

# Personal Mobile Devices Selection Guide

[www.national.com/handheld](http://www.national.com/handheld)

2008 Vol. 1

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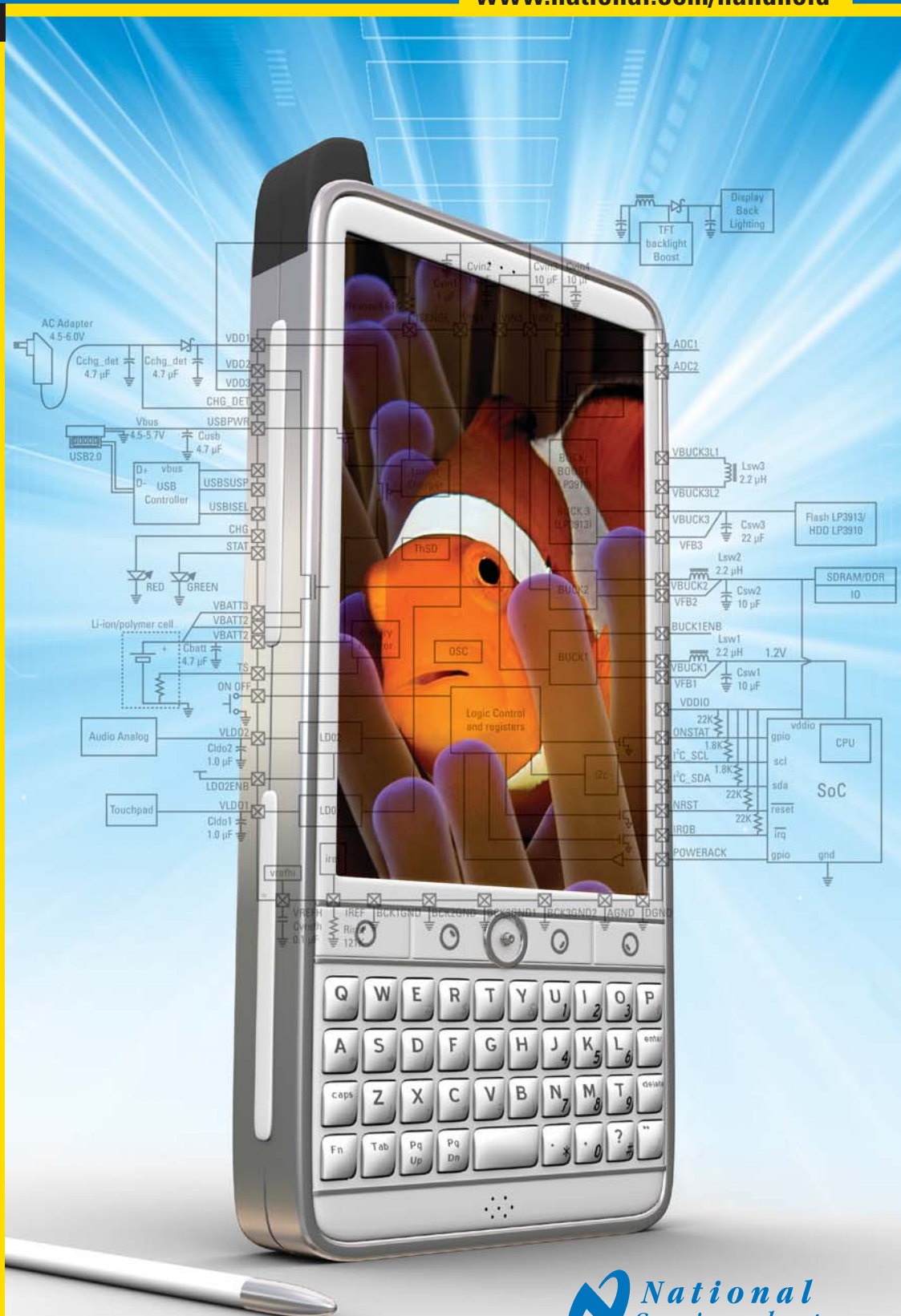
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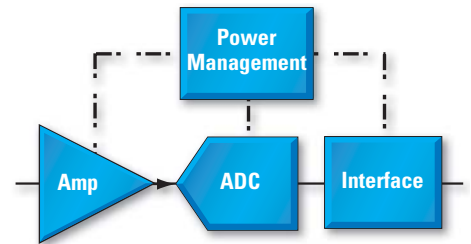


# Optimize Performance at the Lowest Power

## National's PowerWise® Solutions Help Engineers Design Energy Efficient Systems

PowerWise products are analog and mixed-signal semiconductors that balance higher performance with lower power consumption.

PowerWise subsystems are architectural innovations designed to enable energy-efficient systems.



## PowerWise Metrics Help Designers Compare Analog Components

PowerWise metrics are formulas and thresholds that distinguish energy efficient components from those that are less efficient. National has developed PowerWise metrics for 24 product categories and selected the best-in-class energy efficient products in each of these categories. Each PowerWise product has a PowerWise label and rating which summarizes its key specifications.

### PowerWise® Efficiency Ratings (4 out of 24 categories shown)

Product Family	Metric	Threshold	Units
Switching Regulators	Peak Efficiency	≥ 95	%
High-Speed ADCs	$\frac{P}{2^{\text{ENOB}} \cdot F_s \cdot ch}$	≤ 2.5	pJ/conversion
Equalizers	$\frac{P}{T_r \cdot ch}$	≤ 20	pJ/bit
Timing Solutions	$\frac{P \cdot t_j}{ch}$	≤ 55	mW•pS



## PowerWise Resources Help Designers Improve System Performance to Power

Visit [national.com/powerwise](http://national.com/powerwise) for white papers, app notes and design tools that help system engineers by highlighting the optimal balance between performance and power consumption at the component, subsystem and system level.

Find PowerWise products, metrics, white papers, app notes and tools at:  
[national.com/powerwise](http://national.com/powerwise)

The evolution of mobile handsets integrates features beyond simple voice communication transforming the cell phone into a personal mobile device.

National's solutions for displays, RF, integration, illumination, audio, and multimedia provide high-quality technology designed to transform the consumer user experience.

### Displays

Includes display drivers, bridges and backlight drivers that enable vivid display content and intelligent brightness control systems to decrease power consumption.

### RF

DC-DC converters for power amplifiers and low noise LDOs in the RF domain increase talk times.

### Integration

AVS technology coupled with power management ICs provide integrated solutions that save battery power and board space.

### Illumination

Solutions for handset illumination encompass applications such as camera flash, keypad and indicator lighting.

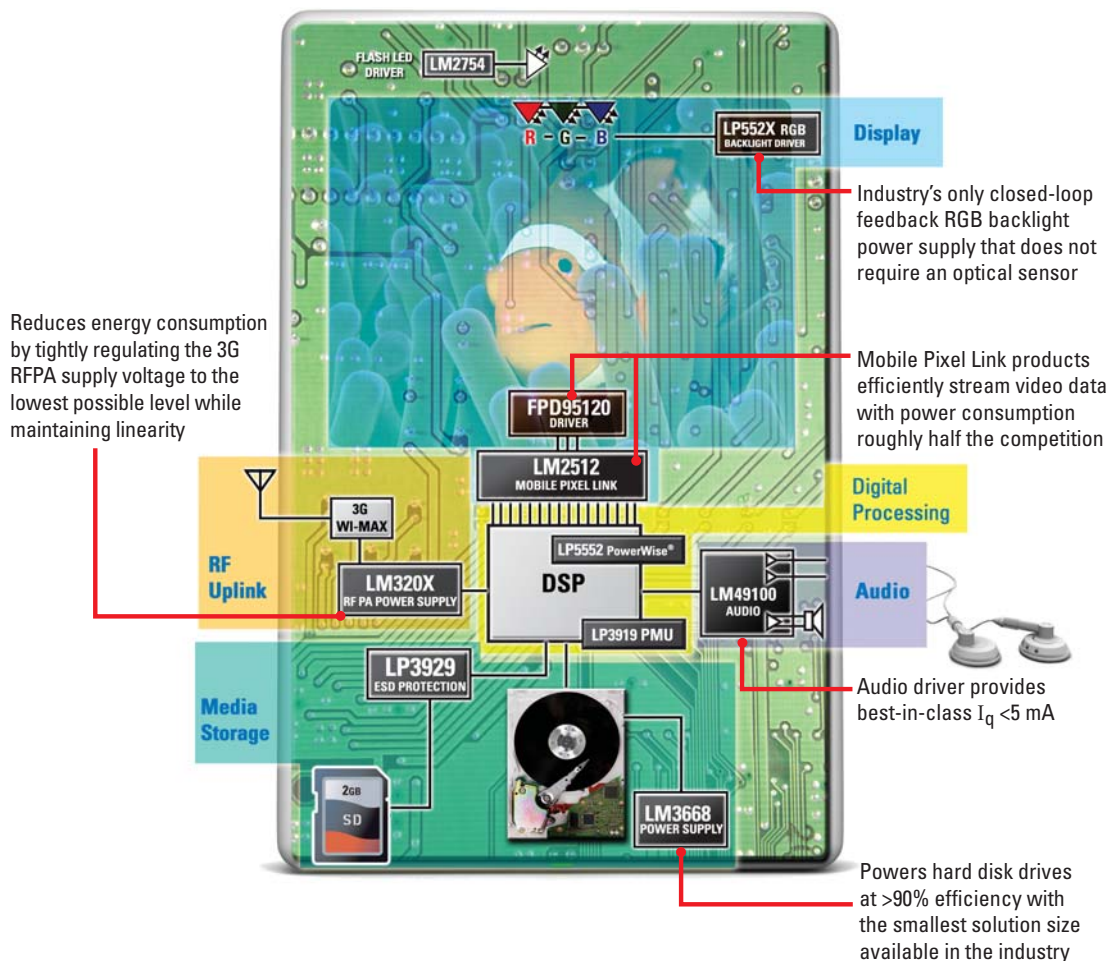
### Audio

National's audio subsystems enable high-quality sound in space-constrained designs.

### Multimedia

National's multimedia solutions deliver high performance for demanding applications like camera and mobile TV modules. The collaboration of these areas of expertise allows National to drive the innovation of handset architecture. To see all of National's personal mobile device solutions, visit:

[www.national.com/handheld](http://www.national.com/handheld)



# Extend Battery Life

- ✓ More features in a smaller space
- ✓ Richer audio & video
- ✓ Enhanced user experience



## National's PowerWise® Solutions Provide Optimal Performance at the Lowest Power

- **Adaptive Voltage Scaling (AVS) technology** reduces energy consumption in digital subsystems via a closed-loop voltage scaling to automatically minimize active and leakage power with minimal system overhead
- **Adaptive RF Power** enables energy savings in handsets by monitoring the RF power output and dynamically adjusting the supply voltage to RF PA
- **RGB LED backlighting** enhances color clarity while lowering power consumption
- **Mobile Pixel Link (MPL)** reduces EMI and interconnect while lowering power consumption
- **Integrated Class D audio subsystems** feature low-noise and very low quiescent current for minimum power consumption
- **Analog Noise Reduction Technology** reduces background noise and delivers more natural-sounding voice quality at one-tenth the power of DSP solutions

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## Inductive-Boost Backlight LED Drivers

Product ID	Input Voltage Range (V)	Maximum Output Voltage (V)	Max LED Current (mA)	Number of LEDs	Switching Frequency (MHz)	Dimming Control Type	Key Features	Packaging
LM2731/33	2.7 to 14	Adjustable up to 20/40	1A/1.5A (switch)	9	600 kHz	PWM	Internal compensation, cycle-by-cycle current limit	SOT23-5
<b>NEW</b> LM3430/32	6 to 40	80+	40 per string	100+	Adjustable up to 2 MHz	Analog, PWM	Dynamic Headroom Control for balanced current through up to 6 strings of LEDs	LLP-12, eTSSOP-28, LLP-24
<b>NEW</b> LM3431	5 to 36	40+	150 per string	30	Adjustable up to 1 MHz	Analog, PWM	Balances current through 3 strings of LEDs	TSSOP-28, LLP-28
LM3500	2.7 to 7	16, 21	30	5	1	PWM	Low feedback voltage; No external Schottky diode	micro SMD-8
LM3501	2.7 to 7	16, 21	30	5	1	Analog	No external Schottky diode	micro SMD-8
LM3502	2.5 to 5.5	16, 25, 35, 44	30	10	1	PWM	2 LED banks for dual-display backlighting	micro SMD-10, LLP-16
LM3503	2.5 to 5.5	16, 25, 35, 44	30	10	1	Analog	2 LED banks for dual-display backlighting	micro SMD-10, LLP-16
LM3508	2.7 to 5.5	17.5	30	4	0.85	PWM	Adjustable PWM signal up to 100kHz; No external Schottky diode	micro SMD-9
<b>NEW</b> LM3509	2.7 to 5.5	21.2	30 per string	10	1.27	I <sup>2</sup> C	Dual-current sinks; 32 exponential dimming steps; 800:1 dimming ratio	LLP-10
LM3519	2.7 to 5.5	18	20	4	2 to 8	PWM	Variable switching frequency	SOT23-6
LM3520	2.7 to 5.5	23	30	5	1.1	PWM	Power supply for OLED subdisplay	LLP-14
LM3557	2.7 to 7.5	26	30	5	1.25	PWM	Input under-voltage protection; Cycle-by-cycle current limit	LLP-8
<b>NEW</b> LM4510	2.7 to 5.5	18	up to 280	—	1	—	Power Supply for OLED display; No external Schottky diode	LLP-10

