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19-2882; Rev 1; 4/04

EVALUATION KIT AVAILABLE

Six-Channel, High-Efficiency, Digital Camera Power Supplies

General Description

The MAX1566/MAX1567 provide a complete power-supply solution for digital cameras. They improve performance, component count, and size compared to conventional multichannel controllers in 2-cell AA, 1-cell lithium-ion (Li+), and dual-battery designs. On-chip MOSFETs provide up to 95% efficiency for critical power supplies, while additional channels operate with external FETs for optimum design flexibility. This optimizes overall efficiency and cost, while also reducing board space.

The MAX1566/MAX1567 include six high-efficiency DC-to-DC conversion channels:

- Step-up DC-to-DC converter with on-chip power FETs
- Main DC-to-DC converter with on-chip FETs, configurable to step **either** up or down
- Step-down core DC-to-DC converter with on-chip FETs
- DC-to-DC controller for white LEDs or other output
- Extra DC-to-DC controller (typically for LCD); two extra controllers on the MAX1566
- Transformerless inverting DC-to-DC controller (typically for negative CCD bias) on the MAX1567

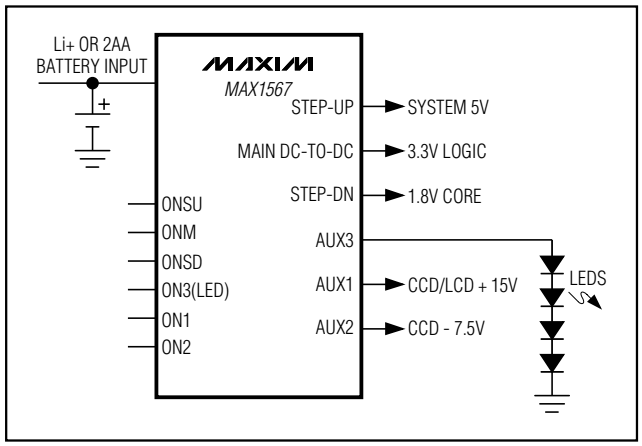
All DC-to-DC channels operate at one fixed frequency settable from 100kHz to 1MHz to optimize size, cost, and efficiency. Other features include soft-start, power-OK outputs, and overload protection. The MAX1566/MAX1567 are available in space-saving 40-pin thin QFN packages. An evaluation kit is available to expedite designs.

Applications

Digital Cameras

PDAs

Typical Operating Circuit



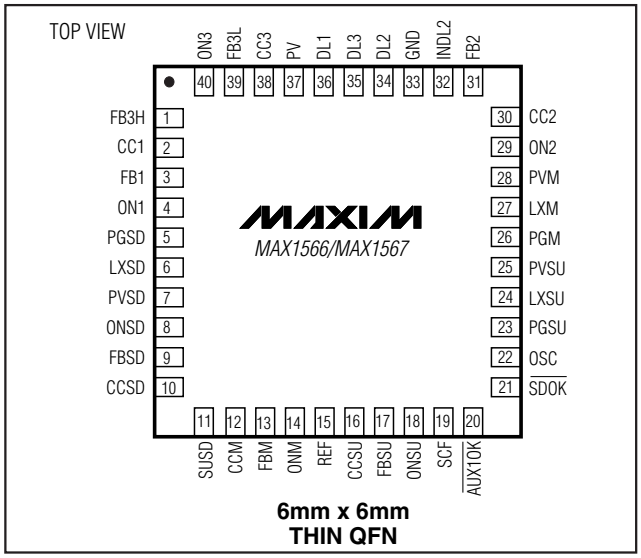
Features

- **95% Efficient Step-Up DC-to-DC Converter**
- **0.7V Minimum Input Voltage**
- **Main DC-to-DC Configurable as Either Step-Up or Step-Down**
- **Combine Step-Up and Step-Down for 90% Efficient Boost-Buck**
- **95% Efficient Step-Down for DSP Core**
- **Regulate LED Current for Four, Six, or More LEDs**
- **Open LED Overvoltage Protection**
- **Transformerless Inverting Controller (MAX1567)**
- **Three Extra PWM Controllers (Two on the MAX1567)**
- **Up to 1MHz Operating Frequency**
- **1µA Shutdown Mode**
- **Soft-Start and Overload Protection**
- **Compact 40-Pin 6mm x 6mm Thin QFN Package**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	AUX2 FUNCTION
MAX1566ETL	-40°C to +85°C	40 Thin QFN 6mm x 6mm	Step-up controller
MAX1567ETL	-40°C to +85°C	40 Thin QFN 6mm x 6mm	Inverting controller

Pin Configuration



6mm x 6mm THIN QFN

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

Six-Channel, High-Efficiency, Digital Camera Power Supplies

ABSOLUTE MAXIMUM RATINGS

PV, PVSU, $\overline{SDOK}$, $\overline{AUX1OK}$, SCF, ON_, FB_, SUSD to GND ..... -0.3V to +6V
PG_ to GND .....-0.3V to +0.3V
DL1, DL3, INDL2, PVM, PVSD to GND …-0.3V to (PVSU + 0.3V)
DL2 to GND .....-0.3V to (INDL2 + 0.3V)
LXSU Current (Note 1) 3.6A
LXM Current (Note 1) 3.6A
LXSD Current (Note 1) 2.25A
REF, OSC, CC_ to GND .....-0.3V to (PVSU + 0.3V)

Continuous Power Dissipation (T_A = +70°C)
40-Pin Thin QFN (derate 26.3mW/°C above +70°C) .2105mW
Operating Temperature Range .....-40°C to +85°C
Junction Temperature .....+150°C
Storage Temperature Range .....-65°C to +150°C
Lead Temperature (soldering, 10s) .....+300°C

Note 1: LXSU has internal clamp diodes to PVSU and PGSU, LXM has internal clamp diodes to PVM and PGM, and LXSD has internal clamp diodes to PVSD and PGSD. Applications that forward bias these diodes should take care not to exceed the devices' power dissipation limits.

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.

ELECTRICAL CHARACTERISTICS

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = 0°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
GENERAL					
Input Voltage Range	(Note 2)	0.7		5.5	V
Step-Up Minimum Startup Voltage (Note 2)	I_{LOAD} < 1mA, T_A = +25°C; startup voltage tempco is -2300ppm/°C (typ) (Note 3)		0.9	1.1	V
Shutdown Supply Current into PV	PV = 3.6V		0.1	10	µA
Supply Current into PV with Step-Up Enabled	ONSU = 3.6V, FBSU = 1.5V (does not include switching losses)		300	450	µA
Supply Current into PV with Step-Up and Step-Down Enabled	ONSU = ONSD = 3.6V, FBSU = 1.5V, FBSD = 1.5V (does not include switching losses)		450	700	µA
Supply Current into PV with Step-Up and Main Enabled	ONSU = ONM = 3.6V, FBSU = 1.5V, FBSD = 1.5V (does not include switching losses)		450	700	µA
Total Supply Current from PV and PVSU with Step-Up and One AUX Enabled	ONSU = ON1 = 3.6V, FBSU = 1.5V, FB2 = 1.5V (does not include switching losses)		400	650	µA
REFERENCE					
Reference Output Voltage	I_{REF} = 20µA	1.23	1.25	1.27	V
Reference Load Regulation	10µA < I_{REF} < 200µA		4.5	10	mV
Reference Line Regulation	2.7 < PVSU < 5.5V		1.3	5	mV
OSCILLATOR					
OSC Discharge Trip Level	Rising edge	1.225	1.25	1.275	V
OSC Discharge Resistance	OSC = 1.5V, I_{OSC} = 3mA		52	80	Ω
OSC Discharge Pulse Width			200		ns
OSC Frequency	R_{OSC} = 47kΩ, C_{OSC} = 100pF		500		kHz

ELECTRICAL CHARACTERISTICS (continued)

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = 0°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
STEP-UP DC-TO-DC					
Step-Up Startup-to-Normal Operating Threshold	Rising edge or falling edge (Note 4)	2.30	2.5	2.65	V
Step-Up Startup-to-Normal Operating Threshold Hysteresis			80		mV
Step-Up Voltage Adjust Range		3.0		5.5	V
Start Delay of ONSD, ONM, ON1, ON2, and ON3 after SU in Regulation			1024		OSC cycles
FBSU Regulation Voltage		1.231	1.25	1.269	V
FBSU to CCSU Transconductance	FBSU = CCSU	80	135	185	µS
FBSU Input Leakage Current	FBSU = 1.25V	-100	0.01	+100	nA
Idle Mode™ Trip Level			150		mA
Current-Sense Amplifier Transresistance			0.275		V/A
Step-Up Maximum Duty Cycle	FBSU = 1V	80	85	90	%
PVSU Leakage Current	V_{LX} = 0V, PVSU = 3.6V		0.1	5	µA
LXSU Leakage Current	V_{LX} = V_{OUT} = 3.6V		0.1	5	µA
Switch On-Resistance	N channel		95	150	mΩ
	P channel		150	250	
N-Channel Current Limit		1.8	2.1	2.4	A
P-Channel Turn-Off Current			20		mA
Startup Current Limit	PVSU = 1.8V (Note 5)		450		mA
Startup t_{OFF}	PVSU = 1.8V		700		ns
Startup Frequency	PVSU = 1.8V		200		kHz
MAIN DC-TO-DC CONVERTER					
Main Step-Up Voltage Adjust Range	SUSD = PVSU	3		5.5	V
Main Step-Down Voltage Adjust Range	SUSD = GND, PVM must be greater than output (Note 6)	2.45		5.00	V
PVM Undervoltage Lockout in Step-Down Mode	SUSD = GND (Note 6)	2.45	2.5	2.55	V
Regulation Voltage		1.231	1.25	1.269	V
FBM to CCM Transconductance	FBM = CCM	80	135	185	µS
FBM Input Leakage Current	FBM = 1.25V	-100	0.01	+100	nA
Idle Mode Trip Level	Step-up mode (SUSD = PVSU)		150		mA
	Step-down mode (SUSD = GND)		100		
Current-Sense Amplifier Transresistance	Step-up mode (SUSD = PVSU)		0.25		V/A
	Step-down mode (SUSD = GND)		0.5		

Idle Mode is a trademark of Maxim Integrated Products, Inc.

Six-Channel, High-Efficiency, Digital Camera Power Supplies

ELECTRICAL CHARACTERISTICS (continued)

