

# Personal Mobile Devices

Solutions Guide

[national.com/portable](http://national.com/portable)

2009 Vol. 1

Audio

RF

Display and Lighting

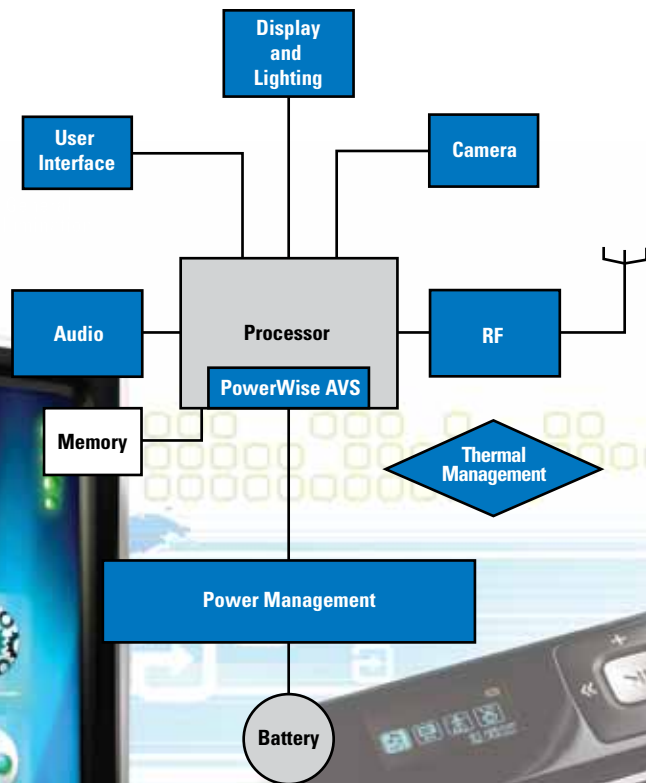
Power Management

Thermal Management

Specialty Products

Designer's Corner

Design Tools



# Enabling Energy Efficiency Through PowerWise® Mobile Device Solutions

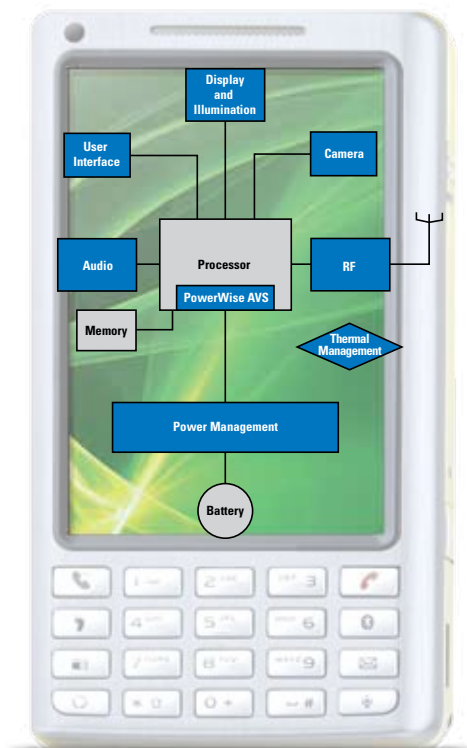
[national.com/portable](http://national.com/portable)

National Semiconductor is a proven and trusted solutions provider and partner in the mobile device market for every major handset maker in the world. National's highest-standard quality, reliable production, and world-class supply chain management make National the clear choice in analog semiconductor products for personal mobile devices.

National's PowerWise® solutions provide energy-efficient, high-value products and subsystems for audio, smart RF management, illumination, and power management. These solutions enable customers to build personal mobile devices with longer battery life between charges; smaller, more convenient form factors; advanced connectivity; higher-quality audio; and more vivid displays.

To enable a richer user experience, National's solutions address portable device challenges through:

- Driving energy efficiency with differentiated PowerWise® solutions that extend battery life
- Enabling next-generation technology through products with increased performance, advanced connectivity, and new features
- Integrating advanced subsystems through system-oriented solutions with high feature density in the smallest solution sizes



## Audio

National's audio solutions feature highest-quality audio with the greatest energy efficiency. The portfolio includes mixed-signal and analog subsystems for high-level integration with sophisticated features, advanced noise reduction for clearer audio, ceramic speaker drivers for thinner designs, high-efficiency headphone amplifiers, and high-performance speaker drivers.

## RF

Smart RF management enables next-generation connectivity with significant energy savings and higher performance. National's RF solutions include DC-DC converters specially designed for RF with dynamic voltage output for increased system efficiency, RF power detectors, frequency synthesizers with very low phase noise, and clock buffers for proper clock distribution while preserving clock accuracy.

## Display and Lighting

National's display and lighting solutions enhance the user experience with energy-efficient backlighting for vivid picture and camera flash solutions. Display SerDes solutions simplify designs by consolidating the display interface. High-efficiency backlighting drivers enhance the image with energy-saving features such as dynamic control. LED flash drivers enable brighter flashes for better image quality, and Lighting Management Units provide complete integrated lighting solutions with advanced lighting effects engines for flexibility and lighting customization.

## Power Management

National is the industry leader in energy-efficient power management solutions from Power Management Units to high-efficiency, small-size discrete switching and linear regulators. National's PowerWise Adaptive Voltage Scaling (AVS) technology coupled with power management ICs provide unparalleled power savings with many integrated features, while discrete switching regulators boast the highest efficiencies in the smallest footprints to save board space.

With this full portfolio of solutions for personal mobile devices, National's technical expertise drives innovative applications and enhances the end user experience.

To see all of National's personal mobile device solutions, visit: [www.national.com/portable](http://www.national.com/portable).

# Table of Contents

---

## Audio

Subsystems .....	2
Noise Reduction .....	6
Ceramic Speaker Drivers .....	7
Headphone Amplifiers .....	8
Boomer® Amplifiers .....	10

## RF

Power Supply for RF Power Amplifiers .....	13
RF Detectors and Frequency Synthesizers .....	14
Clocking Buffers .....	15

## Display and Lighting

Display SerDes .....	16
LED Flash Drivers .....	17
Backlight Drivers .....	18
Lighting Management Units .....	20

## Power Management

Energy Management Units .....	22
Power Management Units .....	23
Switching DC-DC Voltage Regulators .....	25
Low-Noise Low-Dropout Regulators .....	27

<b>Thermal Management</b> .....	28
---------------------------------	----

<b>Specialty Products</b> .....	29
---------------------------------	----

<b>Designer's Corner</b> .....	30
--------------------------------	----

<b>Design Tools</b> .....	33
---------------------------	----

# Audio

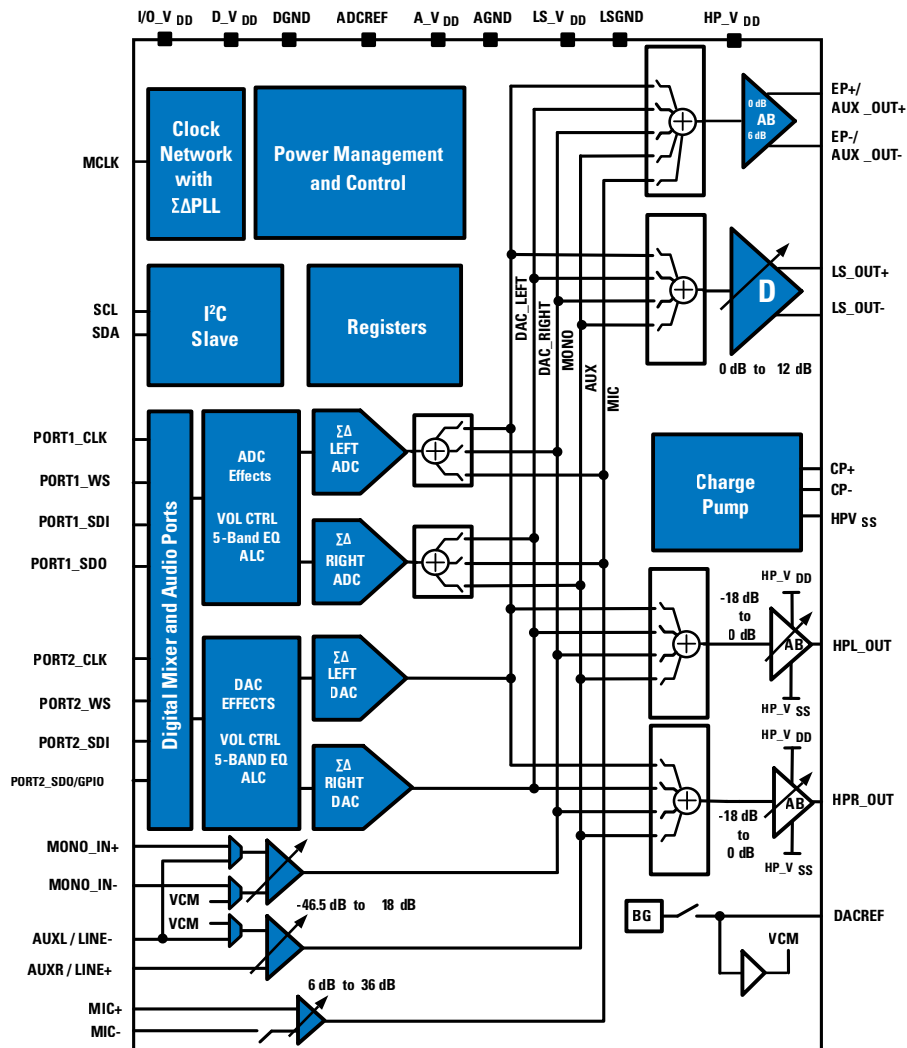
## Mixed-Signal Subsystems/Audio Codecs

### LM49352 – Mono Class D Audio Codec Subsystem with Ground-Referenced Headphone Amplifiers

#### Features

- Low-voltage, true-ground headphone amplifier operation
- High-performance 103 dB SNR stereo DAC
- High-performance 97 dB SNR stereo ADC
- Up to 96 kHz stereo audio playback
- Up to 48 kHz stereo recording
- Dual bidirectional I<sup>2</sup>S- or PCM compatible audio interface
- Read/write I<sup>2</sup>C compatible control interface
- Flexible digital mixer with sample rate conversion

LM49352 Typical Application Circuit



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

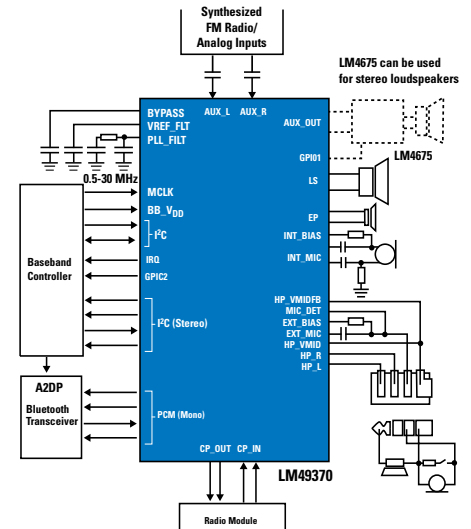
### Features

- Spread spectrum Class D architecture reduces electromagnetic interference (EMI)
- Mono Class D 8Ω amplifier, 490 mW at 3.3V
- Output capacitorless (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 (THD): 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, portable gaming, portable DVD/CD/AAC/MP3 players, and digital cameras/camcorders

### LM49370 Typical Application Circuit



## LM49450 – 2.2W Stereo Boomer® Class D Audio Subsystem

### Features

- 24-bit stereo DAC
- Selectable spread spectrum mode reduces EMI
- Ground-referenced headphone amplifiers with 100 dB SNR
- I²C compatible audio interface; I²C compatible control interface
- Audio sample rates up to 192 kHz
- Advanced click-and-pop suppression
- Micro-power shutdown

### Applications

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

Product ID	Description	Mono Input Ch.	Stereo Input Ch.	Class D Speaker Driver	Packaging
<b>NEW</b> LM49352	1.4W mono Class D speaker, 65 mW ground-referenced headphone with stereo DAC and stereo ADC with I²S/PCM and auxiliary inputs, I²C compatible control, 3D, five band EQ, and AGC	2, PCM	I²S, I²C compatible	✓	micro SMDxt-36
LM49350	1.1W Class D speaker, 69 mW ground-referenced headphone with stereo DAC and stereo ADC with I²S/PCM and auxiliary inputs, I²C compatible control, 3D, five-band EQ, and AGC	2, PCM	I²C compatible	✓	micro SMDxt-36
LM49450	Filterless 2.2W stereo Class D audio subsystem with ground-referenced headphone amplifier, 3D enhancement, and headphone sense	—	2, I²S	✓	LLP-32
LM49370	1.2W mono speaker, 31 mW headphone, 115 mW earpiece with I²C/SPI mode and selectable OCL output	3, PCM	I²S	✓	micro SMDxt-49
LM49321	520 mW mono speaker, 36 mW headphone, 55 mW earpiece with I²C/SPI and lower power MP3 playback mode	1	2, I²S	—	micro SMDxt-36

# Audio

## Analog Subsystems

### LM49151 – PowerWise® Mono Class D Audio Subsystem with Earpiece Driver and Ground-Referenced Headphone Amplifiers

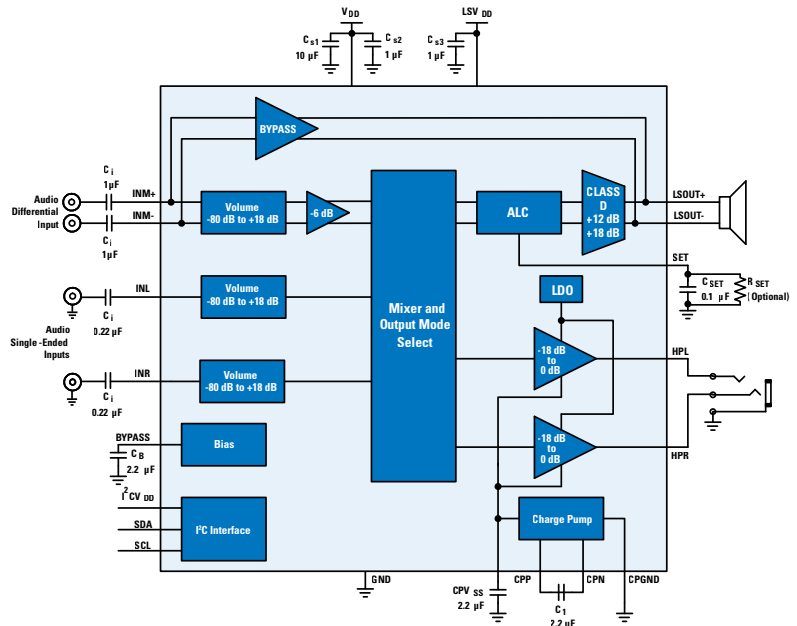
#### Features

- Class D amplifier with E<sup>2</sup>S enhanced emission suppression technology for reduced EMI
- Ground-referenced outputs — eliminates output-coupling capacitors
- I<sup>2</sup>C programmable no clip function with clip control
- Voltage limiter speaker protection
- I<sup>2</sup>C compatible volume and mode control
- Earpiece amplifier
- Advanced click-and-pop suppression
- Low supply current