 PowerWise product

## Switched-Capacitor Boost Backlight LED Drivers

Product ID	Input Voltage Range (V)	Output Voltage (V)	Max LED Current (mA)	Number of LEDs	Switching Frequency (MHz)	Dimming Type	Key Features	Packaging
LM2750	2.9 to 5.6	5, Adj (3.8 to 5.2)	120	10	1.7	PWM	Pre-regulation minimizes input ripple	LLP-10
LM2751	2.8 to 5.5	4.5, 5	80 to 150	10	0.01 to 0.725	PWM	Programmable switching frequencies	LLP-10
<b>NEW</b> LM2755	3 to 5.5	5	90	3	1.25	I <sup>2</sup> C	Independently controlled RGB outputs; Programmable trapezoidal waveforms	micro SMD-18
<b>NEW</b> LM2756	2.7 to 5.5	4.6	180	8	1.3	I <sup>2</sup> C	3 independent LED banks with 2 variable drivers; 32 exponential dimming steps; 800:1 dimming ratio	micro SMD-20
<b>NEW</b> LM2757	2.7 to 5.5	4.1, 4.5, 5	100 to 180	10	1.25	No Dimming	Pre-regulation minimizes input ripple; True input-output and output-input disconnect; High impedance output in shutdown	micro SMD-12
LM27951/52	3 to 5.5	5	120	4	0.75	PWM	Regulated current sources with 0.2% matching	LLP-14
LM27964	2.7 to 5.5	5	180	7 (3 banks)	0.7	I <sup>2</sup> C	3 independent LED banks (Group A = 4 LEDs, Group B = 2 LEDs, Group C up to 80mA) ; Dedicated Keypad LED Driver	LLP-24
LM27965	2.7 to 5.6	5	180	9 (3 banks)	1.27	I <sup>2</sup> C	3 independent LED banks (Group A = 5 LEDs, Group B = 3 LEDs, Group C = 1 LED)	LLP-24
LM27966	2.7 to 5.7	5	180	6 (2 banks)	1.27	I <sup>2</sup> C	2 independent LED banks (Group A = 5 LEDs, Group B = 1 LEDs)	LLP-24

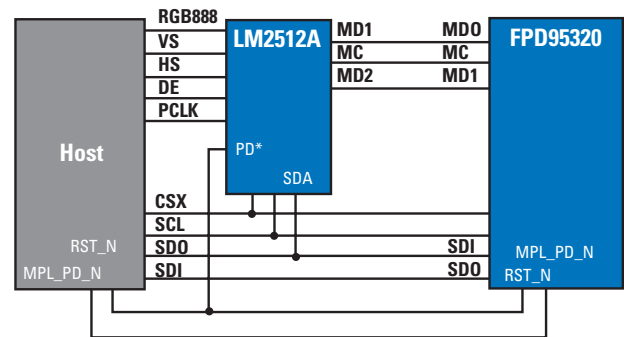
 PowerWise product

# Displays

## LM2512A - Mobile Pixel Link (MPL-1), 24-Bit RGB Display Interface Serializer with Optional Dithering and Look Up Table from the PowerWise® Family

### Features

- 24-bit RGB Interface support up to 640 x 480 VGA format
- Optional 24 to 18-bit dithering
- Optional Look Up Table for independent color correction
- MPL-1 physical layer
- SPI Interface for look up table control and loading
- Low power consumption and powerdown state
- Level translation between host and display
- Optional auto power down on STOP PCLK
- Frame sequence bits auto resync upon data or clock error
- 1.6V to 2.0V core/analog supply voltage
- 1.6V to 3.0V I/O supply voltage range



## FPD95320 - 320-Channel LTPS/CGS Driver with Partial Display Memory and MPL-1 Interface

### Features

- Power savings
- Self-refreshed partial display mode
- Provides timing signal for on-glass charge-sharing circuit
- Standard command set
- Registers initialized from on-chip EEPROM
- Command-triggered profiles can change register settings for modes/gamma settings
- Eliminates frequent host SW changes to update register settings
- 8 user-defined display configurations
- Programmable settings
- Display resolution and glass signal timing
- Video interface timing auto-learning circuit
- VID\_XFR output reduces tearing in partial mode
- Gamma curves and VCOM adjustment
- Video 2x upscale with programmable border

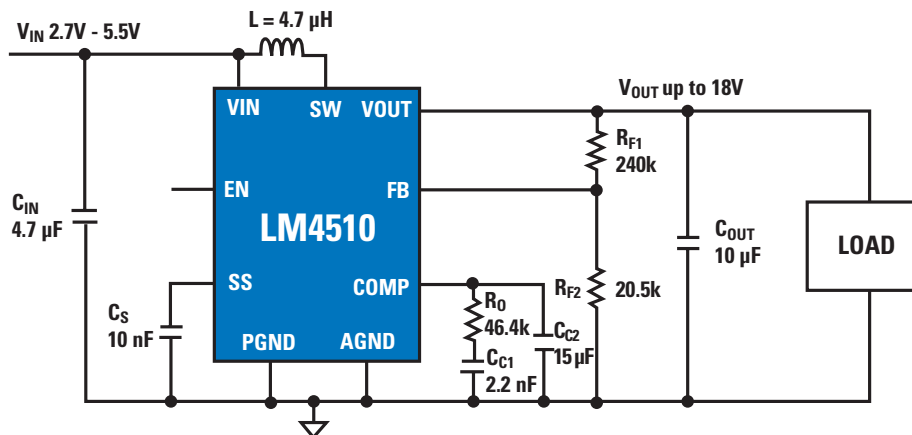


## LM4510 – PowerWise® Synchronous Step-Up DC-DC Converter for White LEDs and/or OLED Displays

### Features

- 18V at 80 mA from 3.2V input
- 5V at 280 mA from 3.2V input
- No external Schottky diode required
- 85% peak efficiency
- True shutdown isolation
- Stable with small ceramic or tantalum output capacitors
- Output short-circuit protection
- Thermal shutdown
- 0.002  $\mu\text{A}$  shutdown current
- 1.0 MHz fixed frequency operation
- Available in low-profile LLP-10 packaging (3 x 3 x 0.8mm)

LM4510 Typical Application Circuit



### Applications

Ideal for use in organic LED panel power supply, charging holster, white LED backlight, USB power supply, class D audio amplifier, camera flash LED driver

# Displays

## LM3509 – PowerWise® High-Efficiency Boost for White LEDs and/or OLED Displays

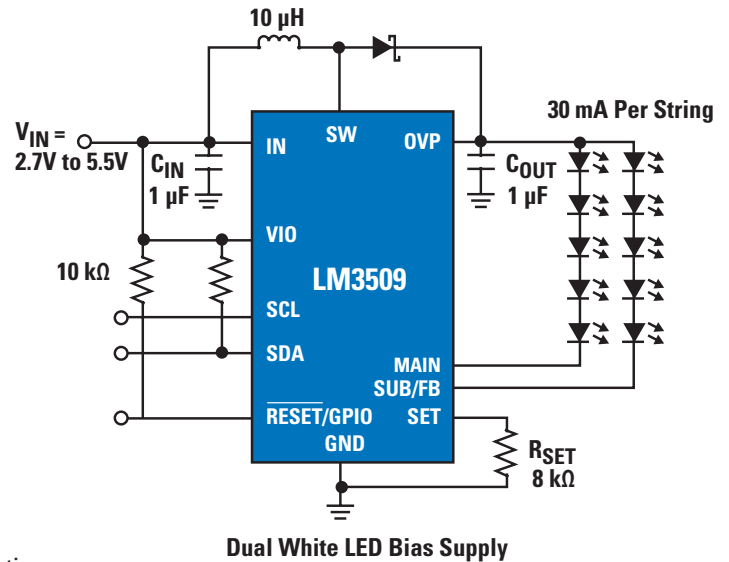
### Features

- Integrated OLED display power supply and LED driver
- Drives up to 10 LEDs at 30 mA
- Drives up to 5 LEDs at 20 mA and delivers up to 21V at 40 mA
- Over 90% Efficient
- 32 exponential dimming steps
- 0.15% accurate current matching between strings
- Internal soft-start limits inrush current
- True shutdown isolation for LED's
- 21V over-voltage protection
- 1.27MHz fixed frequency operation
- General purpose I/O
- Active low hardware reset
- Low-profile 10-pin LLP Package (3 mm x 3 mm x 0.8 mm)

### Applications

Ideal for use in dual display LCD backlighting for portable applications, large format LCD backlighting, OLED panel power supply

LM3509 Typical Application Circuit





## LM2756 – Multiple-Display LED Driver with I<sup>2</sup>C-Compatible Brightness Control

### Features

- Drives up to 8 LEDs with up to 30 mA of diode current each
- 32 exponential dimming steps with 800:1 dimming ratio for group A (up to 6 LEDs)
- 8 linear dimming states for groups B (up to 3 LEDs) and D1C (1 LED)
- Programmable auto-dimming function
- 3 independently controlled LED groups via I<sup>2</sup>C-compatible interface
- Up to 90% efficiency
- Total solution size < 21 mm
- 0.4% accurate current matching
- Internal soft-start limits inrush current
- True shutdown isolation for LEDs
- Wide input voltage range (2.7V to 5.5V)
- Active high hardware enable
- Available in low-profile, micro SMD-20 packaging (1.615 x 2.015 x 0.6 mm)

### Applications

Ideal for use in dual display LCD backlighting for portable applications, large format LCD backlighting, display backlighting with indicator light

## LM2757 – Switched-Capacitor Boost Regulator with High Impedance Output in Shutdown

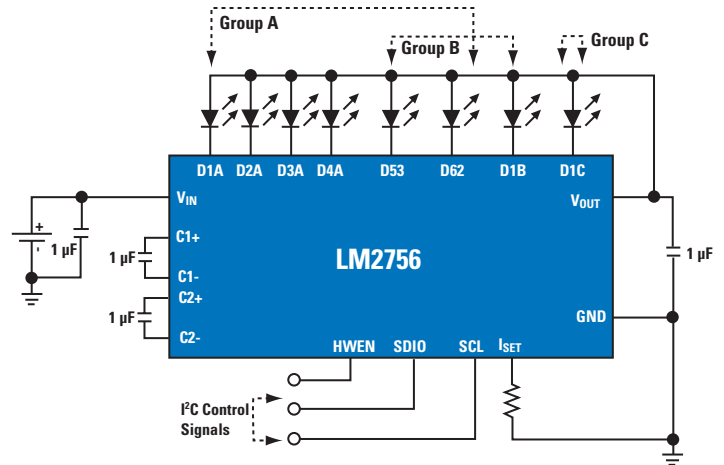
### Features

- Dual gain converter (2x, 3/2x) with up to 93% efficiency
- Inductor-less solution uses only 4 small ceramic capacitors
- Total solution area < 12 mm
- True input-output and output-input disconnect
- Up to 180 mA output current capability (5V)
- Selectable 4.1V, 4.5V or 5.0V output
- Pre-regulation minimizes input current ripple
- 1.24 MHz switching frequency for a low-noise, low-ripple output voltage
- Integrated over current and thermal shutdown protection
- Available in tiny micro SMD-12 packaging (1.2 x 1.6 x 0.4 mm)

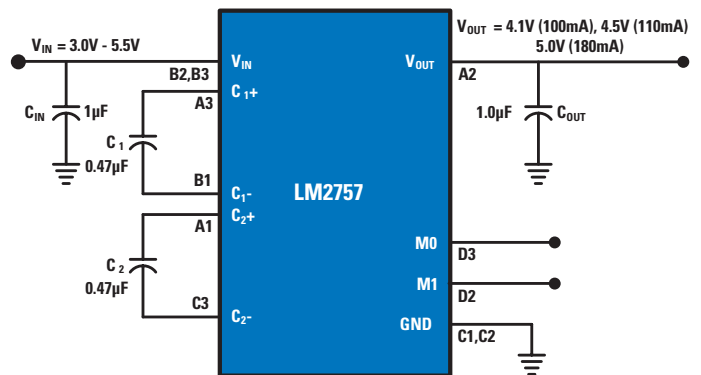
### Applications

USB/USB-OTG power, super capacitor charger, keypad LED driver, audio amplifier power supply

LM2756 Typical Application Circuit



LM2757 Typical Application Circuit



\*Bump D1 is (NC) No Connect

## Step-Down (Buck) Regulators for RF Power Amplifiers

Product ID	Input Max Voltage	Input Min Voltage	Output Min	Output Max	Output Current (mA)	Switching Frequency (KHz)	Soft-Start	Turn on Time ( $\mu$ S)	Bypass Modes	Package
LM3200	5.5	2.7	0.8	3.6	500	2000	—	N/A	Forced and Automatic	micro SMD-10
LM3202	5.5	2.7	1.3	3.16	650	2000	—	N/A	None	micro SMD-8
LM3203	5.5	2.7	0.8	3.6	500	2000	✓	50	Forced	micro SMD-10
LM3204	5.5	2.7	0.8	3.6	500	2000	✓	50	Forced and Automatic	micro SMD-10
LM3205	5.5	2.7	0.8	3.6	650	2000	✓	50	None	LLP-10, micro SMD-8
LM3208	5.5	2.7	0.8	3.6	650	2000	✓	40	None	micro SMD-8

