*Click **here** to ask an associate for production status of specific part numbers.*

MAX20796

Dual-Phase Scalable Integrated Voltage Regulator with PMBus Interface

General Description

The MAX20796 offers a fully integrated, highly efficient, two-phase switching regulator for applications operating from 4.5V to 16V and requiring up to 60A maximum load or 90A with an optional third-phase external power stage. The output voltage range can be configured from 0.5V to 5.5V with some restrictions on duty cycle. The switching regulator uses a fixed-frequency control scheme providing an extremely compact, fast, and accurate power delivery solution for server and telecom applications. Integrated linear regulators allow single-supply operation. To further improve system efficiency and thermal performance, an external 3.3V supply or FET can be used to generate the core supply.

Key system parameters are configured by external resistors, including the selection of soft-start timing, output voltage, switching frequency, PMBus™ address, overcurrent trip point, and loop control parameters. The device operates with either coupled or discrete inductors. Coupled inductor technology offers high performance with a minimum number of input and output capacitors for best-in-class solution cost.

The MAX20796 includes fault protection and reporting capabilities. Inherent positive and negative overcurrent and overtemperature protection ensure a rugged design. Input undervoltage lockout shuts down the device when the input voltage is out of specification. Regulation is halted if the output voltage is outside of a programmable range. A PGOOD pin provides an output signal to show that the output voltage is within range and the system is regulating.

The MAX20796 is offered in a 35-pin, 4mm × 10.5mm FC2QFN package, ideal for use in networking and communication end equipment.

The device is also available as MAX20796A, which is preconfigured for a 1V, 800kHz application with LEAD_LAG enabled.

Applications

- Point-of-Load Voltage Regulators
- Communication, Networking, Servers, and Storage
- Equipment
- Microprocessor Chipsets
- Memory VDDQ
- I/O and Auxiliary Power

Benefits and Features

- Peak Efficiency 92%; Full-Load Efficiency 90% at V_{IN} = 12V, V_{OUT} = 1V
- Operating Input Voltage Range 4.5V to 16V
- Output Voltage Range is 0.5V to 5.5V
- Output Boot Voltage Pin-Strapped Range 0.5V to 5.0V with Direct Feedback
- Integrated Loop Compensation
- Supports Coupled and Discrete Inductors
- PMBus Revision 1.3 Compliant Interface
- Supports External Power Stage to Increase Power Capacity
- Internal Linear Regulators Allow Operation from One Supply Voltage
- Optional External LDO FET for Enhanced Thermal Performance
- Pin-Strapped Configurable Operating Parameters:
  - 32 PMBus Addresses
  - Output Voltage
  - Switching Frequency
  - Overcurrent Protection (OCP) Threshold
  - Soft-Start Time
  - Loop Compensation
- Supports Nonvolatile PMBus Command Storage (Five Writes Available)
- Continuous Conduction Mode Operation Only
- Integrated Accurate Current and Temperature Sensing
- Monotonic Startup and Shutdown, Supports Prebias Startup (Two Phase)
- Fast Peak and Average Overcurrent Protection
- RESTORE Input Pin Resets Output Voltage
- Operating Junction Temperature Range: -40°C to +125°C
- Package: 35-pin, 4mm × 10.5mm, 0.5mm pitch, FC2QFN

PMBus is a trademark of SMIF, Inc.

***Ordering Information** appears at end of data sheet.*

19-100376; Rev 5; 12/21

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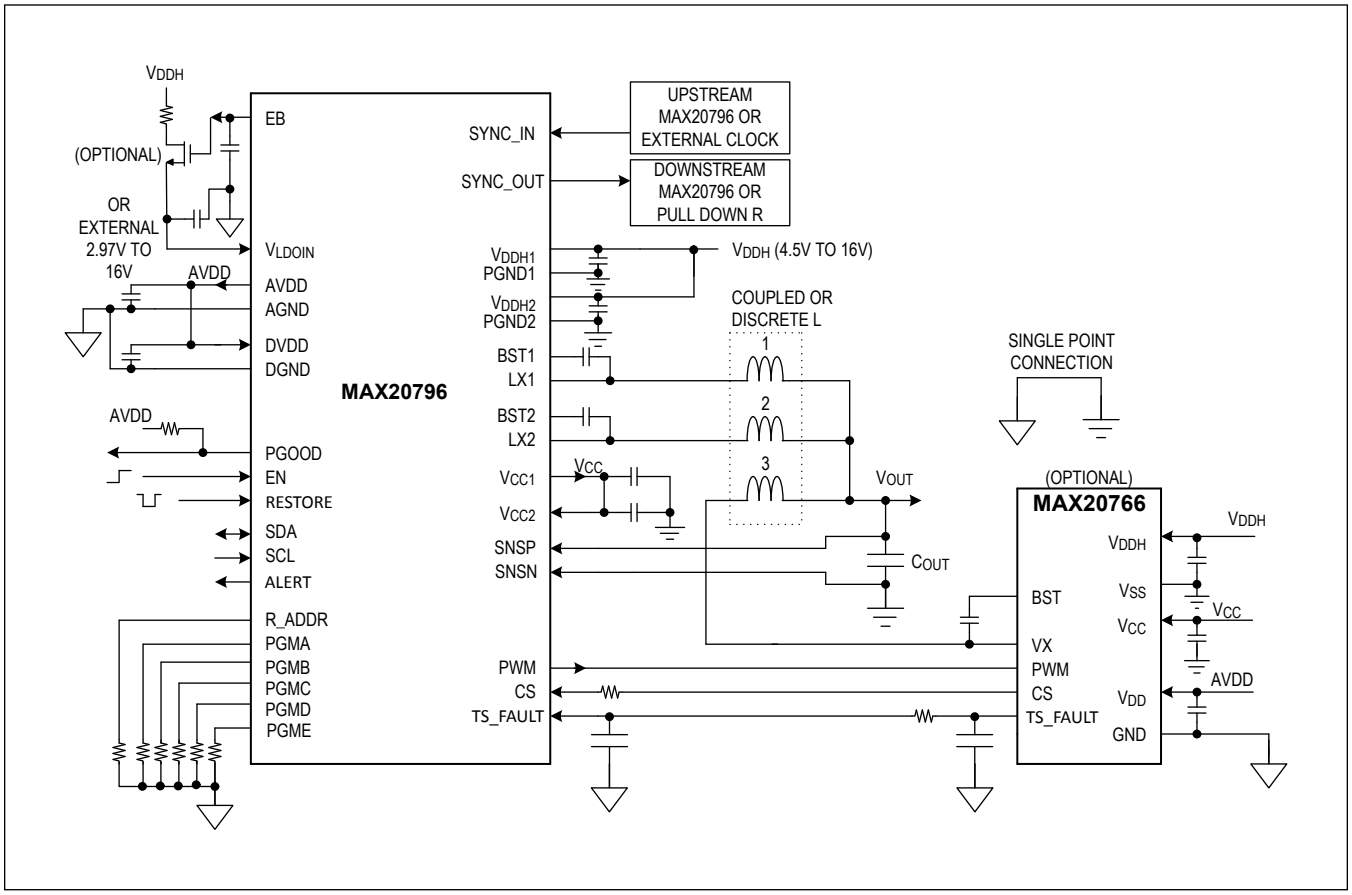
Simplified Application Schematic



Current Ratings

DESCRIPTION	CURRENT RATING* (A)	INPUT VOLTAGE (V)	OUTPUT VOLTAGE (V)
Electrical Rating	60	4.5 to 16	0.5 to 5.5
Thermal Rating T_A = +55°C, 200LFM	60	12	0.8
Thermal Rating T_A = +85°C, 0LFM	42	12	0.8

Current capability is tested with MAX20796 EV kit two-phase configuration.

**For specific operating conditions, refer to the SOA curves in the Typical Operating Characteristics section.*

Absolute Maximum Ratings

$V_{DDH_}$ to PGND_ (Note1) ..... -0.3V to +18V
V_{LDOIN} to PGND_ (Note1) ..... -0.3V to +18V
LX_ to PGND_ (DC) ..... -0.3V to +18V
LX_ to PGND_ (AC) (Note 2) ..... -10V to +23V
BST_ to PGND_ (DC) ..... -0.3V to +20.5V
BST_ to PGND_ (AC) (Note 2) ..... -7V to +25.5V
BST_ to LX_ Differential ..... -0.3V to +2.5V
AVDD, V_{CC1}, V_{CC2} to AGND ..... -0.3V to +2.5V
DVDD to DGND ..... -0.3V to +2.5V
PGND_, DGND to AGND ..... -0.3 to +0.3
SCL, SDA, $\overline{ALERT}$ to AGND ..... -0.3V to +3.7V
RADDR, PGM_, SYNC_IN,SYNC_OUT to DGND ..... -0.3V to +2.5V
$\overline{TS_FAULT}$, $\overline{PWM}$, CS to AGND ..... -0.3V to AVDD + 0.3V
PGOOD, EN, $\overline{RESTORE}$ to AGND ..... -0.3V to +3.7V
EB ..... -0.3V to +7.5V
SNSP to AGND ..... -0.3V to +5.5V
Peak LX_ Current (Note 3) ..... -72A to +72A
Junction Temperature (T_J) ..... +150°C
Storage Temperature Range ..... -65°C to +150°C
Peak Reflow Temperature Lead-Free ..... +260°C
Maximum Average Input Current (I_{VDDH1} + I_{VDDH2}) 28A

Note 1: Input high-frequency bypass capacitors placed not more than 60mil away from the V_{DDH} pin are required to keep inductive voltage spikes within Absolute Maximum Ratings limits.

Note 2: AC is limited to 25ns.

Note 3: Per phase current capability. I_{POCP_R} limits the application below the peak LX_ current rating.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Package Information

35-PIN FC2QFN

Package Code	F354A10F+2
Outline Number	21-100023
Land Pattern Number	90-100044
Thermal Resistance	
Junction to Ambient (θ_{JA}) JEDEC	32.9°C/W
Junction to Ambient (θ_{JA}) on MAX20796CL2EVKIT#	9.6°C/W
Junction to Case (θ_{JC})	0.20°C/W

For the latest package outline information and land patterns (footprints), go to *www.maximintegrated.com/packages*. Note that a "+", "#", or "-" in the package code indicates RoHS status only. Package drawings may show a different suffix character, but the drawing pertains to the package regardless of RoHS status.

Package thermal resistances were obtained using the method described in JEDEC specification JESD51-7, using a four-layer board. For detailed information on package thermal considerations, refer to *www.maximintegrated.com/thermal-tutorial*.

Electrical Characteristics

(Typical Application Circuit, unless otherwise noted, $V_{DDH_}$ = 12V, V_{LDOIN} = 3.3V, -40°C ≤ T_J ≤ +125°C; specifications are production tested at T_A = +32°C; limits within the operating temperature range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
INPUT SUPPLY VOLTAGES AND CURRENTS						
Input Supply Voltage Range	V_{DDH1} V_{DDH2}	V_{DDH1} and V_{DDH2} are shorted together	4.5		16	V
Input Supply Current	I_{VDDH1} + I_{VDDH2}	Shutdown (EN low), V_{DDH1} = V_{DDH2} = 12V, V_{LDOIN} = 3.3V		1		mA
Linear Regulator Input Voltage	V_{LDOIN}		2.97		16	V

Electrical Characteristics (continued)

(Typical Application Circuit, unless otherwise noted, $V_{DDH_}$ = 12V, V_{LDOIN} = 3.3V, -40°C ≤ T_J ≤ +125°C; specifications are production tested at T_A = +32°C; limits within the operating temperature range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Linear Regulator Input Current	I_{LDOIN}	System operational, no load, f_{SW} = 400kHz (two-phase operation). V_{OUT} = 1.0V		86	175	mA
		Shutdown (EN low)		24		
LINEAR REGULATOR (EB PIN)						
External FET Output Set-Point Voltage		$V_{DDH_}$ > 5.1V regulating	2.97	3.06	3.63	V
EB Sink/Source Current	I_{EB}	V_{EB} from 0.7V to 6V	25	48		µA
OUTPUT VOLTAGE RANGE AND ACCURACY						
DC Set-Point Voltage Accuracy		T_J = +32°C, V_{OUT} = 0.6V to 5.0V, measured between SNSP and SNSN pins	-0.8		+0.8	%
Voltage-Sense Input Bias Current	I_{SNSN}	-0.3V < V_{SNSN} < 0.3V	-15		+15	µA
	I_{SNSP}	0V < V_{SNSP} < 5.5V	-240		+240	
SWITCHING FREQUENCY ACCURACY						
Switching Frequency	f_{SW}	PGMx pin-strap or PMBUS programmable		200 to 799		kHz
Switching Frequency Accuracy		(Note 4)		±10		%
INPUT VOLTAGE PROTECTION						
V_{DDH} Undervoltage Lockout	V_{VDDH_UVLO}	Rising V_{DDH}	4.28	4.40	4.54	V
V_{DDH} Undervoltage-Lockout Hysteresis				500		mV
V_{CC} Undervoltage Lockout	V_{VCC_UVLO}	Rising V_{CC}	1.53	1.59	1.63	V
V_{CC} Undervoltage-Lockout Hysteresis				50		mV
AV_{DD} Undervoltage Lockout	V_{AVDD_UVLO}	Rising AV_{DD}	1.53	1.61	1.66	V
AV_{DD} Undervoltage-Lockout Hysteresis				50		mV
V_{BST} Undervoltage Lockout	V_{VBST_UVLO}	Rising V_{BST}	1.46	1.56	1.64	V
V_{BST} Undervoltage-Lockout Hysteresis				50		mV
OUTPUT VOLTAGE PROTECTION						
V_{OUT} Overvoltage Protection (OVP) Rising Threshold (Tracking)		V_{OUT} = 0.500 to 2.437V. Relative to DAC voltage. Direct feedback.	190	210	225	mV
		V_{OUT} = 2.438 to 5.000V. Relative to DAC voltage. Direct feedback.	415	460	485	
OVP Blanking Time		End of TON_RISE to protection active (Note 4)			6	µs

Electrical Characteristics (continued)