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = 0°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Maximum Duty Cycle (Note 6)	Step-up mode (SUSD = PVSU)	80	85	90	%
	Step-down mode (SUSD = GND)		95		
LXM Leakage Current	V_{LXM} = 0 to 3.6V, PVSU = 3.6V		0.1	5	µA
Switch On-Resistance	N channel		95	150	mΩ
	P channel		150	250	
Main Switch Current Limit	Step-up mode (SUSD = PVSU)	1.8	2.1	2.4	A
	Step-down mode (SUSD = GND)	0.70	0.8	0.95	
Synchronous Rectifier Turn-Off Current	Step-up mode (SUSD = PVSU)		20		mA
	Step-down mode (SUSD = GND)		20		
Soft-Start Interval			4096		OSC cycles
STEP-DOWN DC-TO-DC CONVERTER					
Step-Down Output-Voltage Adjust Range	PVSD must be greater than output (Note 7)	1.25		5.00	V
FBSD Regulation Voltage		1.231	1.25	1.269	V
FBSD to CCSD Transconductance	FBSD = CCSD	80	135	185	µS
FBSD Input Leakage Current	FBSD = 1.25V	-100	0.1	+100	nA
Idle Mode Trip Level			100		mA
Current-Sense Amplifier Transresistance			0.5		V/A
LXSD Leakage Current	V_{LXSD} = 0 to 3.6V, PVSU = 3.6V		0.1	5	µA
Switch On-Resistance	N channel		95	150	mΩ
	P channel		150	250	
P-Channel Current Limit		0.65	0.77	0.90	A
N-Channel Turn-Off Current			20		mA
Soft-Start Interval			2048		OSC cycles
$\overline{SDOK}$ Output Low Voltage	0.1mA into $\overline{SDOK}$		0.01	0.1	V
$\overline{SDOK}$ Leakage Current	ONSU = GND		0.01	1	µA
AUX1, 2, 3 DC-TO-DC CONTROLLERS					
INDL2 Undervoltage Lockout		2.45	2.5	2.55	V
Maximum Duty Cycle	FB_ = 1V	80	85	90	%
FB1, FB2 (MAX1566), FB3H Regulation Voltage		1.231	1.25	1.269	V
FB2 (MAX1567) Inverter Regulation Voltage		-0.01	0	+0.01	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = 0°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
FB3L Regulation Voltage		0.19	0.2	0.21	V
AUX1, AUX2 FB to CC Transconductance		80	135	185	µS
AUX3 FBL or FBH to CC Transconductance		50	100	150	µS
FB_ Input Leakage Current		-100	0.1	+100	nA
DL_ Driver Resistance	Output high or low		2.5	7	Ω
DL_ Drive Current	Sourcing or sinking		0.5		A
Soft-Start Interval			4096		OSC cycles
$\overline{AUX1OK}$ Output Low Voltage	0.1mA into $\overline{AUX1OK}$		0.01	0.1	V
$\overline{AUX1OK}$ Leakage Current	ONSU = GND		0.01	1	µA
OVERLOAD PROTECTION					
Overload Protection Fault Delay			100,000		OSC cycles
SCF Leakage Current	ONSU = PVSU, FBSU = 1.5V		0.1	1	µA
SCF Output Low Voltage	0.1mA into SCF		0.01	0.1	V
THERMAL-LIMIT PROTECTION					
Thermal Shutdown			160		°C
Thermal Hysteresis			20		°C
LOGIC INPUTS (ON_, SUSD)					
ONSU Input Low Level	1.1V < PVSU < 1.8V			0.2	V
	1.8V ≤ PVSU < 2.5V			0.4	
	2.5V ≤ PVSU < 5.5V			0.5	
ONSU Input High Level	1.1V < PVSU < 1.8V	(PVSU - 0.2)			V
	1.8V < PVSU < 5.5V	1.6			
ONM, ONSD, ON1, ON2, ON3, SUSD Input Low Level	2.7V < PVSU < 5.5V (Note 8)			0.5	V
ONM, ONSD, ON1, ON2, ON3, SUSD Input High Level	2.7V < PVSU < 5.5V (Note 8)	1.6			V
SUSD Input Leakage			0.1	1	µA
ON_ Impedance to GND			330		kΩ

Six-Channel, High-Efficiency, Digital Camera Power Supplies

ELECTRICAL CHARACTERISTICS

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = -40°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
GENERAL				
Input Voltage Range	(Note 2)	0.7	5.5	V
Step-Up Minimum Startup Voltage (Note 2)	I_{LOAD} < 1mA, T_A = +25°C; startup voltage tempco is -2300ppm/°C (typ) (Note 3)		1.1	V
Shutdown Supply Current into PV	PV = 3.6V		10	µA
Supply Current into PV with Step-Up Enabled	ONSU = 3.6V, FBSU = 1.5V (does not include switching losses)		400	µA
Supply Current into PV with Step-Up and Step-Down Enabled	ONSU = ONSD = 3.6V, FBSU = 1.5V, FBSD = 1.5V (does not include switching losses)		600	µA
Supply Current into PV with Step-Up and Main Enabled	ONSU = ONM = 3.6V, FBSU = 1.5V, FBSD = 1.5V (does not include switching losses)		600	µA
Total Supply Current from PV and PVSU with Step-Up and One AUX Enabled	ONSU = ON1 = 3.6V, FBSU = 1.5V, FB2 = 1.5V (does not include switching losses)		550	µA
REFERENCE				
Reference Output Voltage	I_{REF} = 20µA	1.23	1.27	V
Reference Load Regulation	10µA < I_{REF} < 200µA		10	mV
Reference Line Regulation	2.7V < PVSU < 5.5V		5	mV
OSCILLATOR				
OSC Discharge Trip Level	Rising edge	1.225	1.275	V
OSC Discharge Resistance	OSC = 1.5V, I_{OSC} = 3mA		80	Ω
STEP-UP DC-TO-DC CONVERTER				
Step-Up Startup-to-Normal Operating Threshold	Rising edge or falling edge (Note 4)	2.30	2.65	V
Step-Up Voltage Adjust Range		3.0	5.5	V
FBSU Regulation Voltage		1.231	1.269	V
FBSU to CCSU Transconductance	FBSU = CCSU	80	185	µS
FBSU Input Leakage Current	FBSU = 1.25V	-100	+100	nA
Step-Up Maximum Duty Cycle	FBSU = 1V	80	90	%
PVSU Leakage Current	V_{LX} = 0V, PVSU = 3.6V		5	µA
LXSU Leakage Current	V_{LX} = V_{OUT} = 3.6V		5	µA
Switch On-Resistance	N channel		150	mΩ
	P channel		250	
N-Channel Current Limit		1.8	2.4	A
MAIN DC-TO-DC CONVERTER				
Main Step-Up Voltage Adjust Range	SUSD = PVSU	3.0	5.5	V

ELECTRICAL CHARACTERISTICS (continued)

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = -40°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
Main Step-Down Voltage Adjust Range	SUSD = GND, PVM must be greater than output (Note 6)	2.45	5.00	V
PVM Undervoltage Lockout in Step-Down Mode	SUSD = GND (Note 6)	2.45	2.55	V
Regulation Voltage		1.225	1.275	V
FBM to CCM Transconductance	FBM = CCM	80	185	µS
FBM Input Leakage Current	FBM = 1.25V	-100	+100	nA
Maximum Duty Cycle	Step-up mode (SUSD = PVSU), step-down mode (SUSD = GND) (Note 6)	80	90	%
LXM Leakage Current	V_{LXM} = 0 to 3.6V, PVSU = 3.6V		5	µA
Switch On-Resistance	N channel		150	mΩ
	P channel		250	
Main Switch Current Limit	Step-up mode (SUSD = PVSU)	1.8	2.4	A
	Step-down mode (SUSD = GND)	0.70	0.95	
STEP-DOWN DC-TO-DC CONVERTER				
Step-Down Output Voltage Adjust Range	PVSD must be greater than output (Note 7)	1.25	5.00	V
FBSD Regulation Voltage		1.225	1.275	V
FBSD to CCSD Transconductance	FBSD = CCSD	80	185	µS
FBSD Input Leakage Current	FBSD = 1.25V	-100	+100	nA
LXSD Leakage Current	V_{LXSD} = 0 to 3.6V, PVSU = 3.6V		5	µA
Switch On-Resistance	N channel		150	mΩ
	P channel		250	
P-Channel Current Limit		0.65	0.90	A
$\overline{SDOK}$ Output Low Voltage	0.1mA into $\overline{SDOK}$		0.1	V
$\overline{SDOK}$ Leakage Current	ONSU = GND		1	µA
AUX1, 2, 3 DC-TO-DC CONTROLLERS				
INDL2 Undervoltage Lockout		2.45	2.55	V
Maximum Duty Cycle	FB_ = 1V	80	90	%
FB1, FB2 (MAX1566), FB3H Regulation Voltage		1.225	1.275	V
FB2 (MAX1567) Inverter Regulation Voltage		-0.01	+0.01	V
FB3L Regulation Voltage		0.19	0.21	V
AUX1, AUX2 FB to CC Transconductance		80	185	µS

Six-Channel, High-Efficiency, Digital Camera Power Supplies

ELECTRICAL CHARACTERISTICS (continued)

(V_{PVSU} = V_{PV} = V_{PVM} = V_{PVSD} = V_{INDL2} = 3.6V, **T_A = -40°C to +85°C**, unless otherwise noted.)

PARAMETER	CONDITIONS	MIN	MAX	UNITS
AUX3 FBL or FBH to CC Transconductance		35	150	µS
FB_ Input Leakage Current		-100	+100	nA
DL_ Driver Resistance	Output high or low		7	Ω
$\overline{AUX1OK}$ Output Low	0.1mA into $\overline{AUX1OK}$		0.1	V
$\overline{AUX1OK}$ Leakage Current	ONSU = GND		1	µA
OVERLOAD PROTECTION				
SCF Leakage Current	ONSU = PVSU, FBSU = 1.5V		1	µA
SCF Output Low Voltage	0.1mA into SCF		0.1	V
LOGIC INPUTS (ON_, SUSD)				
ONSU Input Low Level	1.1V < PVSU < 1.8V		0.2	V
	1.8V ≤ PVSU < 2.5V		0.4	
	2.5V ≤ PVSU < 5.5V		0.5	
ONSU Input High Level	1.1V < PVSU < 1.8V	(PVSU - 0.2)		V
	1.8V < PVSU < 5.5V	1.6		
ONM, ONSD, ON1, ON2, ON3, SUSD Input Low Level	2.7V < PVSU < 5.5V (Note 8)		0.5	V
ONM, ONSD, ON1, ON2, ON3, SUSD Input High Level	2.7V < PVSU < 5.5V (Note 8)	1.6		V
SUSD Input Leakage			1	µA

Note 2: The MAX1566/MAX1567 are powered from the step-up output (PVSU). An internal low-voltage startup oscillator drives the step-up starting at approximately 0.9V until PVSU reaches approximately 2.5V. When PVSU reaches 2.5V, the main control circuitry takes over. Once the step-up is up and running, it can maintain operation with very low input voltages; however, output current is limited.

Note 3: Since the device is powered from PVSU, a Schottky rectifier, connected from the battery to PVSU, is required for low-voltage startup.

Note 4: The step-up regulator is in startup mode until this voltage is reached. Do not apply full load current during startup. A power-OK output can be used with an external PFET to gate the load until the step-up is in regulation. See the *$\overline{AUX1OK}$, $\overline{SDOK}$, and SCF Connections* section.

Note 5: The step-up current limit in startup refers to the LXSU switch current limit, not the output current limit.

Note 6: If the main converter is configured as a step-up (SUSD = PVSU), the P-channel synchronous rectifier is disabled until the 2.5V normal operation threshold has been exceeded. If the main converter is configured as a step-down (SUSD = GND), all step-down operation is locked out until the normal operation threshold has been exceeded. When the main is configured as a step-down, operation in dropout (100% duty cycle) can only be maintained for 100,000 OSC cycles before the output is considered faulted, triggering global shutdown.

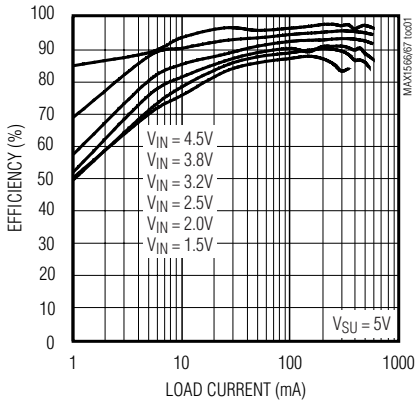
Note 7: Operation in dropout (100% duty cycle) can only be maintained for 100,000 OSC cycles before the output is considered faulted, triggering global shutdown.

Note 8: ONM, ONSD, ON1, ON2, and ON3 are disabled until 1024 OSC cycles after PVSU reaches 2.7V.

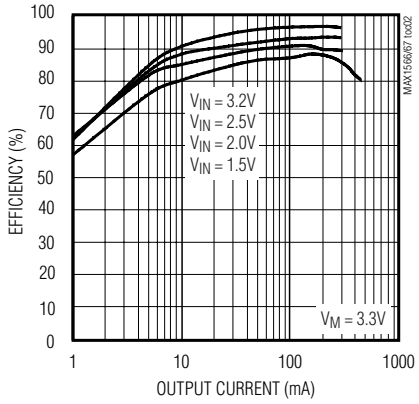
Typical Operating Characteristics

(T_A = +25°C, unless otherwise noted.)

