LM3434 Common Anode Capable High Brightness LED Driver with High Frequency

Dimming



Literature Number: SNVS619A



# Common Anode Capable High Brightness LED Driver with High Frequency Dimming

## **General Description**

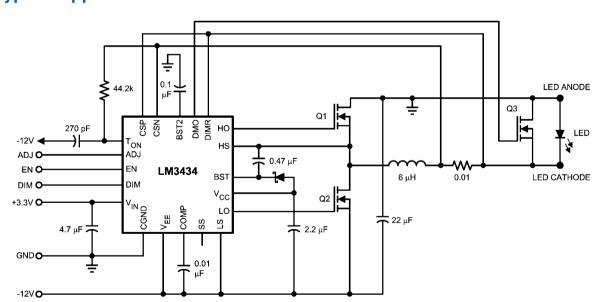
The LM3434 is an adaptive constant on-time DC/DC buck (step-down) constant current controller (a true current source). The LM3434 provides a constant current for illuminating high power LEDs. The output configuration allows the anodes of multiple LEDs to be tied directly to the ground referenced chassis for maximum heat sink efficacy. The high frequency capable architecture allows the use of small external passive components and no output capacitor while maintaining low LED ripple current. Two control inputs are used to modulate LED brightness. An analog current control input is provided so the LM3434 can be adjusted to compensate for LED manufacturing variations and/or color temperature correction. The other input is a logic level PWM control of LED current. The PWM functions by shorting out the LED with a parallel switch allowing high PWM dimming frequencies. High frequency PWM dimming allows digital color temperature control, interference blanking, field sequential illumination, and brightness control. Additional features include thermal shutdown, V<sub>CC</sub> under-voltage lockout, and logic level shutdown mode. The LM3434 is available in a low profile LLP-24 package.

## **Features**

- Operating input voltage range of -9V to -30V w.r.t. LED anode
- Control inputs are referenced to the LED anode
- Output current greater than 6A
- Greater than 30kHz PWM frequency capable
  Negative output voltage capability allows LED anode to be
- tied directly to chassis for maximum heat sink efficacy No output capacitor required
- Up to 1MHz switching frequency
- Low I<sub>O</sub>, 1mA typical
- Soft start
- Adaptive programmable ON time allows for constant ripple current
- LLP-24 package

## **Applications**

- Projection systems
- Solid state lighting
- Automotive lighting

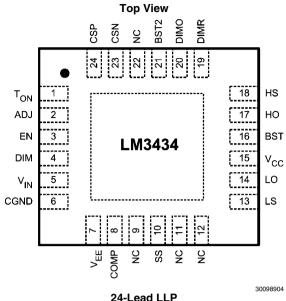


30098931

.M3434 Common Anode Capable High Brightness LED Driver with High Frequency Dimming

## **Typical Application Circuit**

# **Connection Diagram**



24-Lead LLP NS Package Number SQA24A

# **Ordering Information**

Order Number	Spec.	Package Type	NSC Package Drawing	Supplied As	
LM3434SQ	NOPB	LLP-24	SQA24A	1000 Units, Tape and Reel	
LM3434SQX	NOPB	LLP-24	SQA24A	4500 Units, Tape and Reel	

