



LED Applications and Driving Techniques

Chris Richardson



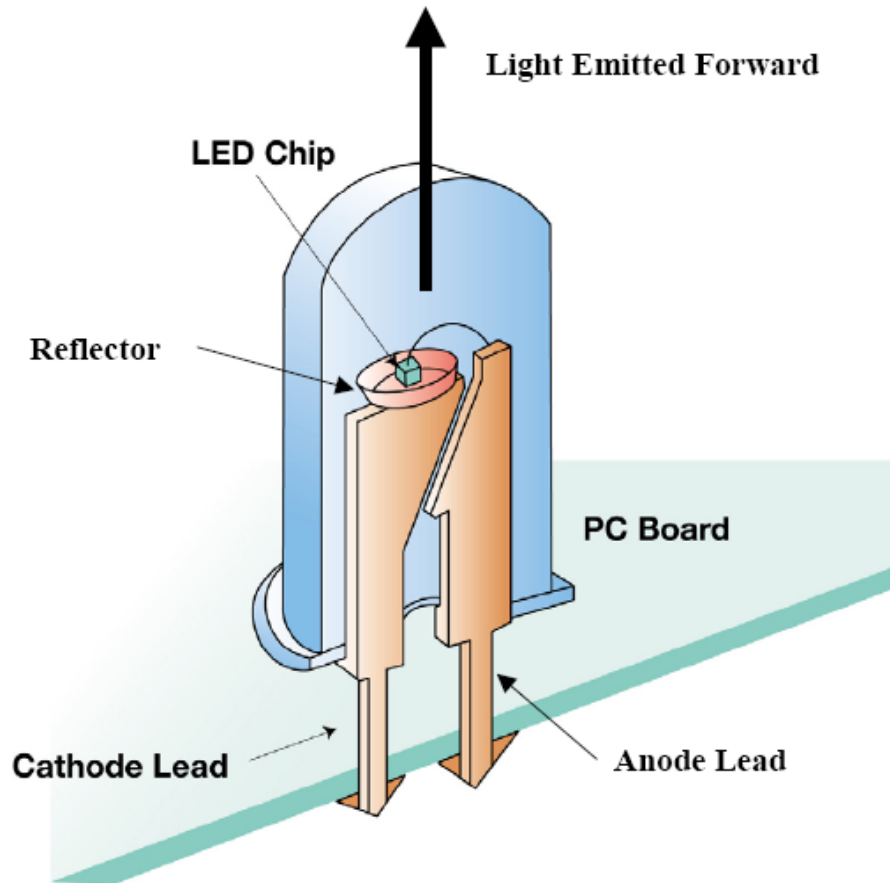
Content

- **LED Basics**
- **LED Applications**
- **LED Driving Techniques**
- **LED Dimming and Contrast Ratios**
- **Lighting Resources and Tools**

LED Basics

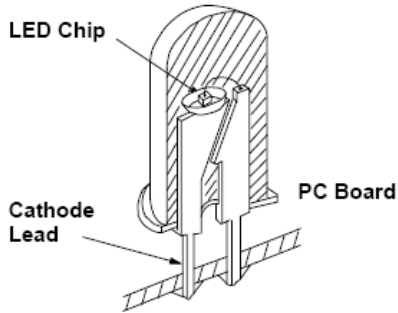


What is an LED?



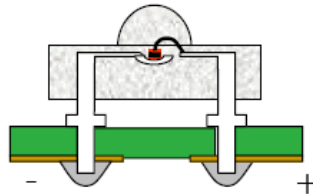


LED Development



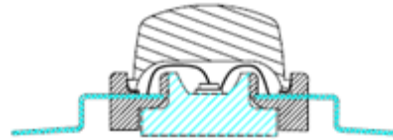
5mm Lamp
2-3 lumens
 $I_F = 30\text{mA}$

1970



SuperFlux
4-8 lumens
 $I_F = 70\text{mA}$

1992



Luxeon
20-40 lumens
 $I_F = 350\text{mA}$

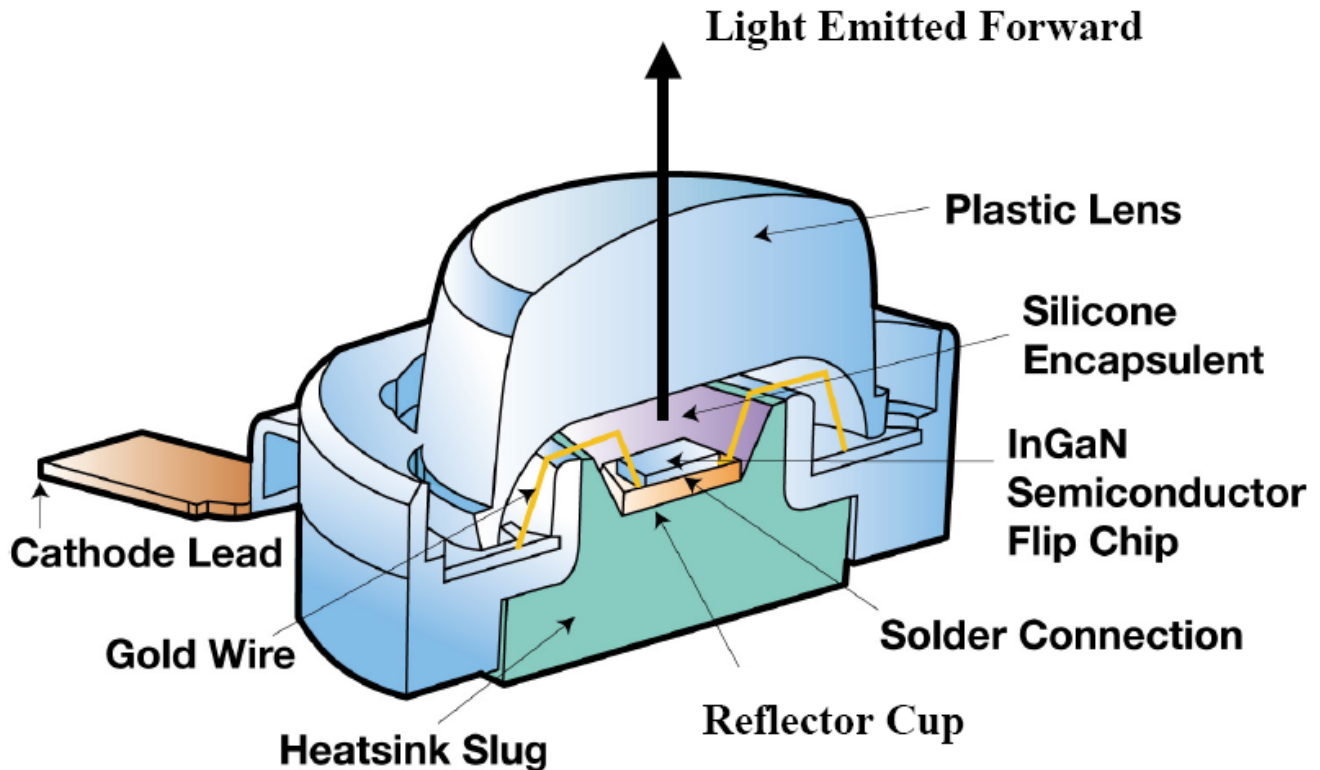
1997

Lumileds
Osram
Cree
Seoul Semi
Avago

$I_F = 700$ to
1.5A

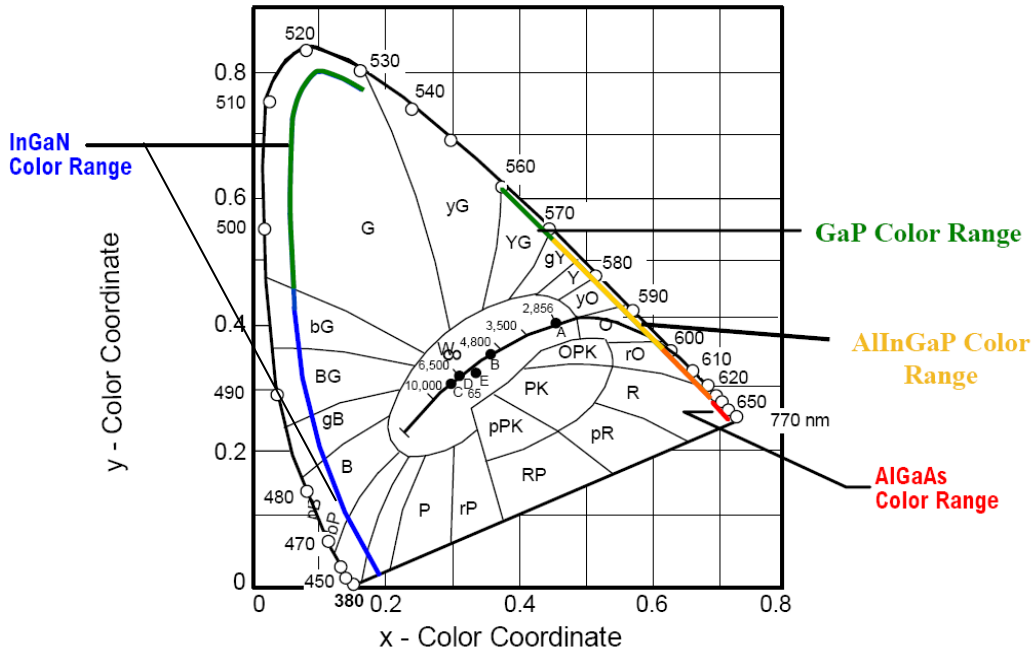
2007

Structure of High Brightness LED





Materials used in color LEDs



White LED:

White light is generated by blue LED striking a phosphor coating



Many New Applications Have Emerged Because.....

- **Typical spec. of HB LED**

- 1 Watt LED

- Full intensity 350mA, Maximum current 500mA
- 2.8V Volt drop @ 350mA

- 3 Watt LED

- Full intensity 700mA, Maximum current 1A
- 4.3V Volt drop @ 700mA

- 5 Watt LED (multi-die package)

- Full intensity 700mA, Maximum current 1A
- 7.1V Volt drop @ 700mA

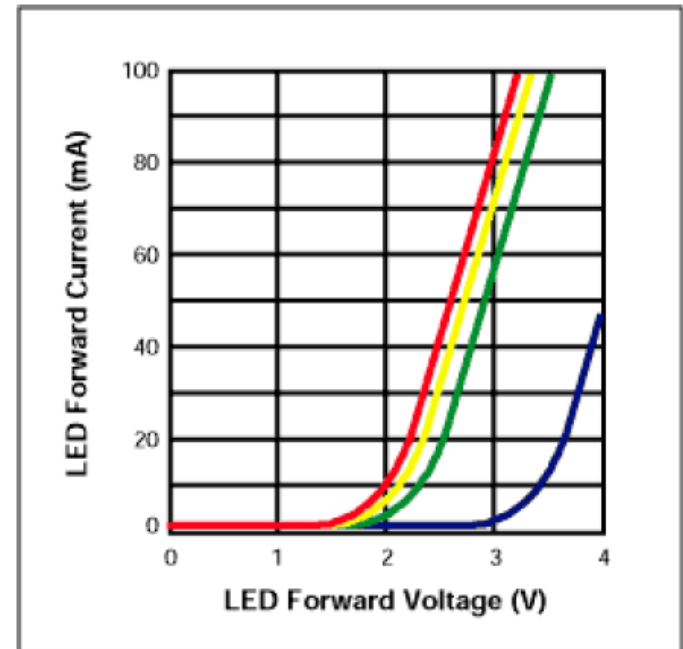
- 5 Watt LED (single-die)

- Full intensity 1.5A



Characteristics of LEDs

- ❑ **Forward Voltage (V_F) drop across LED**
 - **Diodes are current driven!**
- ❑ **Wavelength variations**
 - **Crystal and junction growth defects**
- ❑ **Brightness variations**
 - **Crystal defects resulting formation of phonons and non-radiation energy transfer**
- ❑ **Temperature**
 - **Junction temperature of the device affects each of the parameters above**

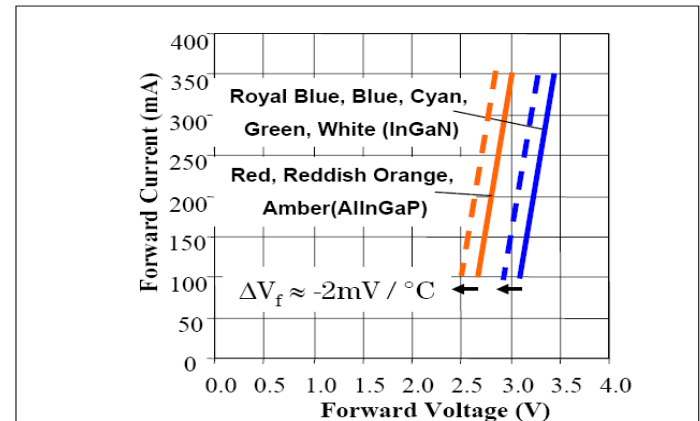
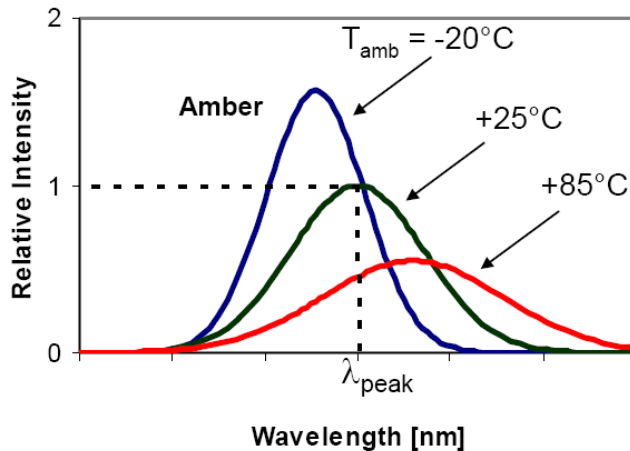
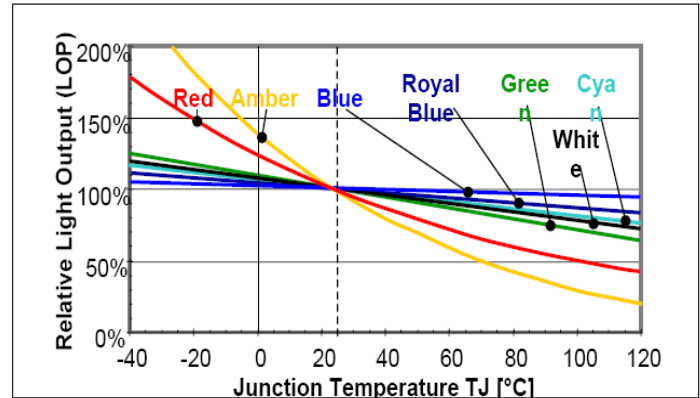