PowerWise product

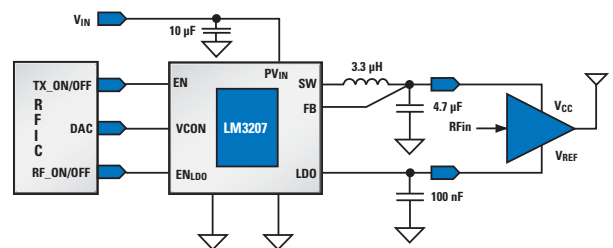
## Low Noise LDOs for Low-Power, Space-Constrained Applications

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Current (mA)	Dropout Voltage (V)	Output Voltage (V)	Adjustable Output	On/Off Pin	Quiescent Current (mA)	PSRR (dB)	Voltage Noise (rms)	Packaging
LP3995	6	2.5	150	0.06	3, 2.8, 1.9	—	✓	0.085	60	25	micro SMD-5, LLP-6
LP3997	6	2	250	0.14	3.3	—	✓	0.055	61	100	MSOP-8
LP3999	6	2.5	150	0.06	1.5, 2.4, 1.8, 2.5, 2.8, 3.3	—	✓	0.085	60	30	micro SMD-5
LP5900	5.5	2.5	150	0.08	1.5, 2.8, 3.3	—	✓	0.025	75	6.5	micro SMD-4
LP5990	5.5	2.2	200	0.15	0.8 to 3.6	—	✓	0.03	55	60	micro SMD-4

## LM3207 – PowerWise® Adjustable DC-DC Converter with Integrated LDO for Powering RF Power Amplifiers

### Features

- Dynamic output voltage control (0.8V to 3.6V) regulates power and maximizes talk time in RF-based systems
- Analog  $V_{CON}$  pin allows voltage control without need for external feedback resistors
- 650 mA maximum load capacity
- Integrated buck regulator plus LDO provide tiny integrated solution for RF PAs
- Fast 3  $\mu$ s  $V_{REF}$  LDO on/off time
- 3GPP standard compliant
- >90% efficiency maximizes battery life and improves reliability of RF sub-system
- Available in micro SMD-9 packaging and integrated solution optimizes solution size



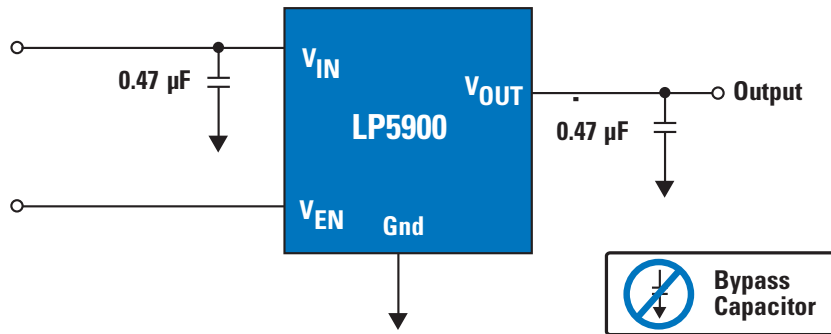
### Applications:

Ideal for use in cellular phones, handheld radios, RF PC cards, battery-powered RF devices

## LP5900 – Low-Noise 150 mA CMOS LDO

### Features

- Industry's lowest noise ( $6.5 \mu V_{RMS}$ ) combined with 85 dB of Power Supply Ripple Rejection guarantees signal integrity
- $25 \mu A$   $I_q$  minimizes current drain when system operates in low-power mode
- Elimination of bypass capacitor reduces BOM to only two ceramic  $0.47 \mu F$  capacitors
- Available in a micro SMD-4 and LLP packaging

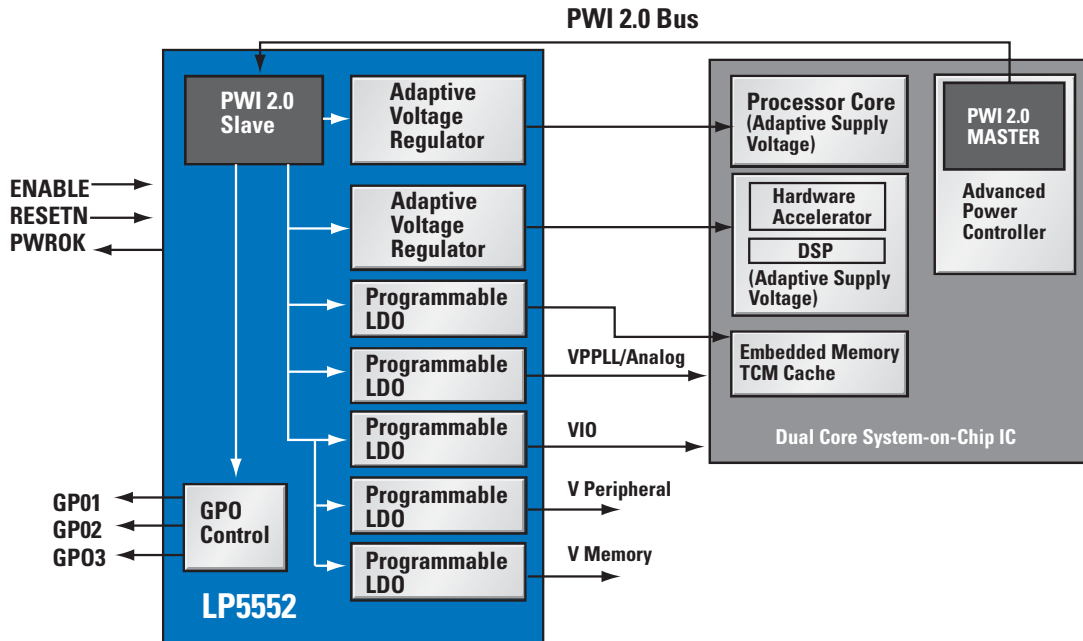


### Applications:

Ideal for use in powering analog and RF signal path ICs, including low-noise amplifiers, voltage-controlled oscillators, and RF receivers

# Integration

## LP5552 – Energy Management Unit Extends Battery Life and Enables New Features

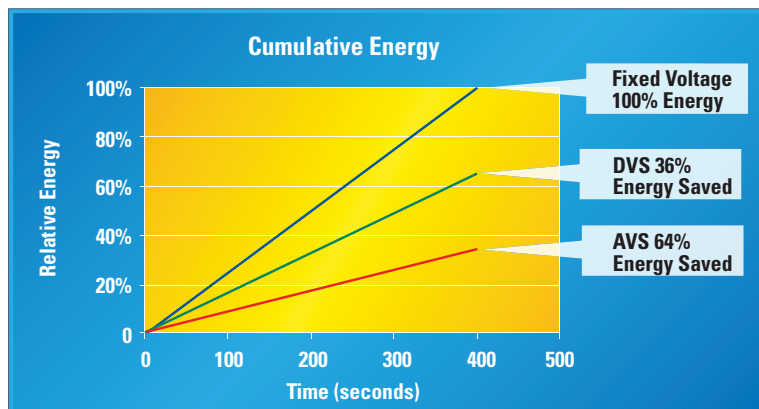


### Applications:

Ideal for use in dual core processors, cellular handsets, handheld radios, PDAs, battery-powered devices, and portable instruments

Product ID	Number of Outputs	Output Voltages and Current	V <sub>IN</sub> Range	Interface	Packaging
LP5550	4	1 Buck: 0.6V to 1.2V, 300 mA 3 LDOs: 0.6V to 3.3V, up to 250 mA	3 to 5.5	PWI 1.0	LLP-16
LP5551	8	2 Bucks: 0.6V to 1.2V, 300 mA 4 LDOs: 0.6V to 3.3V, up to 250 mA N-well bias: -0.3 to +1V (to supply) P-well bias: -1V to +0.3V (to GND)	2.7 to 5.5	PWI 1.0	LLP-36
LP5552	7	2 Bucks: 0.6V to 1.235V, 800 mA 5 LDOs: 0.6V to 3.3V, up to 250 mA	2.7 to 4.8	PWI 2.0	micro SMD-36

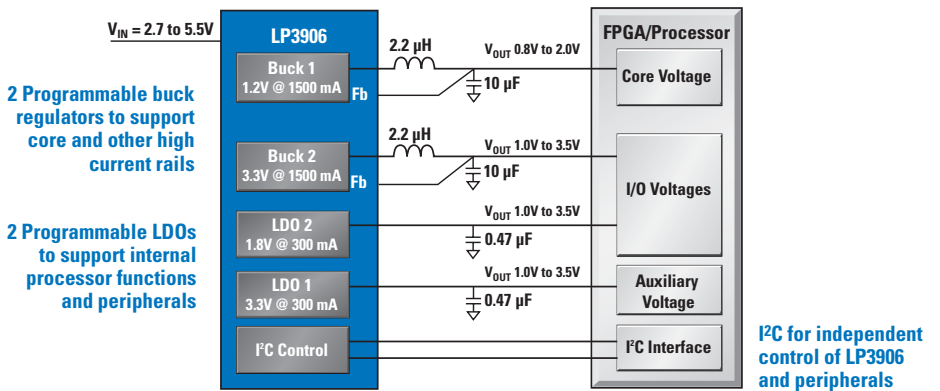
PowerWise product



## LP3906 – PowerWise® Dual High-Current Buck Regulator and Dual Linear Regulator with I<sup>2</sup>C-Compatible Interface

### Features

- Compatible with advanced applications processors and FPGAs
- Low input, low output voltage LDOs
- Additional external enables for each regulator output and a separate enable for the built-in sequence
- I<sup>2</sup>C-compatible interface for independent control of device functions and settings
- Thermal overload protection
- Current overload protection
- Spread spectrum reduces noise
- Available in LLP-24 packaging



### Applications:

Ideal for use in powering application processors, DSPs and FPGAs: Altera Cyclone Series, and Xilinx Spartan series

## LP3907 – PowerWise® Dual High-Current Buck Regulator and Dual Linear Regulator with I<sup>2</sup>C-Compatible Interface

### Features

#### Buck DC-DC Converter

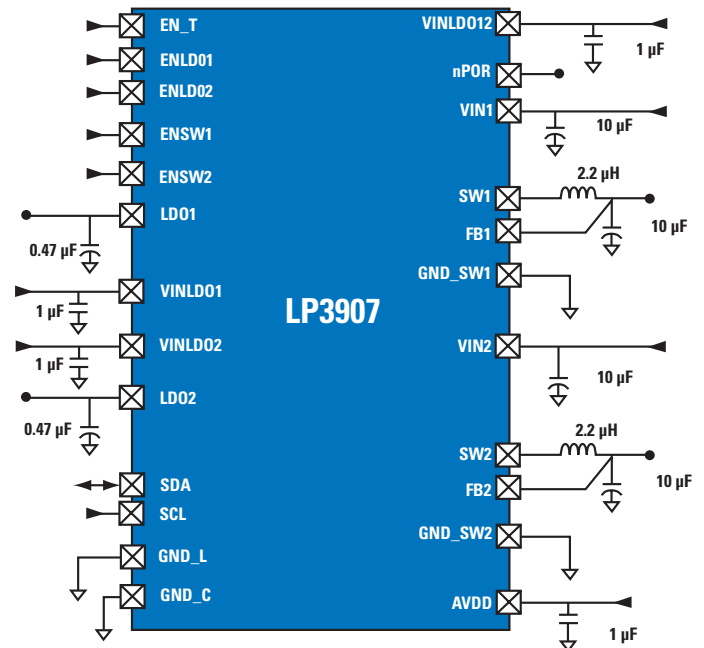
- 1A/600 mA output current
- Programmable  $V_{OUT}$  from:
  - Buck1 : 0.8V to 2.0V at 1A
  - Buck2 : 1.0V to 3.5V at 600 mA

#### Linear Regulators (LDO)

- Programmable  $V_{OUT}$  of 1.0V to 3.5V
- 300 mA output current
- Low input, low output

### Features

- External power-on-reset function for Buck1 and Buck2
- Compatible with advanced applications processors and FPGAs
- I<sup>2</sup>C-compatible interface for independent control of device functions and settings
- Available in LLP-24 packaging (4 × 4 × 0.8 mm)



### Applications:

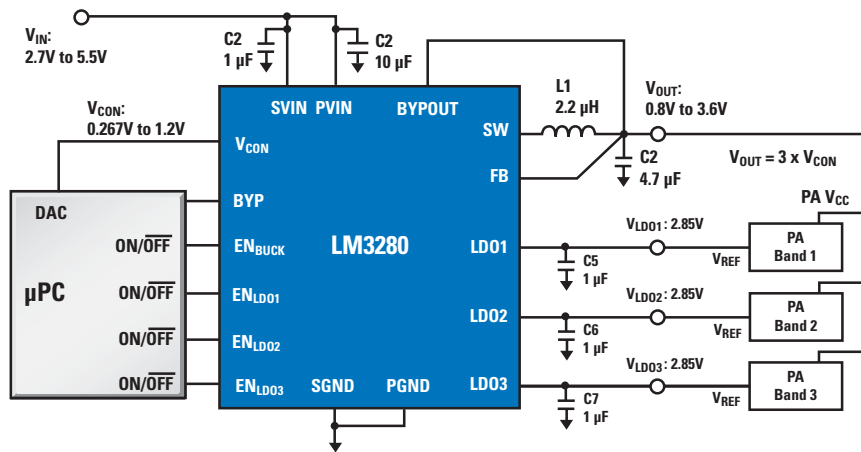
Ideal for use in WiFi chipset power, mobile-TV chipset power, WiMax chipset power, handset sub-system power, and FPGA power