(Typical Application Circuit, unless otherwise noted, $V_{DDH_}$ = 12V, V_{LDOIN} = 3.3V, -40°C ≤ T_J ≤ +125°C; specifications are production tested at T_A = +32°C; limits within the operating temperature range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
V_{OUT} Undervoltage-Protection (UVP) Falling Threshold		V_{OUT} = 0.500 to 2.437V. Relative to DAC voltage. Direct feedback.	-310	-290	-270	mV
		V_{OUT} = 2.438 to 5.000V. Relative to DAC voltage. Direct feedback.	-670	-640	-610	
V_{OUT} UVP and OVP Deglitch Time		(Note 4)		2		µs
OVERCURRENT PROTECTION (OCP)						
Average OCP Rising Threshold per Phase	I_{OCP_AVG}	Pin-strap programmable		10 to 33.3		A
Average OCP Rising Threshold Accuracy		Two phase (Note 4)		±10		%
POWER-STAGE PEAK CURRENT PROTECTION						
Positive Peak Current Rising Threshold per Power Train	I_{POCP_R}	V_{DDH1} = V_{DDH2} = 12V (Note 4)	44.0		62.0	A
Positive Peak Current Falling Threshold per Power Train	I_{POCP_F}	V_{DDH1} = V_{DDH2} = 12V (Note 4)	30.8		42.0	A
Negative Peak Current Limit per Power Train	I_{NOCP}	V_{DDH1} = V_{DDH2} = 12V (Note 4)		-39.2		A
EXTERNAL POWER-STAGE DRIVE INTERFACE (PWM, CS, $\overline{TS_FAULT}$)						
PWM Output	V_{PWM}	Logic high voltage, sourcing 4mA	1.32			V
		Logic low voltage, sinking 4mA			0.4	
Power-Stage Fault Logic-Low Threshold		With respect to AGND		300		mV
OUTPUT ENABLE (EN)						
EN Thresholds	V_{EN_IH}	Input logic-high	0.9			V
	V_{EN_IL}	Input logic-low			0.4	
EN Deglitch Delay				1		µs
Turn-on Response Time		From V_{EN_IH} to T_{ON_DELAY} start (Note 4)		20		µs
Turn-off Response Time	t4	From V_{EN_IL} to T_{OFF_DELAY} start (Note 4)		2		µs
STARTUP TIMING						
Time from EN High to Start of Switching	t_3	T_{ON_DELAY} = 0, two-phase operation with ≥ 1A load (Note 4)		10		µs
Initialization Time (Includes Pin-Strap Read Time)	t_2	V_{DDH}, V_{CC}, AVDD UVLO cleared (Note 4)		10		ms
Soft-Start Time	TON_RISE	Pin-strap programmable TON_ RISE (Note 4)		0.5,1,4,8		ms
		PMBus programmable TON_RISE (Note 4)		0 to 25		

Electrical Characteristics (continued)

(Typical Application Circuit, unless otherwise noted, $V_{DDH_}$ = 12V, V_{LDOIN} = 3.3V, -40°C ≤ T_J ≤ +125°C; specifications are production tested at T_A = +32°C; limits within the operating temperature range are guaranteed by design and characterization.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Soft-Start Time Accuracy		(Note 4)		±5		%
PGOOD PIN						
PGOOD Rising Threshold		V_{OUT} = 0.500 to 2.437V. Relative to DAC voltage. Direct feedback.	-305	-285	-265	mV
		V_{OUT} = 2.438 to 5.000V. Relative to DAC voltage. Direct feedback.	-660	-625	-590	
PGOOD Threshold Hysteresis		V_{OUT} = 0.5V to 5.0V. Direct feedback.		10		mV
PGOOD Output High Leakage Current	I_{PGOOD}	PGOOD pulled to 3.3V through 20kΩ			1	µA
PGOOD Output Low	V_{PGOOD_OL}	I_{PGOOD} = 4mA			0.4	V
R_ADDR, PGMA, PGMB, PGMC, PGMD, PGME PIN						
Total Allowable Resistor Accuracy		(Note 4)			±1	%
Maximum External Stray Capacitance		(Note 4)			5	pF
$\overline{\text{RESTORE}}$ PIN						
$\overline{\text{RESTORE}}$ Logic-Low Voltage	V_{RSTB_IL}	Input voltage falling			0.47	V
$\overline{\text{RESTORE}}$ Logic-High Voltage	V_{RSTB_IH}	Input voltage rising	1.3			V
Input Leakage Current			-12		+12	µA
Deglitch Time		(Note 4)	10			µs
$\overline{\text{RESTORE}}$ Pullup Resistance			150	220	280	kΩ
SYNCHRONIZATION						
SYNC_IN Pin Input Low	V_{SYNC_IL}				0.47	V
SYNC_IN Pin Input High	V_{SYNC_IH}		1.32			V
SYNC_IN Input Duty Cycle		f_{SW} = 800kHz	10		90	%
Synchronization Lock Frequency Range		With respect to pin-strap fSW	-15		+30	%
SYNC_OUT Pin Output Low	V_{SYNC_OL}	Sinking 4mA			0.4	V
SYNC_OUT Pin Output High	V_{SYNC_OH}	Sourcing 4mA	1.31			V
PMBus TELEMETRY						
System ADC Update Rate		Input voltage (Note 4)		13		ms
		Junction temperature (Note 4)		13		
		Output voltage (Note 4)		6.5		
		Output total average current (Note 4)		13		
System ADC Resolution				10		bits

Electrical Characteristics (continued)

(Typical Application Circuit, unless otherwise noted, $V_{DDH_}$ = 12V, V_{LDOIN} = 3.3V, -40°C ≤ T_J ≤ +125°C; specifications are production tested at T_A = +32°C; limits within the operating temperature range are guaranteed by design and characterization.)

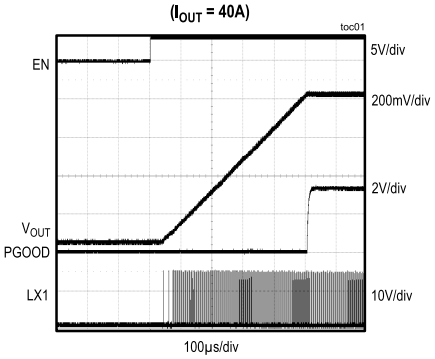
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Telemetry Error		READ_VIN vs. measurement, no load, V_{DDH} = 12V	-3		3	%
		READ_VOUT vs. measurement, V_{OUT} = 1.0V, 0A to 50A load	-1		1	
		READ_IOUT vs. measurement at V_{OUT} = 1.0V, no load	-2.2		+2.2	A
		READ_IOUT vs. measurement at V_{OUT} = 1.0V, 50A load	-3.6		+3.6	
		READ_TEMPERATURE1 vs. measurement, V_{DDH} = 9V to 12V, f_{SW} = 400kHz, V_{OUT} = 0.6V to 1.0V, no load		±4		°C
PMBus/SMBus						
SDA, SCL Input Logic-Low Voltage	V_{BUS_IL}				0.8	V
SDA, SCL Input Logic-High Voltage	V_{BUS_IH}		1.45			V
SDA, SCL, $\overline{ALERT}$ Logic-High Leakage Current		V_{SCL}, V_{SDA} = 3.3V, and $\overline{ALERT}$ = 3.3V			1	µA
SDA, $\overline{ALERT}$ Output Logic-Low		Sinking 4mA			0.4	V
PMBus Operating Frequency	f_{SCL}				1000	kHz
SDA Hold Time from SCL	t_{HD_DAT}	(Note 4)	300			ns
SDA Setup Time from SCL	t_{SU_DAT}	(Note 4)	100			ns
SCL High Period	t_{HIGH}	(Note 4)	0.5			µs
SCL Low Period	t_{LOW}	(Note 4)	0.5			µs

Note 4: Guaranteed by design.

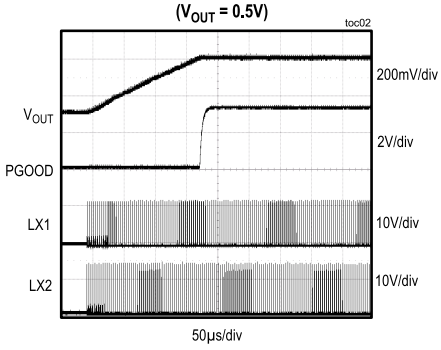
Typical Operating Characteristics

(Typical Application Circuit, V_{DDH} = 12V, V_{LDOIN} = 3.3V, FREQUENCY_SWITCH = 308kHz, T_A = +25°C, V_{OUT} = 3.3V and 5.0V are tested under f_{SW} = 800kHz, unless otherwise noted.)

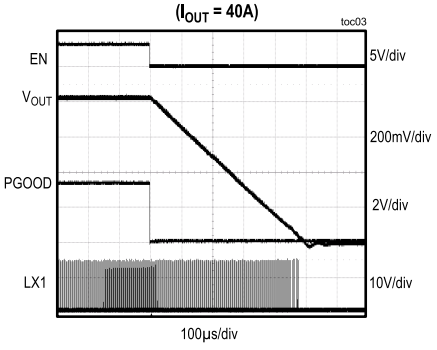
STARTUP
(I_{OUT} = 40A)



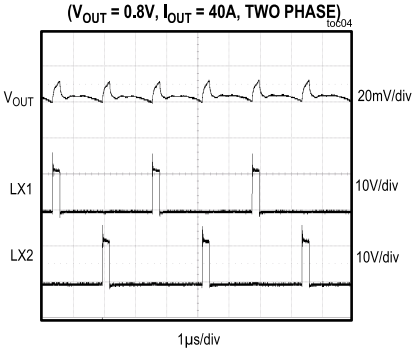
PREBIAS STARTUP
(V_{OUT} = 0.5V)



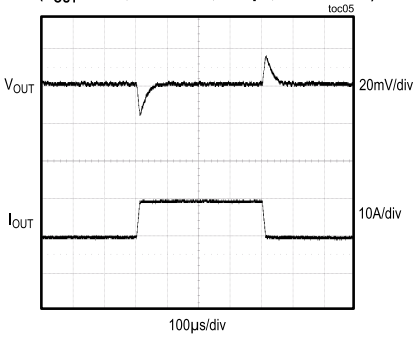
SHUTDOWN
(I_{OUT} = 40A)



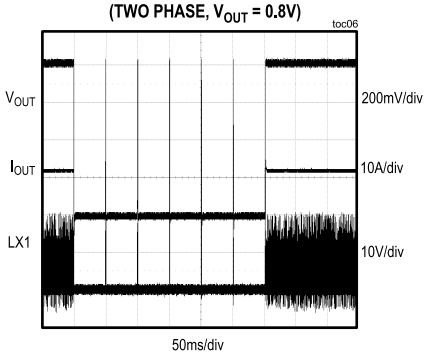
V_{OUT} RIPPLE
(V_{OUT} = 0.8V, I_{OUT} = 40A, TWO PHASE)



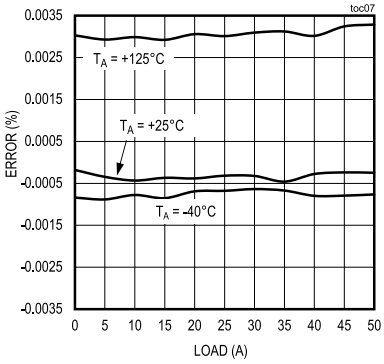
LOAD TRANSIENT
(V_{OUT} = 0.8V, 20A to 30A, 10A/µs, TWO PHASE)



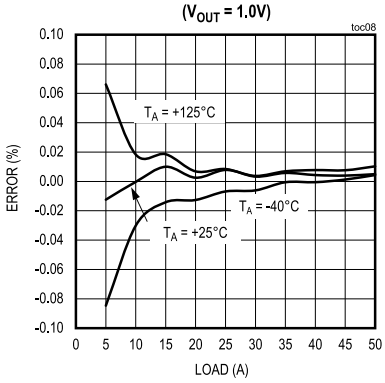
OVERCURRENT PROTECTION AND RECOVERY
(TWO PHASE, V_{OUT} = 0.8V)



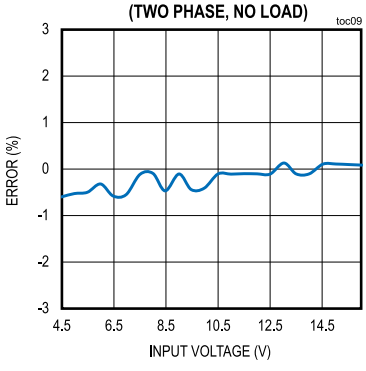
READ_VOUT vs. LOAD
(V_{OUT} = 1.0V)



READ_IOUT vs. LOAD
(V_{OUT} = 1.0V)



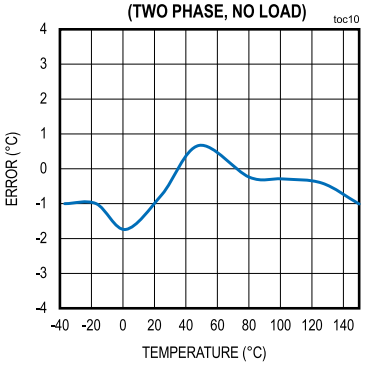
READ_VIN ACCURACY
(TWO PHASE, NO LOAD)



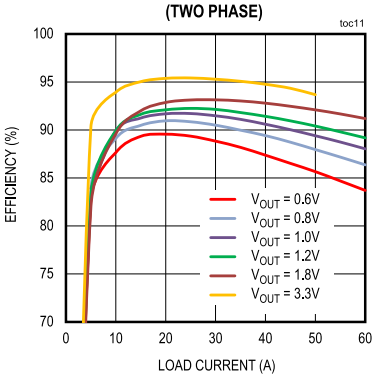
Typical Operating Characteristics (continued)

(Typical Application Circuit, V_{DDH} = 12V, V_{LDOIN} = 3.3V, FREQUENCY_SWITCH = 308kHz, T_A = +25°C, V_{OUT} = 3.3V and 5.0V are tested under f_{SW} = 800kHz, unless otherwise noted.)