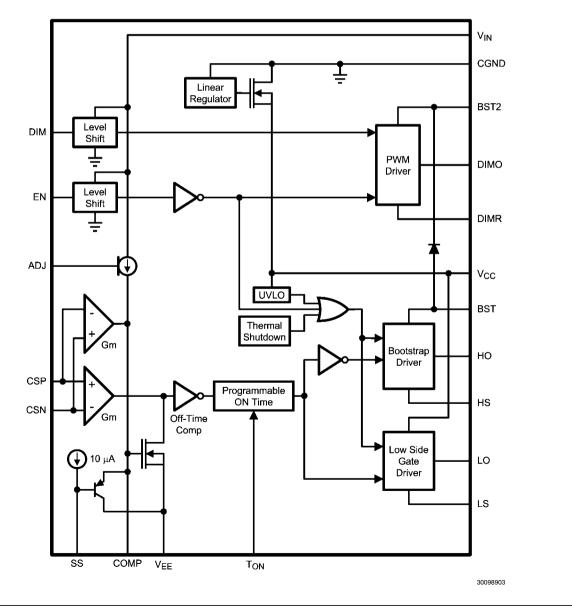
# **Pin Descriptions**

Pin	Name	Function		
1	T <sub>ON</sub>	On-time programming pin. Tie an external resistor ( $R_{ON}$ ) from $T_{ON}$ to CSN, and a capacitor ( $C_{ON}$ ) from $T_{ON}$ to $V_{EE}$ . This sets the nominal operating frequency when the LED is fully illuminated.		
2	ADJ	Analog LED current adjust. Tie to $V_{IN}$ for fixed 60mV average current sense resistor voltate to an external reference to adjust the average current sense resistor voltage (programmed current). Refer to the "V <sub>SENSE</sub> vs. ADJ Voltage" graphs in the <i>Typical Performance Characteristics</i> section and the <i>Design Procedure</i> section of the datasheet.		
3	EN	Enable pin. Connect this pin to logic level HI or $V_{IN}$ for normal operation. Connect this pin to CGND for low current shutdown. EN is internally tied to $V_{IN}$ through a 100k resistor.		
4	DIM	Logic level input for LED PWM dimming. DIM is internally tied to CGND through a 100k resistor		
5	V <sub>IN</sub>	Logic power input: Connect to positive voltage between +3.0V and +5.8V w.r.t. CGND.		
6	CGND	Chassis ground connection.		
7	V <sub>EE</sub>	Negative voltage power input: Connect to voltage between -30V to -9V w.r.t. CGND.		
8	COMP	Compensation pin. Connect a capacitor between this pin and $V_{EE}$ .		
9	NC	No internal connection. Tie to V <sub>EE</sub> or leave open.		
10	SS	Soft Start pin. Tie a capacitor from SS to V <sub>EE</sub> to reduce input current ramp rate. Leave pin oper if function is not used. The SS pin is pulled to V <sub>EE</sub> when the device is not enabled.		
11	NC	No internal connection. Tie to V <sub>EE</sub> or leave open.		
12	NC	No internal connection. Tie to V <sub>EE</sub> or leave open.		
13	LS	Low side FET gate drive return pin.		
14	LO	Low side FET gate drive output. Low in shutdown.		

LM3434

Pin	Name	Function	
15	V <sub>cc</sub>	Low side FET gate drive power bypass connection and boost diode anode connection. Tie a 2.2µF capacitor between $V_{CC}$ and $V_{EE}$ .	
16	BST	High side "synchronous" FET drive bootstrap rail.	
17	HO	High side "synchronous" FET gate drive output. Pulled to HS in shutdown.	
18	HS	Switching node and high side "synchronous" FET gate drive return.	
19	DIMR	LED dimming FET gate drive return. Tie to LED cathode. If PWM dimming is not used this pir may be left open.	
20	DIMO	LED dimming FET gate drive output. DIMO is a driver that switches between DIMR and If PWM dimming is not used this pin may be left open.	
21	BST2	DIMO high side drive supply pin. Tie a $0.1\mu F$ between BST2 and CGND.	
22	NC	No internal connection. Tie to V <sub>EE</sub> or leave open.	
23	CSN	Current sense amplifier inverting input. Connect to current sense resistor negative terminal.	
24	CSP	Current sense amplifier non-inverting input. Connect to current sense resistor positive terminal.	
EP	V <sub>EE</sub>	Exposed Pad on the underside of the device. Connect this pad to a PC board plane connected to V <sub>EE</sub> .	

# **Block Diagram**



LM3434

## Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

V <sub>IN</sub> , EN, DIM, ADJ to CGND	-0.3V to +7V
COMP, SS to V <sub>EE</sub>	-0.3V to +7V
BST to HS	-0.3V to +7V
$V_{CC}$ to $V_{EE}$	-0.3V to +7.5V
CGND, DIMR, CSP, CSN,	
T <sub>ON</sub> to V <sub>EE</sub>	-0.3V to +33V
HS to V <sub>EE</sub> ( <i>Note 2</i> )	-0.3V to +33V
LS to V <sub>EE</sub>	-0.3V to +0.3V
HO output	HS-0.3V to BST+0.3V
DIMO to DIMR	-0.3V to +7V
LO output	LS-0.3V to V <sub>CC</sub> +0.3V

BST2 to V <sub>EE</sub>	-0.3V to 40V
Maximum Junction	150°C
Temperature	
Power Dissipation( <i>Note 3</i> )	Internally Limited
ESD Susceptibility	
( <i>Note 4</i> )	
Human Body Model	2kV

## **Operating Conditions**

Operating Junction	
Temperature Range ( <i>Note 5</i> )	-40°C to +125°C
Storage Temperature	–65°C to +150°C
Input Voltage V <sub>IN</sub> w.r.t. CGND	3.0V to 5.8V
Input Voltage V <sub>EE</sub> w.r.t. CGND	-9V to -30V
ADJ Input Voltage Range to CGND	0V to $V_{\rm IN}$

## **Electrical Characteristics**

Specifications in standard type face are for  $T_J = 25^{\circ}$ C and those with **boldface type** apply over the full **Operating Temperature Range** ( $T_J = -40^{\circ}$ C to +125°C). Minimum and Maximum limits are guaranteed through test, design, or statistical correlation. Typical values represent the most likely parametric norm at  $T_J = +25^{\circ}$ C, and are provided for reference purposes only. Unless otherwise stated the following conditions apply:  $V_{EE} = -12.0$ V and  $V_{IN} = +3.3$ V with respect to CGND.

