_UVLO-})	**1.8**	2.2	**2.5**	V
Input Overvoltage Turn-ON	V_{IN_OVLO-}		**58.3**	60.0		V
Input Overvoltage Turn-OFF	V_{IN_OVLO+}	Instantaneous powertrain shutdown, detected after t_{BLANK}		63.6	**67.3**	V
Input Overvoltage Hysteresis	V_{OVLO_HYST}	(V_{IN_OVLO+}) - (V_{IN_OVLO-})	**2.9**	3.6	**4.3**	V
Output Overvoltage Threshold	V_{OUT_OVP+}	Instantaneous shutdown, detected after t_{PROT}	**56.0**	57.9	**60.0**	V
Minimum Current Limited Vout	V_{OUT_UVP}				**12**	V
Overtemperature Shutdown Setpoint	T_{INT_OTP}	Instantaneous shutdown, detected after t_{PROT}	**125**			°C
Output Power Limit	P_{PROT}		**250**			W
Short Circuit V_{OUT} Threshold	V_{SC_VOUT}			8.8		V
Short Circuit V_{OUT} Recovery Threshold	V_{SC_VOUTR}			9.5		V
Short Circuit CONTROL NODE Threshold	V_{SC_VCN}			7.2		V
Short Circuit CONTROL NODE Recovery Threshold	V_{SC_VCNR}			6.9		V
Short Circuit Timeout	t_{SC}	Short circuit fault detected after V_{SC_VOUT} and V_{SC_VCN} thresholds persist for this time		5		ms
Short Circuit Recovery Time	t_{SCR}	Excludes t_{OFF}		75		ms
Overcurrent (IFB) and Input Over/Undervoltage Blanking Time	t_{BLANK}		**50**	130	**160**	µs
Overtemperature, Output Overvoltage and ENABLE Shutdown Response Time (Hardware)	t_{PROT}			2		µs
Powertrain Supervisory Limits						
Input Undervoltage Turn-ON (Supervisory)	$V_{IN\_UVLO+\_SUPV}$			35.9	**37.0**	V
Input Undervoltage Turn-OFF (Supervisory)	$V_{IN\_UVLO-\_SUPV}$	Powertrain shutdown, detected after t_{LIM_SUPV}	**23.5**	25.7		V
Input Undervoltage Hysteresis (Supervisory)	$V_{UVLO\_HYST\_SUPV}$	($V_{IN\_UVLO+\_SUPV}$) - ($V_{IN\_UVLO-\_SUPV}$)	**8.7**	10.2	**11.7**	V
Undertemperature Shutdown Setpoint (Supervisory)	T_{INT_UTP}	M Grade			-55	°C
Supervisory Limit Response Time	t_{LIM_SUPV}				**150**	µs

Electrical Specifications (cont.)

Specifications apply over all line and load conditions, and trim from 20.0 V to 55.0 V, unless otherwise noted; **Boldface** specifications apply over the temperature range of -55°C < T_{INT} < 125°C; All other specifications are at T_{INT} = 25°C unless otherwise noted.

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Power Output Specifications: Slave Operations (cont.)						
Current Sharing Difference (Slave to Slave)	$I_{OUT\_SHARE\_SS}$	Equal input, output, and SHARE voltage at full load; V_{IN} = 48.0 V, V_{OUT} = 48.0 V			**5**	%
		Equal input, output and SHARE voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°C and ≤ 5°C part-part temp. mismatch			10	%
		Equal input, output, and SHARE voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°C and ≤ 30°C part-part temp. mismatch			15	%
Maximum Array Size	$N_{PRMS\_PARALLEL}$	Maximum number of parallel devices, master-slave configuration			**5**	PRMs
Power Output Specifications: Remote Sense Operation						
Output Voltage Range	V_{OUT}		**20.0**		**55.0**	V
Rated Current Within an Array	I_{OUT_ARRAY}	Remote Sense Operation within an array, up to 5°C case temperature differential			**4.7**	A
		Remote Sense Operation within an array, up to 30°C case temperature differential			**4.2**	A
Rated Power Within an Array	P_{OUT_ARRAY}	Remote Sense Operation within an array, up to 5°C case temperature differential			**225**	W
		Remote Sense Operation within an array, up to 30°C case temperature differential			**200**	W
Current Sharing Difference	$I_{OUT\_SHARE\_RS}$	Equal input, output, and CONTROL NODE voltage at full load; V_{IN} = 48.0 V, V_{OUT} = 48.0 V			**5**	%
		Equal input, output and CONTROL NODE voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°C and ≤ 5°C part-part temp. mismatch			10	%
		Equal input, output, and CONTROL NODE voltage at full load; Over line and trim, with 25°C ≤ T_C ≤ 100°Cand ≤ 30°C part-part temp. mismatch (worst case)			15	%
Maximum Array Size	$N_{PRMS\_PARALLEL}$	Maximum number of parallel devices, Remote Sense configuration, CONTROL NODE externally driven			**10**	PRMs

Line Dropout Characteristics

Specifications apply during a line dropout condition V_{IN} from 30.0 V to 38.0 V , and trim from 20 V to 55 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

Line Dropout Specifications

- After startup if V_{IN} drops below $V_{IN\_DROPOUT\_EN-}$, a 150 msec line dropout timer is enabled
- Operation is sustained down to 30.0 V with specified derating for duration of timer
- Line dropout timer is disabled and normal operation resumes when V_{IN} recovers above $V_{IN\_DROPOUT\_DIS+}$
- Powertrain shutdown is initiated if V_{IN} does not recover to above $V_{IN\_DROPOUT}$ before the timer expires or if Vin falls below $V_{IN\_UVLO-\_SUPV}$

Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Line Dropout Timer Enable Threshold	$V_{IN\_DROPOUT\_EN-}$	Line dropout timer activated when input voltage drops **below** this level	**33.8**	35.0		V
Line Dropout Timer Disable Threshold	$V_{IN\_DROPOUT\_DIS+}$	Line dropout timer disabled when input voltage recovers **above** this level		36.0	**37.5**	V
Line Dropout Timer Duration	$t_{DROPOUT}$	Powertrain shutdown after timer expires	**140**	150		ms
Line Dropout Minimum Operating Voltage	$V_{IN\_DROPOUT\_MIN}$	Minimum input voltage for sustained operation	**30.0**			V
Line Dropout Current Rating	$\%I_{DROPOUT}$	Percentage of rated current, linearly derated to 75% between 38.0 V and 30.0 V, see Figure 42		-18.8 + 3.1 x V_{IN}		%
Line Dropout Power Rating	$\%P_{DROPOUT}$	Percentage of rated power, linearly derated to 75% between 38.0 V and 30.0 V, see Figure 42		-18.8 + 3.1 x V_{IN}		%

Signal Specifications

Specifications apply over all line and load conditions, T_{INT} = 25ºC and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55ºC < T_{INT} < 125ºC.

ENABLE

- The ENABLE pin enables and disables the PRM
- In PRM array configurations, ENABLE pins should be connected in order to synchronize start up
- ENABLE is 5 V with 1.8 mA source capability during normal operation

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Normal Operation	ENABLE Voltage	V_{ENABLE}		**4.7**	5.0	**5.3**	V
		ENABLE Current	I_{ENABLE_OP}				**1.8**	mA
	Start up	ENABLE Source Current	I_{ENABLE_EN}	After t_{OFF}		90		µA
		Minimum Time to Start	t_{OFF}		**13.0**	15.0	**17.0**	ms
Digital Input / Output	Start up	ENABLE Enable Threshold	V_{ENABLE_EN}			2.5	**3.2**	V
	Standby	ENABLE Disable Threshold	V_{ENABLE_DIS}		**0.97**	2.40		V
		ENABLE Resistance (External)	R_{ENABLE_EXT}	Resistance to SGND required to disable the PRM			**235**	Ω
Digital Output	Fault	ENABLE Sink Current to SGND	I_{ENABLE_FAULT}	ENABLE voltage 1 V or above			**4**	mA

VAUX: Auxillary Voltage Source

- Intended to power auxiliary circuits
- 9 V during normal operation with 5 mA source capability