Temperature effect on LED Parameters

As Temperature increases:

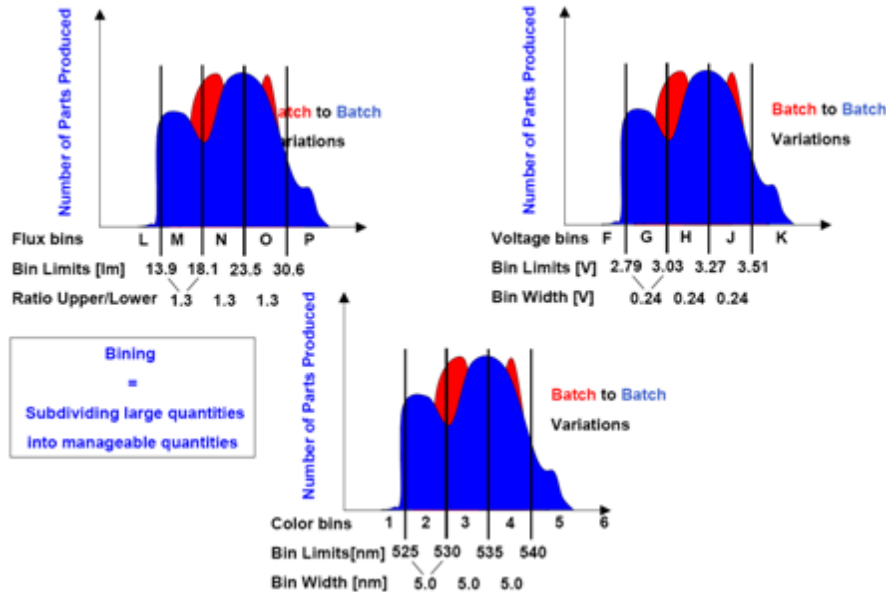
- Light output decreases
- Wavelength gets longer
- Forward voltage decreases





LED Binning

- Manufacturers bin their devices for color/wavelength, brightness, and forward voltage
- Binning for all three characteristics is expensive, and forward voltage is often the specification that is allowed to vary the most



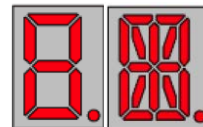


LED Applications



LED Applications

- **Old days**
 - Signal Indicators
 - Numeric and Alpha-numeric displays
- **Nowadays**
 - Automotive
 - Backlights
 - Flashlights for portable device
 - General illumination
 - Projector Light Sources
 - Signage
 - Torch Lights
 - Traffic Lights





Backlight Applications

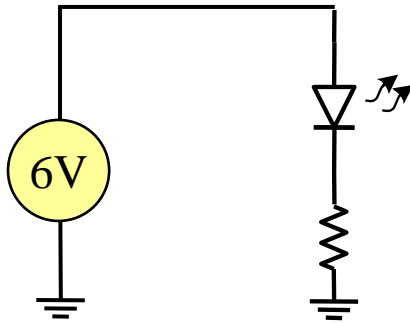
- **Possible because of white LED development**
- **Almost all mobile phone color LCDs use white LED backlighting.**
- **Size of displays from smallest to largest**
 - 1. **Mobile phones, PDAs**
 - 2. **Automotive, aerospace infotainment**
 - 3. **Laptop displays**
 - 4. **Desktop PC monitors**
 - 5. **LCD televisions**



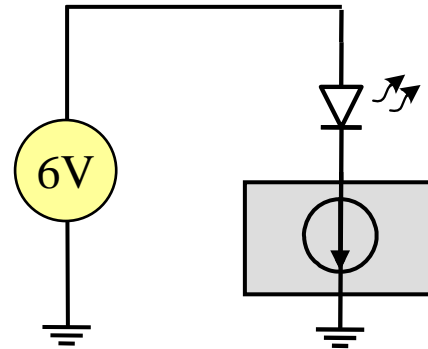
LED Driving Techniques



Resistor Limiting, Linear Regulation



Resistor Limiting



**Linear IC with
Constant Current Source**

Heat dissipation in resistor or linear IC



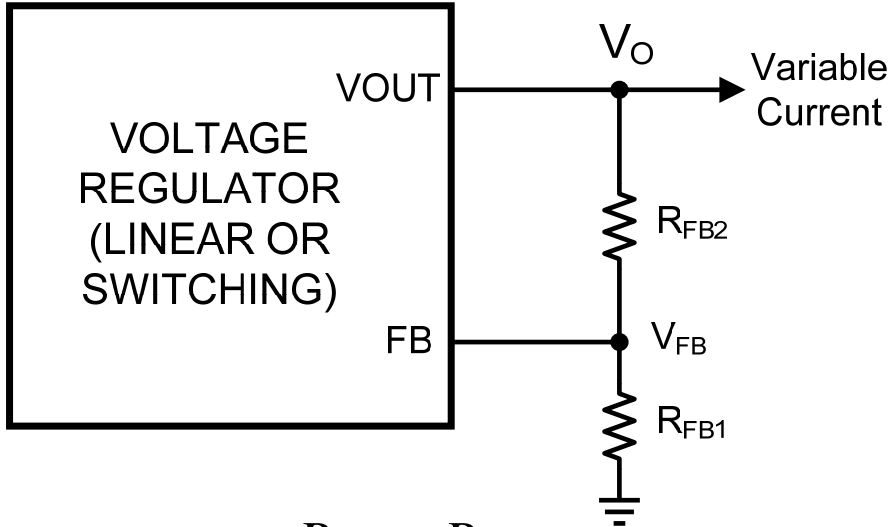
LED Driving Circuit

- **Delivers a constant average current under all conditions (eg. input voltage change, temperature change, V_F change.....)**
- **Controls ripple current at acceptable level under all conditions**

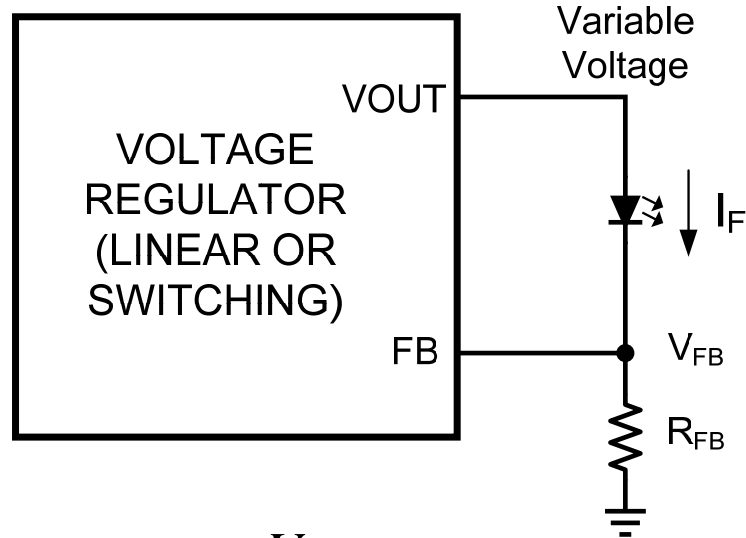
A LED driving circuit is a type of power conversion circuit that delivers constant current instead of constant voltage



Constant Voltage to Constant Current Conversion:



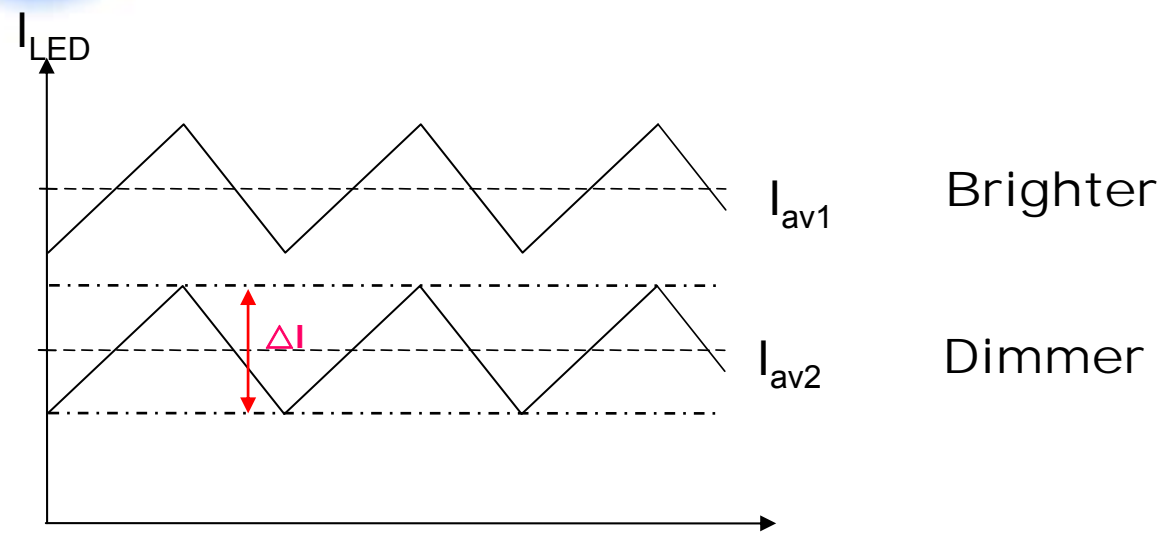
$$V_O = V_{FB} \frac{R_{FB1} + R_{FB2}}{R_{FB1}}$$



$$I_F = \frac{V_{FB}}{R_{FB}}$$



Average Current and Ripple Current

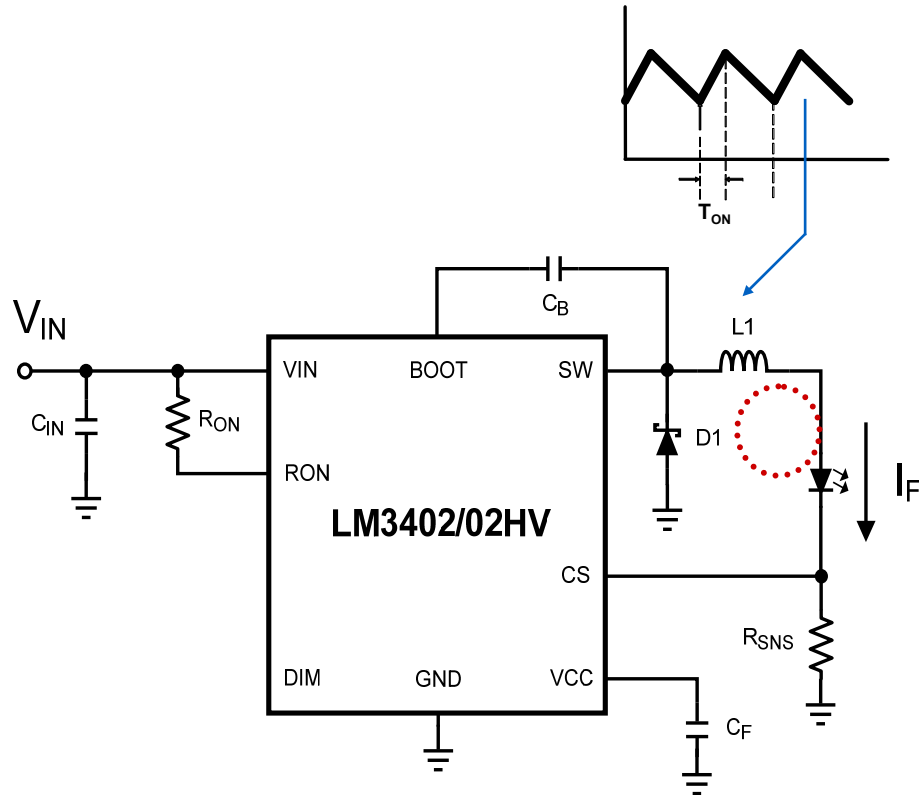


- $I_{av1} > I_{av2}$, thus I_{av1} is brighter than I_{av2} but color also changes
- Human eye cannot detect the high frequency ripple current
- Human eye cannot detect shift in average current of $< 20\%$

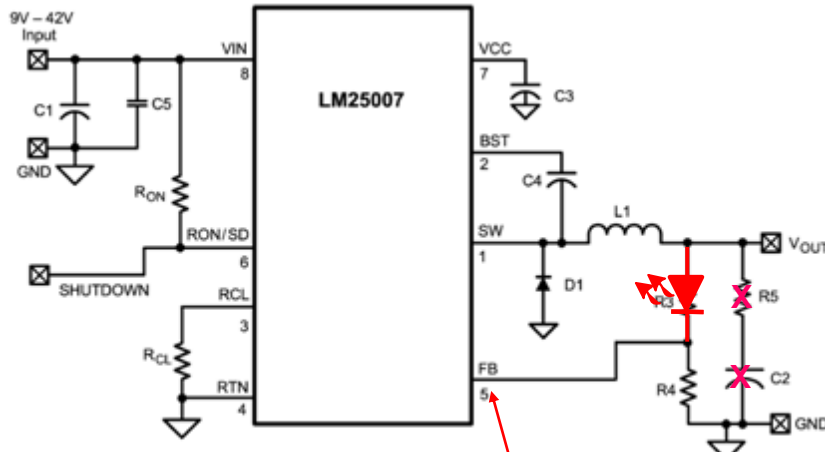


Buck LED Driving

- V_O must be lower than V_{IN}
- Output capacitor is optional
- Typical Application: general lighting



Buck Driving – How it works

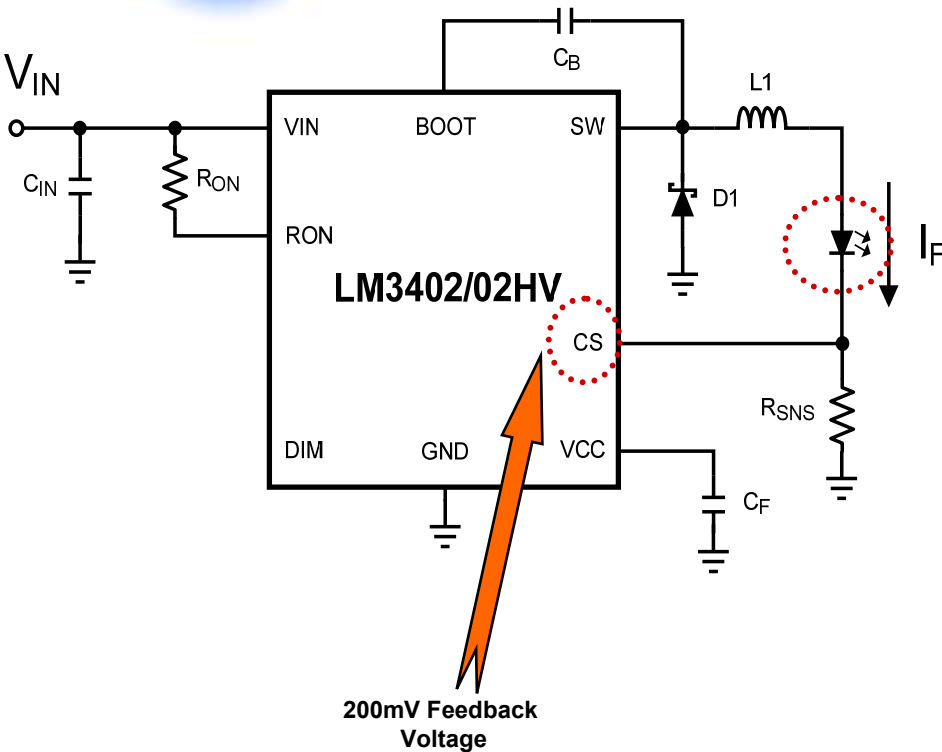


FB voltage is maintained at 2.5V

- If $R4 = 5\Omega$, current passing through $R4 = 0.5A$. Current passing through the LED is also the same because FB is a high impedance pin.
- LED current setting can be done by $R4$.

