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# FAN5640 — Dual High-Side Constant Current Source for High-Voltage Keypad LED Illumination

## Features

- 20V Maximum Driver Input Level
- Dual Output
- 25mA Drive Capability per Channel
- Two Strings of 2-4 LEDs Each
- External Resistor Sets Maximum Current
- Fast Turn-On/Off Capability
- Low Bias Current
- SC70-6 Package
- Thermal Shutdown Protection

## Applications

- Keypad Illumination
- Main Display and Sub-Display Illumination
- Cell Phones, Smart Phones
- Pocket PCs
- PDA, DSC, PMP, and MP3 Players

## Description

The FAN5640 is designed to illuminate one or two strings of keypad LEDs with constant high-side current sources.

The device can drive up to four white LEDs in series at a maximum current of 25mA per channel. If the second channel is not needed, the channels can be tied together to boost output current up to 50mA.

An external resistor programs the maximum output current. Dimming can be accomplished by pulse width modulation of the enable pin or the input supply rail.

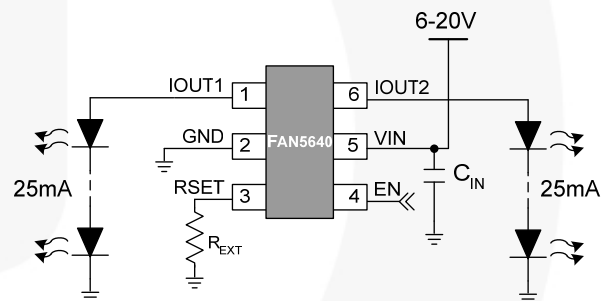


Figure 1. Typical Application

## Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FAN5640S7X	-40°C to 85°C	SC70-6 2x2.2mm	Tape and Reel

## Block Diagram

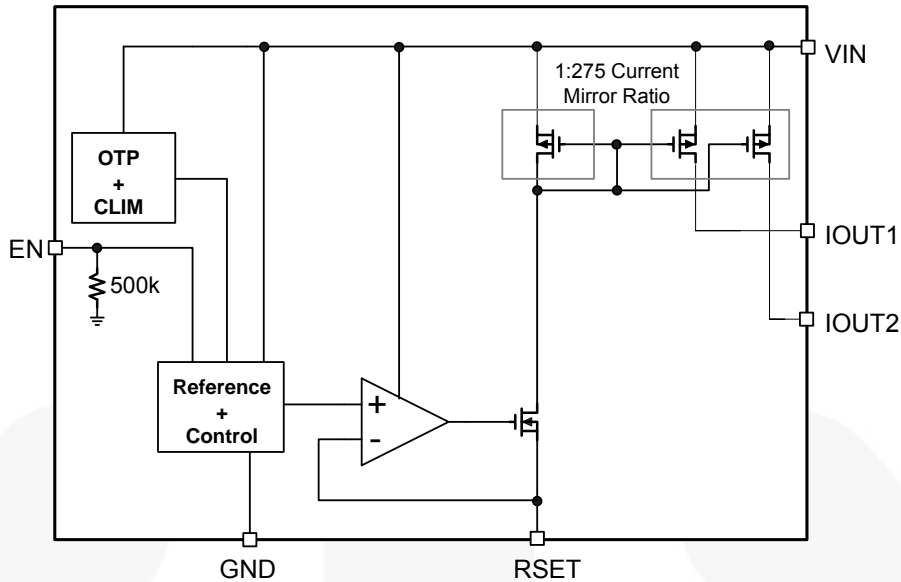


Figure 2. Block Diagram

## Pin Configuration

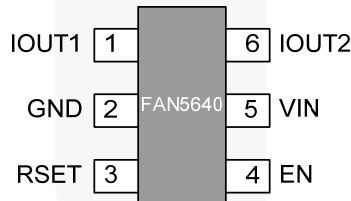


Figure 3. Pin Assignments

## Pin Definitions

Pin #	Name	Description
1	IOUT1	<b>Output Current 1.</b> The programmed current $I_{OUT}$ is sourced from this pin. If only one channel is used, IOUT1 and IOUT2 can be tied together to boost the output current. It can also be left floating or tied to pin 5.
2	GND	<b>Ground</b>
3	RSET	<b>RSET.</b> Connect a programming resistor $R_{EXT}$ to this pin. This pin's output voltage is 0.475V when EN is HIGH. The current through the external resistor establishes the current $I_{OUT}$ , where $I_{OUT} = 275 \cdot [0.475V / R_{EXT}]$ .
4	EN	<b>Enable.</b> When HIGH, the IC applies the programmed current $I_{OUT}$ to both IOUT1 and IOUT2. When LOW, IC enters Shutdown Mode. If pulsed, this pin modulates the output current. The minimum pulse width is determined by the speed of the turn-on circuitry. This pin contains an internal pull-down resistor of 500K $\Omega$ .
5	VIN	<b>Input Supply.</b> Apply 6 to 20V at this pin (see <i>Dropout Limitations under the Application Information section</i> ).
6	IOUT2	<b>Output Current 2.</b> The programmed current $I_{OUT}$ is sourced from this pin. If only one channel is used, IOUT1 and IOUT2 can be tied together to boost the output current. It can also be left floating or tied to pin 5.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter	Min.	Max.	Unit
$V_{EN}$	Enable Voltage	-0.3	6.0	V
	$V_{IN}$ , $V_{IOUT1}$ , $V_{IOUT2}$	-0.3	22.0	V
$I_{RSET}$	Current Sourced by RSET		120	$\mu$ A
$T_J$	Junction Temperature	-40	150	$^{\circ}$ C
$T_{STG}$	Storage Temperature	-65	150	$^{\circ}$ C
$T_L$	Lead Soldering Temperature, 10 Seconds		260	$^{\circ}$ C
ESD	Electrostatic Discharge Protection Level	Human Body Model	2	kV
		Charged Device Model	2	

