AL8400

LINEAR LED DRIVER-CONTROLLER with 200mV CURRENT SENSE VOLTAGE

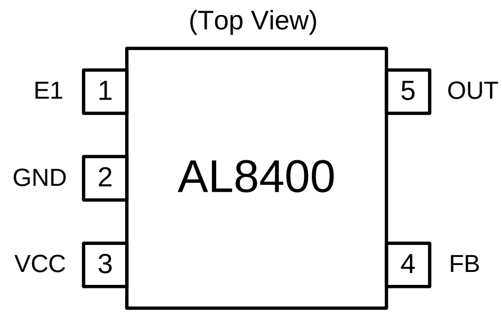
Description

The AL8400 is a 5-terminal adjustable Linear LED driver-controller offering excellent temperature stability and output handling capability. The AL8400 simplifies the design of linear and isolated LED drivers. With its low 200mV current sense 2V FB pin, it controls the regulation of LED current with minimal power dissipation when compared to traditional linear LED drivers. This makes it ideal for medium to high current LED driving.

The AL8400 open-collector output can operate from 0.2V to 18V enabling it to drive external MOSFET and Bipolar transistors. This enables the MOSFET and Bipolar selection to be optimized for the chosen application. It also provides the capability to drive longer LED chains, by tapping V_{CC} from the chain, where the chain voltage may exceed 18V.

It is available in the space saving low profile SOT353 package.

Pin Assignments



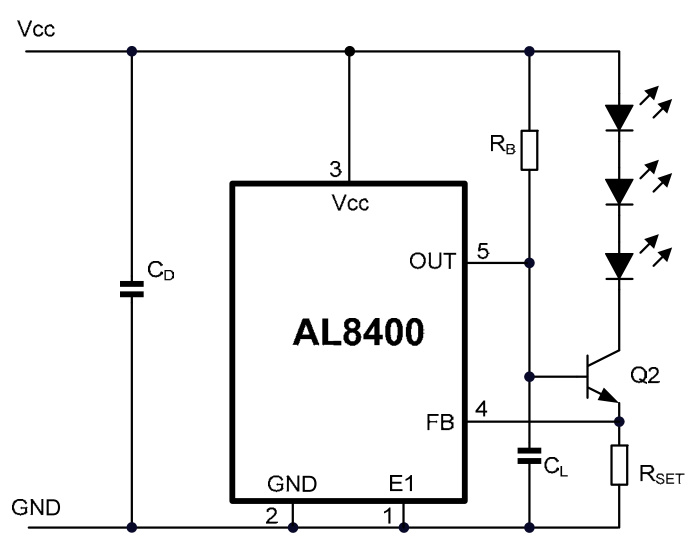
Features

- Low reference voltage (V_{FB} = 0.2V)
- -40 to 125ºC temperature range
- 3% Reference voltage tolerance at 25°C
- Low temperature drift
- 0.2V to 18V open-collector output
- High power supply rejection:
  - (> 45dB at 300kHz)

Applications

- Isolated offline LED converters
- Linear LED driver
- LED signs
- Instrumentation illumination

Typical Application Circuit



$I_{LED} = V_{REF}/R_{SET}$

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Functional Block Diagram

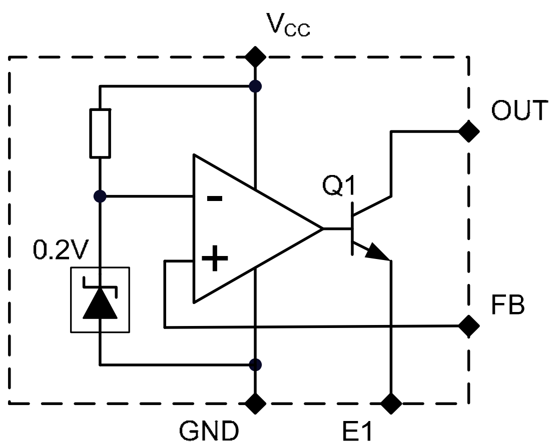

Figure 1. Block Diagram

Pin Descriptions

Pin Number	Name	Function
1	E1	Emitter connection. Connect to GND.
2	GND	Analog Ground. Ground return for reference and amplifier. Connect to E1.
3	V_{CC}	Supply Input. Connect a 0.47µF ceramic capacitor close to the device from V_{CC} to GND.
4	FB	Feedback Input. Regulates to 200mV nominal.
5	OUT	Output. Connect a capacitor close to device between OUT and GND. See the *Applications Information* section.

