

### FEATURES

- Highly integrated feature set gives a high brightness LED driver solution with minimal external components.
- Four current sink channels with adjustable currents from 0 to 500 mA.
- DC LED dimming for noiseless operation.
- 2% (max) matching between LED channels.
- 5% (max) LED current accuracy.
- Operates from  $V_{in}$  of 3.3 V to 30 V. Higher voltages easily accomplished with small external circuit.
- Operates with LED anode supply voltages up to 100 Vdc.
- Feedback output controls external power source for optimal efficiency and safety.
- Multiple ADP8140 ICs can be operated in parallel and control one power supply.
- Secondary side control of isolated power supplies without need of a TL431.
- Dedicated DIM pin for output current reduction.
- Easy connection of a temperature thermistor or light sensor.
- Provides robust protection of the entire system:
  - Power supply overvoltage protection
  - LED Over temperature protection
  - LED Short protection
  - LED Open protection
  - IC Over temperature protection
  - Shorted ISET protection
  - Open ISET and EN protection
- Standby mode for low current consumption
- Fault indicator output
- Available in a thermally enhanced LFCSP package (4x4 mm)

### APPLICATIONS

- High brightness LED lighting
- Large format LED backlighting

### TYPICAL OPERATING CIRCUITS

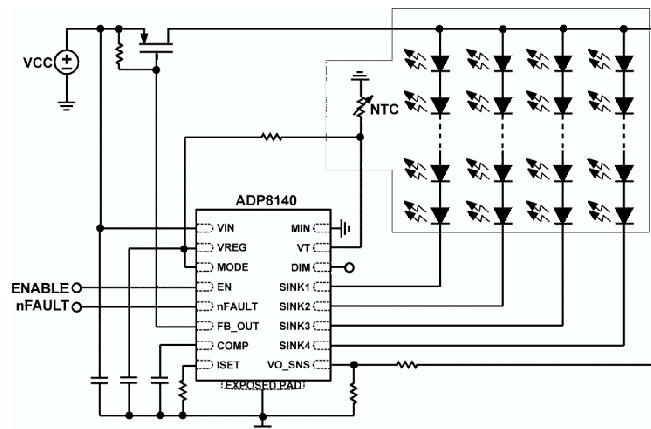


Figure 1. ADP8140 used with Shunt Regulator

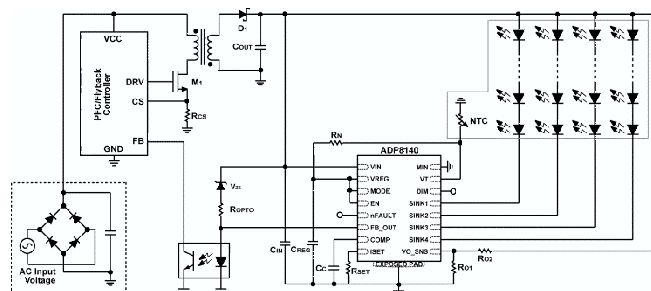


Figure 2. ADP8140 used as Secondary Side Controller

### GENERAL DESCRIPTION

The ADP8140 provides high current control of up to four LED drivers. Each driver can sink up to 500 mA. The sink current is programmed for all four drivers with one external resistor.

The device features a feedback output which controls an external power supply for optimal efficiency. The ADP8140 also protects the LEDs, power supply, and itself against thermal

events, short circuits, overvoltages, and LED open circuits. Multiple ADP8140 ICs are easily connected in parallel to drive additional LED strings, or higher current LEDs. The ADP8140 is available in a small, thermally enhanced, LFCSP (lead frame chip scale package).

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## SPECIFICATIONS

VIN = 12 V, EN=3.0V. Typical values are at Tj = 25°C and are not guaranteed. Minimum and maximum limits are guaranteed from Tj = -40°C to +125°C, unless otherwise noted.

Table 1.

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
<b>SUPPLY</b>						
Input Voltage						
Operating Range	VIN		3.3		30.0	V
Undervoltage Lockout	VUVLO			3.033		V
UVLO Hysteresis	VUVLO_HYS			150		mV
Quiescent Current	IQ					
During Standby	IQ(STBY)	EN = 0 V, all SINKx Zener clamps and VREG remain active, IREG=0μA		TBD	250	μA
During Operation	IQ(ACTIVE1)	EN = 3 V, VIN=7.5 V		TBD	8.0	mA
During Operation	IQ(ACTIVE2)	EN = 3 V, VIN=12 V		TBD	8.0	mA
During Operation	IQ(ACTIVE3)	EN = 3 V, VIN=28 V		TBD	8.0	mA
REG Output						
REG Output Voltage	VREG	VIN=7.5, 12, 24 V, IREG=1 mA	2.85	3.0	3.15	V
REG Source Current	IREG	VIN=7.5, 12, 24 V	15			mA
REG Load Regulation	VREG1	VIN=7.5, 12, 24 V, IREG=0.1 mA to 15 mA		TBD	TBD	V/mA
<b>FEEDBACK OUTPUT</b>						
FB_OUT EA Accuracy	VEA		430	450	470	mV
FB_OUT NMOS Pulldown	FB_PD	SINKx=0V, FB_OUT = 5.0V	12.0	15.0	18.0	mA
FB_OUT Fault Current	FB_FC	Fault activated, FB_OUT = 3.0 V.		TBD	1	μA
Amplifier transconductance	COMPgm		TBD	50	TBD	μmho
Transconductance amplifier output sink/source current	COMP <sub>SOURCE</sub>	COMP pin output source current	TBD	500	TBD	μA
Transconductance amplifier output sink/source current	COMP <sub>SINK</sub>	COMP pin output sink current	TBD	2.0	TBD	mA
Transconductance amplifier output resistance	COMP <sub>RO</sub>			20		MΩ
Low gain EA	Gbuff	Gain in buffer mode Gbuff=Vcomp/MIN(Vsinkx)	-5%	4.0	+5%	
Low gain BW		Low gain buffer mode		100		kHz
<b>ISET</b>						
ISET Accuracy 500mA	ILED <sub>500</sub>	RSET=5.11 kΩ, SINK <sub>1:4</sub> =450mV	-5%	500	+5%	mA
ISET Accuracy 350mA	ILED <sub>350</sub>	RSET=7.32 kΩ, SINK <sub>1:4</sub> =450mV	-5%	350	+5%	mA
ISET Accuracy 100mA	ILED <sub>100</sub>	RSET=25.5 kΩ, SINK <sub>1:4</sub> =450mV	-5%	100	+5%	mA
ISET shorted current		ISET = GND	TBD	570	TBD	mA
ISET open current		ISET = OPEN		13	TBD	mA
<b>CURRENT SINKS</b>						
Current sink headroom voltage at max current	V <sub>HR_500</sub>	ILED = 95% * ILED <sub>500</sub>			VEA <sub>MIN</sub>	mV
Sink matching at max current	I <sub>MATCH1</sub>	Matching = (MAX ISINK – MIN ISINK)/(MAX ISINK + MIN ISINK)*100		TBD	2	%