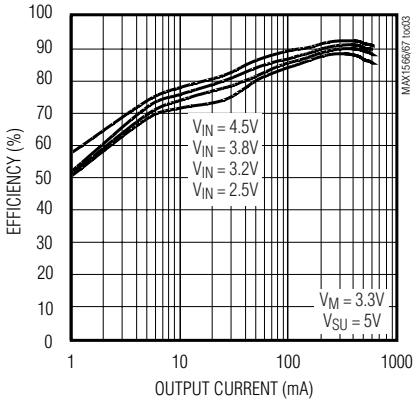
STEP-UP EFFICIENCY vs. LOAD CURRENT



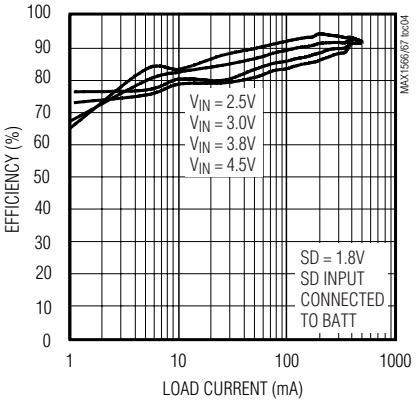
MAIN (STEP-UP) EFFICIENCY vs. LOAD CURRENT



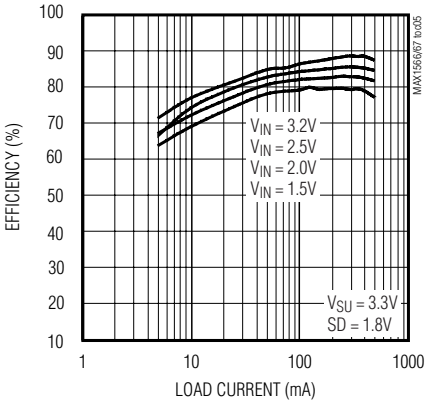
BOOST-BUCK EFFICIENCY (SU + MAIN AS STEP-DOWN) vs. LOAD CURRENT



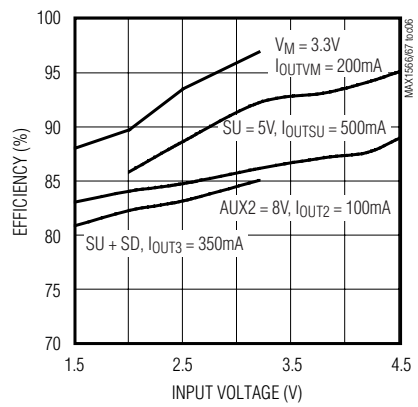
STEP-DOWN EFFICIENCY vs. LOAD CURRENT



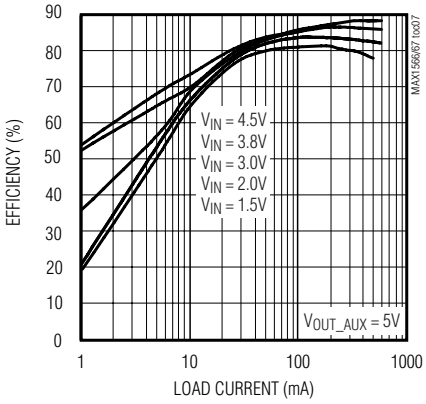
BOOST-BUCK EFFICIENCY (SU + SD) vs. LOAD CURRENT



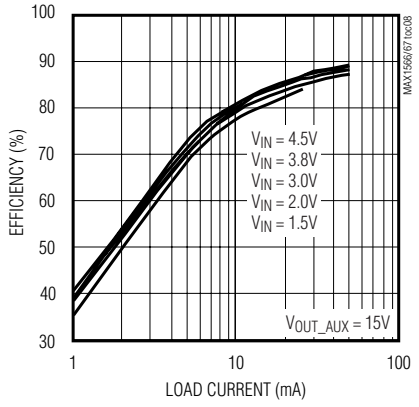
EFFICIENCY vs. INPUT VOLTAGE



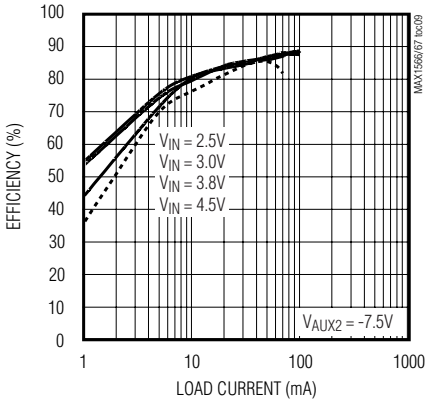
AUX EFFICIENCY vs. LOAD CURRENT



AUX EFFICIENCY vs. LOAD CURRENT



MAX1567 AUX2 EFFICIENCY vs. LOAD CURRENT



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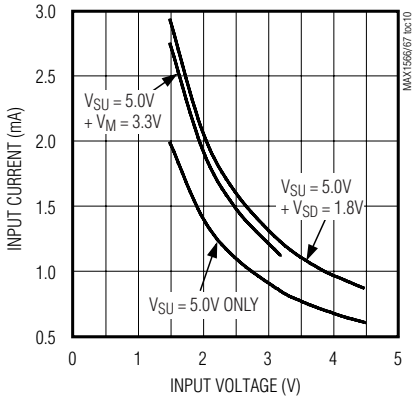
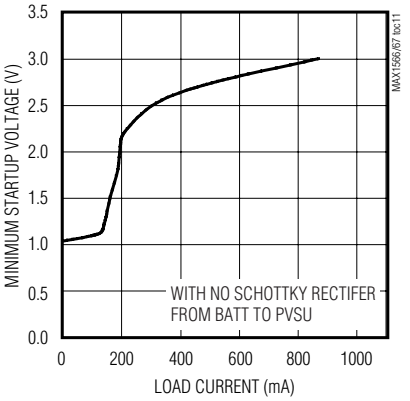
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

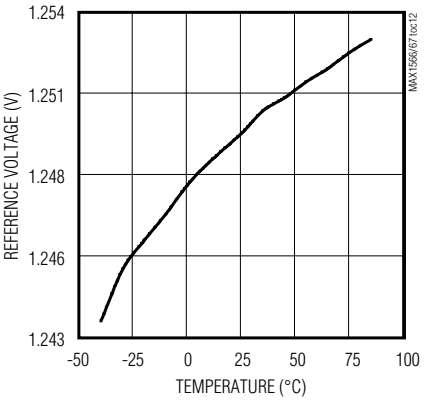
NO-LOAD INPUT CURRENT vs. INPUT VOLTAGE (SWITCHING)



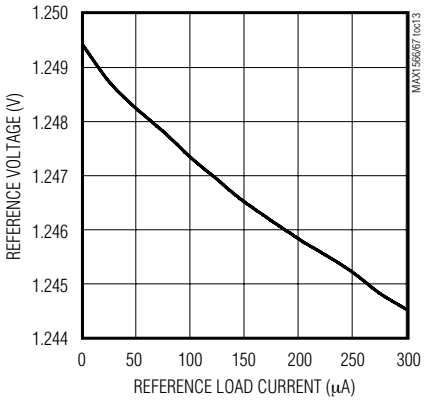
MINIMUM STARTUP VOLTAGE vs. LOAD CURRENT (OUTSU)



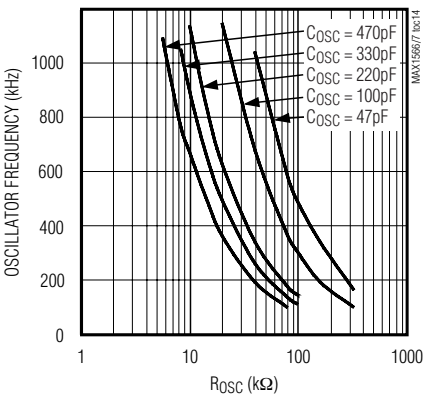
REFERENCE VOLTAGE vs. TEMPERATURE



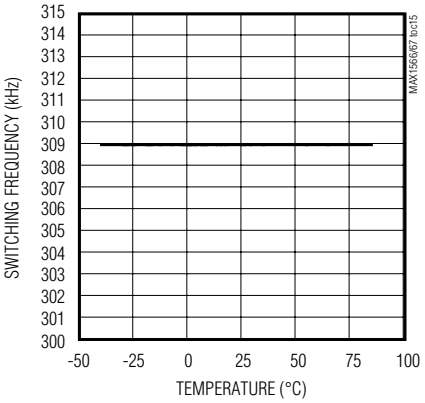
REFERENCE VOLTAGE vs. REFERENCE LOAD CURRENT



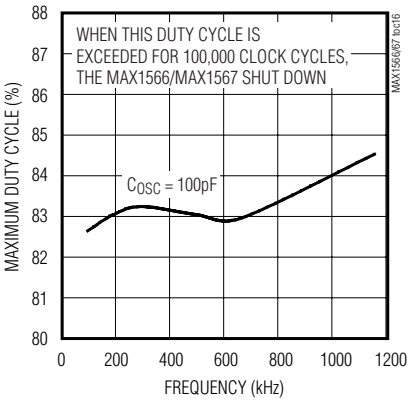
OSCILLATOR FREQUENCY vs. ROSC



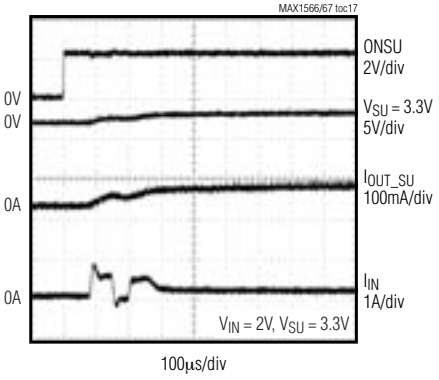
SWITCHING FREQUENCY vs. TEMPERATURE



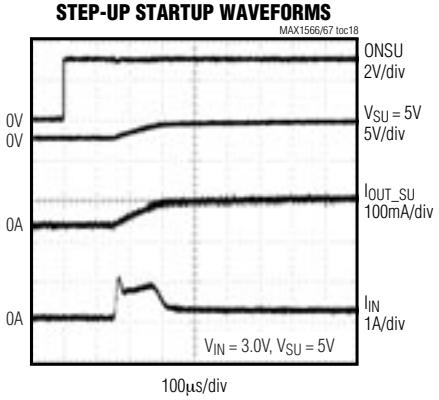
AUX_ MAXIMUM DUTY CYCLE vs. FREQUENCY



STEP-UP STARTUP WAVEFORMS



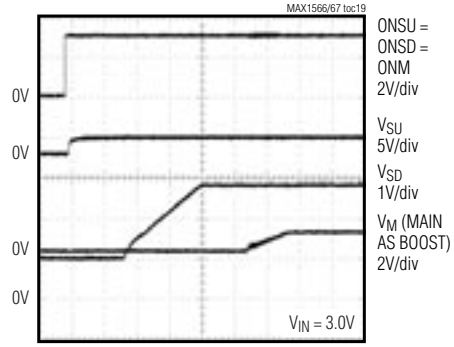
STEP-UP STARTUP WAVEFORMS



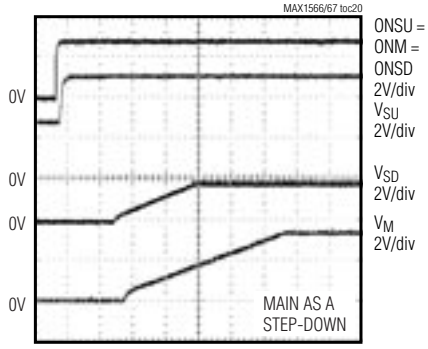
Typical Operating Characteristics (continued)

(T_A = +25°C, unless otherwise noted.)

