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19-1810; Rev 2; 12/03

EVALUATION KIT AVAILABLE

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

General Description

The MAX1774 is a complete power-supply solution for PDAs and other hand-held devices. It integrates two high-efficiency step-down converters, a boost converter for backup battery regulation, and four voltage detectors in a small 32-pin QFN or 28-pin QSOP package.

The MAX1774 accepts inputs from +2.7V to +28V and provides an adjustable main output from 1.25V to 5.5V at over 2A. The secondary core converter delivers an adjustable voltage from 1V to 5V and can deliver up to 1.5A. Both the main and core regulators have separate shutdown inputs.

When the AC adapter power is removed, an external P-channel MOSFET switches input to the main battery. When the main battery is low, the backup step-up converter sustains the main output voltage. When the backup battery can no longer deliver the required load, the system shuts down safely to prevent damage. Four on-board voltage detectors monitor the status of the AC adapter power, main battery, and backup battery.

The MAX1774 evaluation kit is available to help reduce design time.

Applications

Hand-Held Computers

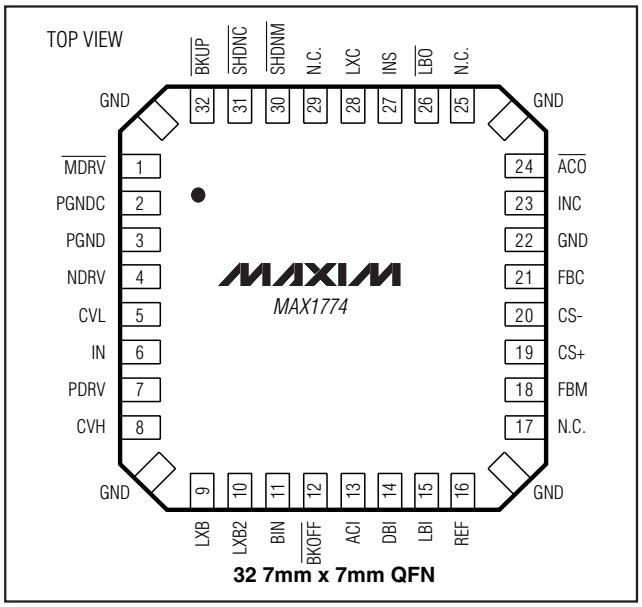
PDAs

Internet Access Tablets

POS Terminals

Subnotebooks

Pin Configurations



32 7mm x 7mm QFN

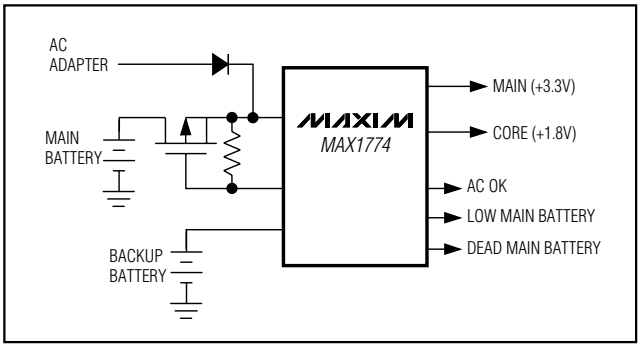
Features

- **Dual, High-Efficiency, Synchronous-Rectified Step-Down Converters**
- **Thin, Small (1mm High) QFN Package**
- **Step-Up Converter for Backup Battery**
- **Main Power**
  - **Adjustable from +1.25V to +5.5V**
  - **Over 2A Load Current**
  - **Up to 95% Efficiency**
- **Core Power**
  - **Adjustable from 1V to 5V**
  - **Internal Switches**
  - **Up to 1.5A Load Current**
  - **Up to 91% Efficiency**
- **Automatic Main Battery Switchover**
- **100% (max) Duty Cycle**
- **Up to 1.25MHz Switching Frequency**
- **Input Voltage Range from +2.7V to +28V**
- **Four Low-Voltage Detectors**
- **170µA Quiescent Current**
- **8µA Shutdown Current**
- **Digital Soft-Start**
- **Independent Shutdown Inputs**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX1774EEI	-40°C to +85°C	28 QSOP
MAX1774EGJ	-40°C to +85°C	32 7mm x 7mm QFN

Functional Diagram



Pin Configurations continued at end of data sheet.

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

ABSOLUTE MAXIMUM RATINGS

IN, $\overline{SHDNM}$, $\overline{MDRV}$, DBI, LBI, ACI, CVH to GND .....-0.3V to +30V
IN to CVH, PDRV .....-0.3V to +6V
BIN to CS-.....-0.3V to +6V
LXB to GND .....-0.3V to (V_{BIN+} 0.7V)
PDRV to GND.....(V_{CVH} - 0.3V) to (V_{IN} + 0.3V)
All Other Pins to GND.....-0.3V to +6V
PGND to GND .....-0.3V to +0.3V
Continuous Power Dissipation
28-Pin QSOP (derate 10.8mW/°C above +70°C).....860mW
32-Pin QFN (derate 23.2mW/°C above +70°C) 1860mW
Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-65°C to +150°C
Temperature (soldering, 10s) .....+300°C

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

(Figure 1, V_{IN} = V_{INS} +12V, V_{INC} = V_{CS-} = V_{CS+} = +3.3V, V_{CORE} = +1.8V, **T_A = 0°C to +85°C,** unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Voltage	V_{IN}		2.7		28	V
Input Quiescent Supply Current	I_{IN}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		18	40	µA
CS- Quiescent Supply Current	I_{CS-}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		110	220	µA
Core Regulator Quiescent Supply Current	I_{INC}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		60	105	µA
Backup Mode BIN Quiescent Supply Current	I_{BIN}	V_{BIN} = +3.3V, CS- open, V_{FBM} = +1.5V, $V_{\overline{SHDNM}}$ = +3.3V, $V_{\overline{BKOFF}}$ = +1.5V, $\overline{SHDNC}$ = GND		60	105	µA
IN Shutdown Supply Current		$\overline{SHDNM}$ = $\overline{SHDNC}$ = GND		8	40	µA
MAIN REGULATOR						
Main Output Voltage Adjust Range			1.25		5.5	V
FBM Regulation Threshold	V_{FBM}	$V_{(CS+ - CS-)}$ = 0 to +60mV, V_{IN} = +3.5V to +28V	1.21	1.25	1.29	V
FBM Input Current	I_{FBM}	V_{FBM} = +1.3V	-0.1		0.1	µA
Current-Limit Threshold		V_{CS+} - V_{CS-}	60	80	100	mV
Minimum Current-Limit Threshold		V_{CS+} - V_{CS-}	5	15	25	mV
Valley Current Threshold		V_{CS+} - V_{CS-}	40	50	60	mV
Zero Current Threshold		V_{CS+} - V_{CS-}	0	5	15	mV
PDRV, NDRV Gate Drive Resistance		V_{CS-} = +3.3V, I_{PDRV}, I_{NDRV} = 50mA		2	5.5	Ω
CS- to CVL Switch Resistance		I_{CVL} = 50mA		4.5	9.5	Ω
PDRV, NDRV Dead Time				50		ns

ELECTRICAL CHARACTERISTICS (continued)

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS-} = V_{CS+} = +3.3V, V_{CORE} = +1.8V, **T_A = 0°C to +85°C,** unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Maximum Duty Cycle			100			%
Minimum On-Time			200	400	650	ns
Minimum Off-Time			200	400	650	ns
CORE REGULATOR						
Input Voltage Range	V_{INC}		2.6		5.5	V
INC Undervoltage Lockout		V_{INC} rising	2.40	2.47	2.55	V
		V_{INC} falling	2.30	2.37	2.45	
Core Output Voltage Adjust Range			1.0		5.0	V
Maximum Core Load Current		V_{CORE} = 1.8V (Note 1)	1	1.5		A
FBC Regulation Threshold	V_{FBC}	V_{INC} = +2.5 to +5.5V, I_{OUTC} = 0 to 200mA	0.97	1.0	1.03	V
FBC Input Current	I_{FBC}	V_{FBC} = +1.3V	-0.1		0.1	µA
Dropout Voltage		I_{OUTC} = 400mA		0.1	0.25	V
LXC Leakage Current	I_{LXC}	V_{INC} = +5.5V, V_{LXC} = 0 to +5.5V	-10		10	µA
LXC P-Channel, N-Channel On-Resistance				0.25	0.5	Ω
LXC P-Channel Current Limit	I_{CLC}		1200	1800	3000	mA
LXC P-Channel Minimum Current			100	250	400	mA
LXC N-Channel Valley Current			900	1400	2400	mA
LXC N-Channel Zero-Crossing Current			40	110	170	mA
LXC Dead Time				50		ns
Max Duty Cycle			100			%
Minimum On-Time			170	400	690	ns
Minimum Off-Time			170	400	690	ns
BACKUP REGULATOR						
Backup Battery Input Voltage	V_{BBATT}		0.9		5.5	V
LXB N-Channel On-Resistance		V_{CS-} = +3.3V, I_{LXB} = 50mA		1.9	3.5	Ω
LXB Current Limit			200	350	600	mA
LXB Leakage Current		V_{LXB} = +5.5V, V_{FBM} = +1.3V			1	µA
BIN Leakage Current	I_{BIN}	V_{BIN} = +5.5V, CS- = $\overline{BKOFF}$ = $\overline{SHDNC}$ = $\overline{SHDNM}$ = GND			1	µA
BIN, CS- Switch Resistance		V_{CS-} = +3.3V, $\overline{BKOFF}$ = GND, $\overline{SHDNM}$ = CVL		7.5	15	Ω
BIN Switch Zero-Crossing Threshold		V_{BIN} = +2.5V, $\overline{BKOFF}$ = $\overline{SHDNC}$ = $\overline{SHDNM}$ = CVL		17	35	mV
LXB Maximum On-Time			2.8	5.6	9.2	µs
Zero Crossing Detector Timeout				40		µs

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

ELECTRICAL CHARACTERISTICS (continued)