#### Applications

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

LM49151 Typical Application Circuit



### LM49101 – Mono Class AB Audio Subsystem with a True-Ground Headphone Amplifier and Earpiece Switch

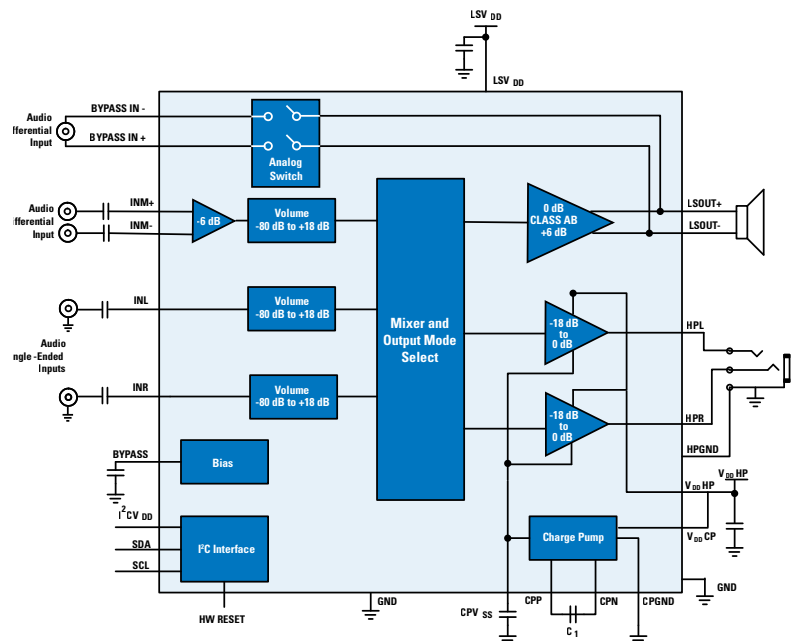
#### Features

- Differential mono input and stereo single-ended input
- Separate earpiece (receiver) differential input
- Analog switch for a separate earpiece path
- 32-step digital volume control (-80 dB to +18 dB)
- Three independent volume channels (left, right, mono)
- Separate headphone volume control
- Flexible output for speaker and headphone output

#### Applications

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

LM49101 Typical Application Circuit



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

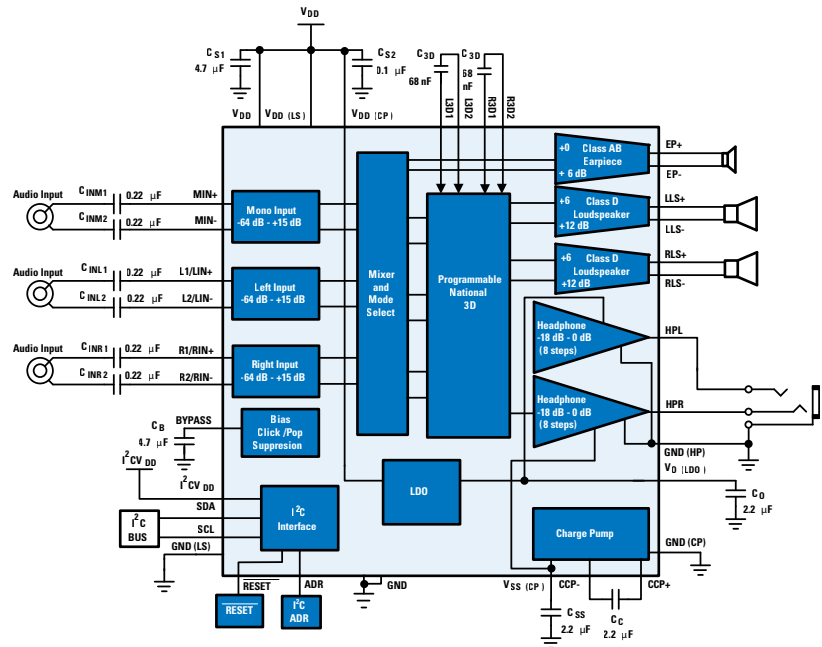
## Features

- Output short-circuit protection
- Thermal overload protection
- Spread spectrum modulation
- I<sup>2</sup>C compatible control interface
- Total harmonic distortion (THD): 0.01%
- RF suppression
- Advanced 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

LM49250 Typical Application Circuit



## Analog and Codec Subsystems

Product ID	Description	Mono Input Ch.	Stereo Input Ch.	THD (%)	Class D Speaker Driver	Packaging
<b>NEW</b> LM49151	1.25W mono Class D audio subsystem with automatic level control, earphone path and ground-referenced headphone amplifier	1	1	0.02	✓	micro SMD-20
LM49150	1.25W mono Class D audio subsystem with earphone path and ground-referenced headphone amplifier	1	1	0.04	✓	micro SMD-20
LM49250	Stereo Class D audio subsystem with ground-referenced headphone amplifier and mono earpiece	1	2	0.14	✓	micro SMD-36
<b>NEW</b> LM49101	1.3W mono Class AB audio subsystem with ground-referenced headphone amplifier and mono earpiece	2	1	0.065	—	micro SMD-25
LM49100	1.275W mono speaker (BTL), 50 mW headphone with I <sup>2</sup> C compatible, mode and volume control, and ground-referenced headphone drivers	1	2	0.035	—	microArray-25
LM49120	1.3W mono speaker, 85 mW headphone with I <sup>2</sup> C/SPI mode and volume control, and selectable OCL output	1	2	0.05	—	micro SMD-16
LM4946	1.3W mono speaker, 85 mW headphone 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
LM49270	2.2W stereo speaker, 155 mW headphone with volume control, National 3D and selectable OCL output	1	2	0.02	✓	LLP-28
LM4949	1.19W stereo speaker, 89 mW headphone with I <sup>2</sup> C compatible mode and volume control and selectable OCL output	1	1 or 2	0.02	✓	micro SMD-25
LM4947	1.19W mono speaker, 87 mW headphone with I <sup>2</sup> C compatible mode and volume control, National 3D and selectable OCL output	1	1 or 2	0.03	✓	micro SMD-25
LM4938	Stereo 2W audio power amplifier with DC volume control, selectable gain, and docking station interface	—	1	0.05	—	eTSSOP-28

# Audio

## Noise Reduction

### LMV1088/89 – Far-Field Noise Suppression Microphone Amplifier

#### Features

- First analog noise suppression solution
- Up to 20 dB of far-field acoustic noise suppression
- Low 1 mA current consumption (1/10th of DSP solution)
- Automatic microphone calibration feature
- Calibration data stored in EEPROM
- Available in micro SMD-36 packaging (3.5 mm x 3.5 mm)
- Available in LQFP-32 packaging (LMV1089)

#### Applications

Ideal for use in mobile handsets, long-boom headsets, and two-way radios

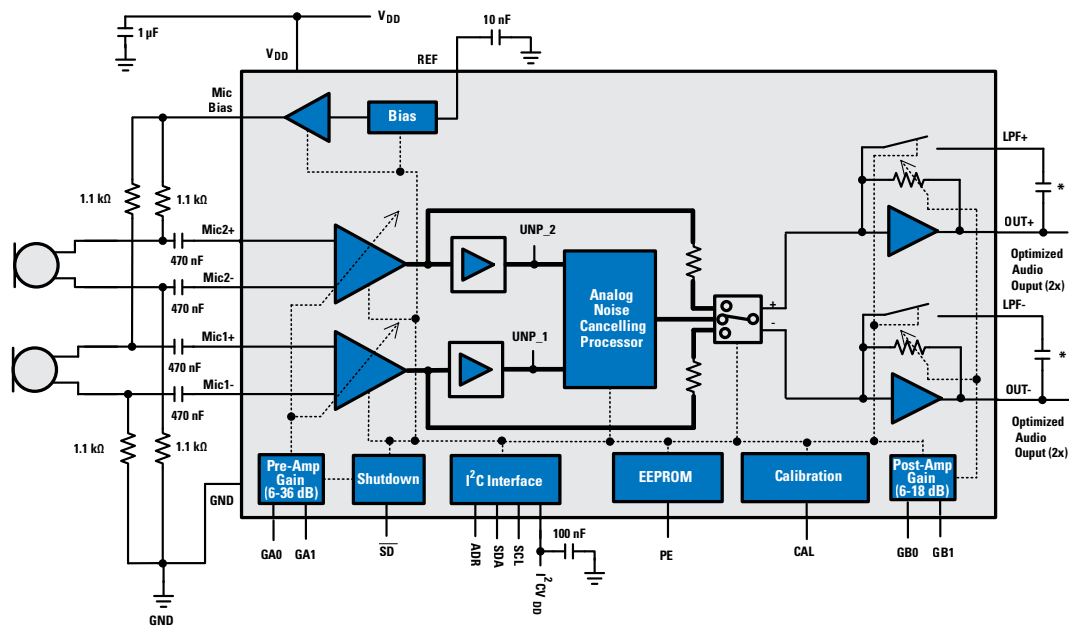
#### Far-Field Noise Suppression (FFNS<sub>E</sub>)

FFNS<sub>E</sub> addresses the ability of the amplifier to reject far-field signals (considered noise) over the desired near-field signal. It describes the ratio of far-field noise (as it rides on the whole signal) between the input and output of the amplifier in decibels.

#### Signal-to-Noise Ratio Improvement Electrical (SNRI<sub>E</sub>)

SNRI<sub>E</sub> describes the ratio of the Far-Field Noise Suppression (FFNS) to near-field (desired) signal amplitude attenuation through the noise suppression process, as measured in decibels.

LMV1088 Typical Application Circuit



### Noise Reduction Microphone Amplifiers

Product ID	Output	Fair-field Noise Suppression (dB) at 300 Hz	SNRI (dB) at 300 Hz	PSRR (dB)	Shutdown	Supply Current (mA)	Supply Voltage Range (V)	Packaging
LMV1088	Single-ended	37	28	85	—	1.0	2.7 to 5.5	micro SMD-36
LMV1089	Differential	37	28	96	✓	1.0	2.7 to 5.5	micro SMD-36, LQFP-32
NEW LMV1090	Differential	43	33	99	✓	0.6	2.7 to 5.5	micro SMD-16

PowerWise® product



### LM48823 – Mono, Bridge-Tied Load, Ceramic Speaker Driver with I<sup>2</sup>C Compatible Volume Control and Reset

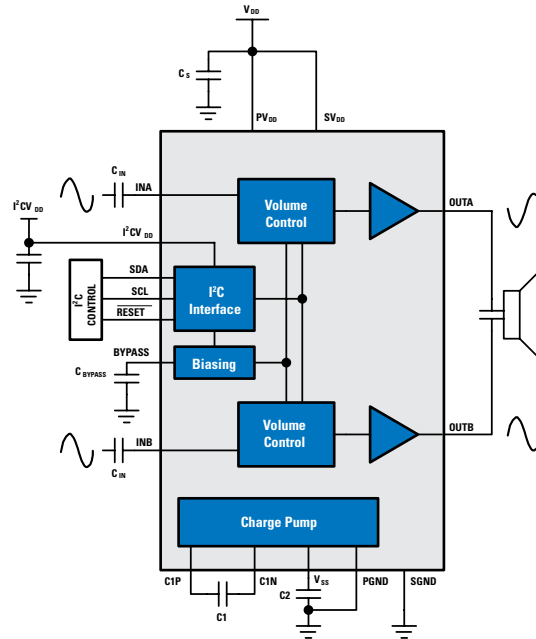
#### Features

- Integrated charge pump
- Bridge-tied load output
- High PSRR
- I<sup>2</sup>C compatible volume and mode control
- Reset input
- Advanced click-and-pop suppression
- Low supply current
- Minimum external components
- Micro-power shutdown
- Available in space-saving micro SMD-16 packaging

#### Applications

Ideal for use in cell phones, smart phones, portable media devices, and notebook PCs

LM48823 Typical Application Circuit



### Boosted Boomer Piezo Ceramic Speaker Drivers

Product ID	Description	THD (%)	Output Voltage (V <sub>p,p</sub> )	Condition	Packaging
LM4802B	12 V <sub>p,p</sub> boosted ceramic speaker driver	0.05	12	V <sub>DD</sub> =4.2V, 2 μF + 30Ω, THD ≤ 1%	LLP-28
LM4953	12.6 V <sub>p,p</sub> ceramic speaker driver with ground reference, ultra-low noise, fixed gain	0.02	12.6	V <sub>DD</sub> =3.6V, 2 μF + 30Ω, THD ≤ 1%	LLP-14
LM4960	24 V <sub>p,p</sub> Piezoelectric speaker driver	0.04	24	V <sub>DD</sub> = 3.0V, 800 nF + 20Ω, THD ≤ 1%	LLP-28
LM4961	15 V <sub>p,p</sub> ceramic speaker driver	0.05	15	V <sub>DD</sub> = 5V, 2 μF + 30Ω, THD ≤ 1%	LLP-28
LM4962	15 V <sub>p,p</sub> ceramic speaker driver with band switch function, can drive LM4951 for stereo solution	0.04	15	V <sub>DD</sub> =5V, 2 μF + 9.4Ω, THD ≤ 1%	micro SMD-20
LM48555	15.5 V <sub>p,p</sub> ceramic speaker driver	0.05	15	V <sub>DD</sub> =5V, 2 μF + 9.4Ω, THD ≤ 1%	micro SMD-12
LM48556	17.5 V <sub>p,p</sub> fully differential ceramic speaker driver	0.03	17.5	V <sub>DD</sub> =4.5V, THD ≤ 1%	micro SMD-12
<b>NEW</b> LM48823	5.4V <sub>RMS</sub> ceramic speaker driver with I <sup>2</sup> C compatible volume control and reset	0.015	5.4V <sub>RMS</sub>	V <sub>DD</sub> = 4.2, RL=2.2 μF+15Ω, THD ≤ 1%	micro SMD-16

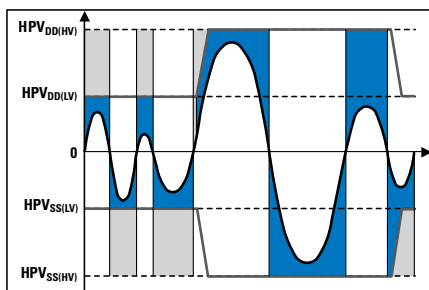
# Audio

## Ground-Referenced Headphone Boomer® Amplifiers

### LM48824 – Class G Headphone Amplifier with I<sup>2</sup>C Compatible Volume Control

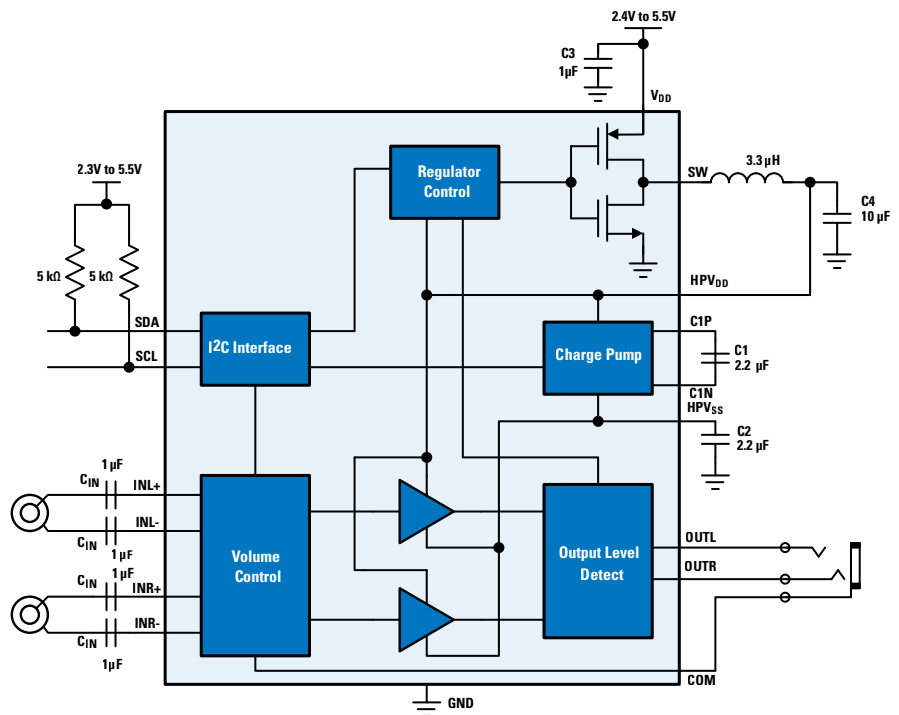
#### Features

- Class G power savings
- Ground-referenced headphone outputs – eliminates output-coupling capacitors
- Common-mode sense
- I<sup>2</sup>C compatible volume and mode control
- High-output impedance in shutdown
- Differential inputs
- Advanced click-and-pop suppression
- Low supply current
- Low total harmonic distortion (THD) mode option