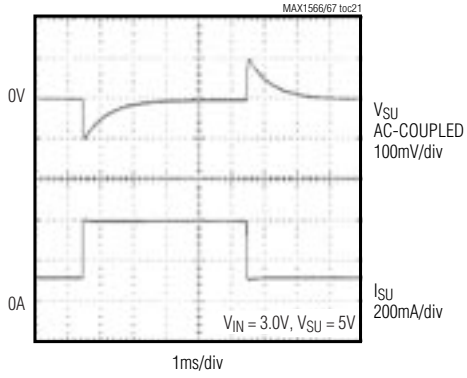
MAIN (STEP-UP MODE) AND STEP-DOWN STARTUP WAVEFORMS



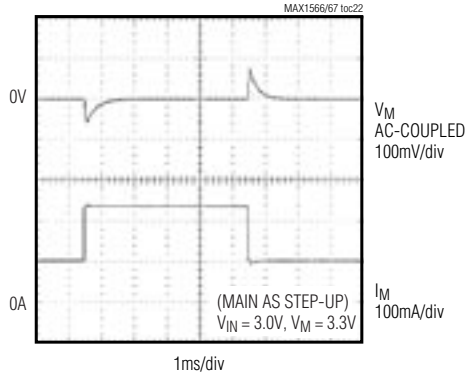
MAIN (STEP-DOWN MODE) AND STEP-DOWN STARTUP WAVEFORMS



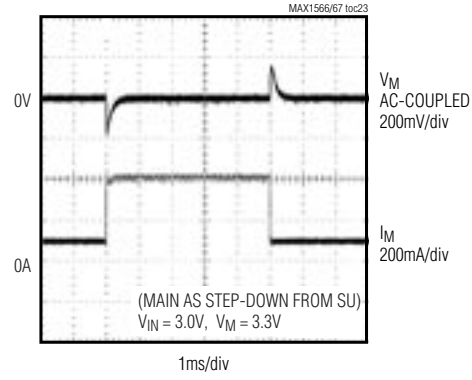
STEP-UP LOAD TRANSIENT RESPONSE



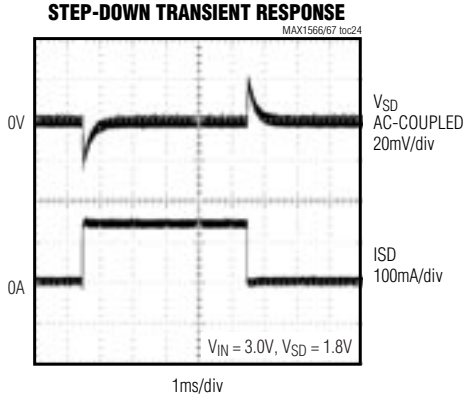
MAIN (STEP-UP MODE) LOAD TRANSIENT RESPONSE



MAIN (STEP-DOWN MODE) LOAD TRANSIENT RESPONSE



STEP-DOWN TRANSIENT RESPONSE



Six-Channel, High-Efficiency, Digital Camera Power Supplies

Pin Description

PIN	NAME	FUNCTION
1	FB3H	AUX3 Controller Voltage Feedback Input. Connect a resistive voltage-divider from the step-up converter output to FBH to set the output voltage. The feedback threshold is 1.25V. This pin is high impedance in shutdown. FB3H can provide conventional voltage feedback (with FB3L grounded) or open-LED protection in white LED drive circuits.
2	CC1	AUX1 Controller Compensation Node. Connect a series resistor-capacitor from this pin to GND to compensate the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *AUX Compensation* section.
3	FB1	AUX1 Controller Feedback Input. The feedback threshold is 1.25V. This pin is high impedance in shutdown.
4	ON1	AUX1 Controller On/Off Input. Logic high = on; however, turn-on is locked out until 1024 OSC cycles after the step-up has reached regulation. This pin has an internal 330kΩ pulldown resistance to GND.
5	PGSD	Power Ground. Connect all PG_ pins to GND with short wide traces as close to the IC as possible.
6	LXSD	Step-Down Converter Switching Node. Connect to the inductor of the step-down converter. LXSD is high impedance in shutdown.
7	PVSD	Step-Down Converter Input. Bypass to GND with a 1µF ceramic capacitor. The step-down efficiency is measured from this input.
8	ONSD	Step-Down Converter On/Off Control Input. Logic high = on; however, turn-on is locked out until 1024 OSC cycles after the step-up has reached regulation. This pin has an internal 330kΩ pulldown resistance to GND.
9	FBSD	Step-Down Converter Feedback Input. The feedback threshold is 1.25V. This pin is high impedance in shutdown.
10	CCSD	Step-Down Converter Compensation Node. Connect a series resistor-capacitor from this pin to GND for compensating the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *Step-Down Compensation* section.
11	SUSD	Configures the Main Converter as a Step-Up or a Step-Down. This function must be hardwired. On-the-fly changes are not allowed. With SUSD connected to PV, the main is configured as a step-up and PVM is the converter output. With SUSD connected to GND, the main is configured as a step-down and PVM is the power input.
12	CCM	Main Converter Compensation Node. Connect a series resistor-capacitor from this pin to GND for compensating the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *Step-Up Compensation* section when the main is used in step-up mode and the *Step-Down Compensation* section when the main is used in step-down mode.
13	FBM	Main Converter Feedback Input. The feedback threshold is 1.25V. This pin is high impedance in shutdown. The main output voltage must not be set higher than the step-up output.
14	ONM	On/Off Control for the Main DC-to-DC Converter. Logic high = on; however, turn-on is locked out until 1024 OSC cycles after the step-up has reached regulation. This pin has an internal 330kΩ pulldown resistance to GND. SUSD pin configures the main converter as a step-up or step-down.
15	REF	Reference Output. Bypass REF to GND with a 0.1µF or greater capacitor. The maximum-allowed REF load is 200µA. REF is actively pulled to GND when the step-up is shut down (all converters turn off).

Pin Description (continued)

PIN	NAME	FUNCTION
16	CCSU	Step-Up Converter Compensation Node. Connect a series resistor-capacitor from this pin to GND for compensating the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *Step-Up Compensation* section.
17	FBSU	Step-Up Converter Feedback Input. The feedback threshold is 1.25V. This pin is high impedance in shutdown.
18	ONSU	Step-Up Converter On/Off Control. Logic high = on. All other ON_ pins are locked out until 1024 OSC cycles after the step-up DC-to-DC converter output has reached its final value. This pin has an internal 330kΩ pulldown resistance to GND.
19	SCF	Open-Drain, Active-Low, Short-Circuit Flag Output. SCF goes open when overload protection occurs and during startup. SCF can drive high-side PFET switches connected to one or more outputs to completely disconnect the load when the channel turns off in response to a logic command or an overload. See the *Status Outputs ($\overline{SDOK}$, $\overline{AUX1OK}$, SCF)* section.
20	$\overline{AUX1OK}$	Open-Drain, Active-Low, Power-OK Signal for AUX1 Controller. $\overline{AUX1OK}$ goes low when the AUX1 controller has successfully completed soft-start. $\overline{AUX1OK}$ goes high impedance in shutdown, overload, and thermal limit.
21	$\overline{SDOK}$	Open-Drain, Active-Low, Power-OK Signal for Step-Down Converter. $\overline{SDOK}$ goes low when the step-down has successfully completed soft-start. $\overline{SDOK}$ goes high impedance in shutdown, overload, and thermal limit.
22	OSC	Oscillator Control. Connect a timing capacitor from OSC to GND and a timing resistor from OSC to PVSU (or other DC voltage) to set the oscillator frequency between 100kHz and 1MHz. See the *Setting the Switching Frequency* section. This pin is high impedance in shutdown.
23	PGSU	Power Ground. Connect all PG_ pins to GND with short wide traces as close to the IC as possible.
24	LXSU	Step-Up Converter Switching Node. Connect to the inductor of the step-up converter. LXSU is high impedance in shutdown.
25	PVSU	Power Output of the Step-Up DC-to-DC Converter. PVSU can also power other converter channels. Connect PVSU and PV together.
26	PGM	Power Ground. Connect all PG_ pins to GND with short wide traces as close to the IC as possible.
27	LXM	Main Converter Switching Node. Connect to the inductor of the main converter (can be configured as a step-up or step-down by SUSD). LXM is high impedance in shutdown.
28	PVM	When SUSD = PVSU, the main converter is configured as a step-up and PVM is the main output. When SUSD = GND, the main is configured as a step-down and PVM is the power input.
29	ON2	AUX2 Controller On/Off Input. Logic high = on; however, turn-on is locked out until 1024 OSC cycles after the step-up has reached regulation. This pin has an internal 330kΩ pulldown resistance to GND.
30	CC2	AUX2 Controller Compensation Node. Connect a series resistor-capacitor from this pin to GND to compensate the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *AUX Compensation* section.

Pin Description (continued)

PIN	NAME	FUNCTION	
31	FB2	AUX2 Controller Feedback Input. This pin is high impedance in shutdown.	MAX1566 (AUX2 is configured as a boost): FB2 feedback threshold is 1.25V.
			MAX1567 (AUX2 is configured as an inverter): FB2 feedback threshold is 0V.
32	INDL2	Voltage Input for AUX2 Gate Driver. The voltage at INDL2 sets the high gate-drive voltage.	MAX1566 (AUX2 is configured as a boost): connect INDL2 to PVSU for optimum N-channel gate drive.
			MAX1567 (AUX2 is configured as an inverter): connect INDL2 to the external P-channel MOSFET source to ensure the P channel is completely off when DL2 swings high.
33	GND	Analog Ground. Connect to all PG_ pins as close to the IC as possible.	
34	DL2	AUX2 Controller Gate-Drive Output. DL2 drives between INDL2 and GND.	The MAX1566 configures DL2 to drive an N-channel FET in a boost configuration. DL2 is driven low in shutdown, overload, and thermal limit.
			The MAX1567 configures DL2 to drive a PFET in an inverter configuration. DL2 is driven high in shutdown, overload, and thermal limit.
35	DL3	AUX3 Controller Gate-Drive Output. Connect to the gate of an N-channel MOSFET. DL3 drives between GND and PVSU and supplies up to 500mA. This pin is actively driven to GND in shutdown, overload, and thermal limit.	
36	DL1	AUX1 Controller Gate-Drive Output. Connect to the gate of an N-channel MOSFET. DL1 drives between GND and PVSU and supplies up to 500mA. This pin is actively driven to GND in shutdown, overload, and thermal limit.	
37	PV	IC Power Input. Connect PVSU and PV together.	
38	CC3	AUX3 Controller Compensation Node. Connect a series resistor-capacitor from this pin to GND for compensating the converter control loop. This pin is actively driven to GND in shutdown, overload, and thermal limit. See the *AUX Compensation* section.	
39	FB3L	AUX3 Controller Current-Feedback Input. Connect a resistor from FB3L to GND to set LED current in LED boost-drive circuits. The feedback threshold is 0.2V. Connect this pin to GND if using only the FB3H feedback. This pin is high impedance in shutdown.	
40	ON3	AUX3 Controller On/Off Input. Logic high = on; however, turn-on is locked out until 1024 OSC cycles after the step-up has reached regulation. This pin has an internal 330kΩ pulldown resistance to GND.	
Pad	EP	Exposed Metal Pad. This pad is connected to ground. Note this internal connection is a soft-connect, meaning there is no internal metal or bond wire physically connecting the exposed pad to the GND pin. The connection is through the silicon substrate of the die and then through a conductive epoxy. Connecting the exposed pad to ground does not remove the requirement for a good ground connection to the appropriate pins.	

Detailed Description

The MAX1566/MAX1567 include the following blocks to build a multiple-output digital camera power-supply system. Both devices can accept inputs from a variety of sources including 1-cell Li+ batteries, 2-cell alkaline or NiMH batteries, and even systems designed to accept both battery types. The MAX1566/MAX1567 include six DC-to-DC converter channels to generate all required voltages:

- Step-up DC-to-DC converter (_SU pins) with on-chip power FETS
- Main DC-to-DC converter (_M pins) with on-chip power FETS that can be configured as either a step-up or step-down DC-to-DC converter
- Step-down core DC-to-DC converter with on-chip MOSFETs (_SD pins)
- AUX1 DC-to-DC controller for boost and flyback converters
- AUX2 DC-to-DC controller for boost and flyback converters (MAX1566)
- AUX2 DC-to-DC controller for inverting DC-to-DC converters (MAX1567)
- AUX3 DC-to-DC controller for white LED as well as conventional boost applications; includes open LED overvoltage protection

Step-Up DC-to-DC Converter

The step-up DC-to-DC switching converter typically is used to generate a 5V output voltage from a 1.5V to 4.5V battery input, but any voltage from V_{IN} to 5V can be set. An internal NFET switch and external synchronous rectifier allow conversion efficiencies as high as 95%. Under moderate to heavy loading, the converter operates in a low-noise PWM mode with constant frequency and modulated pulse width. Switching harmonics generated by fixed-frequency operation are consistent and easily filtered. Efficiency is enhanced under light (<75mA typ) loading by an Idle Mode that switches the step-up only as needed to service the load. In this mode, the maximum inductor current is 150mA for each pulse.