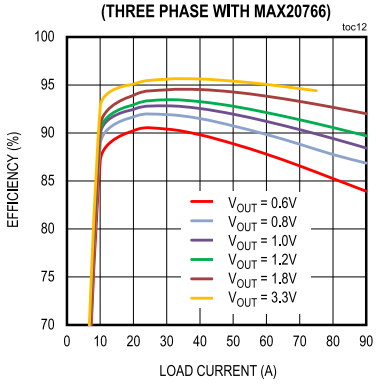
READ_TEMPERATURE_1 ACCURACY (TWO PHASE, NO LOAD)



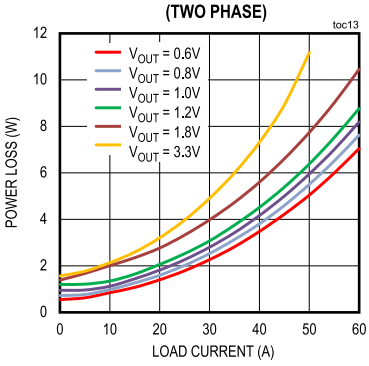
EFFICIENCY (TWO PHASE)



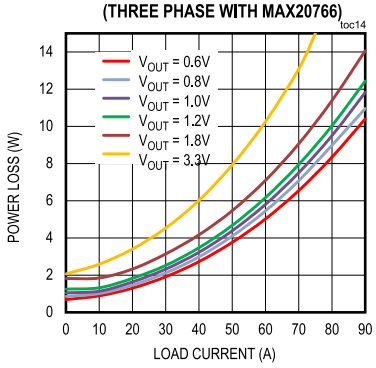
EFFICIENCY (THREE PHASE WITH MAX20766)



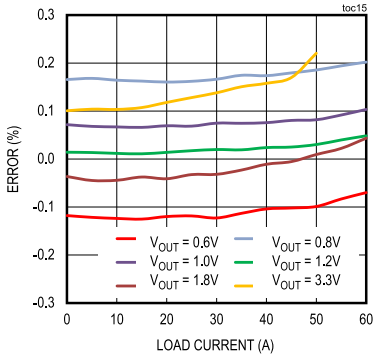
POWER LOSS (TWO PHASE)



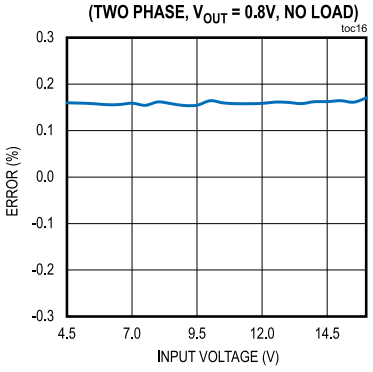
POWER LOSS (THREE PHASE WITH MAX20766)



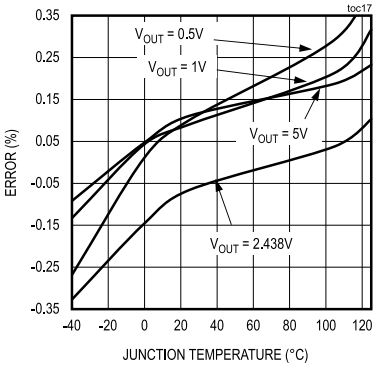
LOAD REGULATION (TWO PHASE)



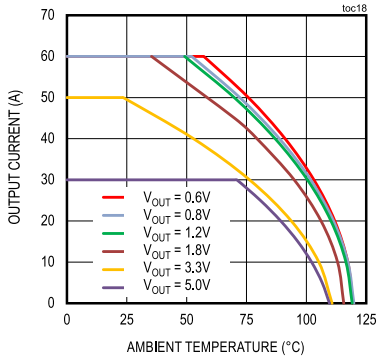
LINE REGULATION (TWO PHASE, V_{OUT} = 0.8V, NO LOAD)



DC SET-POINT VOLTAGE ACCURACY



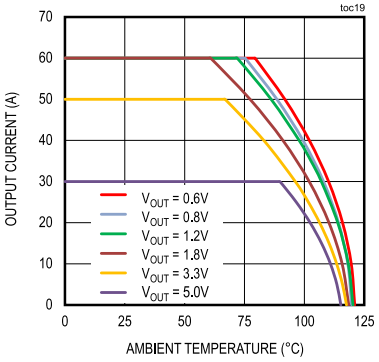
SAFE OPERATING AREA (SOA) (NO AIR FLOW, NO HEATSINK, TWO PHASE)



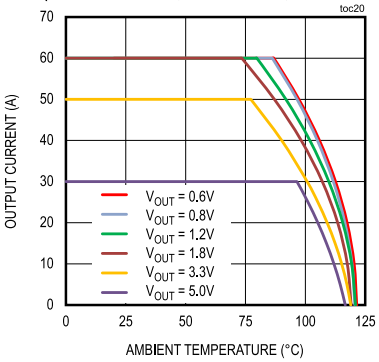
Typical Operating Characteristics (continued)

(Typical Application Circuit, V_{DDH} = 12V, V_{LDOIN} = 3.3V, FREQUENCY_SWITCH = 308kHz, T_A = +25°C, V_{OUT} = 3.3V and 5.0V are tested under f_{SW} = 800kHz, unless otherwise noted.)

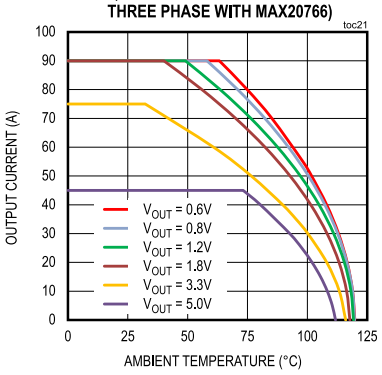
SAFE OPERATING AREA (SOA)
(200LFM AIR FLOW, NO HEATSINK, TWO PHASE)



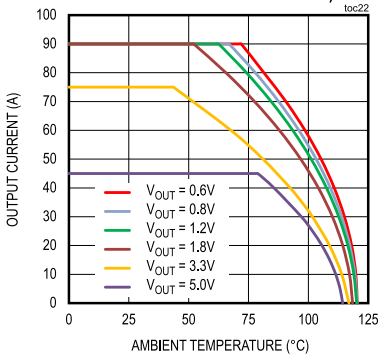
SAFE OPERATING AREA (SOA)
(400LFM AIR FLOW, NO HEATSINK, TWO PHASE)



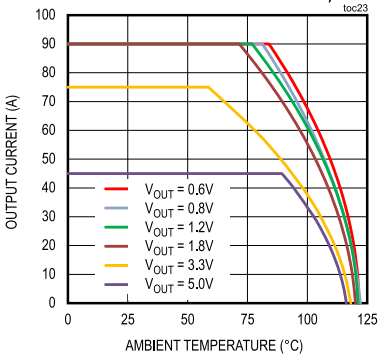
SAFE OPERATING AREA (SOA)
(NO AIR FLOW, NO HEATSINK,
THREE PHASE WITH MAX20766)



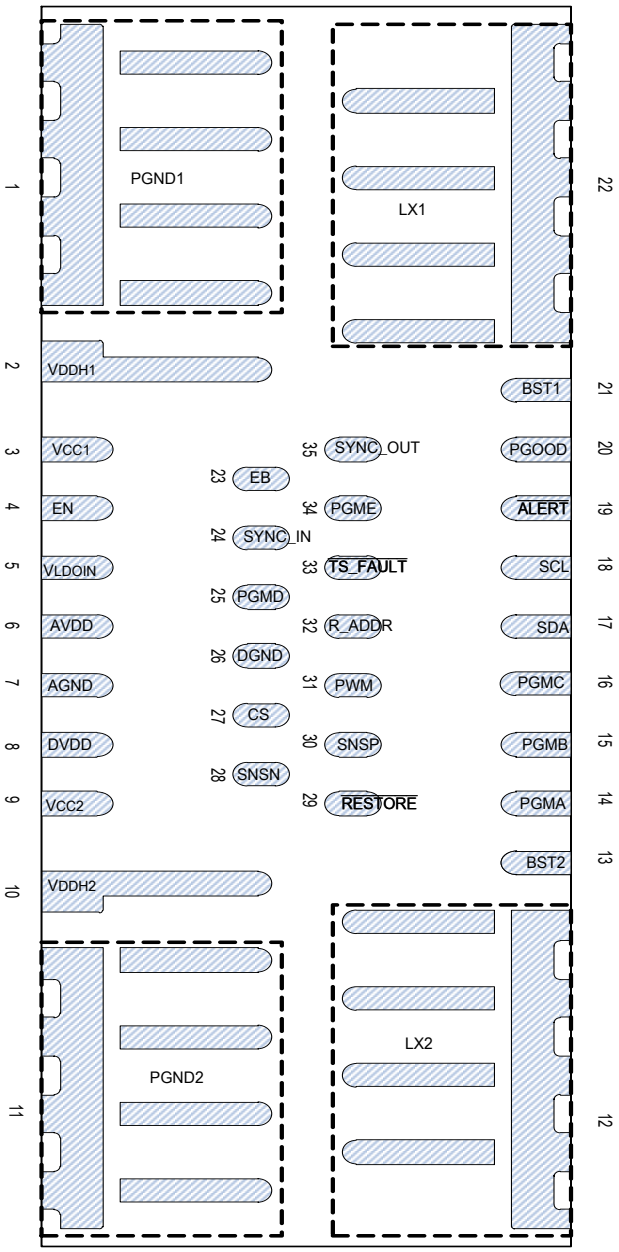
SAFE OPERATING AREA (SOA)
(200LFM AIR FLOW, NO HEATSINK,
THREE PHASE WITH MAX20766)



SAFE OPERATING AREA (SOA)
(400LFM AIR FLOW, NO HEATSINK,
THREE PHASE WITH MAX20766)



Pin Configuration



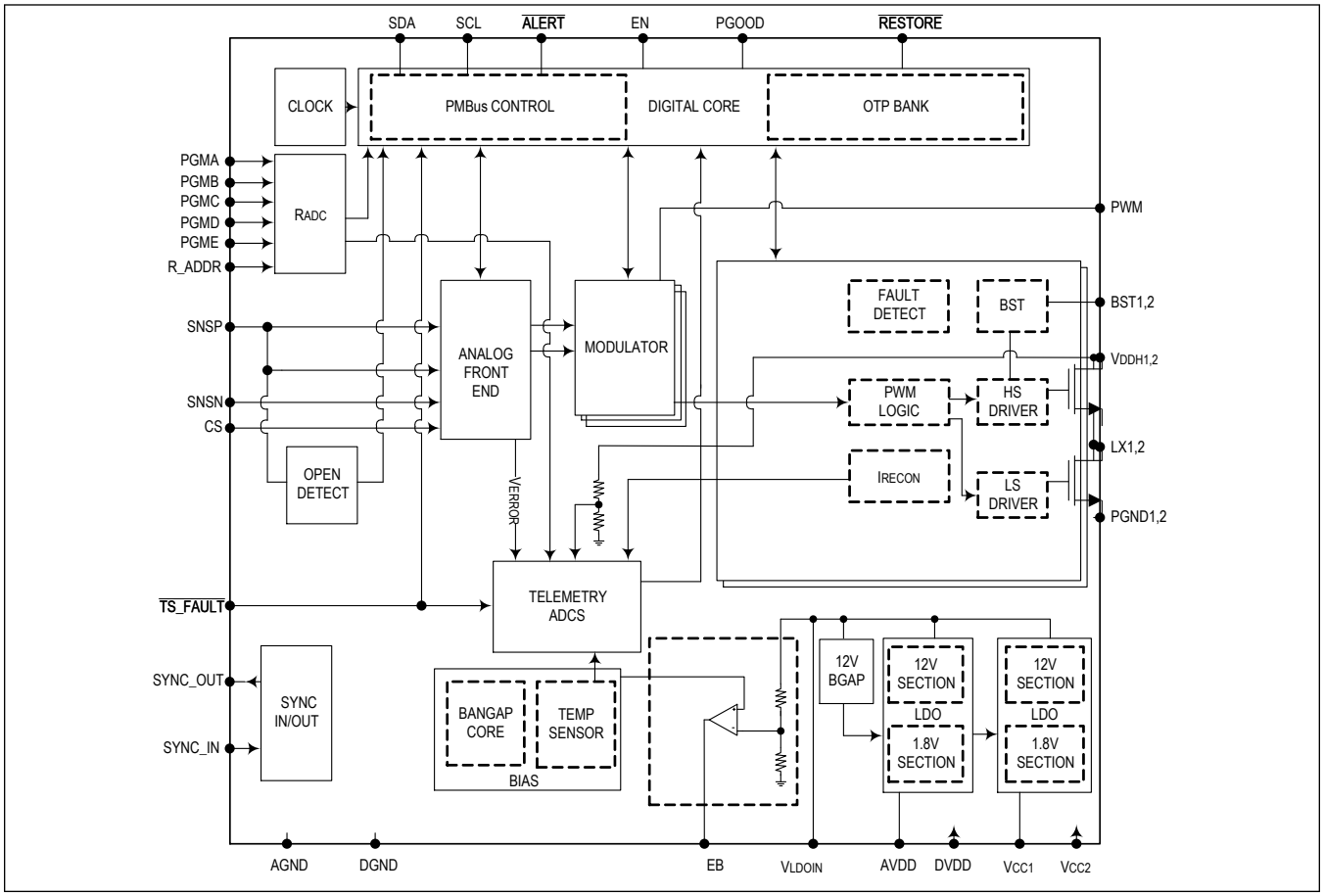
Pin Description

PIN	NAME	FUNCTION
1	PGND1	Power Ground 1
2	V_{DDH1}	Power-Supply Input. The high-side MOSFET switch 1 is connected to this node.
3	V_{CC1}	Internal Linear Regulator Output Pin for Gate Bias Supply. Connect a 4.7µF ceramic capacitor to PGND and place it close to this pin.