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Normal Operation	VAUX Voltage	V_{VAUX}		**8.6**	9.0	**9.5**	V
		VAUX Current	I_{VAUX}				**5**	mA
		VAUX Voltage Ripple	V_{VAUX_PP}	I_{OUT} = 0A, C_{VAUX_EXT} = 0. Maximum specification includes powertrain operation in burst mode.		100	**400**	mV
	Transition	VAUX Capacitance (External)	C_{VAUX_EXT}				**0.04**	µF
		VAUX Fault Response Time	t_{FR_VAUX}	From fault recognition to VAUX = 1.5 V		30		µs

VC: VTM Control

- Pulsed voltage source used to power and synchronize downstream VTM during start up
- 14 V, 10 ms typical voltage pulse

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Start up	VC Voltage	V_{VC_START}	Connected to VTM VC or equivalent, I_{VC} = 115 mA, C_{VC} = 3.2 uF	**13**	14	**18**	V
		VC Available Current	I_{VC_START}	V_C = 14 V, V_{IN} > 20 V	**200**			mA
		VC Duration	t_{VC}		**7**	10	**16**	ms
		VC Slew Rate	dVC/dt	Connected to VTM or equivalent, I_{VC} = 115 mA, C_{VC} = 3.2 uF	**0.02**		**0.25**	V/µs
		ENABLE to VC Delay	$t_{ENABLE\text{-}VC}$			20		µs

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

SGND: Signal Ground

- All control signals must be referenced to this pin, with the exception of VC
- SGND is internally connected to -IN and -OUT

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input / Output	Any	Maximum Allowable Current	I_{SGND}		**-100**		**100**	mA

TRIM

- TRIM is used to select operating mode and trim the output voltage in Adaptive Loop Operation
- Internal pullup to V_{CC_INT} through 10 kΩ resistor
- When pulled below 0.45 V during power up, Remote Sense / Slave Operation is selected
- When allowed to pull up above 0.55 V during power up, Adaptive Loop Operation is selected
- Operating mode is detected during power up and cannot be changed unless input power is cycled

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Normal Operation	Internally Generated VCC	V_{CC_INT}		**3.20**	3.28	**3.36**	V
		Internal Pullup Resistance to V_{CC_INT}	R_{TRIM_INT}	0.5% tolerance resistor	**9.83**	10.00	**10.18**	kΩ
	Mode Detect	Mode Detection Delay	t_{MODE_DETECT}	From ENABLE high to mode detected, after V_{IN} first applied	**100**	150	**200**	µs
		Remote Sense Enable Threshold	$V_{RS\_MODE\_EN}$	Pull **below** this value during first start up after application of power to enable Remote Sense / Slave Operation	**0.45**			V
		Remote Sense Disable Threshold	$V_{RS\_MODE\_DIS}$	Pull **above** this value during first start up after application of power to enable Adaptive Loop Operation			**0.55**	V

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

TRIM (Adaptive Loop Operation Only)

- Provides dynamic trim control over the PRM output voltage in Adaptive Loop Operation
- Sampled prior to every start up to detect if trim is active or inactive
- Output voltage is equal to 20 times the voltage at the TRIM pin when applied TRIM voltage is within the active range
- Trim state is detected during normal operation and cannot be changed until start up is initiated

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Start up	Trim Enable Threshold	V_{TRIM_EN}	Pull **below** this value during start up to enable trim control	**3.10**			V
		Trim Disable Threshold	V_{TRIM_DIS}	Pull **above** this value during start up to disable trim control			**3.20**	V
		Minimum Trim Disable Resistance	$R_{TRIM\_DIS\_MIN}$	Minimum TRIM resistance required to disable trim	**10**			MΩ
		Trim Capacitance (External)	C_{TRIM_EXT}				**100**	pF
		Trim Sample Delay	t_{ENABLE_TRIM}	From ENABLE high to TRIM sampled	**100**	150	**200**	µs
	Normal Operation	TRIM Pin Analog Range	V_{TRIM_RANGE}	See Figure 26	**1.00**		**2.75**	V
		TRIM Gain	G_{TRIM}	V_{OUT} / V_{TRIM}, V_{TRIM} applied within active range		20		V / V
		Trim Accuracy	$\%_{ACC\_TRIM}$	Vout accuracy, exclusive of external resistor tolerance		0.5	**2.0**	%
		V_{OUT} Referred Trim Resolution	V_{OUT_RES}			200		mV
		Trim Latency	t_{TRIM_LAT}		**65**	130	**260**	µs
		Trim Bandwidth	BW_{TRIM}	-3dB point		1.2		kHz

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

AL: Adaptive Loop (Adaptive Loop Operation Only)

- Provides Adaptive Loop load line programming in Adaptive Loop Operation
- Internal pullup to V_{CC_INT} through 10 kΩ resistor
- Sampled prior to every start up to detect if Adaptive Loop load line is active or inactive
- Leave open to disable Adaptive Loop load line
- Not used in Remote Sense Operation

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Start up	AL Enable Threshold	V_{AL_EN}	Pull **below** this value during start up to enable AL load line	**3.10**			V
		AL Disable Threshold	V_{AL_DIS}	Pull **above** this value during start up to disable AL load line			**3.20**	V
		Minimum AL Disable Resistance	$R_{AL\_DIS\_MIN}$	Minimum AL resistance required to disable AL load line	**10**			MΩ
		AL Capacitance (External)	C_{AL_EXT}				**100**	pF
		AL Sample Delay	t_{ENABLE_AL}	From ENABLE high to AL sampled	**100**	150	**200**	µs
	Normal Operation	Internally generated VCC	V_{CC_INT}		**3.20**	3.28	**3.36**	V
		Internal Pullup Resistance to V_{CC_INT}	R_{AL_INT}	0.5% tolerance resistor	**9.83**	10.00	**10.18**	kΩ
		AL Pin Analog Range	V_{AL_RANGE}		**0**		**3.10**	V
		AL Gain	G_{AL}	Positive correction slope, VT inactive		1.0		Ω/V
		AL Load Line Accuracy	$\%_{ACC\_LL\_AL}$	Full load slope accuracy exclusive of external resistor tolerance		0.5	**2.0**	%
		AL Load Line Resolution	LL_{AL_RES}			3		mΩ
		Maximum Output Referred Compensation	$V_{OUT\_AL\_MAX}$	Maximum increase from no load setpoint, V_{OUT} ≤ 55.0 V			**5**	V
		AL Latency	t_{AL_LAT}		**65**	130	**260**	µs
		AL Bandwidth	BW_{AL}	-3dB point		1.2		kHz

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

VT: VTM Temperature (Adaptive Loop Operation Only)

- VTM temperature compensation for Adaptive Loop regulation
- Adjusts the slope of the Adaptive Loop load line to account for changes in VTM output resistance over temperature
- Connect to TM pin of compatible downstream VTM to enable temperature compensation
- Leave disconnected to disable temperature compensation

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Normal Operation	Internal Resistance to SGND	R_{VT_INT}			80.4		kΩ
		VT Enable Threshold	V_{VT_EN}				**2.1**	V
		VT Disable Threshold	V_{VT_DIS}	Pull below this value to disable VT temperature compensation	**1.9**			V
		VT Disable Default Temperature	T_{VT_DIS}	Default AL temperature setting when VT disabled		25		°C
		VT Analog Range	V_{VT_OP}		**2.18**		**3.98**	V
		VT Temperature Coefficient	TC_{VT}	VT within active range, referenced to 2.98 V		30		%/V
			TC_{VT}	VTM TM voltage applied, .01V/°K, referenced to 25°C		0.3		%/C
		VT Resolution	TC_{VT_RES}	VTM TM voltage applied, .01V/°K		0.4		°C
		VT Latency	t_{VT_LAT}		**65**	130	**260**	µs
		Bandwidth	BW_{VT}	-3dB point		1.5		kHz

REF: Reference (Adaptive Loop Operation Only)

- Functions as REF pin in Adaptive Loop Operation
- REF represents the internal voltage reference for the voltage control circuit
- V_{OUT} approximately equal to 20 times REF voltage

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Normal Operation	REF Voltage	V_{REF}	V_{OUT} = 48.0 V, trim inactive		2.4		V
		REF to V_{OUT} Scale Factor	G_{REF_VOUT}	V_{OUT} / V_{REF}		20		V / V
		REF Resistance (External)	R_{REF_EXT}		**10**			MΩ
		REF Capacitance (External)	C_{REF_EXT}				**200**	pF
		REF Voltage Ripple	V_{REF_PP}	Includes burst mode, 20 MHz BW		25		mV
	Transition	ENABLE to REF Delay	t_{ENABLE_REF}	ENABLE low to REF low		130		µs
		VAUX to REF Delay	t_{VAUX_REF}	VAUX = 8.1 V to REF soft start ramp initiated		1		ms