- Buck Converter Output
- Power Savings in Class G
- + ■ Power Dissipated in Class AB
- Power Dissipated in Class G

#### LM48824 Typical Application Circuit

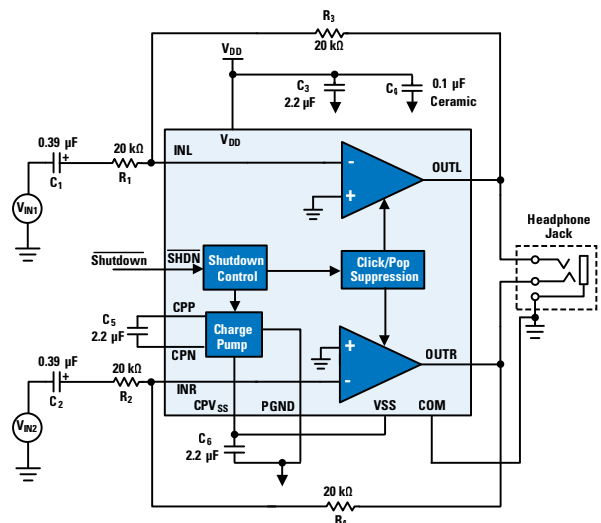


### LM48861 – PowerWise® Ground-Referenced, Ultra-Low Noise, Stereo Headphone Amplifier

#### 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 8 kV HBM contact

#### LM48861 Typical Application Circuit



### Ground-Referenced Headphone Boomer® Amplifiers


Product ID	Description	I <sub>DDQ</sub> (mA)	THD (%)	Output Power THD ≤ 1%, V <sub>CC</sub> = 3V		PSRR (dB)	Supply Voltage Range (V)	Packaging
				16Ω (mW)	32Ω (mW)			
LM4920	50 mW headphone, fixed logic levels, fixed 1.5 V/Vgain	7.0	0.03	43	50	70	1.6 to 4.2	micro SMD-14
LM4982	50 mW headphone, ultra-low noise, IntelliSense, 32-step I <sup>2</sup> C compatible volume control	8.1	0.05	47	51	66	1.6 to 4.0	micro SMD-16
LM48820	95 mW headphone, ultra-low noise, fixed 1.5 V/Vgain	4.7	0.01	95	80	80	1.6 to 4.5	micro SMD-14
LM48821	52 mW headphone, ultra-low noise, direct coupled, I <sup>2</sup> C compatible volume control	3.0	0.015	52	53	82	2.0 to 4.0	micro SMD-16
LM48860	30 mW headphone, ultra-low noise, fixed 1.5V/V gain	4.0	0.014	40	50	80	2.5 to 5.5	micro SMD-12
LM48822	35 mW headphone, ultra-low noise, common mode sense and I <sup>2</sup> C compatible volume control	3.5	0.04	35	40	110	2.4 to 5.5	micro SMD-16
LM48861	22 mW headphone Boomer amplifier, ultra-low noise, and common mode sense	2.0	0.04	22	24	83	1.2 to 2.8	micro SMD-12
NEW LM48824	37 mW Class G Headphone, ultra-low noise, I <sup>2</sup> C compatible volume control	0.9	0.02	37	29	100	2.4 to 5.5	micro SMD-16

 PowerWise® product

### Output Capacitor-less/Capacitor-Coupled Headphone Boomer Amplifiers

Product ID	Description	I <sub>DDQ</sub> (mA)	THD (%)	Output Power THD ≤ 1%, V <sub>CC</sub> = 3V		PSRR (dB)	Supply Voltage Range (V)	Packaging
				16Ω (mW)	32Ω (mW)			
LM4809	105 mW headphone with shutdown low, can drive 8Ω	1.4	0.03	38	25	70	2.0 to 5.5	LLP-8, SOIC-8 Narrow, mini SOIC-8
LM4811	105 mW headphone with up/down volume control, can drive 8Ω	1.3	0.03	38	25	60	2.0 to 5.5	LLP-10, mini SOIC-10
LM4908 <sup>1</sup>	120 mW headphone, 0.1% THD+N	1.6	0.05	35	25	84	2.0 to 5.5	LLP-8, SOIC-8 Narrow, mini SOIC-8
LM4910	35 mW headphone, bypass capacitor-less, OCL output	3.5	0.03	46	28	65	2.0 to 5.5	LLP-8, SOIC-8 Narrow, mini SOIC-8
LM4911	40 mW headphone, low noise, selectable cap-coupled/OCL output	2.0	—	40	25	65	2.0 to 5.5	LLP-10, mini SOIC-10
LM4921	Low-voltage I <sup>2</sup> S 16-bit stereo DAC with stereo headphone power amplifier and volume control	6.0	0.03	50	—	62	2.6 to 5.5	micro SMD-20
LM4925	2-cell, single-ended output, 40 mW stereo headphone audio amplifier	1.0	0.05	40	—	70	1.5 to 3.6	LLP-10, mini SOIC-10
LM4924	40 mW 2-cell headphone with OCL output	1.5	0.01	40	24	66	1.4 to 3.6	LLP-10, mini SOIC-10
LM4929	40 mW headphone with low noise and OCL output	1.5	—	40	25	65	2.0 to 5.5	mini SOIC-10
LM4980	42 mW stereo headphone with 2-cell battery operation and advanced click-and-pop suppression	1.0	0.02	42	28	90	1.5 to 3.3	LLP-10
NEW LM4985	135 mW headphone with OCL or cap-coupled output, 32-step I <sup>2</sup> C compatible volume control	3.0	0.08	45	23	77	2.0 to 5.5	micro SMD-12

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

 PowerWise® product

# Audio

## High-Efficiency Boomer® Class D Amplifiers

### LM48413 – Ultra-Low EMI, Filterless, 2.5W, Stereo, Class D Audio Power Amplifier with E<sup>2</sup>S

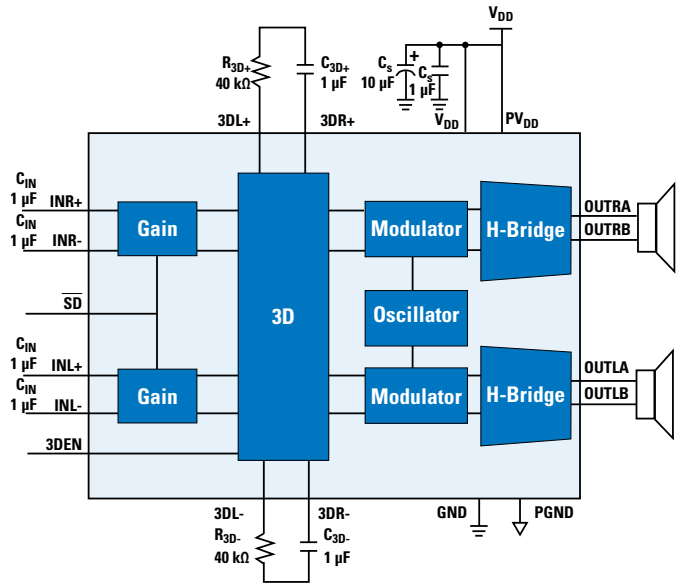
#### Features

- E<sup>2</sup>S system reduces electromagnetic interference (EMI), preserving audio quality and efficiency
- Output short-circuit protection
- Stereo Class D operation
- No output filter required
- National 3D enhancement
- Minimum external components
- Advanced click-and-pop suppression
- Micro-power shutdown

#### Applications

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

LM48413 Typical Application Circuit



### High-Efficiency Boomer Class D Amplifiers

Product ID	Description	THD (%)	Output Power THD ≤ 1%		Packaging
			4Ω (W)	8Ω (W)	
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 2.5W stereo Class D audio power amplifier	0.05	1.9	1.25	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	2.0	1.25	micro SMD-16
LM48413	Stereo, E <sup>2</sup> S, 3D	0.03	—	1.2	micro SMD-18

PowerWise® product

### LM48520 – Boosted Stereo Class D Audio Power Amplifier with Output Speaker Protection and Spread Spectrum

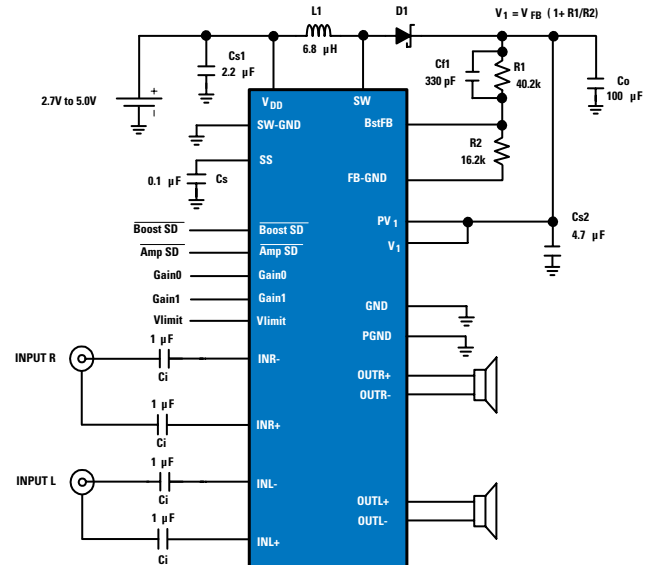
#### Features

- Advanced click-and-pop suppression
- Low 0.04  $\mu\text{A}$  shutdown current
- 78% efficiency
- Filterless Class D
- 2.7V to 5.0V operation
- 4 adjustable gain settings
- Adjustable output swing limiter with soft clipping
- Speaker protection
- Short-circuit protection on audio amplifiers
- Independent boost and amplifier shutdown pins

#### Applications

Ideal for use in mobile phones, PDAs, portable media devices, cameras, and handheld games

LM48520 Typical Application Circuit



### LM48510 – PowerWise® Boosted Boomer Class D Audio Power Amplifier

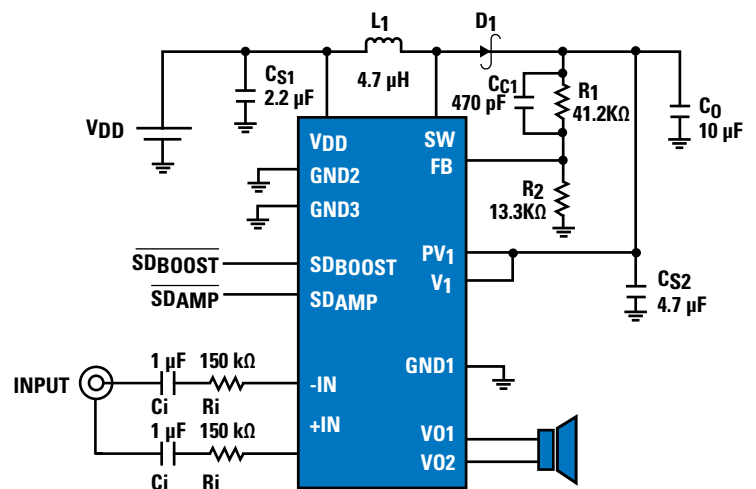
#### Features

- Advanced click-and-pop suppression
- Low 0.01  $\mu\text{A}$  shutdown current
- 76% efficiency
- Filterless Class D
- 2.7V to 5.0V operation ( $V_{DD}$ )
- Externally configurable gain on Class D
- Very fast turn-on time: 17  $\mu\text{s}$
- Independent boost and amplifier shutdown pins

#### Applications

Ideal for use in mobile phones, PDAs, portable media devices, cameras, and handheld games

LM48510 Typical Application Circuit



### Boosted Boomer Moving Coils

Product ID	Description	THD (%)	Output Power at THD $\leq$ 1%		Packaging
			4 $\Omega$ (W)	8 $\Omega$ (W)	
LM4804	1.8W low voltage, high power	0.15	—	1.9 at 4.2V, 2%	LLP-28
LM4805	1W low voltage, high power (supplies 1W down to 3V)	0.25	—	1.2 at 4.2V	LLP-28
LM48510	1.2W boosted Class D	0.07	1.7 at 3.3V	1.2 at 3.3V	LLP-16
LM48511	3W boosted Class D with ultra-low EMI and spread spectrum	0.03	5.4 at 5V	3.0 at 5V	LLP-24
LM48520	1.1W boosted Class D with speaker protection and spread spectrum	0.04	—	1.1 at 3.3V	micro SMD-25

# Audio

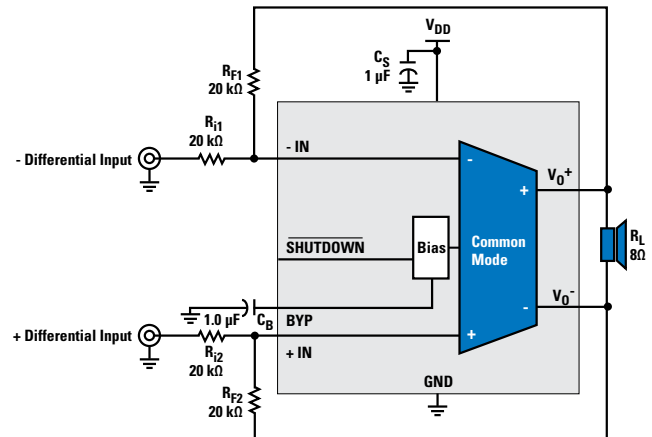
## Mono and Stereo Boomer® Audio Amplifiers

### LM4941 – PowerWise® Boomer 1.25 Watt Fully Differential Audio Power Amplifier with RF Suppression and Shutdown

#### Features

- Improved RF suppression, by up to 20 dB over previous designs in selected applications
- Fully differential amplification
- Available in space-saving micro SMD package
- Ultra-low current shutdown mode
- Can drive capacitive loads up to 100 pF
- Advanced click-and-pop suppression
- 2.4V to 5.5V operation
- No output coupling capacitors, snubber networks, or bootstrap capacitors required

LM4941 Typical Application Circuit



### Fully Differential Mono Boomer Amplifiers

Product ID	Description	THD (%)	Output Power at 1% THD+N $V_{CC} = 5V$		Packaging
			4Ω (W)	8Ω (W)	
LM4923	LM4898 with improved output power	0.02	—	1.1	LLP-8
LM4927	1.3W high PSRR	0.03	2.1	1.3	LLP-8
LM4941	1.25W RF suppression, high PSRR and CMRR	0.04	—	1.25	micro SMD-9, LLP-8

PowerWise® product

### Mono Boomer Audio Amplifiers

Product ID	Description	THD (%)	Output Power $V_{CC} = 5V$		Packaging
			4Ω (W)	8Ω (W)	
LM4819	350 mW audio power amplifier with shutdown mode	1.0	—	0.25	LLP-8, SOIC-8
LM4951	1.8W (at 7.5V) wide voltage range	0.07	—	0.9	micro SMD-9, LLP-10
LM4954	3W (into 3Ω) wide voltage range	0.01	1.6	1.2	micro SMD-9
LM4991	3W (into 3Ω)	0.02	2.13	1.1	LLP-8, SOIC-8
LM4995	1.3W	0.01	—	1.3	micro SMD-9, LLP-8
NEW LM4951A	1.8W (at 7.5V) wide voltage range with short circuit protection	0.07	—	1.8	LLP-10
NEW LM48100	Mono, 1.25W audio power amplifier with output fault detection and volume control	0.02	—	1.25	Exposed-pad TSSOP-14