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended operating conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter	Min.	Typ.	Max.	Unit
$V_{IN}$	Supply Voltage	6		20	V
$V_{EN}$	Enable Voltage			5.5	V
$I_{OUT1}$ , $I_{OUT2}$	Output Current Range Through Each String	2.5		25.0	mA
$T_A$	Operating Ambient Temperature Range <sup>(1)</sup>	-40		+85	$^{\circ}$ C
$T_J$	Operating Junction Temperature Range <sup>(1)</sup>	-40		+125	$^{\circ}$ C

## Thermal Properties

Symbol	Parameter	Min.	Typ.	Max.	Unit
$\Theta_{JA}$	Junction to Ambient Thermal Resistance <sup>(1)</sup>		300		$^{\circ}$ C/W

### Note:

1. Junction-to-Ambient thermal resistance is a function of application and board layout. This data is measured with four-layer, 1s2p boards in accordance with JESD51- JEDEC standard. Special attention must be paid not to exceed the maximum junction temperature.

## Electrical Characteristics

$V_{IN} = 6V$  to  $20V$ ,  $T_A = -40^{\circ}C$  to  $+85^{\circ}C$ , unless otherwise noted. Typical values are at  $T_A = 25^{\circ}C$ ,  $V_{IN} = 14V$ ,  $I_{LED} = 15mA$ .

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
<b>Power Supplies</b>						
$V_{IN}$	Input Voltage Range		6		20	V
$I_Q$	Quiescent Current	Measured at GND pin, $V_{IN} = 20V$		48	65	$\mu A$
		Measured at GND pin, $V_{IN} = 6V$		44	55	
$I_{SD}$	Shutdown Supply Current	$V_{IN} = 20V$ , EN = GND		8	13	$\mu A$
		$V_{IN} = 6V$ , EN = GND		5	8	
$V_{EN}$	Enable High-Level Input Voltage		1.2			V
	Enable Low-Level Input Voltage				0.4	
$I_{EN}$	Enable Input Current	EN = 5V		9	15	$\mu A$
		EN=GND		0.1	1.0	
<b>Regulation</b>						
$I_{LIM1}$	Channel 1 Current Limit <sup>(2)</sup>		30			mA
$I_{LIM2}$	Channel 2 Current Limit <sup>(2)</sup>		30			mA
$\Delta I_{OUT}$	Output Current Accuracy	$2.5mA < I_{OUT} \leq 5mA$ <sup>(3)</sup>	-15		+15	%
		$5mA < I_{OUT} \leq 25mA$ <sup>(3)</sup>	-10		+10	
$I_{MATCH}$	Channel-to-Channel Current Matching <sup>(4)</sup>		-3		+3	%
$V_{DO}$	Output Dropout Voltage	$V_{IN} - V_{OUT}$ at 90% $I_{OUT}$ Programmed $I_{OUT} = 25mA$		1.80	2.50	V
		$V_{IN} - V_{OUT}$ at 90% $I_{OUT}$ Programmed $I_{OUT} = 2.5mA$		0.43	0.60	
$V_{REF}$	Reference Voltage			475		mV
$I_{MIRROR}$	Current Mirror Ratio	$I_{OUT} / I_{RSET}$		275		
$\Delta I_{OUT} / \Delta V_{IN}$	Power Supply Current Dependency	$V_{OUT} = V_{IN} - 2V$ <sup>(5)</sup>		0.5	2.0	%/V
$T_{ON}$	Turn-On Time	$V_{IN} = 14V$ , $I_{OUT} = 12.5mA$ <sup>(6)</sup>		5	8	$\mu s$
TSD	Thermal Shutdown Protection	Rising Temperature		150		$^{\circ}C$
		Hysteresis		20		

### Notes:

- If only one channel is needed,  $I_{OUT1}$  can be tied to  $I_{OUT2}$  to boost maximum current to 50mA.
- $R_{EXT}$  resistor tolerance adds to the specification limit of the pin RSET to determine overall current accuracy.
- Matching defined as  $[(I_{OUT1} - I_{OUT2}) / (I_{OUT1} + I_{OUT2})] \times 100$ .
- $V_{OUT}$  is the total voltage drop across the LED string.
- Measured from EN crossing 1.8V to output current reaching 90% of target  $I_{OUT}$ .

