Industrial and Outdoor (>15W)

AC/DC
- PFC+ Flyback or LLC or HB
- Multi-String/Single-String
- Multi-Transformer for HV LEDs

DC/DC
- Products and Features

Industrial and Outdoor/Infrastructure Lighting LED Driver Solutions
(15W to 250W Applications)

Key Factors
- PFC
- High Efficiency
- Dimming
- Early Payback (low cost)
- Uniform Intensity
- Safety
- Low Maintenance
# Different Power Configurations

<table>
<thead>
<tr>
<th>Applications</th>
<th>Power Level</th>
<th>Primary Topology (AC/DC)</th>
<th>Devices</th>
<th>Output</th>
<th>Secondary Topology</th>
<th>Devices</th>
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<tbody>
<tr>
<td></td>
<td>Downlight Commercial</td>
<td>15 - 50W</td>
<td>Flyback</td>
<td>UCC28810/1 + TPS22210 + LM3444/40/48</td>
<td>Current</td>
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<td>UCC28810/1 + TPS22210 + LM3444/40/48</td>
<td>Current</td>
<td>Linear</td>
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<td>UCC28810/1 + TPS22210 + LM3444/40/48</td>
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<td>Linear</td>
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<td>Outdoor Industrial Infrastructure</td>
<td>&gt;50W</td>
<td>PFC Boost + Buck + LLC</td>
<td>UCC28810 + TPS22210 + LM3444/40/48</td>
<td>Current</td>
<td>Multi-Transformer</td>
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<td></td>
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<td>UCC28810 + TPS22210 + LM3444/40/48</td>
<td>Current</td>
<td>Multi-Transformer</td>
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<td>Current</td>
<td>Linear</td>
<td>LM3465</td>
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<td>UCC28810 + TPS22210 + LM3444/40/48</td>
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<td>Linear</td>
<td>LM3443</td>
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<td>UCC28810 + TPS22210 + LM3444/40/48</td>
<td>Voltage</td>
<td>Buck</td>
<td>TPS925xx / LM3444</td>
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<td></td>
<td>PFC Boost + LLC</td>
<td>UCC28810 + TPS22210 + LM3444/40/48</td>
<td>Voltage</td>
<td>Buck</td>
<td>UCC28811</td>
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<tr>
<td></td>
<td></td>
<td>PFC Boost + Buck + LLC</td>
<td>UCC28810 + TPS22210 + LM3444/40/48</td>
<td>Voltage</td>
<td>Buck</td>
<td>UCC28811</td>
</tr>
</tbody>
</table>

## 15-50W Output Power

- Downlight Commercial
  - 15 - 50W flyback: UCC28810/1, TPS22210, LM3444/40/48
  - UCC28810/1, TPS22210, LM3444/40/48, LM3450A

- Outdoor Industrial Infrastructure
  - >50W PFC Boost + Buck + LLC: UCC28810, TPS22210, LM3444/40/48
  - UCC28810, TPS22210, LM3444/40/48, LM3450A
  - UCC28810, TPS22210, LM3444/40/48, LM3466

- UCC28810, TPS22210, LM3444/40/48, LM3450A

- UCC28810, TPS22210, LM3444/40/48, LM3463

- TPS925xx / LM3444

- UCC28811
LED Lighting Power Configurations

PFC Flyback

Supply with PFC Flyback (current regulation) directly drives LED String(s)

Benefit:
• Simplest method for achieving PFC and driving LEDs

Drawbacks:
• LED will have full rectified LF output current ripple (dependent on output caps)
• No control over current sharing of the various LED strings

Direct Drive Solution
(Example using UCC28810)

Comments – 120/100Hz ripple into LEDs. Short/Open LED fault difficult to manage. Lowest cost with performance implications.
**LED Lighting Power Configurations**

**PFC Flyback + Linear Regulator**

Supply with PFC Flyback (voltage regulation) + Linear Regulator

- **PFC Stage**: Required in any implementation
- **Linear Stage**: Provides constant current and reduced LF ripple
  - LM3464 provides Dynamic Headroom Control

**Benefit:**
- Linear Regulator reduces system EMI compared to multi-buck implementation
- Dynamic Headroom control regulates flyback output voltage for optimized VLED
- Individual String dimming