Main DC-to-DC Converter (Step-Up or Step-Down)

The main converter can be configured as a step-up (Figure 2) or a step-down converter (Figure 1) with the SUSD pin. The main DC-to-DC converter is typically used to generate 3.3V, but any voltage from 2.7V to 5V can be set; however, the main output must not be set higher than the step-up output (PVSU).

An internal MOSFET switch and synchronous rectifier allow conversion efficiencies as high as 95%. Under moderate to heavy loading, the converter operates in a low-noise PWM mode with constant frequency and modulated pulse width. Switching harmonics generated by fixed-frequency operation are consistent and easily filtered. Efficiency is enhanced under light loading (<150mA typical for step-up mode, <100mA typical for step-down mode) by assuming an Idle Mode during which the converter switches only as needed to service the load.

Step-down operation can be direct from a Li+ cell if the minimum input voltage exceeds the desired output by approximately 200mV. Note that if the main DC-to-DC, operating as a step-down, operates in dropout, the overload protection circuit senses an out-of-regulation condition and turns off all channels.

Li+ to 3.3V Boost-Buck Operation

When generating 3.3V from an Li+ cell, boost-buck operation may be needed so a regulated output can be maintained for input voltages above and below 3.3V. In that case, it may be best to configure the main converter as a step-down (SUSD = GND) and to connect its input, PVM, to the step-up output (PVSU), set to a voltage at or above 4.2V (Figures 1 and 3). The compound efficiency with this connection is typically up to 90%. This connection is also suitable for designs that must operate from both 1-cell Li+ and 2 AA cells.

Note that the step-up output supplies both the step-up load and the main step-down input current when the main is powered from the step-up. The main input current reduces the available step-up output current for other loads.

2 AA to 3.3V Operation

In designs that operate only from 2 AA cells, the main DC-to-DC can be configured as a boost converter (SUSD = PVM) to maximize the 3.3V efficiency (Figure 2).

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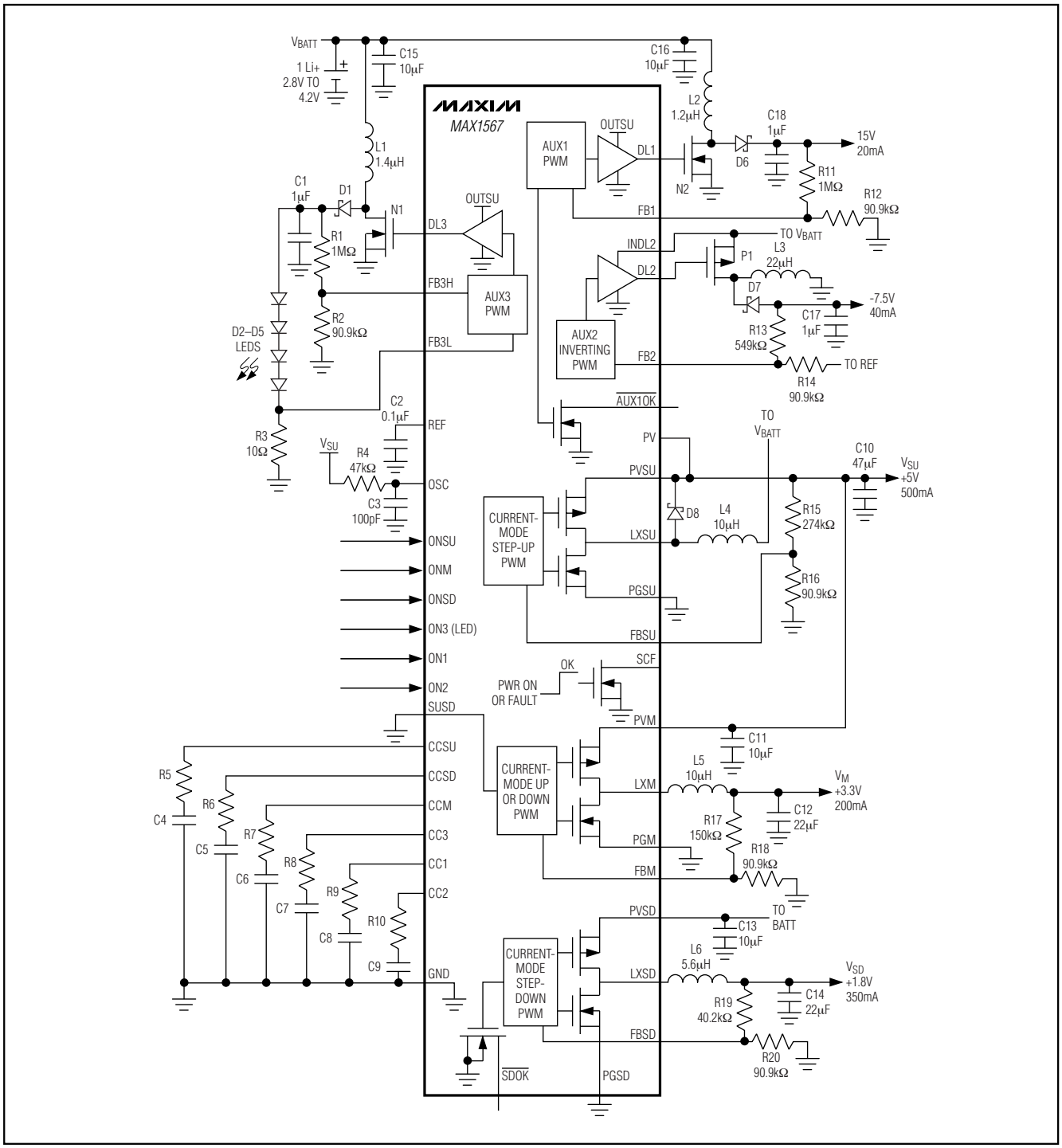

Figure 1. Typical 1-Cell Li+ Powered System (3.3V logic is stepped down from +5V, and 1.8V core is stepped down directly from the battery. Alternate connections are shown in the following figures.)

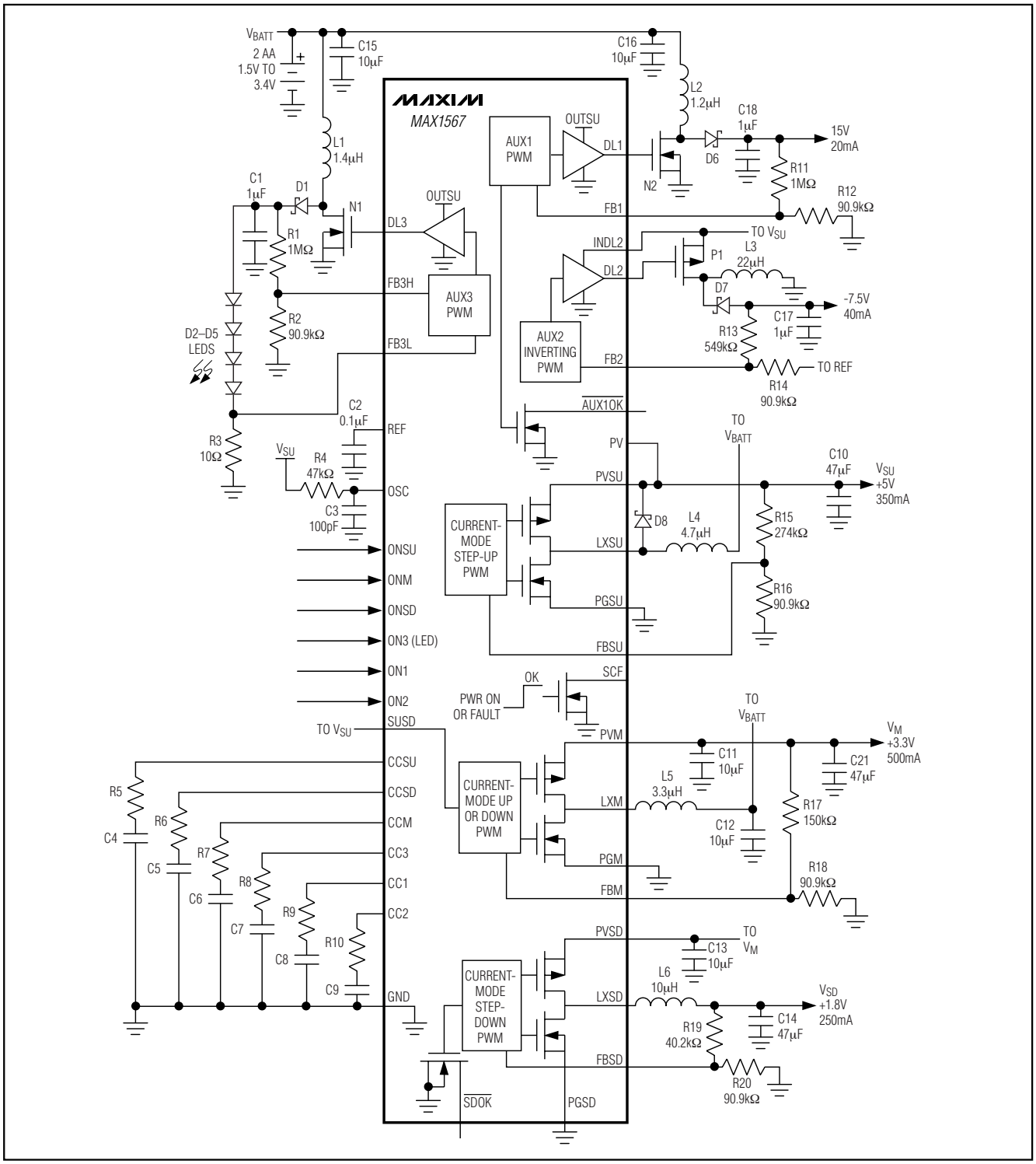

Figure 2. Typical 2-Cell AA-Powered System (3.3V is boosted from the battery and 1.8V is stepped down from V_M (3.3V).)

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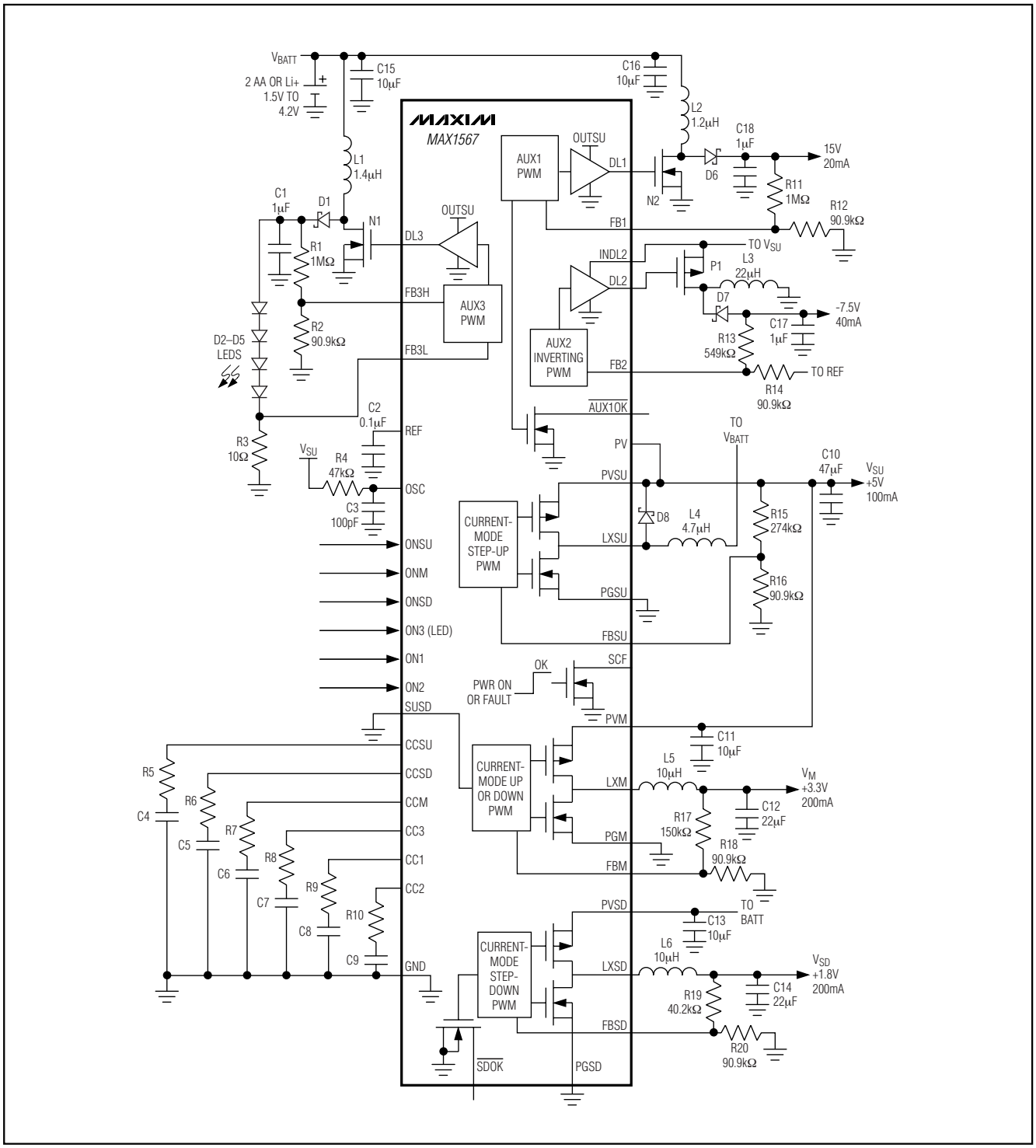


Figure 3. Li+ or Multibattery Input (This power supply accepts inputs from 1.5V to 4.2V, so it can operate from either 2 AA cells or 1 Li+ cell. The 3.3V logic supply and the 1.8V core supply are both stepped down from 5V for true boost-buck operation.)