Symbol	Parameter	Conditions	Min (Note 5)	Typ (Note 6)	Max ( <i>Note 5</i> )	Units	
SUPPLY CL	JRRENT	L				1	
I <sub>IN</sub> V <sub>EE</sub>	V <sub>EE</sub> Quiescent Current	EN = CGND		142	250	μA	
		EN = V <sub>IN</sub> , Not Switching		1.0		mA	
I <sub>IN</sub> V <sub>IN</sub>	V <sub>IN</sub> Quiescent Current	EN = V <sub>IN</sub> , Not Switching		450			
		EN = CGND		35	71	μΑ	
OUTPUT CL	JRRENT CONTROL					•	
V <sub>CS</sub>	Current sense target voltage; $V_{CS} = V_{CSP} - V_{CSN}$	$V_{ADJ} = V_{IN}$	57	60	63	mV	
G <sub>ADJ</sub>	$I_{ADJ} Gain = (V_{ADJ} - CGND)/$ $(V_{CNP} - V_{CSN})$	V <sub>IN</sub> = 3.3V, V <sub>ADJ</sub> = 0.5V or 1.5V w.r.t. CGND	15	16.67	18	V/V	
I <sub>CSN</sub>	Isense Input Current	V <sub>ADJ</sub> = 1V w.r.t. CGND		-50			
		$V_{ADJ} = V_{IN}$		10		μA	
I <sub>CSP</sub>	Isense Input Current	$V_{ADJ} = V_{IN}$		60		<u> </u>	
		V <sub>ADJ</sub> = 1V w.r.t. CGND		1		μA	
Gm	CS to COMP Transconductance; Gm = $I_{COMP} / (V_{CSP} - V_{CSN} - V_{ADJ} / 16.67)$		0.6	1.3	2.2	mS	
ON TIME CO	,						
T <sub>ONTH</sub>	On time threshold	$V_{T_{ON}}$ - $V_{EE}$ at terminate ON time event	230	287	334	mV	
GATE DRIV	E AND INTERNAL REGULATOR	1					
V <sub>CCOUT</sub>	$V_{CC}$ output regulation w.r.t. $V_{EE}$	I <sub>CC</sub> = 0mA to 20mA	6.3	6.75	7.1	V	
V <sub>CCILIM</sub>	V <sub>CC</sub> current limit	$V_{CC} = V_{EE}$		-110		mA	
R <sub>OLH</sub>	HO output low resistance	I = 50mA source		2			
R <sub>OHH</sub>	HO output high resistance	I = 50mA sink		3		Ω	
R <sub>OLL</sub>	LO output low resistance	I = 50mA source		2			
R <sub>OHL</sub>	LO output high resistance	I = 50mA sink		3		Ω	
R <sub>OLP</sub>	DIMO output low resistance	I = 5mA source		20		_	
R <sub>OHP</sub>	DIMO output high resistance	I = 5mA sink		30		Ω	

Symbol	Parameter	Conditions	Min ( <i>Note 5</i> )	Typ (Note 6)	Max ( <i>Note 5</i> )	Units
FUNCTIONA			•	· · · · · · · · · · · · · · · · · · ·		
V <sub>INUVLO</sub>	V <sub>IN</sub> undervoltage lockout	With respect to CGND		1.4		V
V <sub>CCUVLO</sub>	V <sub>CC</sub> - V <sub>EE</sub> undervoltage lockout	On Threshold	6.0	6.6	7.0	v
	thresholds	Off threshold	4.9	5.4	5.8	
V <sub>EN</sub>	Enable threshold, with respect	Device on w.r.t. CGND			1.6	V
	to CGND	Device off w.r.t. CGND	0.6			
R <sub>EN</sub>	Enable pin pullup resistor			100		kΩ
V <sub>DIM</sub>	DIM logic input threshold	DIM rising threshold w.r.t. CGND			1.6	v
		DIM falling threshold w.r.t. 0.6 CGND				
R <sub>DIM</sub>	DIM pin pulldown resistor			100		kΩ
I <sub>ADJ</sub>	ADJ pin current		-1.0		1.0	μA
I <sub>SS</sub>	SS pin source current			10		μA
R <sub>SS</sub>	SS pin pulldown resistance	EN = CGND		1.0		kΩ
AC SPECIFI	CATIONS			··		
T <sub>DTD</sub> LO and HO dead time		LO falling to HO rising dead time		26		
		HO falling to LO rising dead time		28		ns
T <sub>PDIM</sub>	DIM to DIMO propagation	DIM rising to DIMO rising delay		96	175	
delay		DIM falling to DIMO falling delay		40	160	ns
THERMAL S	PECIFICATIONS		-			
T <sub>JLIM</sub>	Junction temperature thermal limit			175		°C
T <sub>JLIM(hyst)</sub>	Thermal limit hysteresis			20		°C
θ <sub>JA</sub>	LLP-24 package thermal resistance	JEDEC 4 layer board		39		°C/W

**Note 1:** Absolute maximum ratings are limits beyond which damage to the device may occur. Operating Ratings are conditions for which the device is intended to be functional, but device parameter specifications may not be guaranteed. For guaranteed specifications and test conditions, see the Electrical Characteristics. **Note 2:** The HS pin can go to -6V with respect to V<sub>EE</sub> for 30ns and +22V with respect to V<sub>EE</sub> for 50ns without sustaining damage.

**Note 3:** The maximum allowable power dissipation is a function of the maximum junction temperature,  $T_J(MAX)$ , the junction-to-ambient thermal resistance,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation at any ambient temperature is calculated using:  $P_D (MAX) = (T_{J(MAX)} - T_A)/\theta_{JA}$ . Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage. Thermal shutdown engages at  $T_J=175^{\circ}C$  (typ.) and disengages at  $T_J=155^{\circ}C$  (typ).

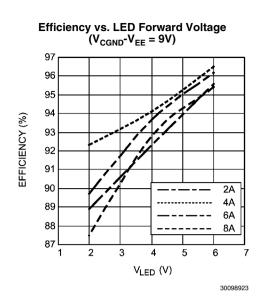
Note 4: Human Body Model, applicable std. JESD22-A114-C.