**Drawbacks:**
- System efficiency could be reduced
- Depending on design LF current ripple could be present on LEDs

**LM3464 Dynamic Headroom Control**

- **Ti Controller Offline AC/DC converter**
- **LM4644 LED driving stage**

**Comments** – Depending on design may/may not have 120/100Hz ripple into LEDs. Short/Open LED easily managed. No increased EMI signature due to added regulators. Balance of cost vs performance. Thermal management, PWM/Analog Dimming options. Good efficiency. More difficult to design.
LED Lighting Power Configurations
PFC Flyback + Linear Regulators

Supply with PFC Flyback (current regulation) + Linear Regulators

- **PFC Stage** -> Required in any implementation
- **Linear Stage** -> Provides constant current and reduced LF ripple
  - LM3466 provides current equalization between strings

**Benefit:**
- Linear Regulator reduces system EMI compared to multi-buck implementation
- Current Equalizer shares LED current ratio-metrically in case of LED open

**Drawbacks:**
- System efficiency could be reduced
- Depending on design LF current ripple could be present on LEDs

---

Dynamic Current Equalizer
(Example using UCC28810 & LM3466)

- **Comments** – 120/100Hz ripple into LEDs. Short/Open LED easily managed. No increase in EMI signature. Slight increase in cost over direct drive solution. Well regulated current through multiple strings of LEDs.
LED Lighting Power Configurations
PFC Flyback + Buck Controller/Converter

Supply with PFC Flyback (voltage regulation) + Buck Controller/Converter

**Benefit:**
- Simplest method for achieving PFC
- LEDs have constant DC current

**Drawbacks:**
- Addition cost of Buck + FET + Inductor + Diode per string

AC/DC with DC/ILED Driver (Two Stage)
(Example using UCC28810 and LM3409)

**Comments** – No 120/100Hz ripple into LEDs. Short/Open LED easily managed. Increased EMI signature due to added regulators. Increased cost of regulators.
>50W Output Power

LED Lighting Power Configurations

PFC Boost + Buck Controller/Converter

Supply with PFC Flyback (voltage regulation) + Buck

- Bridge Rectifier and Input Bridge
- PFC Boost Controller
- Buck Controller or Converter

PFC Stage -> Required in any implementation
DC-DC Stage -> Provides constant current and reduced LF ripple

Benefit:
- LEDs have constant DC current with no LF ripple
- Can drive high number of LEDs in a single-string

Drawbacks:
- Addition cost of Buck + FET + Inductor + Diode
- Non-Isolation Design
### UCC28810EVM-002 Block Diagram

1st stage: TM Boost for PFC

2nd stage: TM Buck for LED current

### Applications

- LED Street & Roadway Lighting
- LED High Bay Industrial Lighting
- DTV LED backlighting

### UCC28810EVM-002 Specification

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
<th>Unit</th>
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</thead>
<tbody>
<tr>
<td>Input Voltage</td>
<td>90-264 VAC</td>
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<td>LED Configuration</td>
<td>17-34 Series</td>
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<tr>
<td>Output Current</td>
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<td>Output Voltage</td>
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<td>Output Power</td>
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<td>Topology</td>
<td>PFC Boost + TM Buck</td>
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<tr>
<td>Dimming Level</td>
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<tr>
<td>Current Sensing</td>
<td>Resistive</td>
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<tr>
<td>Isolation</td>
<td>2500 VAC</td>
<td></td>
</tr>
<tr>
<td>Driver Dimensions</td>
<td>264 x 51 mm</td>
<td></td>
</tr>
</tbody>
</table>

- Universal input non isolated design
- Regulated LED current
- PWM Dimming, 200Hz to 1kHz
- High Efficiency
- Active power factor correction
LED Lighting Power Configurations

PFC Boost + LLC + Linear Regulator

Supply with PFC Boost + LLC (voltage regulation) + Multi-String Linear Regulator

- PFC Stage -> Required in any implementation
- LLC -> High-Efficiency at higher power levels
- Linear Regulator -> LM3464 provides Dynamic Headroom Control

Benefit:
• Linear Regulator reduces system EMI compared to multi-buck implementation
• Dynamic Headroom regulates LLC Controller output voltage for optimized VLED
• Individual String dimming