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS-} = V_{CS+} = +3.3V, V_{CORE} = +1.8V, **T_A = 0°C to +85°C,** unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
REFERENCE						
Reference Voltage	V_{REF}		1.23	1.25	1.27	V
Reference Load Regulation		I_{REF} = 0 to 50µA			10	mV
Reference Line Regulation		V_{CS-} = +2.5V to +5.5V, I_{REF} = 50µA			5	mV
Reference Sink Current			10			µA
CVL, CVH REGULATORS						
CVL Output Voltage	V_{CVL}	I_{CVL} = 50mA, V_{CS-} = 0	2.6	2.8	3.1	V
		I_{CVL} = 50mA, V_{CS-} = +3.3V		3.2		
CVL Switchover Threshold		CS- rising, hysteresis = 100mV typical	2.40	2.47	2.55	V
CVH Output Voltage	V_{CVH}	V_{IN} = +4V, I_{CVH} = 25mA		V_{IN} - 3.4	V_{IN} - 2.8	V
		V_{IN} = +12V, I_{CVH} = 50mA		V_{IN} - 4.2	V_{IN} - 3.7	
CVH Switchover Threshold	V_{IN}	V_{IN} rising, hysteresis = 350mV typ		5.5		V
CVL Undervoltage Lockout		V_{CVL} rising	2.40	2.47	2.55	V
		V_{CVL} falling	2.30	2.37	2.45	
LOW-VOLTAGE COMPARATORS						
Backup Regulator Shutdown Threshold	$V_{\overline{BKOFF}}$	$V_{\overline{BKOFF}}$ rising	0.51	0.55	0.59	V
		$V_{\overline{BKOFF}}$ falling	0.46	0.50	0.54	
$\overline{BKOFF}$ Input Bias Current		$V_{\overline{BKOFF}}$ = +5.5V			1	µA
LBI Threshold	V_{LBI}	V_{LBI} falling, hysteresis = 50mV typical	1.17	1.20	1.23	V
DBI Threshold	V_{DBI}	V_{DBI} falling, hysteresis = 50mV typical	1.17	1.20	1.23	V
$\overline{BKUP}$ Low-Input Threshold			0.4			V
LBI, DBI Input Leakage Current		V_{LBI} = V_{DBI} = +1.3V			100	nA
$\overline{LBO}$, $\overline{BKUP}$, $\overline{ACO}$, $\overline{MDRV}$ Output Low		I_{SINK} = 1mA			0.4	V
$\overline{LBO}$, $\overline{BKUP}$, $\overline{ACO}$, $\overline{MDRV}$ Output Leakage Current		V_{LBI} = +1.3V, V_{ACI} = +12V, $V_{\overline{ACO}}$ = $V_{\overline{LBO}}$ = $V_{\overline{BKUP}}$ = +5.5V, $V_{\overline{MDRV}}$ = +28V			1.0	µA
ACI Threshold		V_{ACI} – V_{INS}, ACI falling		0.22	0.35	V
ACI Input Leakage Current		V_{ACI} = +1.3V			100	nA
INS Input Leakage Current		V_{INS} = +3.3V		1.5	10	µA
LOGIC INPUTS						
$\overline{SHDNM}$, $\overline{SHDNC}$ Input Low Voltage					0.4	V
$\overline{SHDNM}$, $\overline{SHDNC}$ Input High Voltage			2.0			V

ELECTRICAL CHARACTERISTICS (continued)

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS-} = V_{CS+} = +3.3V, V_{CORE} = +1.8V, **T_A = 0°C to +85°C,** unless otherwise noted. Typical values are at T_A = +25°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
$\overline{SHDNM}$, $\overline{SHDNC}$ Input Low Current		$\overline{SHDNM}$ = $\overline{SHDNC}$ = GND	-1		1	µA
$\overline{SHDNC}$ Input High Current		$V_{\overline{SHDNC}}$ = +5.5V			5	µA
$\overline{SHDNM}$ Input High Current		$V_{\overline{SHDNM}}$ = +5V		2	25	µA

ELECTRICAL CHARACTERISTICS

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS-} = V_{CS+} = +3.3V, V_{CORE} = +1.8V, **T_A = -40°C to +85°C,** unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
Input Voltage	V_{IN}		2.7	28	V
Input Quiescent Supply Current	I_{IN}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		40	µA
CS- Quiescent Supply Current	I_{CS-}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		220	µA
Core Regulator Quiescent Supply Current	I_{INC}	V_{FBM} = +1.5V, V_{FBC} = +1.5V, $V_{\overline{SHDNM}}$ = $V_{\overline{SHDNC}}$ = +3.3V		105	µA
Backup Mode BIN Quiescent Supply Current	I_{BIN}	V_{BIN} = +3.3V, CS- open V_{FBM} = +1.5V, $V_{\overline{SHDNM}}$ = +3.3V, $V_{\overline{BKOFF}}$ = +1.5V, $\overline{SHDNC}$ = GND		110	µA
IN Shutdown Supply Current		$\overline{SHDNM}$ = $\overline{SHDNC}$ = GND		40	µA
MAIN REGULATOR					
Main Output Voltage Adjust Range			1.25	5.5	V
FBM Regulation Threshold	V_{FBM}	$V_{(CS+ - CS-)}$ = 0 to +60mV, V_{IN} = +3.5V to +28V	1.21	1.29	V
FBM Input Current	I_{FBM}	V_{FBM} = +1.3V	-0.1	0.1	µA
Current-Limit Threshold		V_{CS+} - V_{CS-}	60	100	mV
Minimum Current-Limit Threshold		V_{CS+} - V_{CS-}	5	25	mV
Valley Current Threshold		V_{CS+} - V_{CS-}	40	60	mV
Zero Current Threshold		V_{CS+} - V_{CS-}	0	15	mV
PDRV, NDRV Gate Drive Resistance		V_{CS-} = +3.3V, I_{PDRV}, I_{NDRV} = 50mA		5.5	Ω
CS- to CVL Switch Resistance		I_{CVL} = 50mA		9.5	Ω
Maximum Duty Cycle			100		%
Minimum On-Time			200	650	ns
Minimum Off-Time			200	650	ns

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

ELECTRICAL CHARACTERISTICS (continued)

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS+} = V_{CS-} = +3.3V, V_{CORE} = +1.8V, **T_A = -40°C to +85°C,** unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
CORE REGULATOR					
Input Voltage Range	V_{INC}		2.6	5.5	V
INC Undervoltage Lockout		V_{INC} rising	2.39	2.55	V
		V_{INC} falling	2.29	2.45	
Core Output Voltage Adjust Range			1.0	5.0	V
Maximum Core Load Current		V_{CORE} = 1.8V (Note 1)	1		A
FBC Regulation Threshold	V_{FBC}	V_{INC} = +2.5 to +5.5V, I_{OUTC} = 0 to 200mA	0.97	1.03	V
FBC Input Current	I_{FBC}	V_{FBC} = +1.3V	-0.1	0.1	µA
Dropout Voltage		I_{OUTC} = 400mA		0.25	V
LXC Leakage Current	I_{LXC}	V_{INC} = +5.5V, V_{LXC} = 0 to +5.5V	-10	10	µA
LXC P-Channel, N-Channel On-Resistance				0.5	Ω
LXC P-Channel Current Limit			1200	3010	mA
LXC P-Channel Minimum Current			100	420	mA
LXC N-Channel Valley Current			880	2450	mA
LXC N-Channel Zero-Crossing Current			40	170	mA
Max Duty Cycle			100		%
Minimum On-Time			160	700	ns
Minimum Off-Time			170	690	ns
BACKUP REGULATOR					
Backup Battery Input Voltage	V_{BBATT}		0.9	5.5	V
LXB N-Channel On Resistance		V_{CS-} = +3.3V, I_{LXB} = 50mA		3.5	Ω
LXB Current Limit			200	600	mA
LXB Leakage Current		V_{LXB} = +5.5V, V_{FBM} = +1.3V		1	µA
BIN Leakage Current	I_{BIN}	V_{BIN} = +5.5V, CS- = $\overline{BKOFF}$ = $\overline{SHDNC}$ = $\overline{SHDNM}$ = GND		1	µA
BIN, CS- Switch Resistance		V_{CS-} = +3.3V, $\overline{BKOFF}$ = GND, $\overline{SHDNC}$ = CVL		15	Ω
BIN Switch Zero-Crossing Threshold		V_{BIN} = +2.5V, $\overline{BKOFF}$ = $\overline{SHDNC}$ = $\overline{SHDNM}$ = CVL		35	mV
LXB Maximum On-Time			2.8	9.2	µs
REFERENCE					
Reference Voltage	V_{REF}		1.220	1.275	V
Reference Load Regulation		I_{REF} = 0 to 50µA		10	mV
Reference Line Regulation		V_{CS-} = +2.5V to +5.5V, I_{REF} = 50µA		5	mV
Reference Sink Current			10		µA

ELECTRICAL CHARACTERISTICS (continued)

(Figure 1, V_{IN} = V_{INS} = +12V, V_{INC} = V_{CS+} = V_{CS-} = +3.3V, V_{CORE} = +1.8V, **T_A = -40°C to +85°C,** unless otherwise noted.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	MAX	UNITS
CVL, CVH REGULATORS					
CVL Output Voltage	V_{CVL}	I_{CVL} = 50mA, V_{CS-} = 0	2.6	3.1	V
CVL Switchover Threshold		V_{CS-} rising, hysteresis = 100mV typical	2.40	2.55	V
CVH Output Voltage	V_{CVH}	V_{IN} = +4V, I_{CVH} = 25mA		V_{IN} - 2.8	V
		V_{IN} = +12V, I_{CVH} = 50mA		V_{IN} - 3.65	
CVL Undervoltage Lockout		V_{CVL} rising	2.40	2.57	V
		V_{CVL} falling	2.30	2.47	
LOW-VOLTAGE COMPARATORS					
Backup Regulator Shutdown Threshold	$V_{\overline{BKOFF}}$	$V_{\overline{BKOFF}}$ rising	0.51	0.59	V
		$V_{\overline{BKOFF}}$ falling	0.46	0.54	
$\overline{BKOFF}$ Input Bias Current		$V_{\overline{BKOFF}}$ = +5.5V		1	µA
LBI Threshold	V_{LBI}	V_{LBI} falling, hysteresis = 50mV typical	1.17	1.23	V
DBI Threshold	V_{DBI}	V_{DBI} falling, hysteresis = 50mV typical	1.17	1.23	V
$\overline{BKUP}$ Low-Input Threshold			0.4		V
LBI, DBI Input Leakage Current		V_{LBI}, V_{DBI} = +28V		100	nA
$\overline{LBO}$, $\overline{BKUP}$, $\overline{ACO}$, $\overline{MDRV}$ Output Low		I_{SINK} = 1mA		0.4	V
$\overline{LBO}$, $\overline{BKUP}$, $\overline{ACO}$, $\overline{MDRV}$ Output Leakage Current		V_{LBI} = +1.3V, V_{ACI} = V_{IN} = +12V, V_{ACO} = $V_{\overline{LBO}}$ = $V_{\overline{BKUP}}$ = +5.5V, $V_{\overline{MDRV}}$ = +28V		1.0	µA
ACI Threshold		V_{ACI} - V_{INS}, ACI falling		0.5	V
ACI Input Leakage Current		V_{ACI} = +1.3V		100	nA
MAIN Input Leakage Current		V_{INS} = +3.3V		10	µA
LOGIC INPUTS					
$\overline{SHDNM}$, $\overline{SHDNC}$ Input Low Voltage				0.4	V
$\overline{SHDNM}$, $\overline{SHDNC}$ Input High Voltage			2.0		V
$\overline{SHDNM}$, $\overline{SHDNC}$ Input Low Current		$\overline{SHDNM}$ = $\overline{SHDNC}$ = GND	-1	1	µA
$\overline{SHDNC}$ Input High Current		$V_{\overline{SHDNC}}$ = +5.5V		5	µA
$\overline{SHDNM}$ Input High Current		$V_{\overline{SHDNM}}$ = +28V		25	µA