Absolute Maximum Ratings

Symbol	Characteristics	Values	Unit
V_{CC}	Supply voltage relative to GND	20	V
V_{OUT}	OUT voltage relative to GND	20	V
V_{FB}	FB voltage relative to GND	20	V
V_{E1}	E1 voltage relative to GND	-0.3 to+0.3	V
T_J	Operating junction temperature	-40 to 150	°C
T_{ST}	Storage temperature	-55 to 150	°C

These are stress ratings only. Operation outside the absolute maximum ratings may cause device failure.
Operation at the absolute maximum rating for extended periods may reduce device reliability.

Package Thermal Data

Package	θ_{JA}	P_{DIS} $T_A = 25°C, T_J = 150°C$
SOT353	400°C/W	310mW

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Recommended Operating Conditions

Symbol	Parameter	Min	Max	Units
V_{CC}	Supply voltage range	2.2	18	V
V_{OUT}	OUT voltage range	0.2	18	
I_{OUT}	OUT pin current	0.3	15	mA
T_A	Operating ambient temperature range	-40	125	°C

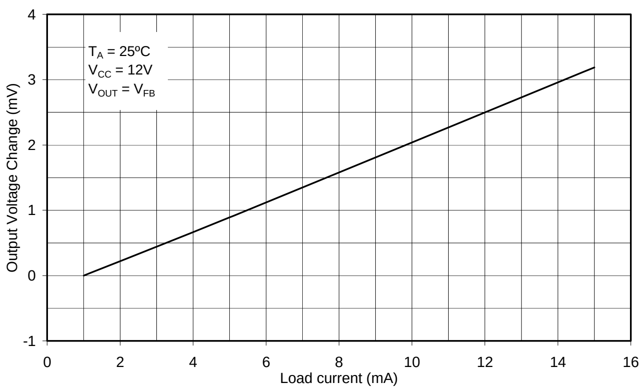
Electrical Characteristics (T_A = 25°C, V_{CC} = 3V; unless otherwise specified)

Operating conditions: T_A = 25°C, V_{CC}= 12V, V_{OUT} = V_{FB}, I_{OUT} = 1mA unless otherwise stated (Note 1).

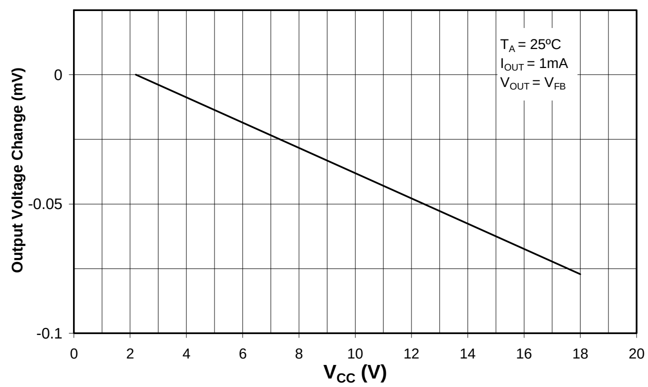
Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
V_{FB}	Feedback voltage		T_A = 25°C	0.194	0.2	0.206	V
			T_A = -40 to 125°C	0.190		0.210	
FB_{LOAD}	Feedback pin load regulation	I_{OUT} = 1 to 15mA	T_A = 25°C		3.1	6	mV
			T_A = -40 to 125°C			*10*	
FB_{LINE}	Feedback pin line regulation	V_{CC} = 2.2V to 18V	T_A = 25°C		0.1	1.5	mV
			T_A = -40 to 125°C			*2*	
FB_{OVR}	Output voltage regulation	V_{OUT} = 0.2V to 18V, I_{OUT} =1mA (Ref. Figure 1)	T_A = 25°C			2	mV
			T_A = -40 to 125°C			*3*	
I_{FB}	FB input bias current	V_{CC} = 18V	T_A = 25°C		-45		nA
			T_A = -40 to 125°C	-200		0	
I_{CC}	Supply current	V_{CC} = 2.2V to 18V, I_{OUT} =10mA	T_A = 25°C		0.48	1	mA
			T_A = -40 to 125°C			1.5	
$I_{OUT(LK)}$	OUT leakage current	V_{CC} = 18V, V_{OUT} = 18V, V_{FB} =0V	T_A = 25°C			0.1	µA
			T_A = 125°C			1	
Z_{OUT}	Dynamic Output Impedance	I_{OUT} = 1 to 15mA f < 1kHz	T_A = 25°C		0.25	0.4	Ω
			T_A = -40 to125°C			0.6	
PSRR	Power supply rejection ratio	f = 300kHz, V_{AC}= 0.3V_{PP}	T_A = 25°C		45		dB
BW	Amplifier Unity Gain Frequency		T_A = 25°C		600		kHz
G	Amplifier Transconductance		T_A = 25°C		4500		mA/V

Note: 1. Production testing of the device is performed at 25 °C. Functional operation of the device and parameters specified over the operating temperature range are guaranteed by design, characterization and process control.