Drawbacks:
• System efficiency could be reduced
**LED Lighting Power Configurations**

**PFC Boost + LLC + Buck Converters/Regulators**

Supply with PFC Boost + LLC (voltage regulation) + Multi-String Buck Regulator

- **Bridge Rectifier**
- **PFC Boost Controller**
- **LLC Controller**
- **Half Bridge**
- **Buck Controller or Converter**

**PFC Stage** -> Required in any implementation
**LLC** -> High-Efficiency at higher power levels
**Buck Regulator** -> Provides constant current and reduced LF ripple

**Benefit:**
- High system efficiency
- Individual String dimming

**Drawbacks:**
- Addition cost of Buck + FET + Inductor + Diode needed for each string

---

**LED Lighting Power Configurations**

**PFC Boost + Buck + HB + Multi-Transformers**

Supply with PFC Boost + Buck (current regulation) + HB + Multi-Transformer (3-Stage)

- **Bridge Rectifier**
- **PFC Boost Controller**
- **Buck Controller or Converter**
- **LLC Controller**
- **Half Bridge**
- **Transformer**

**PFC Stage** -> Required in any implementation
**Low Side Buck** -> Provides constant LED Current and main control
**LLC** -> High-Efficiency at higher power levels
**Series Transformers** -> Provides same current to each LED string

**Benefit:**
- One control section for all string currents,
- Lower part count, higher reliability and lower cost

**Drawback:**
- All strings will be dimmed simultaneously (if individual dimming is required)
UCC28810EVM-003 - SIMPLEDrive™
Series Input, Multiple Parallel Equivalent LED Drive (SIMPLEDrive)

1st stage: TM Boost for PFC
2nd stage: TM Buck for LED current
3rd stage: Resonant Current Half Bridge

>50W

Go to Evaluation Module (EVM) Product Folder

UCC28810EVM-003 Design Tool

>50W

Go to UCC2810EVM-003 Design Tool
UCC28810EVM-003 Specification

<table>
<thead>
<tr>
<th>Specification</th>
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<td>LED Configuration</td>
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<td>Series</td>
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<tr>
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<td>Output Voltage</td>
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<td>Output Power</td>
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<td>Topology</td>
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<td>Efficiency</td>
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<tr>
<td>Power Factor</td>
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<td>Dimming Input</td>
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<td>Current Sensing</td>
<td>Resistive</td>
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<tr>
<td>Isolation</td>
<td>2500 VAC</td>
<td></td>
</tr>
<tr>
<td>Driver Dimensions</td>
<td>369 x 51 mm</td>
<td></td>
</tr>
</tbody>
</table>

UCC28810EVM-003 using SIMPLEDrive

Efficiency

- VIN = 90V
- VIN = 115V
- VIN = 230V
- VIN = 264V

Load - % PWM Dimming

Efficiency - %
### UCC28810EVM-003 using SIMPLEDrive

**String Current Matching**

- Input Voltage - VRMS
- Output Current Matching
- Current Matching

![Graph showing current matching over input voltage range](image1.png)

### UCC28810EVM-003 Open String Protection

- If one string fails the other remain on.
- Each output incorporates a zener and SCR crowbar circuit: D2, SCR1, R1 and R2
- When string fails, zener voltage is exceeded and SCR latches on
- Transformer continues to deliver current to SCR and LED String #2

![Diagram of open string protection circuit](image2.png)

**Waveforms During Normal Operation**

![Waveform chart](image3.png)
**LED Lighting Power Configurations**

**PFC Boost + HB + Multi-transformers (PMP5660)**

Supply with PFC Boost + HB (current regulation) + Multi-Transformer (2-Stage)

- **PFC Stage** -> Required in any implementation
- **LLC** -> High-Efficiency at higher power levels
- **Series Transformers** -> Provides same current to each LED string

**Benefit:**
- One control section for all string currents with a two stage only power supply
- Lower part count, higher reliability and lower cost
- Very High efficiency

**Drawback:**
- All strings will be dimmed simultaneously

---

**LED Lighting Power Configurations**

**PFC Boost + HB + Multi-Transformers (PMP5660)**

---

**LED Lighting Power Configurations**

**PFC Boost + HB + Multi-Transformers (PMP5660)**

---
Test Results on PMP5660 reference design

- Tests performed @ 230Vac, 50Hz and 115Vac, 60Hz input voltage
- Variable number of LED connected: 7…14 LEDs, 700mA nominal
- Measured the unbalance between strings: one string kept @ 14 LEDs while the second connected to a 7…14 LEDs string
- PWM dimming at 200Hz, 18%...98%