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

REF_EN: Reference Enable (Remote Sense and Slave Operation Only)

- Functions as REF_EN pin in Remote Sense and Slave Operation
- REF_EN signals successful start up and powertrain ready to operate
- Intended to power and enable the external feedback circuit reference in Remote Sense Operation
- 3.25 V, 4 mA regulated voltage source

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Normal Operation	REF_EN Voltage	V_{REF_EN}	REF_EN unloaded	**2.72**	3.25	**3.37**	V
		REF_EN Source Impedance	$R_{OUT\_REF\_EN}$			50	**100**	Ω
		REF_EN Current	I_{REF_EN}				**4**	mA
		REF_EN Capacitance (External)	$C_{REF\_EN\_EXT}$				**0.1**	µF
		REF_EN Voltage Ripple	$V_{REF\_EN\_PP}$	Includes burst mode, 20 MHz BW		25		mV
	Transition	ENABLE to REF_EN Delay	$t_{ENABLE\_REF\_EN}$	ENABLE low to REF_EN low		130		µs
		VAUX to REF_EN Delay	$t_{VAUX\_REF\_EN}$	VAUX = 8.1 V to REF_EN high		1		ms

Share (Adaptive Loop and Slave Operation Only)

- Functions as SHARE pin in master slave array configuration
- Current share bus for array operation (master/slave scheme)
- Sources current and provides SHARE signal in master operation
- Sinks constant current when externally driven in active range (Slave Operation)

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Output	Standalone/ Master Operation	SHARE Voltage Active Range	V_{SHARE}		**0.79**		**7.40**	V
		SHARE Available Current	I_{SHARE}	V_{SHARE} > 0.79 V	**2.5**			mA
		SHARE Resistance to SGND	R_{SHARE}			93.3		kΩ
Analog Input	Slave Operation	SHARE Sink Current	I_{SHARE_SINK}	V_{SHARE} > 0.79 V	**0.25**	0.50	**0.75**	mA

Signal Specifications (cont.)

Specifications apply over all line and load conditions, T_{INT} = 25°C and output voltage from 20.0 V to 55.0 V, unless otherwise noted.
Boldface specifications apply over the temperature range of -55°C < T_{INT} < 125°C.

Control Node (Remote Sense Operation Only)

- Functions as CONTROL NODE pin in Remote Sense Operation
- Modulator control node voltage sets power train timing
- Driven by external error amplifier in Remote Sense Operation
- Sinks constant current when externally driven in active range
- Sources current, and clamps voltage to 0.79 V when pulled below active range

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Normal Operation	CONTROL NODE Voltage Active Range	V_{CN}		**0.79**		**7.40**	V
		CONTROL NODE Source Current	I_{CN_LOW}	V_{CN} < 0.79 V			**2.5**	mA
		CONTROL NODE Sink Current	I_{CN_SINK}	V_{CN} > 0.79 V	**0.25**	0.50	**0.75**	mA
		CONTROL NODE Resistance to SGND	R_{CN}			93.3		kΩ

IFB: Current Feedback (Remote Sense Operation Only)

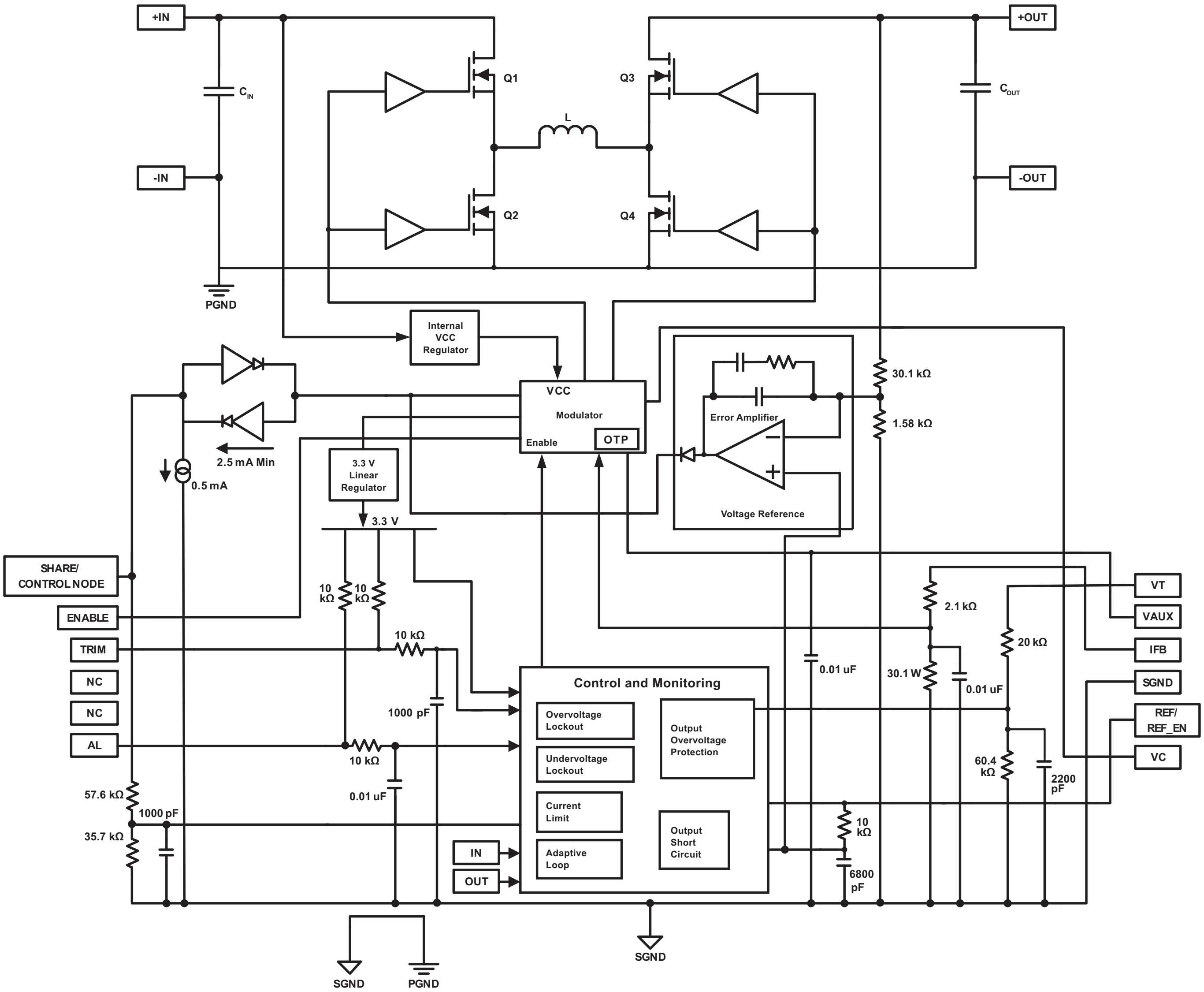
- Functions as IFB pin in Remote Sense Operation
- A voltage proportional to the PRM output current must be supplied externally to the IFB pin in order for the device to properly protect overcurrent events and to enable output current limit (clamp)
- Overcurrent protection trip will cause instantaneous powertrain disable, detected after t_{BLANK}
- Not used for Adaptive Loop Operation

Signal Type	State	Attribute	Symbol	Conditions / Notes	Min	Typ	Max	Unit
Analog Input	Normal Operation	Current Limit (Clamp) Threshold	V_{IFB_IL}	V_{IN} = 48.0 V; V_{OUT} = 48.0 V T_{INT} = 25°C	1.90	2.00	2.10	V
				Over line, trim, and temperature	**1.85**		**2.15**	V
		Overcurrent Protection Threshold	V_{IFB_OC}	Not production tested; guaranteed by design; T_{INT} = 25°C	**2.58**	2.69	**2.80**	V
				Not production tested; guaranteed by design; over line, trim, and temperature	**2.56**		**2.82**	V
		IFB Input Impedance	R_{IFB}		**2.09**	2.13	**2.17**	kΩ
		Current Limit Bandwidth	BW_{IL}			2.0		kHz