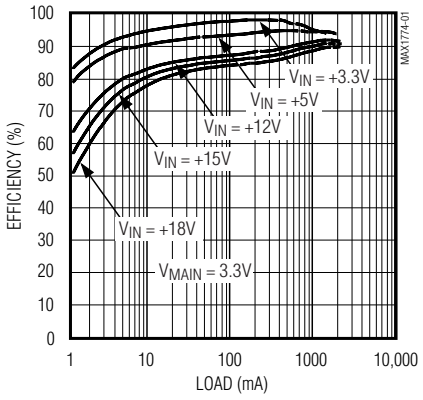
Note 1: This parameter is guaranteed based on the LXC P-channel current limit and the LXC N-channel valley current.
Note 2: Specifications to -40°C are guaranteed by design and not production tested.

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

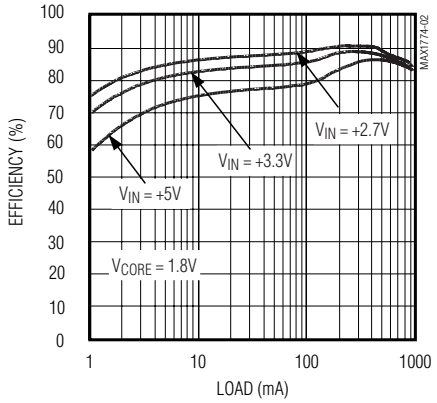
Typical Operating Characteristics

(Circuit of Figure 1, V_{IN} = +5V, V_{INC} = +3.3V, T_A = +25°C, unless otherwise noted.)

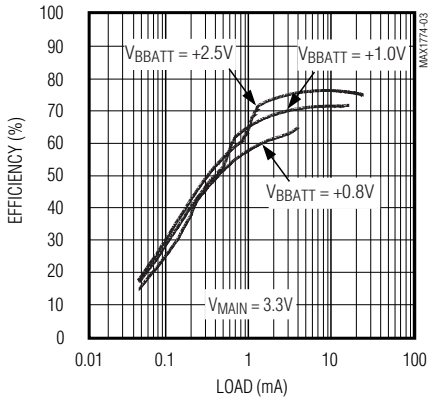
MAIN EFFICIENCY vs. LOAD



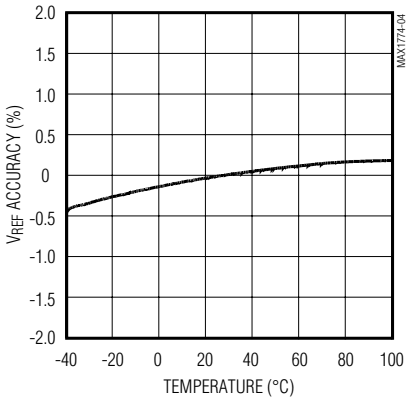
CORE EFFICIENCY vs. LOAD



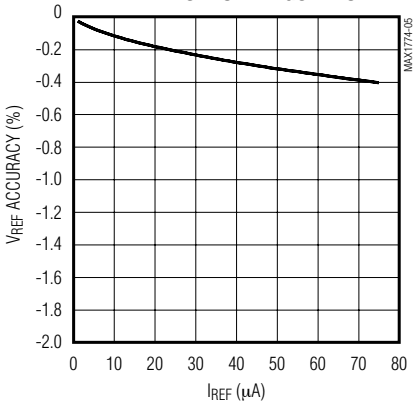
BACKUP EFFICIENCY vs. LOAD



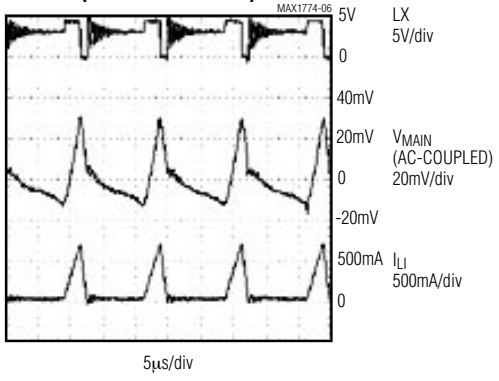
V_{REF} ACCURACY vs. TEMPERATURE



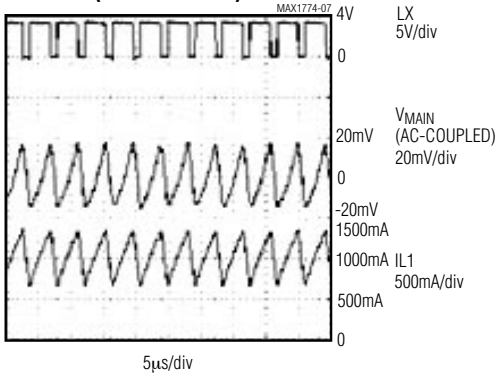
REFERENCE LOAD REGULATION



MAIN SWITCHING WAVEFORMS (LIGHT LOAD 100mA)



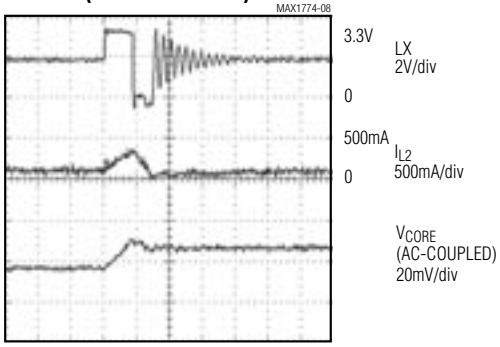
MAIN SWITCHING WAVEFORMS (HEAVY LOAD 1A)



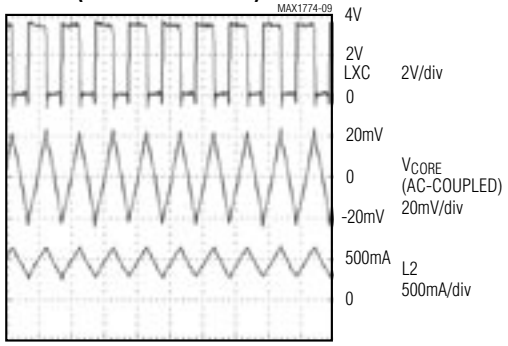
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = +5V, V_{INC} = +3.3V, T_A = +25°C, unless otherwise noted.)

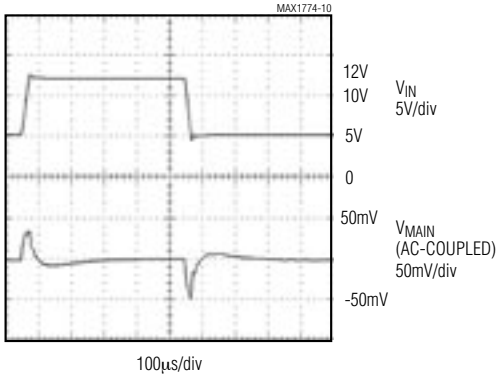
CORE SWITCHING WAVEFORMS (LIGHT LOAD 50mA)



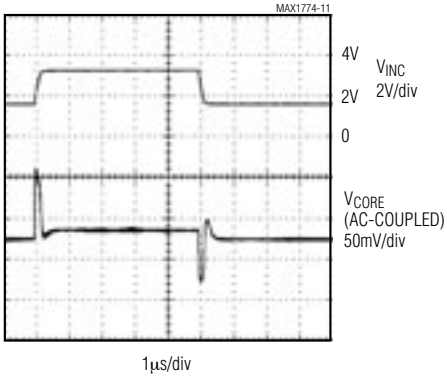
CORE SWITCHING WAVEFORMS (HEAVY LOAD 500mA)