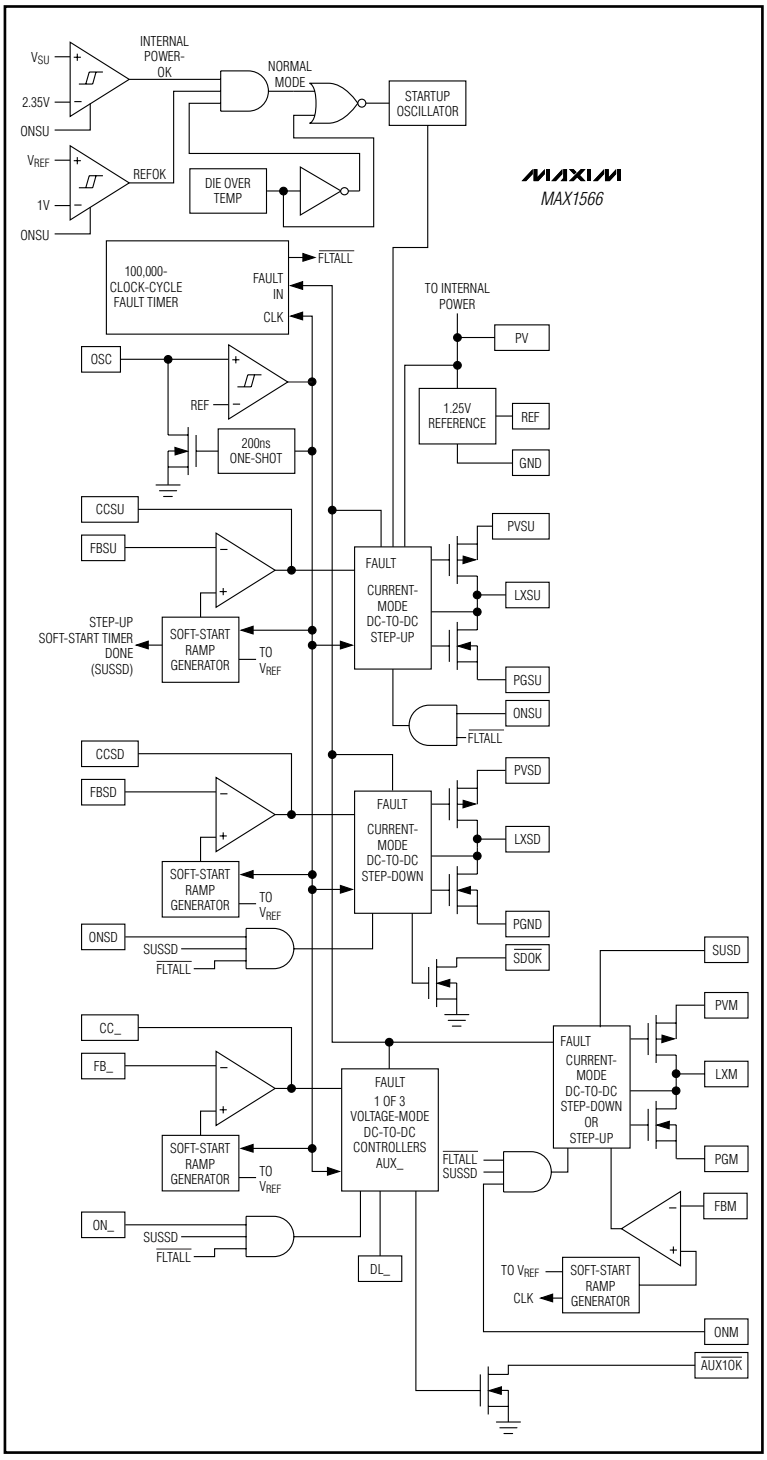


Figure 4. MAX1566 Functional Diagram

Six-Channel, High-Efficiency, Digital Camera Power Supplies

Core Step-Down DC-to-DC Converter

The step-down DC-to-DC is optimized for generating low output voltages (down to 1.25V) at high efficiency. The step-down runs from the voltage at PVSD. This pin can be connected directly to the battery if sufficient headroom exists to avoid dropout; otherwise, PVSD can be powered from the output of another converter. The step-down can also operate with the step-up, or the main converter in step-up mode, for boost-buck operation.

Under moderate to heavy loading, the converter operates in a low-noise PWM mode with constant frequency and modulated pulse width. Efficiency is enhanced under light (<75mA typ) loading by assuming an Idle Mode during which the step-down switches only as needed to service the load. In this mode, the maximum inductor current is 100mA for each pulse. The step-down DC-to-DC is inactive until the step-up DC-to-DC is in regulation.

The step-down also features an open-drain $\overline{SDOK}$ output that goes low when the step-down output is in regulation. $\overline{SDOK}$ can be used to drive an external MOSFET switch that gates 3.3V power to the processor after the core voltage is in regulation. This connection is shown in Figure 15.

AUX1, AUX2, and AUX3 DC-to-DC Controllers

The three auxiliary controllers operate as fixed-frequency voltage-mode PWM controllers. They do not have internal MOSFETs, so output power is determined by external components. The controllers regulate output voltage by modulating the pulse width of the DL_ drive signal to an external MOSFET switch.

On the MAX1566, AUX1 and AUX2 are boost/flyback PWM controllers. On the MAX1567, AUX1 is a boost/flyback PWM controller, but AUX2 is an inverting PWM controller. On both devices, AUX3 is a boost/flyback controller that can be connected to regulate output voltage and/or current (for white-LED drive).

Figure 5 shows a functional diagram of an AUX boost controller channel. A sawtooth oscillator signal at OSC governs timing. At the start of each cycle, DL_ goes high, turning on the external NFET switch. The switch then turns off when the internally level-shifted sawtooth rises above CC_ or when the maximum duty cycle is exceeded. The switch remains off until the start of the next cycle. A transconductance error amplifier forms an integrator at CC_ to maintain high DC loop gain and accuracy.

The auxiliary controllers do not start until 1024 OSC cycles after the step-up DC-to-DC output is in regulation. If the auxiliary controller remains faulted for 100,000 OSC cycles (200ms at 500kHz), then all MAX1566/MAX1567 channels latch off.

Maximum Duty Cycle

The AUX PWM controllers have a guaranteed maximum duty cycle of 80%: all controllers can achieve at least 80% and typically reach 85%. In boost designs that employ continuous current, the maximum duty cycle limits the boost ratio so:

$$1 - V_{IN} / V_{OUT} \leq 80\%$$

With discontinuous inductor current, no such limit exists for the input/output ratio since the inductor has time to fully discharge before the next cycle begins.

AUX1

AUX1 can be used for conventional DC-to-DC boost and flyback designs (Figures 8 and 9). Its output (DL1) is designed to drive an N-channel MOSFET. Its feedback (FB1) threshold is 1.25V.

AUX2

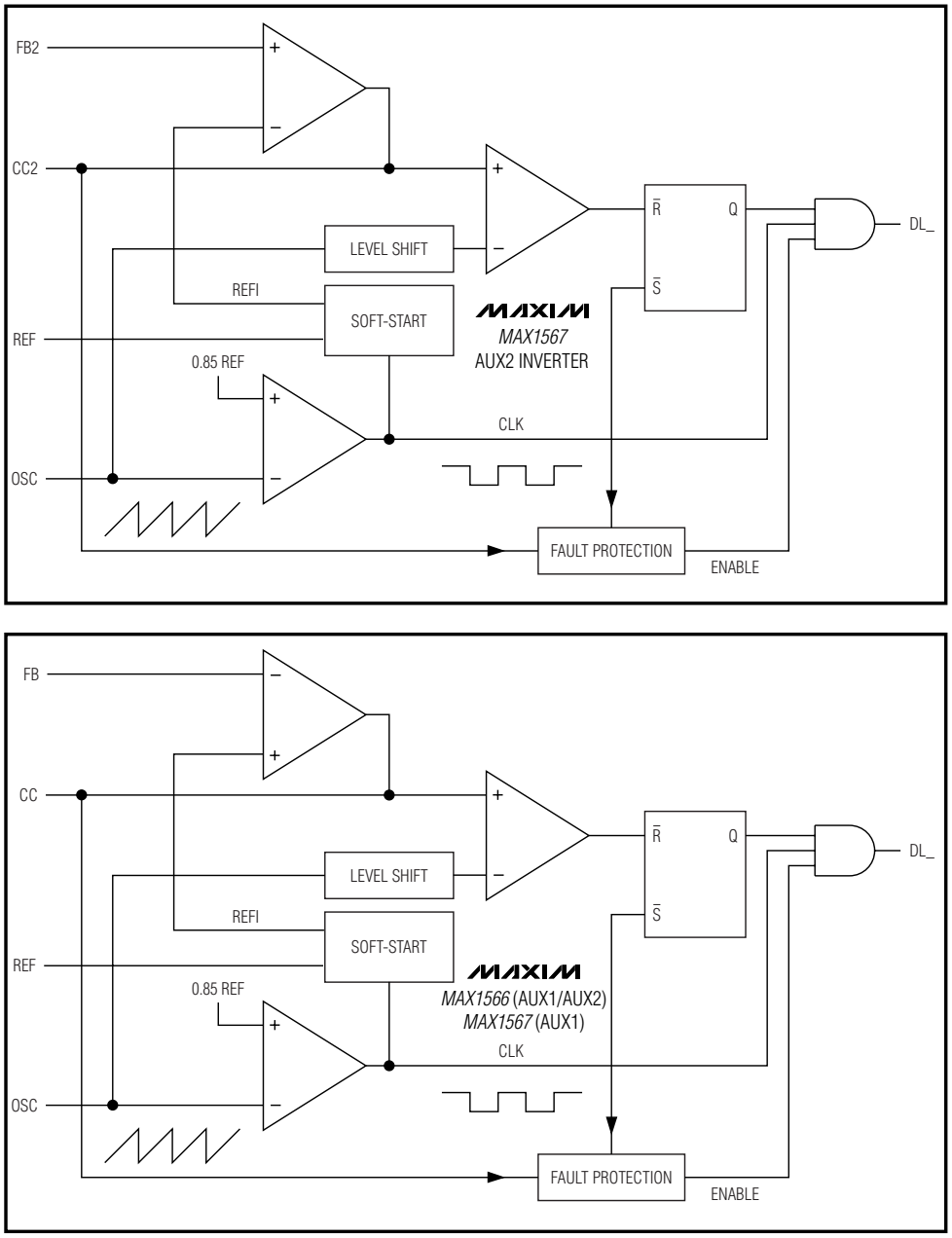
In the MAX1566, AUX2 is identical to AUX1. In the MAX1567, AUX2 is an inverting controller that generates a regulated negative output voltage, typically for CCD and LCD bias. This is useful in height-limited designs where transformers may not be desired.