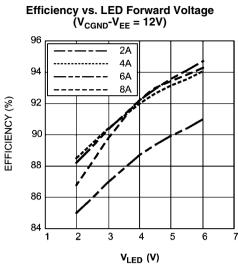
Note 5: All limits guaranteed at room temperature (standard typeface) and at temperature extremes (bold typeface). All room temperature limits are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

Note 6: Typical numbers are at 25°C and represent the most likely norm.

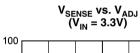
LM3434

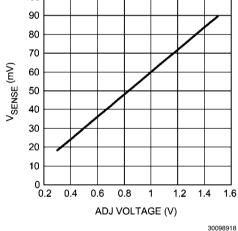
# **Typical Performance Characteristics**

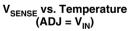


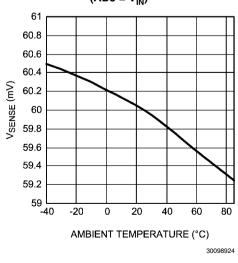


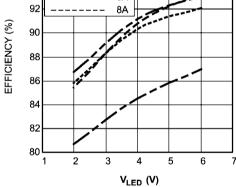
30098922

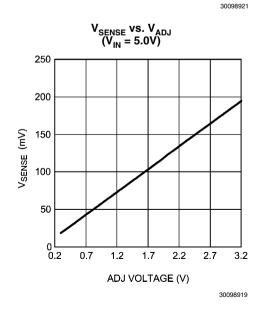




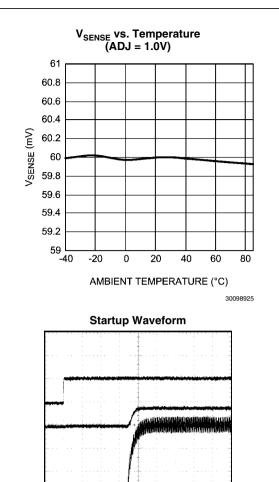


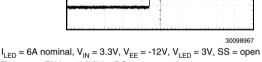








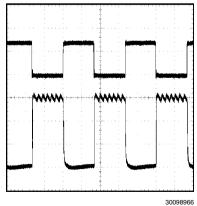




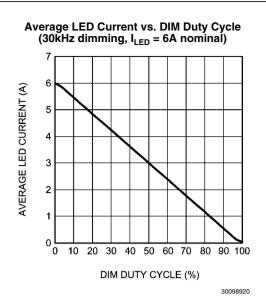
 $I_{LED} = 6A$  nominal,  $v_{IN} = 3.3v$ ,  $v_{EE} = -12v$ ,  $v_{LED} = 3v$ , St Top trace: EN input, 2V/div, DC Middle trace: V input current, 2A/div, DC

Middle trace:  $V_{EE}$  input current, 2A/div, DC Bottom trace:  $I_{LED}$ , 2A/div, DC T = 100µs/div

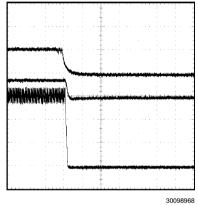
#### 30kHz PWM Dimming Waveform Showing Inductor Ripple Current



$$\begin{split} I_{LED} &= 6A \text{ nominal, } V_{IN} = 3.3V, \, V_{EE} = -12V \\ \text{Top trace: DIM input, } 2V/div, \, DC \\ \text{Bottom trace: } I_{LED}, \, 2A/div, \, DC \\ \text{T} &= 10 \mu s/div \end{split}$$



#### Shutdown Waveform



$$\begin{split} I_{LED} &= 6A \text{ nominal, } V_{IN} = 3.3V, V_{EE} = -12V, V_{LED} = 3V, SS = \text{open} \\ \text{Top trace: EN input, } 2V/\text{div, DC} \\ \text{Middle trace: } V_{EE} \text{ input current, } 2A/\text{div, DC} \\ \text{Bottom trace: } I_{LED}, 2A/\text{div, DC} \end{split}$$

T = 100µs/div

## Operation

#### **CURRENT REGULATOR OPERATION**

The LM3434 is a controller for a Continuous Conduction Buck Converter. Because of its buck topology and operation in the continuous mode, the output current is very well controlled. It only varies within a switching frequency cycle by the inductor ripple current. This ripple current is normally set at 10% of the DC current. Setting the ripple current lower than 10% is a useful tradeoff of inductor size for less LED light output ripple. Additional circuitry can be added to achieve any LED light ripple desired.

The LED current is set by the voltage across a sense resistor. This sense voltage is nominally 60mV but can be programmed higher or lower by an external control voltage.

The running frequency of the converter is programmed by an external RC network in conjunction with the LED's forward voltage. The frequency is nominally set around 200kHz to 500khz. Fast PWM control is available by shorting the output of the current source by a MOSFET in parallel with the LED. During the LED OFF time the running frequency is determined by the RC network and the parasitic resistance of the output circuit including the DIM FET R<sub>DSON</sub>.

The LM3434 system has been evaluated to be a very accurate, high compliance current source. This is manifest in its high output impedance and accurate current control. The current is measured to vary less than 6mA out of 6A when transitioning from LED OFF (output shorted) to LED ON (output ~6V).