Problem: Power dissipation at $R4 = 1.25W!$

Dedicated Buck LED Driver

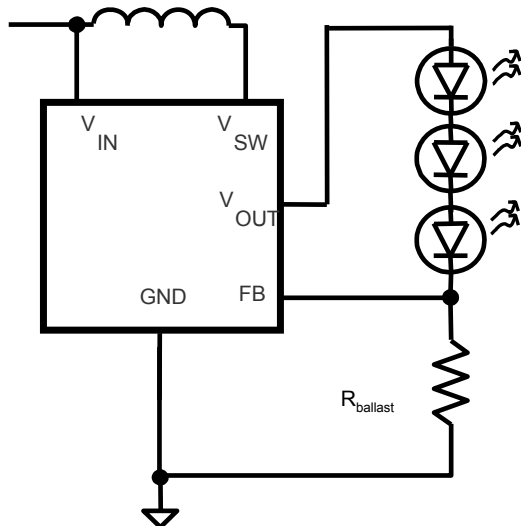


- **FB voltage is reduced to 200 mV**
- **Power dissipation at $R_{SNS} = 0.5A \times 0.2V = 0.1W$.**

Using Boost Regulator: Series LED Connection

- **Pros:**

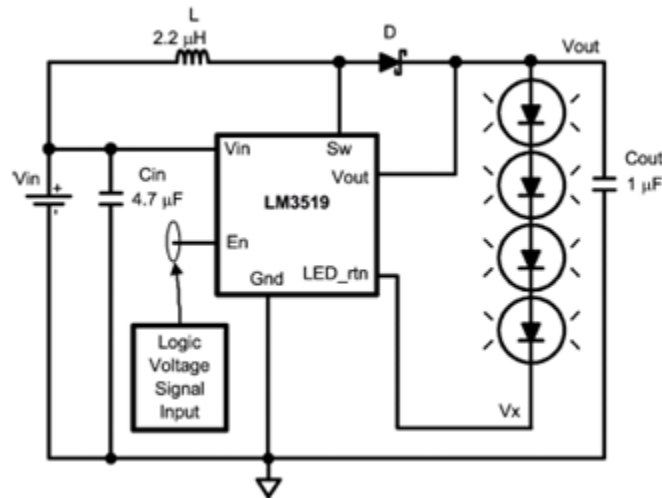
- Matching Guaranteed
- Most efficient drive method
- Easy to route (Only 1 or 2 connections between driver and LEDs)



With external ballast

- **Cons**

- High voltage output is needed
- Output capacitor typically large due to voltage requirement



With internal current sink



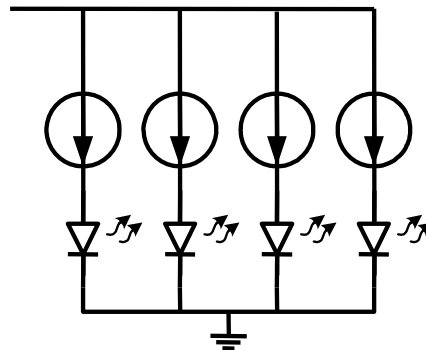
Using Boost Regulator Parallel LED Connection

- **Pros**

- Workable with low-voltage semiconductor processes
- Can work with common anode or common cathode module

- **Cons**

- Good matching requires regulated current sources
- Requires 1 connection per each LED i.e. driver IC requires more pins



Constant current source connection



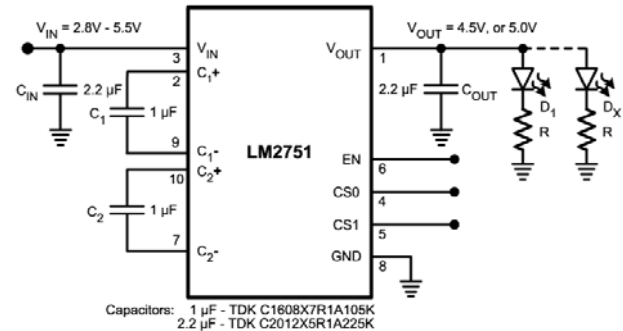
Boost: Inductor based vs Charge Pump

	Charge Pump	Inductor Based
LED Connection	Usually Parallel	Usually Series
Efficiency	Depends on V_{IN}, V_O, and gain mode	Reduced dependence on V_{IN} and V_O
PCB Space	Less	More
Wide Vin – Vout Support	Not Practical	OK
EMI Generation	Less	More, due to presence of inductor

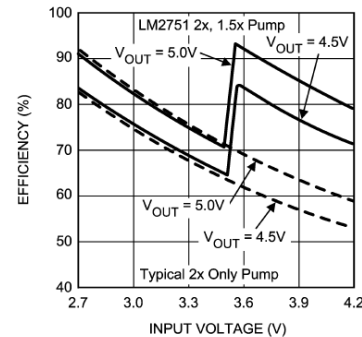


Efficiency of a Charge Pump

- Charge pumps are very efficient if $V_{IN} \times \text{Gain}$ is close to target V_O
- Efficiency drops off as V_{IN} increases.
- 1.5 x mode is introduced to boost efficiency in conversion from one Li-ion battery to 5V V_O

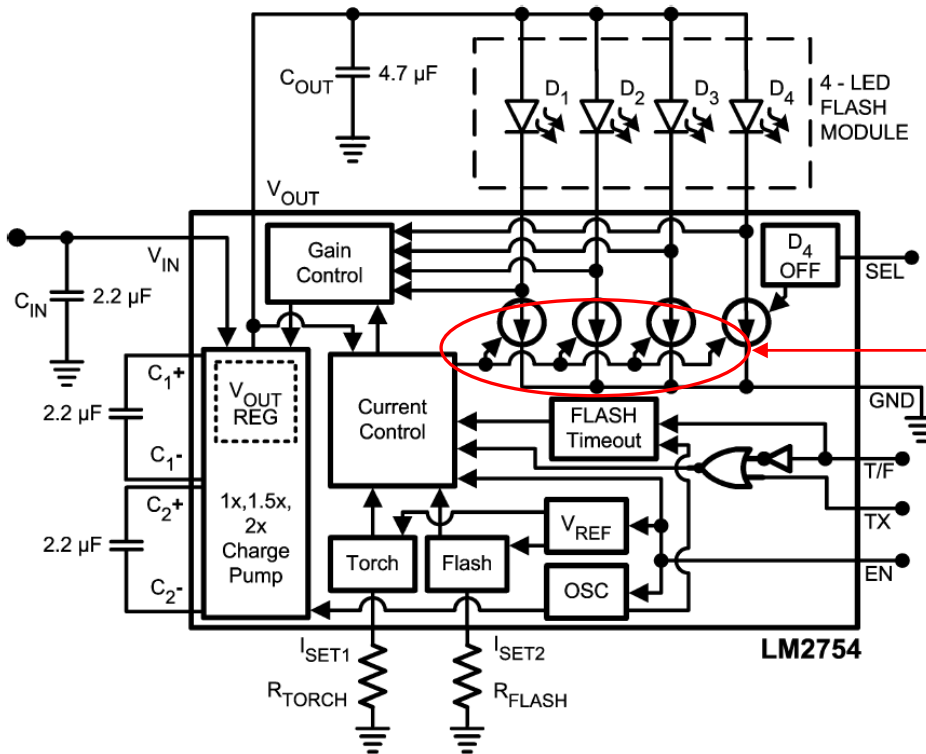


LM2751 2x/1.5x Efficiency vs. 2x Charge Pump Efficiency



LM2751 - 2x, 1.5x charge pump (switched capacitor) white LED driver which can deliver up to 150mA at 725KHz switching frequency.

Charge Pumps with built-in Current Source



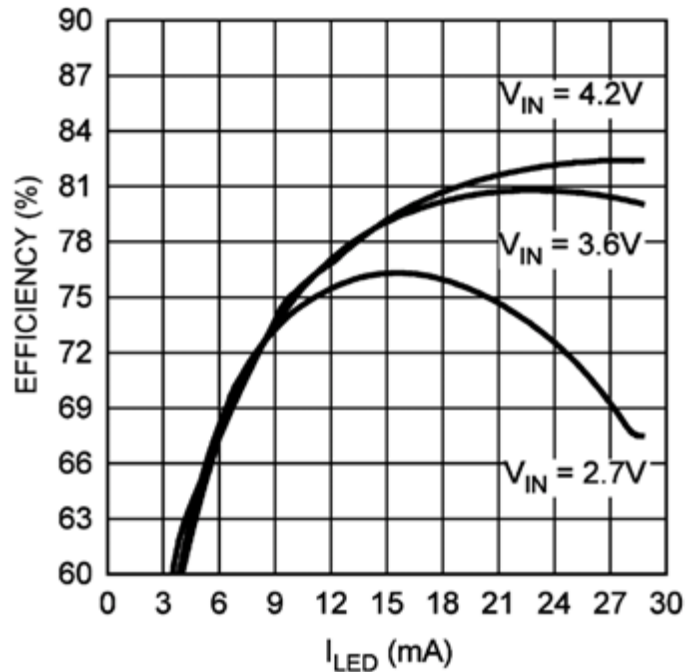
Built-in current source, better current matching in driving several LEDs.

LM2754 - 2x, 1.5x charge pump (switched capacitor) white LED driver which can deliver up to 800mA at 1MHz switching frequency.

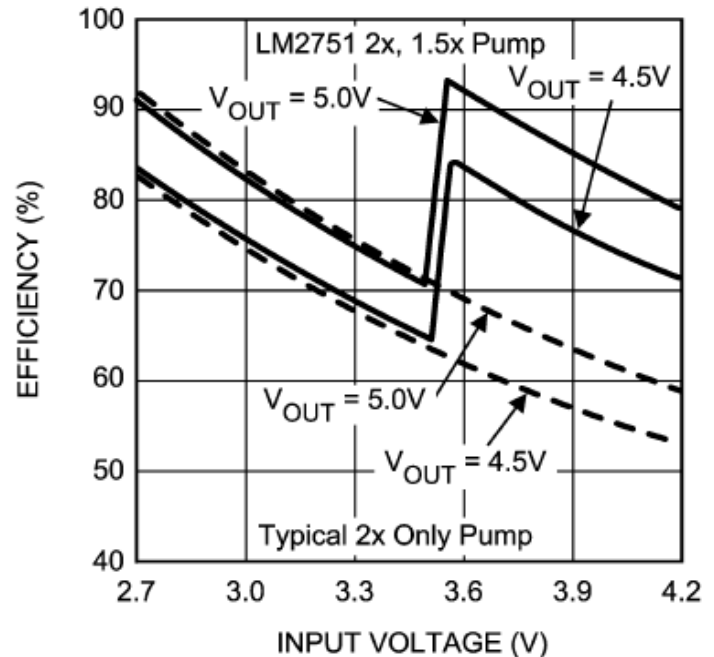


Inductive vs Charge Pump Efficiency Comparison

LM3508 Inductive Boost Efficiency



LM2751 2x/1.5x Efficiency vs. 2x Charge Pump Efficiency



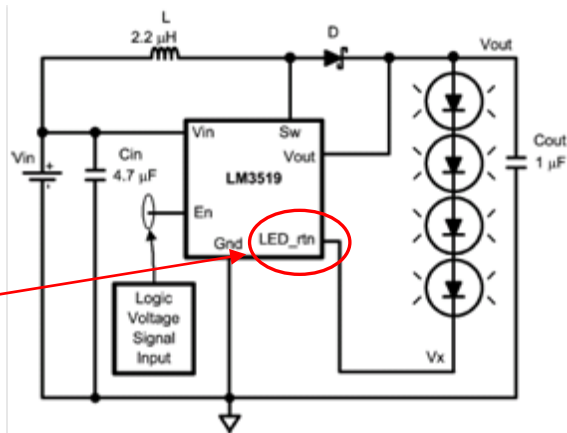


True Shutdown Isolation

• Method 1

- Add switch in return path.

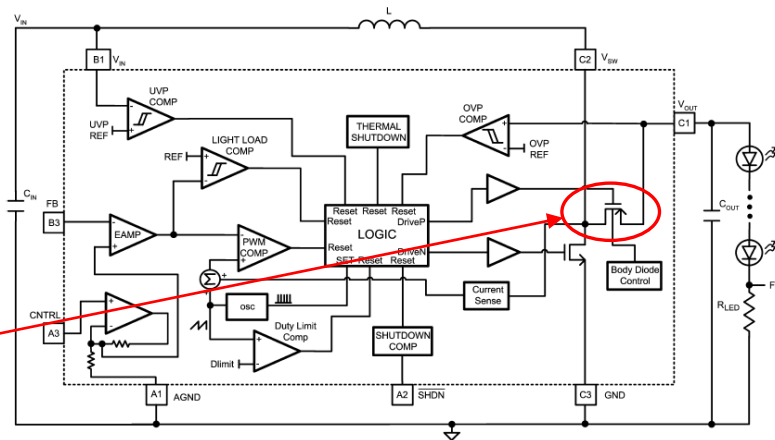
A switch is added to cut off leakage path during shutdown



• Method 2

- Synchronous rectification.