## Typical Characteristics

Unless otherwise noted,  $C_{IN} = 4.7\mu\text{F}$ ,  $V_{EN} = 1.8\text{V}$ ,  $T_A = 25^\circ\text{C}$ , white LED with  $V_F = 3.3\text{V}$  at  $I_{OUT} = 10\text{mA}$ .

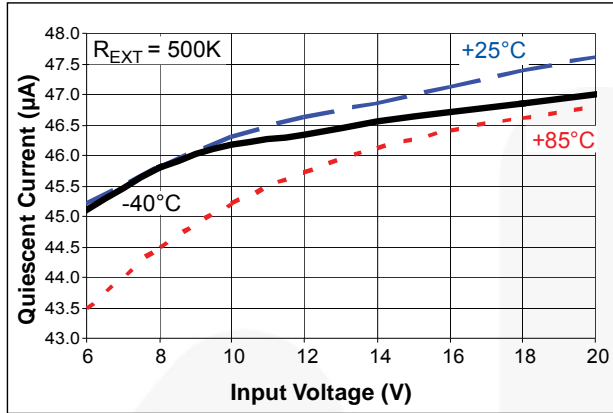


Figure 4. Quiescent Current vs. Input Voltage

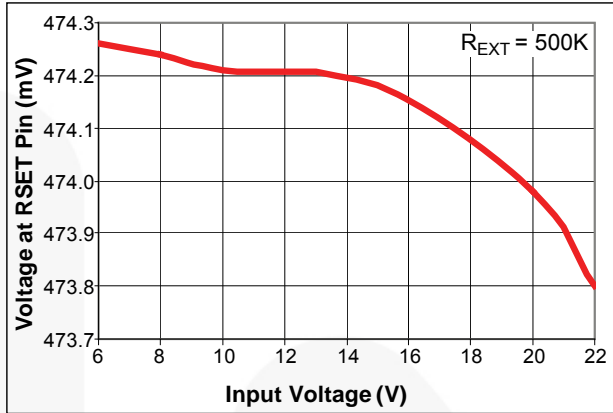


Figure 5. RSET Voltage vs. Input Voltage

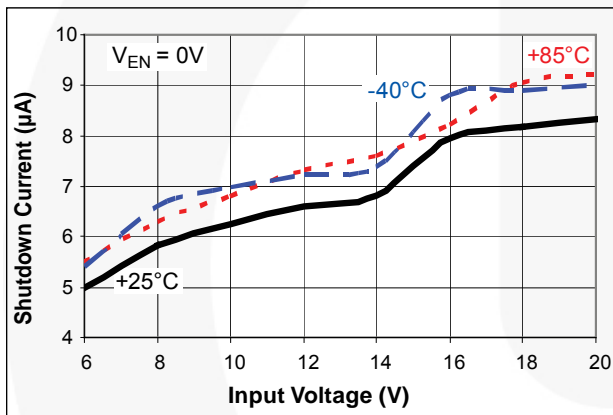


Figure 6. Shutdown Current vs. Input Voltage

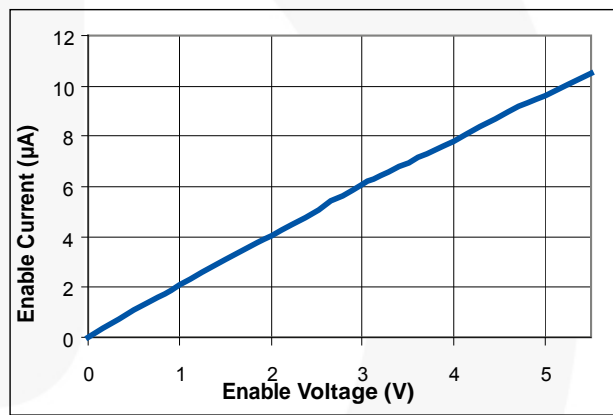


Figure 7. Enable Input Current vs. Enable Voltage

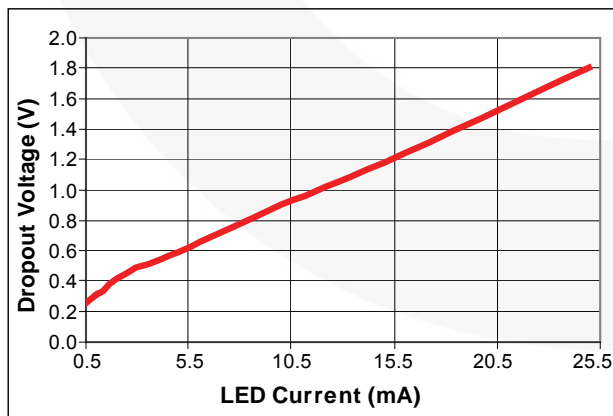


Figure 8. Dropout Voltage vs. LED Current

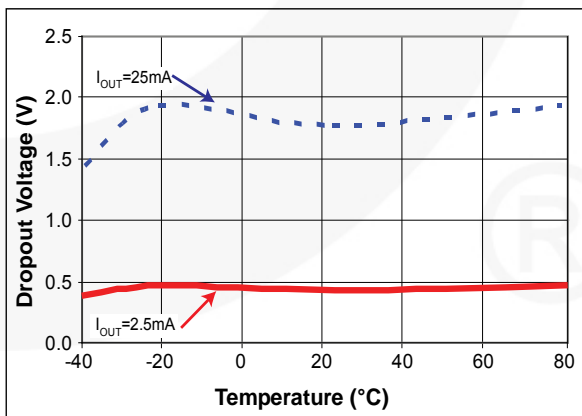


Figure 9. Dropout Voltage vs. Temperature

### Typical Characteristics (Continued)

Unless otherwise noted,  $C_{IN} = 4.7\mu F$ ,  $V_{EN} = 1.8V$ ,  $T_A = 25^\circ C$ , white LED with  $V_F = 3.3V$  at  $I_{OUT} = 10mA$ .