# Integration

## LM3280 – Adjustable Buck DC-DC Converter and 3 LDOs for RF Power Management

### Features

- 2 MHz PWM switching frequency
- Operates from a single Li-Ion cell (2.7V to 5.5V)
- Adjustable output voltage (0.8V to 3.6V) DC-DC
- High-efficiency synchronous buck converter
- 300 mA maximum load capability (PWM mode)
- 500 mA maximum load capability (bypass mode)
- PWM, forced and automatic bypass mode
- 3 low-dropout and fast transient response LDOs
- Current overload protection
- Thermal overload protection
- Available in micro SMD-16 packaging



### Applications:

Ideal for use in handset multi-band PA chipset power, handheld radio, and other battery operated RF devices

## LM26480 – Dual High-Current Buck Regulator and Dual Linear Regulator with Externally Controlled Voltage Outputs

### Features

- 1.5A output current
- $V_{OUT}$  from:
  - Buck1 : 0.8V to 2.0V @ 1.5A
  - Buck2 : 1.0V to 3.3V @ 1.5A
- Up to 96% efficiency
- $\pm 3\%$  FB voltage accuracy
- 2 MHz PWM switching frequency
- PWM - PFM automatic mode change under low loads
- Automatic soft-start

### Linear Regulators (LDO)

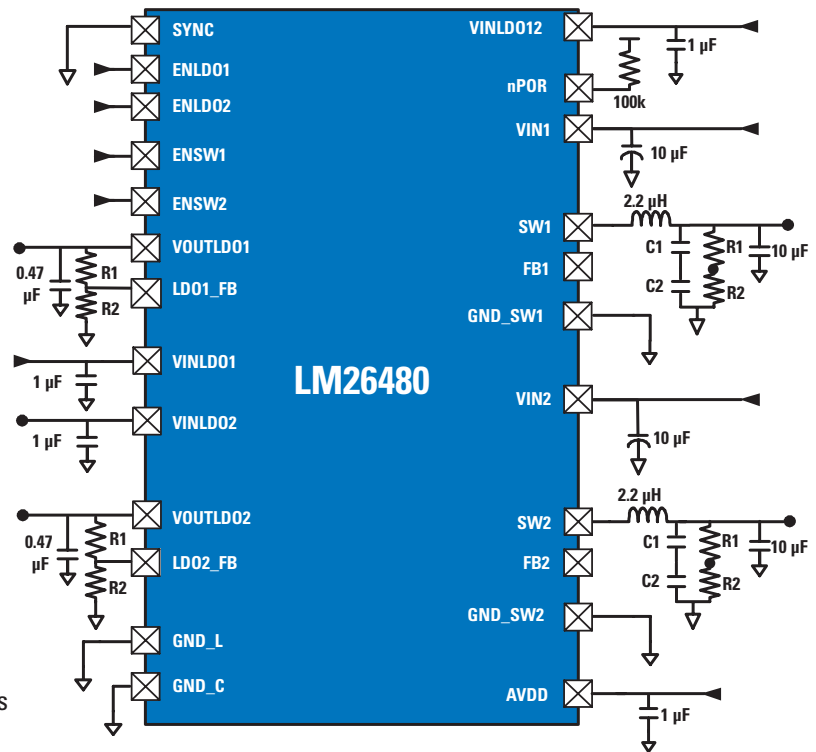
- $V_{OUT}$  of 1.0V to 3.5V
- $\pm 3\%$  FB voltage accuracy
- 300 mA output current
- 25 mV (typ) dropout

### Features

- Compatible with advanced applications processors and FPGAs
- 2 LDOs for powering internal processor functions and I/Os
- Precision internal reference
- Thermal overload protection
- Current overload protection
- External Power-On-Reset function for Buck1 and Buck2
- Undervoltage lock-out detector to monitor input supply voltage
- 24-lead 4 x 4 x 0.8 mm LLP package

### Applications

Ideal for use in core digital power, applications processors, and peripheral I/O power



# Integration

## LP3910/13 – PowerWise® Power Management ICs for Portable Media Players

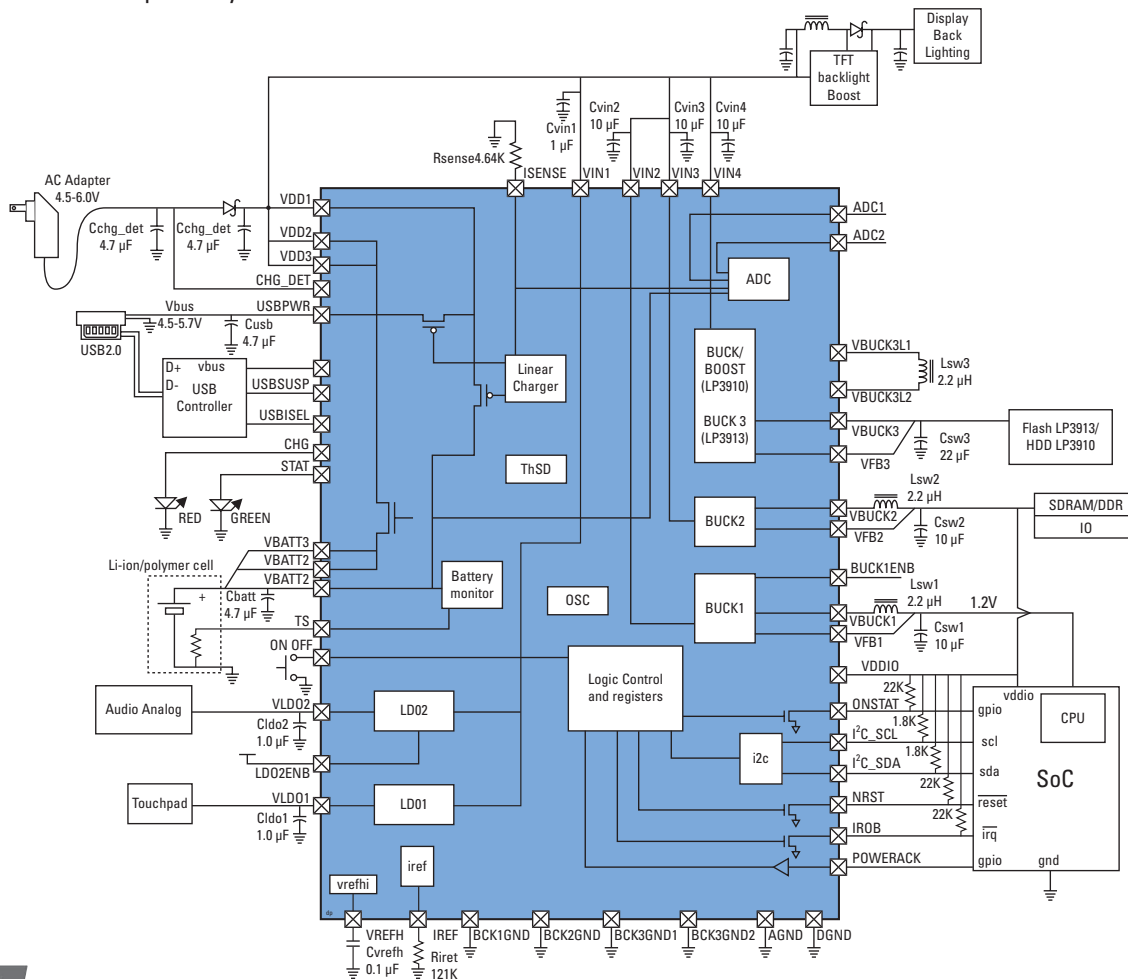
### Features

- Wide load range buck-boost DC-DC converter (LP3910) targeting hard disk drive power management to maintain a constant 3.3V output with a varying battery input voltage
- Linear constant-current/constant-voltage charger for single cell Li-Ion batteries
- Green and red LED charger status Indicators
- 4-channel 8-bit dual slope A/D converter
- High-efficient DVS buck converters: 2 (LP3910) and 3 (LP3913)
- 400 kHz I<sup>2</sup>C-compatible interface
- USB and adapter charging
- System power supply management including power routing
- Voltage and thermal supervisory circuits

- Continuous battery voltage monitoring
- Interrupt request output with 8 sources
- LP3913 is pin-for-pin compatible with the LP3910 hard drive based PMIC
- Available in 6 x 6 x 0.8 mm LLP-48 packaging

### Applications

Ideal for use in powering portable gaming devices, portable media players, hard drive-based MP3 players (LP3910), flash-based portable media players (LP3913), portable navigation systems (LP3913)



Read Application Note: "Powering Portable Media Players (PMP) with Innovative Solutions"

[www.national.com/analogedge](http://www.national.com/analogedge)



## Flash LED Drivers

Product ID	Input Voltage Range (V)	Output Voltage (V)	Max LED Current (mA)	Number of LEDs	Switching Frequency (MHz)	Topology	Key Features	Packaging
LM2754	2.8 to 5.5	5	800	4	1	Switched Capacitor	TX input ensures synchronization with RF power amplifier pulse	LLP-24
<b>NEW</b> LM2758	2.7 to 5.5	5	700	1	1.2	Switched Capacitor	Indicator, torch, and flash modes; Flash timeout protection	micro SMD-12
LM3551/52	2.7 to 5.5	11	1000	4	1.25	Inductive Boost	Flash timeout protection; Shutdown mode via SD pin (LM3551) or EN pin (LM3552)	LLP-14
<b>NEW</b> LM3553	2.7 to 5.5	19	1200	2	1.3	Inductive Boost	Indicator, torch, flash modes, and voltage mode; 128 current levels	LLP-12

 PowerWise product

## Lighting Management Units

Product ID	Description	V <sub>IN</sub> Range	Drive Current for All	Current for Flash Mode	Current Matching	Temp Range (°C)	Packaging
LP3943	LED controller for RGB/white/blue LEDs	2.3 to 5.5	25 mA/LED	—	—	-40 to 125	LLP-24
LP3944	LED controller for RGB/white/blue LEDs	2.3 to 5.5	25 mA/LED	—	—	-40 to 125	LLP-24
LP3950	Color-LED driver with audio sync	3 to 7.2	300 mA	—	3%	-40 to 125	Laminate TCSP-32
<b>NEW</b> LP3952	6-Channel color LED driver with audio synchronization	3 to 5.5	240 mA	—	5%	-30 to 85	micro SMD-36 or micro SMDxt-36
<b>NEW</b> LP39542	Lighting management unit for 4+2 white LEDs, 2 sets RGB LEDs with audio sync and pattern control, and a flash LED driver	3 to 5.5	400 mA	400 mA	0.2% (White LED), 5% (RGB)	-30 to 85	micro SMD-36 or micro SMDxt-36
LP3958	Lighting management unit for controlling 4+2 white LEDs for main and sub display and 3 sets of white LEDs for keypad	3 to 5.5	70 mA total	—	3% (Key)	-30 to 85	micro SMD-25
LP5526	Lighting management unit with high-voltage boost converter with up to 150 mA serial flash LED driver	3 to 5.5	150 mA total	150 mA	2% (RGB)	-30 to 85	micro SMD-25
<b>NEW</b> LP55271	LED driver for camera flash and 4 LEDs with I <sup>2</sup> C programmability, connectivity test, and audio synchronization	3 to 5.5	1A total	400 mA	1%	-30 to 85	micro SMD-30
LM4970	LED controller with LED lighting effects synchronized to audio	2.7 to 5.5	42 mA	—	—	-40 to 85	LLP-14
<b>NEW</b> LP5520	RGB backlight driver with white balance compensation	2.9 to 5.5	180 mA	—	0.2%	-30 to 85	micro SMD-25
<b>NEW</b> LP5521	Fully programmable 3-channel color LED driver with advanced power save features	2.7 to 5.5	75 mA	—	1%	-30 to 85	micro SMD-20
<b>NEW</b> LP5522	Autonomous single LED controller with one wire interface	2.7 to 5.5	20 mA	—	—	-30 to 85	micro SMD-6
<b>NEW</b> LP5524	Parallel LED Driver with PWM brightness control	2.7 to 5.5	100 mA	—	1%	-40 to 85	micro SMD-9
<b>NEW</b> LP55281	Quad RGB LED driver with boost converter and LED connectivity test	3 to 5.5	400 mA	—	5%	-30 to 85	micro SMD-36 or micro SMDxt-36S

 PowerWise product

# Illumination



**LM2755:** Charge pump LED controller with programmable pattern generators that facilitate multi-zone backlighting by independently controlling RGB indicator LEDs