Pin Description (continued)

PIN	NAME	FUNCTION
4	EN	Active-High Enable Input
5	V_{LDOIN}	Internal Linear Regulator Input Supply. Connect an external power supply with a 4.7µF capacitor.
6	AVDD	Internal Linear Regulator Output Pin for Core Power Supply. Connect a 4.7µF ceramic capacitor to AGND and place it close to this pin.
7	AGND	Analog Ground for AVDD Decoupling
8	DVDD	Supply Pin for Digital Circuit. Connect a 1µF ceramic capacitor to DGND and place it close to this pin.
9	V_{CC2}	Internal Linear Regulator Output Pin for Gate Bias Supply. Connect a 4.7µF ceramic capacitor to PGND and place it close to this pin.
10	V_{DDH2}	Power-Supply Input. The high-side MOSFET switch 2 is connected to this node.
11	PGND2	Power Ground 2
12	LX2	Switching Node 2. Connect directly to the output inductor.
13	BST2	Bootstrap Pin for High-Side Switch 2. Connect to BST2 with a 0.22µF ceramic capacitor.
14–16, 25, 34	PGMA, PGMB, PGMC, PGMD, PGME	Program Pin (see Pin Program Table)
17	SDA	SMBus Data
18	SCL	SMBus Clock
19	$\overline{ALERT}$	SMBus Alert. This pin is an open-drain output that pulls low when SMBus interaction is required.
20	PGOOD	Power Good Indication. Open-drain output pin.
21	BST1	Bootstrap Pin for High-Side Switch 1. Connect to BST1 with a 0.22µF ceramic capacitor.
22	LX1	Switching Node 1. Connect directly to the output inductor.
23	EB	External FET Driver Output. Ground for internal Linear Regulator mode; or connect to external nFET gate for external Linear Regulator mode.
24	SYNC_IN	Synchronization Clock Input. Ground it to AGND through a 49.9Ω resistor if not used.
26	DGND	Ground for Digital Circuit. Connect this pin directly to AGND pin.
27	CS	External Power Stage IC Current-Sensing Input. Connect to the external power-stage CS output through a 499Ω resistor, or pulled to AGND if not used.
28	SNSN	Output Voltage Differential-Sense Negative Input
29	$\overline{RESTORE}$	Output Restore Pin. Pull high to AVDD through an external resistor. Falling edge effective, restore to pin-strapped voltage.
30	SNSP	Output Voltage Differential Sense Positive Input
31	PWM	External Power Stage PWM Output. Connect to the external power-stage PWM input, or pulled to AGND if not used.
32	R_ADDR	PMBus Address Program Pin (see Pin Program Table)
33	$\overline{TS_FAULT}$	External Power-Stage $\overline{TS_FAULT}$ Connection. Temperature sense and fault input. Connect a 100pF capacitor to AGND. Float it if not used.
35	SYNC_OUT	Synchronization Clock Output. Connect this pin to the downstream regulator SYNC_IN pin or a pulldown resistor to ground. See Table 2 for details.

Block Diagram



Detailed Description

The MAX20796 is a highly efficient, monolithic, high-performance 60A integrated dual-phase buck regulator, compliant with PMBus specification Revision 1.3. The MAX20796 solution can be paired with an external power stage, such as the MAX20766 to support up to 90A loads.

This architecture uses lossless current sensing to provide a superior control loop with simple design parameters, high-accuracy current reporting, and fast fault protection. The integrated power switches in MAX20796 and MAX20766 provide low switching losses for a wide range of output currents. The external power stage can be included or omitted, allowing a common PCB layout to be used for multiple applications with different output currents.

Key system parameters are set by the programming resistors at the PGMx pins, which select different application configurations by hardware only. These system parameters and other features can be adjusted by using the PMBus interface as well.

The device includes a PMBus interface that provides extensive reporting features and allows reconfiguring the regulator for development purposes or adapting to different conditions. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for more details.

In order to support single-input rail operation, the MAX20796 contains an internal linear regulator to convert the input voltage into the lower voltage that powers the IC internal bias circuitry and gate drive circuitry. Two integrated 1.8V linear regulators, one for AVDD and DVDD and the other for V_{CC1} and V_{CC2}, are employed.

The integrated features simplify the overall implementation, making the MAX20796 solution a completely high power-density solution.

Control Architecture

The MAX20796 control loop is based on the multiphase peak current-mode control architecture. The loop contains multiple amplifier stages and modulator circuits that switch each phase based on its phase current. Figure 1 shows the internal amplifier stages of the controller and how phase-current information is used to generate the phase-control signals by using a two-phase system as an example. The first error amplifier stage is a differential amplifier, which provides an output equal to 2.2 times the error between the reference voltage and the differential remote-sense voltage. Its output voltage (V_{ERR}) is used as the input of the first proportional integral (PI) block used for voltage loop. Then the output voltage of the PI_V block minus the total sensed phase currents ($I_{L_TOT} \times R_{INT}$) are generated as the current-loop error amplifier input (V_{IDES}). After V_{IDES} is handled by another PI amplifier, its output (V_C) along with the slope compensation ramp (V_{RAMP}) and the current balancing info (VOCR), are used for the PWM modulation (MOD) for each phase.

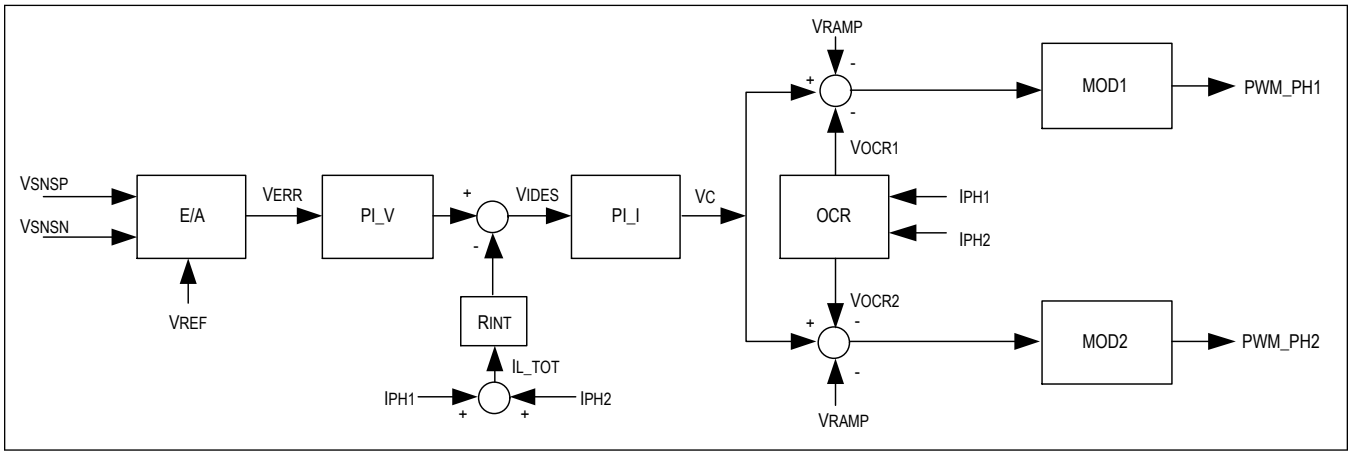


Figure 1. Simplified Control Architecture

Interleaved Operation

Interleaved operation reduces the output current and voltage ripple, and mitigates input capacitor AC current stress.

The MAX20796 has its two phases switching with a 180-degree phase shift. If there is an external power stage, the phase shift is 120 degrees. Both coupled and discrete inductors are supported by this interleaved operation. Coupled inductor technology can effectively reduce the current ripple and it requires less output capacitance to meet the transient requirement, which makes it a good candidate for high-power-density design.

Startup and Shutdown

When AVDD, V_{CCx}, and DVDD are above their rising UVLO thresholds, the device goes through an initialization and phase-detection procedure. Configuration resistors on R_ADDR and PGMx pins are read and checked for valid values. Any faults during the initialization process prevent switching. If an external power stage is present, additional initialization time is needed for the controller to configure itself before switching. Detailed timing can be found in Figure 2. The PMBus communication and telemetry are then active. The V_{DDH} voltage must be above its rising UVLO threshold for the output voltage to turn on.

Depending on how the voltage-regulation enable is configured, an enable signal from the EN pin or the PMBus OPERATION Command might be required for the output voltage to turn on. The default configuration for the enable signal is with the EN pin at the high logic level, with no PMBus command needed.

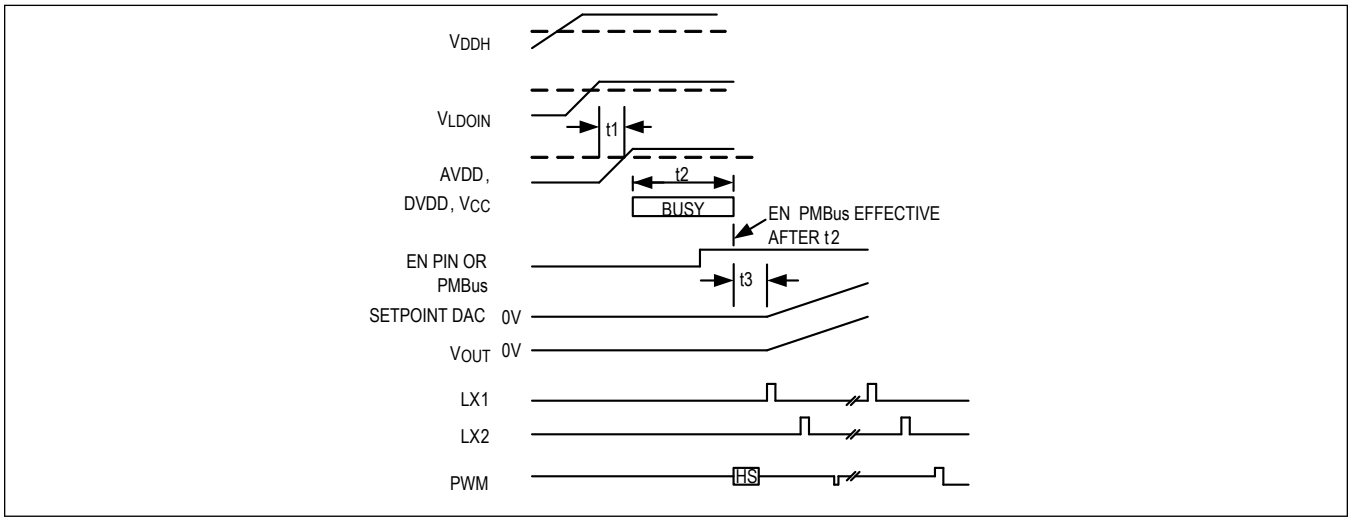


Figure 2. Startup Timing Diagram

When the V_{DDH} voltage is above its rising UVLO threshold and the proper enable signal has occurred, the output voltage turns on after the PMBus programmable TON_ DELAY time. The output voltage starts to ramp up towards the target voltage VOUT_COMMAND, which is initially set by the PGMA resistor with the soft-start time TON_RISE initially set by the PGME resistor. After the output voltage has reached its nominal value, the PGOOD signal is asserted. Table 1 shows the typical timing in the startup and shutdown process.

Depending on how the voltage-regulation enable is configured, the output voltage can be turned off using the EN signal or the PMBus OPERATION Command. By default, the output turnoff time (TOFF_FALL) is the same time as TON_RISE. A delay time can be set by the PMBus command TOFF_DELAY. Note that when V_{OUT} ramps down, energy might be delivered from output to input. The input capacitor should be sized to absorb this energy to prevent a large increase in the V_{DDH} voltage. Figure 3 shows shut down by EN with TOFF_FALL.

Table 1. Startup and Shutdown Timing

	TYPICAL	DESCRIPTION
t1	5ms	Bias-voltage setup time
t2	10ms	Initialization time (PGMx, R_ADDR read time)
t3	150µs	Delay time from EN rise to start of switching
t4	2µs	Delay time from EN falling edge to start of TOFF_DELAY

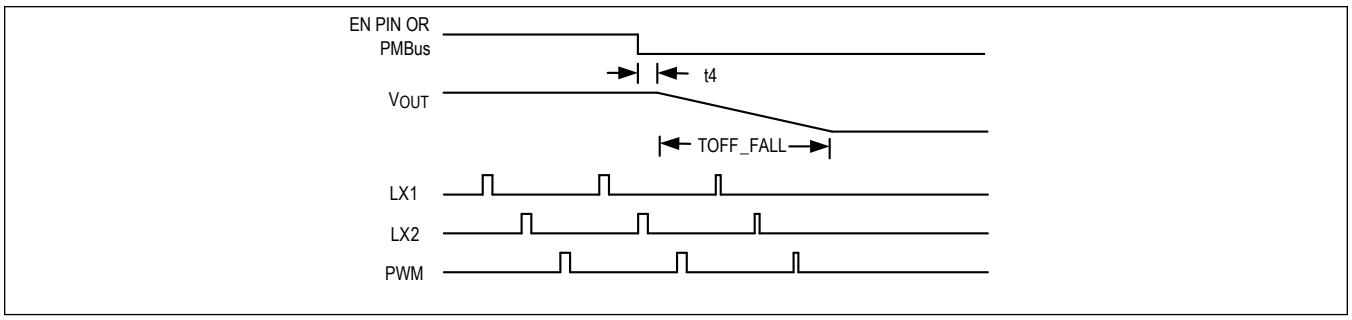


Figure 3. Shutdown Timing Diagram

Prebias Startup

If the output voltage is "prebiased" before regulation is enabled, the MAX20796 generates a monotonic startup ramp with no reverse current, as shown in Figure 4. Two-phase configurations can start monotonically with the output prebias as high as VOUT_COMMAND, but operational characteristics of the MAX20766 external power-stage limit three-phase configurations to a maximum prebias voltage of 500mV.

Internal Linear Regulator

The MAX20796 contains internal linear regulators to support single input rail operation. The linear regulators convert the input voltage from the V_{LDOIN} pin into lower voltages that provide the internal bias for the controller and the gate drive circuitry. V_{LDOIN} can be powered either by V_{DDH} voltage (single input rail operation) or any other supply voltage in range of 2.97V to 16V. A lower input voltage, e.g., 3.3V, is preferred to reduce its internal losses and enhance the overall thermal performance. Decoupling capacitors must be used and put close to output pins, i.e., $V_{CC_}$, AVDD and DVDD to ensure optimum performance.The V_{CC} and AVDD bypass capacitor values must satisfy this equation:

$C_{VCC} < 1.3 \times C_{AVDD} + 0.9\mu F$

Figure 5 shows the diagram of V_{LDOIN} with an external supply voltage.