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
Sink matching at mid current	I <sub>MATCH2</sub>	Matching = (MAX ISINK – MIN ISINK)/(MAX ISINK + MIN ISINK)*100		TBD	2	%
SINKx leakage current	I <sub>SINK(LKG)</sub>	SINKx pin = 4V.		100	TBD	μA
Channel Overvoltage Threshold	CH <sub>CLMP_LO</sub>	Threshold on SINKx to trigger CH_OVP fault and Channel Clamp (low)	TBD	5.5	TBD	V
Channel Overvoltage Hysteresis	CH <sub>CLMP_HYS</sub>	Hysteresis after CH <sub>CLMP_LO</sub> is triggered.	TBD	1.0	TBD	V
Channel Clamp (low) Current	I <sub>CLMP_LO</sub>	Channel pulldown current when SINKx > CH <sub>CLMP_LO</sub>	-20%	ISET	+20%	mA
Channel Clamp (high) Threshold	CH <sub>CLMP_HI</sub>	Threshold on SINKx to trigger Channel Clamp (high)	13.5	15.0	16.5	V
Channel Clamp (high) Hysteresis	CH <sub>CLMP_HYS</sub>	Hysteresis after CH <sub>CLMP_HI</sub> is triggered.	TBD	2.8	TBD	V
Channel Clamp (high) Current	I <sub>CLMP_HI</sub>	Channel pulldown current when SINKx > CH <sub>CLMP_HI</sub>	-20%	510	+20%	mA
INPUT CONTROLS						
Input Threshold (low)	V <sub>IL</sub>	EN			0.5	V
Input Threshold (high)	V <sub>IH</sub>	EN	1.2			V
EN input resistance	R <sub>EN</sub>	EN=1.2 V		400 k		Ω
Mode pin pullup current	I <sub>M</sub>	0V < V <sub>mode</sub> < V <sub>reg</sub>	18	20	22	μA
Mode Threshold 1 30.1k	V <sub>M1</sub>	Threshold for increasing mode voltage to enter DC Buffer operation.	TBD	0.45	TBD	V
Mode Threshold 2 49.9k	V <sub>M2</sub>	Threshold for increasing mode voltage to enter PWM Buffer operation.	TBD	0.75	TBD	V
Mode Threshold 3	V <sub>M3</sub>	Threshold for increasing mode voltage to enter PWM EA operation.	TBD	1.25	TBD	V
LED Scaling Controls						
DIM and VT limit voltage	VT <sub>LIMIT</sub>	VT (and DIM if MODE=GND) voltage to produce 100% I <sub>out</sub>	TBD	2.0	TBD	V
Dimming Accuracy		VT = 1 V, I <sub>LED</sub> =350 mA.	TBD	175	TBD	mA
		DIM=1V, MODE=GND, I <sub>LED</sub> =350mA.				
		DIM=50%, 32kHz, MODE=VREG.				
DIM pin Frequency Range			140 Hz		40 kHz	
MIN comparator hysteresis	V <sub>MINHYS</sub>			70		mV
THERMAL FOLDBACK (internal)						
Thermal Foldback Threshold	TFB <sub>THRES</sub>		TBD	130	TBD	°C
Thermal Shutdown Hysteresis	TSD <sub>HYS</sub>		TBD	20	TBD	°C
FAULT DETECTION						
Fault Threshold	FAULT <sub>THRESH</sub>	Threshold for VO_SNS comparator	-2%	1.2	+2%	V
VO_SNS Hysteresis	VOSNS <sub>HYS</sub>	Hysteresis for VO_SNS comparator		50		mV
Fault Threshold	FAULT <sub>THRESH</sub>	Threshold for nFAULT comparator	-5%	1.2	+5%	V
Fault Hysteresis	FAULT <sub>HYS</sub>	Hysteresis for nFAULT comparator		100		mV
Fault Filter	t <sub>FAULT</sub>	Vo_sns and nFAULT shutdown noise filter		10		Us
VO_SNS bias current	I <sub>VOSNS</sub>			0	TBD	μA

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
nFAULT pulldown	nFAULT <sub>PD</sub>	Fault activated, nFAULT=0.5V	TBD	3.0	TBD	mA
SINK Fault Threshold	SFD <sub>THRESH</sub>	Threshold to remove a sink from the FB loop after a CH_OVP or VOUT_OVP fault	TBD	75	100	mV

## ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
VIN, FB_OUT to GND	–0.3 V to +31 V
SINK1,2,3,4 to GND	–0.3 V to +21 V
VREG, COMP, ISET, VMIN to GND	–0.3 V to +3.6 V
DIM, VT to GND	–0.3 V to +5.0 V
All other pins to GND	–0.3 V to +6.0 V
Operating Ambient Temperature Range	–40°C to +105°C <sup>1</sup>
Operating Junction Temperature Range	–40°C to +125°C
Maximum Junction Temperature	150°C
Storage Temperature Range	–45°C to +150°C
Soldering Conditions	JEDEC J-STD-020
ESD (Electrostatic Discharge)	
Human Body Model (HBM)	± 2.0 kV
Machine Model (MM)	± TBD V
Charged Device Model (CDM)	± TBD kV

<sup>1</sup> The maximum operating junction temperature ( $T_{J(MAX)}$ ) supersedes the maximum operating ambient temperature ( $T_{A(MAX)}$ ). See the Maximum Temperature Ranges section for more information.

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Absolute maximum ratings apply individually only, not in combination. Unless otherwise specified, all voltages are referenced to GND.

## MAXIMUM TEMPERATURE RANGES

The maximum operating junction temperature ( $T_{J(MAX)}$ ) supersedes the maximum operating ambient temperature ( $T_{A(MAX)}$ ). Therefore, in situations where the ADP8866 is exposed to poor thermal resistance and a high power dissipation ( $P_D$ ), the maximum ambient temperature may need to be derated. In these cases, the ambient temperature maximum can be calculated with the following equation:

$$T_{A(MAX)} = T_{J(MAX)} - (\theta_{JA} \times P_{D(MAX)}).$$

## THERMAL RESISTANCE

$\theta_{JA}$  (junction to air) is specified for the worst-case conditions, that is, a device soldered in a circuit board for surface-mount packages. The  $\theta_{JA}$  and  $\theta_{JC}$  (junction to case) are determined according to JESD51-9 on a 4-layer printed circuit board (PCB) with natural convection cooling. The LFCSP exposed pad must be soldered to GND.

Table 3. Thermal Resistance

Package Type	$\theta_{JA}$	$\theta_{JB}$	$\theta_{JC}$	Unit
LFCSP	33.2	12.4	2.4	°C/W