Diode is replaced by MOSFET and it is switched off during shutdown

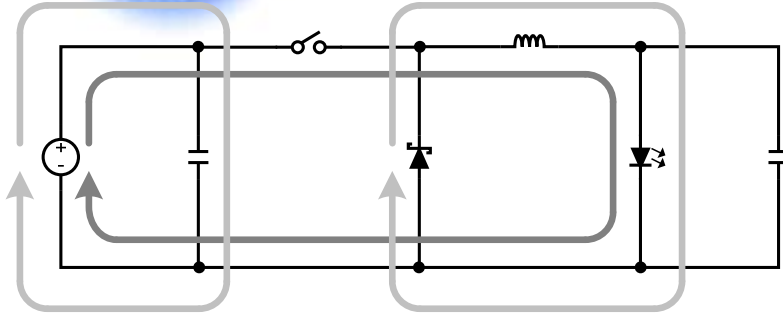




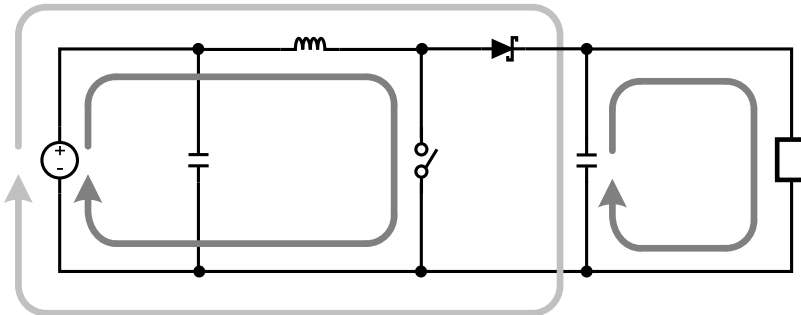
Bucking and Boosting

- **High power LEDs are being adopted into portable lamps (bicycle, mining, flashlight) with varying number and chemistry of batteries**
- **Low-voltage AC lighting (garden path) varies due to I^2R loss**
- **Combine varying V_{IN} with V_F that changes with process and temperature**
- **Requires true buck-boost regulator**

Buck Boost Efficiency < Buck or Boost



Buck: Input direct to output when power switch is on



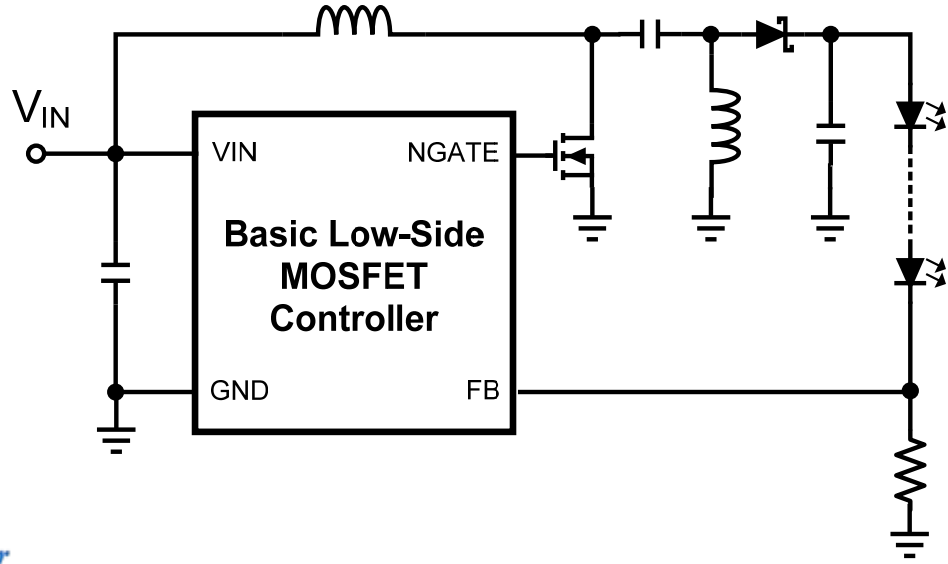
Boost: Input direct to output when power switch is off

Buck-boost: input is never connected directly to output



Buck-Boost Driving: SEPIC Regulator

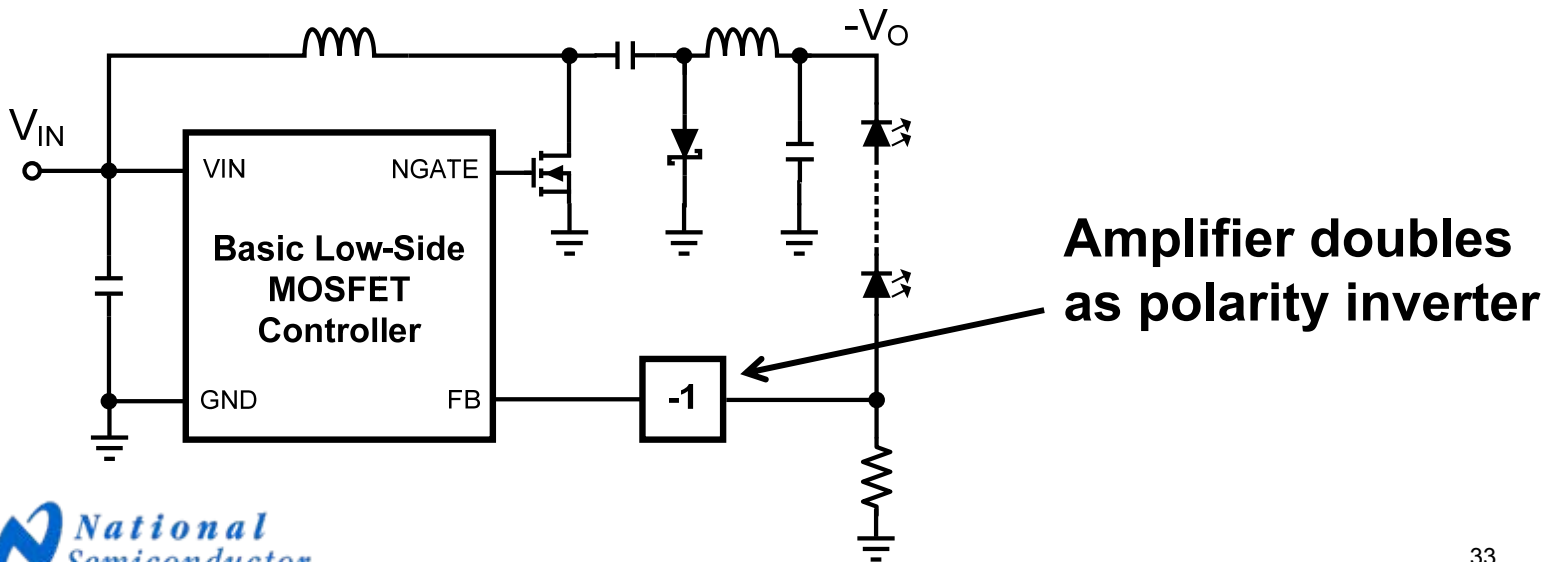
- Uses standard low-side regulator/controller
- Low-side or high-side current sensing
- Requires two inductors or coupled inductor
- Requires an output capacitor



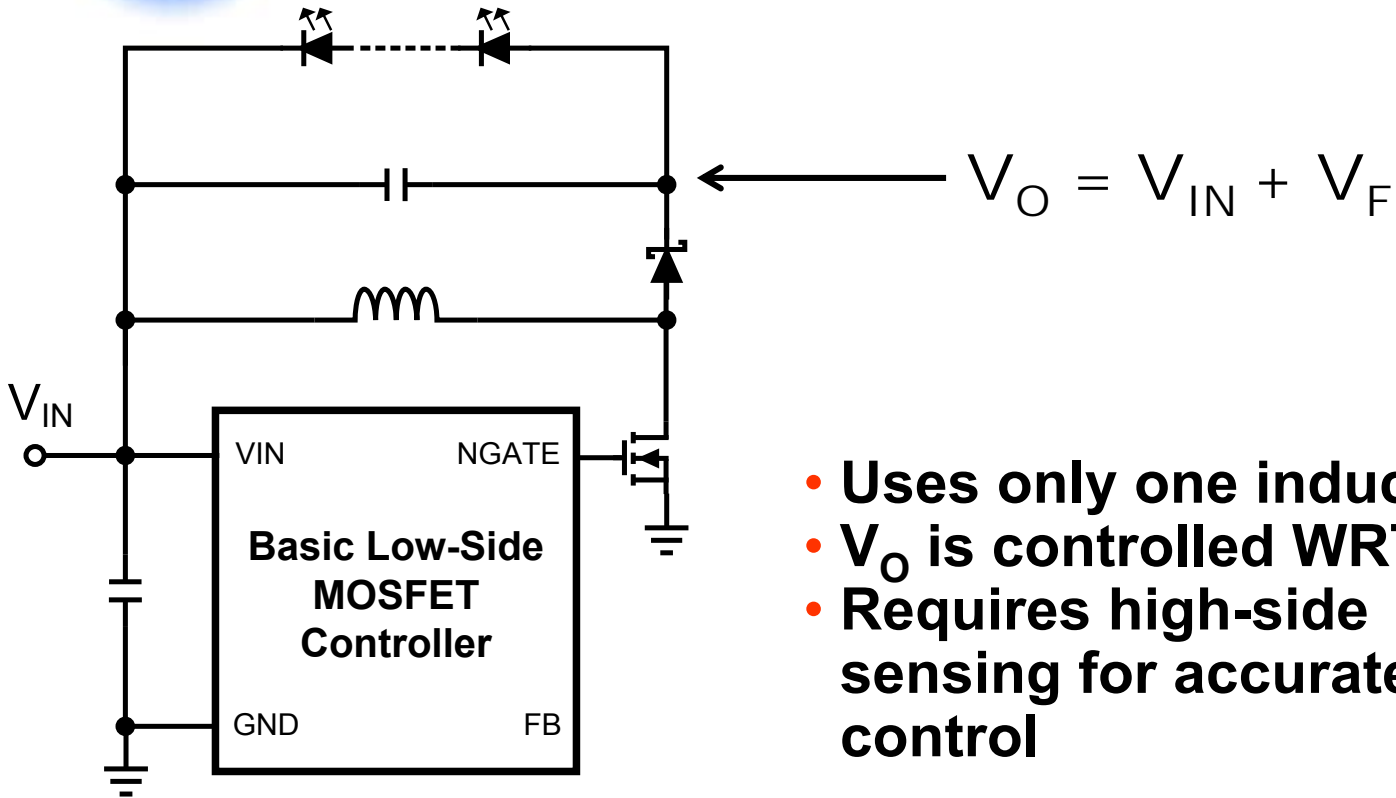


Buck-Boost Driving: Cuk Regulator

- Uses low-side regulator/controller but requires negative FB pin
- Low-side or high-side current sensing
- Negative V_O doesn't matter in current drivers
- Requires two inductors or coupled inductor
- Can run without C_O

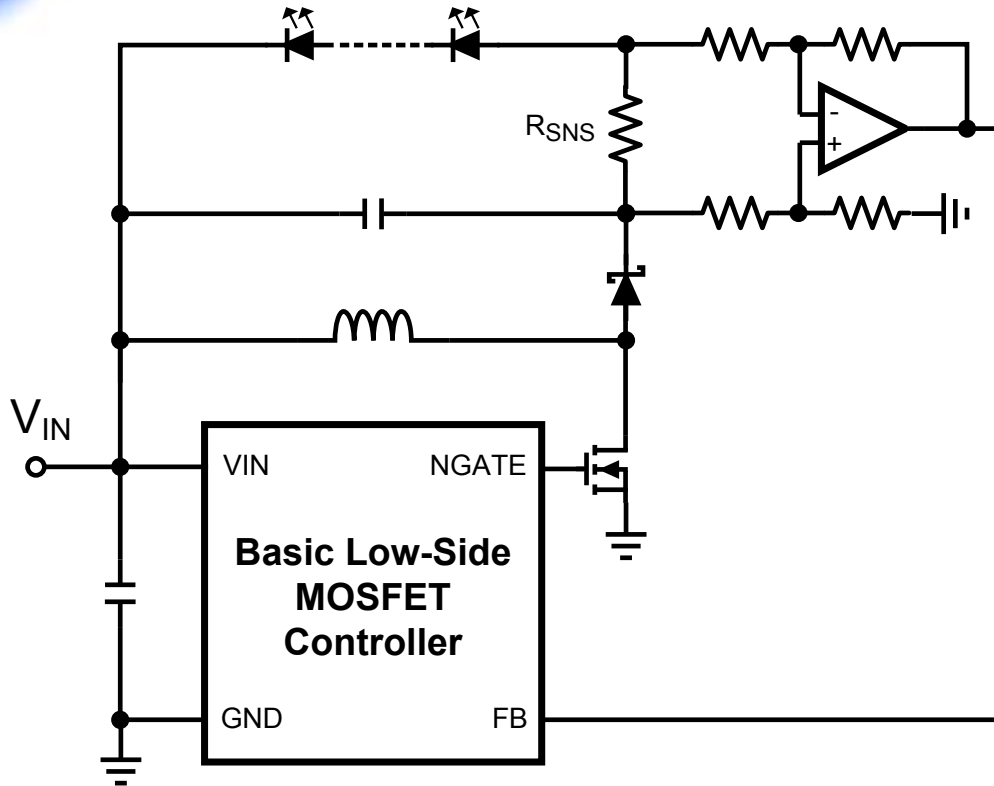


'Floating' Buck-Boost Regulator



- Uses only one inductor
- V_O is controlled WRT V_{IN}
- Requires high-side sensing for accurate I_F control