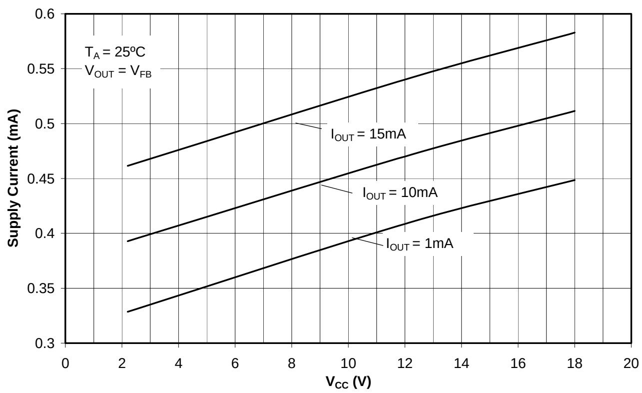
Typical Characteristics



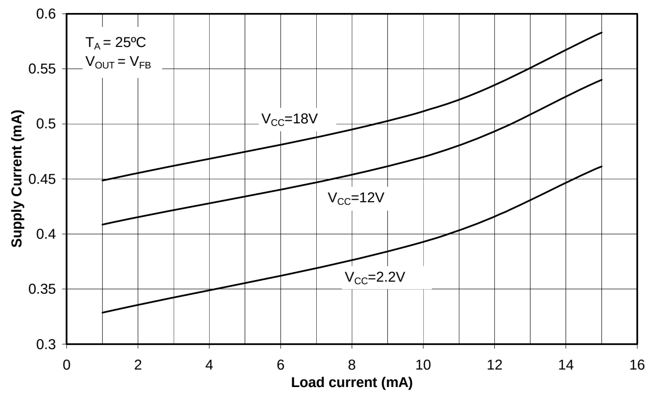
Load regulation



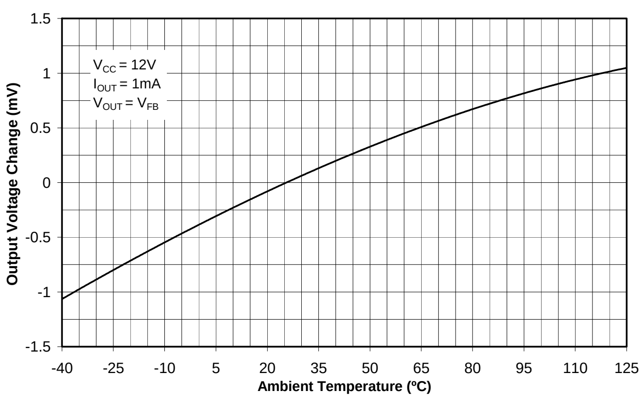
Line regulation



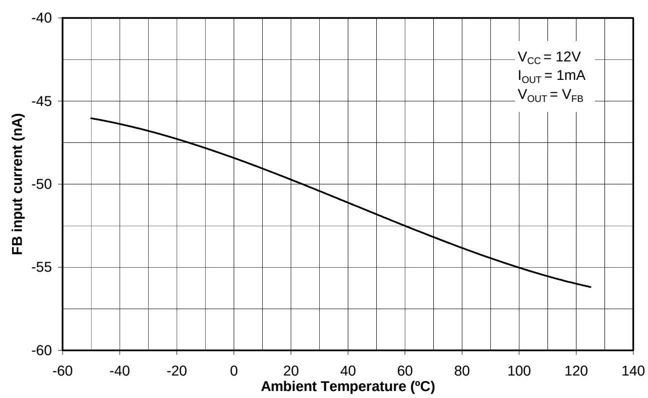
Supply current with input voltage



Supply current with load current

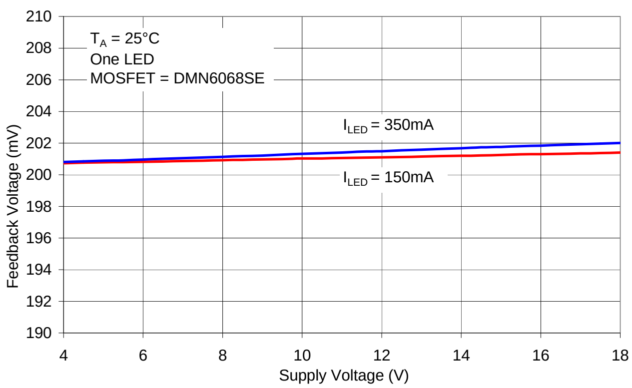


OUT voltage change with Temperature

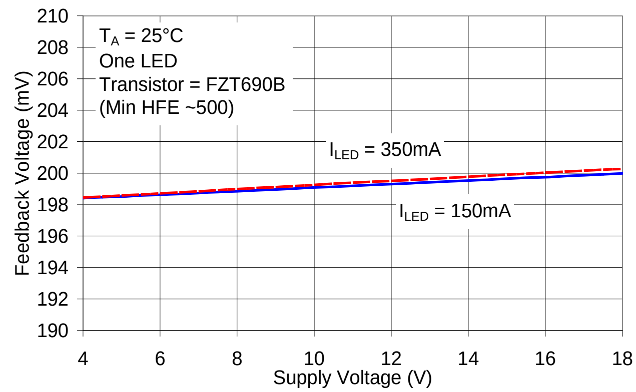


FB input current with Temperature

Typical Characteristics (Continued)



MOSFET driving



Bipolar transistor driving

Application Information

Description

The AL8400 Linear LED driver controller uses an external pass element to drive the LEDs and uses its FB pin to sense the LED current through an external resistor R_{SET}. The pass element is driven by the AL8400's open collector OUT pin which allows the pass element to be either an NPN transistor or N-channel MOSFET. An external resistor, R_B, is required to be connected from the OUT pin to V_{CC}. This resistor supplies the output bias current of the AL8400 together with any current which the pass element requires.

Bipolar transistor as the pass element

For driving at currents in the region of about 50mA to about 400mA, the recommended NPN is DNLS320E in the SOT223 package. The high DC current gain of the DNLS320E is useful in this application, in order to minimize the current in R_B. The design procedure is as follows, referring to Figure 2.