## ESD CAUTION



**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

## PIN CONFIGURATIONS AND FUNCTION DESCRIPTIONS

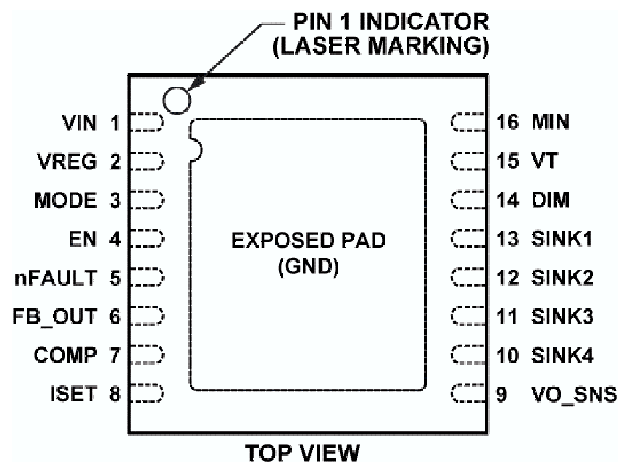


Figure 3. LFCSP Pin Configuration

Table 4. Pin Function Descriptions

Pin No.	Mnemonic	Description
1	Vin	Supply voltage input (3.3 V to 30 V).
2	VREG	Regulated 3.0 V (typ) source. Connect a 2.2 $\mu$ F capacitor from REG to ground.
3	MODE	If MODE = GND, then the part is placed into DC EA operation. If MODE = VREG, then the part is placed into PWM EA operation. If MODE = 30.1 k $\Omega$ resistor to GND, then the part is placed into DC Low Gain Buffer operation. If MODE = 49.9 k $\Omega$ resistor to GND, then the part is placed into PWM Low Gain Buffer operation. Never leave the MODE pin floating. See the MODE Section for more information.
4	EN	Enable input. Pull high (above $V_{IH(MIN)}$ ) to enable the part. EN is internally pulled low with a 400 k $\Omega$ (typical) resistor.
5	nFAULT	Fault output. This pin must be connected to an external pullup resistor. If using multiple ADP8140 ICs in parallel, all the nFAULT pins must be connected together.
6	FB_OUT	Control signal for external power stage. The action of this pin depends on the MODE setting.
7	COMP	Control signal for external power stage. The action of this pin depends on the MODE setting.
8	ISET	Connect a resistor to ground to set the output current. If left floating, the current sinks are set to 14 mA.
9	VO_SNS	Power stage output voltage sensing input. Connect this pin through a resistor divider to the top of the LED strings.
10	SINK4	Current sink for LED channel 4.
11	SINK3	Current sink for LED channel 3.
12	SINK2	Current sink for LED channel 2.
13	SINK1	Current sink for LED channel 1.
14	DIM	DIM input. This pin takes a PWM or DC voltage and reduces or PWM's the output current. The action of this pin depends on the MODE setting.
15	VT	Analog current reduction pin. Typically connected to a thermistor to reduce the LED output current as the temperature increases.
16	MIN	Sets the minimum voltage threshold for the VT pin. VT voltages below the MIN voltage will turn the LEDs off.
EPAD	GND	Ground. Connect the exposed paddle of the LFCSP to GND.

## THEORY OF OPERATION

The ADP8140 provides high current control of up to four LED channels. Each driver can sink up to 500 mA. One external resistor programs the sink current for all four channels. The device features a feedback output that controls an external power supply for optimal efficiency. The ADP8140 also

protects the LEDs, power supply, and itself against thermal events, short circuits, and LED open circuits. Multiple ADP8140 ICs are easily connected in parallel to drive additional LED strings, or higher current LEDs.

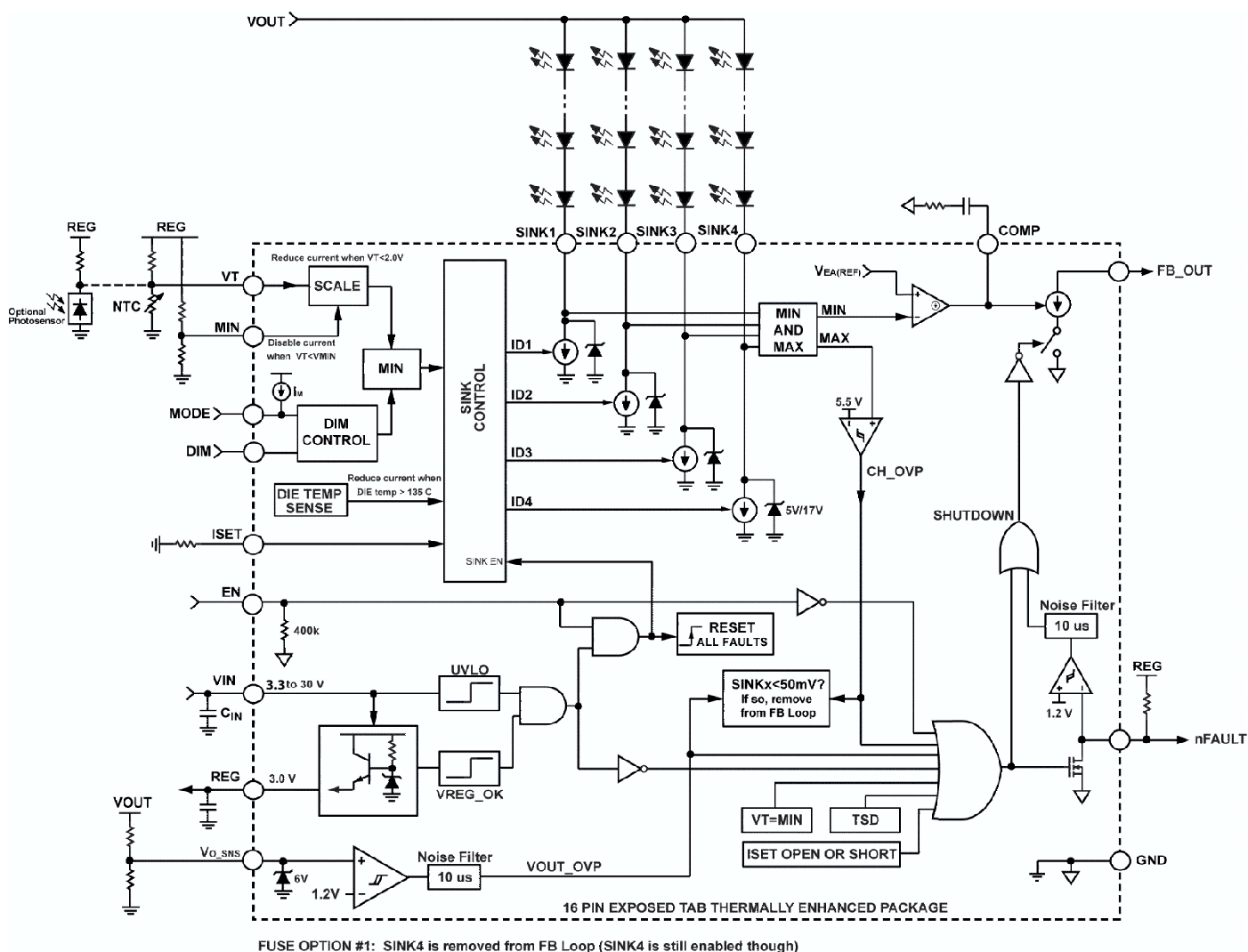


Figure 4. Detailed Block Diagram



## CURRENT SINKS

The ADP8140 contains four internal current sinks. Each current sink is capable of delivering 0-500 mA. To ensure accurate regulation the voltage on the current sinks must be greater than their maximum headroom voltage given in Table 1. This headroom voltage varies somewhat with input voltage and LED output current. The current is set with an external resistor,  $R_{set}$ , using the following equation:

$$R_{set} (k\Omega) = \frac{2576}{I_{LED} (mA)} \quad (eq 1)$$

Several sinks can be combined together for higher currents per string. For example, two sinks can be shorted together to give 2 strings, each at 1 A. Or four sinks combined to give one string at up to 2.0 A.

Each current sink has a maximum rated voltage of 20V. However, the maximum output voltage driving all the current sinks, through the LEDs, is allowed to exceed 20 V. Therefore, the ADP8140 can be safely used in conjunction with power supplies that produce over 100 V for their output. An example is provided at the end of this document.

## POWER CONTROL OPERATION

The ADP8140 controls a power stage with its COMP and FB\_OUT pins. This allows the IC to optimize the efficiency and protection of the LEDs. There are two power control modes that the ADP8140 operates in: Error Amplifier and Low Gain Buffer. The MODE pin is used to select the power control mode.

## MODE PIN OPERATION

The MODE pin is used to set one of four possible modes of operation. The condition of the MODE pin effects the DIM pin input (see “Reducing the LED Current with the DIM” Pin section) and the power mode (see “Power Control Operation”)

MODE	DIM Pin Mode	Power Control
GND	Analog Voltage	Error Amplifier
30.1 k to GND	Analog Voltage	Low Gain Buffer
49.9 k to GND	PWM Signal	Low Gain Buffer
VREG	PWM Signal	Error Amplifier

## ERROR AMPLIFIER POWER CONTROL

In the Error Amplifier Power Control mode, the ADP8140 takes the minimum voltage of the 4 current sinks and applies it to the inverting input of an internal error amplifier. The output of this error amplifier connects to the FB\_OUT inverting buffer.