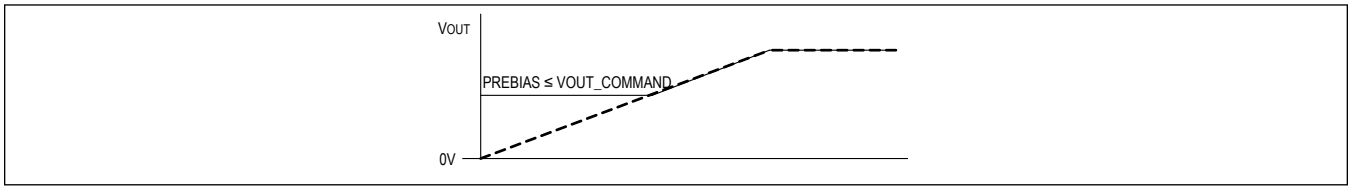


Figure 4. Prebias Startup

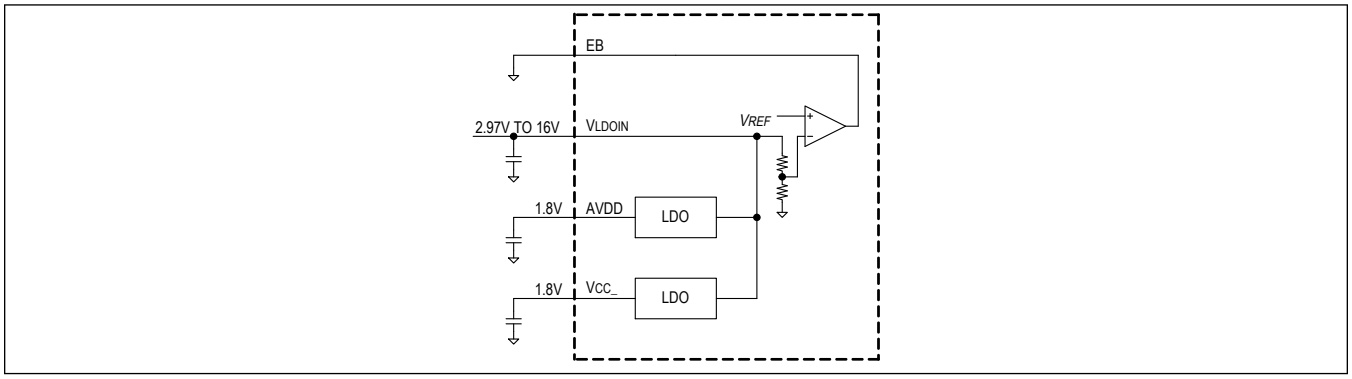


Figure 5. V_{LDOIN} with an External Supply Voltage

To enhance thermal performance when there is no supply voltage other than V_{DDH}, an external nFET can be driven by

the EB pin to generate 3V to feed into the V_{LDOIN} pin, as shown in Figure 6. The external nFET should be selected with sufficient power dissipation capability under the worst thermal case. SQA410EJ-T1_GE3 from Vishay is a good candidate to handle most of the application cases. A series resistor, of about 3Ω to 5Ω is needed on its drain terminal to limit the peak current when V_{DDH} shuts down.

Restore Function ($\overline{\text{RESTORE}}$)

Upon a high-to-low transition of the $\overline{\text{RESTORE}}$ pin, V_{OUT} is restored to the voltage set by PGMA. A 10µs deglitch time is employed to eliminate the possibility of a false $\overline{\text{RESTORE}}$-low signal caused by noise coupling. The output voltage transition rate between the previous and new output voltage is the same rate as the transition between different VOUT_COMMAND voltages determined by TON_RISE/VOUT_COMMAND.

Note that it is permissible for the system to hold the $\overline{\text{RESTORE}}$ signal low indefinitely. As long as RESTORE is low, the MAX20796 forces the restore function, which is:

- The device does not act on any command that directly changes the output voltage, except for bits 6 and 7 of the OPERATION command that turns the supply on or off (0x00, 0x40, or 0x80);
- The device NACKs any VOUT_COMMAND data writes (and discards the new VOUT_COMMAND data), and the corresponding STATUS_CML error flag (invalid data) is set.

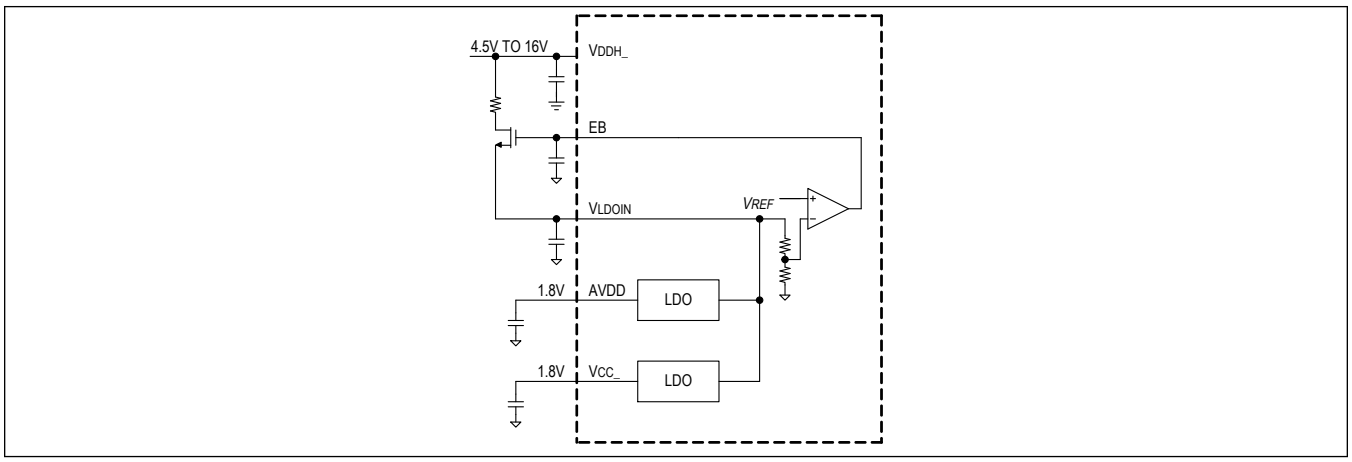


Figure 6. EB Drives a nFET to Generate 3V

Power Good (PGOOD)

The PGOOD pin is an active-high, open-drain output that is used to show that V_{OUT} has settled at the target voltage. PGOOD goes high after a fixed delay after the end of the startup transition (see the *Electrical Characteristics* table). PGOOD is deasserted if the output voltage drops below the PGOOD falling threshold relative to the nominal voltage for any reason.

Orthogonal Current Rebalancing (OCR)

The MAX20796 implements an orthogonal current rebalancing (OCR) feature for enhanced dynamic-current sharing or balancing between different phase currents. This feature maintains current balance during load transients, even at a load-step frequency close to switching frequency or its harmonics. In the MAX20796, the OCR circuit adjusts the individual phase-current control signal from a common average current signal in order to minimize the phase-current imbalance. The individual phase- current control signal is conditioned through the OCR circuit before it reaches individual phase (PWM) modulator. This prevents each phase current from diverging from the average. For example, the new phase current control voltage for phase 1 is given as shown in Equation 1.

Equation 1:

$$V_{CPH1} = V_C - R_{OCR} \times (I_{PH1} - I_{AVG})$$

where,

V_{CPH1} = Phase 1 current-control signal,

V_C = Common average-current control signal,

R_{OCR} = OCR circuit gain resistance,

I_{PH1} = Phase 1 current, and

I_{AVG} = Average current.

Synchronization

Synchronizing multiple units can effectively reduce intermodulation noise and its interference to input current and output voltage. Up to four units of MAX20796 can be connected in the star connection format. The external synchronization clock is not necessary. Figure 7 shows the connection diagram without an external clock signal. In this case, Unit 1, by shorting its SYNC_IN pin to GND, is selected as the master to send out the synchronization clock signal to downstream units. Figure 7 shows how the four units can be connected if there is an external clock signal.

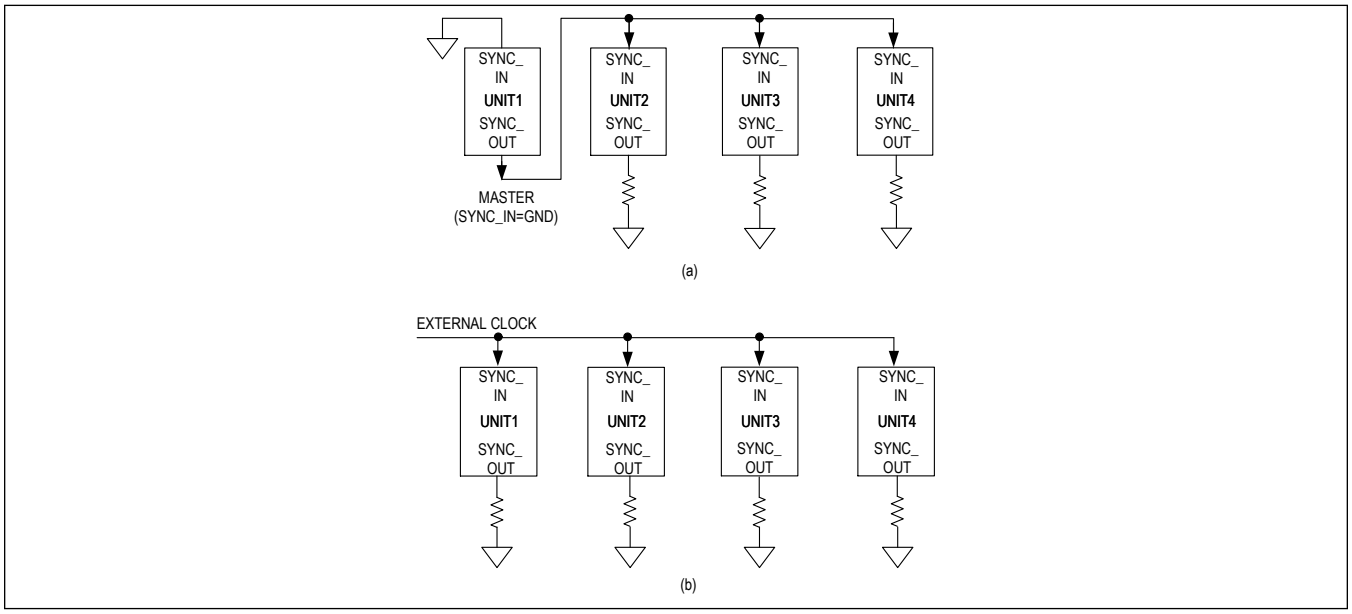


Figure 7. Synchronization Connection Diagram

In addition to synchronization, an interleaving feature is included in the MAX20796. Figure 8 shows the phase-shift timing diagram in a four-unit system as in the Figure 7 (a) configuration. Unit 1 serves as the signal master and its SYNC_OUT is used as the input of Unit 2 to 4. After the SYNC_OUT pulldown resistor is read in the initialization period, each unit is assigned a fixed phase shift relative to its SYNC_IN input-signal rising edge. t_D is the delay time from LX1 to its SYNC_OUT rising edge in Unit 1. Table 2 shows the SYNC_OUT pin-strap table.

If the SYNC_IN signal is disqualified, e.g., the pulse is too narrow, out of lock-in range, or upon sudden loss of signal, the MAX20796 resumes switching smoothly with its pin-strap defined switching frequency.

Fault Handling

SNSP Open Detection

The MAX20796 supports the SNSP pin open-detection at startup. If the SNSP pad or part of its feedback path is unconnected from the output for any reason, the regulator does not startup switching. This protection is only active at startup and is disabled in regulation.

R_ADDR and PGMx Out of Range Detection

During a R_ADDR and PGMx read period in the startup initialization, an error is reported if a pin-strap resistance is out of the defined range and switching is forbidden. STATUS_MFR_SPECIFIC [bit 3], a manufacturer-specific PMBus register, is flagged to report this error.