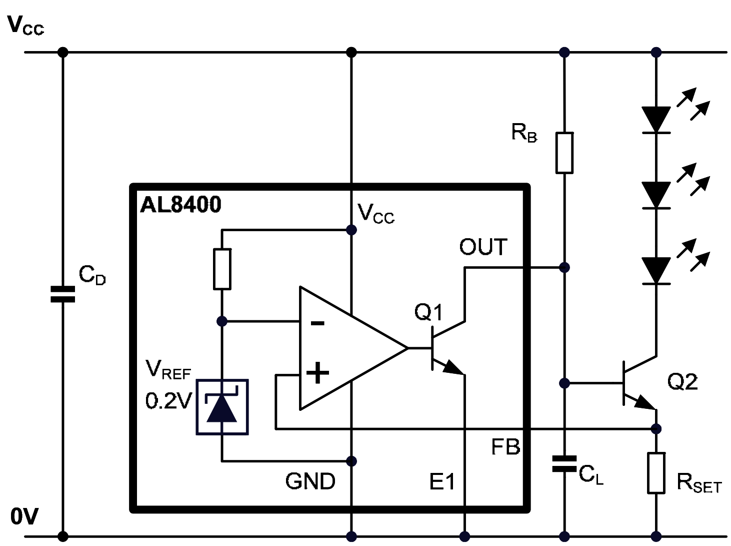


Figure 2. Application Circuit Using Bipolar Transistor

Application Information (Continued)

Bipolar transistor as the pass element (Continued)

There are two important equations for the circuit:
LED circuit path:

1.....$V_{CC} = (V_{LED} + V_{CE} + V_{REF})$

Control drive circuit path

2.....$V_{CC} = (V_{RB} + V_{BE} + V_{REF})$

The maximum total LED voltage plus the reference voltage determines the minimum supply voltage. Substituting into equation 1 yields:

$$V_{CC\,min} = V_{LED} + V_{CEsat} + V_{REF}$$

For a bipolar transistor the voltage (V_{RB}) across bias resistor R_B consists of the base current of Q2 and the output current of the AL8400. So rearranging equation 2 yields the boundaries for allowable R_B values:

$$R_{B\,max} = \frac{V_{CC\,min} - V_{BE\,max} - V_{REF}}{I_{OUT\,min} + I_{B\,max}}$$

where I_{Bmax} is the maximum transistor base current

$$I_{B\,max} = \frac{I_{LED}}{h_{FEmin}}$$ where h_{FEmin} is the minimum DC current gain of the transistor.

$$R_{B\,min} = \frac{V_{CC\,max} - V_{BE\,min} - V_{REF}}{I_{OUT\,max} + I_{B\,min}}$$

where I_{Bmin} is the minimum transistor base current

$$I_{B\,min} = \frac{I_{LED}}{h_{FEmax}}$$ where h_{FEmax} is the maximum DC current gain of the transistor.