The FB\_OUT pin outputs a current which indicates power control. A higher FB\_OUT sink current indicates that more power is required to the LEDs. A lower FB\_OUT sink current

indicates that less power is required for the LEDs. This operation makes the FB\_OUT ideal for any power control application that does not normally have an error amplifier. The two primary applications for this are:

1. Controlling an optocoupler on the secondary side of an isolated power supply
2. Controlling a PMOS transistor to regulate power in a fixed output voltage supply.

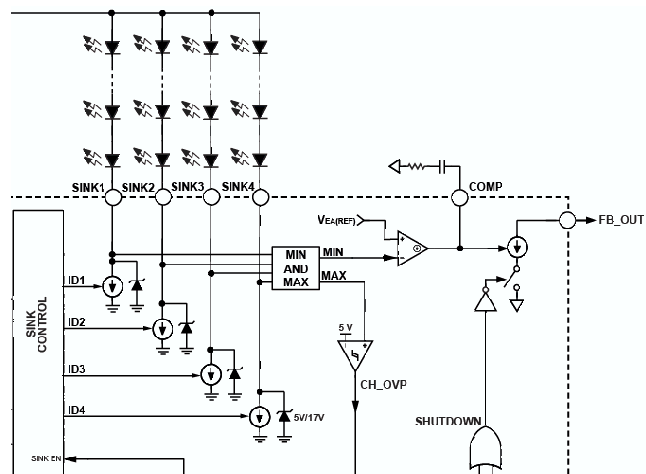


Figure 5. Error Amplifier Power Control

Depending on the power stage used, an RC network will need to be connected to the COMP pin. The COMP pin connects to the output of the FB\_OUT transconductance amplifier. The gain of this amplifier is:

$$GAIN = COMP_{gm} \cdot COMP_{RO} \cdot \frac{1 + s \cdot C \cdot R}{1 + s \cdot C \cdot (COMP_{RO} + R)}$$

Placing a capacitor from COMP to ground adds a pole to the control loop according to:

$$f_P = \frac{1}{2\pi \cdot C \cdot (COMP_{RO} + R)}$$

Placing a resistor in series with that capacitor adds a pole and a zero.

$$f_Z = \frac{1}{2\pi \cdot C \cdot R}$$

where  $COMP_{RO}$  and  $COMP_{gm}$  are given in Table 1

General values and configurations are available for most setups using the Error Amplifier power control can be seen in the Applications section of this document.

## LOW GAIN BUFFER POWER CONTROL

In the Low Gain Buffer Power Control mode, the ADP8140 takes the minimum voltage of the 4 current sinks, multiplies that by  $G_{buff}$  (4.0 typ, see Table 1) and outputs it to the COMP pin. The COMP pin can then be connected to the input of a switched mode power supply controller (SMPS). This mode is

useful for connecting the ADP8140 to power stages that already have their own error amplifier. The bandwidth of the low gain buffer is 100kHz (typ), therefore the SMPS IC's compensation should be set to give a total loop crossover frequency below this.

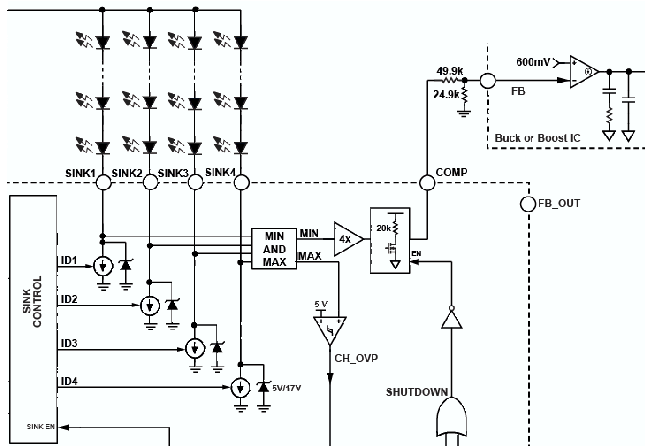


Figure 6. Low Gain Buffer Power Control

A voltage of  $4.0 \times 0.45 \text{ V} = 1.8 \text{ V}$  will appear on the COMP pin when the system is in steady state operation. This 1.8V must be divided down to match the error amplifier reference of the SMPS IC. Typically this reference is 1.2 V or 600mV.

In this mode, it is important to connect the nFAULT pin to the EN of the SMPS IC. This will ensure that the power delivery is immediately shutdown in the event of a fault. The FB\_OUT pin can be left floating or connected to GND. It should not be tied to COMP or any other pin.

General values and configurations are available for most setups using the Low Gain Buffer power control can be seen in the Applications section of this document.

## USING MULTIPLE ADP8140 ICs

Multiple ADP8140 ICs can be combined in parallel to control the same supply. This is advantageous to control more than 4 strings of LEDs or to drive higher currents. For example, using two ADP8140 ICs, four LED strings can be driven at 1000 mA each. Or two strings can be driven at 2.0 A each.

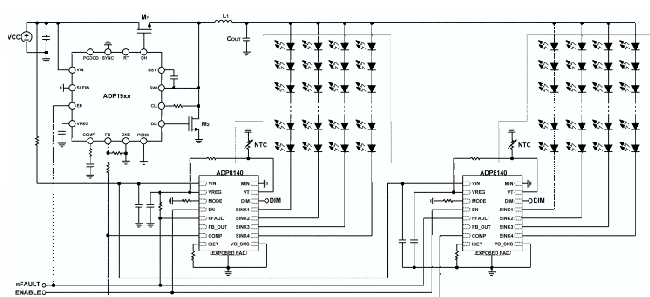


Figure 7. Multiple ADP8140 ICs powered off of one supply (Low Gain Buffer Control shown).

When using multiple ADP8140 ICs in parallel to control one power supply, all of the nFAULT pins must be connected together. If any nFAULT pin goes low, all ADP8140 ICs respond to the event. Most applications will work best if the EN and DIM pins are also connected amongst the ADP8140 ICs, though it is not required. The VT pins may also be connected together, or separate NTC sensors can be used for each ADP8140.

## REDUCING THE LED CURRENT WITH THE DIM PIN

The DIM pin can reduce the output current with either an analog voltage or a PWM signal. The ADP8140's response to the DIM pin depends on the condition of the MODE pin.

If MODE pin voltage is below 0.7V, then the DIM pin functions as an analog voltage input. A DIM voltage of 2V, or greater, does not impact the output current. A DIM voltage of 0V, reduces the output current to 0 mA. Any DIM voltage between 2V and 0V will linearly scale the output current.

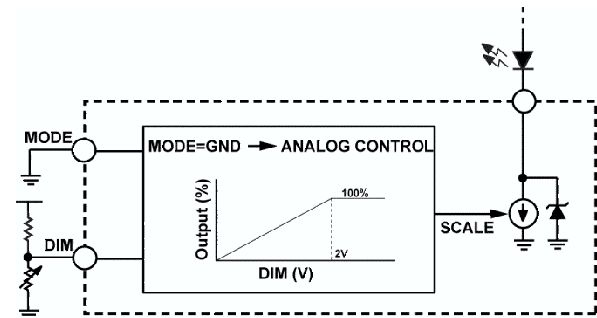


Figure 8. Reducing the output current by applying an analog voltage to the DIM pin.

If MODE is set to a voltage greater than 0.7V, then a PWM duty cycle applied to the DIM pin is internally filtered and used to scale the output currents.