#### PROTECTION

The LM3434 has dedicated protection circuitry running during normal operation. The thermal shutdown circuitry turns off all power devices when the die temperature reaches excessive levels. The  $V_{CC}$  undervoltage lockout (UVLO) comparator protects the power devices during power supply startup and shutdown to prevent operation at voltages less than the minimum operating input voltage. The  $V_{CC}$  pin is short circuit protected to  $V_{EE}$ . The LM3434 also features a shutdown mode which decreases the supply current to approximately 35µA.

The ADJ, EN, and DIM pins are capable of sustaining up to +/-2mA. If the voltages on these pins will exceed either  $V_{IN}$  or CGND by necessity or by a potential fault, an external resistor is recommended for protection. Size this resistor to limit pin current to under 2mA. A 10k resistor should be sufficient. This resistor may be used in any application for added protection without any impact on function or performance.

#### **Output Open Circuit**

The LM3434 can be powered up with an open circuit without sustaining any damage to the circuit. During normal operation the circuit will also tolerate an open circuit condition without sustaining damage provided a schottky diode is placed within the circuit to provide a current path to disharge the energy stored in the inductor. The anode of the schottky should be connected to the negative supply voltage while the cathode should be connected to the point where the inductor and sense resistor intersect. This diode should have a surge current rating equal to that of the maximum LED current driven.

#### **DESIGN PROCEDURE**

This section presents guidelines for selecting external components.

#### SETTING LED CURRENT CONTROL

LM3434 uses average current mode control to regulate the current delivered to the LED (I<sub>LED</sub>). An external current sense resistor (R<sub>SENSE</sub>) in series with the LED is used to convert I<sub>LED</sub> into a voltage that is sensed by the LM3434 at the CSP and CSN pins. CSP and CSN are the inputs to an error amplifier with a programmed input offset voltage (V<sub>SENSE</sub>). V<sub>SENSE</sub> is used to regulate I<sub>LED</sub> based on the following equation:

$$I_{LED} = V_{SENSE}/R_{SENSE}$$

#### **FIXED LED CURRENT**

The ADJ pin sets  $\rm V_{SENSE}.$  Tie ADJ to  $\rm V_{IN}$  to use a fixed 60mV internal reference for  $\rm V_{SENSE}.$  Select  $\rm R_{SENSE}$  to fix the LED current based on the following equation:

 $R_{SENSE} = 60 mV/I_{LED}$ 

#### ADJUSTABLE LED CURRENT

When tied to an external voltage the ADJ pin sets  $\rm V_{\rm SENSE}$  based on the following equation:

$$V_{\text{SENSE}} = (V_{\text{ADJ}} - V_{\text{CGND}})/16.667$$

When the reference on ADJ is adjustable,  $V_{SENSE}$  and  $I_{LED}$  can be adjusted within the linear range of the ADJ pin. This range has the following limitations:

$$0.3V < V_{ADJ} <$$
 (The greater of 1.5V or (V<sub>IN</sub> - 1.9V))

When  $V_{ADJ}$  is less than this linear range the  $V_{SENSE}$  is guaranteed by design to be less than or equal to 0.3V/16.667. When  $V_{ADJ}$  is greater than this linear range and less than  $V_{IN}$  - 1V,  $V_{SENSE}$  is guaranteed by design to be less than or equal to  $V_{ADJ}/16.667$ . If  $V_{ADJ}$  is greater than  $V_{IN}$  - 1V,  $V_{SENSE}$  switches to 60mV.

#### INPUT CAPACITOR SELECTION

A low ESR ceramic capacitor is needed to bypass the MOS-FETs. This capacitor is connected between the drain of the synchronous FET (CGND) and the source of the main switch (V<sub>EE</sub>). This capacitor prevents large voltage transients from appearing at the V<sub>EE</sub> pin of the LM3434. Use a 22µF value minimum with X5R or X7R dielectric. In addition to the FET bypass capacitors, additional bypass capacitors should be placed near the V<sub>EE</sub> and V<sub>IN</sub> pins and should be returned to CGND.

The input capacitor must also be sized to handle the dimming frequency input ripple when the DIM function is used. This ripple may be as high as 85% of the nominal DC input current (at 50% duty cycle). When dimming this input capacitor should be selected to handle the input ripple current.

# RECOMMENDED OPERATING FREQUENCY AND ON TIME "TIME<sub>ON</sub>" CALCULATION

Although the switching frequency can be set over a wide range, the following equation describes the recommended frequency selection given inexpensive magnetic materials available today:

$$f = \frac{A}{\sqrt{I_{LED}}} (MHz)$$

In the above equation A=1.2 for powdered iron core inductors and A=0.9 or less for ferrite core inductors. This difference takes into account the fact that ferrite cores generally become more lossy at higher frequencies. Given the switching frequency f calculated above, TIME<sub>ON</sub> can be calculated. If V<sub>LED</sub> is the forward voltage drop of the LED that is being driven, TIME<sub>ON</sub> can be calculated with the following equation:

$$\mathsf{TIME}_{\mathsf{ON}} = \frac{\mathsf{V}_{\mathsf{LED}}}{\mathsf{f}|\mathsf{V}_{\mathsf{EE}}|}$$