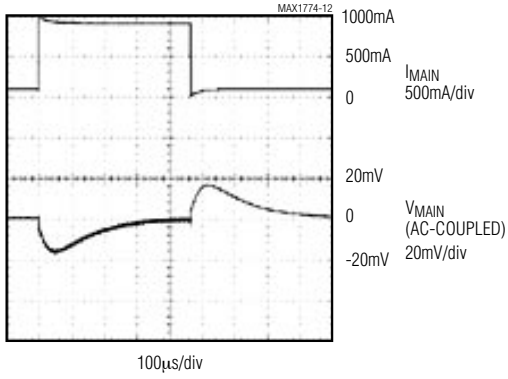
MAIN LINE-TRANSIENT RESPONSE



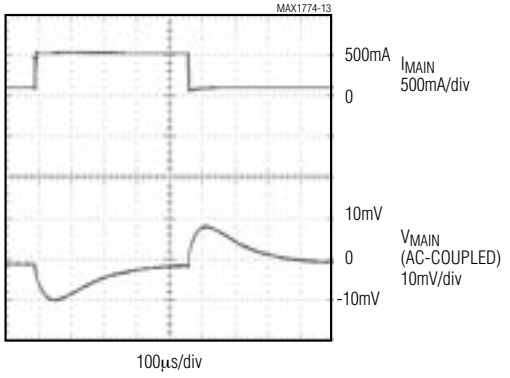
CORE LINE-TRANSIENT RESPONSE



MAIN LOAD-TRANSIENT RESPONSE



MAIN LOAD-TRANSIENT RESPONSE 50mA TO 500mA

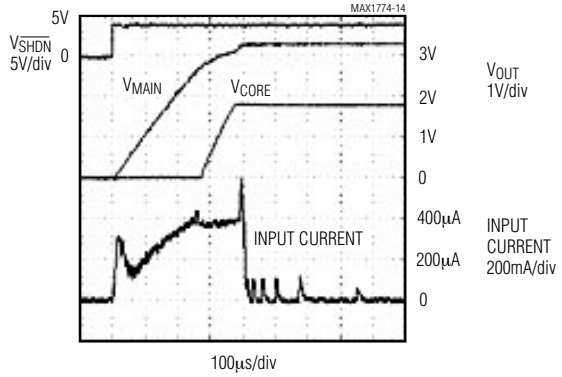


Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

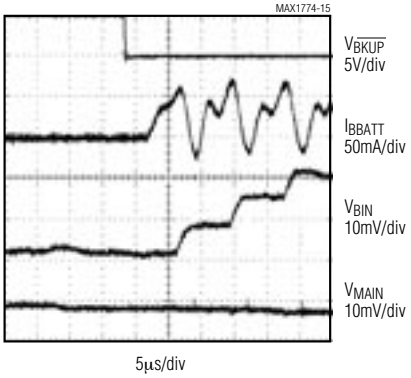
Typical Operating Characteristics (continued)

(Circuit of Figure 1, V_{IN} = +5V, V_{INC} = +3.3V, T_A = +25°C, unless otherwise noted.)

TURN-ON RESPONSE



BACKUP SWITCHOVER RESPONSE



Pin Description

PIN		NAME	FUNCTION
QSOP	QFN		
1	30	$\overline{SHDNM}$	Shutdown for Main Regulator. Low voltage on $\overline{SHDNM}$ shuts off the main output. For normal operation, connect $\overline{SHDNM}$ to IN.
2	31	$\overline{SHDNC}$	Shutdown for Core Regulator. Low voltage on $\overline{SHDNC}$ shuts off the core output. For normal operation, connect $\overline{SHDNC}$ to CVL.
3	32	$\overline{BKUP}$	Open-Drain Backup Input/Output. The device is in backup mode when $\overline{BKUP}$ is low. $\overline{BKUP}$ can be externally pulled low to place the device in backup mode.
4	1	$\overline{MDRV}$	Open-Drain Drive Output. $\overline{MDRV}$ goes low when the ACI voltage drops below the main voltage plus 220mV and device is not in backup. Connect $\overline{MDRV}$ to the gate of the main battery P-channel MOSFET to switch the battery to IN when the AC adapter voltage is not present.
5	2	PGNDC	Power Ground for the Core Converter. Connect all grounds together close to the IC.
6	3	PGND	Power Ground. Ground for NDRV and core output synchronous rectifier. Connect all grounds together close to the IC.
7	4	NDRV	N-Channel Drive Output. Drives the main output synchronous-rectifier MOSFET. NDRV swings between CVL and PGND.
8	5	CVL	Low-Side Bypass. CVL is the output of an internal LDO regulator. This is the internal power supply for the device control circuitry as well as the N-channel driver. Bypass CVL with a 1.0µF or greater capacitor to GND. When CS- is above the CVL switchover threshold (2.47V), CVL is powered from the main output.
9	6	IN	Power Supply Input
10	7	PDRV	P-Channel Drive Output. Drives the main output high-side MOSFET switch. PDRV swings between IN and CVH. The voltage at CVH is regulated at V_{IN} - 4.2V unless the input voltage is less than 5.5V.
11	8	CVH	High-Side Drive Bypass. This is the low-side of the P-channel driver output. Bypass with a 1.0µF capacitor or greater to IN. When the input voltage is less than 5.5V, CVH is switched to PGND.
12	9	LXB	Backup Converter Switching Node. Connect an inductor from LXB to the backup battery and a Schottky diode to BIN to complete the backup converter. In backup mode, this step-up converter powers the main output from the backup battery through BIN.

Pin Description (continued)

PIN		NAME	FUNCTION
QSOP	QFN		
—	10	LXB2	Backup Converter Switching Node. Connect LXB2 to LXB as close to the IC as possible.
13	11	BIN	Backup Battery Input. Connect BIN to the output of the backup boost regulator. Bypass BIN with a 10µF or greater capacitor to GND. When the MAX1774 is in backup mode, BIN powers the main output.
14	12	$\overline{BKOFF}$	Backup Disable Input. Driving $\overline{BKOFF}$ below +0.5V disables the backup mode. In backup mode, the device enters shutdown when this pin is pulled low. $\overline{BKOFF}$ can be driven from a digital signal or can be used as a low battery detector to disable the backup converter when the backup battery is low.
15	13	ACI	AC Adapter Low-Voltage Detect Input. Connect to adapter DC input. When the voltage at ACI falls below the voltage at INS plus +0.22V, $\overline{ACO}$ asserts.
16	14	DBI	Dead Battery Input. Connect DBI to the main battery through a resistive voltage-divider. When DBI drops below +1.20V, no AC adapter is connected ($\overline{ACO}$ is low, but main output still available), $\overline{BKUP}$ asserts.
17	15	LBI	Low-Battery Input. Connect LBI to the main battery through a resistive voltage-divider. When the voltage at LBI drops below +1.20V, $\overline{LBO}$ asserts.
18	16	REF	Reference Voltage Output. Bypass REF to GND with a 0.22µF or greater capacitor.
—	17, 25, 29	N.C.	No Connection. Not Internally Connected.
19	18	FBM	Main Output Feedback. Connect FBM to a resistive voltage-divider to set main output voltage between +1.25V to +5.5V.
20	19	CS+	Main Regulator High-Side Current-Sense Input. Connect the sense resistor between CS+ and CS-. This voltage is used to set the current limit and to turn off the synchronous rectifier when the inductor current approaches zero.
21	20	CS-	Main Regulator Low-Side Current-Sense Input. Connect CS- to the main output.
22	21	FBC	Core Output Feedback. Connect FBC to a resistive voltage-divider to set core output between +1.0V to +5.0V.
23	22	GND	Analog Ground
24	23	INC	Core Supply Input
25	24	$\overline{ACO}$	Low AC Output. Open drain $\overline{ACO}$ asserts when ACI falls below the main output voltage plus 0.22V.
26	26	$\overline{LBO}$	Open-Drain Low-Battery Output. $\overline{LBO}$ asserts when LBI falls below +1.20V.
27	27	INS	Power-Supply Input Voltage Sense Input. Connect INS to the power-supply input voltage.
28	28	LXC	Core Converter Switching Node

Detailed Description

The MAX1774 dual step-down DC-DC converter is designed to power PDA, palmtop, and subnotebook computers. Normally, these devices require two separate power supplies–one for the processor and another higher voltage supply for the peripheral circuitry. The MAX1774 provides an adjustable +1.25V to +5.5V main output designed to power the peripheral circuitry of PDAs and similar devices. The main output delivers up to 2A output current. The lower voltage core converter has an adjustable +1.0V to +5.0V output, providing up to 1.5A output current. Both regulators utilize a proprietary regulation scheme allowing PWM operation at medium to heavy loads, and automatically switch to pulse skipping at light loads for improved efficiency. Under low-battery conditions, the MAX1774 enters backup mode, making use of a low-voltage backup battery and a step-up regulator to power the output. Figure 1 is the MAX1774 typical application circuit.

Operating Modes for the Step-Down Converters

When delivering low output currents, the MAX1774 operates in discontinuous conduction mode. Current through the inductor starts at zero, rises as high as the minimum current limit (I_{MIN}), then ramps down to zero during