PowerWise® product

### Stereo Boomer Amplifiers

Product ID	Description	THD (%)	Output Power THD ≤ 1%, $V_{CC} = 5V$		Packaging
			4Ω (W)	8Ω (W)	
LM4928	1.2W stereo fully differential with RF suppression	0.04	1.8	1.2	micro SMD-16, LLP-14
LM4992	1.07W stereo with independent channel shutdown	0.15	—	1.07	LLP-14

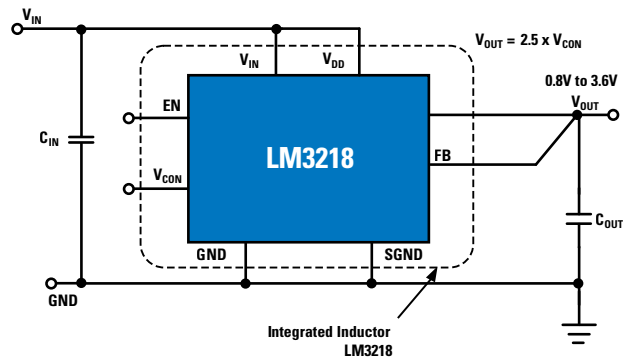
# Power Supply for RF Power Amplifiers

## LM3208/18 – PowerWise® Continuously Adjustable, 650 mA Miniature DC-DC Converter for RF Power Amplifiers

### Features

- Dynamic output voltage control (0.8V to 3.6V) regulates power and maximizes usage time in RF-based systems
- Analog  $V_{CON}$  pin allows voltage control without need for external feedback resistors
- 650 mA maximum load capacity
- 2 MHz buck regulator plus LDO provide tiny integrated solution for RF PAs
- 3GPP standard compliant
- Peak 96% efficiency maximizes battery life and improves reliability of RF sub-system
- LM3218 includes 2.6  $\mu$ H inductor in very small form factor (3 x 2.5 x 1.2 mm)
- Available in micro SMD-8 (LM3208) and LTCC-8 (LM3218) packaging

LM3218 Typical Application Circuit



### Applications:

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

## LM3280 – PowerWise Adjustable Step-Down DC-DC Converter with 3 Integrated Low-Noise LDOs for RF Power Amplifiers and Mobile Applications

### Features

- 2 MHz (typical) PWM switching frequency
- Adjustable output voltage (0.8V to 3.6V)
- PWM, forced and automatic bypass mode
- 3 low-noise and fast-transient-response LDOs
- Current and thermal overload protection
- Available in micro SMD-16 packaging

### Applications:

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

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

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Output Current (mA)	Switching Frequency (kHz)	Soft-Start	Bypass Modes	Packaging
LM3202	5.5	2.7	1.3	3.16	650	2000	—	None	micro SMD-8
LM3203	5.5	2.7	0.8	3.6	500	2000	✓	Forced	micro SMD-10
LM3204	5.5	2.7	0.8	3.6	500	2000	✓	Forced and Automatic	micro SMD-10
LM3205	5.5	2.7	0.8	3.6	650	2000	✓	None	LLP-10, micro SMD-8
LM3208	5.5	2.7	0.8	3.6	650	2000	✓	None	micro SMD-8
<b>NEW</b> LM3218*	5.5	2.7	0.8	3.6	650	2000	✓	None	micro SMD-8
LM3280**	5.5	2.7	0.8	3.6	500	2000	✓	Forced and Automatic	micro SMD-16

PowerWise® product

\* Integrated inductor

\*\* With 3 integrated low-noise LDOs

See page 27 for Low-Noise LDOs for Low-Power Space-Constrained Applications

# RF

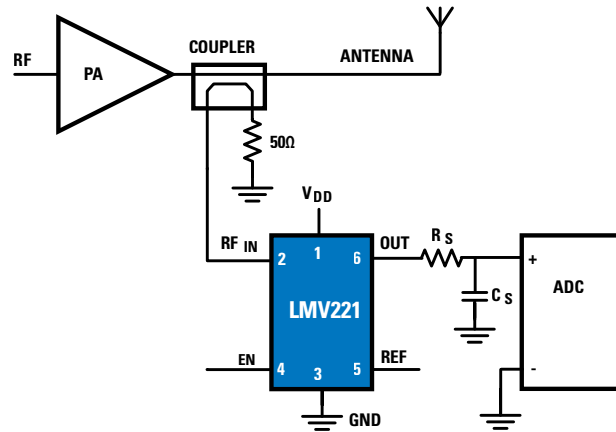
## RF Detectors and Frequency Synthesizers

### LMV221/LMH2100 – 50 MHz to 4 GHz, 40 dB Logarithmic Power Detector for CDMA and WCDMA

#### Features

- 40 dB linear in dB power detection range
- Output voltage range 0.3V to 2V
- Shutdown pin
- Multi-band operation from 50 MHz to 4 GHz
- 0.5 dB accurate temperature compensation
- External configurable output filter bandwidth
- Available in LLP-6 packaging (LMV221) (2.2 x 2.5 x 0.8 mm)
- Available in micro SMD packaging (LMH2100) (0.85 x 1.25 x 0.6 mm)

LMV221 Typical Application Circuit



#### RF Detectors

Product ID	Application	Channels	Supply Voltage Range (V)	Dynamic Range (dB)	Frequency Range (MHz)	Packaging
LMV221	CDMA, WCDMA, GSM, GPRS	1	2.7 to 3.3	40	50 to 3500	LLP-6
LMV225	CDMA, WCDMA, GSM, EDGE, GPRS, TDMA	1	2.7 to 5.0	>30	450 to 2000	micro SMD-4, LLP-6
LMV226	CDMA, WCDMA, GSM, EDGE, GPRS, TDMA	1	2.7 to 5.0	>30	450 to 2000	micro SMD-4
LMV228	CDMA, WCDMA, GSM, EDGE, GPRS, TDMA	1	2.7 to 5.0	>30	450 to 2000	micro SMD-4
LMV232	3G, UMTS, WCDMA, CDMA2000, LAN, GPS	2	2.5 to 3.3	20	50 to 2000	micro SMD-8
LMH2100	CDMA, WCDMA, GSM, GPRS	1	2.7 to 3.3	40	50 to 4000	micro SMD-6
LMV242	GSM, GPRS, TDMA, LAN	2	2.6 to 5.5	50	450 to 2000	LLP-10
LMV243	GSM, GPRS, TDMA, LAN	1	2.7 to 3.3	50	450 to 2000	micro SMD-8

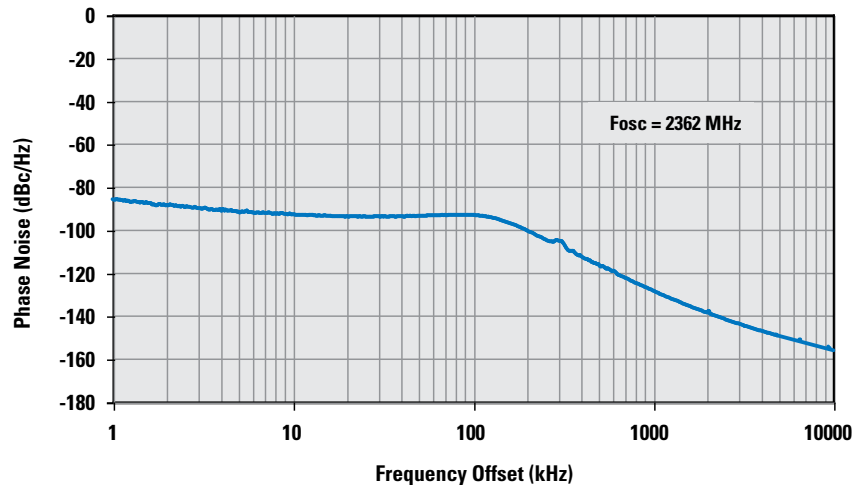
PowerWise® product

### LMX2531 – PLLatinum® Frequency Synthesizer with Integrated VCO

#### Features

- 553 MHz to 3132 MHz frequency range
- Very low phase noise and spurs
- Sigma-Delta fractional-N PLL
- Fully-integrated low-noise VCO
- Low 34 mA (typical) current consumption
- High +4 dBm (typical) output power
- Fast-lock and cycle-slip reduction
- Very low power-down current
- Partially integrated and adjustable loop filter
- 2.8V to 3.2V operation
- 1.8V MICROWIRE® support
- Available in LLP-36 packaging (6 x 6 mm)

LMX2531 Phase Noise

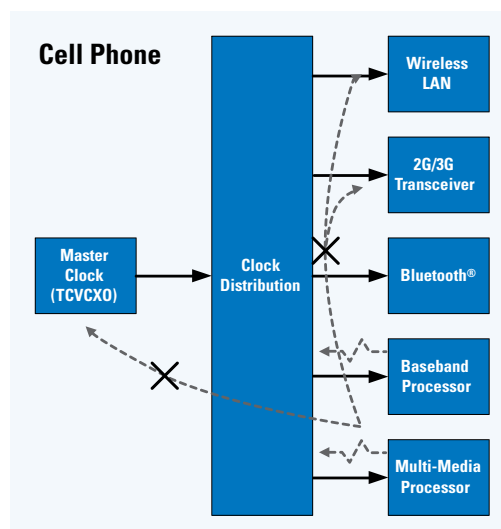




### Master Clock Distribution in Cell Phones; Optimized Clock Distribution Solution

#### Features

- Proper clock distribution circuitry decreases bit error rate
- Isolates master clock from switching noise in digital modules
- Isolates sensitive modules from noise in other modules
- Preserves clock amplitude; high drive capability, minimal clock loading
- Prevents frequency pulling; constant clock load impedance under all conditions
- Preserves clock accuracy; low additive phase noise
- Low power consumption
- Tiny footprint

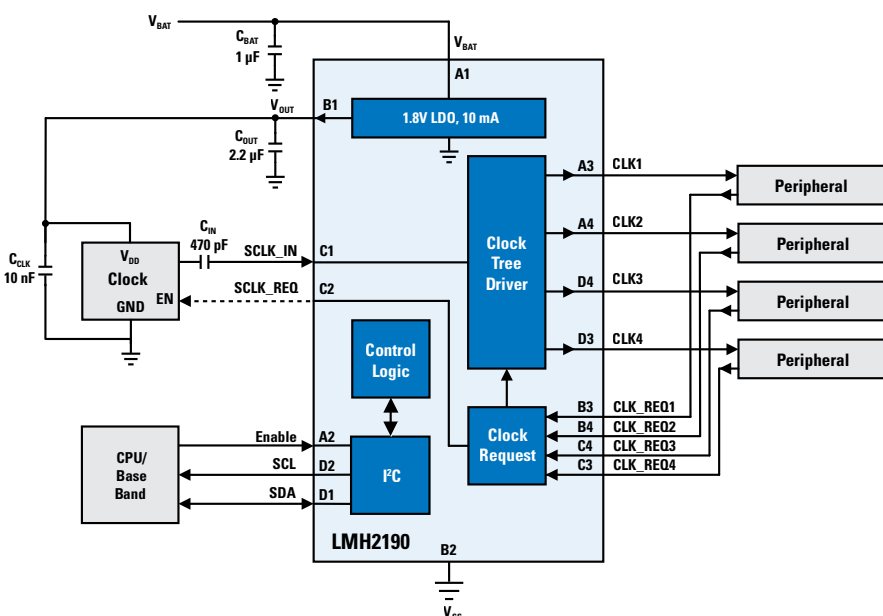


### LMH2190 – Clock Tree Driver and Conditioner

#### Features

- 1 input clock, 4 output clocks
- Excellent phase noise specifications
- Independent clock request pins
- Supports both square or sine wave input
- Clock outputs can be skewed
- High isolation of supply noise to clock input
- Selectable output drive capability from 10 pF to 50 pF
- EMI-controlled output edges and EMI filtering
- Integrated LDO
  - 10 mA output current
  - Low-output voltage noise
- Ultra-low standby current

#### LMH2190 Typical Application Circuit



#### Applications:

Ideal for use in mobile handsets and portable equipment

Product ID	Bandwidth	Channels	I <sub>sup</sub>	Phase Noise	Slew Rate	Shutdown	Output	Packaging
<b>NEW</b> LMH2190	26 MHz	4	3.0 mA	-152 dBc/Hz, 10 kHz offset	N/A	✓	Digital	micro SMD-16 (1.65 x 1.65 mm)
<b>NEW</b> LMH2180	75 MHz	2	2.3 mA	-132 dBc/Hz, 10 kHz offset	106 V/μs	✓	Analog	LLP-8, micro SMD-8
LMV112	40 MHz	2	1.6 mA	-116 dBc/Hz, 10 kHz offset	110 V/μs	✓	Analog	LLP-8
LMV115	30 MHz	1	0.3 mA	n/a	18 V/μs	✓	Analog	SC70-6
LMV116	45 MHz	1	0.6 mA	n/a	40 V/μs	—	Analog	SOT23-5
LMV118	45 MHz	1	0.6 mA	n/a	40 V/μs	✓	Analog	SOT23-6

# Display and Lighting

## Display SerDes

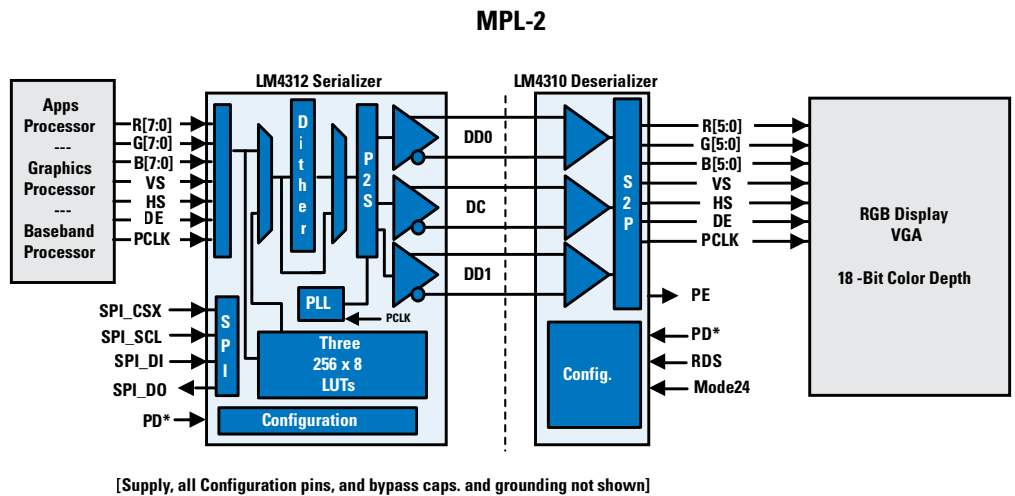
### Mobile Pixel Link

Mobile Pixel Link (MPL) is a robust serial interface between video ports on sources and displays that reduces the number of interface wires. MPL features a robust differential transmission interface with a small magnitude signal to offer system-level low-power and low-EMI benefits. Serialized data is sent in mini-

parallel fashion to simplify the data recovery on the receiver and to eliminate the need for a PLL, thus saving power in the receiver. The number of lanes is also scalable, depending upon the bandwidth required by the end application.