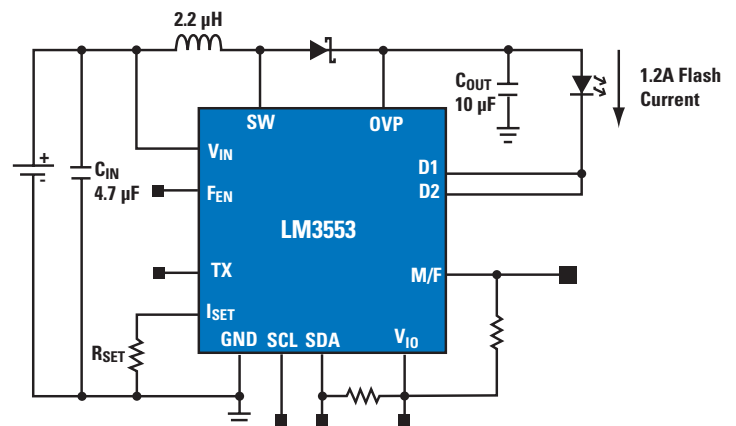
**LM2757:** Smallest inductorless boost regulator for keypad lighting and peripheral features including USB On-The-Go (OTG)

## LM3553 – PowerWise® High-Current Inductive DC-DC Converter for Flash LED Applications

### Features

- Accurate and programmable LED current up to 1.2A in 128 steps delivers optimal input current control
- 90% peak efficiency
- Drives 2 LEDs in series with up to 1.2A from 5V input
- Drives 2 LEDs in series with 600 mA from 2.7V input
- Adjustable over-voltage protection allows for a wide range of applications requiring one or more high current LEDs
- Adjustable switch current limit allows for the use of small inductors with lower saturation currents
- Voltage mode offers a 5V rail for backlight LEDs and/or audio amplifiers
- TX pin forces Torch mode allowing for synchronization between RF power amplifier and Flash/Torch modes
- Total solution size < 29 mm<sup>2</sup> optimizes PCB area occupation
- Available in Low profile LLP-12 packaging (3 mm x 3 mm x 0.8 mm)

### LM3553 Typical Application Circuit



### Applications

Ideal for use in Mobile phones, smart phones, PDAs, portable scanners, medical strobe lights, handheld devices

## LP39542 – PowerWise® Advanced Lighting Management Unit

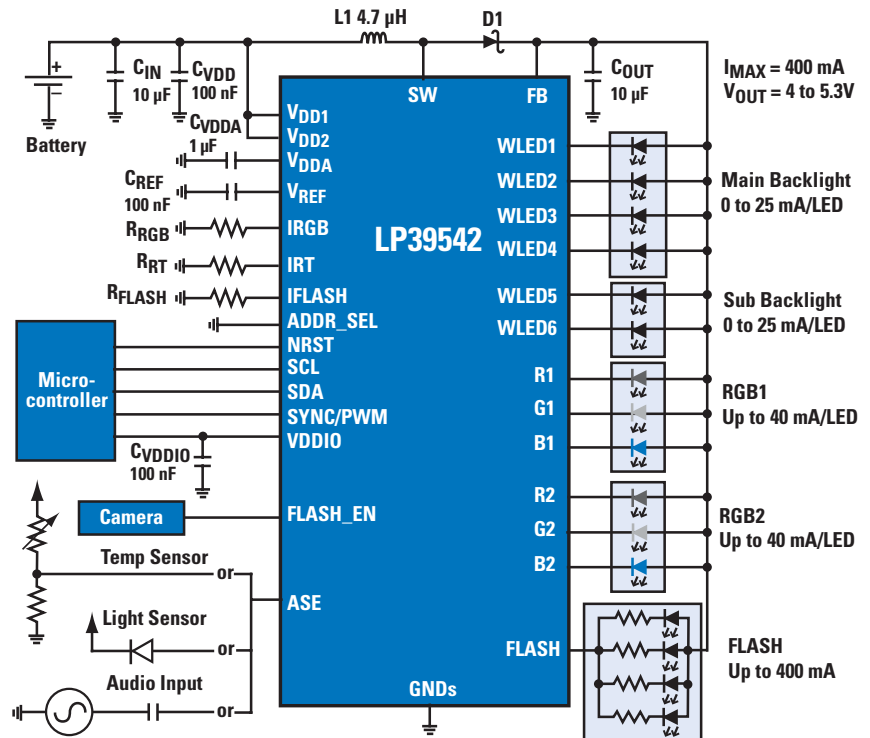
### Features

- Audio synchronization for color/RGB LEDs
- Command-based PWM controlled RGB LED drivers
- Programmable ON/OFF blinking sequences for RGB LED
- High current driver for flash LED with built-in timing and safety feature
- 4+2 or 6 low voltage constant current white LED drivers with programmable 8-bit adjustment (0.25 mA/LED)
- High-efficiency boost DC-DC converter
- I<sup>2</sup>C-compatible interface
- Possibility for external PWM dimming control
- Possibility for clock synchronization for RGB timing
- Ambient light and temperature sensing possibility
- Available in micro SMD-36 packaging (3.0 x 3.0 x 0.6 mm)

### Applications

Ideal for use in cellular phones, PDAs, MP3 players

LP39542 Typical Application Circuit



# Illumination

## LP55281 – PowerWise® Quad RGB Driver

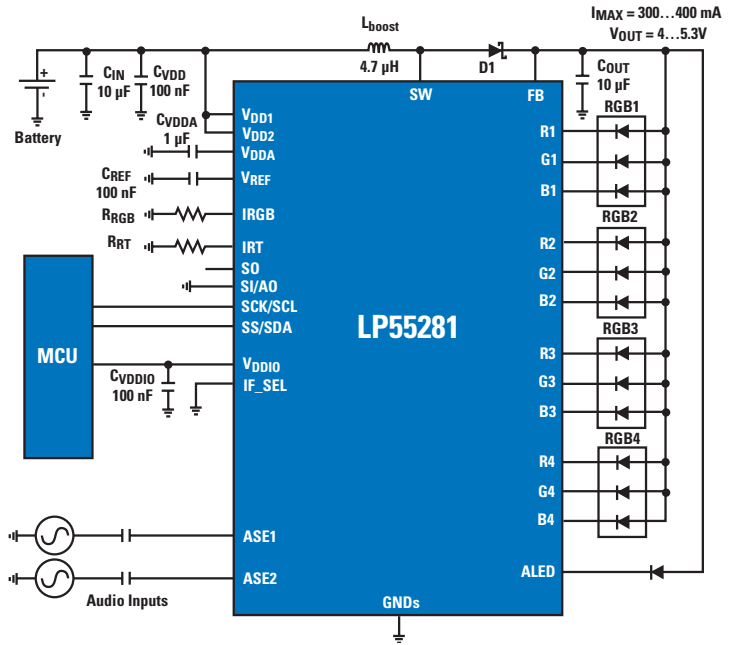
### Features

- Audio synchronization for a single fun light LED
- 4 PWM controlled RGB LED drivers
- High efficiency boost DC-DC converter
- SPI/I<sup>2</sup>C-compatible interface
- 2 addresses in I<sup>2</sup>C-compatible interface
- LED connectivity test through the serial interface
- Available in micro SMD-36 (3 mm x 3 mm x 0.6 mm) or micro SMDxt-36 packaging (3 mm x 3 mm x 0.65 mm)

### Applications

Ideal for use in cellular phones, PDAs, MP3 players

LP55281 Typical Application Circuit

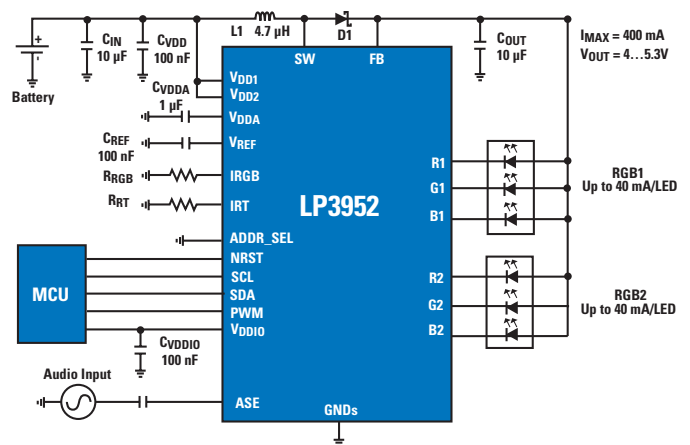


## LP3952 – PowerWise® 6-Channel Color LED Driver with Audio Synchronization

### Features

- Constant current and PWM controlled color LED drivers
- Maximum current 40 mA / output in constant current mode, supports also switch mode control with 50 mA maximum current / output
- Complete audio synchronization for color/RGB LEDs with amplitude, frequency, and speed optimization
- Command-based lighting pattern generator for RGB LEDs
- Programmable ON/OFF blinking sequences for RGB1 outputs
- High-efficiency boost DC-DC converter with programmable V<sub>OUT</sub> and f<sub>SW</sub>
- I<sup>2</sup>C-compatible interface
- Possibility for external PWM dimming control
- Available in micro SMDxt-36 packaging (3.0 mm x 3.0 mm x 0.65 mm)

LP3952 Typical Application Circuit



### Applications

Ideal for use in cellular phones, PDAs, MP3 players

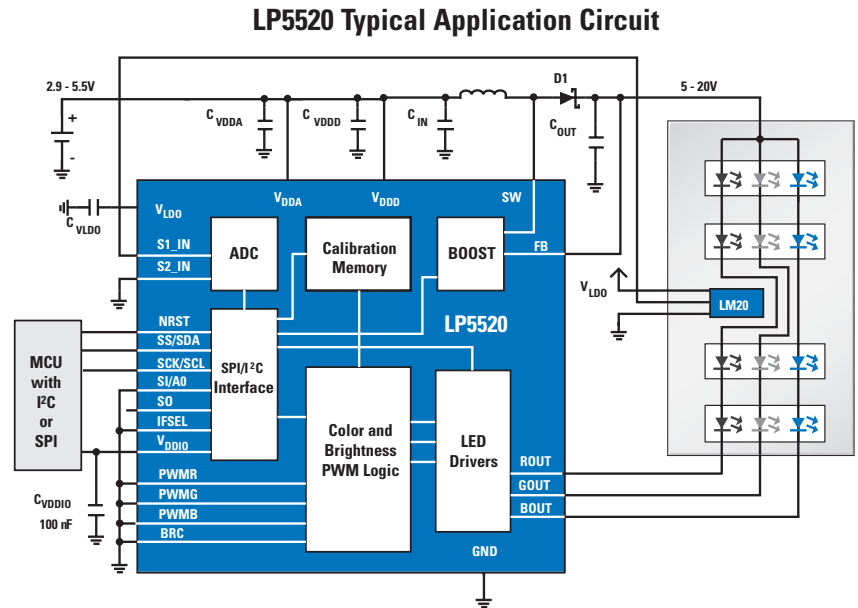
## LP5520 – RGB Backlight LED Driver

### Features

- Temperature compensated LED intensity and color
- Individual calibration coefficients for each color
- Color accuracy  $\Delta X$  and  $\Delta Y \leq 0.003$
- 12-bit ADC for measurement of 2 sensors
- Adjustable current outputs for RGB LED
- 0.2% typical LED output current matching
- PWM control inputs for each color
- SPI and I<sup>2</sup>C-compatible interface
- Stand-alone mode with 1 wire control
- Sequential mode for one color at a time
- Magnetic high efficiency boost converter
- Available in micro SMD-25 packaging (2.77 x 2.59 x 0.6 mm)

### Applications

Ideal for use in color LCD display backlighting, LED lighting applications, non-linear temperature compensation, ambient light compensation



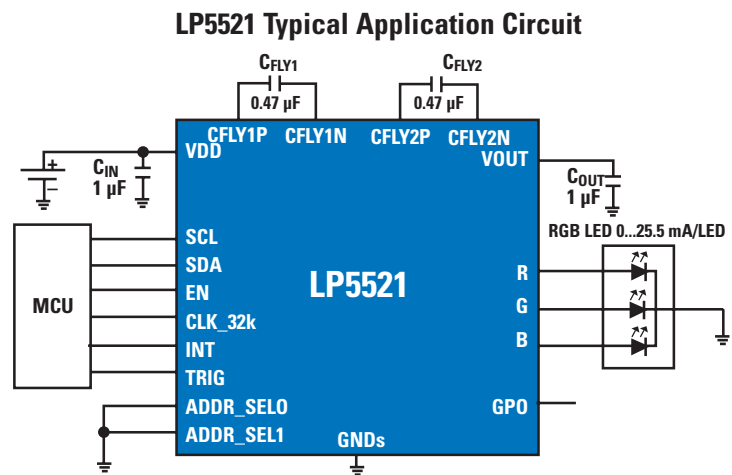
## LP5521 – PowerWise® Programmable 3-Channel LED Driver

### Features

- Adaptive charge pump with 1x and 1.5x gain provides up to 95% LED drive efficiency
- Charge pump with soft-start and overcurrent/short circuit protection
- Low input ripple and EMI
- Very small solution size, no inductor or resistors required
- 200 nA typical shutdown current
- Automatic power save mode
- I<sup>2</sup>C-compatible interface
- Independently programmable constant current outputs with 8-bit current setting and 8-bit PWM control
- Typical LED output saturation voltage 50 mV and current matching 1%

### Applications

Fun/indicator lights, LCD sub-display backlighting, keypad RGB backlighting and phone cosmetics, vibra, speakers, waveform generator



