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# FAN5610

## LED Driver for White, Blue, or Any Color LED

### Features

- LED Driver for Four Parallel-connected LEDs
- Low Voltage Drop (<350mV) to Support Direct Li-ion Applications with Low VF LEDs
- Independent Control Loop for each LED
- Regulated, Matched Constant Current in LEDs
- No External Components
- No EMI, No Switching Noise
- Built-in DAC for Digital and PWM Brightness Control
- Up to 91% Maximum Efficiency
- Up to 84mA (21mA/LED) Bias Current
- 2.7V to 5.5V Input Voltage Range
- ICC < 1µA in Shutdown Mode
- 3mm x 3mm MLP-8 Package

### Applications

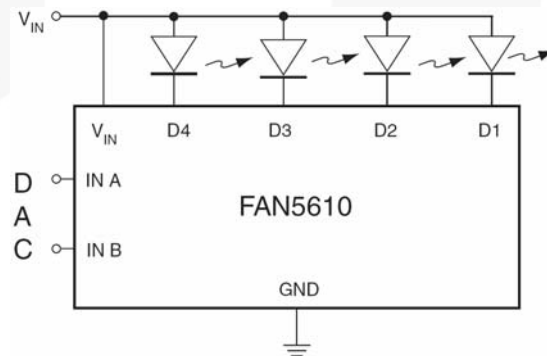
- Cell Phones
- Handheld Computers
- PDA, DSC, MP3 Players
- LCD Display Modules
- Keyboard Backlight
- LED Displays

### Description

The FAN5610 generates matched current source drives for a maximum of four LEDs. Since each LED current source has its own self-regulating loop, precise current matching is maintained even if there is a substantial forward voltage spread among the LEDs. LED pre-selection therefore is not required. To minimize voltage drop and maximize efficiency, the value of the internal current sense resistors connected in series with the LEDs is very low (10Ω). This is an important consideration for direct DC-driven white LEDs in battery-powered systems.

The LED current can be set to 0mA (OFF Mode), 7mA, 14mA, and 21mA with a built-in, two-bit, digital-to-analog converter. Customized current settings can also be used. When the control bits are set to zero, the internal circuitry is disabled and the quiescent current drops below 1µA.

Both digital input lines (A, B) can be pulse-width-modulated (PWM). Using PWM, any value of average LED current can be obtained within the 1 to 20 mA range. The FAN5610 is available in an 8-lead 3x3mm MLP package.



Typical Application

### Ordering Information

Part Number	Operating Temperature Range	Package	Packing Method
FAN5610MPX	-40 to +85°C	3x3mm, 8-Lead, Molded Leadless Package (MLP)	Tape and Reel

All packages are lead free per JEDEC: J-STD-020B standard.

## Pin Configuration

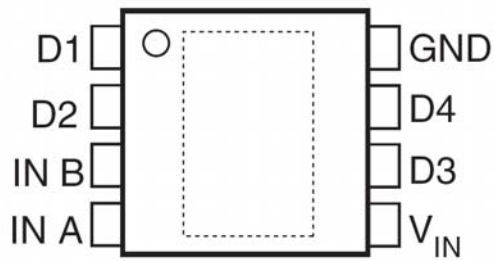


Figure 1. Pin Configuration

## Pin Definitions

Pin Name	Description
D1	Cathode of Diode No.1
D2	Cathode of Diode No. 2
IN B	DAC Input B, Active High
IN A	DAC Input A, Active High
V <sub>IN</sub>	Input Voltage
D3	Cathode of Diode No. 3
D4	Cathode of Diode No. 4
GND	Ground

## 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
$V_{IN}$	IN A / IN B Voltage to GND	-0.3	6.0	V
$T_L$	Lead Soldering Temperature, 10 Seconds		+300	°C
$T_{JA}$	Operating Junction Temperature Range		+150	°C
$T_{STG}$	Storage Temperature	-55	+150	°C
ESD	Human Body Model, JESD22-A114	4		kV
	Charged Device Model, JESD22-C101	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
$V_{IN}^{(1)}$	Input Voltage Range	2.7		5.5	V
$T_A$	Operating Ambient Temperature Range	-40	+25	+85	°C

### Note:

- The minimum operating voltage depends on the LED operating voltage, as described in the *Application Information* section.