The AUX2 MOSFET driver (DL2) in the MAX1567 is designed to drive P-channel MOSFETs. INDL2 biases the driver so V_{INDL2} is the high output level of DL2. INDL2 should be connected to the P-channel MOSFET source to ensure the MOSFET turns completely off when DL2 is high. See Figure 10 for a typical inverter circuit.

AUX3 DC-to-DC Controller, LED Driver

The AUX3 step-up DC-to-DC controller has two feedback inputs, FB3L and FB3H, with feedback thresholds of 0.2V (FB3L) and 1.25V (FB3H). If used as a conventional voltage-output step-up, FB3L is grounded and FB3H is used as the feedback input. In that case, AUX3 behaves exactly like AUX1.

If AUX3 is used as a switch-mode boost current source for white LEDs, FB3L provides current-sensing feedback, while FB3H provides (optional) open-LED overvoltage protection (Figure 7).



IN 1024 CLOCK CYCLES, SOFT-START RAMPS UP REFI FROM 0V TO V_{REF} IN MAX1566/MAX1567 AUX_ BOOST CONTROLLERS AND RAMPS DOWN REFI FROM V_{REF} TO 0V IN MAX1567 AUX2 INVERTER.

Figure 5. AUX Controller Functional Diagram

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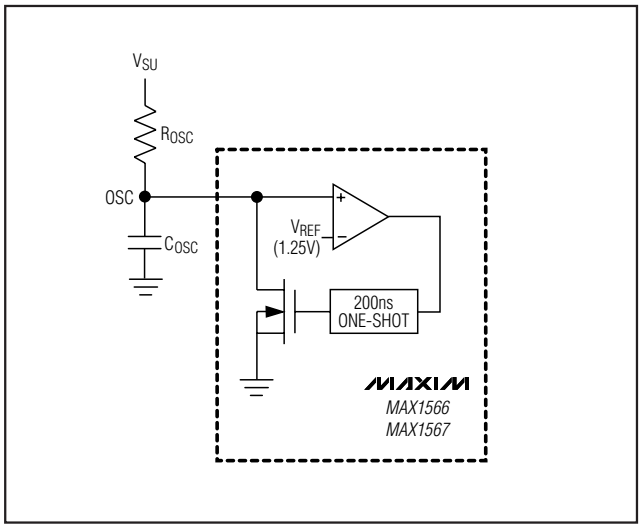

Figure 6. Oscillator Functional Diagram

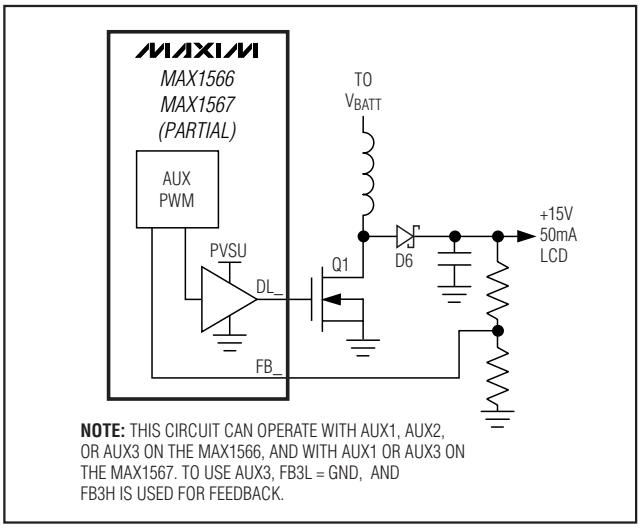

Figure 8. +15V LCD Bias with Basic Boost Topology

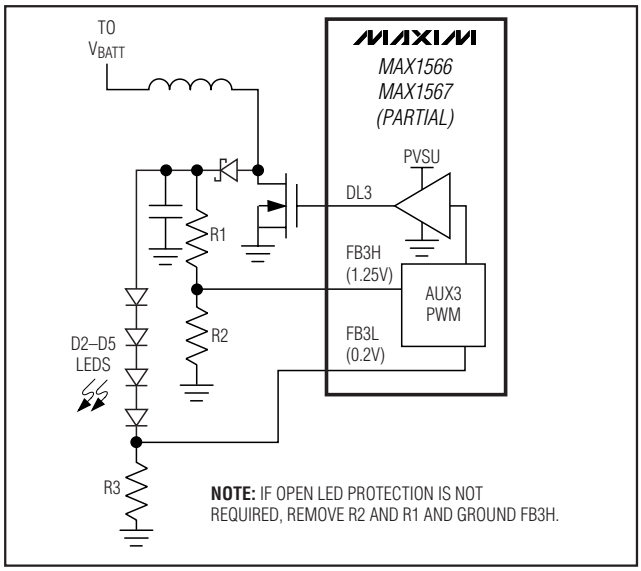

Figure 7. LED drive with open LED overvoltage protection is provided by the additional feedback input to AUX3, FB3H.

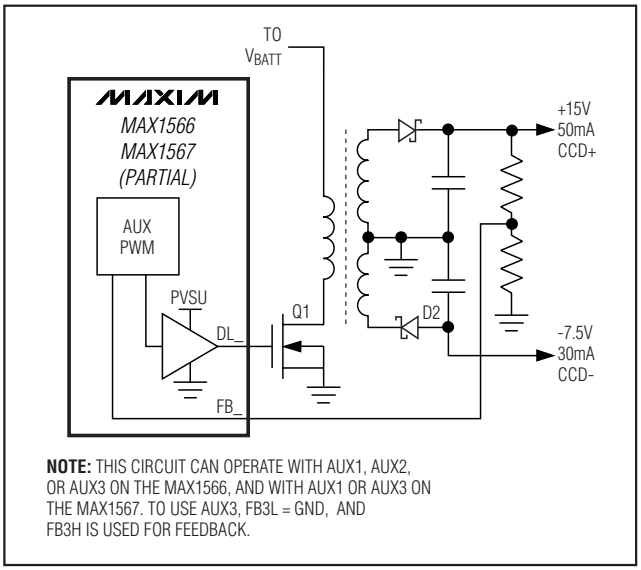

Figure 9. +15V and -7.5V CCD Bias with Transformer

Master-Slave Configurations

The MAX1566/MAX1567 support MAX1801 slave PWM controllers that obtain input power, a voltage reference, and an oscillator signal directly from the MAX1566/MAX1567 master. The master-slave configuration allows channels to be easily added and minimizes system cost by eliminating redundant circuitry. The slaves also control the harmonic content of noise because their operating frequency is synchronized to that of the MAX1566/MAX1567 master converter. A MAX1801 connection to the MAX1566/MAX1567 is shown in Figure 14.

Status Outputs ($\overline{SDOK}$, $\overline{AUX1OK}$, SCF)

The MAX1566/MAX1567 include three versatile status outputs that can provide information to the system. All are open-drain outputs and can directly drive MOSFET switches to facilitate sequencing, disconnect loads during overloads, or perform other hardware-based functions.

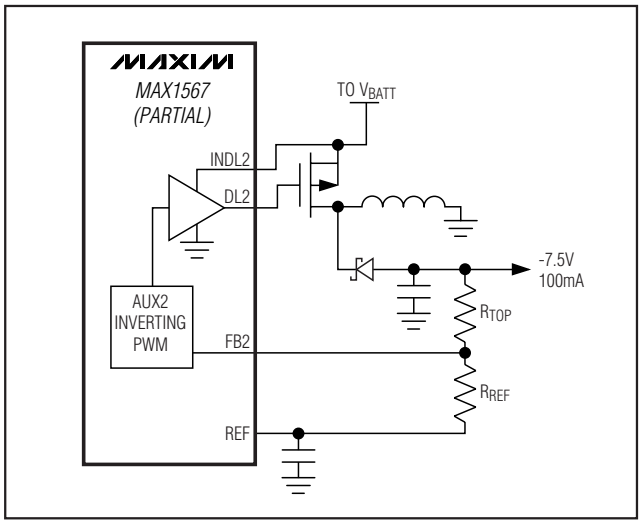

Figure 10. Regulated -7.5V Negative CCD (Bias is provided by conventional inverter (works only with the MAX1567).)

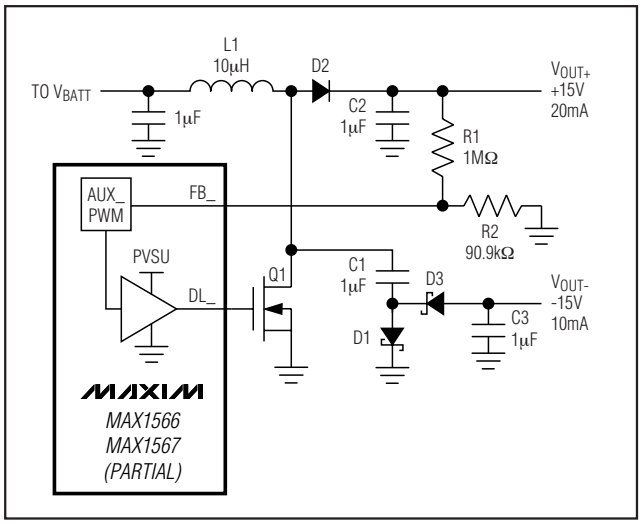

Figure 11. ±15V Output Using an AUX-Driven Boost with Charge-Pump Inversion

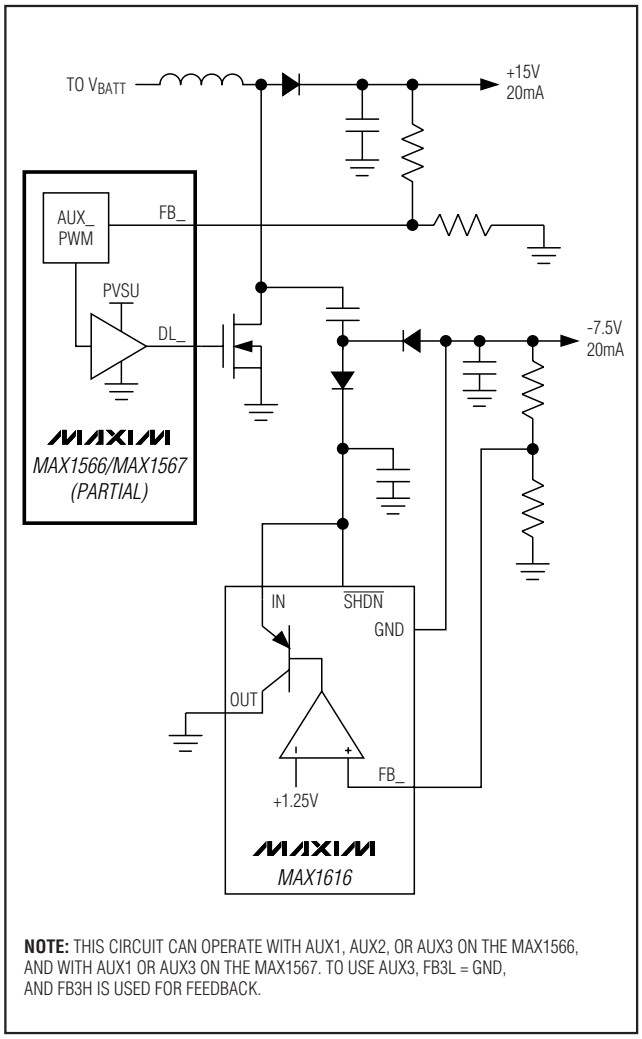

Figure 12. +15V and -7.5V CCD Bias Without Transformer Using Boost with a Diode-Capacitor Charge Pump (A positive-output linear regulator (MAX1616) can be used to regulate the negative output of the charge pump.)

$\overline{\text{SDOK}}$ pulls low when the step-down has successfully completed soft-start. $\overline{\text{SDOK}}$ goes high impedance in shutdown, overload, and thermal limit. A typical use for $\overline{\text{SDOK}}$ is to drive a P-channel MOSFET that connects 3.3V power to the CPU I/O after the CPU core is powered up (Figure 15), thus providing safe sequencing in hardware without system intervention.