Input current and voltage:

- No dimming, 115Vac, 60Hz
- 40% dimming, 115Vac, 60Hz
- 80% dimming, 115Vac, 60Hz
- 80% dimming, 230Vac, 50Hz
Efficiency and power factor vs. output power

Power factor vs. output power @ 230Vac and 115Vac, no dimming

Total efficiency vs. # of LEDs for each string, no dimming

String Current Regulation

Output current regulation (here +/-0.5%) with same # of LEDs for each string

>50W

Texas Instruments
String Current Unbalance

Output current unbalance (max -5.7%) on string #1 when on the string #2 is connected a variable # of LEDs

Portfolio Overview
UCC28810/1
LED Lighting Power Controller

**Features**
- Implements Single Stage Power Factor Correction
- Transformer Zero Energy Detection
- Transition Mode Control
- Application Circuit Implements Phase-Cut Dimming
- Advanced Transient Response, Accurate Internal Vref, Low Start Up Current, 750mA Gate Drive
- UVLO, Over-Voltage, and Open-Loop Detection

**Benefits**
- Meets Power Factor Correction Standards for Lighting Products
- High Efficiency, Low EMI Performance
- Compatible with Large Installed base of TRIAC Based Dimmers
- Improves Reliability and Life Time of Lighting Fixture
- Protects Against Faults and Abnormal Conditions

**Applications**
- AC Input General Illumination, HB LED Applications
- PFC Front-End for Multi-Stage Lighting Designs

TOOLS
- UCC28810EVM-001 (Universal, 25W)
- UCC28810EVM-002 (Universal, 100W), Multi-Stage (Design Calculator)
- UCC28810EVM-003 (Universal, 110W), Multi-Stage (Design Calculator)
TPS92210
PFC Offline LED Lighting Driver Controller

**Features**
- Flexible Operating Modes: Peak Primary Current, Constant On-Time, or both
- Cascoded MOSFET Configuration
- Works with TRIAC Dimmers
- Transformer Zero Energy Detection
- Discontinuous Conduction or Transition Mode Operation
- Advanced Over-Current Protection and Integrated Over-voltage Protection

**Benefits**
- Constant On-Time implements Single Stage Power Factor Correction (PFC)
- Fast start up; Line Surge Ruggedness Better Than Internal HV FET
- Continuous Exponential Dimming
- High Efficiency, Low EMI
- No Reverse Recovery Loss in Output Rectifier
- Protects Driver Against Fault Conditions

**Applications**
- Residential LED Lighting Drivers: A19 (E26/27, E14), PAR30/38, GU10
- Lighting Applications: Light Bulb Replacement, Sconces, Wall Washers, Architectural and Display Lighting, Commercial Troffers and Downlights

TOOLS
- TPS92210EVM-647 (110V)
- TPS92210EVM-613 (230V)
- Design Calculator

SimpLEDrive™ shown

TPS92020
Resonant-Switching Driver Controller for LED Lighting

**Features**
- LLC Resonant Switching Controller
- Half-Bridge Topology
- Fixed or Variable Switching Frequency Control
- Programmable Soft-Start
- Over-Temperature and Current Limit Protection
- Implements Ti SimpLEDrive™ Multi-String Topology

**Benefits**
- Zero Current Switching for High-Efficiency
- High Power (High Light Output) Lighting Applications
- Tune to Resonant Frequency of LLC for Higher Efficiency
- Provides Flexible Dimming Option
- Protects Against Faults and Abnormal Operating Conditions
- Transformer Scalable High Light Output Designs

**Applications**
- Commercial and Industrial LED Lighting Applications: High Bay, Street Lighting, Area Lighting

TOOLS
- UCC28810EVM-003 (Universal, 110W), Multi-Stage Design Calculator

SimpLEDrive™ shown
Linear DC/DC

DC/DC LED Lighting Solutions

<table>
<thead>
<tr>
<th>Boost</th>
<th>Controllers</th>
<th>Converters</th>
<th>Buck</th>
<th>Controllers</th>
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<td>TPS92510</td>
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</table>