#### TIMING COMPONENTS (R<sub>ON</sub> and C<sub>ON</sub>)

Using the calculated value for TIME<sub>ON</sub>, the timing components R<sub>ON</sub> and C<sub>ON</sub> can be selected. C<sub>ON</sub> should be large enough to dominate the parasitic capacitance of the T<sub>ON</sub> pin. A good C<sub>ON</sub> value for most applications is 1nF. Based on calculated TIME<sub>ON</sub>, C<sub>ON</sub>, and the nominal V<sub>EE</sub> and V<sub>LED</sub> voltages, R<sub>ON</sub> can be calculated based on the following equation:

$$R_{ON} = \frac{TIME_{ON}}{C_{ON}(0.3/(|V_{EE}|-V_{LED}))}$$

#### **INDUCTOR SELECTION**

The most critical inductor parameters are inductance, current rating, and DC resistance. To calculate the inductance, use the desired peak to peak LED ripple current ( $I_{RIPPLE}$ ),  $R_{ON}$ , and  $C_{ON}$ . A reasonable value for  $I_{RIPPLE}$  is 10% of  $I_{LED}$ . The inductor value is calculated using the following equation:

$$L = \frac{0.3 \times R_{ON} \times C_{ON}}{I_{RIPPLE}}$$

#### For all $V_{LED}$ and $V_{EE}$ voltages, $I_{RIPPLE}$ remains constant and is only dependent on the passive external components $R_{ON}$ , $C_{ON}$ , and L.

The I<sup>2</sup>R loss caused by the DC resistance of the inductor is an important parameter affecting the efficiency. Lower DC resistance inductors are larger. A good tradeoff point between the efficiency and the core size is letting the inductor I<sup>2</sup>R loss equal 1% to 2% of the output power. The inductor should have a current rating greater than the peak current for the application. The peak current is I<sub>LED</sub> plus 1/2 I<sub>RIPPLE</sub>.

#### **POWER FET SELECTION**

FETs should be chosen so that the  $I^{2}R_{DSON}$  loss is less than 1% of the total output power. Analysis shows best efficiency

with around  $8m\Omega$  of  $R_{DSON}$  and 15nC of gate charge for a 6A application. All of the switching loss is in the main switch FET. An additional important parameter for the synchronous FET is reverse recovery charge ( $Q_{RR}$ ). High  $Q_{RR}$  adversely affects the transient voltages seen by the IC. A low  $Q_{RR}$  FET should be used.

#### **DIM FET SELECTION**

Choose a DIM FET with the lowest  $R_{DSON}$  for maximum efficiency and low input current draw during the DIM cycle. The output voltage during DIM will determine the switching frequency. A lower output voltage results in a lower switching frequency. If the lower frequency during DIM must be bound, choose a FET with a higher  $R_{DSON}$  to force the switching frequency higher during the DIM cycle.

#### Placement of the Parallel Dimming FET

When using a FET in parallel with the LED for PWM dimming special consideration must be used for the location of the FET. The ideal placement of the FET is *directly* next to the LED. Any distance between this FET and the LED results in line inductance. Fast current changes through this inductance can induce large voltage spikes due to v = Ldi/dt. These can be mitigated by either reducing the distance between the FET and the LED and/or slowing the PWM edges, and therefore the dt. by using some gate resistance on the FET. In cases where the dimming FET is not placed close to the LED and/ or very fast switching edges are desired the induced voltages can become great enough to damage the dimming FET and/ or the LM3434 HS pin. This can also result in a large spike of current into the LED when the FET is turned off. In these cases a snubber should be placed across the dimming FET to protect the device(s).

#### **BOOTSTRAP CAPACITORS**

The LM3434 uses two bootstrap capacitors and a bypass capacitor on V<sub>CC</sub> to generate the voltages needed to drive the external FETs. A 2.2 $\mu$ F ceramic capacitor or larger is recommended between the V<sub>CC</sub> and LS pins. A 0.47 $\mu$ F is recommended between the HS and BST pins. A 0.1 $\mu$ F is recommended between BST2 and CGND.

#### SOFT-START CAPACITOR

The LM3434 integrates circuitry that, when used in conjunction with the SS pin, will slow the current ramp on start-up. The SS pin is used to tailor the soft-start for a specific application. A capacitor value of  $0.1\mu$ F on the SS pin will yield a 12mS soft start time. For most applications soft start is not needed.