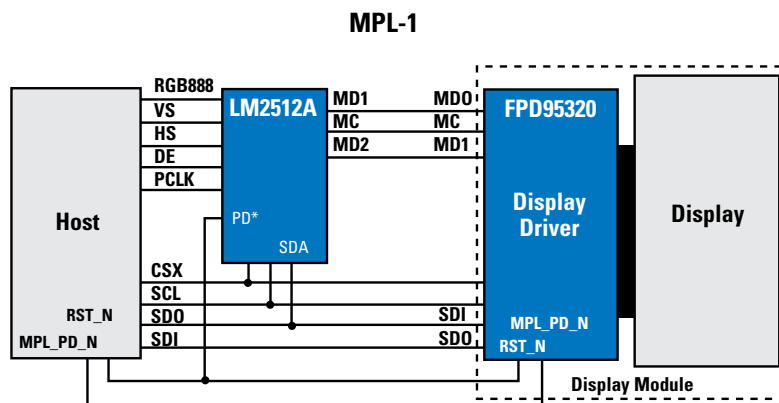
#### MPL-2 Solution

- Most flexible
- Robust differential interface
- Wide clocking range that supports many resolutions
- SLVS physical layer



#### MPL-1 Solution

- Ideal for H-VGA displays (320 x 480)
- 18-bit - 24-bit color depth
- FPD95320 display driver integrates MPL-1 deserializer



Product ID	Function	Bits	Max PCLK Freq (Hz)	Interface	I/O Levels	Special Features	Packaging
LM4308	Master/Slave	18	30	CPU	MPL-2	Write and read supported	LLP/microArray
LM4310	Receiver	18 or 24	30	RGB	MPL-2	Sleep mode	LLP
LM4312	Transmitter	18 or 24	30	RGB	MPL-2	Sleep mode, optional dithering	LLP
LM2512A	Transmitter	24	20	RGB	MPL-1	24 - 18-bit dither	LLP/microArray
FPD95320 *	Receiver	18	—	RGB	MPL-1	Support for partial display modes	Bumped die

\*Chip on Glass (COG) display driver

# Display and Lighting

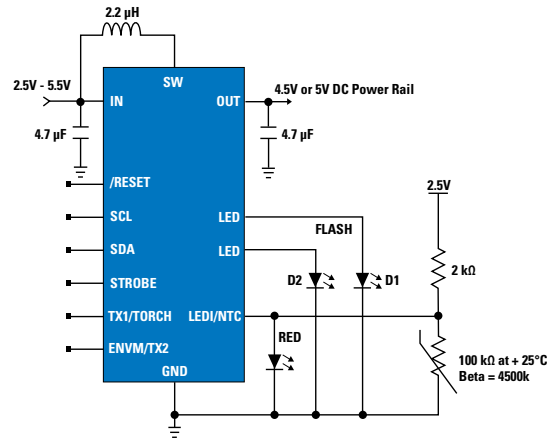
## LED Flash Drivers

### LM3554 – 1.2A Dual Flash LED Driver

#### Features

- 1.2A dual flash LED driver for high-brightness flash
- Grounded-cathode LED operations for optimized routing and thermal implementation
- Flash, torch, and indicator modes support camera and video
- I<sup>2</sup>C compatible bus interface with system reset or strobe control
- Protection mechanisms: LED thermal sense, fault detection, input voltage monitoring, and current scaleback
- RF power amplifier synchronization and flash timeout

LM3554 Typical Application Circuit

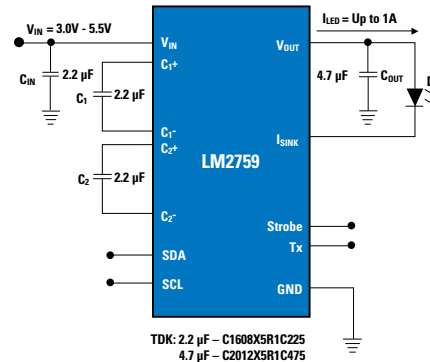


### LM2759 – PowerWise® 1A Switched Capacitor Flash LED Driver with I<sup>2</sup>C Compatible Bus Interface

#### Features

- Adaptive 1x, 1.5x and 2x gains for maximum efficiency, up to 90% efficient
- Load disconnect in shutdown
- Accurate input current control during gain transitions
- RF power amplifier synchronization and flash timeout
- Flash, torch, and indicator modes support camera and video
- Flash trigger through I<sup>2</sup>C compatible bus or via strobe pin
- Programmable flash pulse duration, and torch and flash currents via I<sup>2</sup>C compatible bus interface
- Solution area < 22 mm<sup>2</sup> with no inductor required

LM2759 Typical Application Circuit



### 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	5.0	800	4	1.0	Switched Capacitor	TX input ensures synchronization with RF power amplifier pulse	LLP-24
LM2758	2.7 to 5.5	5.0	700	1	1.2	Switched Capacitor	Indicator, torch, and flash modes, Flash timeout protection	micro SMD-12
NEW! LM2759	3.0 to 5.5	5.0	1000	1	1.0	Switched Capacitor	Indicator, torch, and flash modes, Flash timeout protection	LLP-12
NEW! LM3530	2.7 to 5.5	Variable up to 5.3V	5000	2+	1.0	Switched Capacitor	Indicator, torch, and flash modes, high-current super capacitor architecture	LLP-20
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
LM3553	2.7 to 5.5	19	1200	2	1.3	Inductive Boost	Indicator, torch, and flash modes, and voltage mode, 128 current levels	LLP-12
NEW! LM3554	2.5 to 5.5	5.6	1200	2	2.0	Inductive Boost	Indicator, torch, and flash modes, thermal sensing current scaleback	micro SMD-16

PowerWise® product

# Display and Lighting

## Backlight Drivers

### LM3530 – PowerWise® Content-Adjustable Backlight-Control-Compliant Series White LED Driver

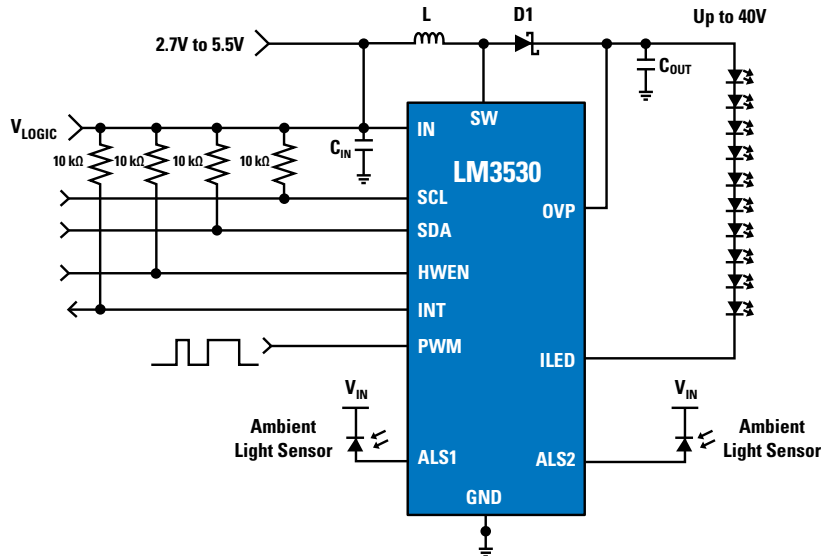
#### Features

- Drives up to 10 white LEDs in series
- 5-zone ALS capability
- Supports CABC implementation
- Programmable dimming: effective bit  $10^{12}$
- 128-step log or linear dimming
- Up to 90% efficiency
- Minimized energy consumption
- Hardware-enable, processor interrupt
- Available in low-profile micro SMD packaging

#### Applications

Ideal for use in display LCD backlighting for portable applications

LM3530 Typical Application Circuit



### LM3528 – High-Efficiency, Multi-Display LED Driver with 128 Exponential Dimming Steps and Integrated OLED Power Supply

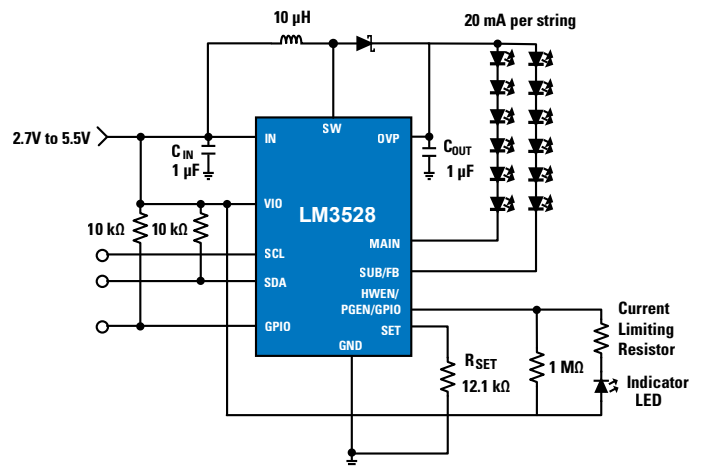
#### Features

- 128 exponential dimming steps
- Integrated OLED display power supply and LED driver
- True shutdown isolation
- Dedicated programmable general purpose I/O
- Programmable auto-dimming function
- Programmable pattern-generator output for LED indicator function
- Up to 90% efficiency
- Available in micro SMD-12 packaging (1.2 x 1.6 x 0.6 mm)

#### Applications










Ideal for dual-display and large format LCD backlighting, OLED panel power supply, and display backlighting with indicator light


LM3528 Typical Application Circuit









Dual White LED Bias Supply with Indicator LED

## 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
LM3519 	2.7 to 5.5	18	20	4	2.0 to 8.0	PWM	Variable switching frequency	SOT23-6
LM3500 	2.7 to 7.0	16, 21	30	5	1.0	PWM	Low feedback voltage, no external Schottky diode	micro SMD-8
LM3501	2.7 to 7.0	16, 21	30	5	1.0	Analog	No external Schottky diode	micro SMD-8
LM3502 	2.5 to 5.5	16, 25, 35, 44	30	10	1.0	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	1.0	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 100 kHz, no external Schottky diode	micro SMD-9
LM3557 	2.7 to 7.5	26	30	5	1.25	PWM	Input under-voltage protection, cycle-by-cycle current limit	LLP-8
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
<b>NEW</b> LM3528	2.5 to 5.5	22	30 per string	12	1.27	I <sup>2</sup> C	Multi-display LED driver with 128 exponential dimming steps and integrated OLED power supply	micro SMD-12
LP5520 	2.9 to 5.5	22	180	12	1.0	PWM	RGB backlight driver	micro SMD-25
LM4510 	2.7 to 5.5	18	Up to 280	—	1.0	—	Power supply for OLED display, no external Schottky diode	LLP-10
<b>NEW</b> LM3530	2.5 to 5.5	40	1A	10	0.5	PWM	Content-adjusted backlighting control support, ambient light sensing capability	micro SMD-12, LLP-10
LM2731/33	2.7 to 14	Adjustable up to 20/40	1A/1.5A (switch)	9	0.6	PWM	Internal compensation, cycle-by-cycle current limit	SOT23-5

 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	5.0, 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, 5.0	80 to 150	10	0.01 to 0.725	PWM	Programmable switching frequencies	LLP-10
LM2755 	3.0 to 5.5	5.0	90	3	1.25	I <sup>2</sup> C	Independently controlled RGB outputs, programmable trapezoidal waveforms	micro SMD-18
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
LM2757 	2.7 to 5.5	4.1, 4.5, 5.0	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 	3.0 to 5.5	5.0	120	4	0.75	PWM	Regulated current sources with 0.2% matching	LLP-14
LM27964	2.7 to 5.5	5.0	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 80 mA), dedicated keypad LED driver	LLP-24
LM27965 	2.7 to 5.6	5.0	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	5.0	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

# Display and Lighting

## Lighting Management Units

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

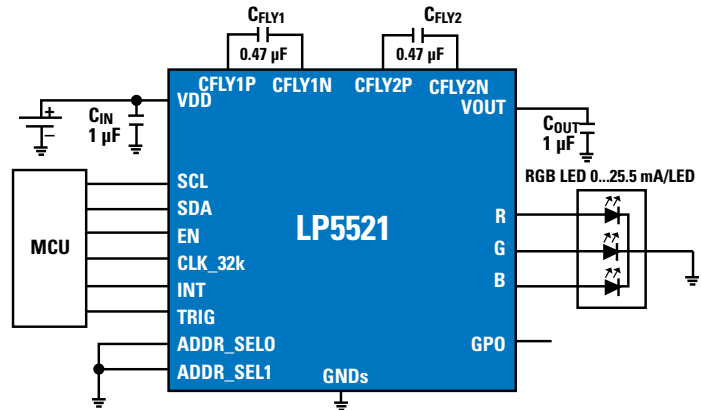
#### Features

- 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 bus 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, and keypad RGB backlighting and phone cosmetics

LP5521 Typical Application Circuit



### LP8501 – PowerWise Multi-Purpose, 9-Output LED Driver

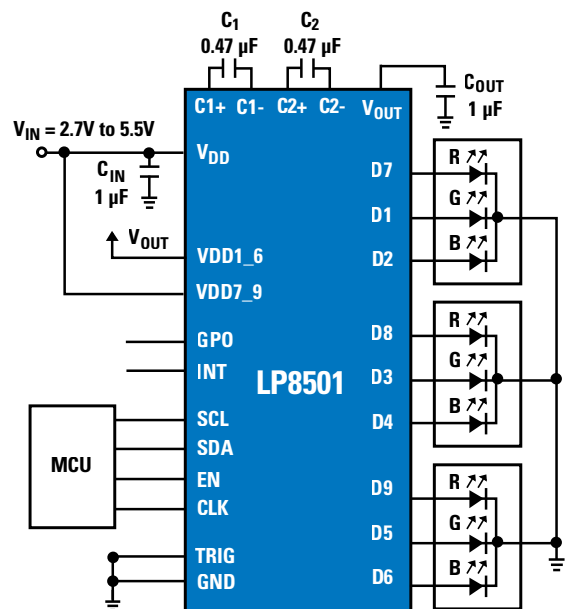
#### Features

- Three independent program execution engines for user-defined programs with large SRAM memory for storing lighting programs
- 9 programmable-source (high-side) driver outputs with 25.5 mA full-scale current, 8-bit current setting resolution, and 12-bit PWM control resolution
- Flexible grouping possibility for all 9 outputs including GPO into three groups with group PWM and fade-in/fade-out controls
- Built-in LED test
- Adaptive charge pump with 1x and 1.5x gain provides up to 95% LED drive efficiency and with soft-start and overcurrent/short-circuit protection
- Automatic power-save mode; IVDD = 10 µA (typical)

#### Applications

Ideal for use in fun and indicator lights, LED backlighting, haptic feedback, and programmable current source

LP8501 Typical Application Circuit



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

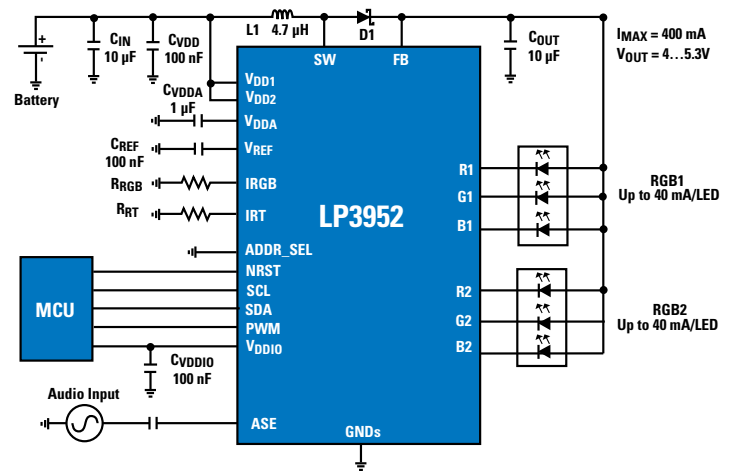
### Features

- Constant-current and PWM-controlled color LED drivers
- Up to 40 mA/output in constant-current mode, supports 50 mA/output in switch-mode control
- Complete audio synchronization for color/RGB LEDs with amplitude, frequency, and speed optimization
- Command-based lighting pattern generator for RGB LEDs
- I<sup>2</sup>C compatible bus interface
- Available in micro SMDxt-36 (3 x 3 x 0.65 mm)