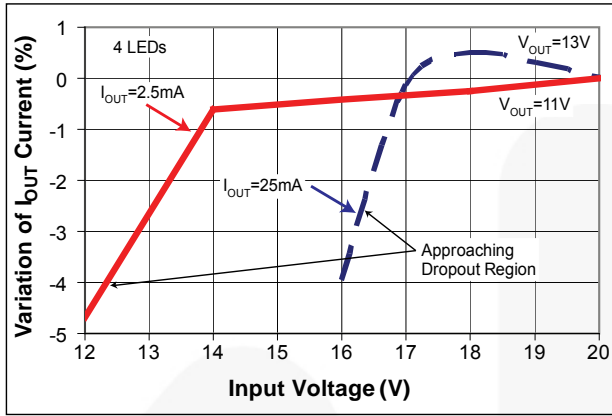


Figure 10. Line Regulation

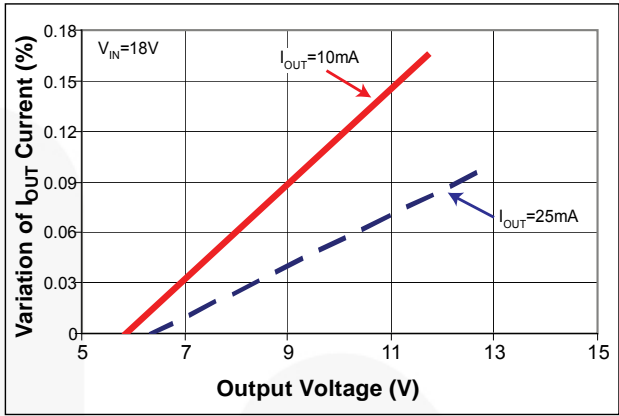


Figure 11. Variation of  $I_{OUT}$  Current vs. Output Voltage

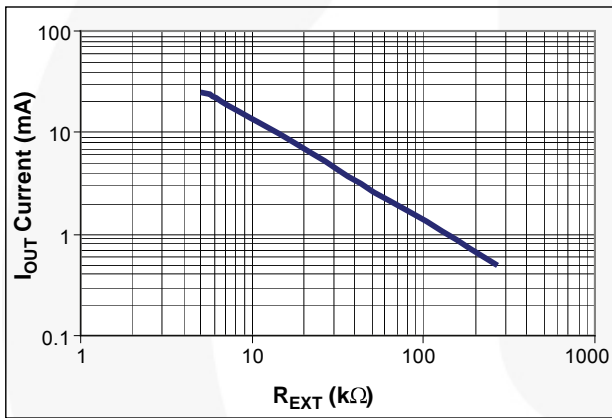


Figure 12.  $I_{OUT}$  Current vs.  $R_{EXT}$  Voltage

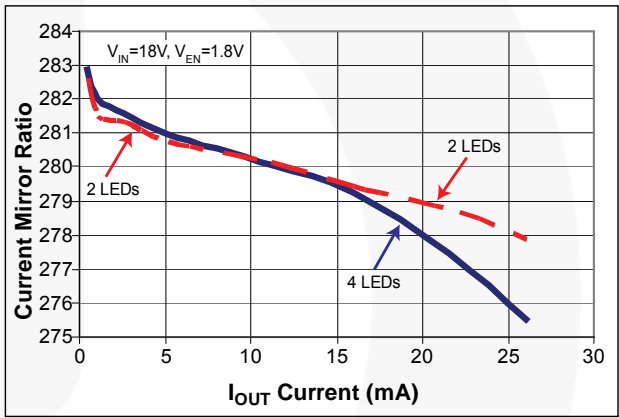


Figure 13. Current Mirror Ratio vs. LED Current

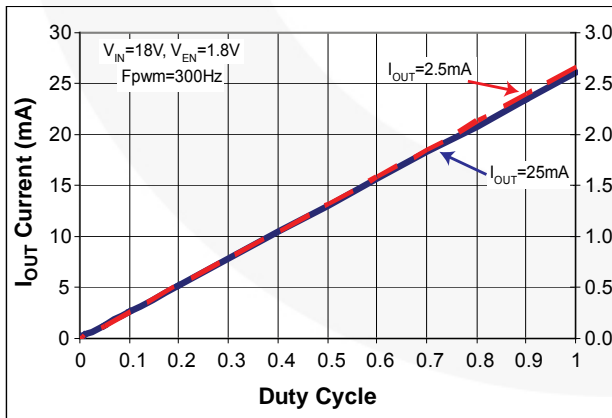


Figure 14. PWM Dimming on EN Pin

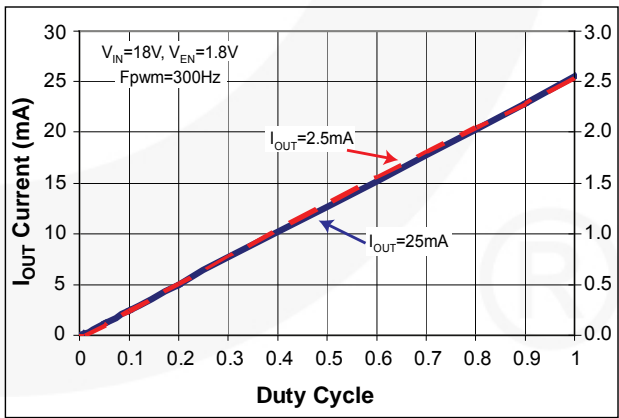