#### **ENABLE OPERATION**

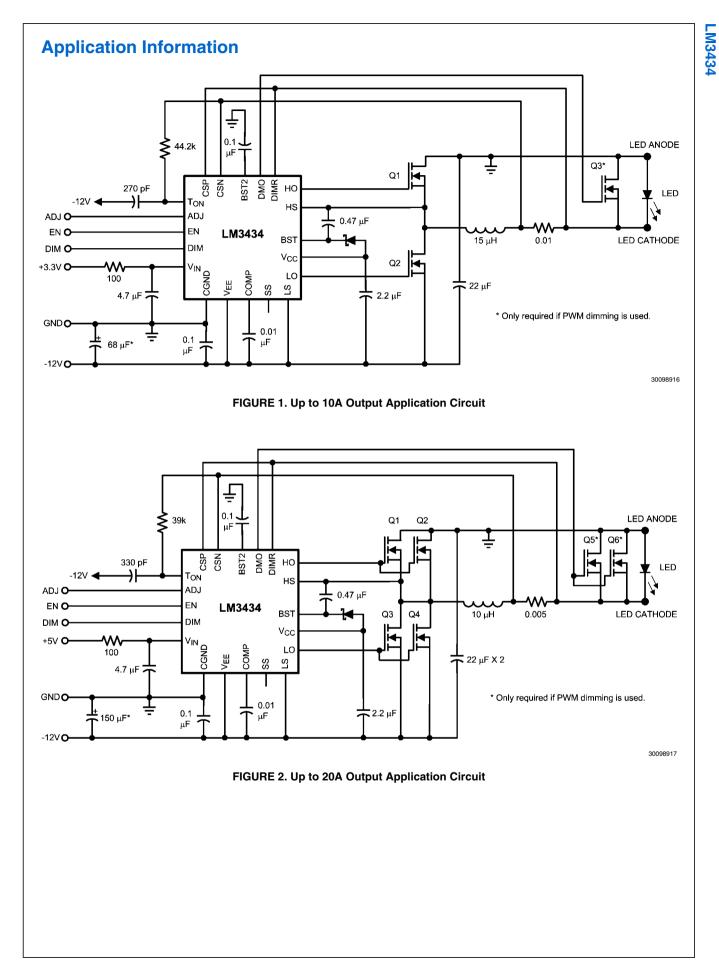
The EN pin of the LM3434 is designed so that it may be controlled using a 1.6V or higher logic signal. If the enable function is not used, the EN pin may be tied to  $V_{\rm IN}$  or left open. This pin is pulled to  $V_{\rm IN}$  internally through a 100k pull up resistor.

#### **PWM DIM OPERATION**

The DIM pin of the LM3434 is designed so that it may be controlled using a 1.6V or higher logic signal. The PWM frequency easily accomodates more than 40kHz dimming and can be much faster if needed. If the PWM DIM pin is not used, tie it to CGND or leave it open. The DIM pin is tied to CGND internally through a 100k pull down resistor.

#### LAYOUT CONSIDERATIONS

The LM3434 is a high performance current driver so attention to layout details is critical to obtain maximum performance. The most important PCB board design consideration is minimizing the loop comprised by the main FET, synchronous FET, and their associated decoupling capacitor(s). Place the V<sub>CC</sub> bypass capacitor as near as possible to the LM3434. Place the PWM dimming/shunt FET as close to the LED as possible. A ground plane should be used for power distribution to the power FETs. Use a star ground between the LM3434 circuitry, the synchronous FET, and the decoupling capacitor(s). The EP contact on the underside of the package must be connected to  $V_{EE}$ . The two lines connecting the sense resistor to CSN and CSP must be routed as a differential pair directly from the resistor. A Kelvin connection is recommended. It is good practice to route the DIMO/DIMR, HS/HO, and LO/LS lines as differential pairs. The most important PCB board design consideration is minimizing the loop comprised by the main FET, synchronous FET, and their associated decoupling capacitor(s). Optimally this loop should be orthogonal to the ground plane.



## Some Recommended Inductors (Others May Be Used)

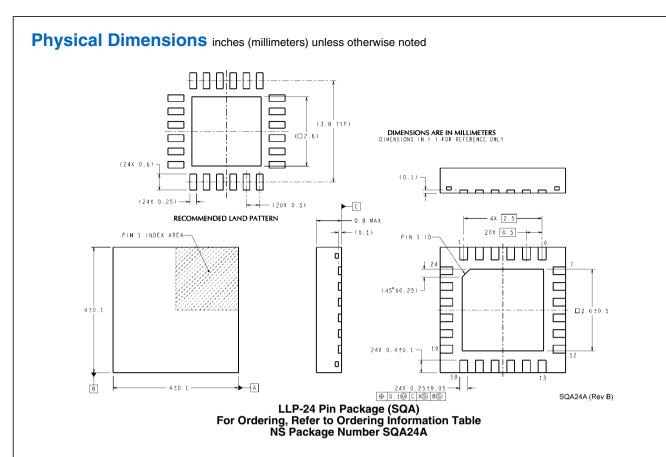
Manufacturer	Inductor	Contact Information
Coilcraft	GA3252-AL series, SER1360 series, and SER2900 series	www.coilcraft.com 800-322-2645
Coiltronics	HCLP2 series	www.coiltronics.com
Pulse	PB2020 series	www.pulseeng.com

## Some Recommended Input/Bypass Capacitors (Others May Be Used)

Manufacturer	Capacitor	Contact Information
Vishay Sprague	293D, 592D, and 595D series tantalum	www.vishay.com
		407-324-4140
Taiyo Yuden	High capacitance MLCC ceramic	www.t-yuden.com
		408-573-4150
Cornell Dubilier	ESRD seriec Polymer Aluminum Electrolytic	www.cde.com
	SPV and AFK series V-chip series	www.cde.com
MuRata	High capacitance MLCC ceramic	www.murata.com