Finally, the bipolar selection is also influenced by the maximum power dissipation

$$P_{TOT} = I_{LED} * (V_{CC} – V_{LED} – V_{REF}) = I_{LED} * V_{CE}$$

Since this determines the package choice (θ_{JA}) in order to keep the junction temperature below the maximum value allowed.

$$T_J = T_A + P_{TOT} \bullet \theta_{JA}$$

Bipolar Example

The driver is required to control 2 series connected LEDs at 150mA ±10%, each having a forward voltage of 3V minimum and 3.6V maximum. Hence the minimum operating supply voltage is 3.6*2 + 0.2 = 7.4V. The actual supply voltage given is 8V ±5%, i.e. 7.6V minimum. We will use the DNLS320E bipolar transistor (Q2).

The DNLS320E datasheet shows:

h_{FEmin} is 500 @ I_C = 100mA, 400 @ I_C = 2A,

The datasheet graph shows a very slow variation at his current, so a value of 500 is appropriate.

Then $I_{B\,max} = \frac{150}{500}$ = 0.3mA

The minimum recommended I_{OUT} for AL8400 is 0.3mA and the maximum V_{BE}, according to the DNLS320E datasheet graph, is approximately 0.8V at -55°C.

From these the maximum allowed bias resistor value is:

$$R_{B\,max} = \frac{7.6 - 0.8 - 0.2}{0.0003 + 0.0003} = 11k\Omega$$

To ensure that the output capability of the AL8400 is not exceeded at maximum V_{IN}, maximum h_{FE} and minimum V_{BE}, these values should be substituted back into the R_B equation to determine the minimum allowable value for R_B.

h_{FEmax} is about 1200 @ I_C = 100mA, and a temperature of 85°C which results in:

$$I_{B\,min} = \frac{150}{1200} = 0.125mA$$

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Application Information (Continued)

Bipolar Example (Continued)

The maximum recommended I_{OUT} for AL8400 is 15mA.
The minimum V_{BE}, according to the DNLS320E datasheet graph, is approximately 0.4V at 85°C and assuming V_{CCmax} = 8.4V, then the bias resistor value is:

$$R_{B\,min} = \frac{8.4 - 0.4 - 0.2}{0.015 + 0.000125} = 516\Omega$$ this is less than 11kΩ and so the AL8400 output current is within its ratings.

The value of R_{SET} is V_{REF}/I_{LED} so:

R_{SET} = 0.2/0.15 = 1.333Ω ➔ 1.3Ω is practical.

Finally, the maximum power dissipation of the external bipolar transistor is:

$P_{TOT} = I_{LED} * V_{CEMAX}$
$= I_{LED} * (V_{CC} - V_{LED\_MIN} - V_{REF}) = 0.27W$

This determines the package choice (θ_{JA}) in order to keep the junction temperature of the bipolar below the maximum value allowed.

$T_J = T_A + P_{TOT} \bullet \theta_{JA}$
$= T_A + 0.27*125 = T_A + 33.75^{\circ}C$

N-channel MOSFET as the pass element

Alternatively, an N-channel MOSFET may be used in the same configuration. The current in R_B is then reduced compared to the case in which the bipolar transistor is used. For LED currents up to about 400mA a suitable MOSFET is DMN6068SE in the SOT223 package. The design procedure is as follows, referring to Figure 3.

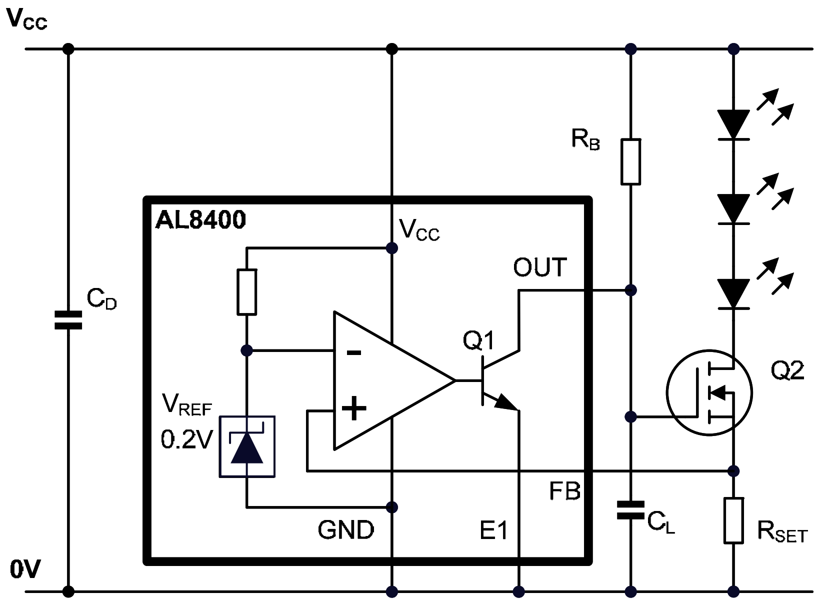


Figure 3. Application Circuit Using MOSFET

The equations (1 and 2) for the bipolar transistor are transformed into:
LED circuit path:
1.....$V_{CC} = (V_{LED} + V_{DS} + V_{REF})$
Control drive circuit path
2.....$V_{CC} = (V_{RB} + V_{GS} + V_{REF})$