$\overline{\text{AUX1OK}}$ pulls low when the AUX1 controller has successfully completed soft-start. $\overline{\text{AUX1OK}}$ goes high impedance in shutdown, overload, and thermal limit. A typical use for $\overline{\text{AUX1OK}}$ is to drive a P-channel MOSFET that connects 5V power to the CCD after the 15V CCD bias (generated by AUX1) is powered up (Figure 16).

SCF goes high (high impedance, open drain) when overload protection occurs. Under normal operation, SCF pulls low. SCF can drive a high-side P-channel MOSFET switch that can disconnect a load during power-up or when a channel turns off in response to a logic command or an overload. Several connections are possible for SCF. One is shown in Figure 17 where SCF provides load disconnect for the step-up on fault and power-up.

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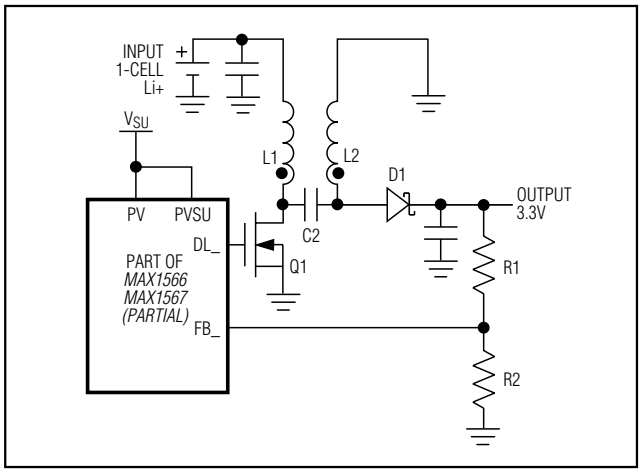

Figure 13. SEPIC Converter Additional Boost-Buck Channel

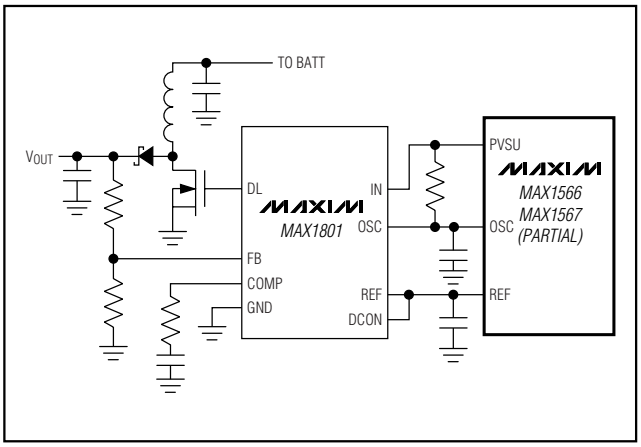

Figure 14. Adding a PWM Channel with an External MAX1801 Slave Controller

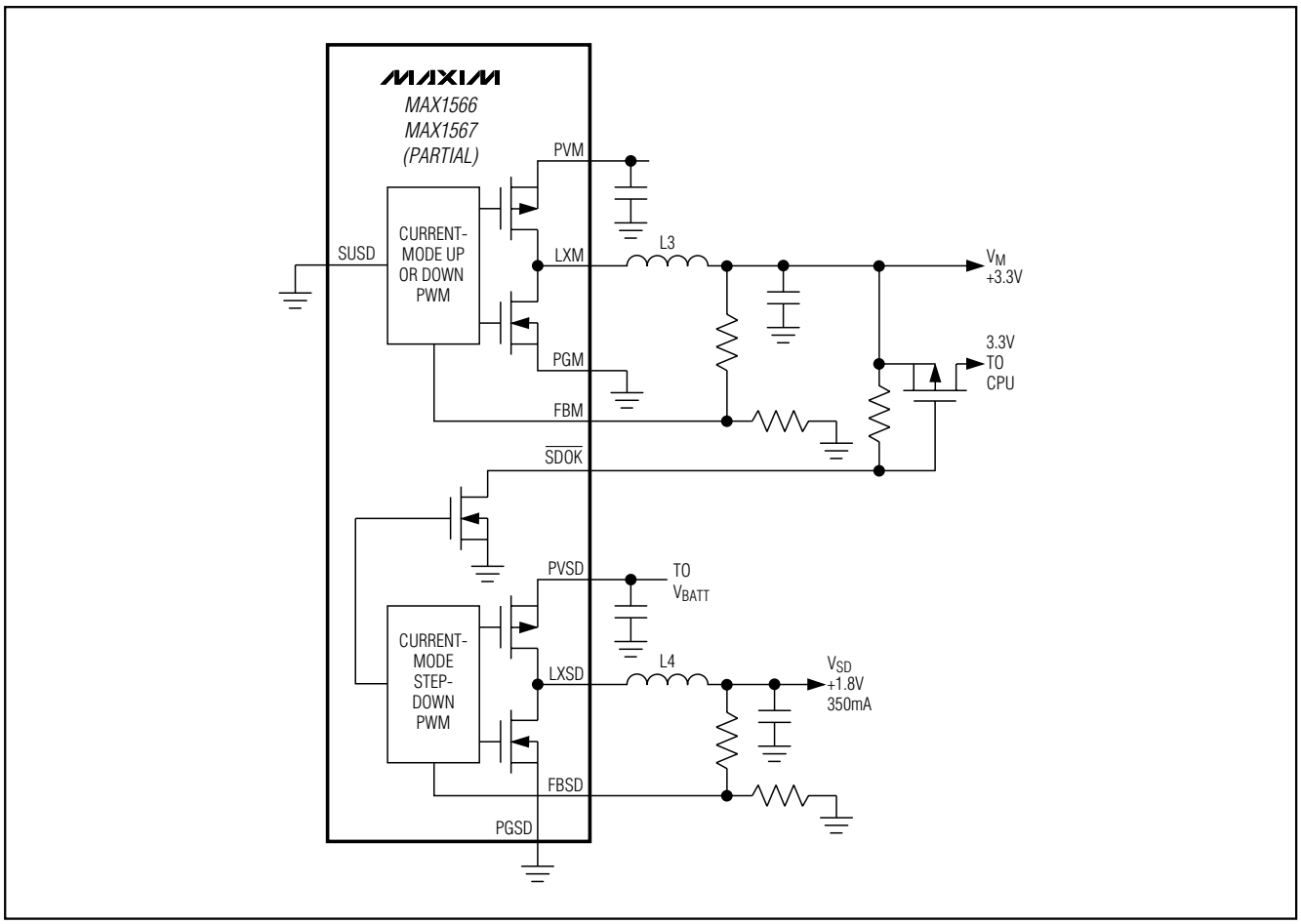

Figure 15. Using $\overline{SDOK}$ to Drive External PFET that Gates 3.3V Power to CPU After 1.8V Core Voltage Is in Regulation

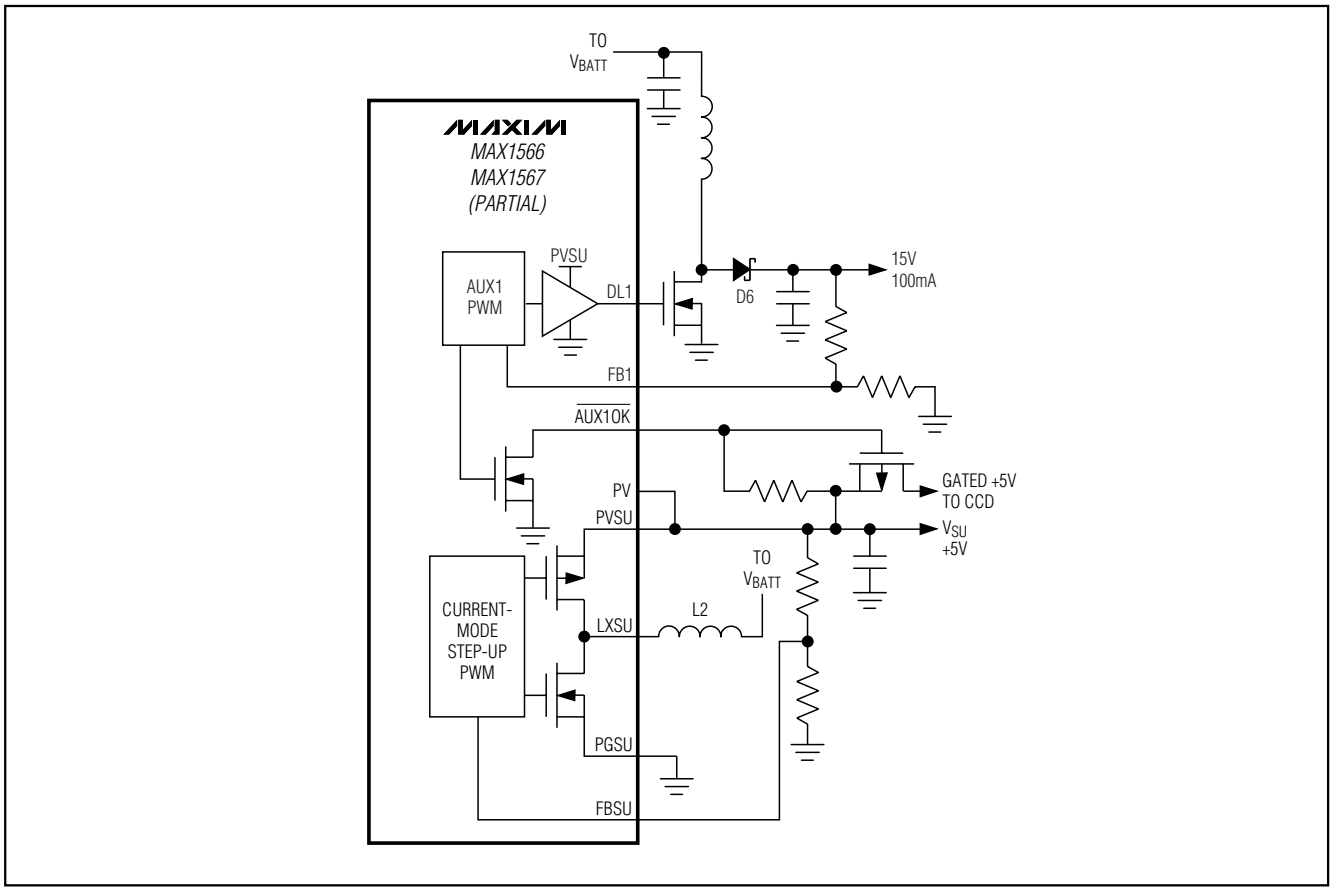

Figure 16. $\overline{AUX1OK}$ Drives an External PFET that Gates 5V Supply to the CCD After the +15V CCD Bias Supply Is Up

Soft-Start

The MAX1566/MAX1567 channels feature a soft-start function that limits inrush current and prevents excessive battery loading at startup by ramping the output voltage of each channel up to the regulation voltage. This is accomplished by ramping the internal reference inputs to each channel error amplifier from 0V to the 1.25V reference voltage over a period of 4096 oscillator cycles (16ms at 500kHz) when initial power is applied or when a channel is enabled.

The step-down soft-start ramp takes half the time (2048 clock cycles) of the other channel ramps. This allows the step-down and main outputs to track each other and rise at nearly the same dV/dt rate on power-up. Once the step-down output reaches its regulation point (1.5V or 1.8V typ), the main output (3.3V typ) continues to rise at the same ramp rate. See the *Typical Operating Characteristics* Main and Step-Down Startup Waveforms graphs.

Soft-start is not included in the step-up converter to avoid limiting startup capability with loading.

Fault Protection

The MAX1566/MAX1567 have robust fault and overload protection. After power-up, the device is set to detect an out-of-regulation state that could be caused by an overload or short. If any DC-to-DC converter channel (step-up, main, step-down, or any of the auxiliary controllers) remains faulted for 100,000 clock cycles (200ms at 500kHz), then **all** outputs latch off until the step-up DC-to-DC converter is reinitialized by the ONSU pin or by cycling the input power. The fault-detection circuitry for any channel is disabled during its initial turn-on soft-start sequence.

An exception to the standard fault behavior is that there is no 100,000 clock cycle delay in entering the fault state if the step-up output (PVSU) is dragged below its 2.5V UVLO threshold or is shorted. In this case, the