Figure 15. PWM Dimming on VIN Pin

### Typical Characteristics (Continued)

Unless otherwise noted,  $C_{IN} = 4.7\mu\text{F}$ ,  $V_{EN} = 1.8\text{V}$ ,  $T_A = 25^\circ\text{C}$ , white LED with  $V_F = 3.3\text{V}$  at  $I_{OUT} = 10\text{mA}$ .

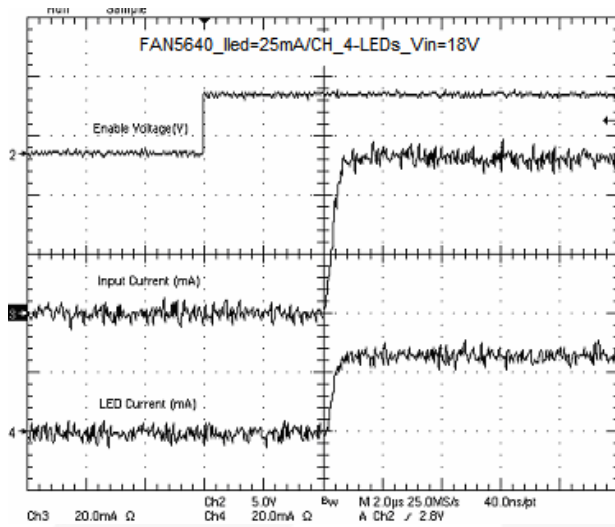


Figure 16. Turn-On at Full Load

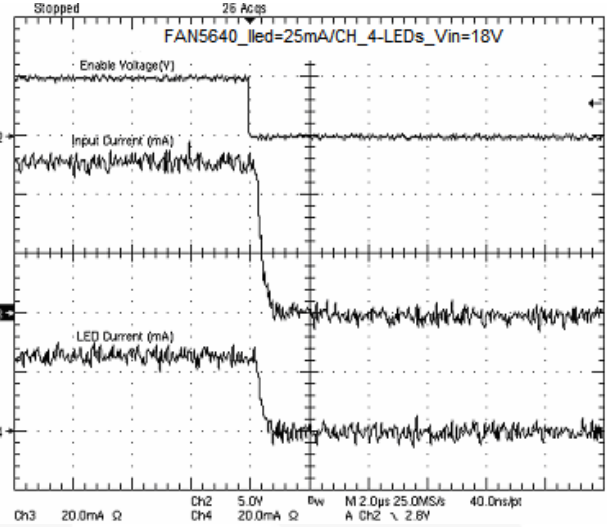


Figure 17. Turn-Off at Full Load

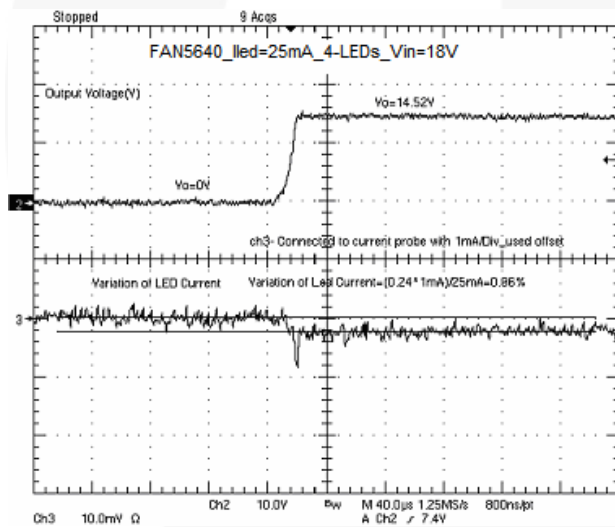


Figure 18. Load Transient Response ( $V_{OUT}$  Low to High)