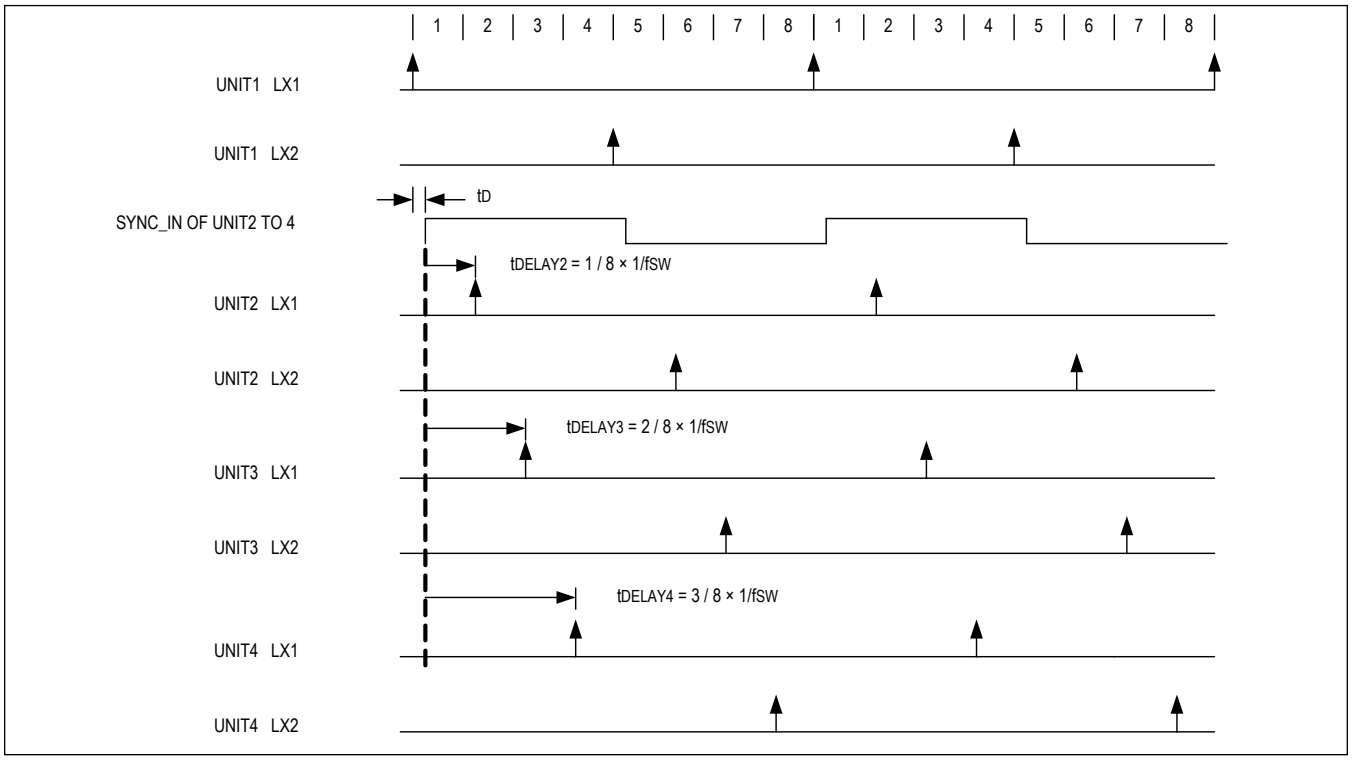


Figure 8. Phase Shift Timing Diagram for Four Synchronized Devices

Table 2. Phase Shift in Synchronization

SYNC_OUT PIN-STRAP R(Ω)	PHASE POSITION, SYNC_IN RISING TO LX1, LX2 RISING (NO EXTERNAL POWER-STAGE)	PHASE POSITION, SYNC_IN RISING TO LX1, LX2, LX3 RISING (WITH EXTERNAL POWER-STAGE)
453	130°, 310°	130°, 250°, 370°
549	100°, 280°	100°, 220°, 340°
681	160°, 340°	160°, 280°, 400°
976	85°,265°	85°, 205°, 325°
1180	175°, 355°	175°, 295°, 415°
1400 (no clock output)	40°, 220°	40°, 160°, 280°
≥ 1690 or open (clock output active)	40°, 220°	40°, 160°, 280°

Overvoltage Protection (Tracking OVP)

The MAX20796 overvoltage protection compares the output-feedback voltage to the VOUT_COMMAND value. If the output voltage exceeds VOUT_COMMAND plus the tracking OVP threshold (see the *Electrical Characteristics* table), an OVP fault is triggered, PGOOD is deasserted, and the device stops switching by turning off both highside and low-side FETs immediately. The OVP default response is "Shutdown and Retry" mode, which can also be changed through PMBus command, VOUT_OV_ FAULT_RESPONSE. In "Shutdown and Retry" mode, the system first shuts down switching, deasserts PGOOD, waits for about 50ms and then restarts if the OVP fault disappears. In "Ignore" mode, the system allows switching to continue, but deasserts PGOOD and flags in the corresponding bit in the STATUS_VOUT register. The OVP fault bit can be cleared by toggling the output enable state off and back on.

Undervoltage Protection (UVP)

The MAX20796 undervoltage protection compares the output-feedback voltage to the VOUT_COMMAND value. If the output voltage is smaller than the VOUT_ COMMAND minus the UVP threshold (see the *Electrical Characteristics* table), an UVP fault is triggered, PGOOD is deasserted, and the device stops switching by turning off both high-side and low-side FETs immediately. The UVP default response is "Shutdown and Retry" mode, which can also be changed through the PMBus command, VOUT_UV_FAULT_RESPONSE. In "Shutdown and Retry" mode, the system first shuts down switching, deasserts PGOOD, waits for about 50ms and then restarts. In "Ignore" mode, the system just allows switching to continue, but deasserts PGOOD and flags the corresponding bit in STATUS register. The UVP fault bit can be cleared by toggling the output enable state off and back on.

Overvoltage Protection (Umbrella OVP)

To gain a second level of protection, the absolute output voltage ($V_{SNSP} - V_{SNSN}$) is monitored and compared with fixed thresholds during operation. Two fixed thresholds, 2.5V or 6.0V, are set corresponding to VOUT_COMMAND in range of 0.5V to 2.437V or 2.438V to 5.0V, respectively. Both tracking and umbrella OVP mechanisms are handled by the same VOUT_OV_FAULT_RESPONSE and reported together as STATUS_VOUT [bit 7].

Overcurrent Protection (Average OCP)

The total positive average current is compared to the number of phases times the per-phase OCP threshold defined by PGMD. Once an OCP fault is triggered, switching is shut down and PGOOD is deasserted. An OCP fault is not a latching fault and is registered in the fault log. Depending on the IOUT_OC_FAULT_RESPONSE command setting, the regulator begins "Shutdown and Retry" (factory default) after about 50ms or "Shutdown only" without restart. The shutdown and retry continues until the load current falls below the threshold.

Overcurrent Protection (Power Stage Peak OCP)

Besides average OCP, the MAX20796 has the instantaneous cycle-by-cycle peak current protection in each power train. The internal lossless current sense technology is used and intended to operate only in extreme overcurrent conditions to protect the integrated FETs. Its threshold is fixed as shown in the *Electrical Characteristics* table. Once the power-stage peak OCP is triggered, the relevant phase turns off the high-side FET and turns on its low-side FET to keep its peak current at a safe level. Since the protection is based on the instantaneous current, the ripple current must be considered when calculating the maximum average current per phase. The maximum positive DC-phase current before clamping can be calculated as shown in Equation 2.

Equation 2:

$$I_{PHASE_DC_MAX_POS} = I_{POCP_R} - \frac{I_{PH_P-P}}{2}$$

Where: I_{PH_P-P} is the peak-to-peak phase-current ripple in the inductor.

The MAX20796 also has a negative cycle-by-cycle overcurrent protection (NOCP) for each power train. Its threshold is also fixed as shown in the *Electrical Characteristics* table. If the NOCP threshold is reached, the low-side FET turns off and the high-side FET turns on for protection. Equation 3 shows the maximum negative DC current per phase.

Equation 3:

$$I_{PHASE_DC_MAX_NEG} = I_{NOCP} + \frac{I_{PH,\,PP}}{2}$$

Undervoltage Lockout (UVLO)

The MAX20796 includes UVLO circuits on the AVDD, $V_{CC_}$, and $V_{DDH_}$ supply input pins. The UVLO thresholds are specified in the *Electrical Characteristics* table. If a UVLO event is detected, the system stops regulating. Once the faulted input voltage rises above its UVLO rising threshold, the device reinitializes a new startup process.

Overtemperature Protection

Overtemperature protection ensures the power train as well as the controller works within a safe temperature range. There are two temperatures monitored in the MAX20796. READ_TEMPERATURE_1 reports the integrated power train junction temperature. If there is an external power stage connected, READ_ TEMPERATURE_2 reports its junction temperature by monitoring the $\overline{TS_FAULT}$ pin voltage. If any temperature is over the programmed threshold, the fault is triggered. The regulator shuts down switching immediately by turning off both FETs, waiting for about 50ms off time, and then restarting if the junction temperature drops below threshold. STATUS_TEMPERATURE is flagged to report the fault. The factory default threshold is typically 150°C and it can be programmed using the PMBus commands. OT_FAULT_RESPONSE can be programmed to “Shutdown and Retry” (factory default) or “Shutdown only.”

Fault Handling Table

The following table summarizes the fault types and system responses. “Configurable” means some of these options, “ignore,” “shutdown” and “shutdown and retry,” can be selected through PMBus. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for details.

Table 3. Fault Handling

FAULT PROTECTION	STATUS PIN	STATUS REGISTER	RESPONSE	RESPONSE REGISTER	FAULT LIMIT REGISTER
A/DVDD UVLO	N/A	N/A	Reset	N/A	N/A
$V_{CC_}$ UVLO	$\overline{ALERT}$	STATUS_MFR_ SPECIFIC	Stop regulating until UVLO condition clears	N/A	N/A
$V_{DDH_}$ UVLO	$\overline{ALERT}$	STATUS_INPUT	Shutdown and retry	N/A	N/A
BST_ UVLO	$\overline{ALERT}$	STATUS_MFR_ SPECIFIC	Stop regulating until UVLO condition clears	N/A	N/A
V_{OUT} Tracking OVP	$\overline{ALERT}$/PGOOD	STATUS_VOUT	Configurable	VOUT_OV_FAULT_ RESPONSE	VOUT_OV_FAULT_ LIMIT
V_{OUT} Umbrella OVP	$\overline{ALERT}$/PGOOD	STATUS_VOUT	Configurable	VOUT_OV_FAULT_ RESPONSE	Fixed
V_{OUT} UVP	$\overline{ALERT}$/PGOOD	STATUS_VOUT	Configurable	VOUT_UV_FAULT_ RESPONSE	VOUT_UV_FAULT_ LIMIT
Average OCP	$\overline{ALERT}$	STATUS_IOUT	Configurable	IOUT_OC_FAULT_ RESPONSE	IOUT_OC_FAULT_ LIMIT
Power-Stage Peak OCP (cycle-by-cycle)	N/A	N/A	Duty-cycle truncation	N/A	Fixed
Overtemperature	$\overline{ALERT}$	STATUS_ TEMPERATURE	Configurable	OT_FAULT_ RESPONSE	OT_FAULT_LIMIT
Power-Stage Fault	$\overline{ALERT}$/ $\overline{TS_FAULT}$	STATUS_MFR_ SPECIFIC	Configurable	SLV_FAULT_ RESPONSE	N/A
Power-Stage TSENSE Fault	$\overline{ALERT}$/ $\overline{TS_FAULT}$	STATUS_ TEMPERATURE	Configurable	OT_FAULT_ RESPONSE	OT_FAULT_LIMIT
PT VX Short	N/A	N/A	Configurable	SLV_FAULT_ RESPONSE	N/A
SNSP Open	$\overline{ALERT}$	STATUS_MFR_ SPECIFIC	No startup	N/A	N/A

Table 3. Fault Handling (continued)

PGMx Out-of-Range Fault	$\overline{\text{ALERT}}$	STATUS_MFR_SPECIFIC	No startup	N/A	N/A

Nonvolatile PMBus Memory

The MAX20796 features nonvolatile memory for storage of PMBus command values, which is only guaranteed to retain values correctly when written while V_{DDH} is 10V to 16V, and while junction temperature is 0°C to 50°C. STORE_USER_ALL and STORE_INVENTORY commands are not sent when these conditions are not met.. The memory capacity is such that there are 5 possible storage "slots." One slot can store most of the PMBus command sets. The contents of the "default" and "user" stores overrides pin-strap command values where appropriate, according to the parameter loading-precedence requirements of the PMBus specification.

At any time, the number of remaining storage slots can be determined by reading the OTP_REMAINING command. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for more information.

Pin-Strap Programmability

PMBus Address

The PMBus address can be programmed by the R_ADDR resistor. 32 PMBus addresses can be pre-set by pin-strap.

Pin-Strap Output Voltage and VOUT_COMMAND

The PGMA pin-strap resistor is used to set the output voltage, i.e., the initial value of VOUT_COMMAND. From 0.5V to 1.8V, each step is 50mV. Above 1.8V, only the commonly used rail voltages, e.g., 2.5V, 3.3V, and 5V can be programmed with direct feedback.

To set the output voltage other than by the pin-strap resistor, either use VOUT_COMMAND through the PMBus interface or add a feedback divider to set the output voltage.

Once VOUT_COMMAND is initially set by the pin-strap PGMA resistor or from nonvolatile memory, do not change the output voltage with VOUT_ COMMAND, or MARGIN_HIGH/LOW while regulating by more than ±25%. The slew rate for decreasing the output voltage must not exceed -0.5V/ms, as set by -VOUT_COMMAND/ TOFF_FALL. The slew rate for startup and shutdown can be higher than this value if desired.

In the case, when output voltage is not included in the pin-strap table and VOUT_COMMAND is not available, the MAX20796 also supports the feedback divider method to set the arbitrary output voltage. The new output voltage can be calculated as:

Equation 4:

$$V_{OUT} = V_{DAC} \times (1 + \frac{R1 + R3}{R2})$$

where R_1 is the resistor between output and the SNSP pin, R_3 is the resistor between ground and the SNSN pin, and R_2 is the resistor between the SNSP and SNSN pins. R_1 is equal to R_3.

V_{DAC} is the setpoint voltage via pin-strap, (e.g., 0.6V or 1.0V, etc).

Refer to *Typical Application Circuit*, where $R_1 = R_{10}$, $R_2 = R_{11}$, and $R_3 = R_5$.

R_1 and R_2 are suggested to select small values (e.g., 100Ω or below) in order to avoid output voltage setting error caused by SNSP input bias current; $(R_1 + R_3)// R_2$, or any series resistor on SNSP path should be much below 1.6kΩ to avoid falsely triggering SNSP open detection at startup. The resistors in the divider circuit must be sized appropriately to accommodate the power dissipation. Typically, 1/8W resistors are sufficient.

Voltage-Loop Gain and Zero

Voltage loop compensation can be set by the PGMB pin-strap resistor. Eight different voltage-loop gains (I_{DES_GAIN}) and four different voltage loop zeros (f_{ZV}) can be selected independently by this pin. To set a different voltage loop gain or zero, I_{DES_GAIN} and F_ZERO commands can be used through the PMBus interface. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for details.