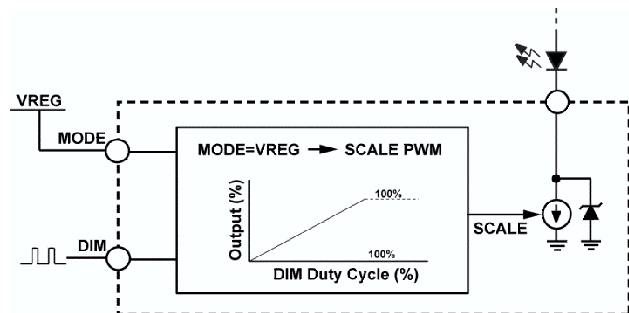


Figure 9. Reducing the average output current by pulse width modulating the current sinks with the DIM pin.

## IMPLEMENTING LED THERMAL PROTECTION

The ADP8140 controller has a VT pin which can be connected to an external NTC (negative temperature coefficient) resistor. This NTC is typically placed on the LED heat sink. Selecting the value of the NTC and the resistor in the network shapes the slope of the VT voltage in response to the LED temperature. VT voltages above 2V produce no reduction in output current.

Below 2V, the output current is reduced 1% per 20 mV. The LED channels are set to 0 mA when the voltage on the VT pin is below the voltage on the MIN pin. If the VT pin voltage rises above the MIN threshold, plus some hysteresis, then the current sinks are re-enabled at their current set by the VT pin.

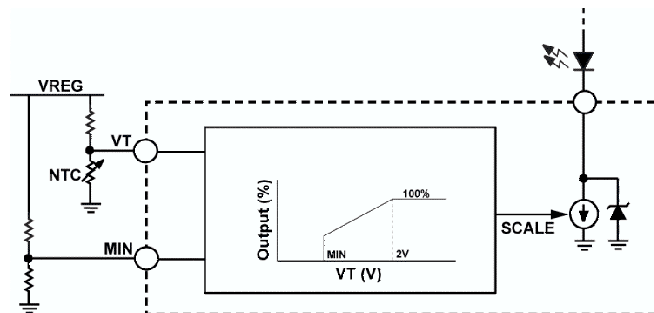


Figure 10. Using an external NTC to implement LED thermal protection.

In place of an NTC resistor, a light sensor can be used on the VT pin. This will dim or brighten the LEDs in response to the lighting conditions.

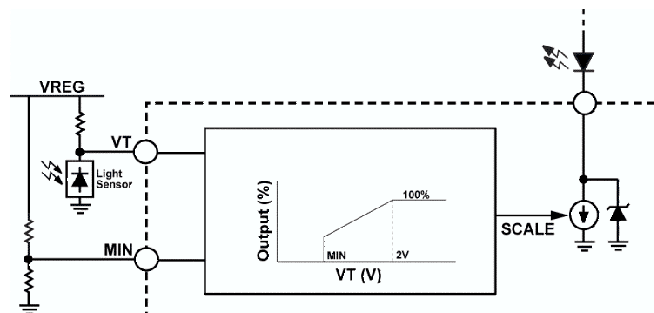


Figure 11. Using a light sensor to dim the LEDs with increasing light intensity.

## EFFECT OF LED VF MISMATCH

The forward voltage (Vf) of each LED varies from unit to unit. In general, LEDs within the same wafer lot will have a normal distribution with a standard deviation of about 20 mV. The electrical specification for Vf given in the LED's datasheet will always be much wider than this. It is sometimes necessary to consult the LED's manufacturer directly for a more realistic gauge of the Vf's variation. Using the information on the Vf variation, we can calculate two very important parameters in any multi string LED design:

1. The maximum current sink voltage
2. The maximum current sink power dissipation

The ADP8140 always controls the FB\_OUT pin to regulate the output voltage to provide the minimum amount of headroom voltage on the current sinks. One of the current sinks will be regulated to V<sub>REFEA</sub> (typ 450 mV). The voltage seen on the other three SINK pins will vary based on the distribution of Vf's. For a given lot of LEDs, the Vf and the change in Vf with

temperature should be relatively consistent. Given a Vf distribution, the maximum voltage that will appear on any of the SINK pins can be statistically calculated. For example, suppose a mean Vf of 3.5 V and a normal distribution with a standard deviation of 70 mV (This gives a Vf spread of 3.2 to 3.8 V -- much larger than is normally seen within one lot of LEDs). A statistical analysis of such a distribution reveals the following graph of the maximum voltage that may appear on any of the SINK pins:

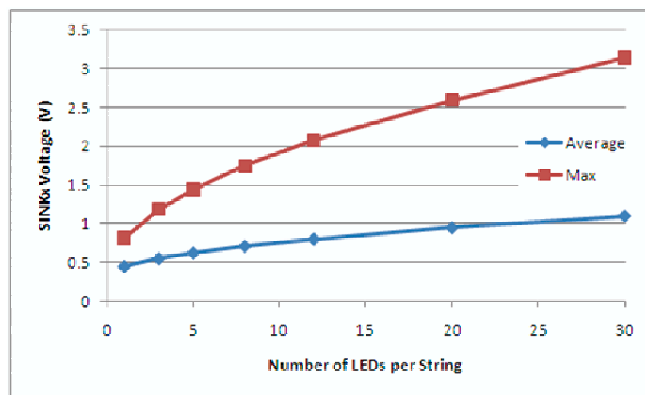


Figure 12. Statistical analysis of the voltage on the SINKx Pins given a normal distribution of Vf's with a standard deviation of 70 mV. Note, the Max value is the average plus 6 standard deviations of the distribution.

Note that even with 30 LEDs per channel, the average and maximum (average plus six standard deviations) SINKx voltages remain relatively small. The value is well below the ADP8140's threshold for shorted LED protection (see the Channel OVP information in the Overvoltage Protection section below).

The second item impacted by the LED Vf variation, the maximum current sink power dissipation, derives directly from the voltages present at each current sink. Specifically, the ADP8140's power dissipation can be represented as:

$$P_{diss} = (V_{SINK1} + V_{SINK2} + V_{SINK3} + V_{SINK4}) \cdot I_{LED}$$

Again, a statistical analysis based on the LED's Vf distribution can be performed to predict the total power dissipation within the ADP8140. For the same distribution used above and an LED current of 350 mA, the following graph gives the average and maximum power dissipations:

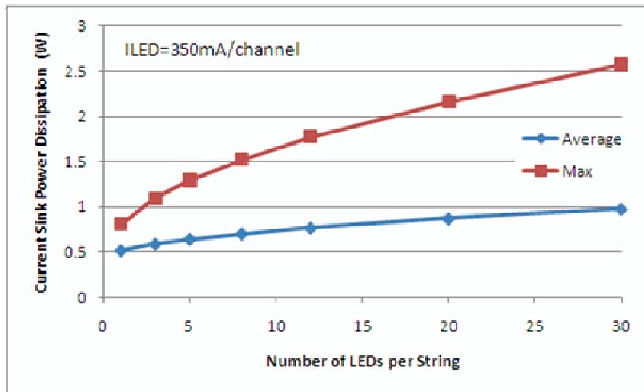


Figure 13. Statistical analysis of the total (all 4 strings) power dissipation for a normal distribution of  $V_f$ s with a standard deviation of 70 mV and an LED current of 350 mA. Note, the Max value is the average plus 6 standard deviations of the distribution.

## MANAGING THE ADP8140'S POWER DISSIPATION

Now that the predicted power dissipation is known, the next step is to determine if the ADP8140's package is able to adequately dissipate that power. The maximum power that the ADP8140 is able to dissipate is found by following this procedure:

Maximum ADP8140  $T_j$  (before entering thermal foldback) = 130°C

Maximum Board Temperature = 85°C

$\Psi_{jB} = 12.4 \text{ } ^\circ\text{C/W}$  (Given in Table TBD)

Assume 100% of the power dissipates through the exposed pad to the board.

$$\begin{aligned} \text{Max } P_{\text{diss}} &= (T_j - T_{\text{board}}) / \Psi_{jB} \\ &= (130 - 85) / 12.4 = 3.6 \text{ W} \end{aligned}$$

For high power dissipations ( $P_{\text{diss}}$ ) it is imperative to follow the layout guidelines given in the Layout Guidelines section.