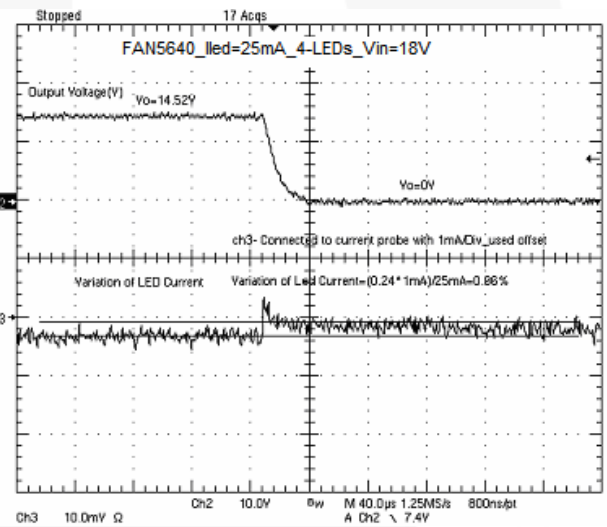


Figure 19. Load Transient Response ( $V_{OUT}$  High to Low)



## Application Information

### Setting the Output Current Level

An internally generated reference current is mirrored on the MOSFETs connected to the outputs IOUT1 and IOUT2 (pins 1 and 6, respectively). The current mirror ratio is 275 (typical). The voltage on pin 3 (RSET) is 0.475V in steady state; therefore, the programmed current through each of the outputs is:

$$I_{OUT} = 275 \times \frac{0.475}{R_{EXT}} \quad \text{EQ. 1}$$

where  $R_{EXT}$  is the external resistor connected from pin 3 to ground. Increasing this external programming resistor reduces the output current. For the maximum rated 25mA rating of each output, the minimum value of the external resistor is:

$$R_{EXT} = 275 \times \frac{0.475}{I_{OUT}} = 275 \times \frac{0.475}{0.025} = 5.225k\Omega \quad \text{EQ. 2}$$

The LED output current accuracy is  $\pm 10\%$  for 25mA current (see the *Electrical Characteristics table*). In the worst-case scenario, the calculated value of  $I_{OUT}$  can lead to an error of  $\pm 10\%$  in the LED current. Since the tolerance of  $R_{EXT}$  also affects the LED current accuracy, a precision resistor should be chosen to have the least effect on the overall accuracy of the LED current (see *Figure 12*).

### Floating vs. Tied Outputs

Unused outputs can be left floating. The current through is zero, regardless of the current programmed at pin 3. However, ESD protection is enhanced if the unused output pin is tied to  $V_{IN}$  (pin 5).

If the two output pins are tied together, they can deliver a combined 50mA for the same programming resistor of 5.225k $\Omega$ .

### External Capacitors

Because the FAN5640 is stable without capacitors on the outputs, no capacitors are recommended. Typical input decoupling usually present on incoming supply rails should suffice in most applications. If necessary, a small input capacitance may be placed between the input pin and ground without adverse effects.

### Dropout Limitations

As for any LDO regulator, there are limitations on how close the input and output rails can be to maintain regulation. The minimum difference is referred to as the dropout. The relevant information is provided in the Typical Performance curve Dropout Voltage vs. LED Current (see *Figure 8*). The equation for the data is:

$$V_{DO} = 0.35V + I_{OUT} \times 64\Omega \quad \text{EQ. 3}$$

This is equivalent to an  $R_{DS}$  of 64 $\Omega$  with an additional offset of 350mV. This equation is helpful in determining the minimum dissipation in the device and the lowest input voltage for a given application.

### Multiple LED Displays

For portable applications, the FAN5640 can be powered from the output of any typical boost regulator. Multiple LED displays can be created with the FAN5640 powered from the output of the FAN5333, as shown in *Figure 20*. Note that the output voltage of the FAN5333 depends upon the number of LEDs in its output string. Being conscious of the minimum dropout requirements of the FAN5640; if three series LEDs are required to be present at its output, then the FAN5333 should have four series LEDs in its output string.