Floating Buck Boost with High-side Sense



LED Dimming and Contrast Ratios



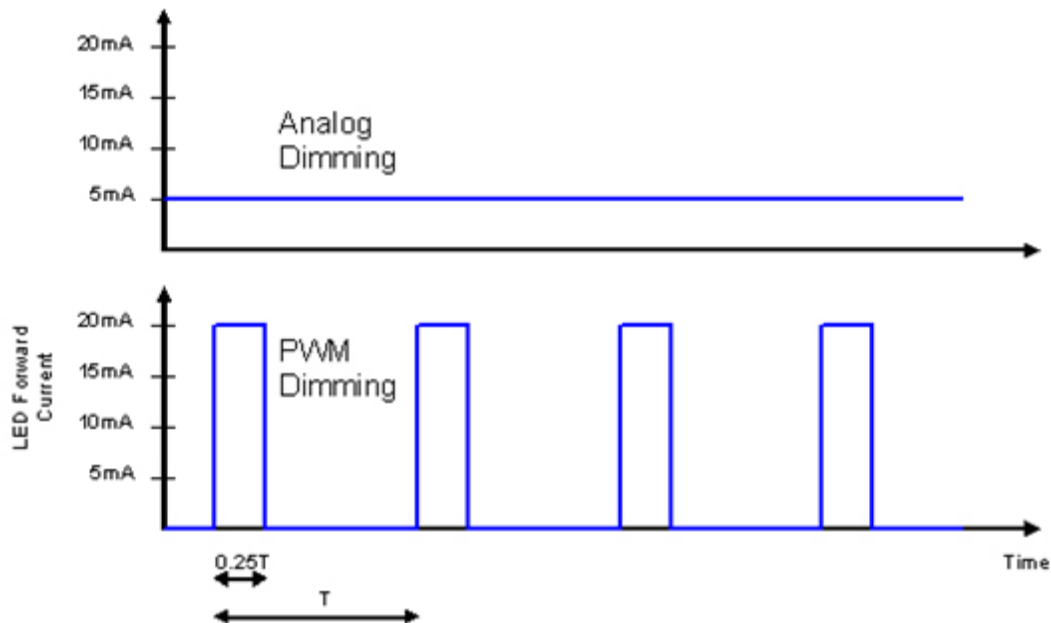
Adjusting Light Level with LEDs

- **“Analog Dimming”**
 - Linear adjustment of current through LEDs
 - Causes shift in peak and dominant wavelength in monochromatic LEDs
 - Causes shift in Correlated Color Temperature (CCT) in white LEDs
 - Difficult to optimize driver efficiency
- **“Digital Dimming” (PWM Dimming)**
 - Drive at only one current level
 - Turn LEDs on and off at $> 120\text{Hz}$
 - Human eye integrated and averages light above this frequency



PWM Dimming Control

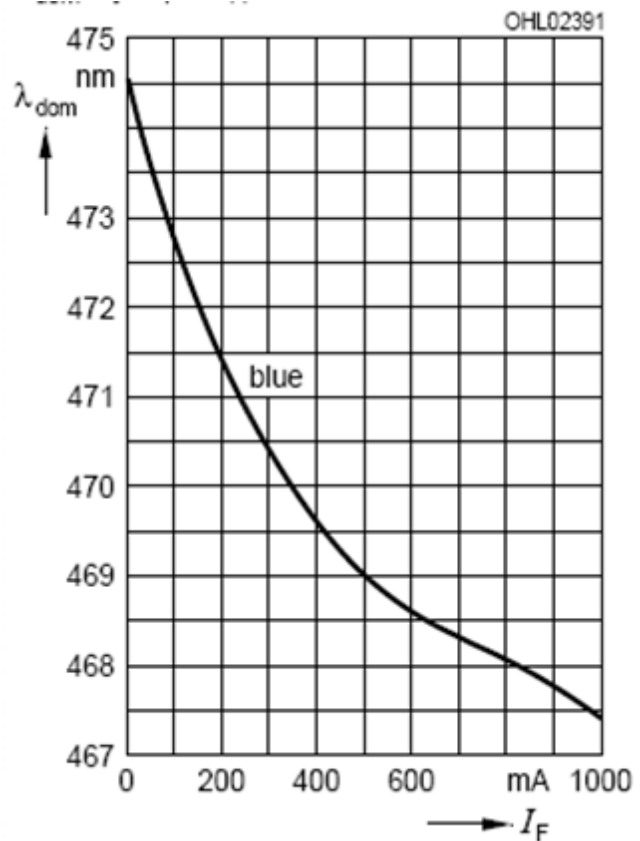
- PWM signal (EN/SD pin, FET, or special PWM pin)
 - “Average” Brightness proportional to Duty Cycle (D):
 $D = t_{ON} / T$





Controlling Color

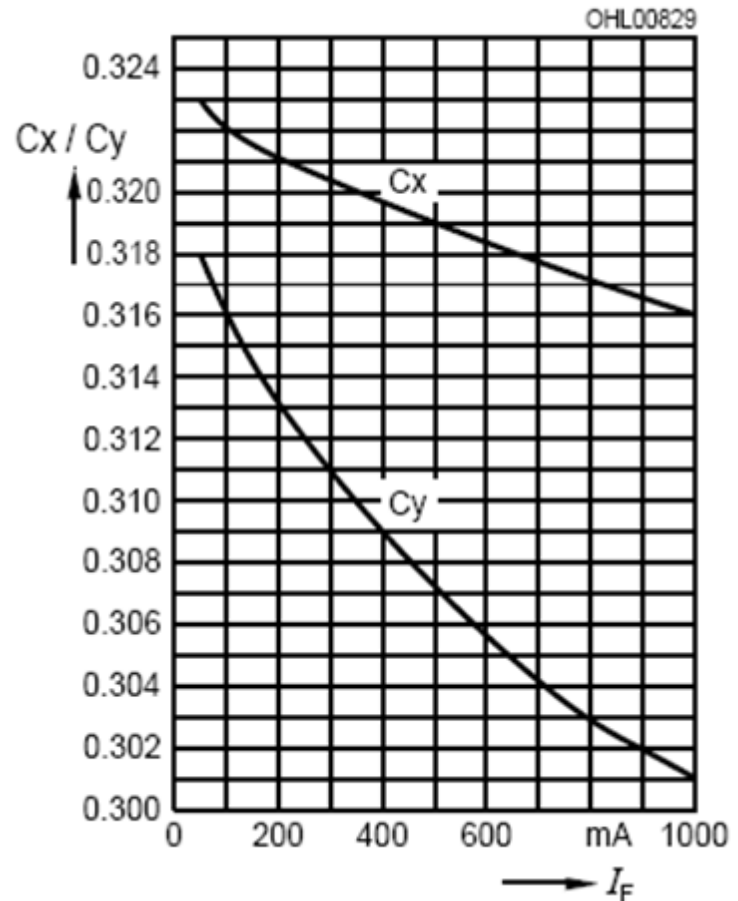
- **Colored LEDs shift their peak/dominant wavelength as I_F changes**
- **Requires control of I_F and Δi_F**
- **Accuracy of I_F is highly dependent on the application**





Controlling CCT

- CCT provides the basis for “cool” white (more blue) and “warm” white (more red.)
- CCT shifts with I_F
- Much easier to see than with colored LEDs

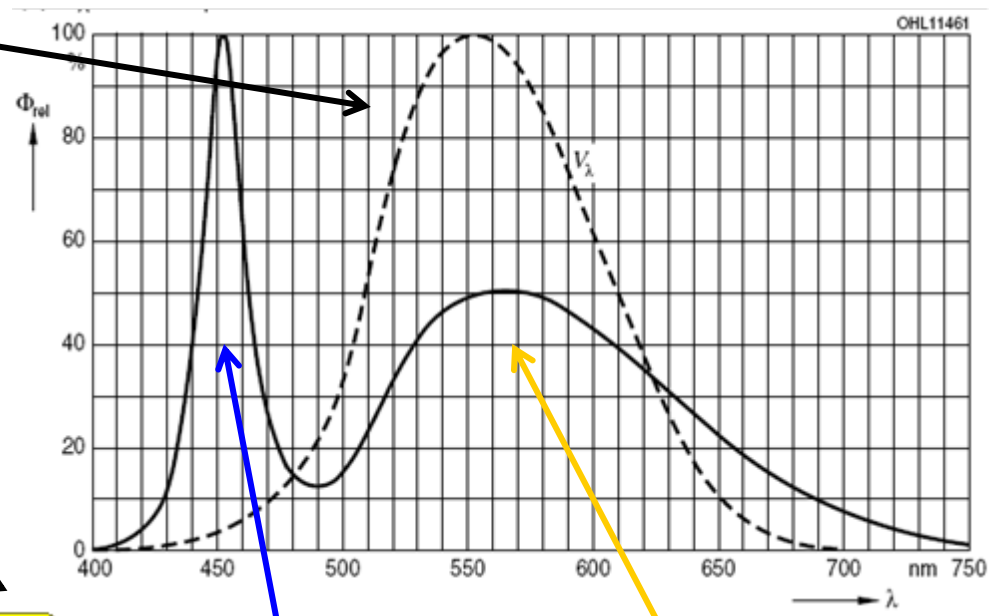
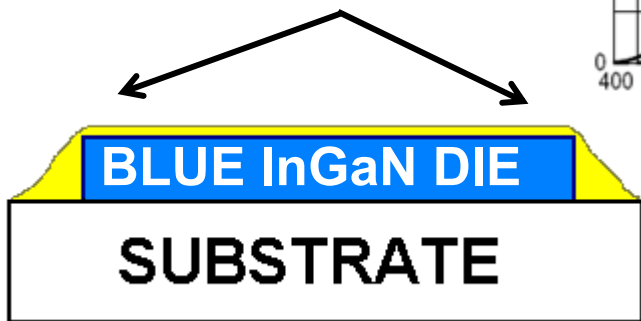




White LED Structure

Human eye color sensitivity curve

BROAD RANGE PHOSPHOR



From LED

From phosphor



CCT Shift

More Yellow



1W LED driven at 50 mA continuous

More Blue



Same 1W LED driven at 300 mA with 1/6th duty cycle (500Hz)



PWM Dimming with Switching Regulators

- **Use buck regulator whenever possible**
- **Only the buck can eliminate the output capacitor***
- **No RHP zero means fastest control loops (when using clocked regulators)**
- **Easy implementation of hysteretic and controlled on-time (COT) control**
 - **Even faster loops!**

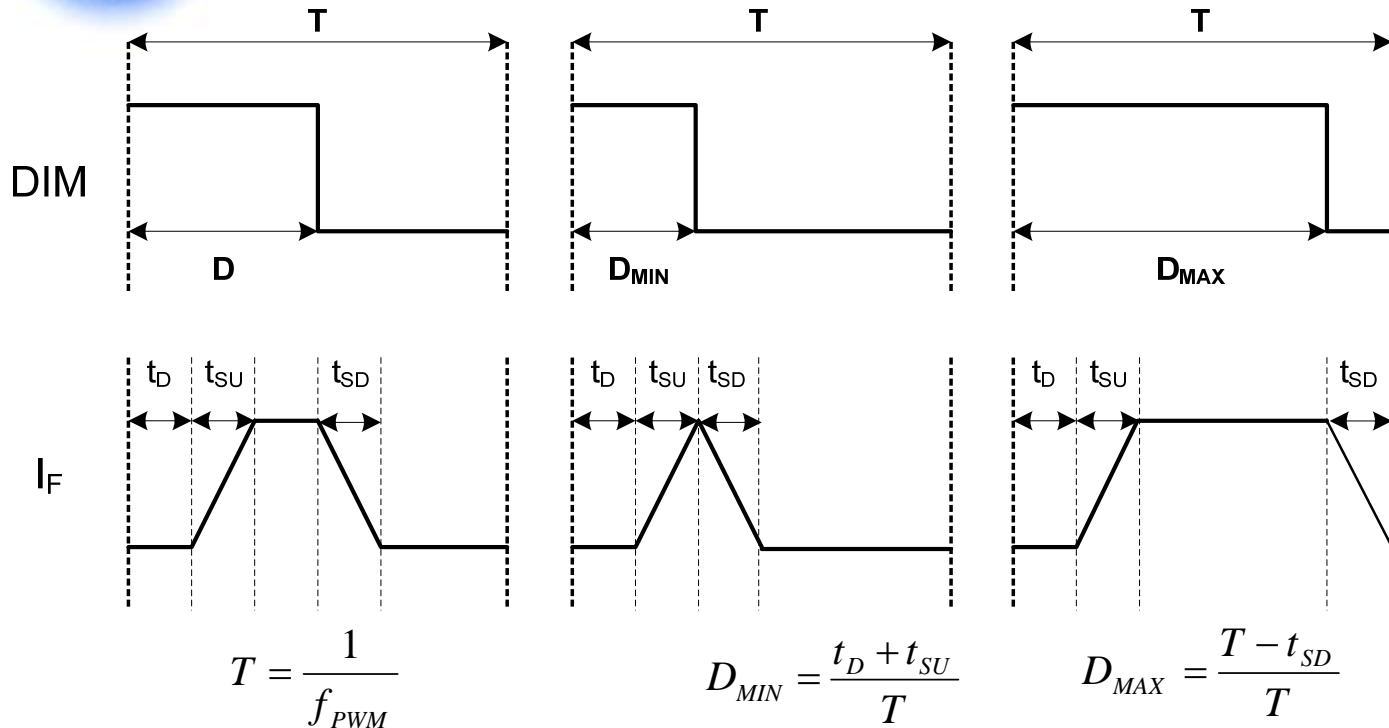


Contrast Ratio

- **1 : Wishful Thinking**
- **Contrast ratio is highly dependent on the external components**
- **Therefore, it is highly susceptible to specmanship**
- **One definition of contrast ratio is $1/D_{\text{DIM(MIN)}}$, where $D_{\text{DIM(MIN)}} = 2 / f_{\text{SW}}$**
 - **Circuit must be on DCM/CCM boundary**