## ADP8140 FAULT PROTECTIONS

To ensure the safety of the LEDs, the ADP8140 IC, and the power source, the ADP8140 includes a comprehensive array of detection and protection features. These include:

- Power supply overvoltage protection
- LED Over temperature protection
- LED Short protection

- LED Open protection
- IC Over temperature protection
- Shorted ISET protection
- Open ISET and EN protection

The features are summarized on the flow chart of Figure 14.

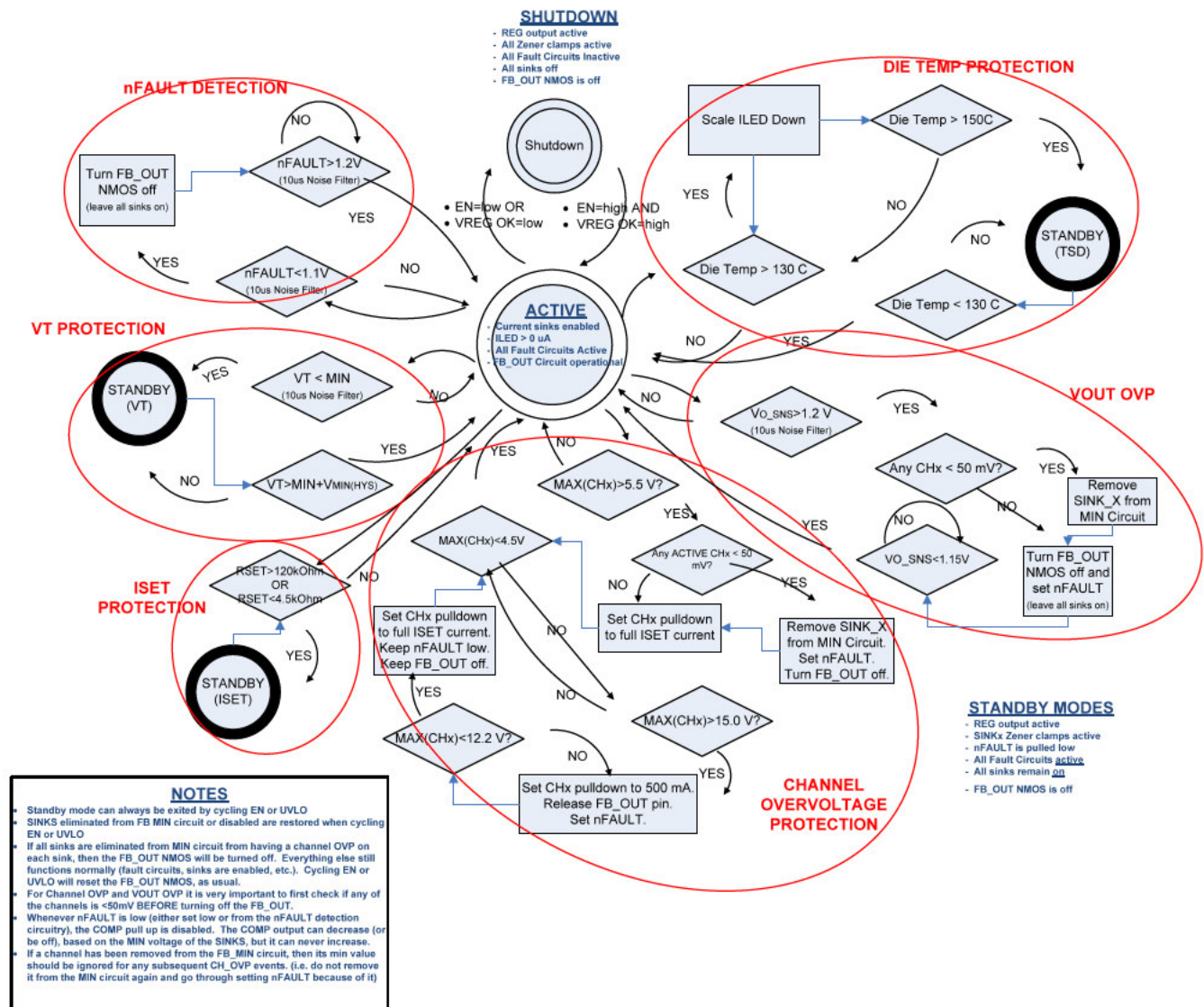


Figure 14. ADP8140 Fault Flow Chart

## STARTUP SEQUENCE

To start the ADP8140 VIN must be applied in excess of the UVLO threshold and the EN pin must be high. However, even with EN low, the VREG pin produces a constant 3.0V on its output. VREG can be used as a low current supply, as needed.

In this operation, with EN low, the ADP8140 consumes no more than 250  $\mu$ A.

When EN also goes high, then the sinks startup. There is an 8 ms delay, a time necessary for the DIM mode to determine the PWM state of its input. When the sinks are enabled, the

nFAULT pin is released and the COMP and FB\_OUT pins begin their normal regulation. When EN goes low, the SINK pins are left on for another 100us to bleed off any voltage from the power stage. The part then enters low current consumption operation.

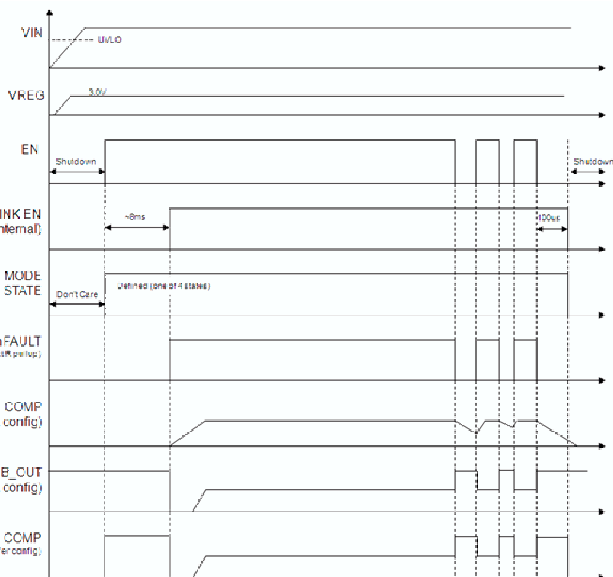


Figure 15. Startup timing and signals

## DIE TEMPERATURE PROTECTION

As explained above, a higher voltage on the ADP8140's sink pins creates a higher power dissipation within the ADP8140. If this increase in power dissipation causes the die temperature on the ADP8140 to rise above 130°C (typ), then the IC automatically begins to reduce the output current on all four sinks. If the die temperature continues to rise, then the ADP8140 shuts down all the current sinks and releases the pulldown on the FB\_OUT pin. When the temperature drops below 130°C, the ADP8140 restarts. If the fault or high power dissipation persists, then the sequence repeats.

## OVERVOLTAGE PROTECTION

An LED open circuit can result from a bad solder connection or damaged LED. An open LED string results in the current sink headroom falling to a very low level. The feedback loop naturally interprets this as a request for more power, and so the FB\_OUT current is increased. This can quickly lead to a case where the output voltage is too high. This increase in output voltage is detected by either the VO\_SNS pin or the SINKx pins.

The VO\_SNS pin senses the output voltage of the power supply through an external resistor divider. VO\_SNS is then compared to an internal threshold (1.2 V typical). If the output voltage rises such that the VO\_SNS pin is greater than 1.2 V, then an output overvoltage fault (VOUT\_OVP) is declared. During a VOUT\_OVP fault, the FB\_OUT pulldown

NMOS is released, causing the power stage to shutdown. The LED current sinks are left enabled during this event. When VO\_SNS drops to 1.15 V (typical), the FB\_OUT function resumes its normal operation.