NC: No Connect

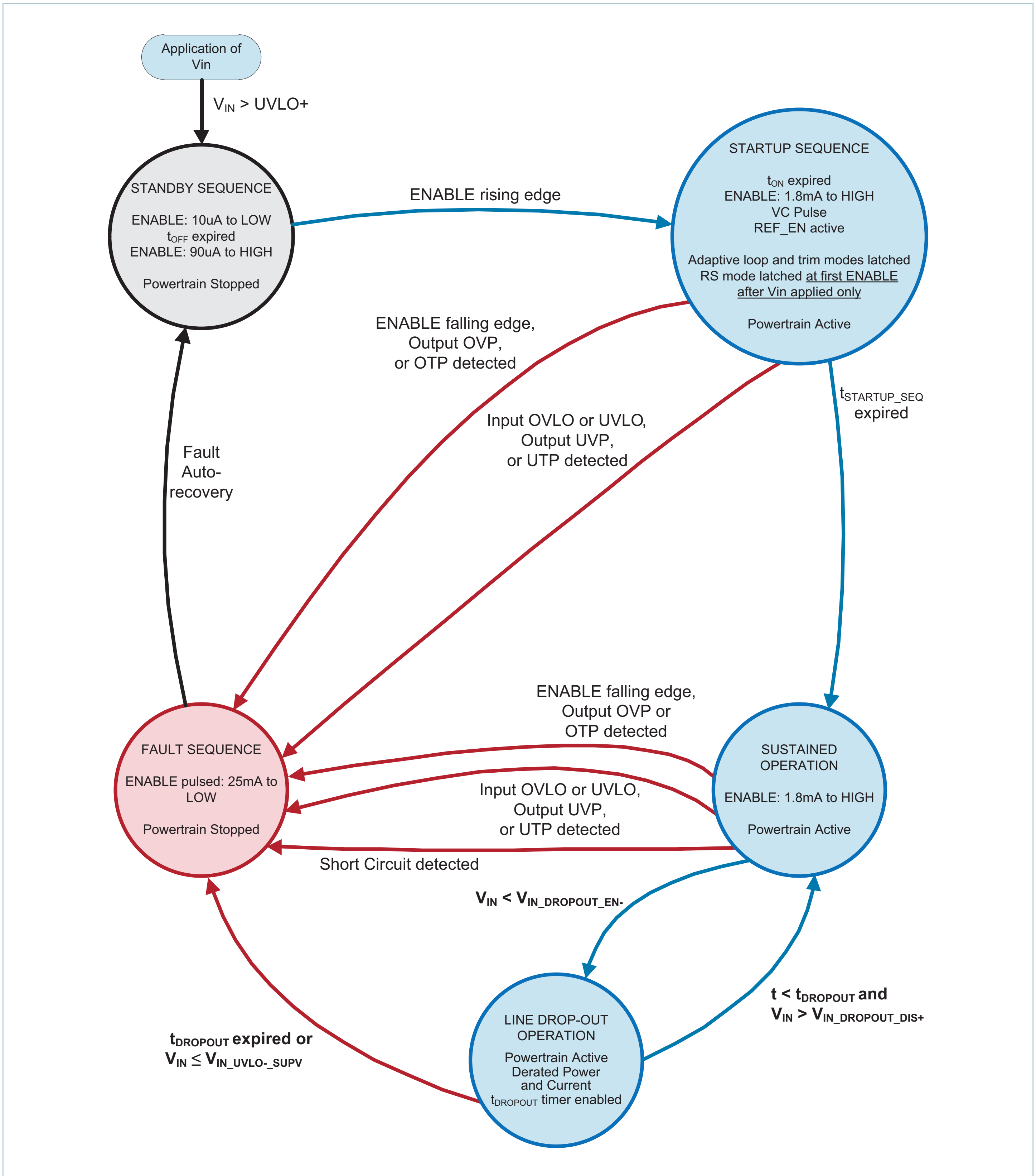
- Reserved for factory use only
- No connections should be made to these pins