NEW PRODUCT

Application Information (Continued)

N-channel MOSFET as the pass element (Continued)

The maximum total LED voltage plus the reference voltage determines the minimum supply voltage. Substituting into equation 3 yields:

$$V_{CCmin} = V_{LED} + V_{DSMIN} + V_{REF}$$

The MOSFET DC gate current is negligible, so the bias resistor R_B has only to provide the minimum output current of the AL8400. So rearranging equation 4 yields the boundaries for allowable R_B values:

$$R_{Bmin} = \frac{V_{CCmax} - V_{GSmin} - V_{REF}}{I_{OUTmax}}$$

Where I_{OUTmax} is the AL8400 maximum output current

$$R_{Bmax} = \frac{V_{CCmin} - V_{GSmax} - V_{REF}}{I_{OUTmin}}$$

Where I_{OUTmin} is the AL8400 minimum output current

Note that in the case of a single LED, the MOSFET gate-source voltage may be too high for operation over the desired supply voltage range. If the gate source voltage at the operating current is V_{GSMAX}, we must have:

$V_{RBmin} + V_{GSmax} + V_{REF} < V_{CC}$ where V_{RBmin} is the minimum voltage drop across R_B.

V_{RBmin} is determined by the operating voltage range. At the top of the range, the current is required to be not greater than 15mA.

The supply voltage is usually the LED voltage plus a margin for transistor saturation voltage, plus V_{REF}. The bias amounts to the voltage across R_B plus V_{REF} (0.2V). Therefore the use of the MOSFET may not be practical for driving a single LED if the V_{GS} is too high. Then either a MOSFET with lower V_{GS} must be selected, or a bipolar NPN device must be used.

Finally, the MOSFET selection is also influenced by the maximum power dissipation

$$P_{TOT} = I_{LED} * (V_{CC} – V_{LED} – V_{REF}) = I_{LED} * V_{DS}$$

Since this determines the package choice (θ_{JA}) in order to keep the junction temperature below the maximum value allowed.

$$T_J = T_A + P_{TOT} \bullet \theta_{JA}$$

MOSFET Example

The driver is required to control 2 series connected LEDs at 150mA ±10%, each having a forward voltage of 3V minimum and of 3.6V maximum. Hence the minimum operating supply voltage is 3.6*2 + 0.2 = 7.4V. The actual supply voltage given is 8V ±5%, i.e. 7.6V minimum. We will use the DMN6068SE N-channel MOSFET (Q2),

The minimum recommended I_{OUT} for AL8400 is 0.3mA.

The maximum V_{GS} is not stated explicitly, but from the datasheet graphs it is expected to be approximately 3.8V at -50°C. (Here we have used the graphs of Typical Transfer and Normalized $V_{GS(th)}$ versus temperature.)

So R_{Bmax} = (7.6 – 3.8 - 0.2) / 0.0003 = 12kΩ

To ensure that the output capability of the AL8400 is not exceeded at maximum V_{IN} and minimum V_{GS} these values should be substituted back into the R_B equation to determine the minimum allowable value for R_B.

The maximum recommended I_{OUT} for the AL8400 is 15mA. The minimum V_{GS} is about 1V and assuming V_{CCmax} = 8.4V:

$$R_{Bmin} = \frac{8.4 - 1 - 0.2}{0.015} = 480\Omega$$

this is less than 12kΩ and so the AL8400 output current is within its ratings.

The value of R_{SET} is V_{REF}/I_{LED}

R_{SET} = 0.2/0.15 = 1.333Ω ➔ 1.3Ω is practical.

Application Information (Continued)

MOSFET Example (Continued)

Finally, the maximum power dissipation of the external MOSFET is:

$$P_{TOT} = I_{LED} * V_{DSMAX}$$
$$= I_{LED} * (V_{CC} - V_{LEDMIN} - V_{REF}) = 0.27W$$

This determines the package choice (θ_{JA}) in order to keep the junction temperature below the maximum value allowed.

$$T_J = T_A + P_{TOT} \bullet \theta_{JA}$$
$$= T_A + 0.27*62.5 = T_A + 16.86^{\circ}C$$

Stability

In order to maintain the stability of the current control loop, a capacitor, C_L, is required to be connected from the OUT pin to Ground. The value is determined by the minimum time constant, $C_L R_B \geq 1ms$. For example if $R_B = 10k\Omega$, then C_L must be 0.1µF or greater. The capacitor type is recommended to be X7R ceramic.