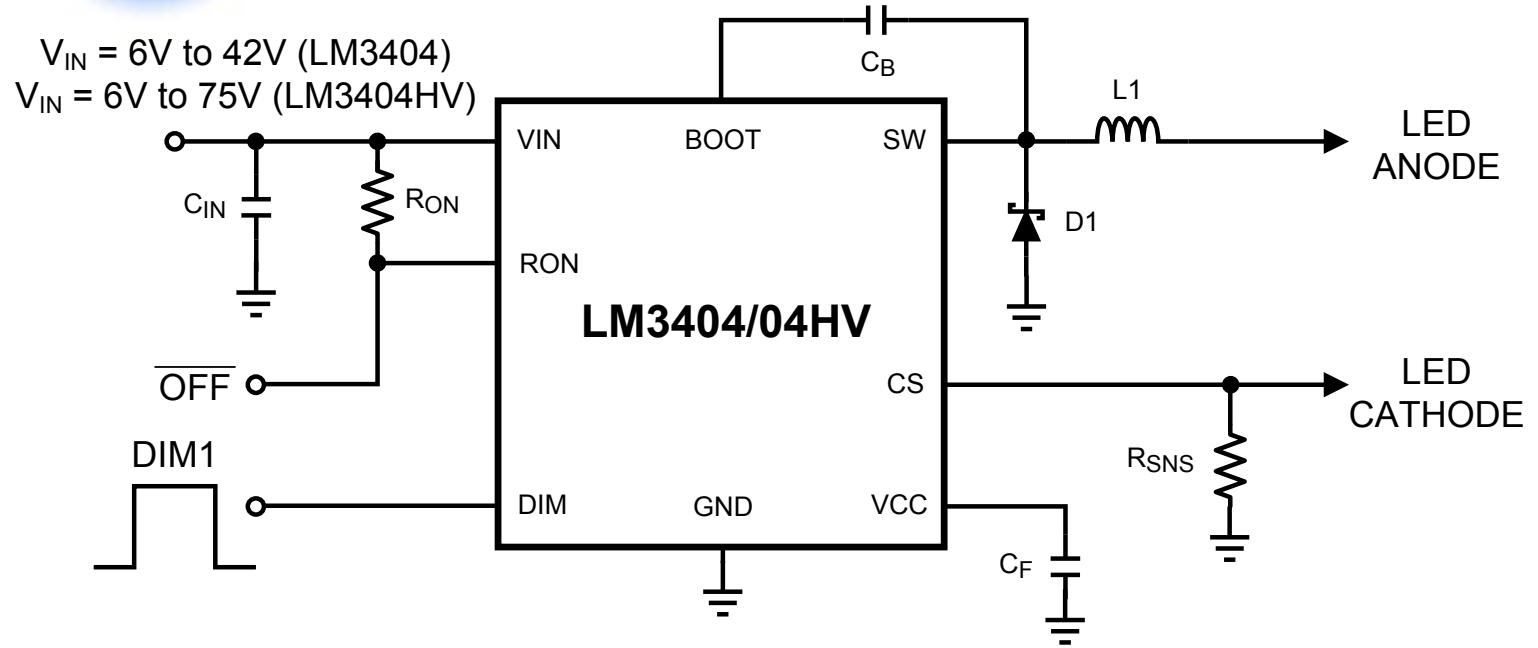
Frequency and Duty Cycle Limits



Rise and fall times where I_F is between 0 and 100% cause further error

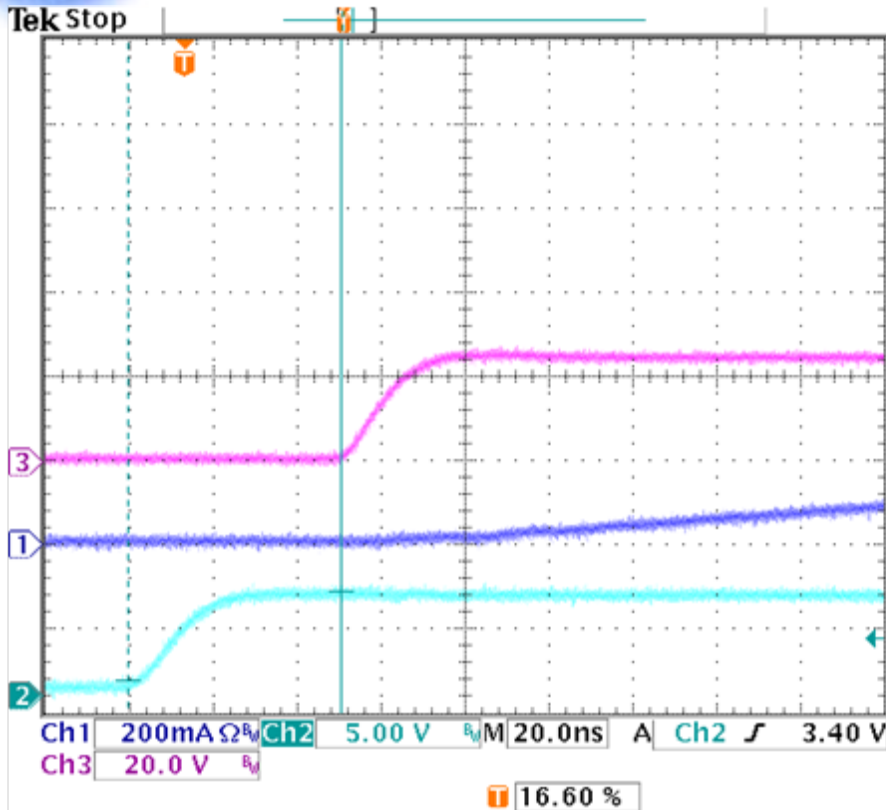


LM3404 Eval Board



Drives a 1W white (InGaN) LED at 1A from 24V

LM3404 Delay, t_D



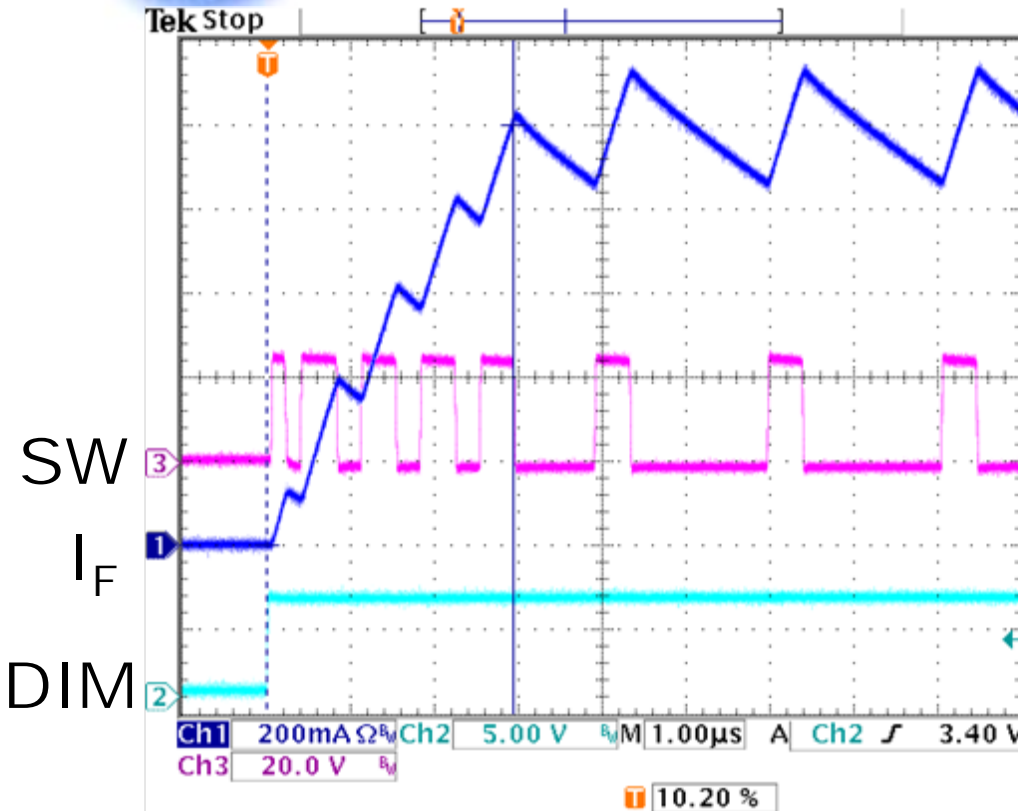
$t_D = 51 \text{ ns}$

Δ : 5.30 V
@: 6.20 V
 Δ : 50.8ns
@: 37.2ns

Bandgap, analog functions were already powered

15 Nov 2006
11:54:30

LM3404 Slew Up, t_{SU}



Δ : 1.00 A
 $@$: 1.00 A
 Δ : 2.94 μ s
 $@$: 2.92 μ s

$t_{SU} = 3 \mu\text{s}$

$$\Delta i_L = \Delta i_F \text{ (no } C_O \text{)}$$

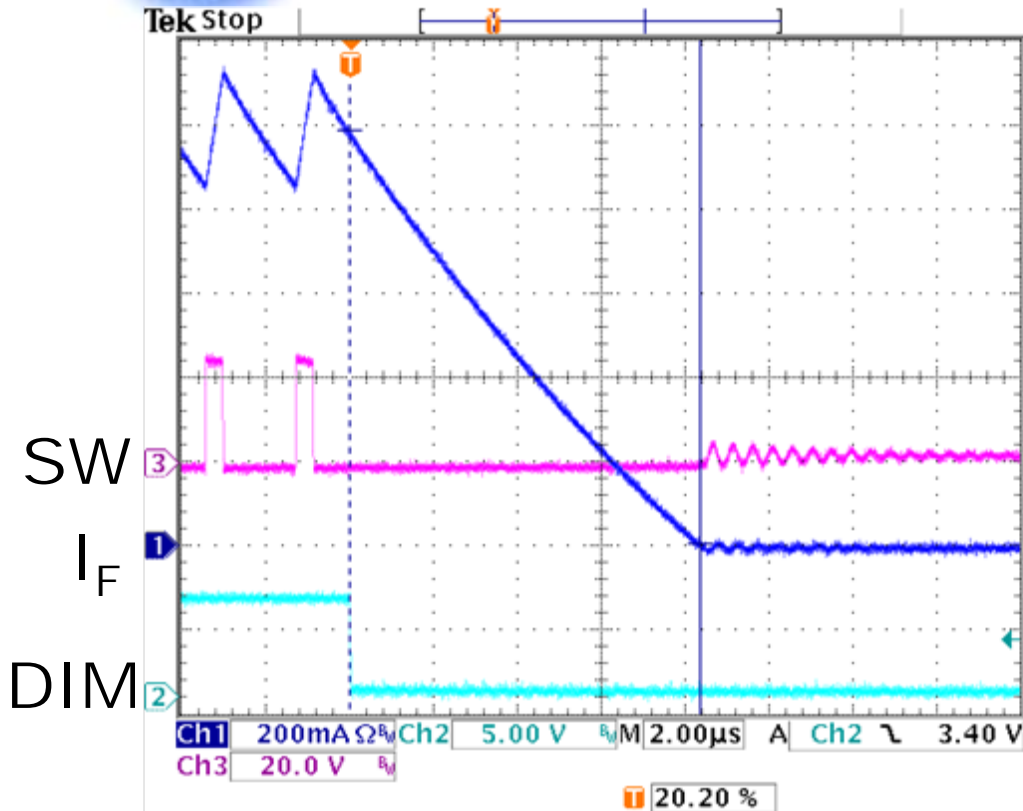
$$\Delta i_L = (V_{IN} - V_O) / L$$

Limited by $t_{OFF-MIN}$

$$t_{OFF-MIN} = 300 \text{ ns}$$

15 Nov 2006
11:56:12

LM3404 Slew Down, t_{SD}



$$\Delta i_L = -V_O / L$$

$$t_{SU} = 8.4 \mu s$$

15 Nov 2006
11:57:32



Calculate the Contrast Ratios

$$f_{\text{DIM}} = 500 \text{ Hz}, T_{\text{DIM}} = 2 \text{ ms}$$

- **LM3404**
- **$t_{\text{D}} + t_{\text{SU}} = 3.05 \mu\text{s}$**
- **$D_{\text{MIN}} = 3.05 / 2000 = 0.001525$**
- **$\text{CR} = 1 / D_{\text{MIN}} = 655 : 1$**



Low Frequency (< 1 kHz)

- **General and automotive applications**
- **More efficient: less transitions**
- **Duty cycle requirements not as strict: 10% to 90% is typical**
- **Usually achievable by using the DIM or EN pins**



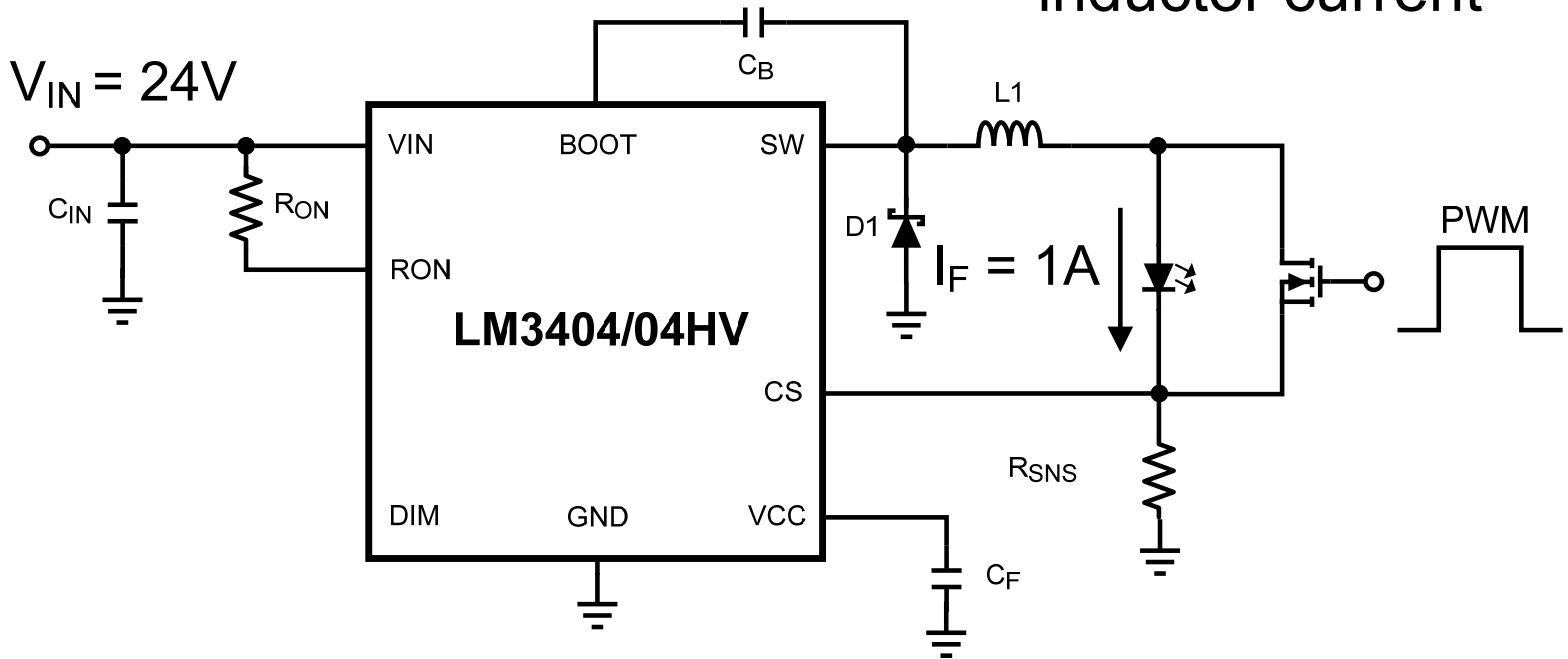
High Frequency (> 10 kHz)