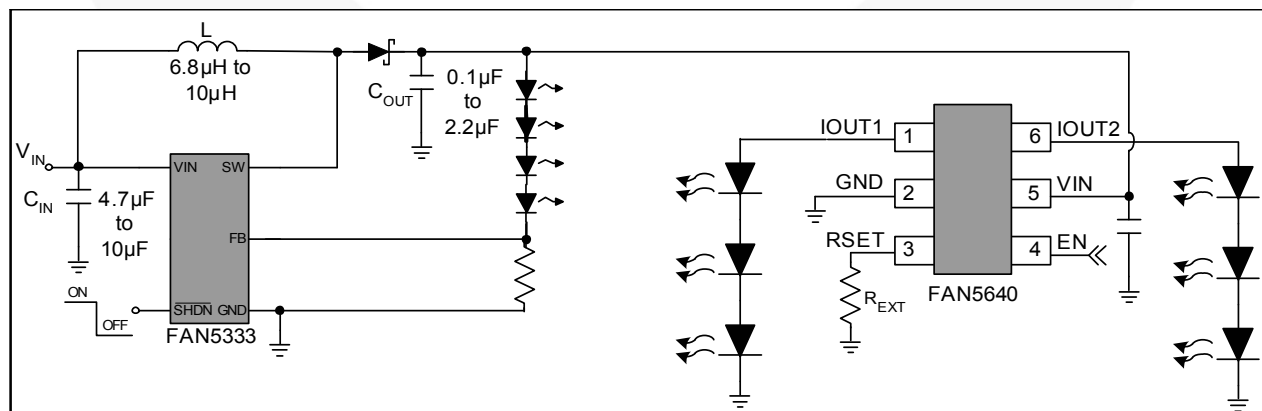


Figure 20. LED Display Example

### PWM Dimming

PWM dimming can be implemented by toggling the enable (EN) pin (pin 4). The recommended PWM frequency range is 100Hz to 3kHz. For example, if the rise time is 2.2μs, the actual duty cycle applied internally to the output MOSFETs is slightly less than the duty cycle of the signal applied on the enable pin. This leads to a slight non-linearity in the measured LED current. That error is:

$$\frac{\Delta I_{OUT}}{I_{OUT\_SET}} = -\frac{(2.2\mu \times f_{PWM})}{D_{PWM}} \times 100\% \quad \text{EQ. 4}$$

For example, at a PWM frequency of 3kHz, with an applied duty cycle of 10%, the typical error is:

$$\frac{\Delta I_{OUT}}{I_{OUT\_SET}} = -\frac{(2.2\mu \times 3k)}{0.1} \times 100 = -6.6\% \quad \text{EQ. 5}$$

So, if R<sub>SET</sub> is 5.225kΩ, the theoretically expected LED current, with a PWM duty cycle of 10%, is 2.5mA. However, the actual (measured) LED current is less by 6.6%. It is (1-0.066) multiplied by 2.5mA, which is 2.335mA. In this way, the actual LED current for any PWM duty cycle and frequency can be estimated.

### Input Rail Dimming

The LEDs can also be dimmed by modulating the input supply rail. See *Figure 15, PWM Dimming By VIN Pin, under Typical Characteristics*. A maximum frequency of 1KHz is recommended.

### Power Dissipation

At an ambient temperature (T<sub>A</sub>), the power dissipation (P<sub>D</sub>) and the junction temperature (T<sub>J</sub>) are related to each other as described in the following equation:

$$T_J = T_A + P_D \times \Theta_{JA} \quad \text{EQ. 6}$$

where:

$$P_D = (V_{IN} - V_O) \times I_{OUT\_Total} + V_{IN} \times I_Q + \frac{V_{RSET}}{R_{EXT}} \times (V_{IN} - V_{RSET})$$

and

$$I_{OUT\_Total} = I_{OUT1} + I_{OUT2}$$

The quiescent current (I<sub>Q</sub>) can be found in the Electrical Characteristics section. The junction-to-ambient thermal resistance (Θ<sub>JA</sub>) puts a limit on V<sub>O\_MAX</sub>, I<sub>OUT\_MAX</sub>, and the maximum dropout (V<sub>IN-V\_O</sub>)<sub>MAX</sub>. This affects the number of LEDs used, the current used to drive them, and so on. Ensure that thermal shutdown does not occur. The formula that correlates all these variables is:

$$(V_{IN} - V_O)_{MAX} = \frac{T_{J\_MAX} - T_{A\_MAX}}{\Theta_{JA} \times I_{OUT\_Total}} \quad \text{EQ. 7}$$

This should be solved for T<sub>J\_MAX</sub> and the result verified as less than the over-temperature shutdown threshold of 150°C (typical). An additional 25°C margin is recommended to account for tolerances on the shutdown threshold; T<sub>J\_MAX</sub> should not exceed 125°C. The Θ<sub>JA</sub> is dependent on the surrounding PCB layout and can be around 300°C/W for an SC-70 package. This can be improved by providing a heat sink of surrounding copper ground on the PCB. The addition of backside copper with vias, stiffeners, and other enhancements can reduce this value. The heat contributed by the dissipation of other devices located nearby must be included in design considerations. Once the limiting parameters in these two relationships have been determined, the design can be modified to ensure that the device remains within specified operating conditions. If overload conditions are not considered, it is possible for the device to enter a thermal cycling loop, in which the circuit enters a shutdown condition, cools, re-enables, and again overheats and shuts down repeatedly due to an unmanaged fault condition.