Functional Block Diagram



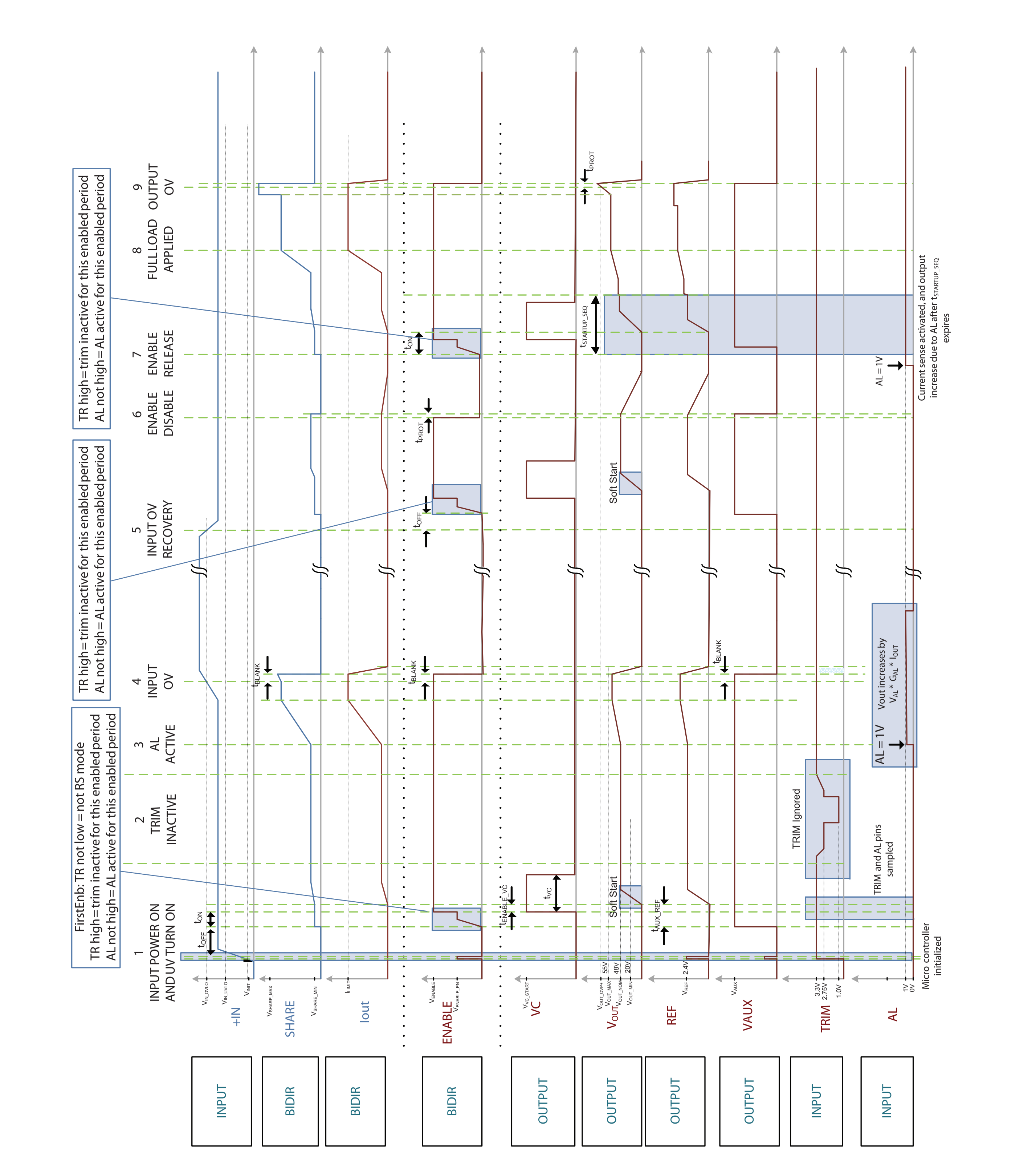
High Level Functional State Diagram

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



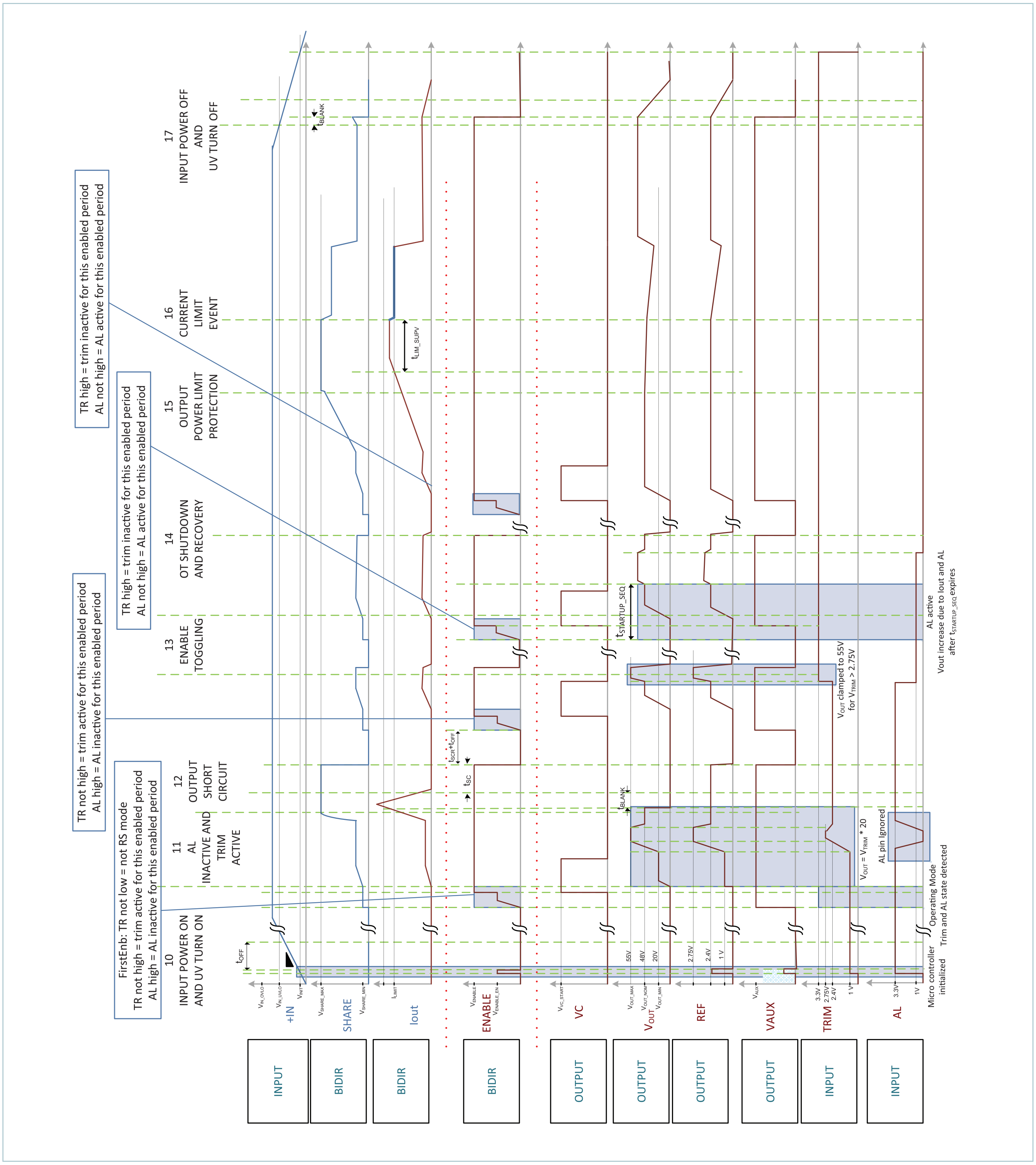
Timing Diagrams (Adaptive Loop Operation)

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



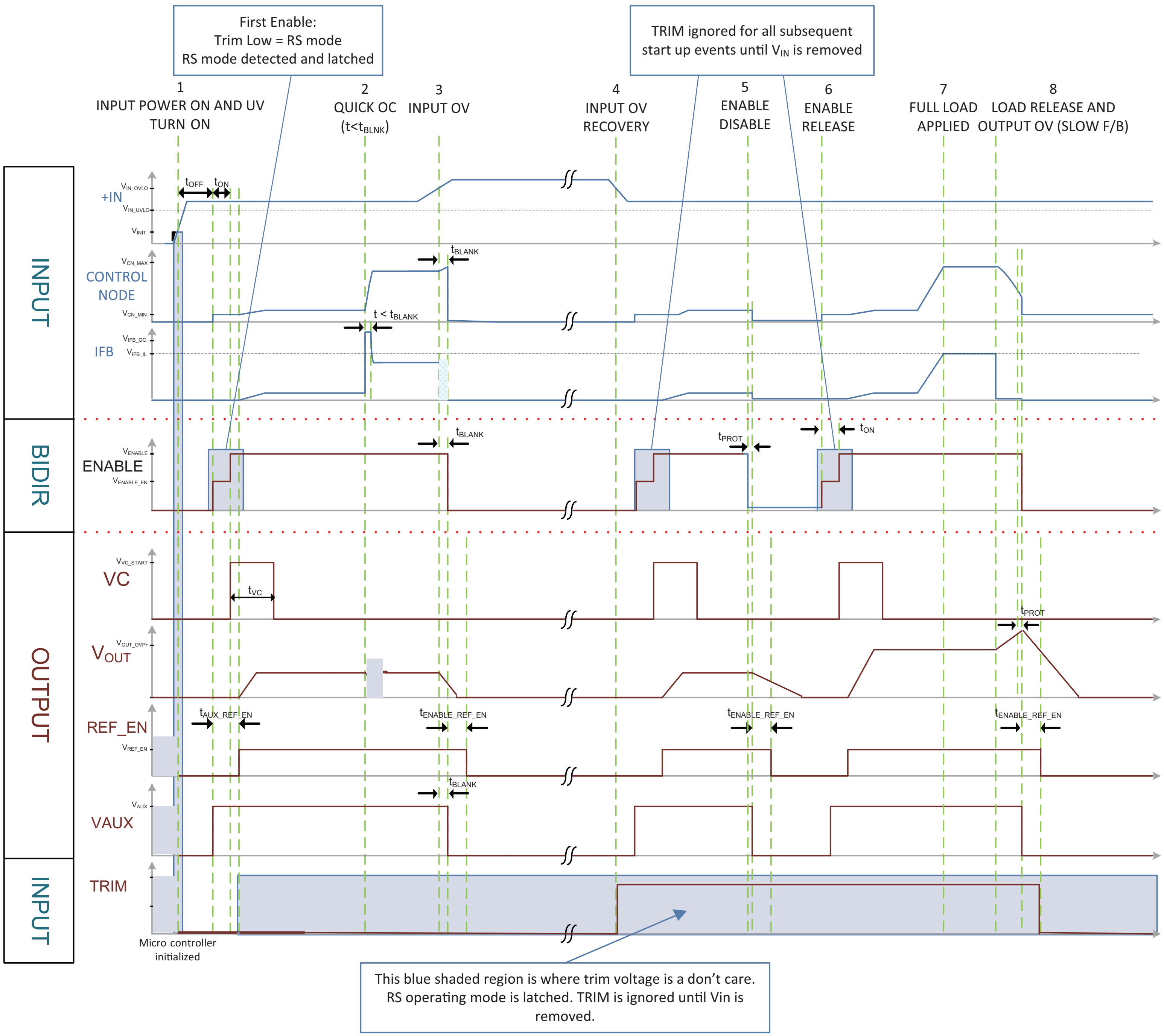
Timing Diagrams (Adaptive Loop Operation) (cont.)