Table 4. Pin-Strap Configurations

		R_ADDR	PGMA	PGMB		PGMC		PGMD		PGME	
BIN #	R_{NOM} (Ω)	PMBus ADDRESS	VOUT_ COMMAND (V)	IDES_ GAIN (V/V)	f_{ZV} (kHz)	R_{INT} (Ω)	f_{ZC} (kHz)	PWM_RAMP SLEW RATE (V/µs)	POSITIVE AVERAGE OCP THRESHOLD (PER PHASE) (A)	TON_ RISE (ms)	FREQUENCY SWITCH f_{SW} (kHz)
0	37.4	0x10h	0.5	0.98	10.3	4522	5	0.425	10	0.5	200
1	45.3	0x11h	0.55	1.258	10.3	3668	5	0.425	13.3	0.5	308
2	54.9	0x12h	0.6	1.536	10.3	2964	5	0.425	16.7	0.5	400
3	68.1	0x13h	0.65	1.814	10.3	2209	5	0.425	20	0.5	444
4	82.5	0x14h	0.7	2.092	10.3	1761	5	0.425	23.3	0.5	500
5	97.6	0x15h	0.75	2.37	10.3	1257	5	0.425	26.7	0.5	571
6	118	0x16h	0.8	2.648	10.3	1098	5	0.425	30	0.5	666
7	140	0x17h	0.85	2.926	10.3	878	5	0.425	33.3	0.5	799
8	169	0x18h	0.9	0.98	16.5	4522	12.4	1.27	10	1	200
9	205	0x19h	0.95	1.258	16.5	3668	12.4	1.27	13.3	1	308
10	249	0x1Ah	1	1.536	16.5	2964	12.4	1.27	16.7	1	400
11	374	0x1Bh	1.05	1.814	16.5	2209	12.4	1.27	20	1	444
12	453	0x1Ch	1.1	2.092	16.5	1761	12.4	1.27	23.3	1	500
13	549	0x1Dh	1.15	2.37	16.5	1257	12.4	1.27	26.7	1	571
14	681	0x1Eh	1.2	2.648	16.5	1098	12.4	1.27	30	1	666
15	976	0x1Fh	1.25	2.926	16.5	878	12.4	1.27	33.3	1	799
16	1.18k	0x20h	1.3	0.98	19.6	4522	18	3.18	10	4	200
17	1.4k	0x21h	1.35	1.258	19.6	3668	18	3.18	13.3	4	308
18	1.69k	0x22h	1.4	1.536	19.6	2964	18	3.18	16.7	4	400
19	2.05k	0x23h	1.45	1.814	19.6	2209	18	3.18	20	4	444
20	2.49k	0x24h	1.5	2.092	19.6	1761	18	3.18	23.3	4	500
21	8.25k	0x25h	1.55	2.37	19.6	1257	18	3.18	26.7	4	571
22	9.76k	0x26h	1.6	2.648	19.6	1098	18	3.18	30	4	666
23	11.8k	0x27h	1.65	2.926	19.6	878	18	3.18	33.3	4	799
24	14.0k	0x28h	1.7	0.98	28.8	4522	21.9	4.46	10	8	200
25	16.9k	0x29h	1.75	1.258	28.8	3668	21.9	4.46	13.3	8	308
26	20.5k	0x2Ah	1.8	1.536	28.8	2964	21.9	4.46	16.7	8	400
27	24.9k	0x2Bh	2.5	1.814	28.8	2209	21.9	4.46	20	8	444
28	30.1k	0x2Ch	3.3	2.092	28.8	1761	21.9	4.46	23.3	8	500
29	37.4k	0x2Dh	5	2.37	28.8	1257	21.9	4.46	26.7	8	571
30	45.3k	0x2Eh	0.8	2.648	28.8	1098	21.9	4.46	30	8	666
31	54.9k	0x2Fh	0.7	2.926	28.9	878	21.9	4.46	33.3	8	799

Current-Loop Gain and Zero

Current-loop compensation can be set by the PGMC pinstrap resistor. Eight different current-loop gains (R_{INT}) and four different current-loop zeros (f_{ZC}) can be selected independently by this pin. Larger R_{INT} gives higher current loop gain.

Compensation Ramp and OCP Thresholds

An internal PWM ramp compensation is used to improve overall loop stability. Its slew rate can be programmed using the PGMD pin-strap resistor. This pin also sets up system average positive OCP thresholds, which is shown as per phase average current in the table. To get the total output current, the selected value needs to be multiplied by the actual phase count. To use other ramp slew rate values, the PWM_RAMP command can be used through the PMBus interface. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for details.

Soft Time and Switching Frequency

PGME pin-strap resistor can be used to program soft-start time (TON_RISE) and switching frequency (fSW). Four different soft-start times and eight different switching frequencies can be programmed with PGME. For other soft-start times, the TON_RISE command can be used through the PMBus interface. Refer to *Application Note 6453: MAX20796 PMBus User Guide* for details.

Application Circuit Design Procedure

Output Capacitor Selection

The primary factors in determining the total required output capacitance (C_{OUT}) are the maximum allowable output voltage overshoot and undershoot ("sag" and "soar") during load transients. In step-down converters, the voltage overshoot (ΔV_{OST}) during unloading is the dominant factor in setting the required C_{OUT} because less forcing voltage is available to reduce the inductor current. For an unloading current-step (ΔI) and maximum allowed output-voltage overshoot (ΔV_{OST}), the minimum required output capacitance can be estimated as in Equation 5.

Equation 5:

$$C_{OUT} = \frac{(\frac{\Delta I}{N} + \frac{I_{PH_P-P}}{2})^2 \times L \times N}{2 \times \Delta V_{OST} \times V_{OUT}}$$

where:

L = Inductance per phase

N = Number of phases

I_{PH_P-P} = Peak-to-peak phase-current ripple in the inductor

V_{OUT} = Nominal output voltage

Selecting a higher total C_{OUT} value increases design margin against component variation and effective capacitance loss due to voltage bias.

For example, in a two-phase application, V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor), unloading step ΔI = 10A, ΔV_{OST} = 3% of 0.8V input (= 24mV), the minimum AC capacitance can be calculated at 450µF. If any polymer capacitor is used, their equivalent-series resistance and inductance (ESR, ESL) cause output voltage ripple increase. Thus, sufficient capacitance margin and ceramic capacitors must be considered on the output side to further reduce the overshoot in order to meet the overall transient specs.

Output Inductor Selection

For single-phase discrete inductors, the phase current peak-to-peak ripple (I_{PH_P-P} is calculated as in Equation 6.

Equation 6:

$$I_{PH_P-P} = \frac{(V_{DDH} - V_{OUT}) \times V_{OUT}}{f_{SW} \times L \times V_{DDH}}$$

For coupled inductors driven with duty cycle ≤ 1/N, the approximate inductor peak-to-peak phase-current ripple can be calculated as in Equation 7.

Equation 7:

$$I_{PH_P-P} = \frac{V_{OUT}}{f_{SW} \times L}(\frac{1}{N} - \frac{V_{OUT}}{V_{DDH}})$$

where:

I_{PH_P-P} = Peak-to-peak phase-current ripple in the inductor

f_{SW} = Switching frequency

L = Inductance per phase

N = Number of phases

V_{DDH} = Input voltage

V_{OUT} = Nominal output voltage

A compromise should be made between output inductance and output capacitance. Too large of an inductance reduces current and voltage ripple, but still needs a larger output capacitance to suppress output voltage overshoot and

undershoot in the load transient. Usually 30% to 40% of I_{PH_P-P} over the full load current is a good start point to design the application circuit. For example, in a two-phase application, V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor), f_{SW} = 400kHz, I_{PH_P-P} can be estimated to be 8.66A.

Input-Capacitor Selection

The selection and placement of input capacitors are important considerations. High-frequency input capacitors serve to control switching noise. Bulk input capacitors are designed to filter the pulsed DC current that is drawn by the regulator. For the best performance, lowest cost and smallest size target, multilayer ceramic chip (MLCC) capacitors with 1210 or smaller case sizes, 47µF or smaller capacitance values, 16V or 25V voltage ratings, and X5R or better temperature characteristics are recommended as bulk. A high-frequency input capacitor should be placed as close as possible to the V_{DDH} pins on the same side of PCB as the part.

It is recommended to choose the bulk and MLCC input capacitance to control the peak-to-peak input voltage ripple to 2% to 3% of its nominal value. The minimum input capacitance in accordance with Equation 8 (suppose duty cycle ≤ 1/N).

Equation 8:

$$C_{IN} \geq \frac{I_{OUT_MAX} \times (V_{DDH} - N \times V_{OUT})}{f_{SW} \times V_{DDH}^{2} \times V_{DDH_P-P}}$$

where:

C_{IN} = Input capacitance (MLCC)

I_{OUT_MAX} = Maximum load current

N = Number of phases

V_{DDH_P-P} = Target peak-to-peak input voltage ripple

Because the bulk input capacitors must source the pulsed DC-input current of the regulator, the power dissipation, and ripple-current rating for these capacitors are far more important than that for the output capacitors. The total RMS current that all input capacitors must withstand can be approximated using Equation 9.

Equation 9:

$$I_{RMS_CIN} = \frac{I_{OUT_MAX}\sqrt{V_{OUT} \times (V_{DDH} / N - V_{OUT})}}{V_{DDH}}$$

For example, in a two-phase application, V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor), f_{SW} = 400kHz, $I_{OUT, MAX}$ = 40A and V_{DDH_P-P} = ±3% x 12V (= 72mV), C_{IN} AC capacitance can be estimated to be 80µF. Considering derating due to DC-bias voltage, the recommended minimum capacitance is 2 x 47µF (bulk) and 1.0µF + 0.1µF (high frequency) for each V_{DDH} pin.

Internal Compensation (f_{ZV}, f_{ZC}, R_{INT}, PWM Ramp, I_{DES_GAIN}) Selection

The MAX20796 uses peak current-mode control to simplify compensation design. The control loop can be stabilized by selecting appropriate I_{DES_GAIN} values, f_{ZV}, f_{ZC}, R_{INT} and PWM ramp slew rate under certain power stage parameters, e.g., L and C_{OUT}. No external compensation network is required.

Voltage and current loop zeros should be selected smaller or equal to the power-stage double-pole frequency to compensate the phase delay, which can be estimated in Equation 10.

Equation 10:

$$f_{ZV},\ f_{ZC} \leq \frac{1}{2\pi\sqrt{\frac{L}{N} \times C_{OUT}}}$$

For example, in a two-phase application (N = 2), V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor), f_{SW} = 400kHz and C_{OUT} = 1mF, f_{ZV}, f_{ZC} < 22.5kHz. Usually, picking up lower frequency zeros, e.g., 10.3kHz to 16.5kHz, gains more phase margin.

R_{INT} sets the internal S/N ratio at the modulator within the limits of the allowed voltage swing across R_{INT} (ΔV_R_{INT}), for which peak-to-peak voltage ΔV_R_{INT} is 0.2V. Then the maximum R_{INT} can be calculated with Equation 11 with a

duty cycle < 1/N.

Equation 11:

$$R_{INT} = \frac{2 \times 10^5 \times L \times f_{SW} \times \Delta V_R_{INT}}{V_{OUT} \times (1 - N \times \frac{V_{OUT}}{V_{DDH}})}$$

For example, in a two-phase application, V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor) and f_{SW} = 400kHz. R_{INT} can be calculated to be 2.3kΩ. Choose 1761Ω or 2209Ω from Table 4.

The PWM ramp slew rate sets the slope compensation ramp rate for all phases. Its minimum value is equal to the downslope equivalent slew rate in Equation 12. A larger value is preferred in order to reduce switching jitter. Table 5 shows the R_{INT} and PWM ramp values for a two-phase use case with I_{DES_GAIN} = 0.98V/V.

Table 5. R_{INT} and PWM Ramp Selection

V_{DDH} (V)	V_{OUT} (V)	f_{SW} (kHz)	R_{INT} (kΩ)	PWM_RAMP (V/Ms)	f_{ZV} (kHz)
9 to 12	0.8 to 1.0	308, 400	1761	0.425	10.3
9 to 12	1.0 to 1.8	308, 400	1098	0.425	10.3
9 to 12	0.8 to 1.0	500, 667	2964	1.27	16.5
9 to 12	1.0 to 1.8	500, 667	2209	1.27	16.5
9 to 12	3.3	667 to 800	2209	1.27	19.5

For other use case compensation calculations, see Equation 12:

Equation 12:

$$PWM_RAMP = N \times \frac{1.25 \times R_{INT}}{10^5} \times (\frac{V_{OUT}}{L})$$

For stability purposes, the voltage loop bandwidth (BW) must be 1/5 to 1/3 of the switching frequency. Consider the case of using MLCC output capacitors that have nearly ideal impedance characteristics in the frequency range of interest with negligible ESR and ESL. The voltage loop BW can be estimated with Equation 13.

Equation 13:

$$BW_{VL} = \frac{1}{2 \times \pi \times C_{OUT} \times R_{AC}}$$

R_{AC} = AC droop resistance,

$$R_{AC} = \frac{1}{506 \times I_{DES_GAIN}}$$

(for $V_{OUT} \leq$ 2.437V)

$$R_{AC} = \frac{1}{230 \times I_{DES_GAIN}}$$

(for V_{OUT} > 2.437V) with direct feedback.

Where,

C_{OUT} = Total equivalent small-signal AC capacitance of the MLCC caps.

For example, in a two-phase application, V_{DDH} = 12V, V_{OUT} = 0.8V, L = 100nH (coupled inductor), f_{SW} = 400kHz, C_{OUT} = 1mF and I_{DES_GAIN} = 0.98, the estimated voltage-loop BW = 79kHz.

PCB Layout Guidelines

- For electrical and thermal reasons, the second copper layer from the top and bottom of the PCB should be reserved for continuous power ground (PGND) planes.
- An analog ground copper polygon or island can be used to connect all analog control-signal grounds. This “quiet” analog ground polygon should be connected to the PGND via a single via close to pin 7 (AGND). The analog ground

should be used as a shield and ground reference for the control signals (R_ ADDR, PGM_, PWM, SNSP, SNSN, and TS_FAULT).