# Audio

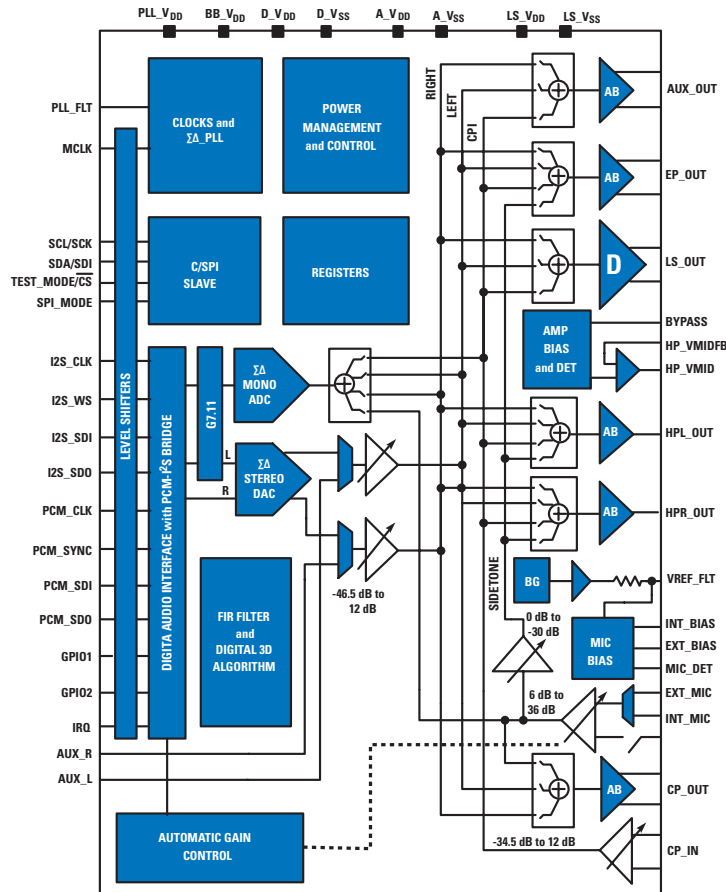
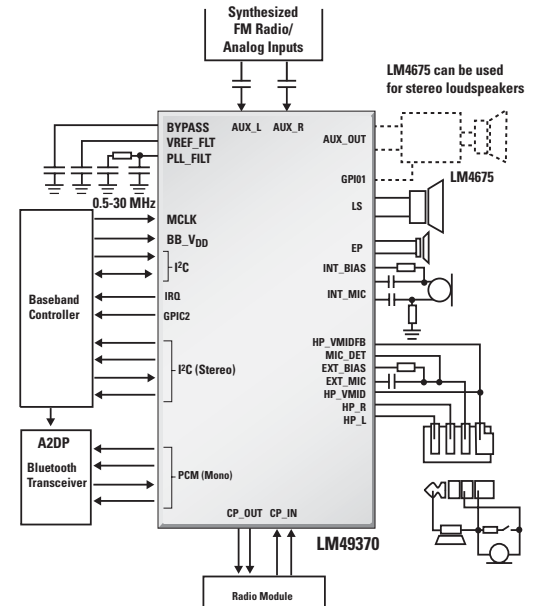
## LM49370 – PowerWise® Audio Codec Subsystem with Ultra-Low EMI, Class D Amplifier, and a PCM Interface for Bluetooth Transceivers

### Features

- Spread spectrum Class D architecture reduces EMI
- Mono Class D 8Ω amplifier, 490 mW at 3.3V
- OCL or AC-coupled headphone operation
- 33 mW stereo headphone amplifier at 3.3V
- 115 mW earpiece amplifier at 3.3V
- Digital 3D stereo enhancement
- Total harmonic distortion: 0.04%
- Available in micro SMDxt-49 packaging (4 x 4 mm)

### Applications:

Ideal for use in smart phones, mobile phones and multimedia terminals, PDAs, Internet appliances and portable gaming, portable DVD/CD/AAC/MP3 players, and digital cameras/camcorders



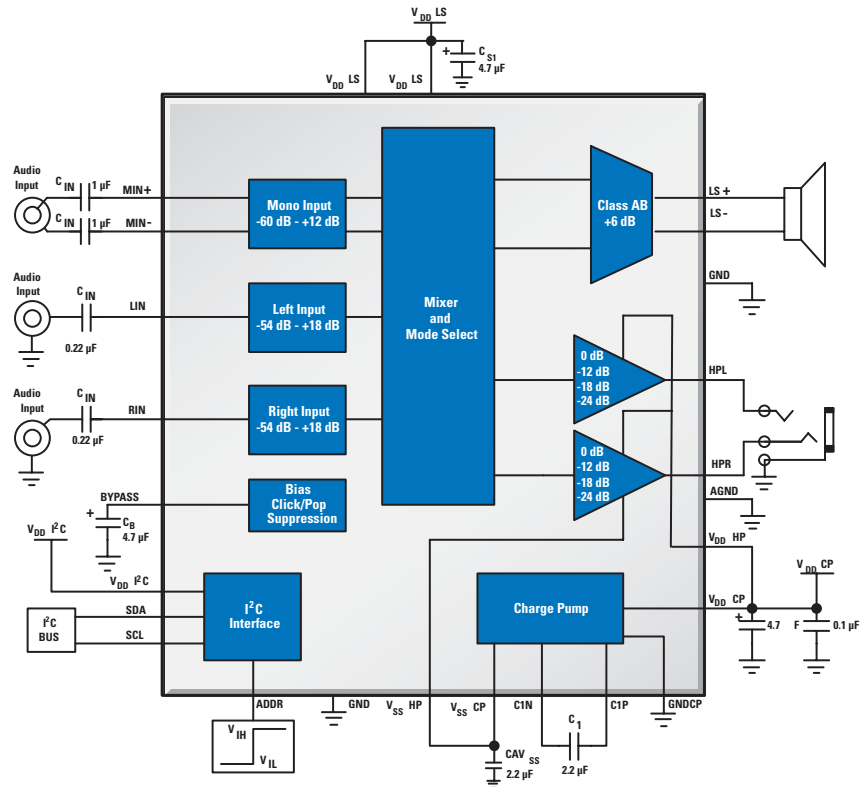
## LM49100 – PowerWise® Mono Class AB Audio Subsystem with a True-Ground Headphone Amplifier

### Features

- Very low power consumption
- 5 mA  $I_{DDQ}$  with speaker and headphone enabled
- Mono and stereo inputs
- Thermal overload protection
- Total harmonic distortion: 0.035%
- I<sup>2</sup>C control interface
- Input mute attenuation
- 2nd stage headphone attenuator
- 32-step digital volume control
- Ten operating modes
- Minimum external components
- Click-and-pop suppression
- Micro-power shutdown
- RF suppression
- Available in space-saving GR-25 packaging (3 x 3 mm)

### Applications:

Ideal for use in mobile phones, personal media / MP3 players, portable navigation, laptops, and VoIP devices



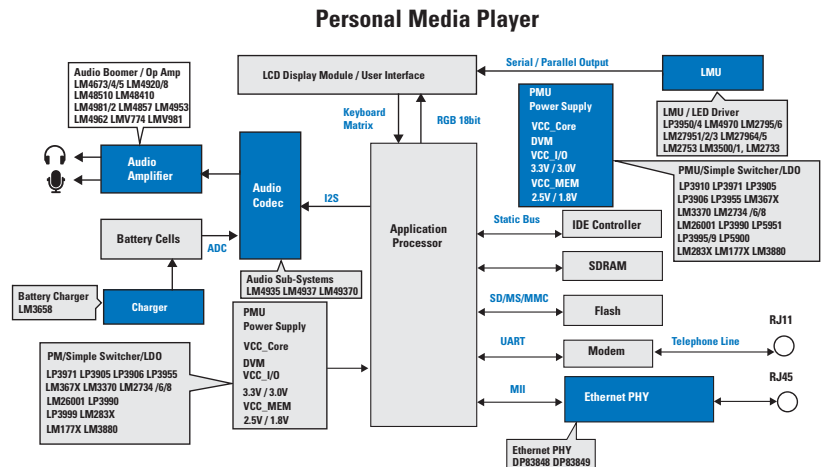
## LM49250 – Stereo Boomer® Class D Audio Subsystem with Ground-Referenced Headphone Amplifier and Mono Earpiece

### Features

- Output short circuit protection
- Thermal overload protection
- Spread spectrum modulation
- I<sup>2</sup>C control interface
- Total harmonic distortion: 0.01%
- RF suppression
- Click-and-pop suppression
- Micro-power shutdown
- Available in space-saving micro SMD-36 packaging

### Applications:

Ideal for use in mobile phones, personal media / MP3 players, portable navigation, and VoIP devices



# Audio

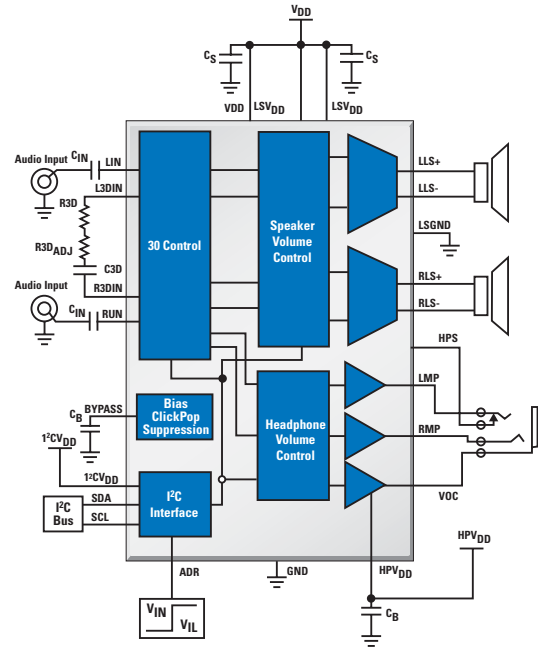
## LM49270 – Boomer® Filterless 2.2W Stereo Class D Audio Subsystem with OCL Headphone Amplifier, 3D Enhancement, and Headphone Sense

### Features

- Stereo filterless Class D amplifier
- Selectable OCL/CC headphone amplifier
- Headphone sense ability
- National's 3D enhancement
- RF suppression
- I<sup>2</sup>C control interface
- 32-step digital volume control
- Total harmonic distortion: 0.02%
- Available in space-saving LLP-28 packaging

### Applications:

Ideal for use in portable media players, smart phones, PDAs, and laptops



Product ID	Description	Mono Input Ch.	Stereo Input Ch.	THD (%)	Class D Speaker Driver	Packaging
LM4845	1.15W mono speaker 75 mW headphone Boomer with I <sup>2</sup> C/SPI volume and mode control, programmable National 3D and selectable OCL HP output	1	1	0.5	—	micro SMD-25
LM4846	1.15W mono speaker 75 mW headphone Boomer with I <sup>2</sup> C/SPI volume and mode control, programmable National 3D and selectable OCL HP output	1	1	0.5	—	micro SMD-25
LM4851	1.1W mono speaker 115 mW differential headphone Boomer with SPI control	1	1	0.3	—	LLP-24, micro SMD-18
LM4852	1.1W mono speaker 60 mW headphone Boomer with I <sup>2</sup> C control	1	1	1	—	LLP-24, micro SMD-18
LM4855	1.1W mono speaker 115 mW differential headphone Boomer with SPI control	2	1	0.5	—	LLP-24, micro SMD-18
LM4856	1.1W mono speaker 60 mW headphone Boomer with I <sup>2</sup> C control	2	1	0.5	—	LLP-24, micro SMD-18
LM4857	1.2W stereo speaker, 75 mW headphone, 135 mW earpiece Boomer and line out with I <sup>2</sup> C mode and volume control and National 3D	1	1	0.05	—	LLP-28, micro SMD-30
LM4888	1.3W stereo speaker, 90 mW headphone Boomer with National 3D	—	1	0.06	—	LLP-24
LM4938	Stereo 2W audio power amp with DC volume control, selectable gain, and docking station interface	—	1	0.05	—	TSSOP-28 exp pad
4 mm LM4946	1.3W mono speaker, 85 mW headphone Boomer with I <sup>2</sup> C/SPI mode and volume control, National 3D and selectable OCL output	1	2	0.05	—	LLP-24, micro SMD-25
LM4947	1.19W mono speaker, 87 mW headphone Boomer with I <sup>2</sup> C mode and volume control, National 3D and selectable OCL output	1	1 or 2	0.03	✓	micro SMD-25
LM4949	1.19W stereo speaker, 89 mW headphone Boomer with I <sup>2</sup> C mode and volume control and selectable OCL output	1	1 or 2	0.02	✓	micro SMD-25
LM49270	2.2W stereo speaker, 155 mW headphone with volume control, National 3D and selectable OCL output	1	2	0.02	✓	LLP-28
NEW LM49100	1.275W mono speaker (BTL), 50 mW headphone Boomer with I <sup>2</sup> C, mode and volume control, and true-ground headphone drivers	1	2	0.035	—	Micro Array
NEW LM49250	Stereo Boomer Class D audio subsystem with ground-referenced headphone amplifier and mono earpiece	1	2	0.14	✓	micro SMD-36