## DC Electrical Characteristics

$V_{IN} = 3.3V$  to  $5.5V$ ,  $T_A = 25^\circ C$ , unless otherwise noted. **Boldface** values indicate specifications over the ambient operating temperature range.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
$I_{IN}$	Supply Current, OFF Mode	IN A = 0, IN B = 0		<1	<b>2</b>	$\mu A$
$I_{OUT}$	Output Current Accuracy	$V_D > 0.3V$ , IN A = 1, IN B = 1	<b>14.8</b>	21.0	<b>26.0</b>	mA
$I_{MATCH}$	LED to LED Current Matching	$V_{IN} = 3.6V$ , IN A = 1, IN B = 1	<b>-7.5</b>		<b>7.5</b>	%
$V_{IN\_DAC}$	DAC Input Voltage Threshold	LOW	<b>0</b>		<b><math>0.3 \times V_{IN}</math></b>	V
		HIGH	<b><math>0.6 \times V_{IN}</math></b>		<b><math>V_{IN}</math></b>	
	Peak Efficiency	LED $V_F = 3V$ at 20mA		91		%

Block Diagram

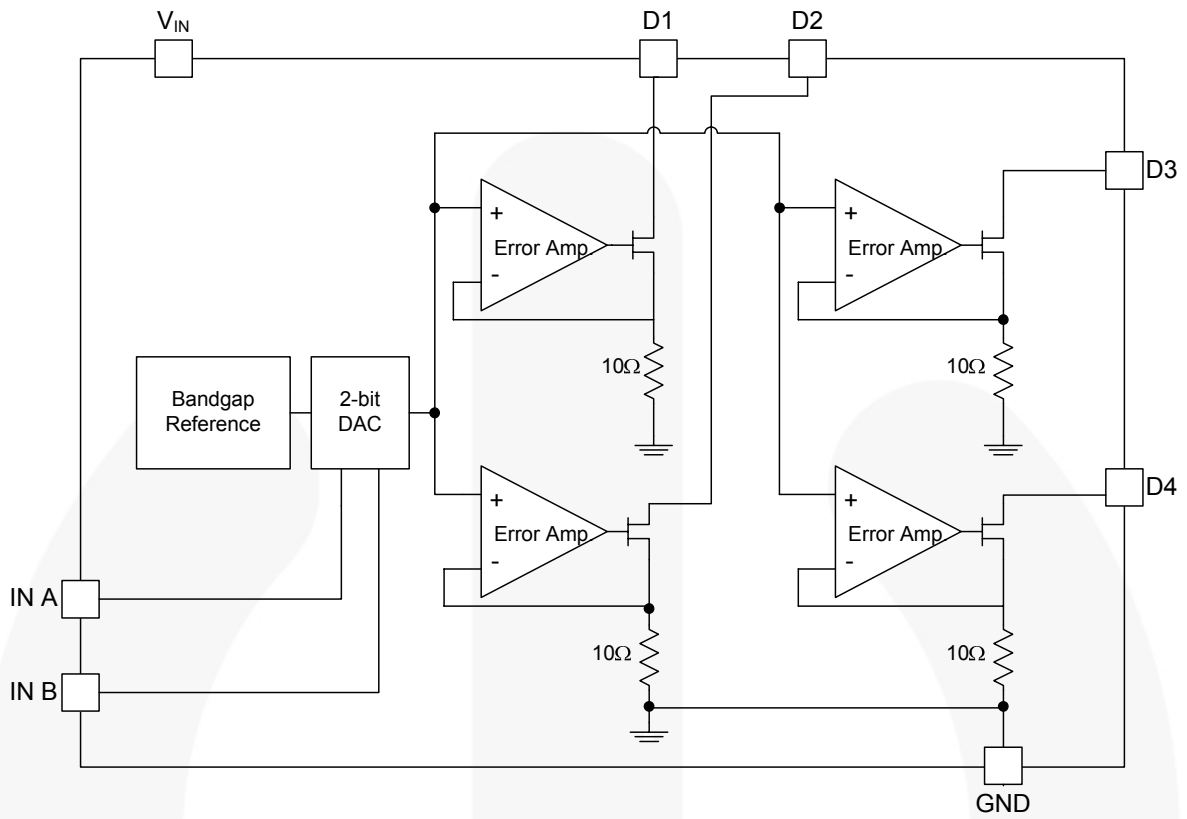


Figure 2. Block Diagram

## Typical Performance Characteristics

Unless otherwise specified,  $T_A = 25^\circ\text{C}$  and using Fairchild QTLP670IW Super Bright LED.