- **Technical requirements force the users to high frequency**
- **Generation of white light from RGB in backlights, video projectors**
- **Machine vision and industrial inspection**
 - **Fast slew rates for light pulses that sync to sensors and cameras**
- **Loss of efficiency due to the transitions**
- **Usually requires a parallel dimming FET**



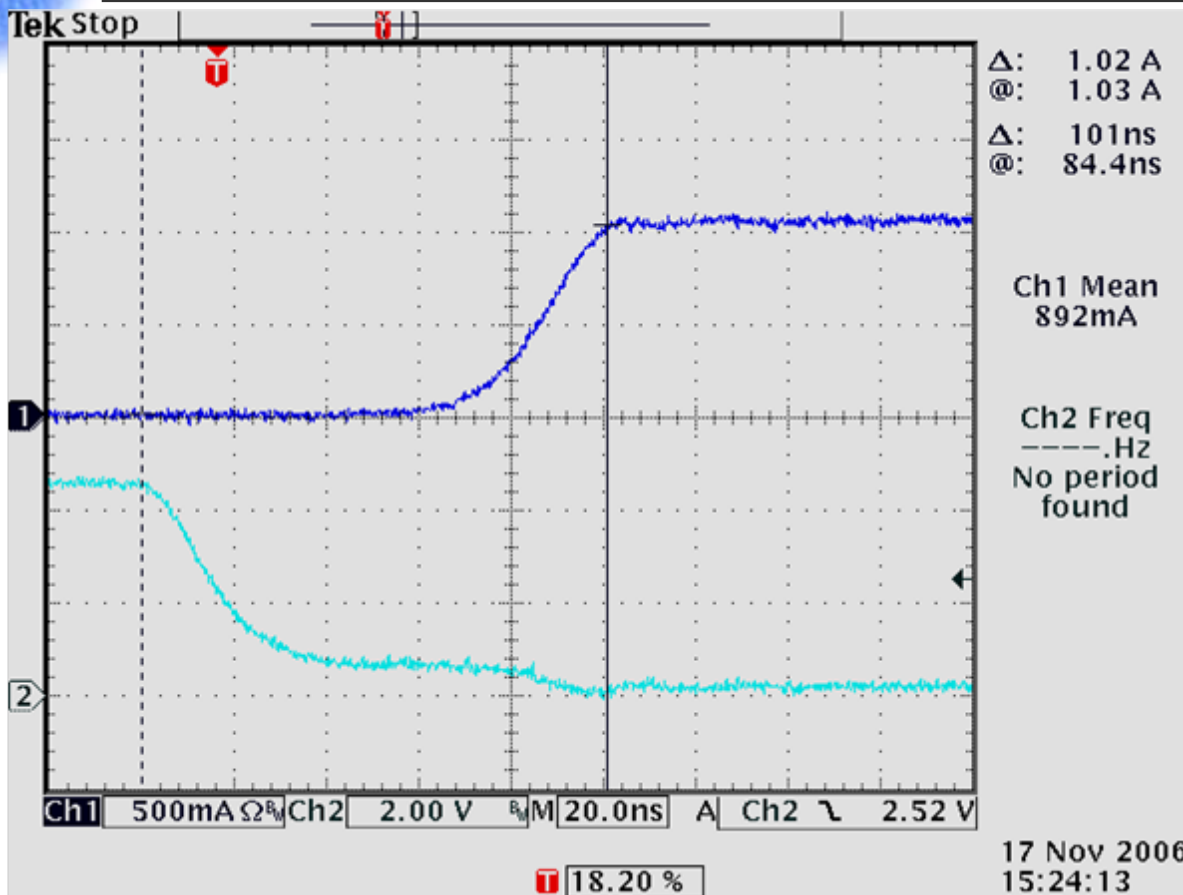
Parallel FET Dimming

Continuous inductor current



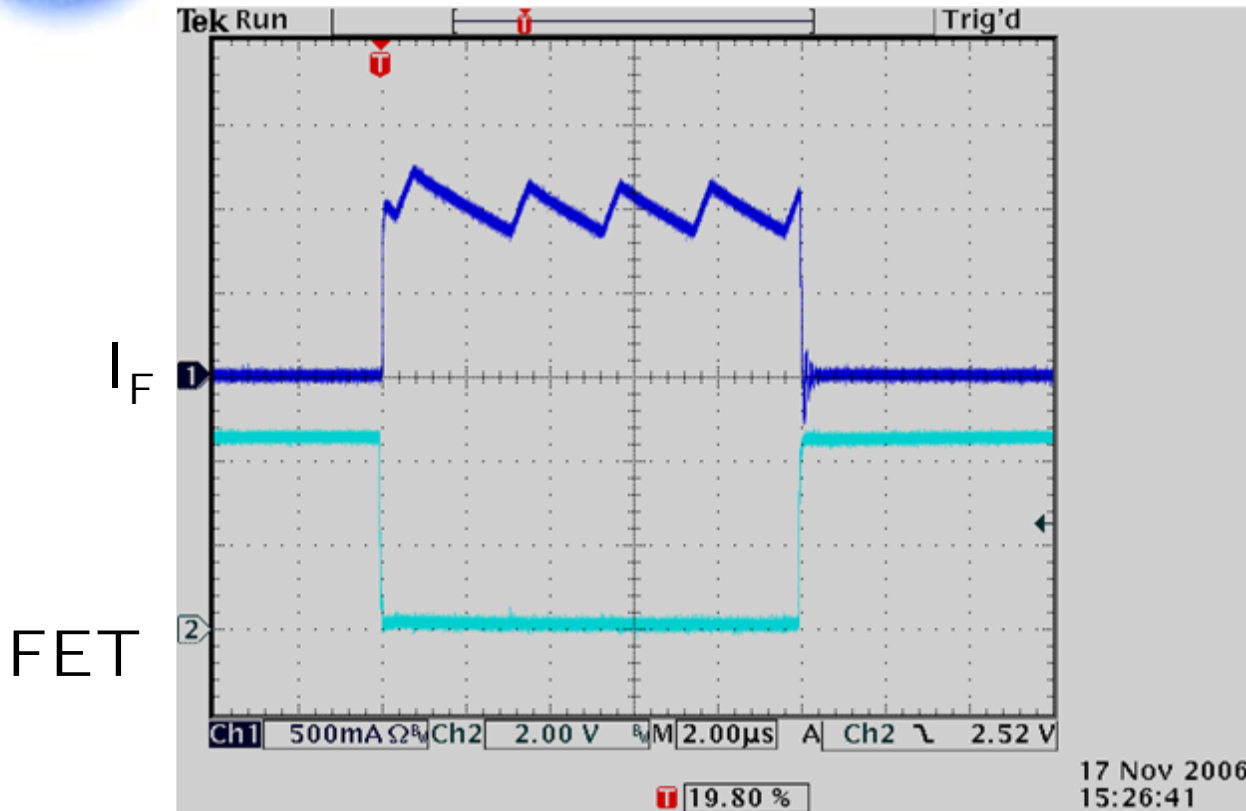
Parallel FET Results

FET
GATE





Parallel FET Results

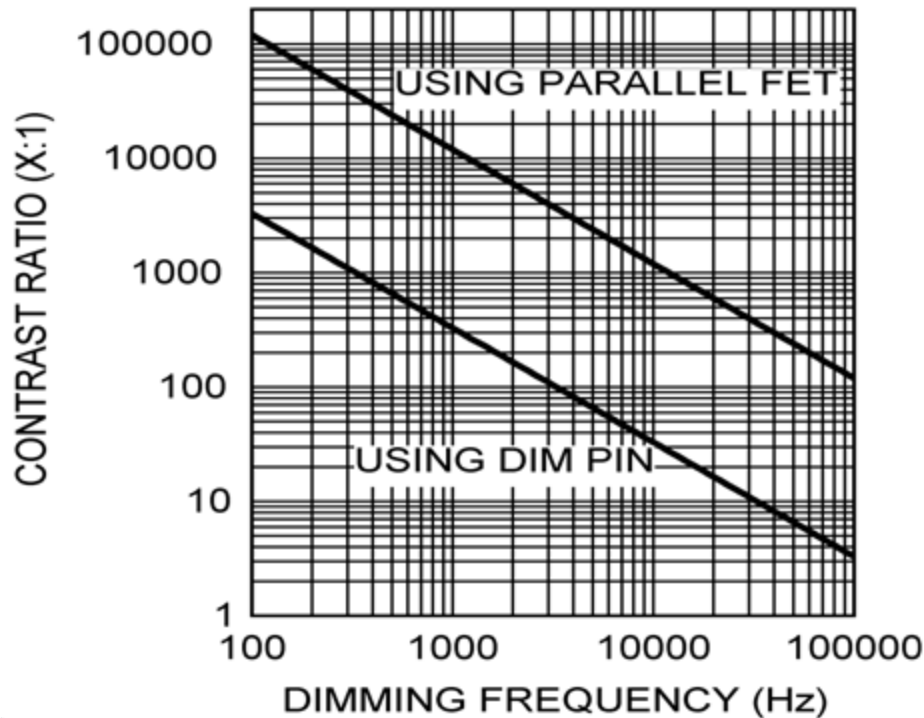


17 Nov 2006
15:26:41



CR Vs. f_{DIM}

- **Circuit parameters placed a limit on the minimum dimming on-time, $t_{MIN} = D_{MIN} \times f_{DIM}$**





New LED Driving Tools

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The Sight & Sound of Innovation

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Deutsche Version

LED Product Information

New Products:

- LP5520 RGB Backlight LED Driver
- LP5521 Programmable Three Channel LED Driver
- LP5522 Programmable LED Driver
- LP55281 Quad RGB Driver
- LM3509 High Efficiency Boost for White LEDs and/or OLED Displays with Dual Current Sinks and IC Compatible Brightness Control
- LM3402/LM3404 0.5A/1.0A Constant Current Buck Regulator for High Power LED Drivers, V_{in} Range from 6V to 42V
- LM3402HV/LM3404HV 0.5A/1.0A Constant Current Buck Regulator for High Power LED Drivers, V_{in} Range from 6V to 73V
- LM5022 60V Low Side Controller for Boost and SEPIC regulators, Allows Control of an External Mosfet to Deliver Higher Current to LEDs
- LM2754 800mA Switched Capacitor Flash LED Driver with Time-Out Protection
- LM3405 500kHz/1.6MHz 1A Constant Current Buck Regulator for LED Driver
- LM2754 800mA Switched Capacitor Flash LED Driver with Time-Out Protection
- LM27965 Dual Display White LED Driver with I²C Compatible Brightness Control
- LM27966 White LED Driver with I²C Compatible Interface

LED Product Tables:

- High Brightness LED Drivers
- Low Power White-LED Drivers
- Lighting Management Units (LMU)

NEW! LED Lighting Management Solutions Selection Guide (pdf 980KB)

LED Reference Design Library
Proven designs for various lighting applications, including automotive, general illumination, flashlights, and architectural lighting

Other WEBENCH Designs:

- LM2750 Low Noise Regulator Switched Capacitor Boost Regulator
- LM3557 Step-Up Converter for White LED Applications Switched Cap Converter

Online Education:

- Online Seminar: Lighting Solutions for Portable Devices

Press Releases:

LED WEBENCH

LED Selection

Select from the list below or enter your custom values:

V_f 3.0 V I_f 0.35 Amps Manufacturer: ALL

Vendor	Family	Part Number	Color	Vf	Is	Lm P/W	View
OSRAM	Power TOPLED®	LT-6650	blue	3.4	0.03	1.2	
OSRAM	Power TOPLED®	LT-6650	green	3.4	0.03	3.95	
OSRAM	Power TOPLED®	LW-6650	white	3.4	0.03	4	
OSRAM	Power TOPLED®	LA-6X75	amber	2.15	0.05	2.95	

Configuration and Options

V_{in} Min 25.0 V Number of LEDs: - Series 1 V_{LED} 3.0 V

V_{in} Max 42.0 V - Parallel 1 I_{out} 0.35 Amps

[Click here for full version of WEBENCH LED Designer](#)

Show Recommended Power LED ICs

LED Lighting

LED Lighting Overview
Regardless of type, color, size, or power, all LEDs work best when driven with a constant current. LED manufacturers specify the characteristics (such as lumens, beam pattern, color) of their devices at a specified forward current (I_f) not at a specific forward voltage (V_f). Most power supply ICs are designed to provide constant voltage outputs over a range of currents, hence it can be difficult to ascertain which parts will work for a given application from the device datasheet alone. With an array of LEDs, the main challenge is to ensure that every LED in the array is driven with the same current. Placing all the LEDs in a series string ensures that exactly the same current flows through each device.

Low-Power LEDs
Low-power LEDs are ideal for lighting portable electronics because they are efficient, easy to drive, small, thin, robust, and low noise. When running off a Lithium-Ion battery (typically 3.7V output voltage), each low-power LED requires up to 4V at 30 mA. To operate more than one LED for a lighting solution, an LED driver is needed to boost the voltage and regulate the current to optimize LED output.

For low-powered LEDs, National offers LED drivers for both parallel and series solutions. Parallel drivers with built-in, actively-matched, high- and low-side current sources, high efficiency, and a low total component count are available with inductive-boost converters, switched-capacitor boost converters, or no boost at all. National's series of LED drivers with inductive-boost converters provide solutions that combine very high efficiency with low noise and a small footprint. All of these solutions are optimized to drive 2 to 10 LEDs, and are available in the industry's smallest packaging: tiny micro-SMD BGA and versatile LLP (Leadless Leadframe Package) and CSP-leadless



Step 1 - Enter Design Inputs

Enter input voltage range

Enter Number of LEDs

Narrow LED choice by vendor and/or color

Select an LED from the list

Step 1: Choose your LED(s)

Manufacturer: Avago Cree Nichia OSRAM Philips Lumileds

Color: All

Desired LED Operating Current: $I_f = 0.35$ Amps

Or Define Your Custom LED:

$V_f = 3.2$ V

$R_d = 1.91$ Ohms

Click on a row to select your LED:

Vendor	Family	Part Number	Color	V _f	I _o	T _j	L _u Plat	View
Cree	XLamp® 7090	XR7090RD-L1-0001	red-orange	3	0.35	49		
Cree	XLamp® XR-C	XRCWHT-L1-WC-414-0-01	cool	3.5	0.35	60		
Cree	XLamp® XR-E	XREWHT-L1-WC-P3-0-01	cool	3.3	0.35	80		
OSRAM	Golden DRAGON®	LB-W5SM	blue	3.2	0.35	21		
OSRAM	Golden DRAGON®	LT-W5SM	green	3.2	0.35	33		
OSRAM	Golden DRAGON®	LW-W5SM	white	3.2	0.35	33		

Step 2: Configuration and Options

V_{in} Min: 15 V

V_{in} Max: 30 V

Number of LEDs: - Series: 1 - Parallel: 1

Total LED Load: V_{LED} = 3.2 V, I_{out} = 0.35 Amps

Show Recommended Power LED ICs

Back to power supply design page

OR

LED Reference Designs Library

Browse LED reference design library

Show Recommended Parts



Step 2 - Choose an LED Driver

National Semiconductor **MY WEBENCH** [Help](#)

1 Choose a Part 2 Create a Design 3 Analyze a Design 4 Build It! 5 Test It! [Demo](#)

[Design Requirements](#) [Recommended Parts](#) [MY Designs](#)

Your Design Specifications

Input Voltages	Output #1
VinMin = 15.0V	Vout = 3.2V
VinMax = 30.0V	Iout = 0.35A

Solution Selector found 10 solutions.