#### Some Recommended MOSFETs (Others May Be Used)

Manufacturer	MOSFET	Contact Information
Siliconix	Si7386DP (Main FET, DIM FET)	www.vishay.com/company/brands/
	Si7668ADP (Synchronous FET)	siliconix/
	Si7790DP (Main FET, Synchronous FET, DIM FET)	
ON Semiconductor NTMFS4841NHT1G (Main FET, Synchronous FET, DIM		www.onsemi.com
	FET)	



# Notes

For more National Semiconductor product information and proven design tools, visit the following Web sites at: www.national.com

Pr	oducts	Design Support		
Amplifiers	www.national.com/amplifiers	WEBENCH® Tools	www.national.com/webench	
Audio	www.national.com/audio	App Notes	www.national.com/appnotes	
Clock and Timing	www.national.com/timing	Reference Designs	www.national.com/refdesigns	
Data Converters	www.national.com/adc	Samples	www.national.com/samples	
Interface	www.national.com/interface	Eval Boards	www.national.com/evalboards	
LVDS	www.national.com/lvds	Packaging	www.national.com/packaging	
Power Management	www.national.com/power	Green Compliance	www.national.com/quality/green	
Switching Regulators	www.national.com/switchers	Distributors	www.national.com/contacts	
LDOs	www.national.com/ldo	Quality and Reliability	www.national.com/quality	
LED Lighting	www.national.com/led	Feedback/Support	www.national.com/feedback	
Voltage References	www.national.com/vref	Design Made Easy	www.national.com/easy	
PowerWise® Solutions	www.national.com/powerwise	Applications & Markets	www.national.com/solutions	
Serial Digital Interface (SDI)	www.national.com/sdi	Mil/Aero	www.national.com/milaero	
Temperature Sensors	www.national.com/tempsensors	SolarMagic™	www.national.com/solarmagic	
PLL/VCO	www.national.com/wireless	PowerWise® Design University	www.national.com/training	

THE CONTENTS OF THIS DOCUMENT ARE PROVIDED IN CONNECTION WITH NATIONAL SEMICONDUCTOR CORPORATION ("NATIONAL") PRODUCTS. NATIONAL MAKES NO REPRESENTATIONS OR WARRANTIES WITH RESPECT TO THE ACCURACY OR COMPLETENESS OF THE CONTENTS OF THIS PUBLICATION AND RESERVES THE RIGHT TO MAKE CHANGES TO SPECIFICATIONS AND PRODUCT DESCRIPTIONS AT ANY TIME WITHOUT NOTICE. NO LICENSE, WHETHER EXPRESS, IMPLIED, ARISING BY ESTOPPEL OR OTHERWISE, TO ANY INTELLECTUAL PROPERTY RIGHTS IS GRANTED BY THIS DOCUMENT.

TESTING AND OTHER QUALITY CONTROLS ARE USED TO THE EXTENT NATIONAL DEEMS NECESSARY TO SUPPORT NATIONAL'S PRODUCT WARRANTY. EXCEPT WHERE MANDATED BY GOVERNMENT REQUIREMENTS, TESTING OF ALL PARAMETERS OF EACH PRODUCT IS NOT NECESSARILY PERFORMED. NATIONAL ASSUMES NO LIABILITY FOR APPLICATIONS ASSISTANCE OR BUYER PRODUCT DESIGN. BUYERS ARE RESPONSIBLE FOR THEIR PRODUCTS AND APPLICATIONS USING NATIONAL COMPONENTS. PRIOR TO USING OR DISTRIBUTING ANY PRODUCTS THAT INCLUDE NATIONAL COMPONENTS, BUYERS SHOULD PROVIDE ADEQUATE DESIGN, TESTING AND OPERATING SAFEGUARDS.

EXCEPT AS PROVIDED IN NATIONAL'S TERMS AND CONDITIONS OF SALE FOR SUCH PRODUCTS, NATIONAL ASSUMES NO LIABILITY WHATSOEVER, AND NATIONAL DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY RELATING TO THE SALE AND/OR USE OF NATIONAL PRODUCTS INCLUDING LIABILITY OR WARRANTIES RELATING TO FITNESS FOR A PARTICULAR PURPOSE, MERCHANTABILITY, OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

#### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS PRIOR WRITTEN APPROVAL OF THE CHIEF EXECUTIVE OFFICER AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

Life support devices or systems are devices which (a) are intended for surgical implant into the body, or (b) support or sustain life and whose failure to perform when properly used in accordance with instructions for use provided in the labeling can be reasonably expected to result in a significant injury to the user. A critical component is any component in a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system or to affect its safety or effectiveness.

National Semiconductor and the National Semiconductor logo are registered trademarks of National Semiconductor Corporation. All other brand or product names may be trademarks or registered trademarks of their respective holders.

#### Copyright© 2010 National Semiconductor Corporation

For the most current product information visit us at www.national.com



National Semiconductor Americas Technical Support Center Email: support@nsc.com Tel: 1-800-272-9959

National Semiconductor Europe Technical Support Center Email: europe.support@nsc.com National Semiconductor Asia Pacific Technical Support Center Email: ap.support@nsc.com National Semiconductor Japan Technical Support Center Email: jpn.feedback@nsc.com

#### **IMPORTANT NOTICE**

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
		u Hama Dawa	a O a Al a a m

**TI E2E Community Home Page** 

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265 Copyright © 2011, Texas Instruments Incorporated