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

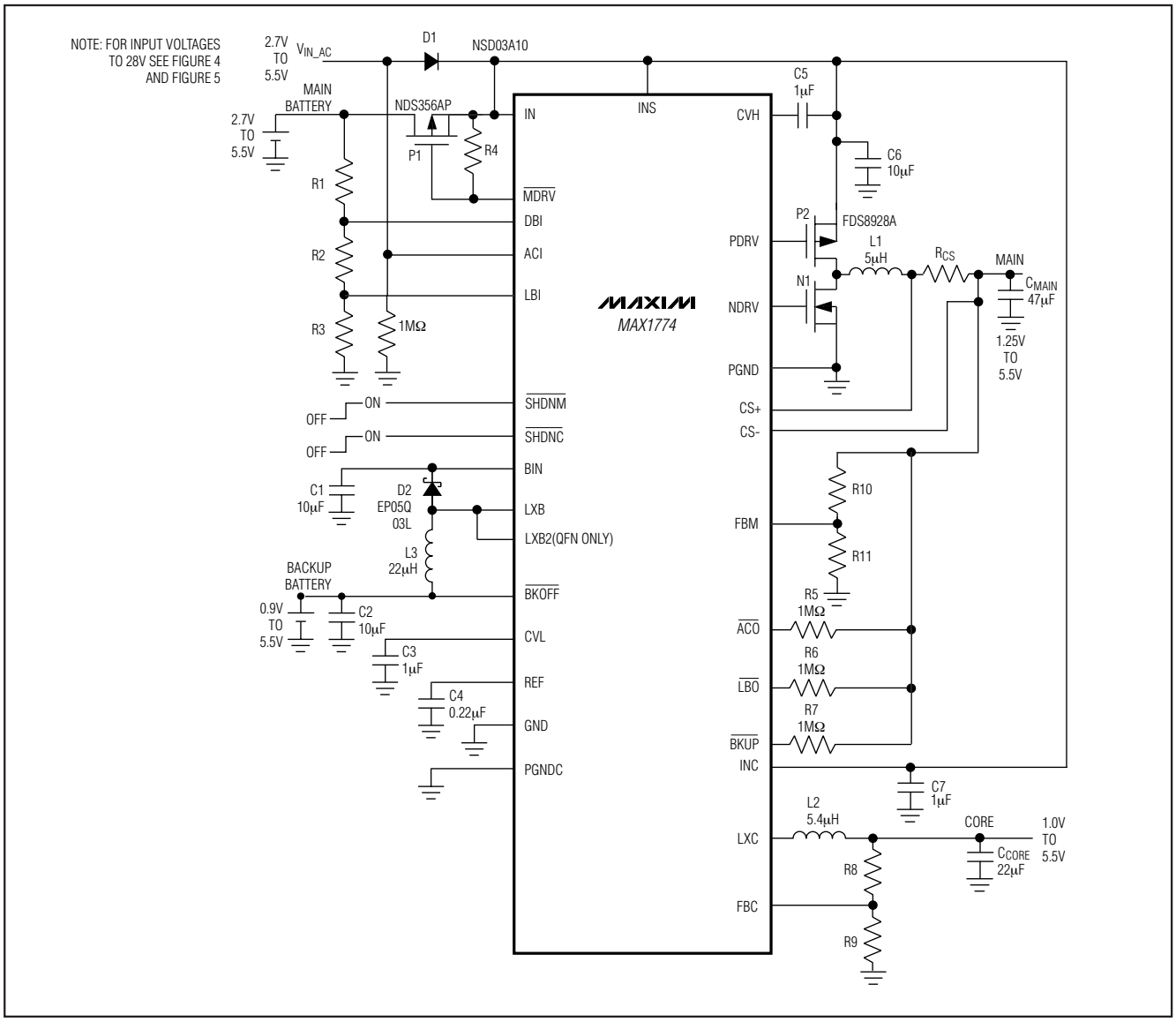


Figure 1. Typical Application Circuit For Low-Input Voltage Applications

each cycle (see *Typical Operating Characteristics*). The switch waveform may exhibit ringing, which occurs at the resonant frequency of the inductor and stray capacitance, due to the residual energy trapped in the core when the rectifier MOSFET turns off. This ringing is normal and does not degrade circuit performance.

When delivering medium-to-high output currents, the MAX1774 operates in PWM continuous-conduction mode. In this mode, current always flows through the inductor and never ramps to zero. The control circuit adjusts the switch duty cycle to maintain regulation without exceeding the peak switching current set by the current-sense resistor.

100% Duty Cycle and Dropout

The MAX1774 operates with a duty cycle up to 100%, extending the input voltage range by turning the MOSFET on continuously when the supply voltage approaches the output voltage. This services the load when conventional switching regulators with less than

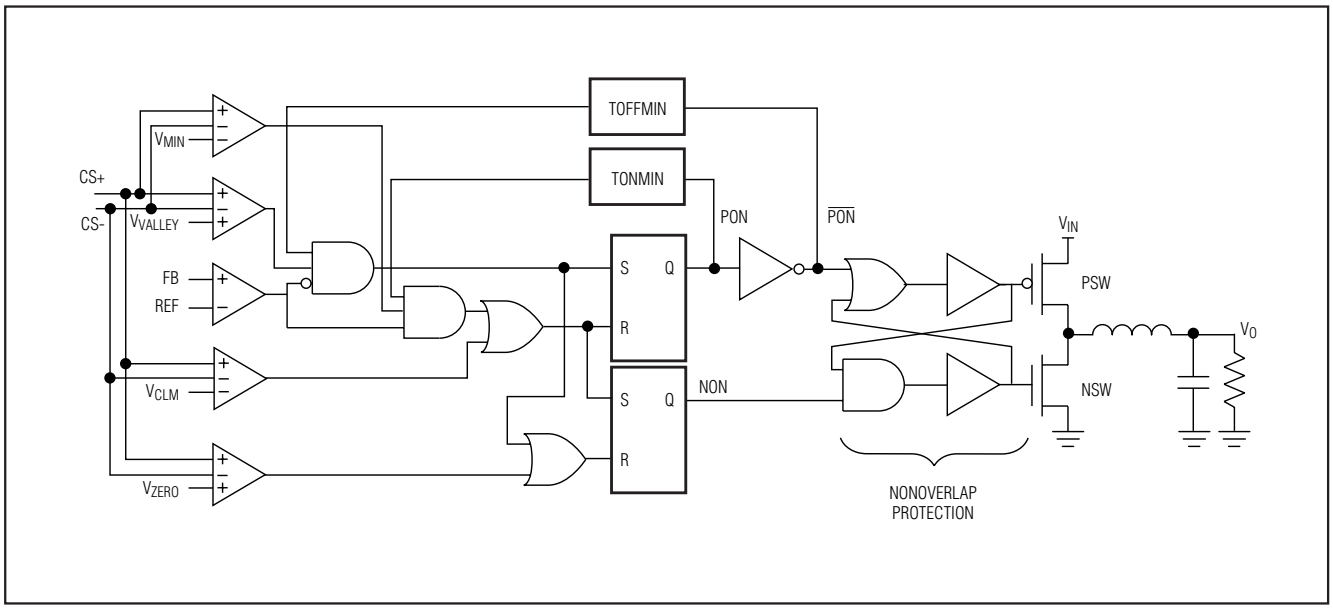


Figure 2. Simplified Control System Block Diagram

100% duty cycle fail. Dropout voltage is defined as the difference between the input and output voltages when the input is low enough for the output to drop out of regulation. Dropout depends on the MOSFET drain-to-source on-resistance, current-sense resistor, and inductor series resistance, and is proportional to the load current:

$$V_{DROPOUT} = I_{OUT} [R_{DS(ON)} + R_{SENSE} + R_L]$$

Regulation Control Scheme

The MAX1774 has a unique operating scheme that allows PWM operation at medium and high current, automatically switching to pulse-skipping mode at lower currents to improve light-load efficiency. Figure 2 shows a simplified block diagram.

Under medium and heavy load operation, the inductor current is continuous and the part operates in PWM mode. In this mode, depending on the duty cycle, either the minimum on-time or the minimum off-time sets the switching frequency. The duty cycle is approximately the output voltage divided by the input voltage. If the duty cycle is less than 50%, the minimum on-time controls the frequency, and the frequency is approximately $f \approx 2.5MHz \times D$, where D is the duty cycle. If the duty cycle is greater than 50%, the minimum off-time sets the frequency, and the frequency is approximately $f \approx 2.5MHz \times (1 - D)$.

In both cases, the error comparator regulates the voltage. For low duty cycles (<50%), the P-channel MOSFET is turned on for the minimum on-time, causing fixed-on-time operation. During the MOSFET on-time, the output voltage rises. Once the MOSFET is turned off, the voltage drops to the regulation threshold, when another cycle is initiated. For high duty cycles (>50%), the MOSFET remains off for the minimum off-time, causing fixed-off-time operation. In this case, the MOSFET remains on until the output voltage rises to the regulation threshold. Then the MOSFET turns off for the minimum off-time, initiating another cycle.

By switching between fixed-on-time and fixed-off-time operation, the MAX1774 can operate at high input-output ratios and still operate up to 100% duty cycle for low dropout. When operating from fixed-on-time operation, the minimum output voltage is regulated, but in fixed-off-time operation, the maximum output voltage is regulated. Thus, as the input voltage drops below approximately twice the output voltage, a decrease in line regulation can be expected. The drop in voltage is approximately $V_{DROP} \approx V_{RIPPLE}$. At light output loads, the inductor current is discontinuous, causing the MAX1774 to operate at lower frequencies, reducing the MOSFET gate drive and switching losses. In discontinuous mode, under most circumstances, the on-time will be a fixed minimum on-time of 400ns.

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

The MAX1774 features four separate current-limit threshold detectors and a watchdog timer for each of its step-down converters. In addition to the more common peak-current detector and zero-crossing detector, each converter also provides a valley-current detector, and a minimum-current detector. The valley-current detector is used to force the inductor current to drop to a lower level after hitting peak current before allowing the P-channel MOSFET to turn on. This is a safeguard against inductor current significantly overshooting above the peak current when the inductor discharges too slowly when V_{OUT}/L is small. The minimum-current detector ensures that a minimum current is built up in the inductor before turning off the P-channel MOSFET. This helps the inductor to charge the output near dropout when the dI/dt is small (because $(V_{IN} - V_{OUT}) / L$ is small) to avoid multiple pulses and low efficiency. This feature, however, is disabled during dropout and light-load conditions where the inductor current may take too long to reach the minimum current value. A watchdog timer overrides the minimum current after the P-channel MOSFET has been on for longer than about 10µs.

Main Step-Down Converter

The main step-down converter features adjustable +1.25V to +5.5V output delivering up to 2A from a +2.7V to +28V input (see *Setting the Output Voltages*). The use of external MOSFETs and current-sense resistor maximizes design flexibility. The MAX1774 offers a synchronous-rectifier MOSFET driver that improves efficiency by eliminating losses through a diode. The two MOSFET drive outputs, PDRV and NDRV, control these external MOSFETs. The output swing of these outputs is limited to reduce power consumption by limiting the amount of injected gate charge (see *Internal Linear Regulators* section for details). Current-limit detection for all main converter current limits is sensed through a small-sense resistor at the converters' output (see *Setting the Current Limit* section). Driving the $\overline{SHDNM}$ pin low puts the main converter in a low-power shutdown mode. The core regulator, low-voltage detectors, and backup converter are still functional when the main converter is in shutdown. When the MAX1774 enters backup mode, the main converter and its current sensor are shut off.

Core Step-Down Converter

The core step-down converter produces a +1.0V to +5.0V output from a +2.6V to +5.5V input. The low-voltage input allows the use of internal power MOSFETs, taking advantage of their low $R_{DS(ON)}$, improving efficiency and reducing board space. Like the main converter, the core regulator makes use of a synchronous-rectifying N-channel MOSFET, improving efficiency and eliminating the need for an external Schottky diode. Current sensing is internal to the device, eliminating the need for an external sense resistor. The maximum and minimum current limits are sensed through the P-channel MOSFET, while the valley current and zero-crossing current are sensed through the N-channel MOSFET. The core output voltage is measured at FBC through a resistive voltage-divider. This divider can be adjusted to set the output voltage level (see *Setting the Output Voltages*). The core input can be supplied from the main regulator or an external supply that does not exceed +5.5V (see *High-Voltage Configuration and Low-Voltage Configuration* sections). The core converter can be shut down independent of the main converter by driving $\overline{SHDNC}$ low. If the main converter output is supplying power to the core and is shut down, $\overline{SHDNM}$ controls both outputs. In this configuration, the core converter continues to operate when the MAX1774 is in backup mode.