### LED Selection

The FAN5640 is designed to drive 2-4 LEDs or a higher number of monochrome LEDs. The maximum number of LEDs per channel can be calculated as a function of V<sub>IN</sub> and the sum of the forward voltage of each LED at the maximum specified current. The minimum number of LEDs driven by FAN5640 is the result of calculating the maximum power dissipated by the IC in the given operating conditions. The forward voltage of LEDs depends upon type of LEDs and the manufacturer. In terms of maximum number of LEDs and LED current, refer to the Dropout Voltage vs. LED Current graph in the Typical Characteristics (see *Figure 8*).

Manufacturer	Part	Website
HARVATEK	HT-T169TW	www.harvatek.com
NICHIA	NSSW1087	www.nichia.com

Physical Dimensions

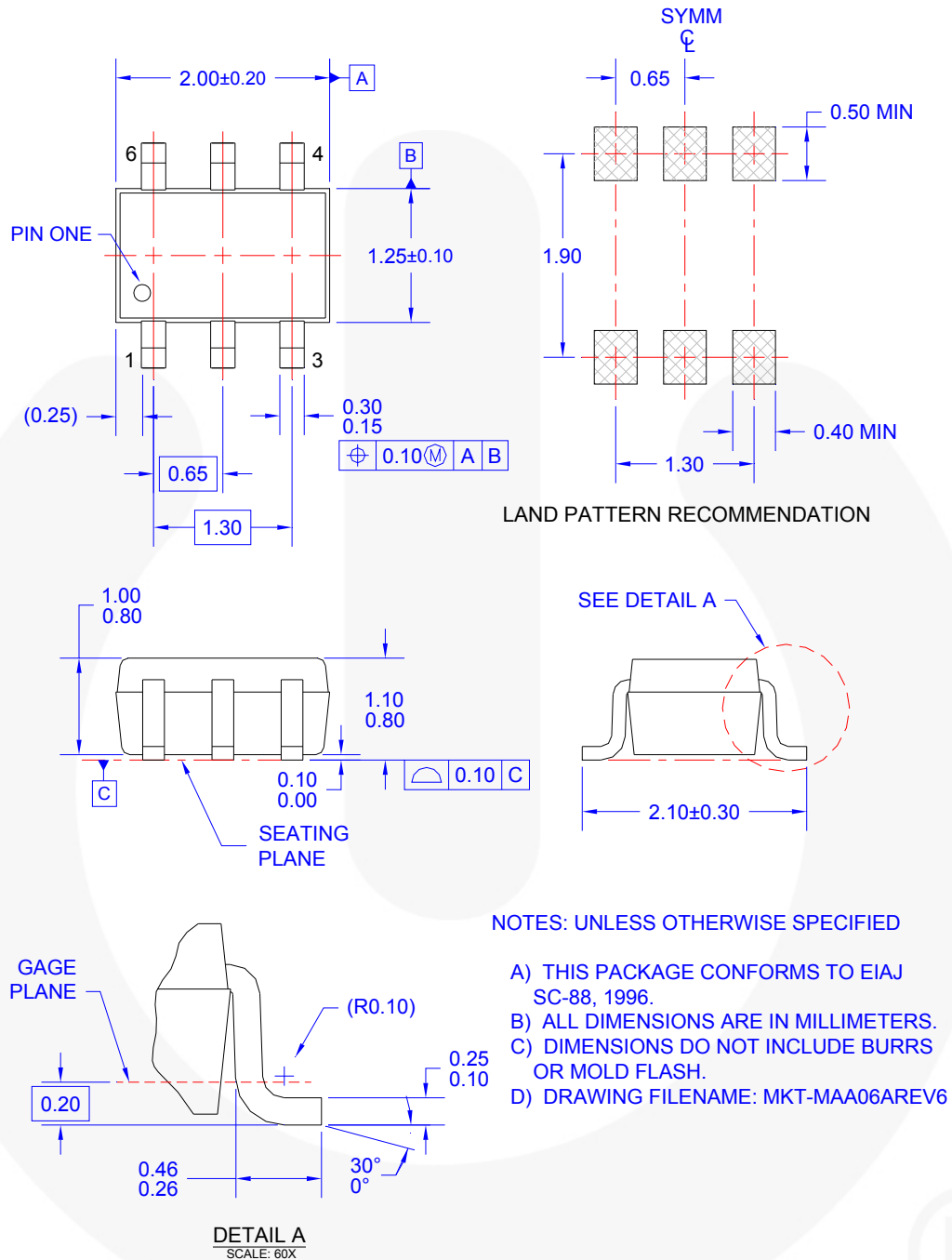


Figure 21. 6-Lead SC-70 Package Dimensions





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