### Applications

Ideal for use in cellular phones, PDAs, and MP3 players

LP3952 Typical Application Circuit



## Lighting Management Units

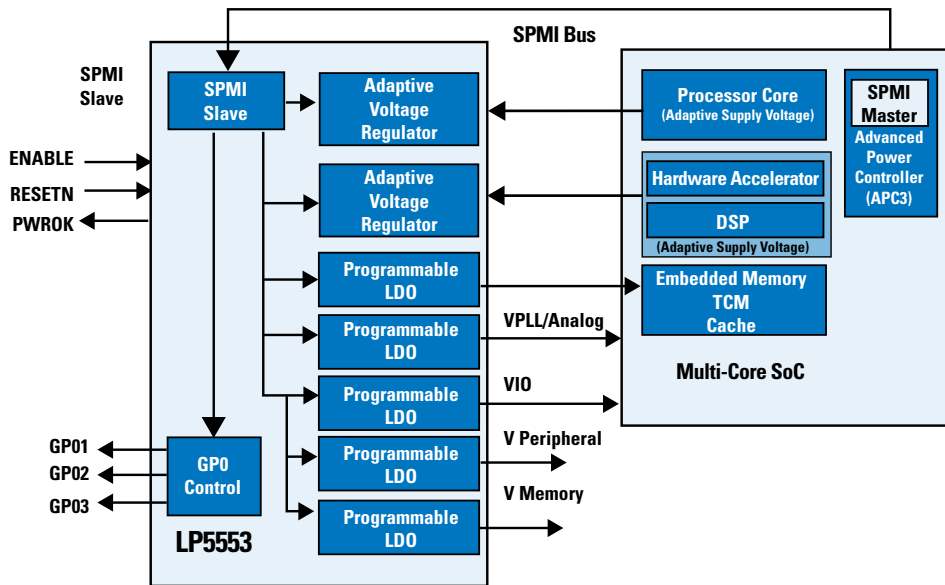
Product ID	V <sub>IN</sub> Range	Topology	Max Number LEDs	Flash Current	Autonomous Lighting Engine	Description	Packaging
LP3943	2.3 to 5.5	Parallel, inductive	16	—	—	LED controller for RGB/white/blue LEDs	LLP-24
LP3944	2.3 to 5.5	Parallel, inductive	8	—	—	LED controller for RGB/white/blue LEDs	LLP-24
LM2755	2.7 to 5.5	Parallel, charge pump	3	—	✓	3-channel charge pump LED controller with I <sup>2</sup> C compatible bus interface	micro SMD-18
LP3950	3.0 to 7.2	Parallel, inductive	6	—	—	Color-LED driver with audio sync	Laminate TCSP-32
LP3952	3.0 to 5.5	Parallel, inductive	6	—	—	6-channel color LED driver with audio synchronization	micro SMD-36 or micro SMDxt-36
LP39542	3.0 to 5.5	Parallel, inductive	13	400 mA	—	Lighting management unit for 4+2 white LEDs, 2 sets RGB LEDs with audio sync and pattern control, and a flash LED driver	micro SMD-36 or micro SMDxt-36
LP3958	3.0 to 5.5	Series, inductive	13	—	—	Lighting management unit for controlling 4+2 white LEDs for main and sub display and 3 sets of white LEDs for keypad	micro SMD-25
LP5526	3.0 to 5.5	Series, inductive	5	150 mA	—	Lighting management unit with high-voltage boost converter with up to 150 mA serial flash LED driver	micro SMD-25
LP55271	3.0 to 5.5	Parallel, inductive	5	400 mA	—	LED driver for camera flash and 4 LEDs with I <sup>2</sup> C compatible programmability, connectivity test, and audio synchronization	micro SMD-30
LM4970	2.7 to 5.5	Parallel, inductive	3	—	—	LED controller with LED lighting effects synchronized to audio	LLP-14
NEW LP5521	2.7 to 5.5	Parallel, charge pump	3	—	✓	Fully programmable 3-channel color LED driver with advanced power save features	micro SMD-20
NEW LP5522	2.7 to 5.5	Series	1	—	✓	Autonomous single LED controller with one wire interface	micro SMD-6
NEW LP5523	2.7 to 5.5	Parallel, charge pump	9	—	✓	Fully programmable 9-channel LED driver with advanced power save features and 3 independent program execution engines	micro SMD-25
LP5524	2.7 to 5.5	Parallel	4	—	—	Parallel LED Driver with PWM brightness control	micro SMD-9
LP55281	3.0 to 5.5	Parallel, inductive	12	—	—	Quad RGB LED driver with boost converter and LED connectivity test	micro SMD-36 or micro SMDxt-36S
NEW LP8501	2.7 to 5.5	Parallel, charge pump	9	—	✓	Fully programmable 9-channel LED driver with advanced power save features	micro SMD-25

PowerWise® product

# Power Management

## Energy Management Units

### LP5553 – 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 (V)	Interface	Packaging
LP5550	4	1 Buck: 0.6V to 1.2V, 300 mA 3 LDOs: 0.6V to 3.3V, up to 250 mA	3.0 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
NEW LP5553	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	SPMI	micro SMD-36

PowerWise® product

PowerWise® Adaptive Voltage Scaling (AVS) technology is an advanced closed-loop technology for reducing active and standby energy consumption of digital processing engines and ASICs. Hardware Power Monitor (HPM) is designed into the digital engine together with an Advanced Power Controller (APC) to monitor the performance of the silicon based on process and temperature variation. Information is fed back to an Energy Management Unit (EMU) which then sets the voltage precisely according to the processor's needs. The AVS technology enables optimum energy management delivery to the processors, ASICs, and systems on a chip (SoCs), which maximizes overall system energy savings. AVS is suited to power-constrained applications such as portable devices, USB-powered peripherals, consumer electronics, and high-volume systems including data centers and cellular basestations. Anywhere an ASIC, processor, or SoC is used, designers can implement AVS.



# Power Management

## Power Management Units

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

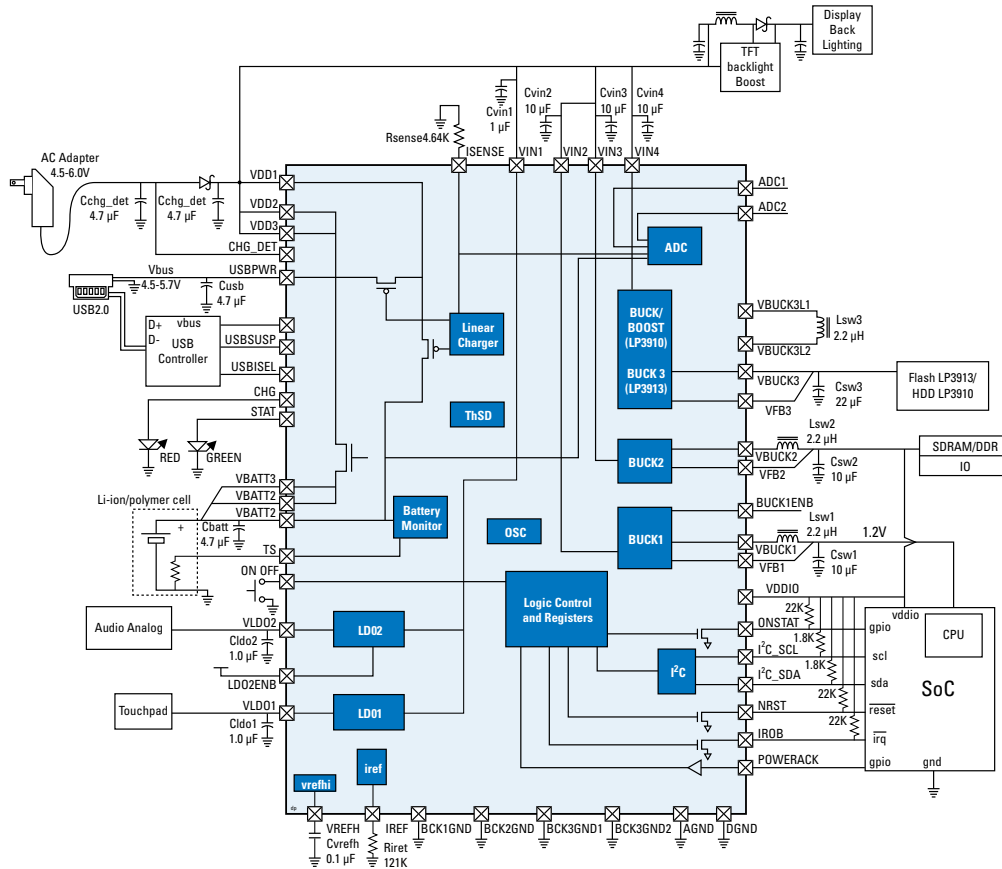
#### Features

- Wide load range buck-boost DC-DC converter (LP3910)
- Linear constant-current/constant-voltage charger for single cell Li-Ion batteries
- 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 bus interface
- USB and adapter charging with status indicator LEDs
- System power supply management including power routing

- Voltage and thermal supervisory circuits
- Continuous battery voltage monitoring
- LP3913 is pin-for-pin compatible with the LP3910
- Available in LLP-48 packaging (6 x 6 x 0.8 mm)

#### Applications

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



### Power Management Units for Applications Processors

Product ID	DC-DC 1 (mA)	DC-DC 2 (mA)	DC-DC 3 (mA)	LDO 1 (mA)	LDO 2 (mA)	LDO 3 (mA)	LDO 4 (mA)	LDO 5 (mA)	LDO 6 (mA)	Charger Current (mA)	Features	Packaging
LP3910	600	600	1000	150	150	—	—	—	—	1000	Dynamic voltage scaling	LLP-48
LP3913	600	600	500	150	150	—	—	—	—	1000	Dynamic voltage scaling	LLP-48
LP3970	650	650	—	100	1000	150	150	300	50	—	5 additional LDOs, back-up battery charger	LLP-48
LP3971	1600	1600	1600	300	150	150	150	370	30	—	Back-up battery charger	LLP-40
LP3972	11600	1600	1600	300	150	150	150	400	30	—	Back-up battery charger	LLP-40

# Power Management

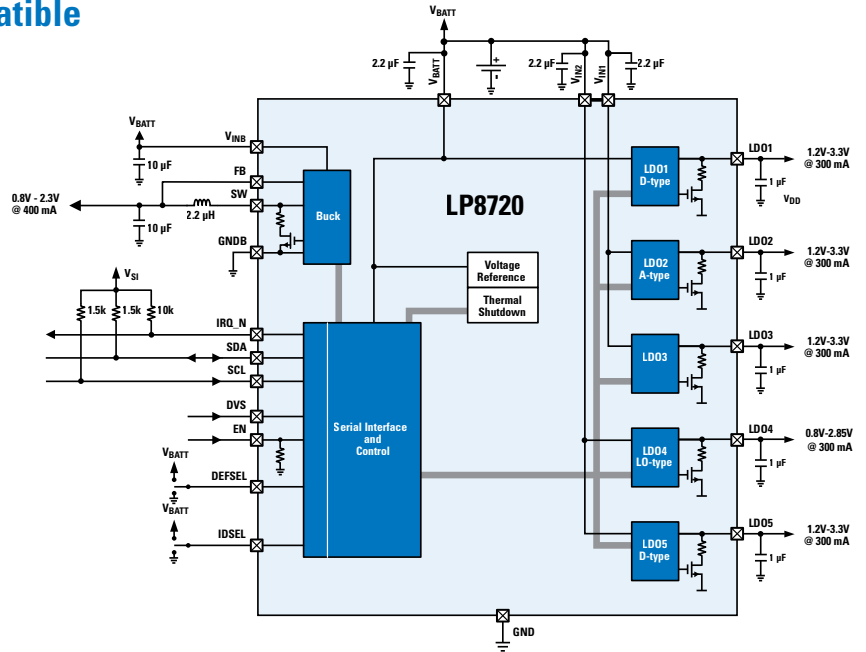
## Power Management Units

### LP8720 – One Step-Down DC-DC and Five Linear Regulators with I<sup>2</sup>C Compatible Bus Interface

#### Features

- 5 low-noise LDO's for up to 300 mA
- One high-efficiency synchronous magnetic buck regulator, I<sub>OUT</sub> 400 mA
- High-efficiency PFM mode at low I<sub>OUT</sub>
- Auto-mode PFM/PWM switch
- Low inductance 2.2 μH at 2 MHz clock
- Dynamic voltage scale control
- I<sup>2</sup>C compatible bus interface for the controlling of internal registers
- Available in micro SMD-20 packaging (2.5 x 2 mm)

LP8720 Typical Application Circuit



### Power Management Units for Multimedia Processors and Camera Modules

Product ID	DC-DC 1 (mA)	DC-DC 2 (mA)	LDO 1 (mA)	LDO 2 (mA)	LDO 3 (mA)	LDO 4 (mA)	LDO 5 (mA)	LDO 6 (mA)	LDO 7 (mA)	LDO 8 (mA)	LDO 9 (mA)	Charger Current (mA)	Packaging
<b>NEW</b> LP8720*	400	—	300	300	300	300	300	—	—	—	—	—	micro SMD-20
LP3906	1500	1500	300	300	—	—	—	—	—	—	—	—	LLP-24
LP3907	1000	600	300	300	—	—	—	—	—	—	—	External Power-on-reset	micro SMD-25, LLP-24

PowerWise® product

\*PowerWise dynamic voltage scaling

### Power Management Units for Cellular Baseband Processors

Product ID	DC-DC 1 (mA)	DC-DC 2 (mA)	LDO 1 (mA)	LDO 2 (mA)	LDO 3 (mA)	LDO 4 (mA)	LDO 5 (mA)	LDO 6 (mA)	LDO 7 (mA)	LDO 8 (mA)	LDO 9 (mA)	Charger Current (mA)	Packaging
LP3917**	800	600	300	300	300	150	150	150	150	150	80	—	micro SMDxt-49
LP3918	—	—	300	300	150	150	150	80	80	—	—	950	micro SMD-25
LP3919**	800	600	300	300	300	300	300	300	300	300	300	1200	micro SMDxt-49
LP3921*	—	—	300	300	150	150	150	80	80	—	—	950	LLP-32

PowerWise® product

\* Integrated audio power amplifier

\*\* Integrated USB transceiver

# Power Management

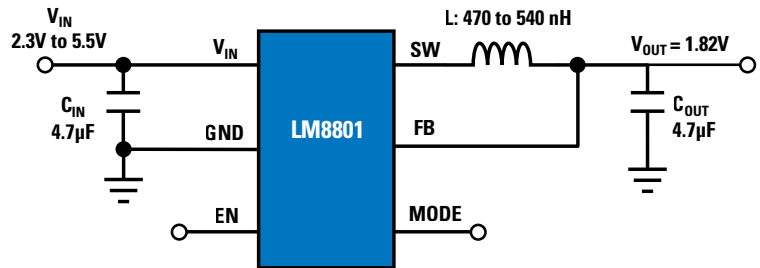
## Switching DC-DC Voltage Regulators

### LM8801 – PowerWise® High-Precision, 6 MHz, 600 mA Synchronous Step-Down DC-DC Converter

#### Features

- Over 90% efficiency at 6 MHz operation
- 600 mA maximum load capability
- 6 MHz PWM fixed switching frequency (typical)
- 27  $\mu$ A (typical) quiescent current in PFM mode
- Wide input voltage range: 2.3V to 5.5V
- $\pm$ 1.5% DC output voltage precision over temperature
- Best-in-class load transient response
- Low output ripple in PFM mode
- Automatic PFM/PWM mode switching
- Current overload and thermal shutdown protection
- Internal soft-start
- Total solution size < 7 mm<sup>2</sup> with thin micro SMD-6 packaging

#### LM8801 Typical Application Circuit



#### Applications

Ideal for mobile phones, MP3 players, wireless LAN, PDAs, pocket PCs, and portable hard disk drives