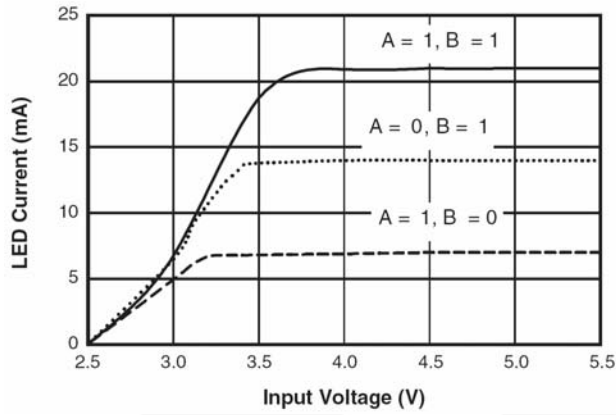


Figure 3. LED Current vs. Input Voltage (Low  $V_F$  - White LED)

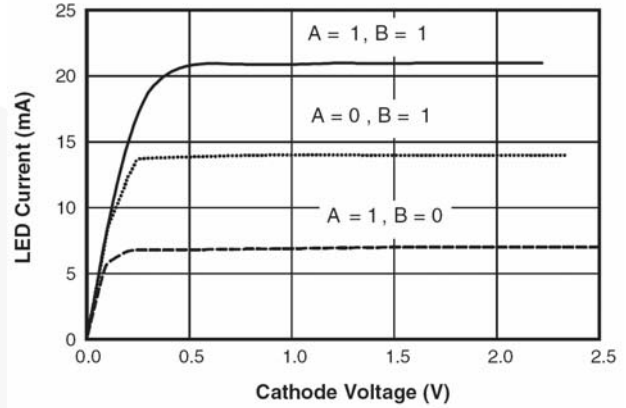


Figure 4. LED Current vs. Cathode Voltage

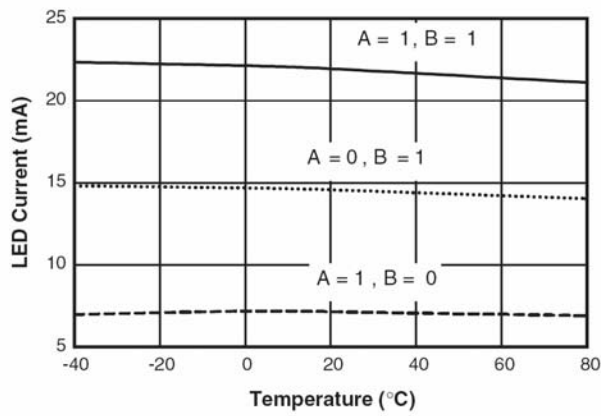


Figure 5. LED Current vs. Temperature

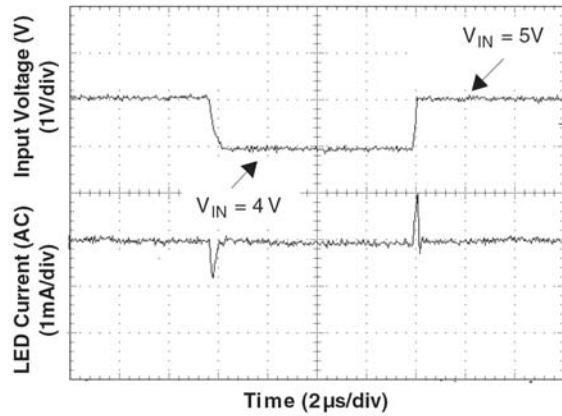


Figure 6. Line Transient Response

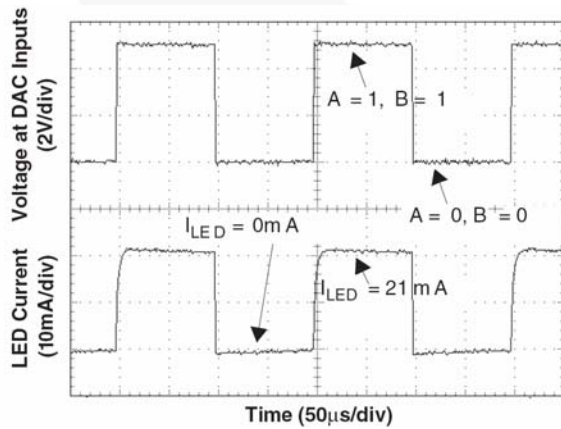


Figure 7. DAC Transient Response

## Functional Description

### Digital LED Brightness Control

#### Digital Control

A digital-to-analog converter selects the following modes of operation: OFF, 7mA, 14mA, and 21mA, per diode. In addition, by turning the "IN B" pin ON and OFF, the current can be modulated between 8 to 20mA to achieve any  $I_{AVERAGE}$  value.