For best stability a power supply decoupling capacitor, C_D is recommended, 0.1µF minimum, X7R ceramic, connected between V_{CC} and Ground.

OFFLINE LED LAMPS

The configuration of the AL8400 also makes it suitable for controlling the current of an offline (mains) isolated LED lamp by way of an opto-coupler to drive the feedback pin of the primary-side switching controller.

The current sensing of the LED current is done via R_{SET} but the OUT pin now drives the cathode of the diode in the opto-coupler. See Figure 4 below.

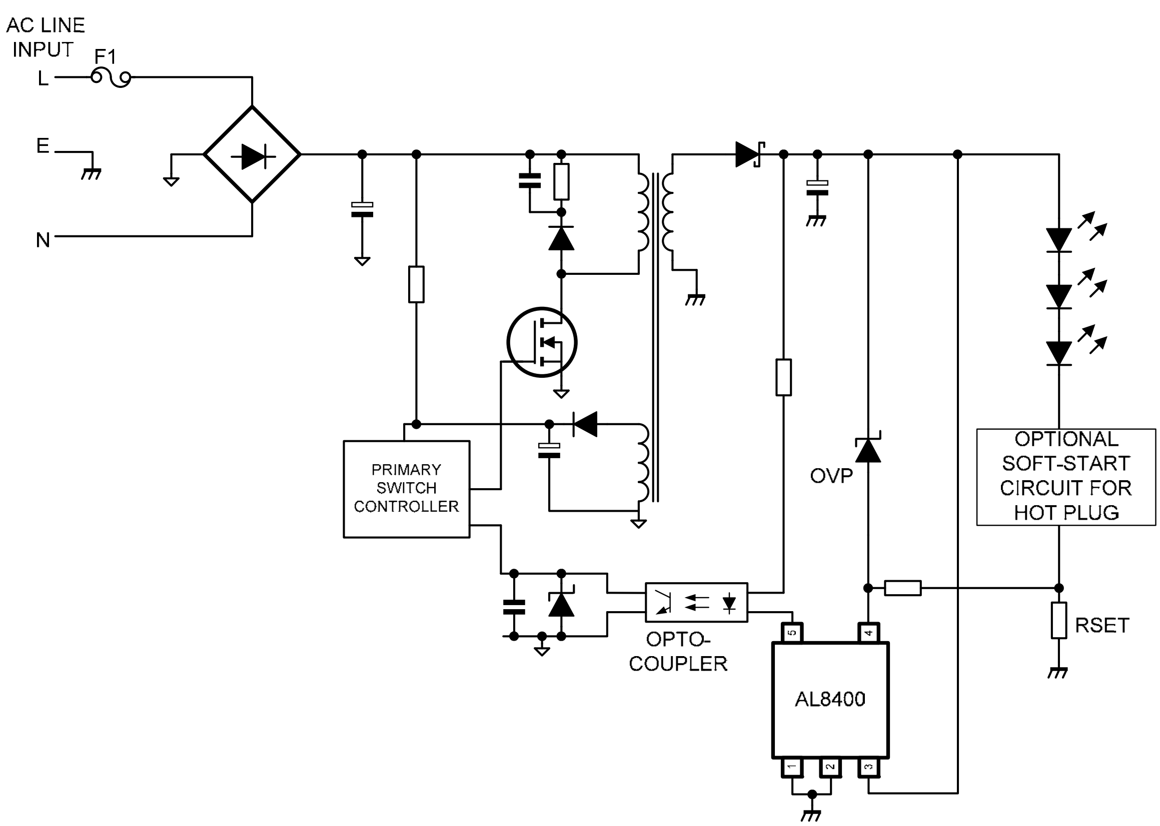


Figure 4. Off-line LED Drive Application of AL8400

Application Information (Continued)

High voltage operation

The AL8400 also provides the capability to drive longer LED chains as the voltage across the LED chain is determined by the external switch. The lower supply voltage for the AL8400 can be derived from the supply to the LED chain either by putting a series resistor to the AL8400's V_{CC} pin and putting a suitable zener diode from its V_{CC} to GND Figure 5 or by tapping its V_{CC} from the LED chain Figure 6.