### High Switching Frequency Single Buck Regulators ( $F_{sw} \geq 2$ MHz)

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Output Current (mA)	Frequency Range (KHz) & Sync	On/Off Pin	PWM Mode	Packaging
<b>NEW</b> LM8801	5.5	2.3	1.79	1.84	600	6000	✓	PWM, Auto PFM PWM	micro SMD-6
<b>NEW</b> LM34917A	33	8.0	2.5	30	1250	2000	✓	Constant on-time	micro SMD-12
<b>NEW</b> LM34930	30	8.0	2.5	30	1000	up to 2000	—	Constant on-time	micro SMD-12
LM2830	5.5	3.0	0.6	4.5	1000	1600, 3000	✓	Current	SOT23-5, LLP-6
LM2831	5.5	3.0	0.6	4.5	1500	550, 1600, 3000	✓	Current	SOT23-5, LLP-6
LM2832	5.5	3.0	0.6	4.5	2000	550, 1600, 3000	✓	Current	LLP-6, eMSOP-8
<b>NEW</b> LM2833	5.5	3.0	0.6	4.5	3000	1500, 3000	✓	Current	LLP-10, eMSOP-10
LM2734/Z	20	3.0	0.8	18	1000	550, 1600/3000	✓	Current	SOT23-6
LM3671	5.5	2.7	1.1	3.3	600	2000	✓	Voltage with input feedforward	SOT23-5, LLP-6, micro SMD
LM3673	5.5	2.7	1.1	3.3	350	2000	✓	Voltage with input feedforward	micro SMD-5
LM3674	5.5	2.7	1.0	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	✓	Voltage with input feedforward	micro SMD-5
LM3678	5.5	2.5	0.8	3.3	1500	3300	✓	PWM only	LLP-10
LM3679	5.5	2.5	1.2	1.8	350	3000	✓	Auto	micro SMD-5
LM3686*	5.5	2.7	0.7	3.0	900	2400, 3400	✓	Auto	micro SMD-12
LM3691	5.5	2.3	0.75	1.8	1000	4000	✓	Voltage with input feedforward	micro SMD-6








PowerWise® product


\*includes 1 LILO LDO (350 mA) and 1 general purpose LDO (300 mA)

# Power Management



## Switching DC-DC Voltage Regulators

### Single Output Buck Regulators (Fsw <2 MHz)

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Output Current (mA)	Frequency Range (KHz) and Sync	On/Off Pin	PWM Mode	Packaging
LM3661	5.5	2.7	1.05	1.4	450	600	✓	Current	micro SMD-10
LM34910/C	36/50	8.0	2.5	33/45	1250	1000	✓	Constant on-time	LLP-10
LM34914	40	8.0	2.5	37	1250	1300	✓	Constant on-time	LLP-10
LM34919 	40	8.0	2.5	35	600	1600	✓	Constant on-time	micro SMD-10
LM2852 	5.5	2.85	0.8	3.3	2000	500, 1500	✓	Voltage	eTSSOP-14
LM2853 	5.5	3.0	0.8	3.3	3000	550	✓	Voltage	eTSSOP-14
LM2854 	5.5	2.95	0.8	VIN	4000	500, 1000	✓	Voltage	eTSSOP-16
LM2736	18	3.0	1.25	16	750	550, 1600	✓	Current	SOT23-6
LM2738	20	3.0	0.8	18	1500	500, 1600	✓	Current	LLP-8, eMSOP-8
 LM2841	42	4.5	0.765	34	300	550, 1250	✓	Current	TSOT-23
 LM2842	42	4.5	0.765	34	600	550, 1250	✓	Current	TSOT-23
LM3670 	5.5	2.5	0.7	3.3	350	1000	✓	Voltage with input feedforward	SOT23-5




 PowerWise® product

### Dual-Output Buck Regulators

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Output Current (mA)	Frequency Range (KHz) and Sync	On/Off Pin	PWM Mode	Packaging
LM3370 	5.5	2.7	1.0	3.3	600 per channel	1500, 2000	✓	Voltage	LLP-16, micro SMD-20
LM26400Y	3.0	20	0.6	16	2000 per channel	520	✓	Current	LLP-16, eTSSOP-16
 LM26420	5.5	3.0	0.8	4.5	2000	550, 2200	✓	Current	LLP-16, eTSSOP-16


 PowerWise® product


### Boost Regulators

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Switch Current (mA)	Frequency Range (KHz) and Sync	On/Off Pin	PWM Mode	Packaging
LM2731 	14	2.7	1.23	22	1.5	600, 1600	✓	Current	SOT23-5
LM2733 	14	2.7	3.0	40	1.0	600, 1600	✓	Current	SOT23-5
LM2735 	5.5	2.7	3.0	24	2.25	475, 1500	✓	Current	SOT23-5, MSOP-8, LLP-6

 PowerWise® product

### Buck-Boost Regulators

Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output Min (V)	Output Max (V)	Max Output Current (mA)	Frequency Range (KHz) and Sync	On/Off Pin	PWM Mode	Packaging
LM3668 	5.5	2.5	3.0, 2.8	3.3, 5.0	1000	1600 to 2700, Sync	✓	Voltage	LLP-12

 PowerWise® product

# Power Management

## Low-Noise Low-Dropout Regulators




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


Product ID	Output Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Dropout Voltage (V)	Output Voltage (V)	Adjustable Output	On/Off Pin	Quiescent Current (mA)	PSRR (dB)	Voltage Noise ( $\mu\text{V}_{\text{RMS}}$ )	Packaging
LP3995	150	6.0	2.5	0.06	1.9, 2.8, 3.0	—	—	0.085	60	25	micro SMD-5, LLP-6
LP3997	250	6.0	2.0	0.14	3.3	—	✓	0.055	61	100	MSOP-8
LP3999	150	6.0	2.5	0.06	1.5, 1.8, 2.4, 2.5, 2.8, 3.3	—	—	0.085	60	30	micro SMD-5
LP5900	150	5.5	2.5	0.08	1.5, 2.8, 3.3	—	—	0.025	75	6.5	micro SMD-4
LP5990	200	5.5	2.2	0.15	0.8 to 3.6	—	—	0.03	55	60	micro SMD-4
<b>NEW</b> LP8900	200	5.5	1.8	0.11	1.2 to 3.6	—	✓	0.085	75	6.0	micro SMD-6
LP3871/74	800	7.0	2.5	0.24	1.8 to 5.0	✓	✓	5.0	73	150	TO-263-5, SOT-223-5, TO-220-5
LP3878	800	16	2.5	0.475	1.0 to 5.5	✓	✓	0.18	60	18	LLP-8, PSOP-8
LP3879	800	6.0	2.5	—	1.2, 1.0	—	✓	0.2	60	18	LLP-8, PSOP-8

### Multi-Output LDOs


Product ID	Input Max Voltage (V)	Input Min Voltage (V)	Output 1 $V_{\text{OUT,Min}}$ (V)	Output 2 $V_{\text{OUT,Min}}$ (V)	Output 1 $I_{\text{OUT,Max}}$ (mA)	Output 2 $I_{\text{OUT,Max}}$ (mA)	Dropout Voltage (V)	Quiescent Current (mA)	Error Flag	Power on Reset	Packaging
<b>NEW</b> LP8900	5.5	1.8	1.2	1.2	200	200	0.11	0.085	—	—	micro SMD-6
LP3986	6.0	2.5	2.5	2.8	300	150	0.06	0.115	—	—	micro SMD-8
LP3996	6.0	2.0	0.8	0.8	150	300	0.21	0.035	✓	✓	LLP-10
LP5996	6.0	2.0	0.8	0.8	150	300	0.21	0.035	—	—	LLP-10
LP2966	7.0	2.7	1.8	1.8	150	150	0.135	0.34	✓	—	LLP-16, PSOP-8, SO-8
LP2967	16	2.1	1.8	2.5	150	150	0.275	0.2	—	—	micro SMD-8, MSOP-8

### Low-Iq LDOs

Product ID	Output Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Dropout Voltage (V)	Quiescent Current (mA)	On/Off Pin	Output Voltage (V)	Packaging
LP3981	300	6.0	2.7	0.132	0.07	✓	2.5, 2.7, 2.8, 2.83, 3.03, 3.3	LLP-6, MSOP-8
LP3982	300	6.0	2.5	0.12	0.09	✓	1.8, 2.5, 2.82, 3.3, Adj	LLP-8, MSOP-8
LP3983 	5.0	6.0	2.5	—	0.014	✓	1.6, 2.5	micro SMD-5
LP3984	150	6.0	2.5	0.06	0.08	✓	1.5, 1.8, 3.1	micro SMD-4, SOT23-5
LP3985	150	6.0	2.5	0.06	0.085	✓	2.5, 2.8, 3.0, 3.3, 4.7, 5.0	micro SMD-5, SOT23-5
LP3987 	150	6.5, 6.0	$V_{\text{OUT}} + 0.2$	0.06	0.085	✓	2.5, 2.6, 2.8, 2.85, 3.0	micro SMD-5
LP3988	150	6.0	2.5	0.08	0.085	✓	1.85, 2.5, 2.6, 2.85, 3.0	micro SMD-5, SOT23-5
LP3990	150	6.0	2.0	0.06	0.043	✓	0.8, 1.2, 1.35, 1.5, 1.8, 2.5, 2.8	micro SMD-4, SOT23-5, LLP-6
LP3991 	300	3.6	1.65	0.075, 0.8	0.05	✓	0.8, 1.2, 1.3, 1.5, 1.8, 2.5, 2.8, 3.0	micro SMD-4

 PowerWise® product

### Low-Input/Low-Output LDOs

Product ID	Output Current (mA)	Input Max Voltage (V)	Input Min Voltage (V)	Dropout Voltage (V)	Output Voltage (V)	On/Off Pin	Packaging
LP5951 	150	5.5	1.8	0.029	1.3, 1.5, 1.8, 2.0, 2.5, 2.8, 3.0, 3.3	✓	SOT23-5, SC70-5
LP5952	350	4.5	0.9	0.061	0.7, 1.0, 1.2, 1.3, 1.4, 1.5, 1.6, 1.8, 2.0	✓	micro SMD-5

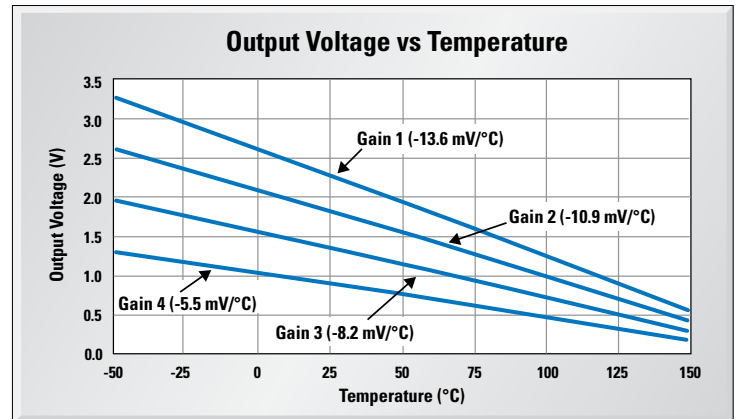
 PowerWise® product

# Thermal Management

## LM94021/22/23 – PowerWise® Low-Voltage, Low-Power 1.5 to 5.5V Analog Temperature Sensor

### Features

- Next-generation LM20
- Supply voltage 1.5V to 5.5V
- $\pm 1.5^{\circ}\text{C}$  temperature accuracy
- Four configurable gains for optimum sensitivity vs. supply and temperature
- Low 5.4  $\mu\text{A}$  quiescent current
- Wide temperature range of  $-50^{\circ}\text{C}$  to  $+150^{\circ}\text{C}$
- Short-circuit protected output
- New: LM94023 - micro SMD, dual gain
- Evaluation board available
- Available in SC-70 packaging



### Applications:

Ideal for use in low-voltage, battery-powered systems such as cellular phones, PDAs, MP3 players, and digital cameras

Product ID	Supply Current ( $\mu\text{A}$ )	Output Drive		Output	Packaging
		Source ( $\mu\text{A}$ )	Sink ( $\mu\text{A}$ )		
LM94022	5.4	50	50	Class AB	SC-70
<b>NEW</b> LM94023	5.4	50	50	Class AB	micro SMD

## LM26LV – PowerWise® 1.6V Lowest-Power, Factory-Preset Temperature Switch and Temperature Sensor

### Features

- Ultra-low supply voltage: 1.6V to 5.5V for all trip points
- Ultra-low supply current: 8  $\mu\text{A}$  (typical)
- Highest accuracy with temperature trip point accuracy of  $\pm 2.3^{\circ}\text{C}$  (0 to  $69^{\circ}\text{C}$ )
- $0^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  temperature trip point range,  $-50^{\circ}\text{C}$  to  $150^{\circ}\text{C}$  analog output temperature range
- Trip-test pin allows in-situation testing to verify connectivity and comparator function
- Analog output can be overdriven for trip point testing
- Push-pull and open-drain digital outputs in same packaging
- Buffered  $V_{\text{TEMP}}$  output drives external circuits, such as A/D converters
- $5^{\circ}\text{C}$  hysteresis
- Available in LLP-6 packaging (2.2 x 2.5 mm) (SC-70 footprint)

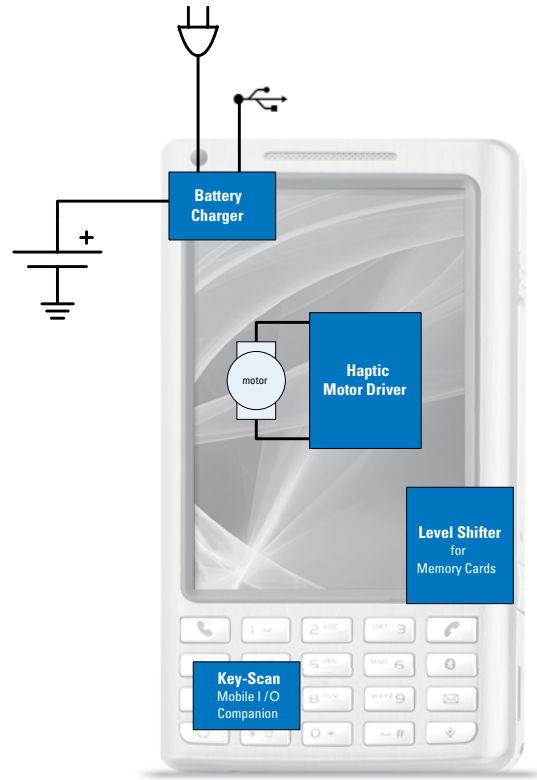
### Applications:

Ideal for use in consumer applications including notebooks and cell phones

Product ID	Key Features	Description
LM94023	1.5V to 5.5V, $\pm 1.5^{\circ}\text{C}$ accuracy, micro SMD	Lowest-power, ultra-low voltage analog temperature sensor
<b>NEW</b> LM26LV	1.6V to 5.5V, $\pm 2.3^{\circ}\text{C}$ , $-50^{\circ}\text{C}$ to $150^{\circ}\text{C}$ factory preset set point, LLP-6	Lowest-power analog temperature sensor
<b>NEW</b> LM26	2.7V to 5.5V, $\pm 3^{\circ}\text{C}$ , $-40^{\circ}\text{C}$ to $125^{\circ}\text{C}$ factory preset set point, SOT-23	Small, low-power analog temperature switch plus analog temperature sensor
LM27	2.7V to 5.5V, $\pm 3^{\circ}\text{C}$ , $120^{\circ}\text{C}$ to $150^{\circ}\text{C}$ factory preset set point, SOT-23	Small, low-power analog temperature switch plus analog temperature sensor
<b>NEW</b> LM57	2.4V to 5.5V, $\pm 1.5^{\circ}\text{C}$ accuracy, user-programmable set point, LLP-8	Low-power temperature switch plus analog temperature sensor
LM56	2.7V to 10V supply voltage, $\pm 3^{\circ}\text{C}$ accuracy, user programmable set point SOP-8, MSOP-8	Low-power temperature switch plus analog temperature sensor

PowerWise® product

# Specialty Products



## Battery Charger

Product ID	Full Charge $V_{MAX}$	Input Min. (V)	Input Max. (V)	Battery Cells	Chemistry	Charge Current (mA)	Charge Modes	On/Off Pin	Packaging
LM3658	4.2	4.35	6	1	Li-Ion or Li-Polymer	500 to 1000 (Wall) or 100 or 500 (USB)	Prequal, CC, CV, top-off, maintenance	✓	LLP-10

## Specialty Motor Drivers

Product ID	Description	Supply Voltage Range (V)	Quiescent Current	Wake up Time (ms)	Output Current $V_{DD} = 3V$ (mA)	Shutdown	Packaging
LM4570	Haptic motor driver	2.4 to 5.5	1.9 at 3V supply	2.4	192	✓	LLP-8
LM48556	Mono ceramic speaker driver	2.7 to 5.0	4.8 at 3.6V supply	0.5	—	✓	micro SMD-12

## Level Shifter

Product ID	Supply Voltage (V)	Level Transition (V)	On-Chip LDO	LDO Current (mA)	Frequency Options	ESD Protection	Packaging
LM3929	2.7 to 3.3	1.8 to 2.85 bidirectional	For SD card and card interface	200	25 MHz, 50 MHz	8 kV direct, 5 kV air	micro SMD-24

## Mobile I/O Companion Supporting Key-Scan, I/O Expansion, PWM, and ACCESS.bus Host Interface

Product ID	Max Keypad	Special Function	Key Debounce	GPIOs	External Interrupts	Input Min (V)	Input Max (V)	Host Interface Bus Speed	Special Features
LM8333	72	8	Yes	4	2	2.2	2.75	400 KHz	PWM outputs multiplexed

# Designer's Corner

## Designing Energy-Efficient Handheld Illumination Solutions

Portable battery sources are constantly challenged by the handheld applications' increasing functionality and power demands. By better understanding the applications' energy consumption, designers can produce energy-efficient solutions that will conserve battery life and provide a better end-user experience.