- The AVDD, DVDD decoupling capacitors should also be connected to the analog ground, and placed as close as possible to the AVDD and DVDD pin.
- The $V_{CC_}$ decoupling capacitors should also be connected to the PGND, and placed as close as possible to the $V_{CC_}$ pins.
- The pin-strap resistors (PGMA, PGMB, PGMC, PGMD, PGME, and R_ADDR) should be placed close to the IC and away from noisy signals.
- Sufficient input capacitor should be used to mitigate the AC current flowing outside of the buck converter.
- The closest input decoupling capacitor should be located within 60 mils of the $V_{DDH_}$ pins; otherwise, excessive spike voltage induced at the $V_{DDH_}$ pins increases voltage stress on the device significantly.
- Vias should not be used on the LX_ pin land pattern copper pour if the inductors are placed on the same side of the PCB as the MAX20796. However, vias are preferred on the PGND_land pattern between the pin "fingers." Sufficient PGND vias are also needed close to the PGND_ pin pads.
- The 0.22µF boost capacitors should be placed as close as possible to the LX_ and BST pins, on the same side of the PCB as the MAX20796.

PMBus Command

Table 6 shows the supported PMBus command list. For the detailed PMBus command definition and its application note, refer to *Application Note 6453: MAX20796 PMBus User Guide*. The MAX20796 is available preconfigured for specific applications, as shown in Table 7.

Table 6. Supported PMBus Command List

OPERATION	STATUS_BYTE
ON_OFF_CONFIG	STATUS_WORD
VOUT_MODE	STATUS_VOUT
VOUT_COMMAND	STATUS_IOUT
VOUT_TRIM	STATUS_INPUT
VOUT_MAX	STATUS_TEMPERATURE
VOUT_MARGIN_HIGH	STATUS_CML
VOUT_MARGIN_LOW	STATUS_OTHER
VOUT_MIN	STATUS_MFR_SPECIFIC
MFR_VOUT_MIN	READ_VIN
FREQUENCY_SWITCH	READ_VOUT
INTERLEAVE	READ_IOUT
TON_DELAY	READ_TEMPERATURE_1
TON_RISE	READ_TEMPERATURE_2
TOFF_DELAY	TELEMETRY_ADDR
TOFF_FALL	TELEMETRY_DATA
CLEAR_FAULTS	LEAD_LAG
VOUT_OV_FAULT_LIMIT	IDES_GAIN
VOUT_OV_FAULT_RESPONSE	F_ZERO
VOUT_OV_WARN_LIMIT	ROCR_RINT
VOUT_UV_WARN_LIMIT	PWM_RAMP
VOUT_UV_FAULT_LIMIT	CAPABILITY
VOUT_UV_FAULT_RESPONSE	PMBUS_REVISION
IOUT_OC_FAULT_LIMIT	IC_DEVICE_ID
IOUT_OC_FAULT_RESPONSE	IC_DEVICE_REV

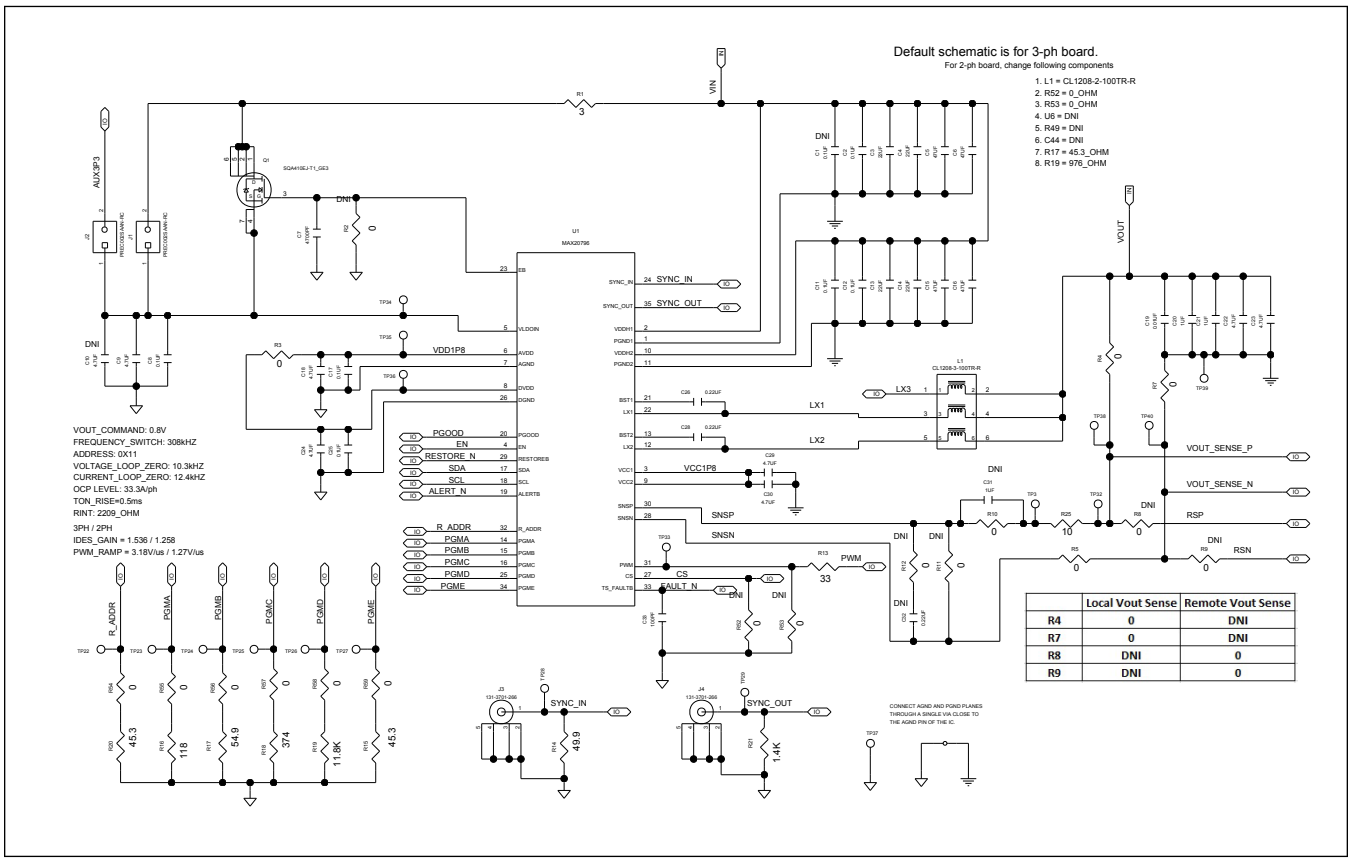
Table 6. Supported PMBus Command List (continued)

IOUT_OC_WARN_LIMIT	WRITE_PROTECT
OT_FAULT_LIMIT	STORE_USER_ALL
OT_FAULT_RESPONSE	RESTORE_USER_ALL
OT_WARN_LIMIT	OTP_REMAINING
TON_MAX_FAULT_LIMIT	STORE_INVENTORY
TON_MAX_FAULT_RESPONSE	FORCE_PEC
SLV_FAULT_RESPONSE	RESTORE_MAXIM_ALL
SMBALERT_MASK	

Table 7. Configuration Details

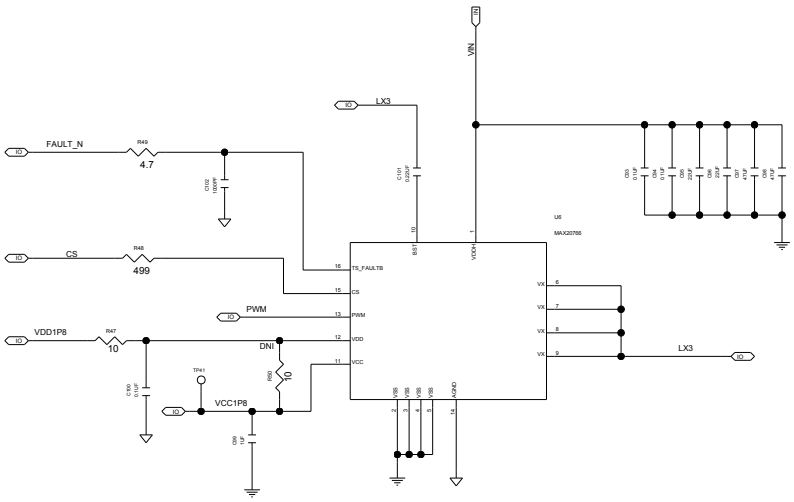
PART NUMBER	DESCRIPTION	COMMAND	VALUE	DATA
MAX20796	Unconfigured	All commands	Pin-strap, default	Pin-strap, default
MAX20796A	Scenario A	VOUT_COMMAND	1.000V	0x0200
		VOUT_MAX 1.250V 0x0280	1.250V	0x0280
		FREQUENCY_SWITCH	800kHz	0x0320
		VOUT_OV_WARN_LIMIT	1.125V	0x0240
		VOUT_UV_WARN_LIMIT	0.875V	0x01C0
		IOUT_OC_WARN_LIMIT	54A	0xE360
		TON_RISE	1ms	0xF004
		LEAD_LAG	0.81/disabled/disabled	0x01
		All other commands	Default values	Default values

Typical Application Circuits

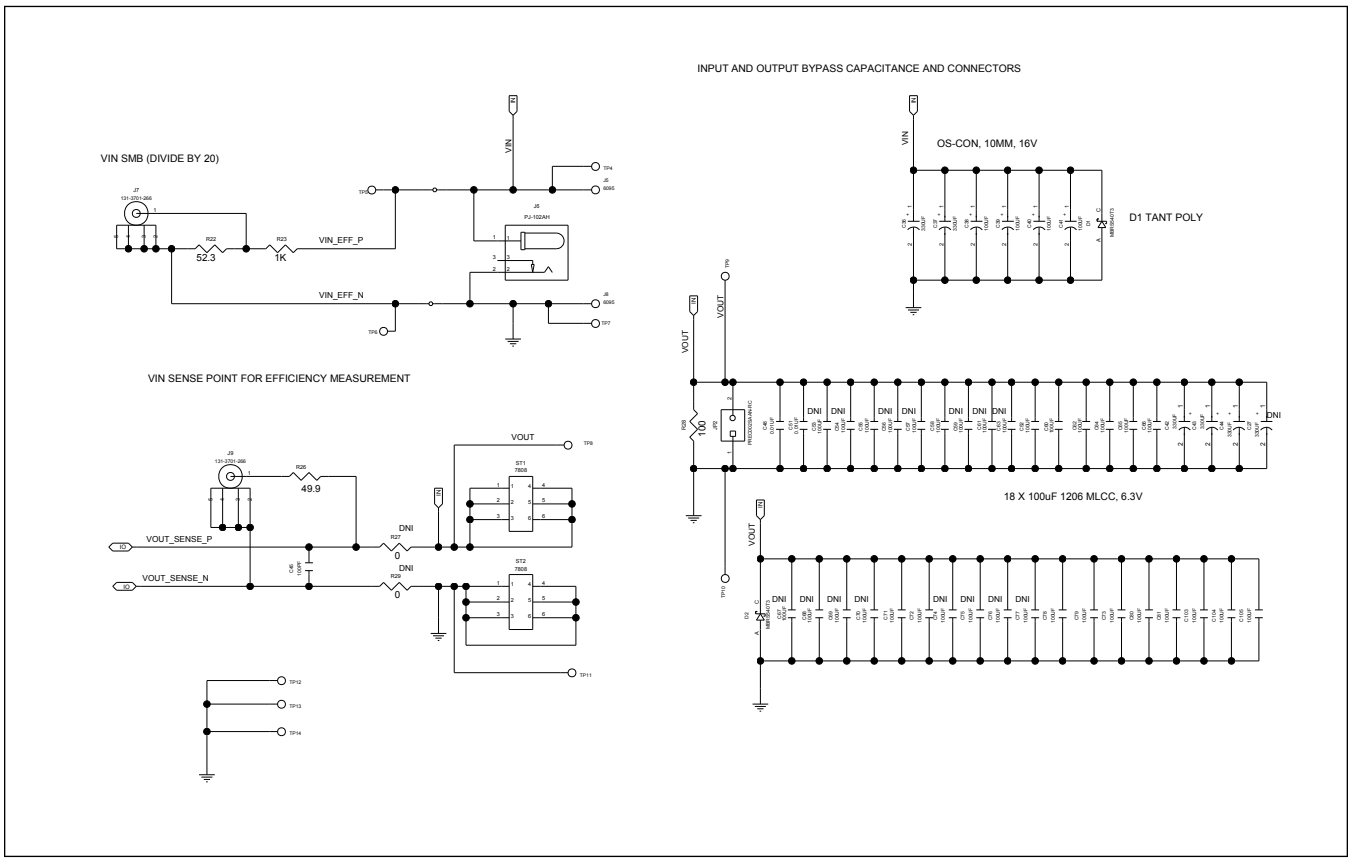


Typical Application Circuits (continued)

OPTIONAL EXTERNAL POWER-STAGE



Typical Application Circuits (continued)



Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	CONFIGURATION (TABLE 7)
MAX20796GFB+	-40°C to +125°C	35 FC2QFN	None
MAX20796GFB+T	-40°C to +125°C	35 FC2QFN	None
MAX20796AGFB+	-40°C to +125°C	35 FC2QFN	Scenario A
MAX20796AGFB+T	-40°C to +125°C	35 FC2QFN	Scenario A

+Denotes a lead(Pb)-free/RoHS-compliant package.

T = Tape and reel.

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	7/18	Initial release	—
1	2/19	Updated *Benefit and Features*, *Absolute Maximum Ratings*, *Electrical Characteristics*, *Typical Operating Characteristics*, *Pin Description*, Figure 2, Figure 3, Table 2, *Detailed Description*, Table 4, Table 6, and *Typical Application Circuits*	1, 3–5, 9, 13, 16, 17, 20, 22–25, 27–31
2	3/19	Updated *Absolute Maximum Ratings*, *Electrical Characteristics* table, and *Detailed Description* section	3–5, 15, 19, 21, 22, 25–28
3	11/19	Added MAX20796A preconfigured version. Corrected feedback circuit equation. Simplified Peak Overcurrent Protection symbols. Minor corrections and clarifications.	1, 3, 5, 17, 18, 21, 22, 28, 32
4	3/20	Added the PMBus nonvolatile memory commands and description. Clarified the VCC and AVDD bypass capacitor requirements.	1, 17, 21, 22, 28
5	12/21	Updated *Package Information*, *Typical Operating Characteristics*, and *Applications Information* section	7, 12–14, 33

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