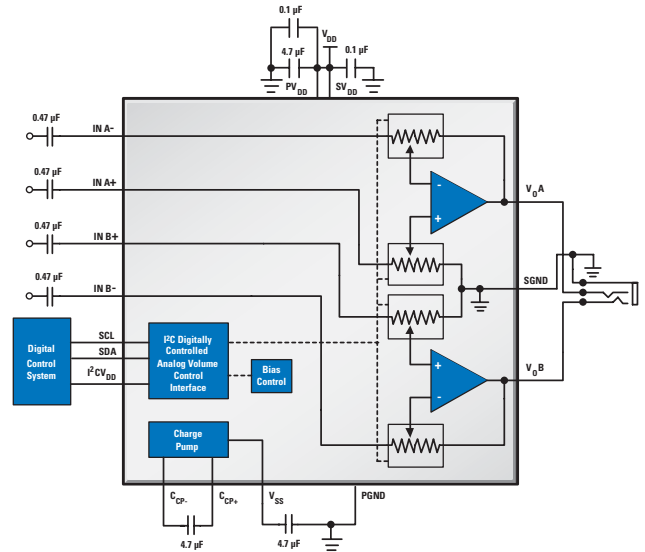
## LM48821 – Boomer Direct Coupled, Ultra-Low Noise, 52 mW Differential Input Stereo Headphone Amplifier with I<sup>2</sup>C Volume Control

### Features

- Ground-referenced outputs
- Differential inputs
- I<sup>2</sup>C volume and mode controls
- Ultra low current shutdown mode
- Advanced output transient suppression circuitry eliminates noise during turn-on and turn-off transitions
- 1.8V to 4V operation (I<sup>2</sup>CV<sub>DD</sub>)
- No output coupling capacitors, snubber networks, bootstrap capacitors, or gain setting resistors required
- Available in micro SMD-16 packaging

### Applications:

Ideal for use in notebook PCs, desktop PCs mobile phones PDAs, portable electronic devices, and MP3 players



## LM48861 – Ground-Referenced, Ultra-Low Noise, Stereo Headphone Amplifier

### Features

- Ground referenced outputs - eliminates output coupling capacitors
- Common-mode sensing
- Advanced click-and-pop suppression
- Low supply current
- Low power shutdown mode
- Minimum external components
- Micro-power shutdown
- ESD protection of 8kV HBM contact
- Available in space-saving 12 bump µSMD package

### Applications:

Ideal for use in mobile phones, personal media / MP3 players, PDAs, laptops, and other portable electronic devices

Product ID	Description	THD (%)	PSSR (dB)	Supply Voltage Range (V)	Output Power THD ≤ 1%, V <sub>CC</sub> = 3V		Packaging
					16Ω (mW)	32Ω (mW)	
LM4920	50 mW headphone Boomer, fixed logic levels, fixed 1.5 V/Vgain	0.03	70	1.6 to 4.2	43	50	micro SMD-14
LM4982	50 mW headphone Boomer amp, ultra-low noise, IntelliSense, 32-step I <sup>2</sup> C volume control	0.05	66	1.6 to 4.0	47	51	micro SMD-16
4 mm NEW LM48820	95 mW headphone Boomer, ultra-low noise, fixed 1.5 V/Vgain	0.01	80	1.6 to 4.5	95	80	micro SMD-14
LM48821	52 mW headphone Boomer, ultra-low noise, direct coupled, I <sup>2</sup> C volume control	0.015	82	2 to 4	52	53	micro SMD-16
LM48860	30 mW headphone Boomer amp, ultra-low noise, fixed 1.5V/V gain	0.025	80	2.5 to 5.5	40	50	micro SMD-12
LM48861	24 mW headphone Boomer amp, ultra-low noise (V <sub>CC</sub> =1.5V)	0.04	83	1.2 to 2.8V	24	22	micro SMD-12

# Audio

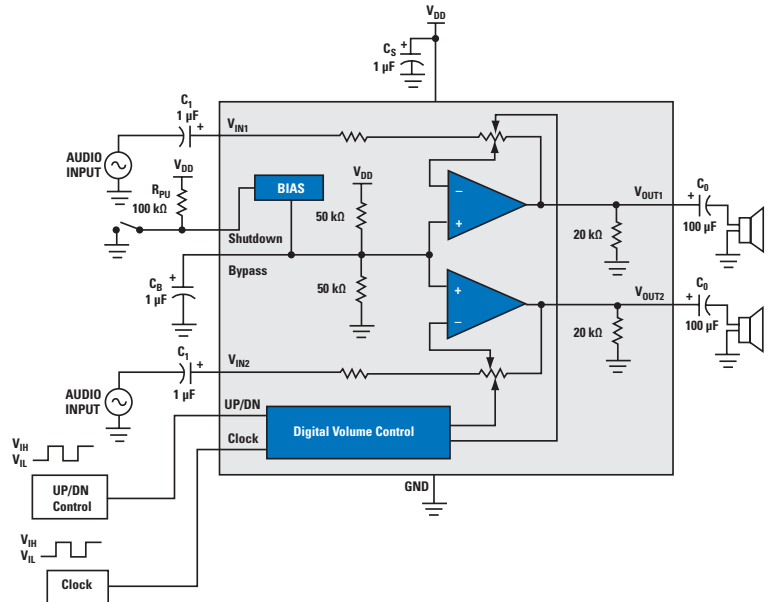
## LM4811 – Dual 105 mW Headphone Amplifier with Digital Volume Control and Shutdown Mode

### Features

- Digital volume control range from +12 dB to -33 dB
- LD and MSOP surface mount packaging
- Click-and-pop suppression circuitry
- No bootstrap capacitors required
- Low shutdown current
- Available in LLP-10 and mini SOIC-10 packaging

### Applications:

Ideal for use in cellular phones, MP3, CD, DVD players, PDAs, and portable electronics



## OCL/CC Headphone Boomer Amplifiers

Product ID	Description	THD (%)	PSRR (dB)	Output Power THD ≤ 1%, V <sub>CC</sub> = 3V	
				16Ω (mW)	32Ω (mW)
LM4809	105 mW headphone Boomer with shutdown low, can drive 8Ω	0.03	70	38	25
LM4811	105 mW headphone Boomer with up/down volume control, can drive 8Ω	0.03	60	38	25
LM4908 <sup>1</sup>	120 mW headphone Boomer amp, 0.1% THD+N	0.05	84	35	25
LM4910	35 mW headphone Boomer amp, bypass capacitor-less, OCL output	0.03	65	46	28
LM4911	40 mW headphone Boomer, low noise, selectable cap-coupled/OCL output	—	65	40	25
LM4912	40 mW headphone Boomer amp, low noise, with mute	—	65	40	25
LM4916	1.5V, mono 85 mW BTL output, 14 mW stereo headphone audio amplifier	0.2	66	—	—
LM4921	Low-voltage IS 16-bit stereo DAC with stereo headphone power amplifiers and volume control	0.03	62	—	—
LM4925	2-cell, single-ended output, 40 mW stereo headphone audio amplifier	0.05	70	—	—
LM4924	40 mW 2-cell headphone Boomer amp with OCL output	0.01	66	40	24
LM4929	40 mW headphone Boomer with low noise and OCL output	—	65	40	25
LM4980	42 mW stereo headphone Boomer with 2-cell battery operation and click/pop suppression	0.02	90	42	28
NEW LM4985	135 mW headphone Boomer with OCL or cap-coupled output, 32-step I <sup>2</sup> C volume control	0.08	77	45	23

<sup>1</sup>10 kV ESD Rated

PowerWise® product

## LM48411 – Ultra-Low EMI, Filterless, 2.5W, Stereo, Class D Audio Power Amplifier with E<sup>2</sup>S







### Features

- E<sup>2</sup>S system reduces EMI preserving audio quality and efficiency
- Output short circuit protection
- No output filter required for inductive loads
- Logic selectable gain
- Independent shutdown control
- Minimum external components
- Click-and-pop suppression circuitry
- Micro-power shutdown mode
- Available in space-saving micro SMD-16 packaging (0.5 mm pitch)

### Applications:

Ideal for use in mobile phones, PDAs, and other portable electronic devices

### High-Efficiency Boomer Class D

Product ID	Description	THD (%)	Output Power THD ≤ 1%		Packaging
			4Ω (W)	8Ω (W)	
LM4666 <sup>1</sup>	Stereo	0.65	—	450 mW	LLP-14
LM4671	Mono filterless	0.04	2.21	1.19	micro SMD-9
 LM4673 	Mono filterless	0.02	2.15	1.24	micro SMD-9, LLP-8
LM4674 	Stereo filterless	0.05	1.9	1.25	micro SMD-16, LLP-16
LM4674A 	Filterless 2.5 stereo Class D audio power amplifier	—	—	—	micro SMD-16
LM4675 	Mono, ultra-low EMI	0.02	2.2	1.3	micro SMD-9, LLP-8
LM48310	Mono filterless, E <sup>2</sup> S	0.03	2.1	1.3	LLP-10
 LM48410	Stereo, ultra-low EMI, filterless, 3D	0.025	1.9	1.2	LLP-24
LM48411	Stereo filterless, E <sup>2</sup> S	0.03	2	1.25	micro SMD-16

<sup>1</sup> V<sub>DD</sub> = 3V

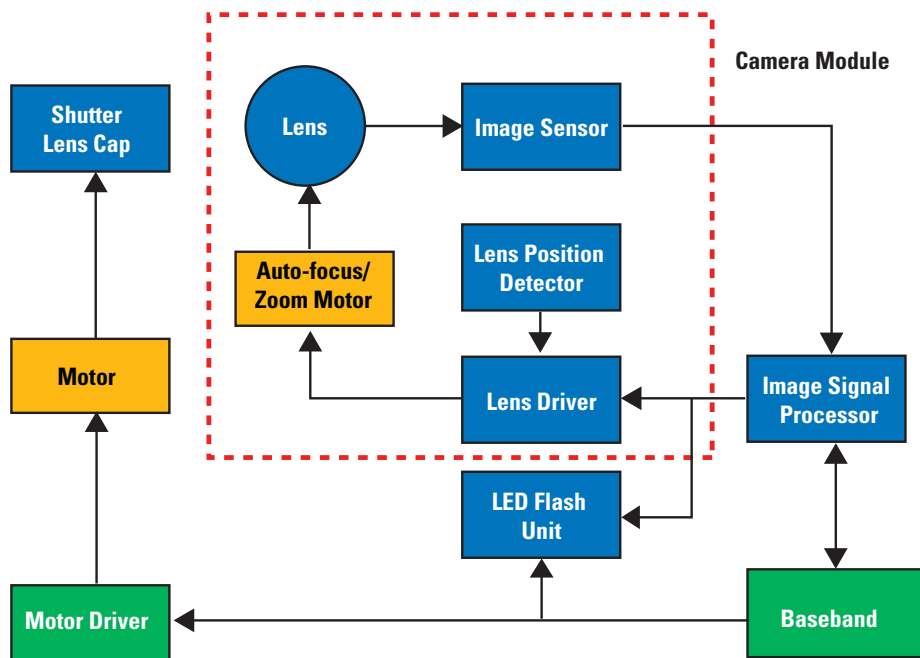
 PowerWise product

### High-Efficiency Overture Class D

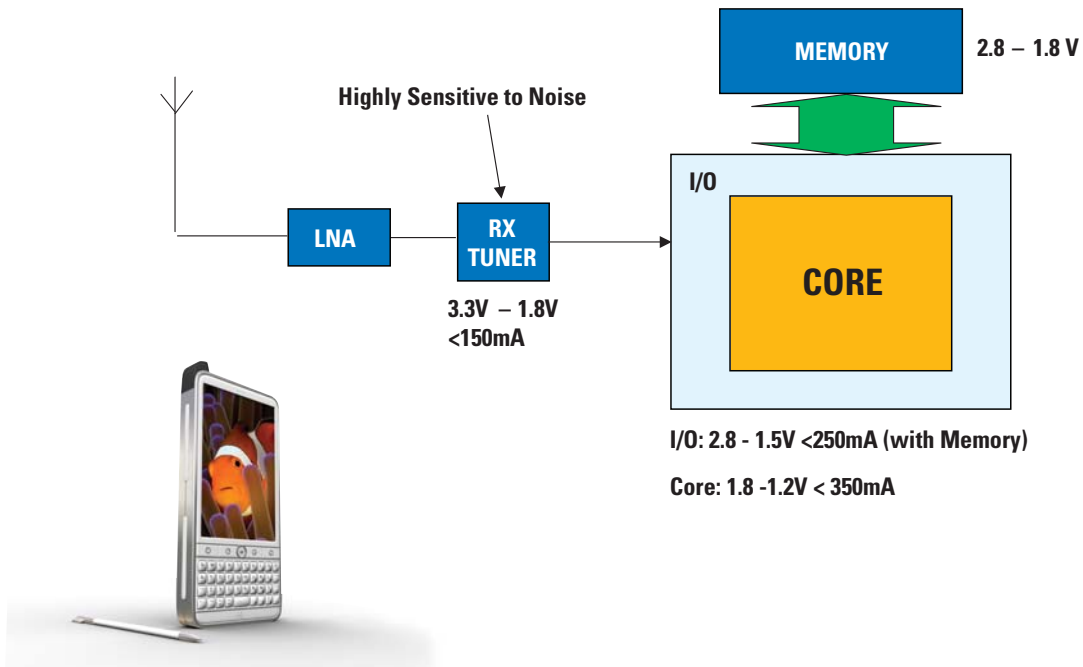
Product ID	Mono/ Stereo	Supply Voltage (V)	Output Power THD ≤ 1%		Output Power THD ≤ 10%		Typical THD Ratings (%)	THD Measurement Conditions (W at V <sub>S</sub> = 3V, R <sub>L</sub> = 8Ω unless otherwise specified)	Supply Voltage Range (V)	Shutdown	Packaging
			4Ω (W)	8Ω (W)	4Ω (W)	8Ω (W)					
LM4668	Mono	12	—	6	—	7.5	0.2	P <sub>O</sub> = 1 at V <sub>S</sub> = 12V	9 to 14	Low	LLP-14, TSSOP-20
LM4680	Mono	12	—	6	—	7.5	0.2	P <sub>O</sub> = 1 at V <sub>S</sub> = 12V	9 to 14	Low	LLP-14
LM4681	Stereo	12	—	6	—	7.5	0.2	P <sub>O</sub> = 1 at V <sub>S</sub> = 12V	9 to 16	Low	LLP-48
LM4682	Stereo	12	—	6	—	7.5	0.2	P <sub>O</sub> = 1 at V <sub>S</sub> = 12V	9 to 15	Low	LLP-48