### Conserving Energy in Portable Displays

Display backlighting presents a significant energy challenge as handheld displays increase in size, resolution, and brightness. A typical small display module can require between three to ten LEDs for proper illumination.

To address the backlit display's energy consumption, one power-efficient method to drive LEDs is the switched capacitor. This technique connects the input voltage to a multiple-gain switched capacitor that produces a regulated output. The output voltage equals the gain multiplied by the input voltage during open loop operation. Closed loop operation enables a fixed output that should be slightly higher than the LED forward voltage and any voltage drop. The difference between output voltage and forward voltage is the headroom that needs to be monitored to ensure current flow. The switched capacitor remains in the most efficient gain over the widest input voltage consuming the least amount of energy through gain transitions that maintain regulation based on LED forward voltage and load requirements. Dual gain boost modes (1x and 3/2x for the LM2755 and LM2756; 2x and 3/2x for the LM2757) allow for the highest possible efficiency over a wide input voltage range resulting in longer battery life.

Consumer trends continue to dictate smaller portable devices, making PCB area much more valuable. The switched capacitor topology offers an added benefit as an inductor-less solution that saves on solution size and bill of materials. The LM2755, LM2756, and LM2757 are examples of switched capacitor boost technology that drive up to 10 LEDs (each driving up to 30 mA of diode current). This smaller solution provides the ability to place the driver in a local area, versus a central area, which reduces EMI.

Programmability of white LEDs is important to control display illumination. For example, when an end-user is having a conversation on a mobile phone, they are no longer interacting with the display, and the display has the option to dim. Both the LM2755 and LM2756 include an I<sup>2</sup>C compatible interface that controls the display illumination based on handset operation.

**Figure 1** shows the 32 exponential dimming step settings with an 800:1 dimming ratio which enables true perceived linear brightness level control and a dimming profile that leads to a smooth on/off display transition. The human eye is a logarithmic

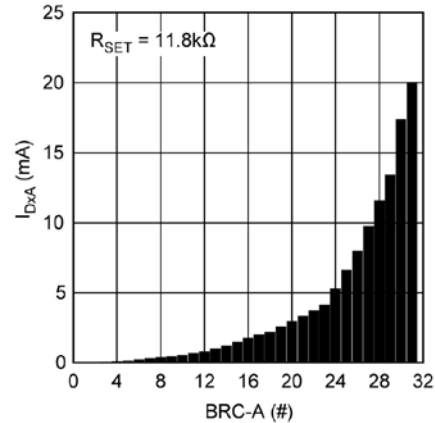


Figure 1. 32 Exponential Brightness Levels

detector as it responds to light in terms of equal ratios rather than equal increments. What is recognized to be the linear augmentation of brightness is in reality exponential. By allowing the backlight to be dimmed or turned off, the designer gains flexibility and the ability to save battery life.

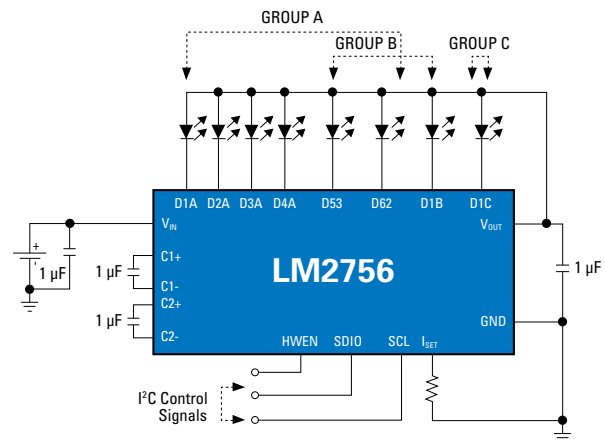


Figure 2. LM2756 Typical Application Circuit

**Figure 2** is a typical application circuit of the LM2756. The LM2756 drives 8 LEDs separated in three independently controlled groups for multiple display purposes. The following equation configures the LED current levels:

$$I_{DxA/B/C} (A) = 189 \times (V_{ISET} / R_{SET})$$

With a properly selected resistor ( $R_{SET}$ ) placed between  $I_{SET}$  and GND, the desired level of current can be passed through the LEDs connected to  $DxA$  and  $DxB$ , where  $x$  is a number referring to the particular LED current sink and  $A$ ,  $B$ , and  $C$  refers to the particular group of LEDs.



Once the current level is set, analog current scaling internally dims the LEDs using the I<sup>2</sup>C compatible interface. The 32 exponential analog brightness levels shown in **Figure 1** can be configured for the LEDs in Group A, while LEDs in Group B and Group C can handle 8 linear analog brightness levels.

With the ability to separately control several groups of LEDs, a single LED driver can control a main display, a secondary sub-display or keypad LEDs, and an indicator LED. The LM2756 integrates these features by incorporating eight current sinks and dividing them into three groups. Four current sinks are comprised in Group A, while Group B and Group C have one current sink each. By manipulating a register, two extra sinks (D53 and D62) are available for either Group A or Group B. This allows 4, 5, or 6 LEDs to be used for the main display, leaving extra LEDs for additional lighting features.

## Peripheral Lighting

Personal mobile devices have greater illumination needs than just the main display. Supplemental LEDs are required for further lighting functions consuming more battery energy. Keypad lighting is an important characteristic of handheld applications that does not require as much LED current matching as current-sourced main display backlighting drivers. The LM2757 provides the smallest switched capacitor, voltage-sourced, boost solution to illuminate keypad LEDs with up to 90% efficiency. Indicator LEDs alert end-users of low battery, battery charging activity, and incoming messages. These LEDs can also be used in fun-lighting applications.

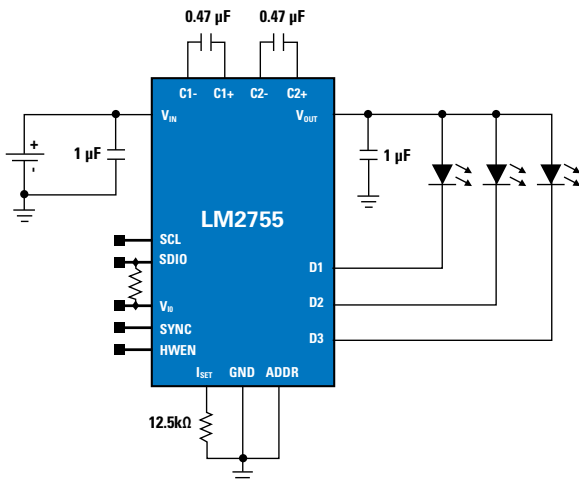


Figure 3. LM2755 Typical Application Circuit

With three independent RGB LED outputs, the LM2755 permits programmable blinking patterns, via I<sup>2</sup>C compatible interface, for each output enabling multiple zone lighting.

For indicator and cosmetic lighting purposes, LEDs usually require a generated pattern. The LM2755, shown in **Figure 3**, allows the designer to program a trapezoidal dimming waveform to independently control each output. The following equations calculate the durations of the delay, rise, fall, high, and low times shown on the waveform in **Figure 4**:

$T_{STEP} = 50\mu s \times 2^{(N+1)}$  if using the internal clock  
 or  $T_{STEP} = (1/f_{PWM}) \times 2^{(N+1)}$  if using the external clock on the SYNC pin

$$t_{rise/fall\ Total} = T_{STEP} \times (n_{high} - n_{low}) \times n_{Trise/fall},$$

where  $0 \leq n_{Trise/fall} \leq 255$

$$t_{rise\ or\ fall\ Total} = 50\mu s \times (n_{high} - n_{low}),$$

where  $n_{Trise/fall} = 0$

$$t_{high\ or\ low} = T_{STEP} \times (n_{high/low} + 1),$$

where  $0 \leq n_{Thigh/low} \leq 255$

$$t_{delay} = T_{STEP} \times n_{delay},$$

where  $0 \leq n_{delay} \leq 255$

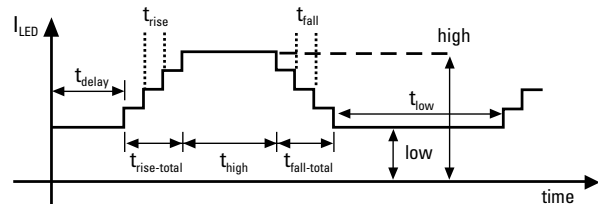


Figure 4. LM2755 LED Timing Control

The variables  $n_{Trise}$ ,  $n_{Tfall}$ ,  $n_{Thigh}$ , and  $n_{Tlow}$  are numbers between 0 and 255 while  $n_{high}$  and  $n_{low}$  are selected numbers between 0 and 31 that become the brightness level boundaries when the dimming waveform enable bits are set to '1'. N is a number from 0 to 7 that is stored in the Time Step register. The PWM modulating signal period,  $f_{PWM}$ , is set to a default value of 50  $\mu s$ . If using an external clock, this signal period becomes:  $f_{PWM} = f_{SYNC}/32$ . The custom waveforms only need to be programmed once for each output. After the values have been set, the I<sup>2</sup>C compatible interface toggles start and stop times for the lighting pattern. Timing control features, like the one found in the LM2755, are an ideal tool for any peripheral lighting needs.

# Designer's Corner

## Designing Energy-Efficient Handheld Illumination Solutions

### Enabling New Display Technologies

Efficient power conversion for white LEDs provides diminishing returns. Designing towards organic LED (OLED) displays can solve a designer's energy problems. Normal LCD displays rely on white LED backlighting, while OLED displays rely on each pixel to directly produce light, making colors more vibrant. OLED displays conserve more energy by illuminating the display without a backlight. To do this, every pixel is turned on and off as needed by circuitry controlling each column of pixels. A pixel can contain one diode for monochromatic displays, or three diodes (red, green, and blue) for full-color displays. Unlike LCD display modules, the diodes are embedded within the OLED display module. In the case of Passive Matrix OLED (PMOLED) displays, the power supply is used to pre-charge an entire row of pixels, usually with voltages beyond the normal 5V. The amount of voltage applied depends on the number of pixels in each row or the size of the OLED display panel.

**Figure 5** shows the LM4510 OLED driver which offers currents between 80 mA and 280 mA, and voltages between 5V and 18V from a Li-Ion battery input. This switching regulator provides a small energy efficient solution by maximizing power efficiency up to 85% and eliminating an external Schottky diode. Smart solutions like the LM4510 pave the way for next-generation technologies in portable media devices.

Consumers continue to demand greater media-centric functionality from their portable handheld devices, including high-quality video, audio, and other media-rich features, without sacrificing size or battery life. To meet this challenge, designers must develop innovative solutions that conserve energy and deliver the cutting-edge performance and design consumers have grown to expect from their portable handheld devices.

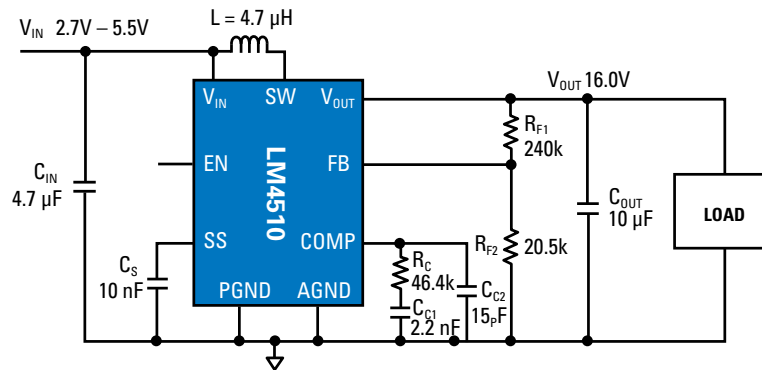


Figure 5. LM4510 Typical Application Circuit

# Design Tools

## Resources for Next-Generation Design



Design, build, and test analog circuits in this online design and prototyping environment.

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



Register to receive updates on the products and technical topics that interest you—spam-free!

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



Expand your knowledge and understanding of analog with our free online educational training tool.

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



Published bi-monthly, the Power Designer technical articles cover key power design tips and techniques for today's design engineers.

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



Published bi-monthly, the Signal Path Designer technical articles cover analog signal path tips and techniques for today's design engineers.

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



National's monthly analog design technical journal.

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



Easy, natural-language online search engine provides quick access to products and technical information.

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



Tune in to learn technical energy-saving tips, hosted by National's PowerWise® Technologist, Richard Zarr, and streamed 24/7 on the web.

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

### Tools for Energy-Efficient Designs

Access white papers, reference designs, and application notes on PowerWise® products and systems.

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

### Parametric Catalog and Search

Search for desired product folder, product database by attributes of interest.

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

### Application Solutions

Access over 100 dynamic diagrams for medical systems, consumer electronics, communications, and many more applications.

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

### Application Notes

Access hundreds of application notes on a variety of design topics from product to end application-specific app notes.

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

### FPGA Design Guides

These design guides feature National device solutions by part number for different FPGA manufacturers, including Xilinx and Altera.

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

### Document Library

Find end market solutions and products using National's Solutions Guides.

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

# Worldwide Design Centers and Manufacturing Facilities



- Design Centers
- Manufacturing Facilities

## Design Centers

### USA:

Chandler, Arizona  
Federal Way, Washington  
Fort Collins, Colorado  
Grass Valley, California  
Indianapolis, Indiana  
Longmont, Colorado  
Norcross, Georgia  
Phoenix, Arizona  
Salem, New Hampshire  
Santa Clara, California  
South Portland, Maine  
Tucson, Arizona

### EUROPE:

Delft, Netherlands  
Unterhaching, Germany  
Greenock, Scotland  
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  
South Portland, Maine  
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 Fürstenfeldbruck  
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)