Alternatively, the output voltage may not rise high enough to trigger VO\_SNS, but it may rise high enough to cause one of the SINKx pins to exceed 5.0V (typical). Or a shorted LED may cause the SINKx pins to exceed this level. To prevent excessive power dissipation and damage to the IC, when a SINKx pin rises above 5.0 V, a channel over voltage (CH\_OVP) fault is declared. During a CH\_OVP fault, the FB\_OUT pulldown NMOS is released, causing the power stage to shutdown. The LED current sinks are left enabled during this event. When the SINKx voltage drops to 5.0 V (typical), the FB\_OUT function resumes its normal operation.

Continued output overvoltage operation degrades efficiency and can affect the lifetime of passive components. Therefore, when an overvoltage condition is detected (either VOUT\_OVP or CH\_OVP), then any open LED current sinks are identified and removed from the feedback loop.

During a VOUT\_OVP or CH\_OVP event, the nFAULT pin is pulled low. nFAULT is released high when the overvoltage condition has ended.

## OPERATING THE ADP8140 FROM HIGHER INPUT VOLTAGES

The ADP8140 is capable of operating from an input voltage (Vin) range of 3.3 to 30 V. However, higher voltages can be used to power the ADP8140, as long as an appropriate current limiting circuit is used.

It is sometimes sufficient to limit the voltage on VIN by placing a Zener diode on VIN and limiting the current with a resistor from the input voltage to the VIN pin. This method could be used if standby power dissipation is not an issue.

Alternatively, if the supply voltage range is small, an additional Zener between the supply and VIN will shift the voltage at the VIN pin below 30 V. This method adds minimal power dissipation in both standby and active modes.

However, a more robust voltage limiter uses a Zener, an NPN, and two resistors. This simple circuit gives the required operating Iq during normal operation, but also reduces the standby current when the ADP8140 is disabled. The circuit is shown in Figure 16.

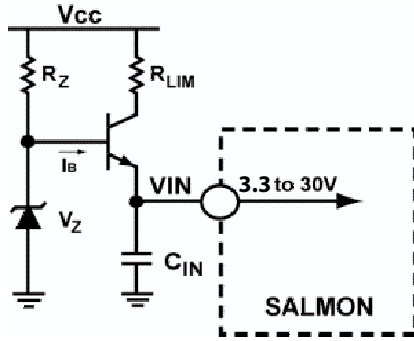


Figure 16. VIN current limiting circuit for high input voltages

$V_Z$  is selected to be below the minimum value of the ADP8140's active VIN clamp (given in Table 1). The VIN voltage will be regulated to  $V_Z - 0.7\text{ V}$ . The resistor,  $R_Z$ , should be selected to limit the current when the ADP8140 is disabled, yet still provide enough current to reverse bias the Zener and drive the NPN when the ADP8140 is active. The current through  $R_Z$  is given by:

$$I_{RZ} = (V_{CC} - V_Z) / R_Z$$

$$I_{RZ} = \frac{V_{CC} - V_Z}{R_Z}$$

A value of  $100\text{ }\mu\text{A}$  at the minimum expected  $V_{CC}$  is generally sufficient. Even at maximum  $V_{CC}$ , this will only contribute a few mW of power dissipation during standby.

RLIM limits the maximum current during transients. A value of a few hundred ohms is sufficient. When the ADP8140 is active, the additional, worst case, power dissipation from this limit circuitry is given by:

$$\begin{aligned} \Delta P_{DISS(ACTIVE)} &= (V_{CC_{MAX}} - V_{Z(MIN)} + 0.7\text{ V}) \cdot I_Q \\ &= (48\text{ V} - 24\text{ V} + 0.7\text{ V}) \cdot 3\text{ mA} = 74\text{ mW} \end{aligned}$$

#### LAYOUT GUIDELINES

1. The exposed pad of the ADP8140 must be properly connected to a heat sink. This includes soldered to the board and connected to a large plane of ground metal with an array of thermal vias.
2. The ADP8140 has been designed for easy layout with single sided metal core substrates. If FR4 substrate used, thermal vias must be used between the LFCSP exposed pad and a large ground trace on the opposite side of the board.

## ADP8140 + 24 VDC INPUT

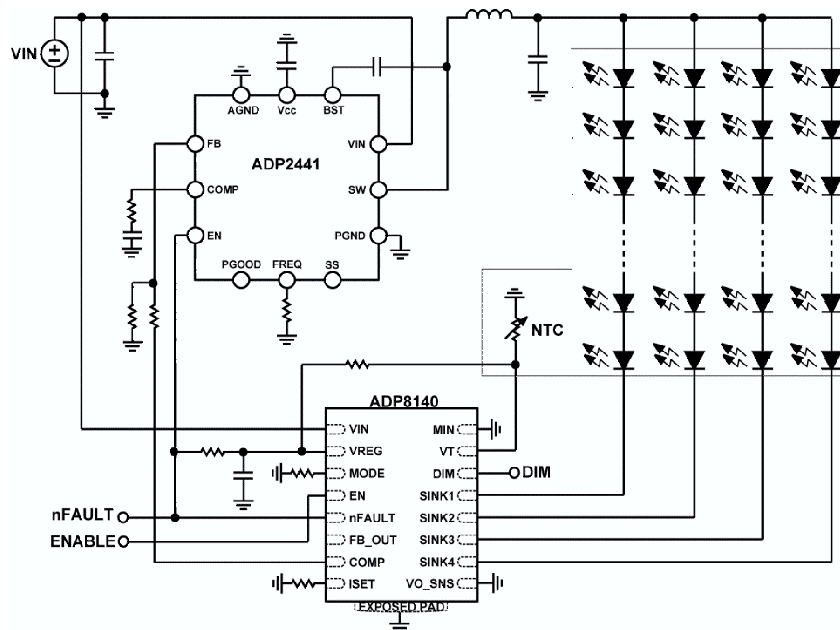


Figure 17.

## ADP8140 SECONDARY SIDE CONTROL DESIGN EXAMPLE

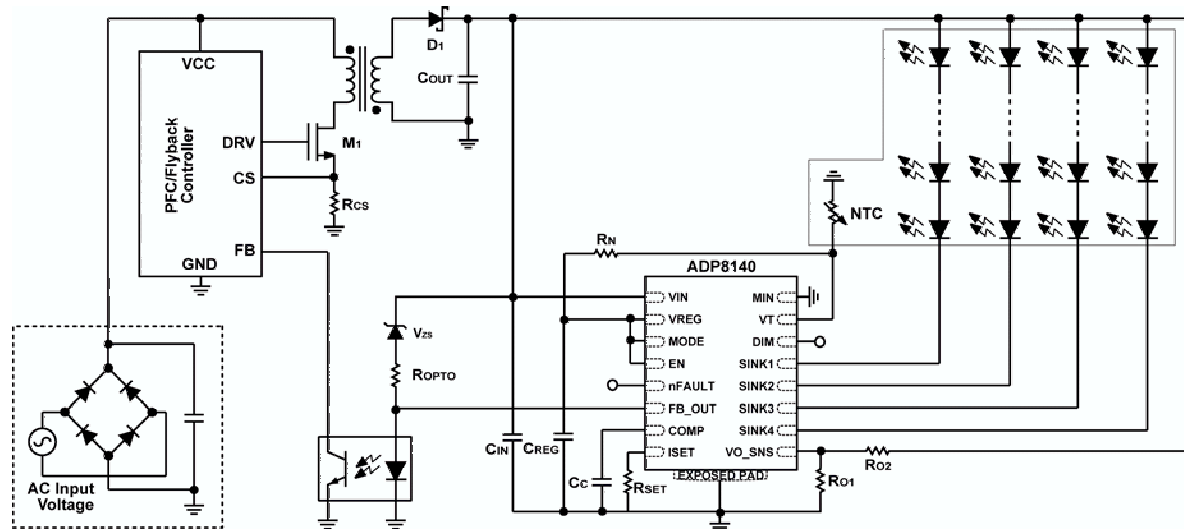


Figure 18.