# Multimedia

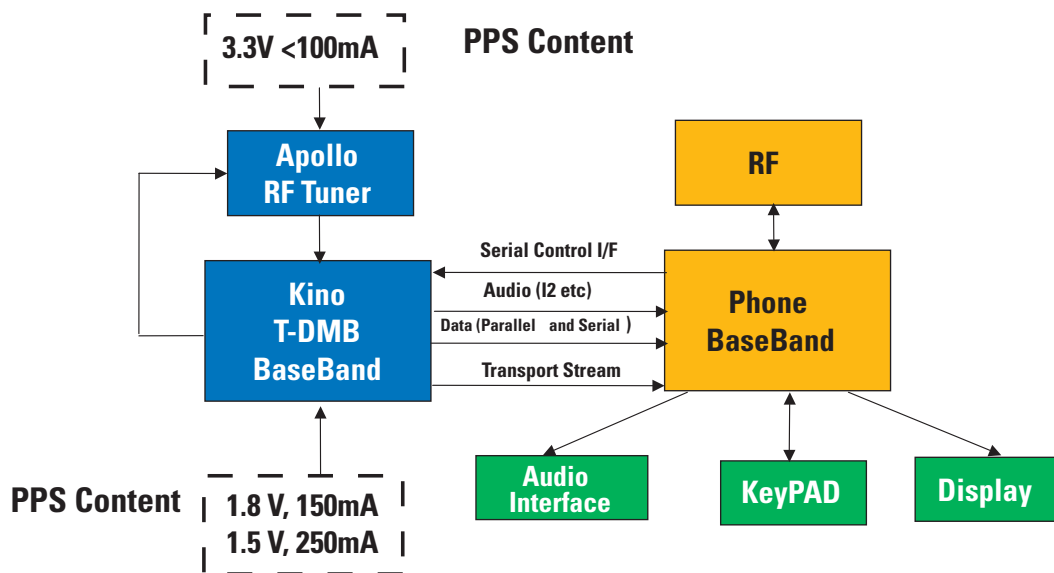
## Camera Module



## Mobile TV: DVB-H or S-DMB/T-DMB



## Mobile TV: T-DMB Chipset Requirements

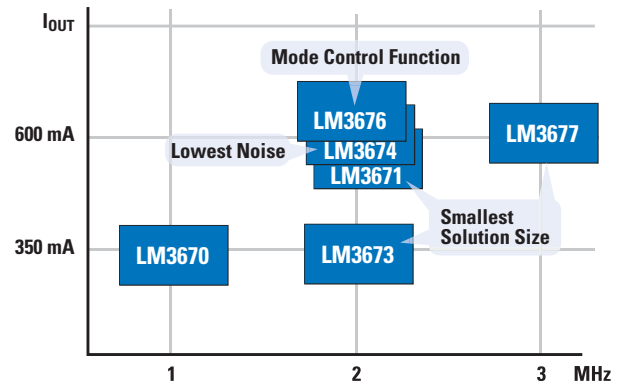
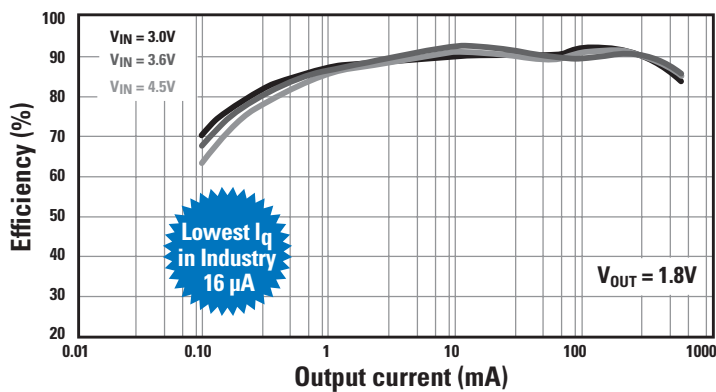


# Multimedia

## LM3677 – PowerWise® Highest Efficiency DC-DC Converters in Smallest Solution Size

### Features

- >90% efficiency in PWM mode and lowest standby I<sub>q</sub> (16 µA) in the industry
- Smallest switcher in the industry, 3 MHz switching frequency (1 µH chip inductor) and tiny ceramic capacitors
- Tight V<sub>OUT</sub> accuracy, tiny V<sub>OUT</sub> ripple (5 mV peak-peak) and excellent transient response
- Available in micro SMD-5 packaging for optimal solution size



### Applications:

Ideal for use in powering digital subsystems in portable devices where size and efficiency are important

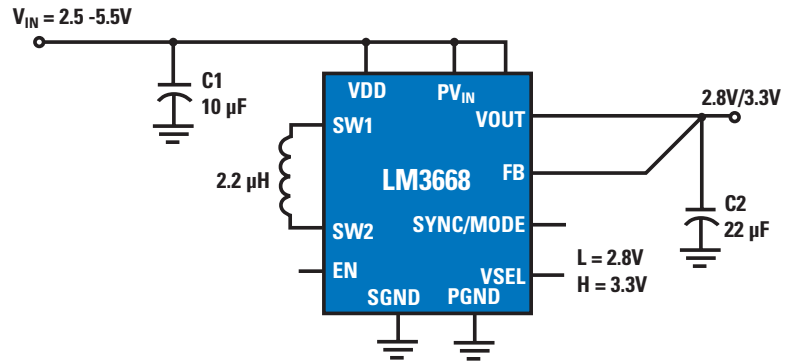
Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Output Current (mA)	Frequency Range (KHz) & Sync (computed field)	On/Off Pin	PWM Mode	Packaging
LM2612	5.5	2.8	1.05	1.8	400, 300	500 to 1000, Sync	✓	Current	micro SMD-10
LM2612BL	5.5	2.8	1.05	1.8	400, 300	500 to 1000, Sync	✓	Current	micro SMD-10
LM2614	5.5	2.8	1	3.6	400	500 to 1000, Sync	✓	Current	micro SMD-10
LM2618	5.5	2.8	1.8	1.92	400, 300	500 to 1000, Sync	✓	Current	micro SMD-10
LM2619	5.5	2.8	1.5	3.6	500	500 to 1000, Sync	✓	Current	micro SMD-10
LM2651	14	4	1.24	13	1500	3000	✓	Current	TSSOP-16
LM3670	5.5	2.5	0.7	3.3	350	1000	✓	Voltage with input feedforward	SOT23-5
LM3671	5.5	2.7	1.1	3.3	600	2000	✓	Voltage with input feedforward	SOT23-5, LLP-6
LM3673	5.5	2.7	1.1	3.3	350	2000	✓	Voltage with input feedforward	micro SMD-5
LM3674	5.5	2.7	1.1	3.3	600	2000	✓	Voltage with input feedforward	SOT23-5
LM3676	5.5	2.9	1.1	3.3	600	2000	✓	Voltage with input feed forward	LLP-8
LM3677	5.5	2.7	1.2	3.3	600	3000	✓	Auto	micro SMD-5
LM3678	5.5	2.5	0.8	3.3	1500	3300	✓	PWM only	LLP-10
LM3679	5.5	2.5	1.8	1.8	350	3000	✓	Auto	micro SMD-5
LM3691	5.5	2.3	0.75	1.8	1000	4000	✓	Auto	micro SMD-6

PowerWise product

## LM3668 – Inductive Buck-Boost DC-DC Converter

### Features

- 1A current capability
- Voltage select pin allows output voltage flexibility (2.8V/3.3V)
- Mode pin toggles between automatic PFM/PWM operation or forced PWM operation
- Frequency sync from 1.6 MHz to 2.7 MHz allows customization for lowest noise in system
- $V_{IN}$  range from 2.5V to 5.5V supports Li-Ion batteries
- >90% efficiency maximizes battery life
- Low  $I_q$  (45  $\mu$ A) in standby mode decreases current leakage in design
- Excellent transient response allows  $V_{OUT}$  to stay within regulation under all conditions
- Available in tiny LLP-12 packaging



### Applications:

Ideal for use in handset peripherals, MP3 players, pre-regulation for linear regulators, PDAs, portable hard disk drives, and WiMax modems

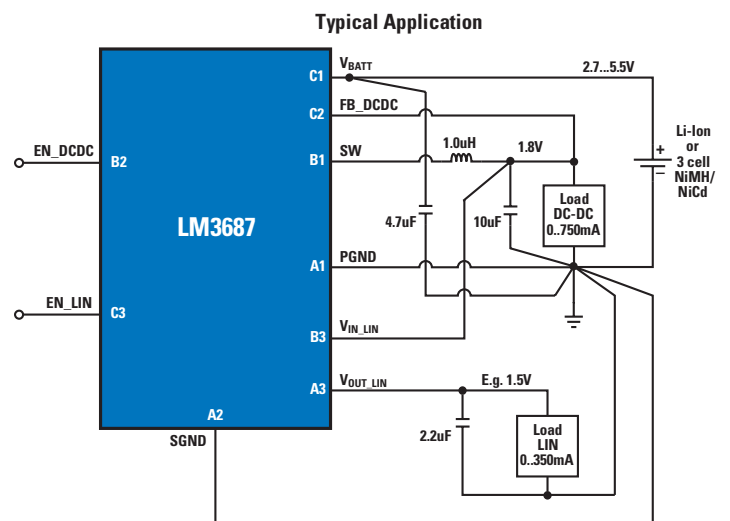
## LM3687 – DC-DC Converter with Integrated Linear Regulator in Tiny Package

### Features

- Combined load current of 750 mA
- Dual output voltage rails (DC-DC converter: 1.8V, linear regulator: 1.5V)
- Automatic PFM/PWM mode switching maximizes battery life
- Design flexibility for independent or combined operation
- Fast 2 MHz switching frequency decreases solution size
- Low quiescent current prevents excessive current loss in standby mode
- Startup mode option when input voltage for linear regulator is not sufficiently high
- Available in tiny micro SMD-9 packaging for optimizing solution size

### Applications:

Ideal for use in mobile phones, handheld radios, PDAs, Palm-top PCs, portable instruments, and battery-powered devices



# Worldwide Design Centers and Manufacturing Facilities



- Design Centers
- Manufacturing Facilities

## Design Centers

### USA:

Arlington, Texas  
Calabasas, California  
Chandler, Arizona  
Federal Way, Washington  
Fort Collins, Colorado  
Grass Valley, California  
Indianapolis, Indiana  
Longmont, Colorado  
Norcross, Georgia  
Phoenix, Arizona  
Rochester, New York  
Salem, New Hampshire  
San Diego, California  
Santa Clara, California  
South Portland, Maine  
Tucson, Arizona

### EUROPE:

Delft, Netherlands  
Fürstfeldbruck, Germany  
Unterhaching, Germany  
Greenock, Scotland  
Kemi, Finland  
Milan, Italy  
Oulu, Finland  
Tallinn, Estonia

### ASIA:

Bangalore, India  
Hangzhou, China  
(joint with Zhejiang University)  
Hong Kong, China  
Tokyo, Japan

## Manufacturing Facilities

### Wafer (Die) Fabrication:

Arlington, Texas USA  
South Portland, Maine USA  
Greenock, Scotland

### Chip Test and Assembly:

Melaka, Malaysia  
Suzhou, China

## World Headquarters

2900 Semiconductor Drive  
Santa Clara, CA 95051  
USA  
+1 408 721 5000  
[www.national.com](http://www.national.com)

## Mailing Address:

PO Box 58090  
Santa Clara, CA 95052  
[support@nsc.com](mailto:support@nsc.com)

## European Headquarters

Livry-Gargan-Str. 10  
82256 Fürstfeldbruck  
Germany  
+49 8141 35 0  
[europe.support@nsc.com](mailto:europe.support@nsc.com)

## Asia Pacific Headquarters

2501 Miramar Tower  
1 Kimberley Road  
Tsimshatsui, Kowloon  
Hong Kong  
+852 2737 1800  
[ap.support@nsc.com](mailto:ap.support@nsc.com)

## Japan Headquarters

Beside KIBA  
2-17-16  
Kiba, Koto-ku  
Tokyo, 135-0042, Japan  
+81 3 5639 7300  
[jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)