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



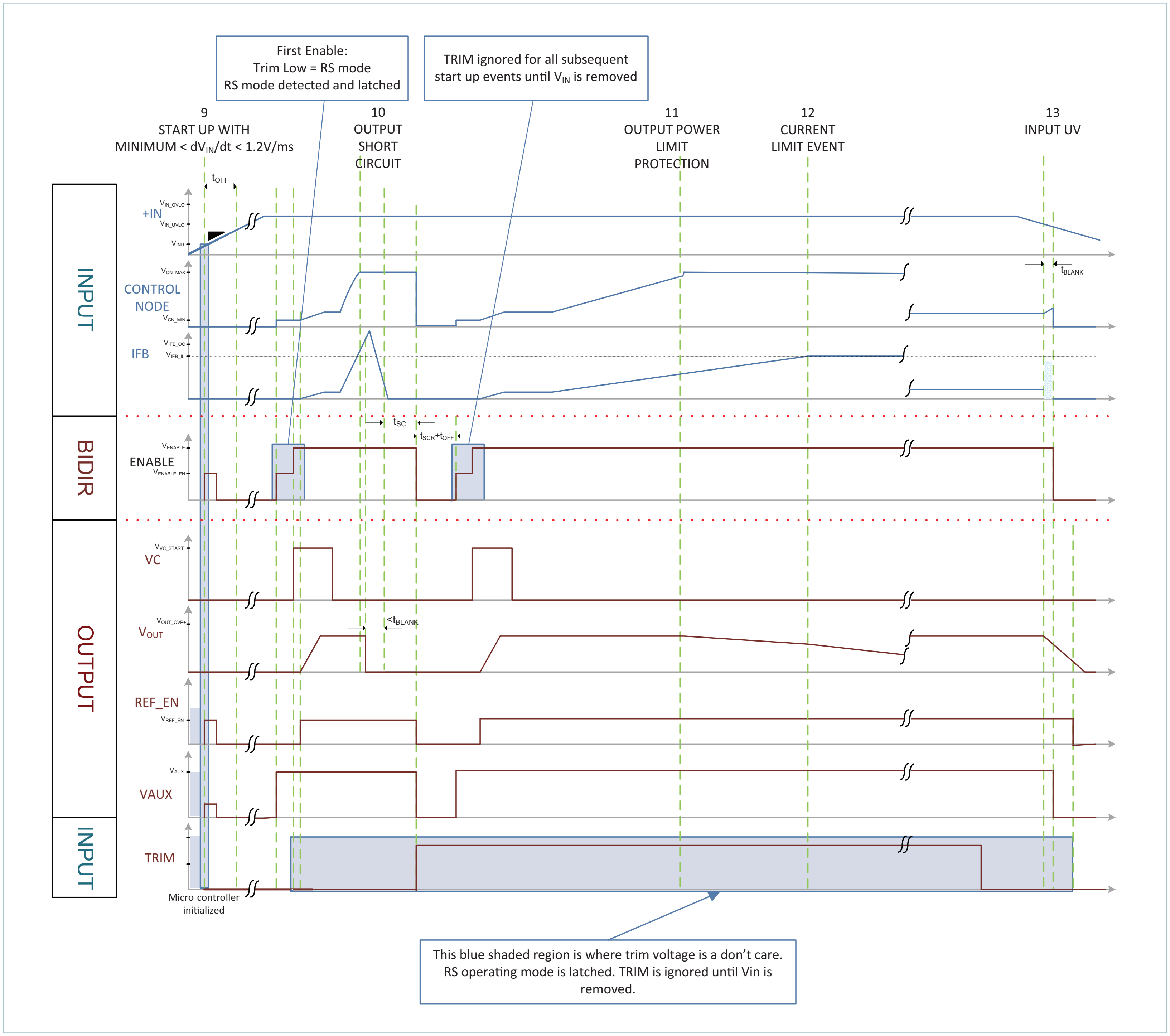
Timing Diagrams (Remote Sense Operation)

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



Timing Diagrams (Remote Sense Operation) (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.

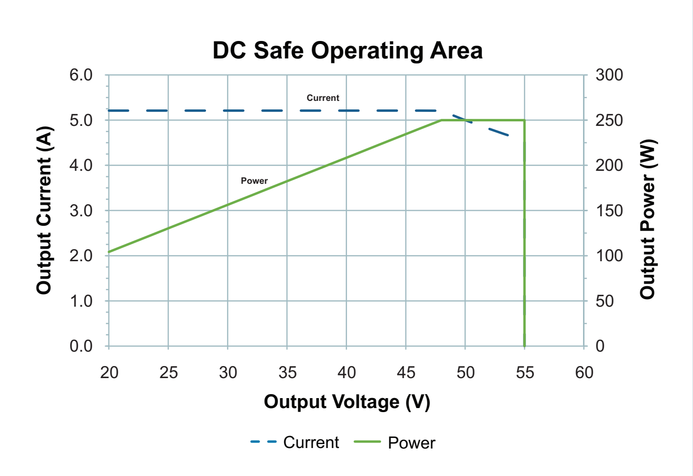


Figure 1 *— DC Safe Operating Area (SOA)*

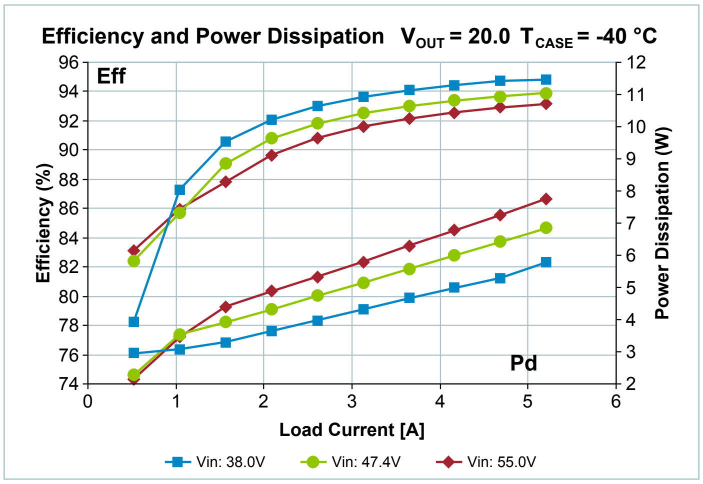


Figure 4 *— Total efficiency and power dissipation vs. V_{IN} and I_{OUT} V_{OUT} = 20.0 V, T_{CASE} = -40°C*

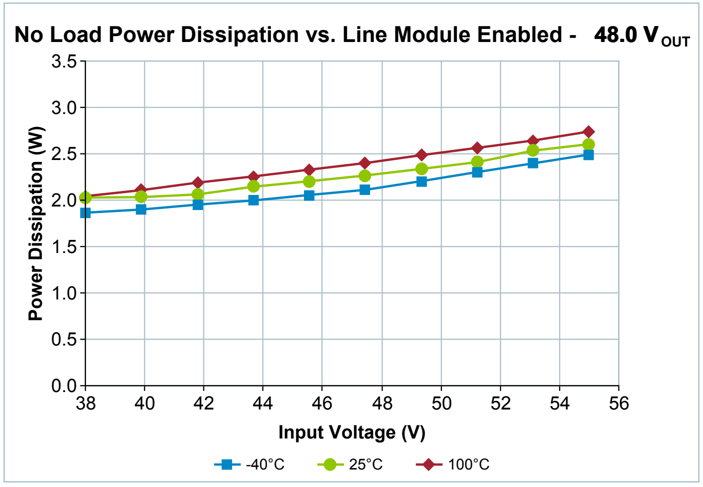


Figure 2 *— No Load Power Dissipation vs. V_{IN}, module enabled*

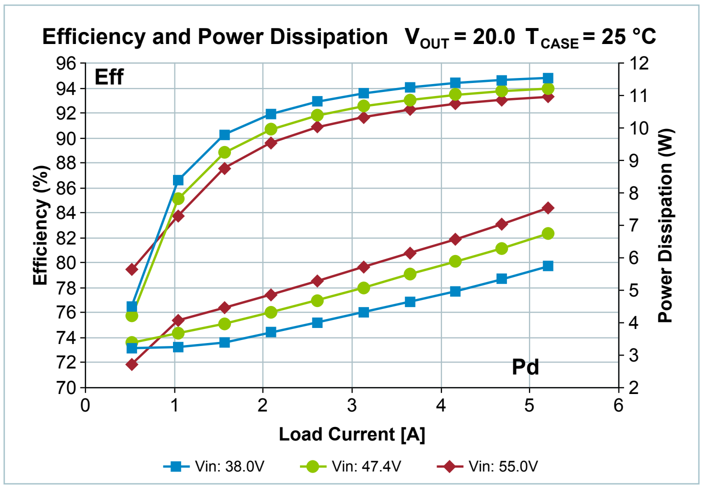


Figure 5 *— Total efficiency and power dissipation vs. V_{IN} and I_{OUT} V_{OUT} = 20.0 V, T_{CASE} = 25°C*