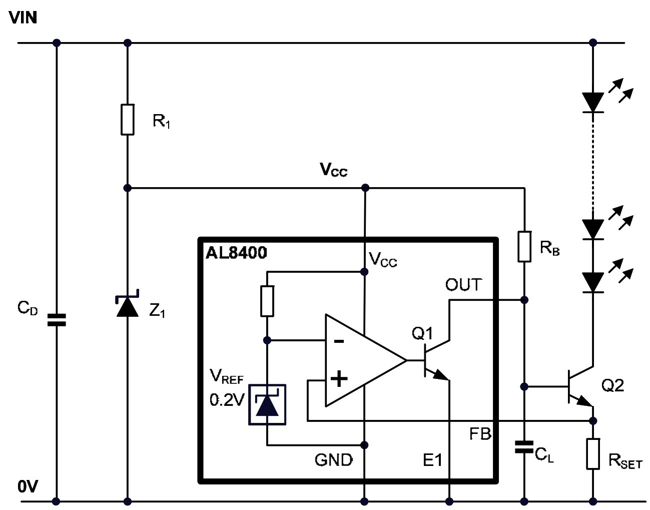


Figure 5. High voltage operation with zener diode from VIN

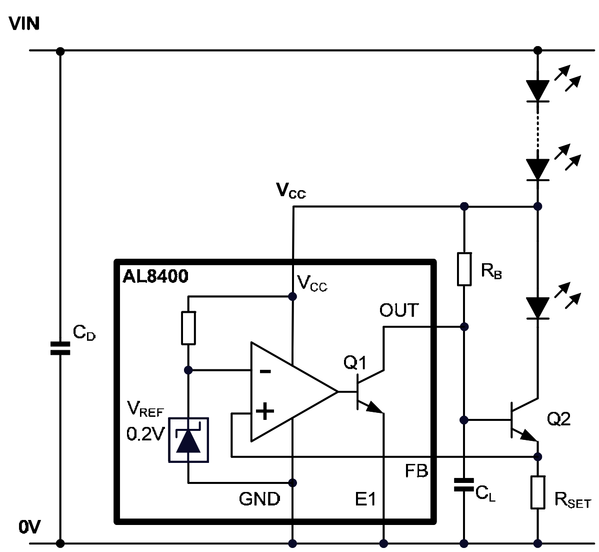


Figure 6. High voltage operation tapping V_{CC} from the LED string

When the supply voltage for the AL8400 is derived using a zener diode, care has to be taken in dimensioning the resistor R1. The current spilled from V_{IN} has to be enough to polarize the zener and to supply the LED driver. On the other hand, when the supply voltage for the AL8400 is derived from the LED string, care has to be taken in dimensioning the resistor R_B. The current spilled from the LED chain can reduce the accuracy of the system and brightness matching between the LED.

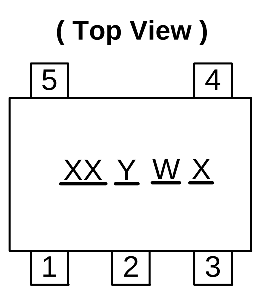
Ordering Information

Device	Package Code	Packaging (Note 3)	7" Tape and Reel	
			Quantity	Part Number Suffix
AL8400SE-7	SE	SOT353	3000/Tape & Reel	-7

Notes: 2. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied. Please visit our website at http://www.diodes.com/products/lead_free.html
3. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at http://www.diodes.com/datasheets/ap02001.pdf.

Marking Information

(1) SOT353

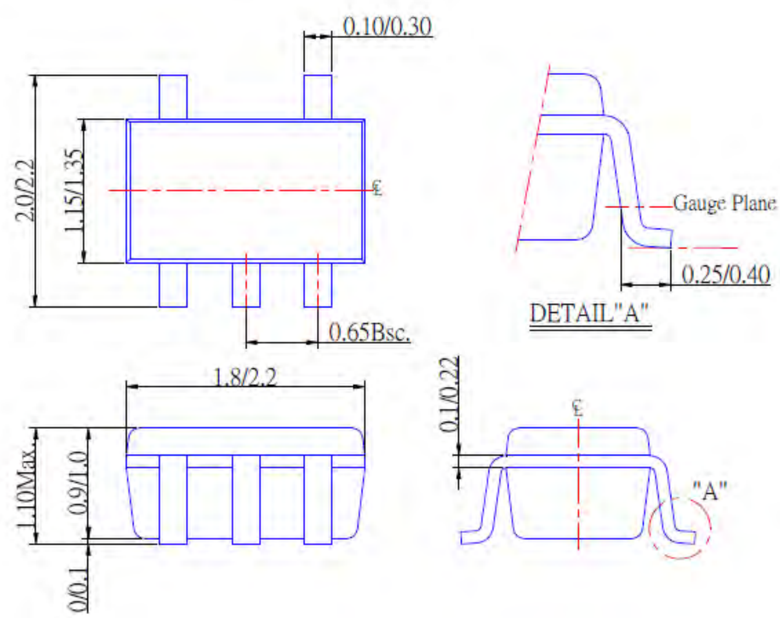


XX : Identification code
Y : Year 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents 52 and 53 week
X : A~Z : Green

Part Number	Package	Identification Code
AL8400SE-7	SOT353	B4

Package Outline Dimensions (All Dimensions in mm)

(1) Package Type: SOT353



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