## ADP8140 AND 24VDC RAIL DESIGN EXAMPLE

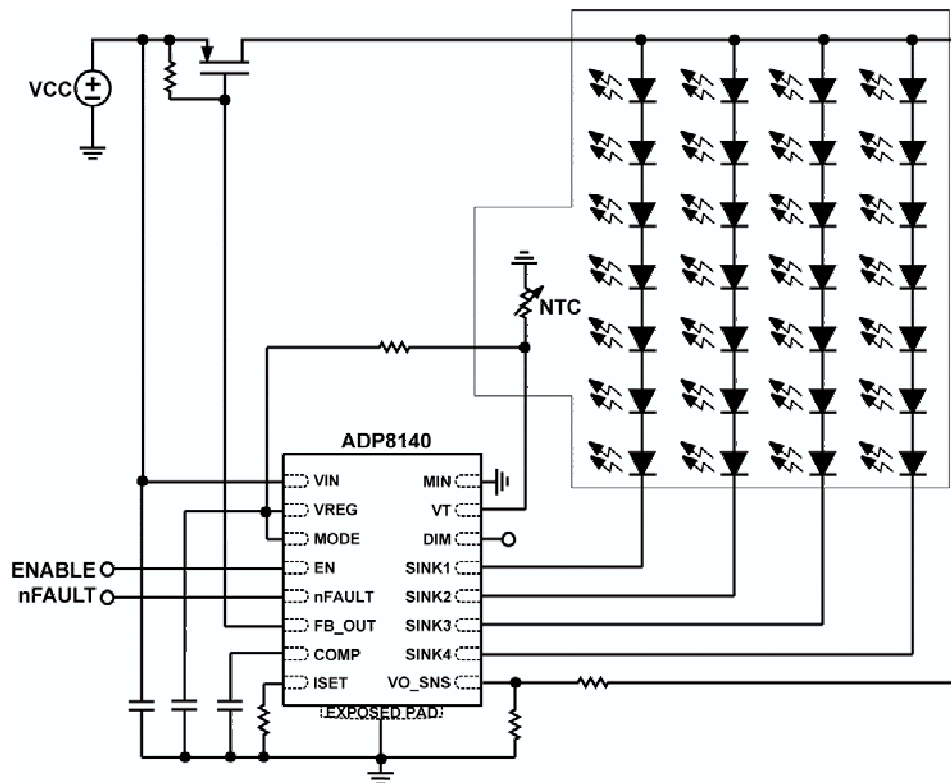


Figure 19.

## MULTIPLE ADP8140S WITH A 24VDC RAIL DESIGN EXAMPLE

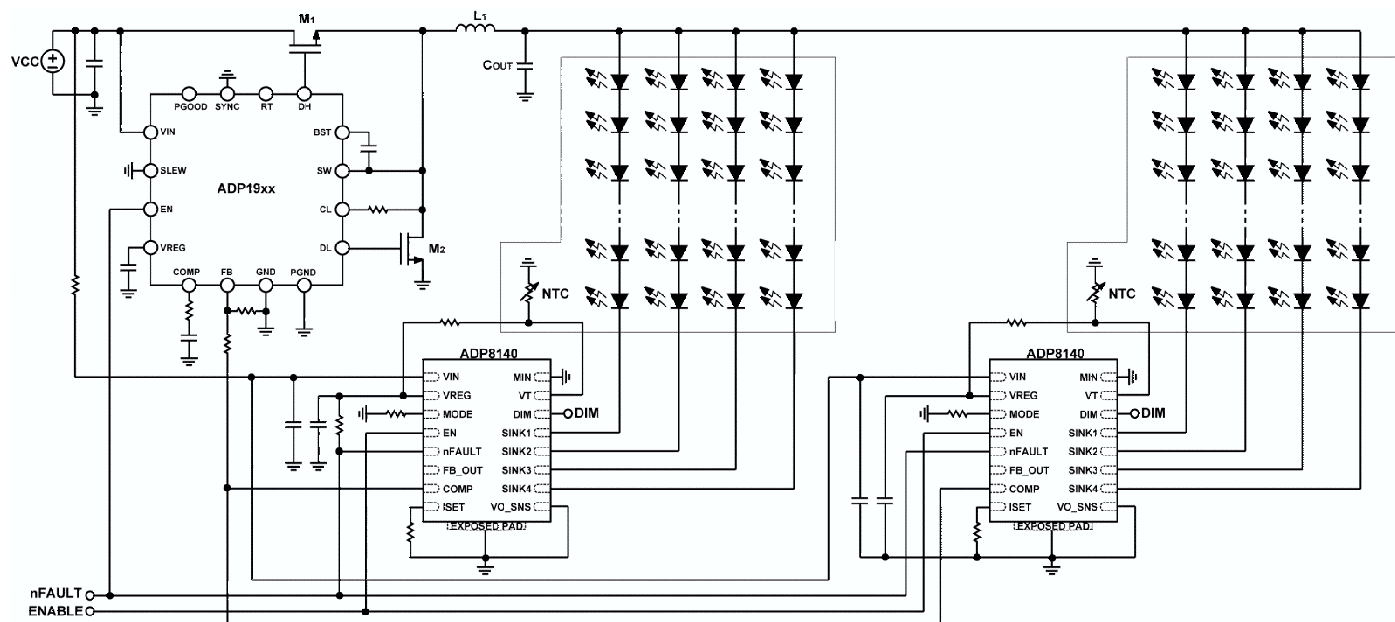
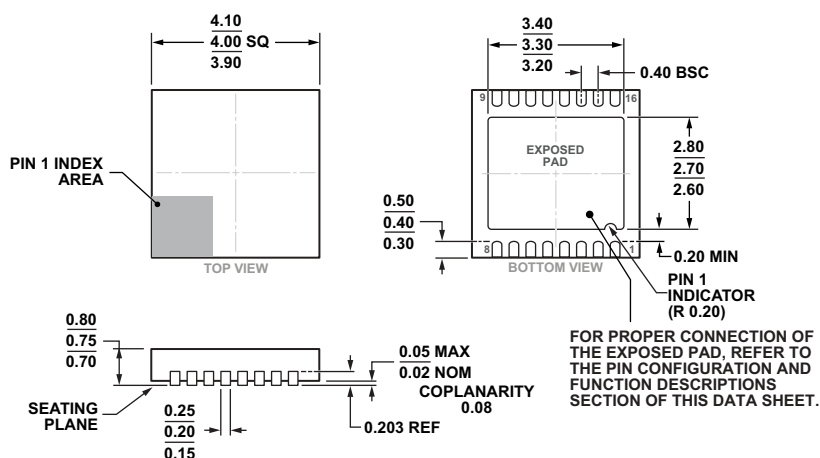


Figure 20.

## OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-229-WGGE.

Figure 21. 16-Lead Lead Frame Chip Scale Package [LFCSP\_WD]  
 4 x 4 mm Body, Very Very Thin Dual  
 (CP-16-29)  
 Dimensions shown in millimeters

## ORDERING GUIDE

Model <sup>1</sup>	Temperature Range	Package Description	Package Option
ADP8140ACPZ_TBD	-40 to +125°C	16-Lead LFCSP_WD	CP-16-29

<sup>1</sup> Z = RoHS Compliant Part.