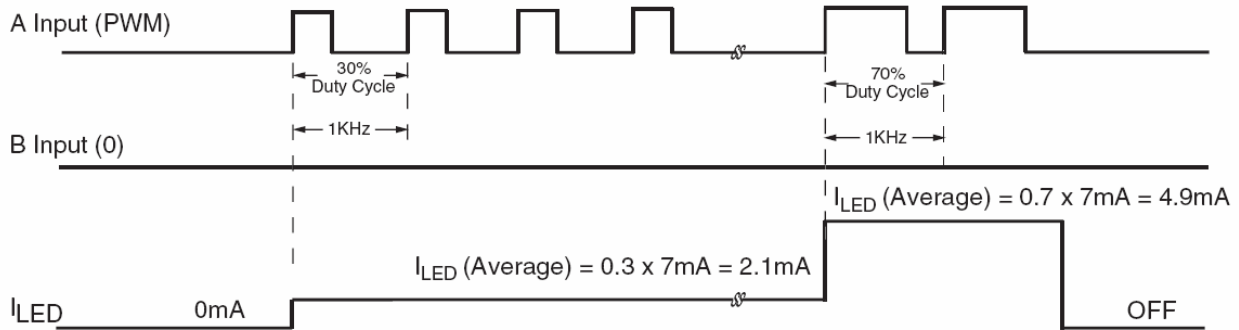
#### Digital Control with PWM

Any pin can be modulated by a variable duty cycle ( $\delta$ ) pulse train. Care should be taken not to use too low a frequency, otherwise a flickering effect can be seen. The minimum range is between 100Hz to 5kHz. For the maximum range of LED current, A and B can be modulated at the same time.

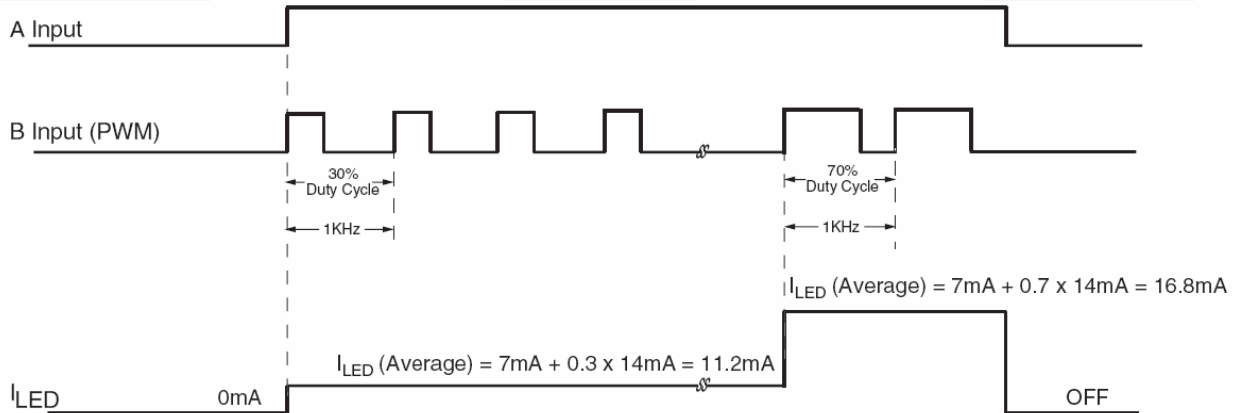
**Table 1. Digital Control Brightness Modes**

A	0	1	0	1
B	0	0	1	1
$I_{LED}$	OFF	7mA	14mA	21mA

#### Digital Control with PWM



**Figure 8. A is PWM and B is LOW.  $I_{LED} (average) = \delta \times 7mA$ , where  $\delta$  is duty cycle.<sup>(2)</sup>**