Voltage Monitors and Battery Switchover

The MAX1774 offers voltage monitors ACI, LBI, DBI, and $\overline{BKOFF}$ that drive corresponding outputs to indicate low-voltage conditions. The AC adapter low-voltage detect input, ACI, is typically connected to the output of an AC-to-DC converter. When the voltage at ACI drops below the INS sense input plus 0.22V, the low AC output, $\overline{ACO}$, is asserted. Figure 3 shows a simplified block diagram.

The low and dead battery monitors (LBI and DBI) monitor the voltage at MAIN_BATT through a resistive voltage-divider. When the voltage at LBI falls below +1.20V, the low-battery output flag, $\overline{LBO}$, is asserted.

When both VIN_AC and MAIN_BATT are present, the MAX1774 chooses one of the two supplies determined by ACI. To facilitate this, the MAX1774 provides an open-drain MOSFET driver output ($\overline{MDRV}$). This drives an external P-channel MOSFET used to switch the MAX1774 from the AC input to the battery. $\overline{MDRV}$ goes low when $\overline{ACO}$ is low, the main battery is not dead, and the MAX1774 is not in backup mode.

The MAX1774 enters backup mode when the voltage at DBI is below +1.20V and VIN_AC is not present to the board. Under these conditions, the $\overline{BKUP}$ output is asserted (low), and the device utilizes its boost converter and a low-voltage backup battery to supply the main output. The $\overline{BKUP}$ pin can be driven low externally, forcing the MAX1774 to enter backup mode. If the voltage at $\overline{BKOFF}$ is less than 0.5V, the backup converter is disabled. $\overline{BKOFF}$ can be driven from a digital signal, or can be used as a low-battery detector to disable the backup converter when the backup battery is low.

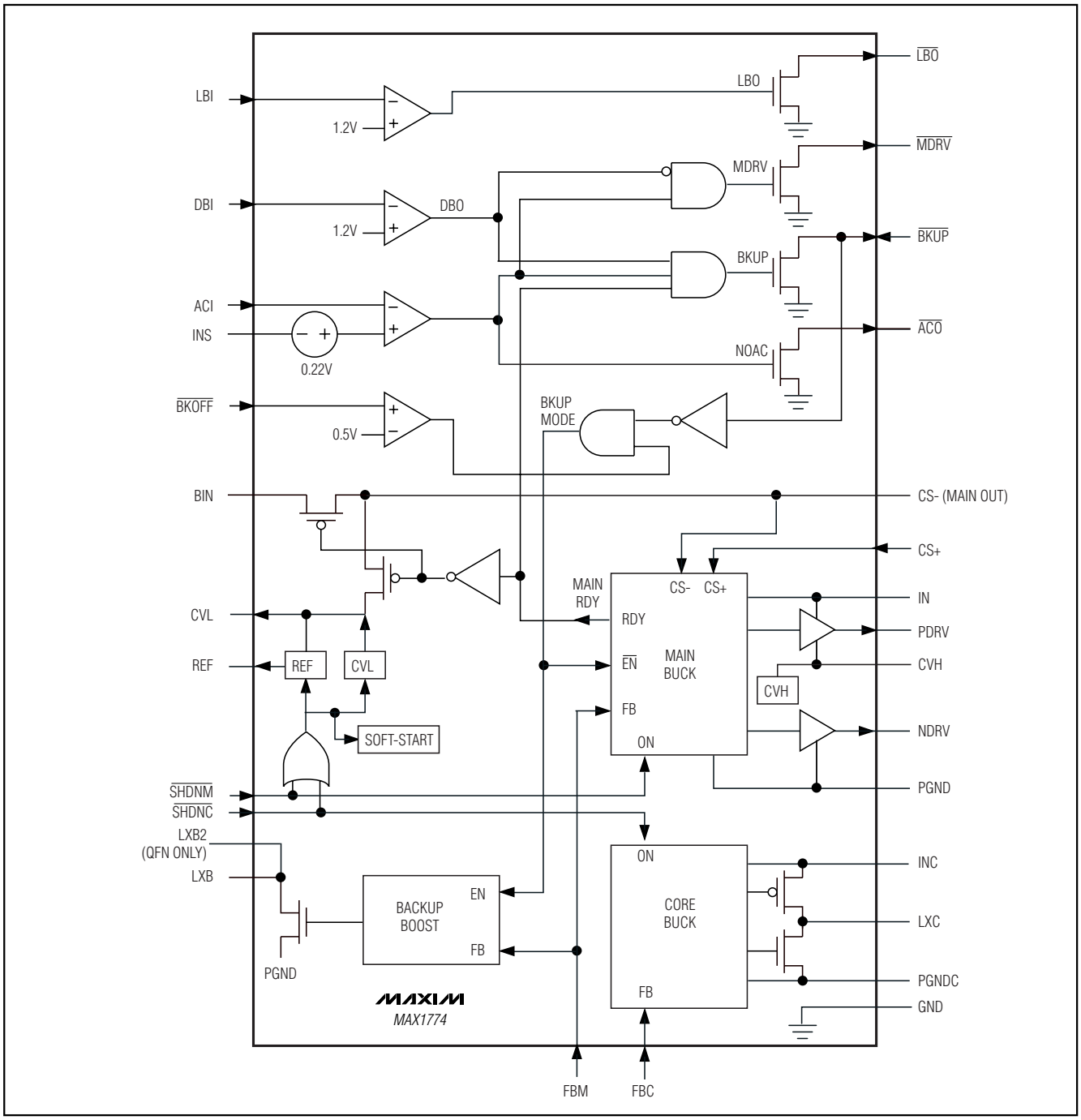


Figure 3. Simplified Block Diagram

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

Place 1MΩ pullup resistors from the main output to ACO, LBO, and BKUP. Use a 1MΩ pullup resistor from MDRV to IN.

When not in backup mode, the backup regulator is isolated from the main output by an internal switch. When the MAX1774 is in backup mode, the main converter is disabled, and the output of the backup regulator is connected to the main output. The core converter is still operable while in backup mode. The backup step-up converter cannot drive the typical main load current. The load at main must be reduced before entering backup mode.

If BKUP is de-asserted (goes high), the MAX1774 exits backup mode and resumes operation from the main battery or the AC adapter input. If BKOFF goes low, or the backup battery discharges where it cannot sustain the main output load, the backup converter shuts off. To restart the main converter, apply power to V_{IN_AC} or MAIN_BATT.

The backup converter uses an external Schottky diode and internal power NMOS switch. Since this converter shares the same output as the main buck converter, it shares the same feedback network. This automatically sets the backup converter output voltage to that of the main converter. The backup converter generates an output between +1.25V and +5.5V from a +0.9V to +5.5V input, and provides a load current up to 20mA. When the MAX1774 is in backup mode, the main current- sense circuit is turned off to conserve power.

When the output is out of regulation, the maximum inductor current limit and zero-current detectors regulate switching. The N-channel MOSFET is turned on until the maximum inductor current limit is reached, and shuts off until the inductor current reaches zero. When the output is within regulation, switching is controlled by the maximum pulse width, LXB, switch current limit, zero crossing, and the feedback voltage.

Internal Linear Regulators

There are two internal linear regulators in the MAX1774. A high-voltage linear regulator accepts inputs up to +28V, reducing it to +2.8V at CVL to provide power to the MAX1774. If the voltage at CS- is greater than +2.47V, CVL is switched to CS-, allowing it to be driven from the main converter, improving efficiency. CVL supplies the internal bias to the IC and power for the NDRV gate driver.

The CVH regulator output provides the low-side voltage for the main regulator's PDRV output. The voltage at CVH is regulated at 4.2V below V_{IN} to limit the voltage swing on PDRV, reducing gate charge and improving efficiency (Figure 3).

Reference

The MAX1774 has a trimmed internal +1.25V reference at REF. REF can source no more than 50µA. Bypass REF to GND with a 0.22µF capacitor.

Design Procedure

Low-Voltage Configuration

To improve efficiency and conserve board space, the core regulator operates from low input voltages, taking advantage of internal low-voltage, low-on-resistance MOSFETs. When the input voltage remains below 5.5V, run the core converter directly from the input by connecting INC to IN (Figure 1). This configuration takes advantage of the core's low-voltage design and improves efficiency.

High-Voltage Configuration

For input voltages greater than 5.5V, cascade the main and core converters by connecting INC to the main output voltage (Figure 4). In this configuration, the core converter is powered from the main output. Ensure that the main output can simultaneously supply its load and the core input current.

Backup Converter Configuration

The MAX1774 provides a backup step-up converter to power the device and provide the main output voltage when other power fails. The backup converter operates from a +0.9V to +5.5V battery. For most rechargeable batteries, such as NiCd or NiMH, the simple circuit of Figure 5 can be used to recharge the backup battery. In this circuit, the backup battery is charged through R1 and D10. Consult the battery manufacturer for charging requirements. To prevent the backup battery from overdischarging, connect a resistive voltage-divider from the backup battery to BKOFF. Resistor values can be calculated through the following equation:

$$R12 = R13 \times [(V_{BU} / V_{\overline{BKOFF}}) - 1]$$

where $V_{\overline{BKOFF}}$ = 0.5V, and V_{BU} is the minimum acceptable backup battery voltage. Choose R13 to be less than 150kΩ.

Setting the Output Voltages

The main output voltage is set from +1.25V and +5.5V with two external resistors connected as a voltage-divider to FBM (Figure 1). Resistor values can be calculated by the following equation:

$$R10 = R11 \times [(V_{OUTM} / V_{FBM}) - 1]$$

where V_{FBM} = +1.25V. Choose R11 to be 40kΩ or less.