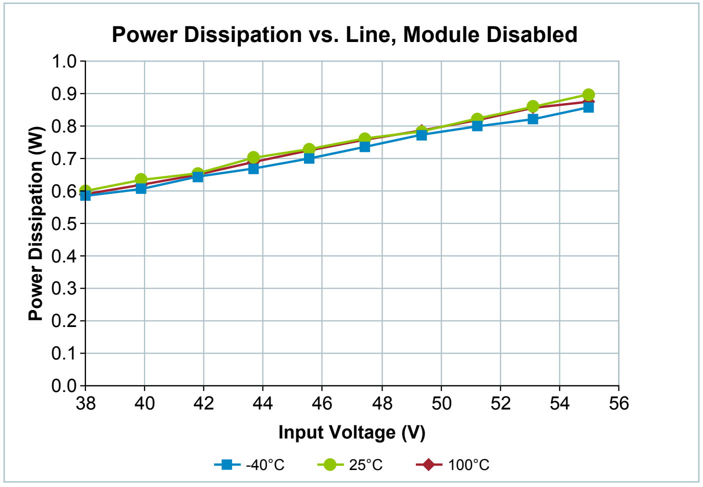


Figure 3 *— No Load Power Dissipation vs. V_{IN}, module disabled - Enable = Low*

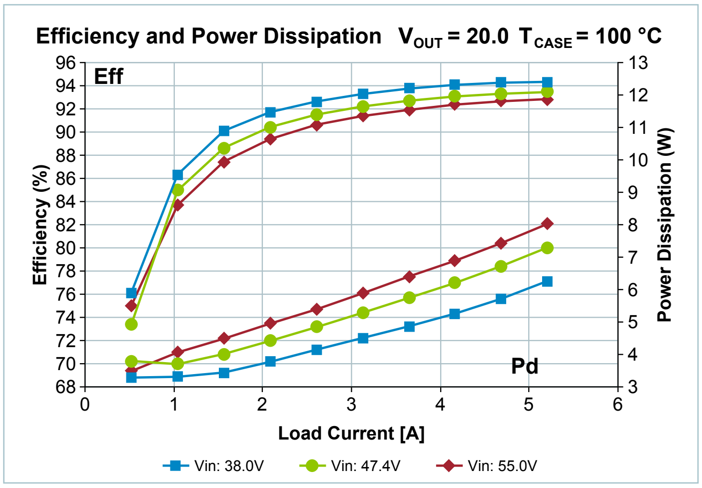


Figure 6 *— Total efficiency and power dissipation vs. V_{IN} and I_{OUT} V_{OUT} = 20.0 V, T_{CASE} = 100°C*

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.