* Primary Topology Listed. Additional Topologies Supported.
**LM3466**

**Smart Linear LED Driver for Multi-Channel LED Systems**

**Features**
- Wide Input Voltage Range: 6 to 70V
- 70V, 1.5A MOSFET with 2A Limit
- Works with Constant Current Power Supplies
- Automatic Equalization
- LED Open, LED Short Detection
- Thermal Shutdown

**Benefits**
- Support Up to 20 LEDs in Series
- Regulates LED String Current Based on User Settings
- Balances Current of Every Active String, Even if String Voltages Are Not Equal
- Fault Flag Notifies MCU of Abnormal Condition
- Protects LM3466 Against High-Temperature Conditions

**Applications**
- LED Street Lighting, High-Bay Lighting
- Multi-String LED Luminaires

---

**DC/DC Buck Converters for LED Lighting**

![Graph showing DC/DC Buck Converters for LED Lighting](image-url)
**TPS92510**
Wide Vin Range Buck Driver for HB LED Lighting

**Features**
- Input Operating Range: 3.5V to 60V
- IOUT up to 1.5A with Integrated MOSFET
- VREF = 200mV
- Thermal Foldback
- 100kHz to 2.5MHz Adjustable Switching Frequency
- PWM Dimming: 100Hz – 1kHz
- UVLO, Over-Current, and Over-Temperature Protection

**Benefits**
- Suitable for a Wide Variety of LED Applications
- Reduced BoM and PCB Space
- Low Power Dissipation in Current Sense Resistor
- Improves LED Reliability and Maintains Reduced Light Output During High LED Temp. Conditions
- Flexible Inductor Selection
- Accurate Control of Light Intensity
- Protects IC During Fault and Abnormal Operating Conditions

**Applications**
- Street Lighting, High-Bay Lighting, MR-16
- Emergency, Flash Lights
- Automotive Lighting

![TPS92510EVM-A011](image)

**LM3402/LM3402HV**
0.5A Constant Current Buck Reg. for Driving HB LEDs

**Features**
- VIN range from
  - 6V to 42V (LM3402)
  - 6V to 75V (LM3402HV)
- Hysteretic Operation with Controlled On-Time
- Integrated 0.5A N-Channel MOSFET
- PWM Dimming Input
- Over-Temperature, LED Open/Short Protection

**Benefits**
- Two voltage grades optimized for different application needs
- No Control Loop Compensation Required
- Easily Drives 1W HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Protects Against Abnormal and Fault Conditions

**Applications**
- LED General Illumination
- Industrial Lighting
- Automotive Lighting

![LM3402EVAL/NOPB](image)
LM3404/LM3404HV
1A Constant Current Buck Reg. for Driving HB LEDs

**Features**
- VIN range from
  - 6V to 42V (LM3404)
  - 6V to 75V (LM3404HV)
- Hysteretic Operation with Controlled On-Time
- Integrated 1A N-Channel MOSFET
- PWM Dimming Input
- Over-Temperature, LED Open/Short Protection

**Benefits**
- Two voltage grades optimized for different application needs
- No Control Loop Compensation Required
- Easily Drives 3W HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Protects Against Abnormal and Fault Conditions

**Applications**
- LED General Illumination
- Industrial Lighting
- Automotive Lighting

LM3406/LM3406HV
1.5A Constant Current Buck Reg. for Driving HB LEDs

**Features**
- VIN range from
  - 6V to 42V (LM3406)
  - 6V to 75V (LM3406HV)
- Hysteretic Operation with Controlled On-Time
- Up to 1.5A Constant Current Output
- PWM Dimming Input
- Over-Temperature, LED Open/Short Protection

**Benefits**
- Two Voltage Grades Optimized for Different Application Needs
- No Control Loop Compensation Required
- Easily Drives a Variety of HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Protects Against Abnormal and Fault Conditions

**Applications**
- LED General Illumination
- Industrial Lighting
- Automotive Lighting
LM3405/LM3405A
1.6MHz Constant Current Buck Reg. for Driving HB LEDs