The core regulator output is adjustable from +1.0V to +5.0V through two external resistors connected as a

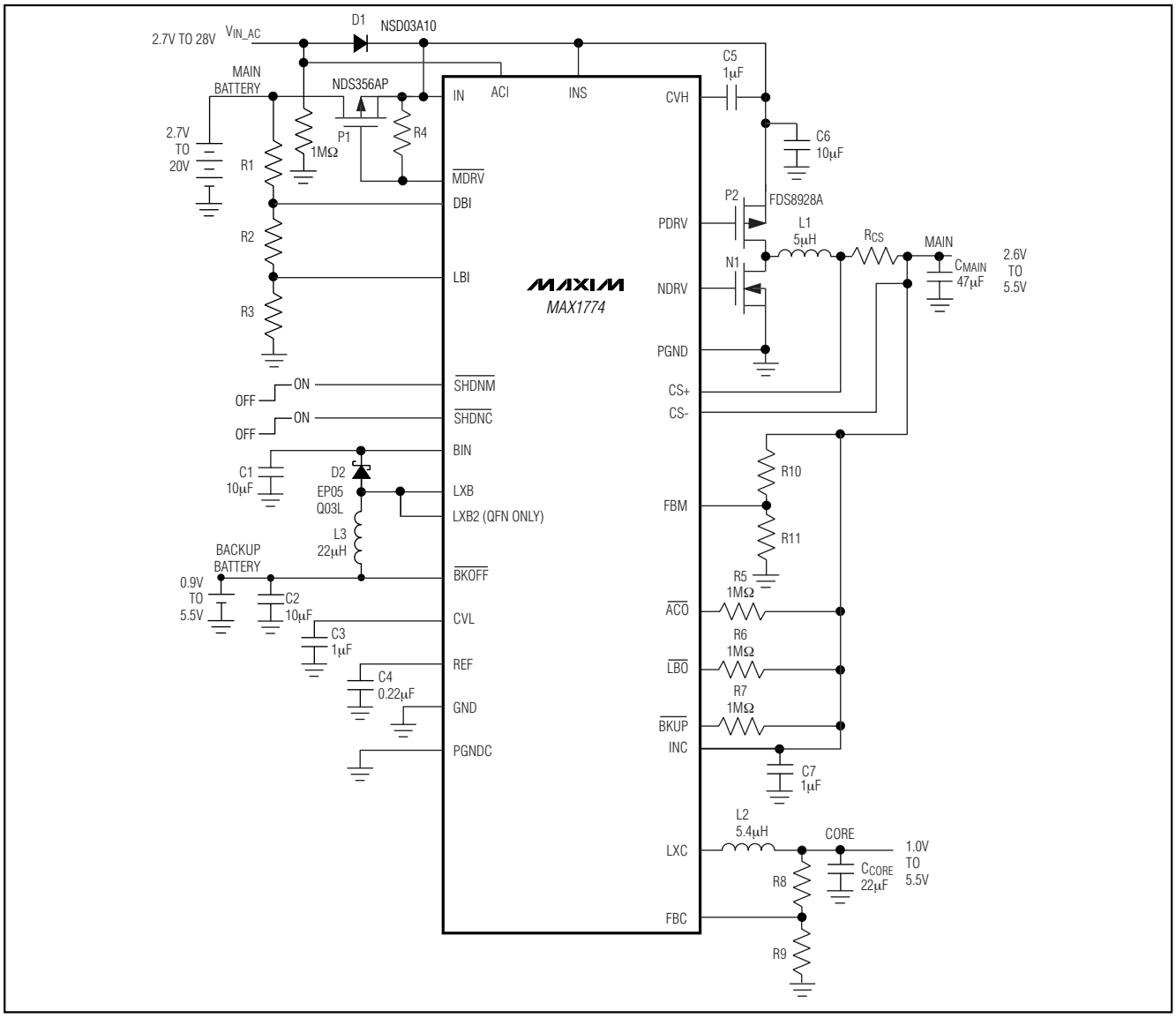


Figure 4. Typical Application Circuit (Cascaded)

voltage-divider to FBC (Figure 1). Resistor values can be calculated with the following equation:

$$R8 = R9 \times [(V_{OUTC} / V_{FBC}) - 1]$$

where V_{FBC} = +1.0V. Choose R9 to be 30kΩ or less.

Setting the Current Limit

The main regulator current limit is set externally through a small current-sense resistor, R_{CS} (Figure 1). The value of R_{CS} can be calculated with the following equation:

$$R_{CS} = V_{CLM} / (1.3 \times I_{OUT})$$

where V_{CLM} = 80mV is the current-sense threshold, and I_{OUT} is the current delivered to the output. The core and backup converter current limits are set internally and cannot be modified.

Careful layout of the current-sense signal traces is imperative. Place R_{CS} as close to the MAX1774 as possible. The two traces should have matching length and width, be as far as possible from noisy switching sig-

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

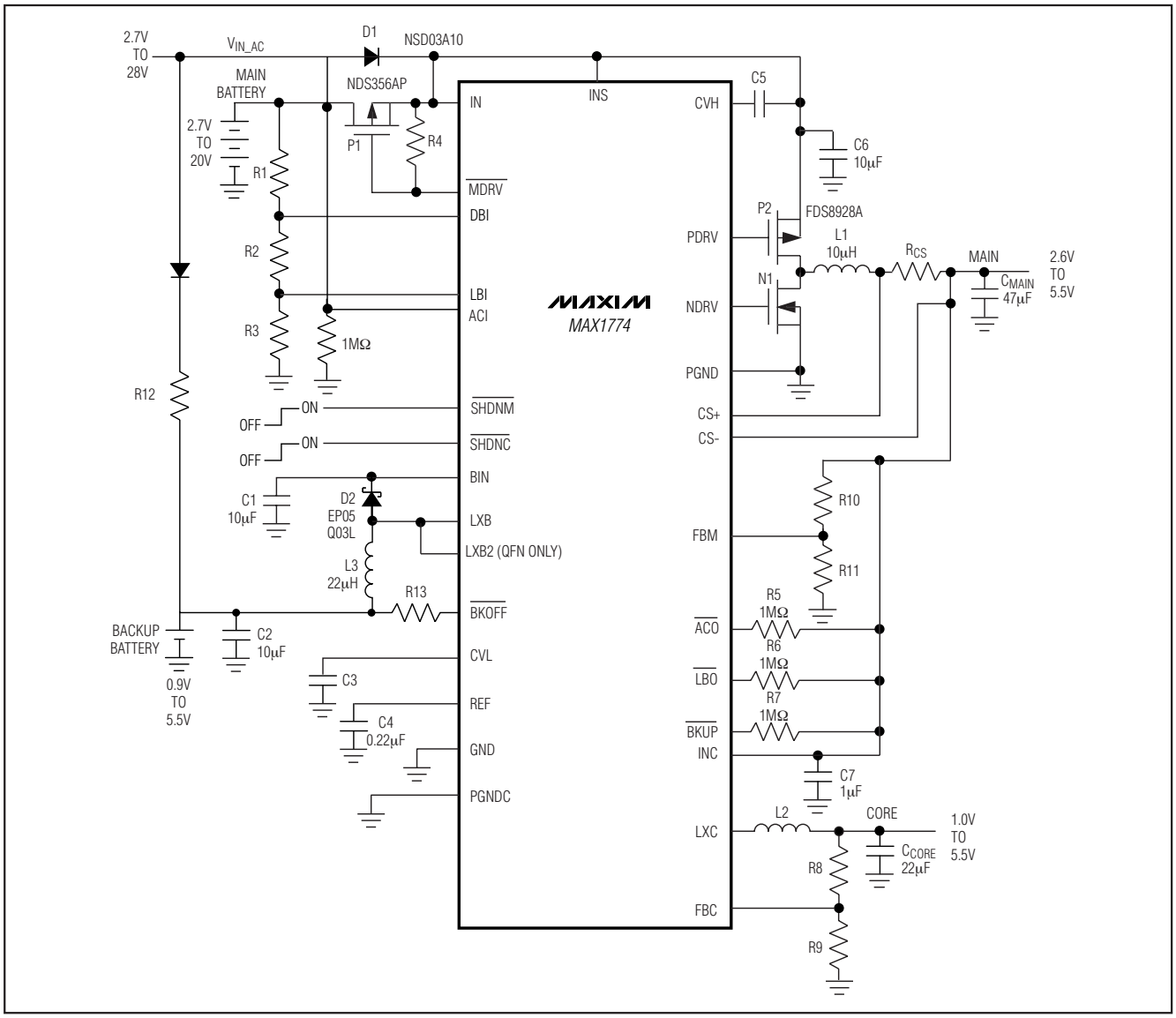


Figure 5. Typical Application Circuit (with Recharge)

nals, and be close together to improve noise rejection. These traces should be used for current-sense signal routing only and should not carry any load current. Refer to the *MAX1774 evaluation kit* for layout examples.

Setting the Voltage Monitor Levels

The low battery and dead battery detector trip points can be set by adjusting the resistor values of the divider string (R1, R2, and R3) in Figure 1 according to the following equations:

$$R1 = (R2 + R3) \times [(V_{BD} / V_{TH}) - 1]$$

$$R2 = R3 \times [(V_{BL} / V_{BD}) - 1]$$

where V_{BL} is the low battery voltage, V_{BD} is the dead battery voltage, and V_{TH} = +1.20V. Choose R3 to be less than 250kΩ.

Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

Inductor Selection

The essential parameters for inductor selection are inductance and current rating. The MAX1774 operates with a wide range of inductance values.

Calculate the inductance value for either CORE or MAIN, L_{MIN} :

$$L_{(MIN)} = (V_{IN} - V_{OUT}) \times (t_{ON(MIN)} / I_{RIPPLE})$$

where t_{ONMIN} is typically 400ns, and I_{RIPPLE} is the continuous conduction peak-to-peak I_{RIPPLE} current.

In continuous conduction, I_{RIPPLE} should be chosen to be 30% of the maximum load current. With high inductor values, the MAX1774 begins continuous-conduction operation at a lower fraction of full load (see *Detailed Description*).

The inductor's saturation current must be greater than the peak switching current to prevent core saturation. Saturation occurs when the inductor's magnetic flux density reaches the maximum level the core can support and inductance starts to fall. The inductor heating current rating must be greater than the maximum load current to prevent overheating. For optimum efficiency, the inductor series resistance should be less than the current-sense resistance.

Capacitor Selection

Choose the output filter capacitors to service input and output ripple current with acceptable voltage ripple. ESR in the output capacitor is a major contributor to output ripple. For the main converter, low-ESR capacitors such as polymer or ceramic capacitors are recommended. For the core converter, choosing a low-ESR tantalum capacitor with enough ESR to generate about 1% ripple voltage across the output is helpful in ensuring stability.