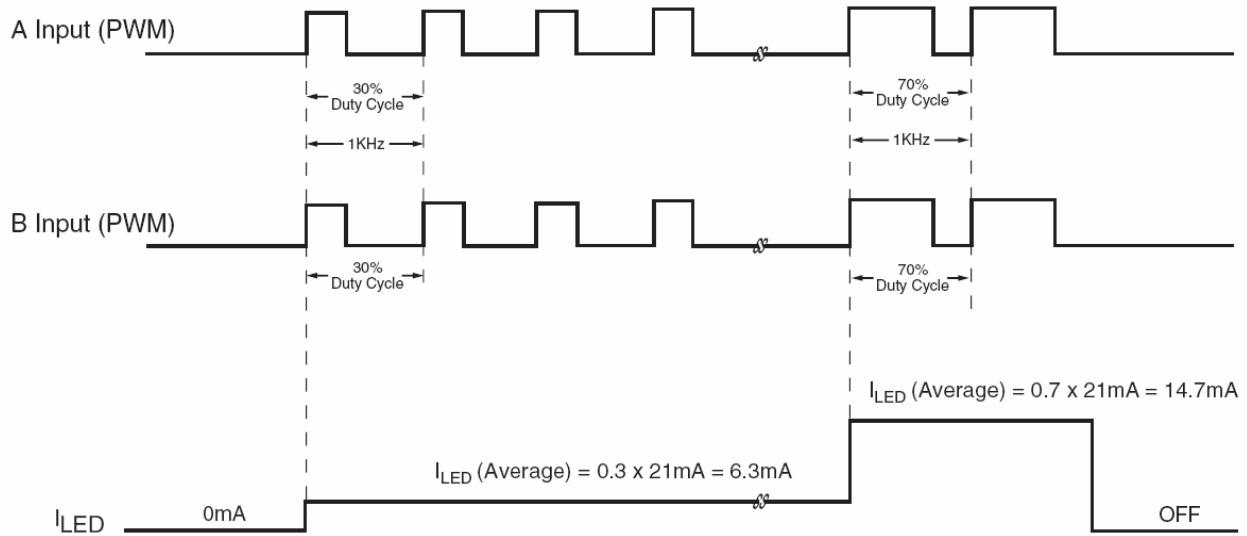


**Figure 9. A is HIGH and B is PWM.  $I_{LED} (average) = 7mA + \delta \times 14mA$ , where  $\delta$  is duty cycle.<sup>(3,4)</sup>**

#### Notes:

- Proportionally select the duty cycle to achieve a typical LED current between 1mA to 6mA.
- If either input A or B is HIGH continuously, the other input can be modulated at a maximum rate of 30kHz. If this is not the case, the maximum rate of modulation should be limited to 1kHz.
- Proportionally select the duty cycle to achieve a typical LED current between 8mA to 20mA.

**Digital Control with PWM (Continued)**



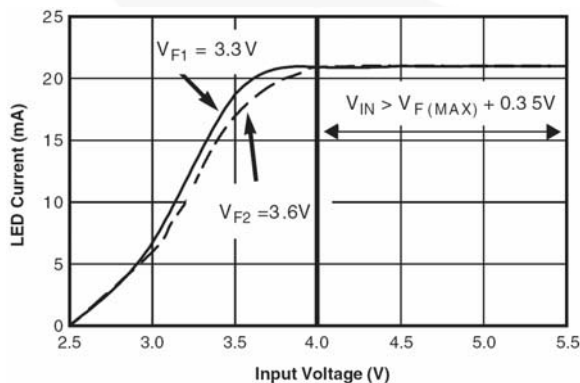
**Figure 10. A and B are PWM.  $I_{LED}(\text{average}) = \delta \times 21\text{mA}$ , where  $\delta$  is duty cycle.<sup>(5)</sup>**

**Note:**

5. Proportionally select the duty cycle to achieve a typical LED current between 1mA to 20mA.

**Application Information**

As seen in the block diagram in Figure 2, the FAN5610 includes four independent current regulators able to maintain a programmable constant current through LEDs, regardless of their forward voltage. This is true over a wide range of input voltages, starting from  $V_{F\_max} + 0.35\text{V}$ , where  $V_{F\_max}$  is the highest forward voltage among the LEDs driven by FAN5610. The independence of current (LED current changes less than 1%) with change in  $V_{IN}$  and  $V_F$  for  $V_{IN} > V_{F\_max} + 0.35\text{V}$ , is shown in Figure 11.