**Features**
- VIN range from
  - 3V to 15V (LM3405)
  - 3V to 22V (LM3405A)
- Fixed 1.6MHz Switching Frequency
- 1A Continuous Current Capability
- PWM Dimming Input (100Hz to 5kHz)
- Internally Compensated
- Over-Temperature, LED Open/Short Protection

**Benefits**
- Two voltage grades optimized for different application needs
- Small Surface Mount Inductor, Capacitors
- Easily Drives 3W HB LEDs
- Allows for External Source Such as a MCU to Control LED Brightness
- Simplifies Design Complexity
- Protects Against Abnormal and Fault Conditions

**Applications**
- LED General Illumination
- Industrial Lighting
- LED Flashlights

LM3407
350mA Constant Current Floating Buck Reg. for Driving HB LEDs

**Features**
- Input Operating Range 4.5 to 30V
- Output Voltage Range: 0.1VIN to 0.9VIN
- Adjustable Switching Frequency: 300kHz to 1MHz
- Separate Enable and PWM Input Pins
- Internally Compensated
- UVLO, Thermal Shutdown and Open-Circuit Protection

**Benefits**
- Suitable for a Wide Variety of LED Applications
- Allows for Optimization of Efficiency Versus Inductor Size
- External Source Can Control LED Brightness
- Disabling the Device Lowers IQ to < 60μA
- Simplifies Design and Reduces Component Count
- Protects Against Abnormal and Fault Conditions

**Applications**
- LED General Illumination
- Industrial Lighting
- LED Flashlights
**LM3414/LM3414HV**

1A Floating Buck for Driving HB LEDs

**Features**
- Input Operating Range
  - 4.5 to 42V (LM3414)
  - 4.5 to 65V (LM3414HV)
- Adjustable LED current: 350-1000mA
- Adjusted Switching Frequency: 250kHz to 1MHz
- Analog and PWM Dimming
- Internally Compensated
- UVLO, Thermal Shutdown and Open-Circuit Protection

**Benefits**
- Two Voltage Grades Optimized for Different Application Needs
- Supports 1-3W HB LEDs
- Allows for Optimization of Efficiency versus Inductor Size, Reduced EMI
- Up to 1/10 Switching Frequency (PWM)
- Simplifies Design and Reduces Component Count
- Protects Against Abnormal and Fault Conditions

**Applications**
- High Light Output Designs (Troffers, Architectural Lighting)
- MR-16 Replacement
- Automotive Lighting

**Tools**
- LM3414HVMREVAL/NOPB
- LM3414HVSDEVAL/NOPB

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**LM3464/LM3464A**

4-Channel High-Voltage, Constant Current LED Driver with Dynamic Headroom Voltage Monitoring

**Features**
- Wide Input Voltage Range
  - 12 to 60V (LM3464)
  - 12 to 95V (LM3464A)
- Dynamic Headroom Control
- Analog and PWM Dimming
- LED Open, LED Short Detection
- Thermal Detection with Foldback

**Benefits**
- Two voltage grades optimized for different application needs
- Provides Feedback to AC/DC Converter to Ensure Maximum Efficiency
- Optimize for LED Color Shift and Brightness Control
- Fault Flag Notifies MCU of Abnormal Condition
- Maintains LEDs ON, but at Reduced Brightness Until LED Over-Temperature Condition Clears.

**Applications**
- LED Street Lighting, High-Bay Lighting
- Multi-String LED Luminaires

**Tools**
- LM3464-120V24W/NOPB
- LM3464EVAL/NOPB
**LM3463**
6-Ch High-Voltage, Constant Current LED Driver with Dynamic Headroom Voltage Monitoring and 4-Ch PWM

**Features**
- Wide Input Voltage Range
  - 18 to 95V
- Dynamic Headroom Control
- Analog and 4-Ch PWM Dimming/SPI interface
- LED Open, LED Short Detection
- Thermal Detection with Foldback

**Benefits**
- Two voltage grades optimized for different application needs
- Provides Feedback to AC/DC Converter to Ensure Maximum Efficiency
- Optimize for LED Color Shift and Brightness Control
- Fault Flag Notifies MCU of Abnormal Condition
- Maintains LEDs ON, but at Reduced Brightness Until LED Over-Temperature Condition Clears.

**Applications**
- LED Street Lighting, High-Bay Lighting
- Multi-String LED Luminaries

Q&A?