Voltage ripple is the sum of contributions from ESR and the capacitor value:

$$V_{RIPPLE} \approx V_{RIPPLE,ESR} + V_{RIPPLE,C}$$

For tantalum capacitors, the ripple is determined mostly by the ESR. Voltage ripple due to ESR is:

$$V_{RIPPLE,ESR} \approx (R_{ESR}) \times I_{RIPPLE}$$

For ceramic capacitors, the ripple is mostly due to the capacitance. The ripple due to the capacitance is approximately:

$$V_{RIPPLE,C} \approx L\ I_{RIPPLE}{}^2 C_{OUT}\ V_{OUT}$$

where V_{OUT} is the average output voltage.

These equations are suitable for initial capacitor selection. Final values should be set by testing a prototype or evaluation kit. When using tantalum capacitors, use good soldering practices to prevent excessive heat from damaging the devices and increasing their ESR. Also, ensure that the tantalum capacitors' surge-current ratings exceed the startup inrush and peak switching currents.

The input filter capacitor reduces peak currents drawn from the power source and reduces noise and voltage ripple at IN, caused by the circuit's switching. Use a low-ESR capacitor. Two smaller value low-ESR capacitors can be connected in parallel if necessary. Choose input capacitors with working voltage ratings higher than the maximum input voltage.

MOSFET Selection

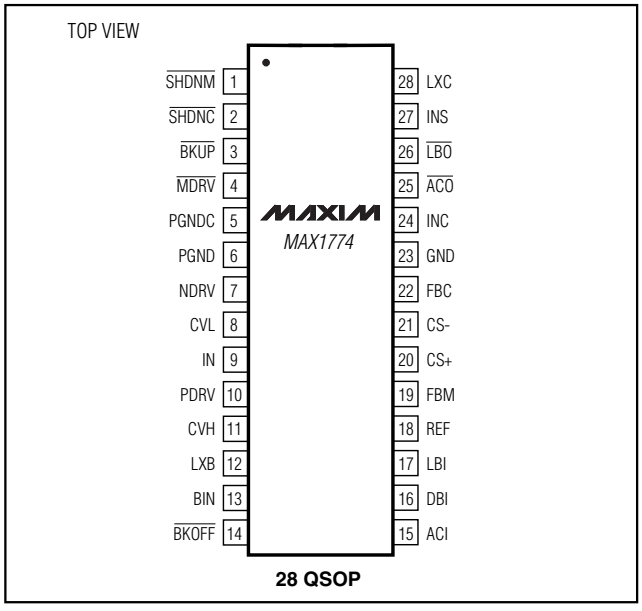
The MAX1774 drives an external enhancement-mode P-channel MOSFET and a synchronous-rectifier N-channel MOSFET. When selecting the MOSFETs, important parameters to consider are on-resistance ($R_{DS(ON)}$), maximum drain-to-source voltage ($V_{DS(MAX)}$), maximum gate-to-source voltage ($V_{GS(MAX)}$), and minimum threshold voltage ($V_{TH(MIN)}$).

Chip Information

TRANSISTOR COUNT: 4545

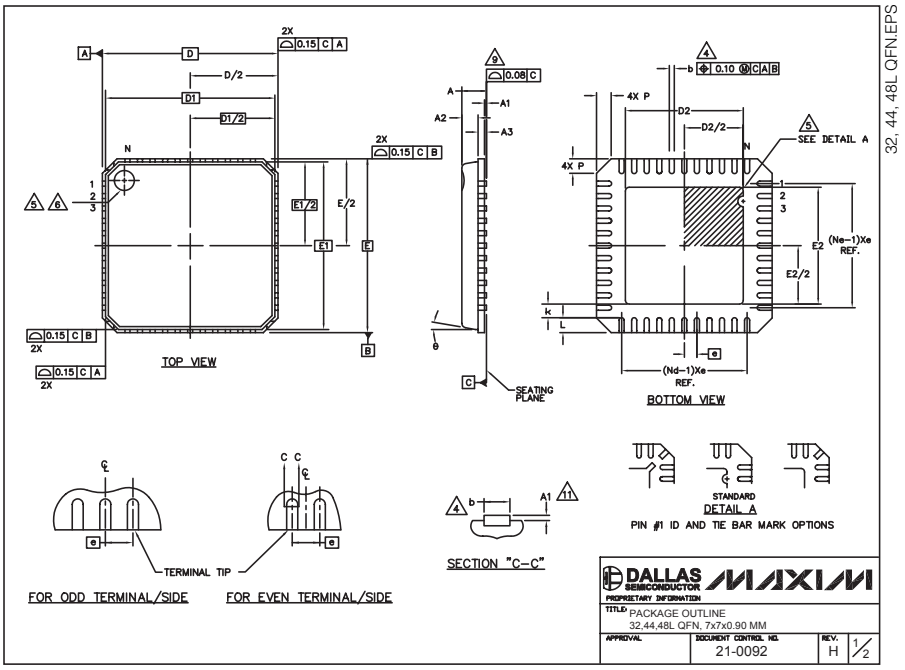
PROCESS: BiCMOS

Pin Configurations (continued)



Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

Package Information



COMMON DIMENSIONS									
PKG	32L 7x7			44L 7x7			48L 7x7		
SYMBOL	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.80	0.90	1.00	0.80	0.90	1.00	0.80	0.90	1.00
A1	0.00	0.01	0.05	0.00	0.01	0.05	0.00	0.01	0.05
A2	0.00	0.65	1.00	0.00	0.65	1.00	0.00	0.65	1.00
A3	0.20 REF			0.20 REF			0.20 REF		
b	0.23	0.28	0.35	0.18	0.23	0.30	0.18	0.23	0.30
D	6.90	7.00	7.10	6.90	7.00	7.10	6.90	7.00	7.10
D1	6.75 BSC			6.75 BSC			6.75 BSC		
E	6.90	7.00	7.10	6.90	7.00	7.10	6.90	7.00	7.10
E1	6.75 BSC			6.75 BSC			6.75 BSC		
e	0.65 BSC			0.50 BSC			0.50 BSC		
k	0.25	-	-	0.25	-	-	0.25	-	-
L	0.35	0.55	0.75	0.35	0.55	0.75	0.30	0.40	0.50
N	32			44			48		
Nd	8			11			12		
Ne	8			11			12		
P	0.00	0.42	0.60	0.00	0.42	0.60	0.00	0.42	0.60
U	0°		12°	0°		12°	0°		12°

EXPOSED PAD VARIATIONS						
PKG. CODES	D2			E2		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
G3277-2	4.55	4.70	4.85	4.55	4.70	4.85
G4477-1	3.65	3.80	3.95	3.65	3.80	3.95
G4477-2	4.55	4.70	4.85	4.55	4.70	4.85
G4477-3	3.15	3.30	3.45	3.15	3.30	3.45
G4877-1	4.95	5.10	5.25	4.95	5.10	5.25
G4877-2	5.45	5.60	5.75	5.45	5.60	5.75

NOTES:

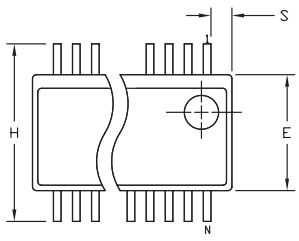
1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM).
2. DIMENSIONING & TOLERANCES CONFORM TO ASME Y14.5M. – 1994.
3. N IS THE NUMBER OF TERMINALS.
   Nd IS THE NUMBER OF TERMINALS IN X-DIRECTION & Ne IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
4. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25mm FROM TERMINAL TIP.
5. THE PIN #1 IDENTIFIER MUST EXIST ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR INK/LASER MARKED. DETAILS OF PIN #1 IDENTIFIER IS OPTIONAL, BUT MUST BE LOCATED WITHIN ZONE INDICATED.
6. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
7. ALL DIMENSIONS ARE IN MILLIMETERS.
8. PACKAGE WARPAGE MAX 0.08mm.
9. APPLIED FOR EXPOSED PAD AND TERMINALS.
   EXCLUDE EMBEDDED PART OF EXPOSED PAD FROM MEASURING.
10. MEETS JEDEC MO220 EXCEPT DIMENSION "b" MINIMUM.
11. APPLY ONLY FOR TERMINAL.
12. THIS PACKAGE OUTLINE APPLIES TO ANVIL SINGULATION(STEPPED SIDES).

DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION
TITLE: PACKAGE OUTLINE, 32,44,48L QFN, 7x7x0.90 MM
APPROVAL
DOCUMENT CONTROL NO. 21-0092
REV. H
2/2

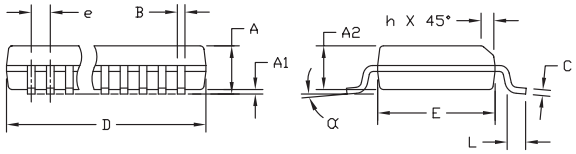
Dual, High-Efficiency, Step-Down Converter with Backup Battery Switchover

Package Information (continued)

QSOP.EPS



DIM	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	.061	.068	1.55	1.73
A1	.004	.0098	0.102	0.249
A2	.055	.061	1.40	1.55
B	.008	.012	0.20	0.30
C	.0075	.0098	0.191	0.249
D	SEE VARIATIONS			
E	.150	.157	3.81	3.99
e	.025 BSC		0.635 BSC	
H	.230	.244	5.84	6.20
h	.010	.016	0.25	0.41
L	.016	.035	0.41	0.89
N	SEE VARIATIONS			
α	0°	8°	0°	8°



VARIATIONS:

	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.	N	
D	.189	.196	4.80	4.98	16	AB
S	.0020	.0070	0.05	0.18		
D	.337	.344	8.56	8.74	20	AD
S	.0500	.0550	1.270	1.397		
D	.337	.344	8.56	8.74	24	AE
S	.0250	.0300	0.635	0.762		
D	.386	.393	9.80	9.98	28	AF
S	.0250	.0300	0.635	0.762		

NOTES:
1). D & E DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
2). MOLD FLASH OR PROTRUSIONS NOT TO EXCEED .006" PER SIDE.
3). CONTROLLING DIMENSIONS: INCHES.
4). MEETS JEDEC MO137.

DALLAS SEMICONDUCTOR MAXIM
PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, QSOP .150", .025" LEAD PITCH

APPROVAL	DOCUMENT CONTROL NO.	REV.	
	21-0055	E	1/1