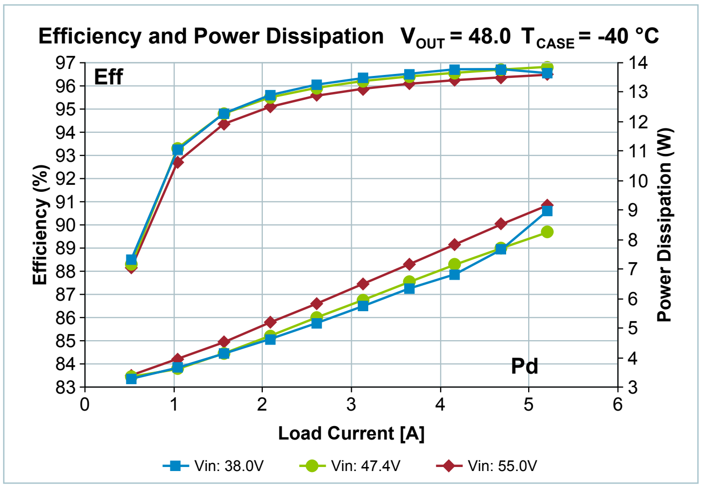


***Figure 7** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 48.0 V, T_{CASE} = -40°C

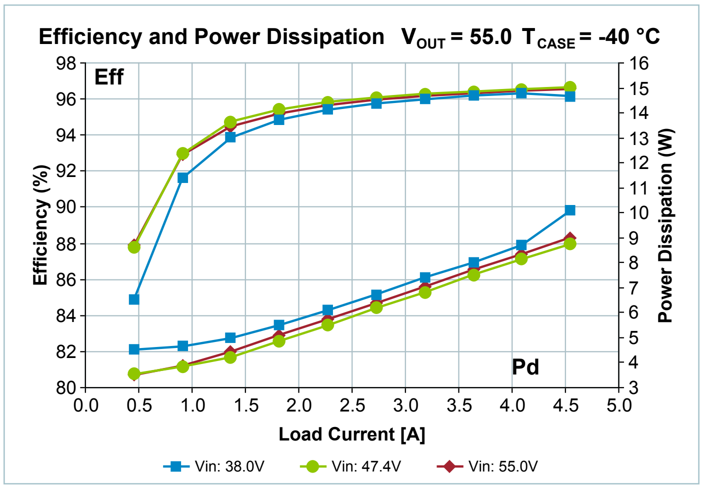


***Figure 10** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 55.0 V, T_{CASE} = -40°C

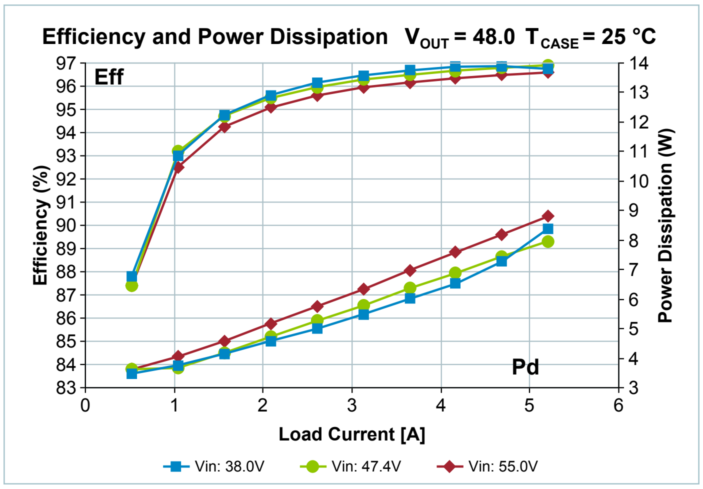


***Figure 8** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 48.0 V, T_{CASE} = 25°C

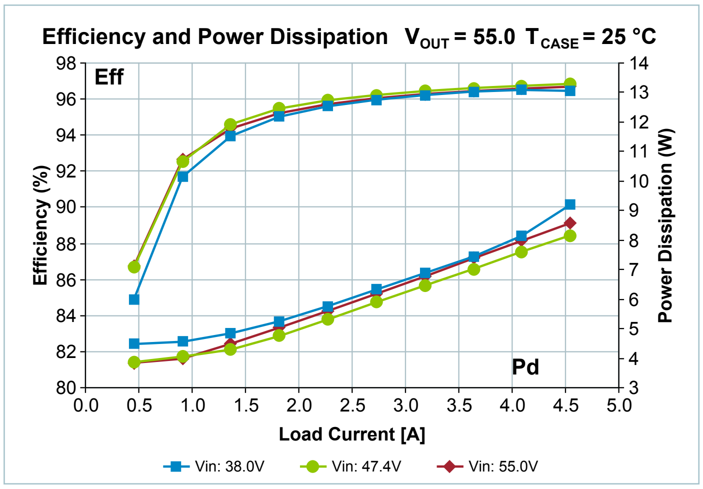


***Figure 11** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 55.0 V, T_{CASE} = 25°C

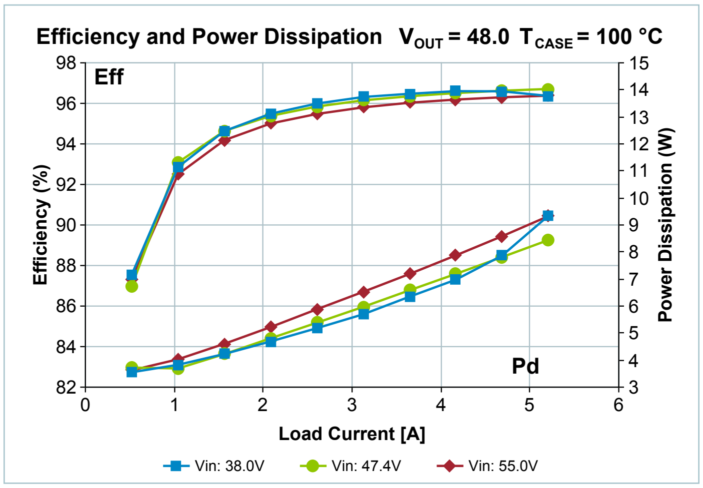


***Figure 9** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 48.0 V, T_{CASE} = 100°C

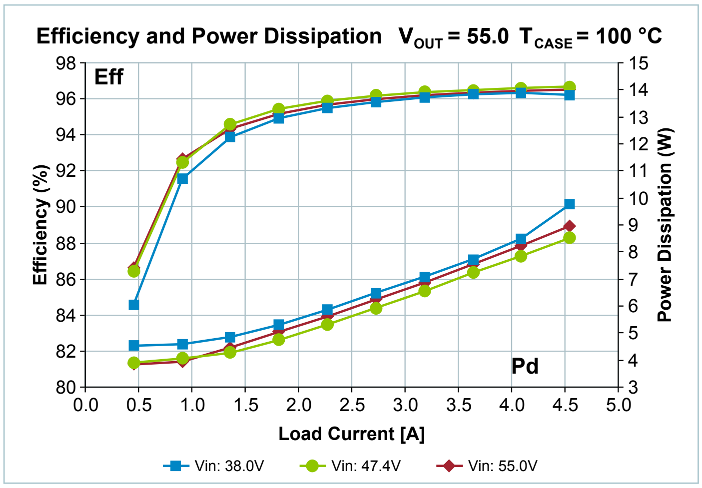


***Figure 12** — Total efficiency and power dissipation vs. V_{IN} and I_{OUT}*
V_{OUT} = 55.0 V, T_{CASE} = 100°C

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.

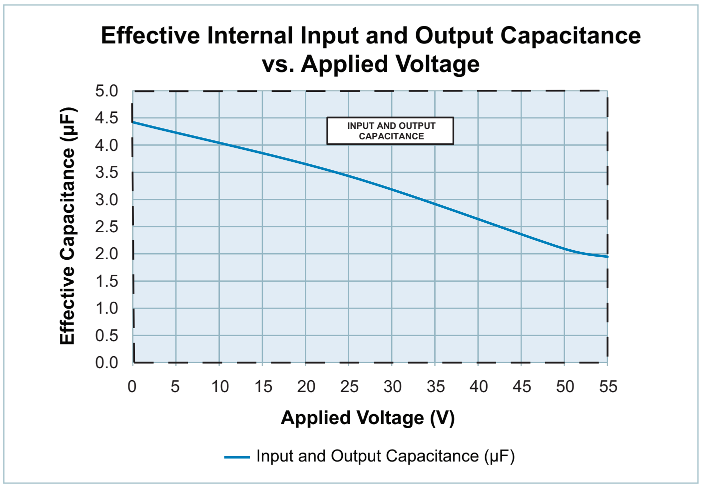


Figure 13 *— Effective Internal Input and Output Capacitance vs. Voltage – Ceramic Type*

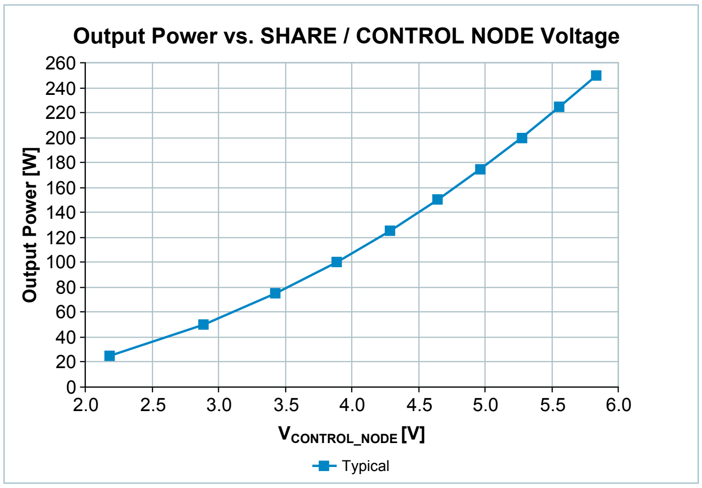


Figure 16 *— Output Power vs. SHARE / CONTROL NODE Voltage; V_{IN} = 48.0 V, V_{OUT} = 48.0 V, T_{CASE} = 25°C*

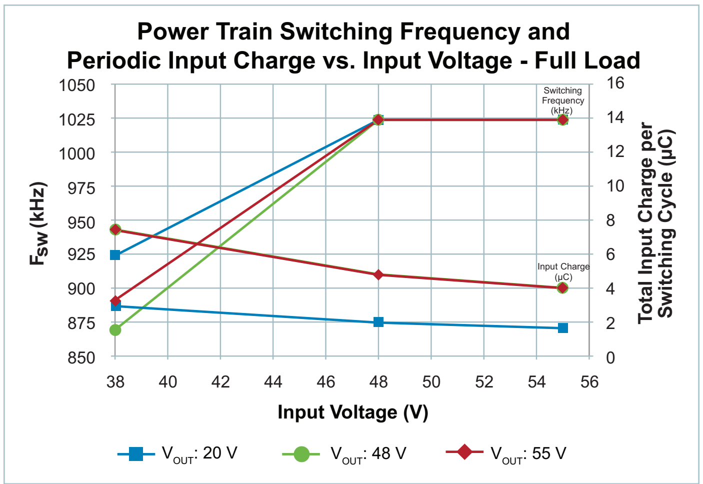


Figure 14 *— Typical Power Train Switching Frequency and Periodic Input Charge vs. V_{IN}, V_{OUT}; I_{OUT} = 5.21 A*

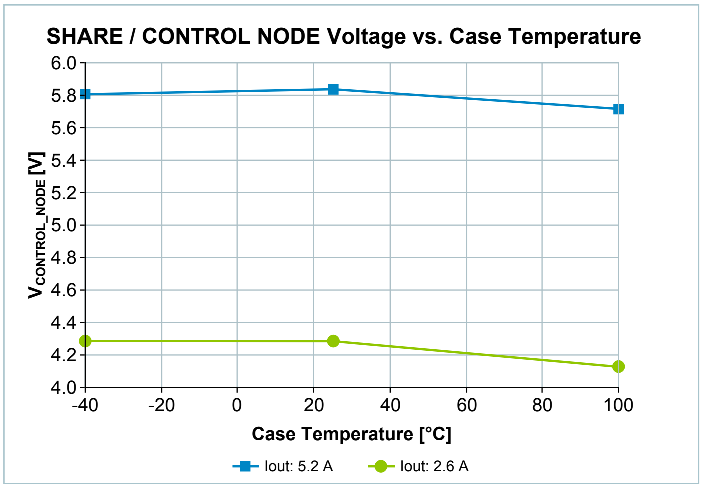


Figure 17 *— Typical SHARE / CONTROL NODE Voltage vs. T_{CASE} and I_{OUT}; V_{IN} = 48.0 V, V_{OUT} = 48.0 V*

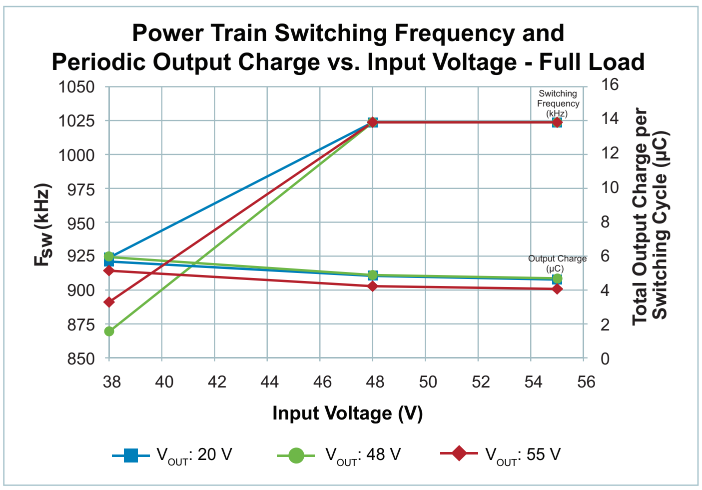


Figure 15 *— Typical Power Train Switching Frequency and Periodic Output Charge vs. V_{IN}, V_{OUT}; I_{OUT} = 5.21 A*