Recommended Devices

Switching Regulator
High efficiency regulator

LM3402
[Start Your Design](#)

Topology	BUCK
Max Current	0.5 A
Typical Efficiency	91%
On/Off Pin	Y
Error Pin	N
Price	\$1.25
Frequency	1800 kHz

[Switching Regulators]

[C](#) - Circuit Calculator [Ref](#) - Reference Design [S](#) - Webtherm Simulation [E](#) - Electrical Simulation [B](#) - Build It

Recommended Switching Regulators - BUCK Topology

#	Product Folder	Create	WEBENCH Tools	Est. Price	Typ. Eff.	On/Off	Err. Pin	Sync	Soft Start	AdjIpk	Design Considerations	Freq. kHz	Max Curr.
1	LM3402	Start Your Design	C E	\$1.25	91%	Y	N	N	N	N		1800	0.5A
2	LM3402HV	Start Your Design	C E	\$1.50	91%	Y	N	N	N	N		1800	0.5A
3	LM3404	Start Your Design	C E	\$1.50	92%	Y	N	N	N	N	Available in SO-8 and PSOP-8	1800	1.0A

Choose part





Step 3 - Optimize and Customize

National Semiconductor MYWEBENCH®
 1 Choose a Part 2 Create a Design 3 Analyze a Design 4 Build It!
 Components Operating Values Schematic MY Designs
 Design 171680_6815: LM3402MM Power Design
 Device: LM3402 Created: Jul 12 2007 6:10 PM
 VinMin = 25.0 V Vout[1] = 3.42 V
 VinMax = 42.0 V Iout[1] = 0.35 A
 Copy Rename Notes Report Share

Key operating values:
 Frequency,
 Efficiency
 Peak to Peak I_{LED}
 Temperature

Optimization Operating Values

Frequency	193 kHz	LED Ipp	34 mA (9 %)
Efficiency	72 %	LED Rd	0.1 Ohms
Duty Cycle	10 %	IC Dissipation	0.11 W
FootPrint	220.4 mm ²	IC Tj	53.02 °C

Optimization Tuning

Foot Print (excluding LEDs): 220.4 mm²

Efficiency: 72 %

User Preferred Freq (Hz)
 193000 < 287301

No Output Cap

User Preferred LED Ipp %
 System Defined

Optimize Circuit

Optimization knob:

Customize design for:
 No output cap
 Specify peak to peak
 LED ripple

Components

Part	Manufacturer	Part#	Attributes	Top View
Cb	Vishay Vitramon	VJ1206Y103KBBAT4X	0.01 uF	Select Alternate Part
Cbyp	TDK	C3216X7R2A104K	0.1 uF	Select Alternate Part
Cin	MuRata	GRM32ER72A105K	1 uF, 0.03 Ohms	Select Alternate Part
Cout	Custom	Custom	NumCaps=1 2.474375745086152E-5 F, 0.0010 Ohm	Select Alternate Part
D1	Diodes Inc.	B180-13	0.79 V	Select Alternate Part
D_LED	Custom	Custom	0.35 A, 0.1 , 3.42 V	Select Alternate Part
L1	TDK	SLF10145T-151MR79-PF	150 uH, 0.35 Ohms	Select Alternate Part



Optimize for Efficiency

Design 171680_6815: LM3402MM Power Design
 Device: LM3402
 VinMin = 25.0 V Vout[1] = 3.42 V
 VinMax = 42.0 V Iout[1] = 0.35 A
 Created: Jul 12 2007 6:10 PM

Optimization Operating Values

Frequency	98 kHz	LED Ipp	62 mA (17 %)
Efficiency	78 %	LED Rd	0.1 Ohms
Duty Cycle	10 %	3C Dissipation	0.07 W
FootPrint	937.3 mm ²	3C Tj	45.03 °C

Optimization Tuning

Foot Print (excluding LED): 937.3 mm² Efficiency: 78 %

Decrease Footprint << >> Increase Efficiency

Optimize Circuit

Components

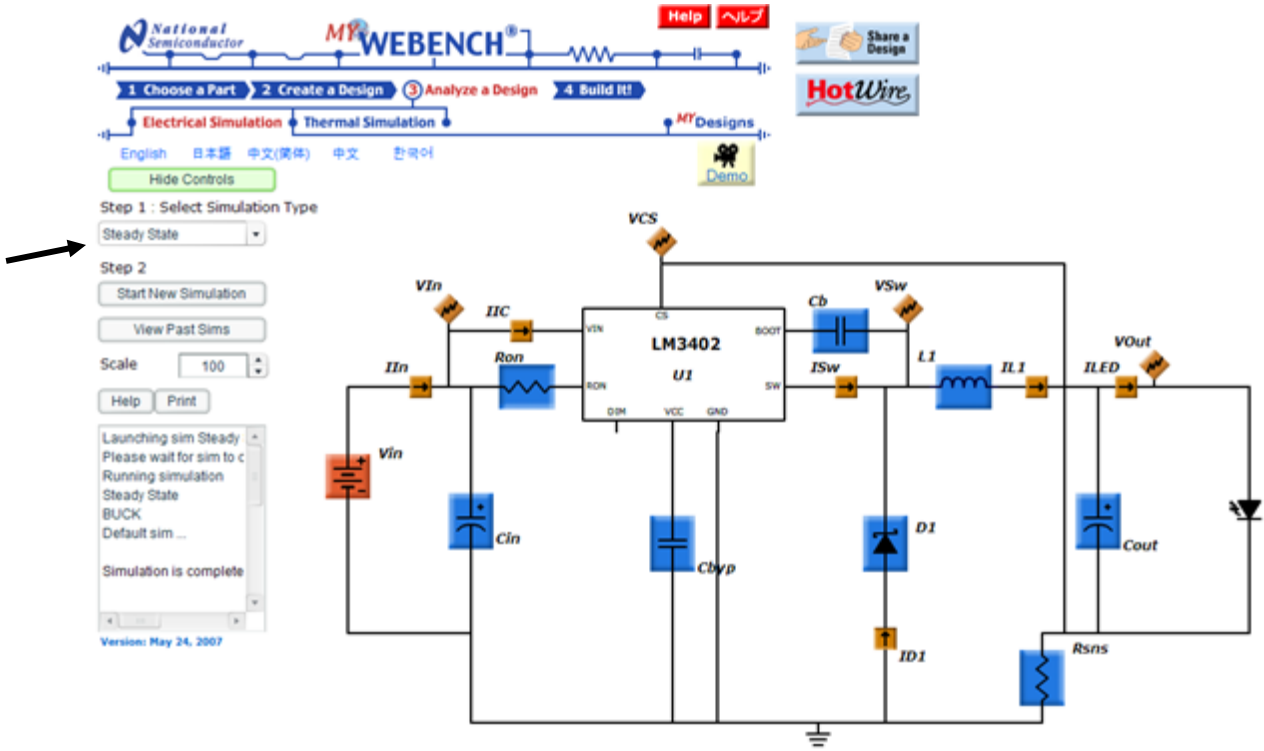
Part	Manufacturer	Part#	Attributes	Top View	
Cb	Vishay-Vitramon	V31206Y103KBBAT4X	0.01 uF		Select Alternate Part
Cbyp	TDK	C3216X7R2A104K	0.1 uF		Select Alternate Part
Cin	MuRata	GRM32ER72A105K	1 uF, 0.03 Ohms		Select Alternate Part
Cout	Nichicon	UPL11121MPH	120 uF, 0.1 Ohms		Select Alternate Part
D1	ON Semiconductor	MBR53100T3	0.62 V		Select Alternate Part
D_LED/Custom	Custom	Custom	0.35 A, 0.1, 3.42 V		Select Alternate Part
L1	JW Miller	PM2120-331K	330 uH, 0.1 Ohms		Select Alternate Part
Ron	Panasonic	ER0-6ENF2743V	274000 Ohms		Select Alternate Part

Optimization for efficiency:
 Lowers switching frequency, emphasizes low component power dissipation



Step 4 - Simulate Electrical Behavior

Spice simulation includes:
Steady state
Input transient
PWM dimming
Startup



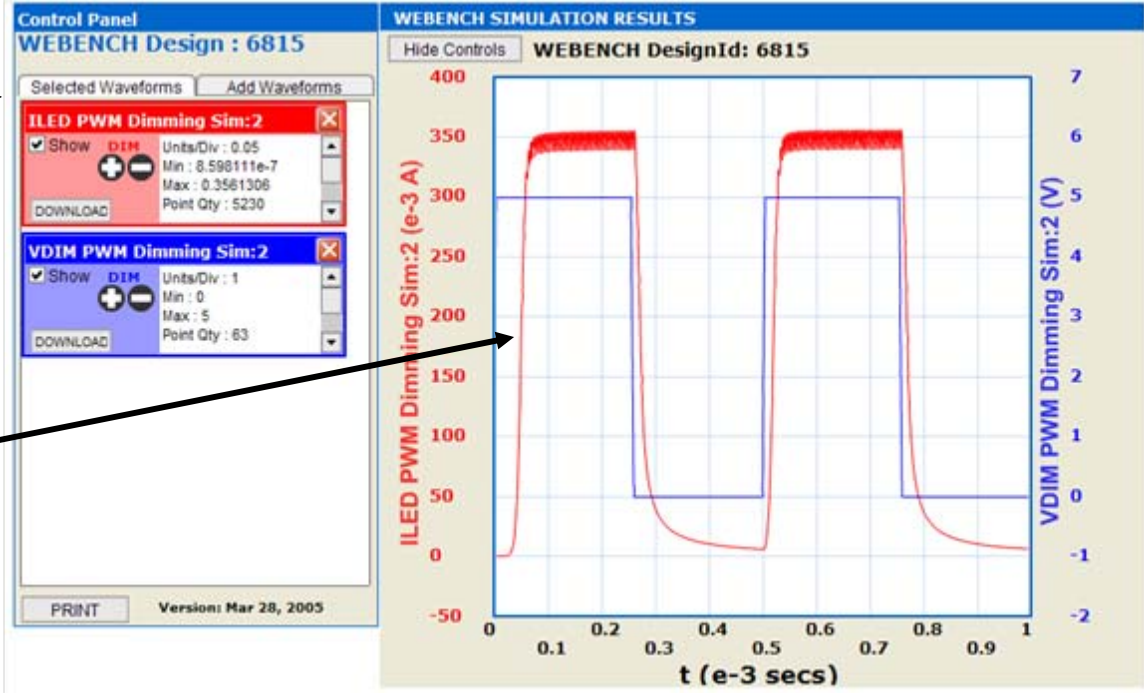


View Waveforms

Add/delete waveforms



Click and drag mouse to zoom in on plot





Build It!

- **Latest addition to LED WEBENCH® for LM3402/02HV and LM3404/04HV**
- **Generic evaluation board accepts a wide variety of external components**
- **User orders and receives a kit with blank PCB and all external components as selected through LED Webench**
- **Simply solder, connect to LEDs, and go**
- **Note: LEDs are not included**

LED Reference Design Library

<http://power.national.com>

Modify

LM2698 Design Document

View/Print PDF

Description Specifications Schematic Bill of Materials

Description

Title: LM2698 8 x 4 LED Array Driver for Knokia

This design drives 32 White LEDs in eight strings of 4, 20mA per string. The circuit consists of a power section optimized to deliver a total of 160mA to the LED array. The first string is controlled by the feedback loop to 20mA. The remaining strings are controlled by the current mirrors created by the PNP transistors at the top of each string.

This design uses the LM2698 SIMPLE SWITCHER® PWM boost converter. The 1.9A, 18V, 0.2ohm internal switch enables the LM2698 to provide efficient power conversion to outputs ranging from 2.2V to 17V. It can operate with input voltages as low as 2.2V and as high as 12V. Current-mode architecture provides superior line and load regulation and simple frequency compensation over the device's 2.2V to 12V input voltage range. The LM2698 sets the standard in power density and is capable of supplying 12V at 400mA from a 5V input. The LM2698 can also be used in flyback or SEPIC topologies.

The LM2698 features a pin selectable switching frequency of either 600kHz or 1.25MHz. This promotes flexibility in component selection and filtering techniques.

A shutdown pin is available to suspend the device and decrease the quiescent current to 5µA. An external compensation pin gives the user flexibility in setting frequency compensation, which makes possible the use of small, low ESR ceramic capacitors at the output. Switchers Made Simple® software is available to insure a quick, easy and guaranteed design. The

Customize

LM2698 Design Document for Knokia

National Semiconductor
LM2698
June 2006

1.0 Design Specifications

Inputs	Outputs #1
VINMIN=0	VOUT1=16
VINMAX=0	VOUT16=160

2.0 Design Description

The circuit consists of a power section optimized to deliver a total of 160mA to the LED array. The first string is controlled by the feedback loop to 20mA. The remaining strings are controlled by the current mirrors created by the PNP transistors at the top of each string.

3.0 Schematic

4.0 Bill of Materials

Part	Manufacturer	Part#	Attribution
CC	Vishay	VJ9905H472000AT	4.7uF
Cin	TDK	C32X67R1E100M	Non-Capacit, 10uF
Co	TDK	C32X67R1E100M	10uF
D1	Vishay	S912	0.5-V
L1	TDK	SELFOCT-330MR1S-2	33uH, 50m Ohms
Q1	Vishay	2N4306	
Q2	Vishay	2N4306	

FIGURE 1. Example Schematic Showing Connection for all Components.

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Custom datasheet of the resulting design