**Figure 11. Current Regulation Performance**

Program the LED's brightness by applying a continuous voltage level or a PWM signal at the inputs of the built-in digital to analog converter (DAC). When a PWM signal is utilized to drive the DAC inputs, the current through the LEDs is switched between two levels with the PWM signal frequency. Consequently, the average current changes with the duty cycle. The LED current waveform tracks the PWM signal, so the LEDs brightness depends on the duty cycle.

For white LEDs, the spectral composition is optimal at a current level specified by the manufacturer. The DAC inputs should be programmed to set the current required to achieve white LED spectrum and PWM used for dimming. To maintain the "purest" white, the current through the LEDs should be switched between zero and a specified current level (usually around 20mA) corresponding to the white light chromaticity coordinate.

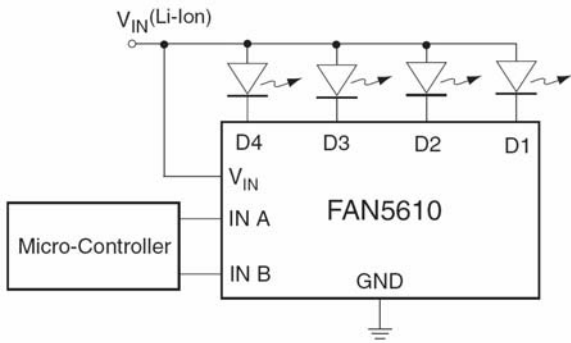
Conversion errors are minimized, and the best LED-to-LED matching is achieved over the entire range of average current settings, when PWM brightness control is used to modulate the LED current between zero and the maximum value ( $A=1, B=1$ ).



## Application Examples

### Example 1: Drive low $V_F$ white or blue LEDs directly from single-cell Li-ion

When using white or blue low- $V_F$  LEDs, and utilizing the driver's low voltage drop, only 3.45V in  $V_{IN}$  is needed for the full 20mA LED current. Usually at 3.1V, there is still 5mA current available for the LEDs. The single-cell Li-ion is utilized in most applications, like cell phones or digital still cameras. In most cases, the Li-ion battery voltage level only goes down to 3.0V voltage level, not down to the full discharge level (2.7V), before requesting the charger.



**Figure 12. Drive Low  $V_F$  White or Blue LEDs Directly from Single-cell Li-ion**

- $V_{DROD} \sim 0.35V$  (1)
- $V_F$  (at 20mA) < 3.1V (Low  $V_F$ ) (2)
- $V_{IN}$  (at 20mA) =  $V_{DROD} + V_F = 3.45V$  (3)
- $V_{IN}$  (at 5mA typical)  $\sim 3.1V$  (4)

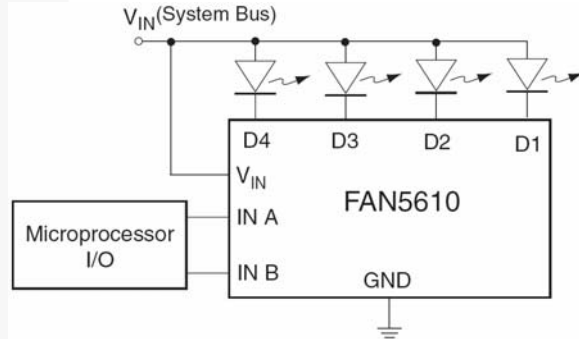
where  $V_{IN}$  = single-cell Li-ion voltage.

#### Key Advantages:

- No boost circuit needed for the LCD or keyboard backlight
- Driver directly connected to a Li-ion battery
- No EMI, no switching noise, no boost efficiency lost, no capacitor, no inductor

### Example 2: Drive high $V_F$ white or blue LEDs from existing bus from 4.0V to 5.5V

High- $V_F$  white or blue LEDs have forward-voltage drop in the range of 3.3V to 4.0V. Driving these LEDs with the maximum current of 20mA for maximum brightness usually requires a boost circuit for a single-cell Li-ion voltage range. In some cases, there is already a voltage bus in the system that can be utilized. Due to the low voltage drop,  $V_{IN}$  needs to be only 350mV higher than the voltage  $V_F$  of LEDs connected to FAN5610.



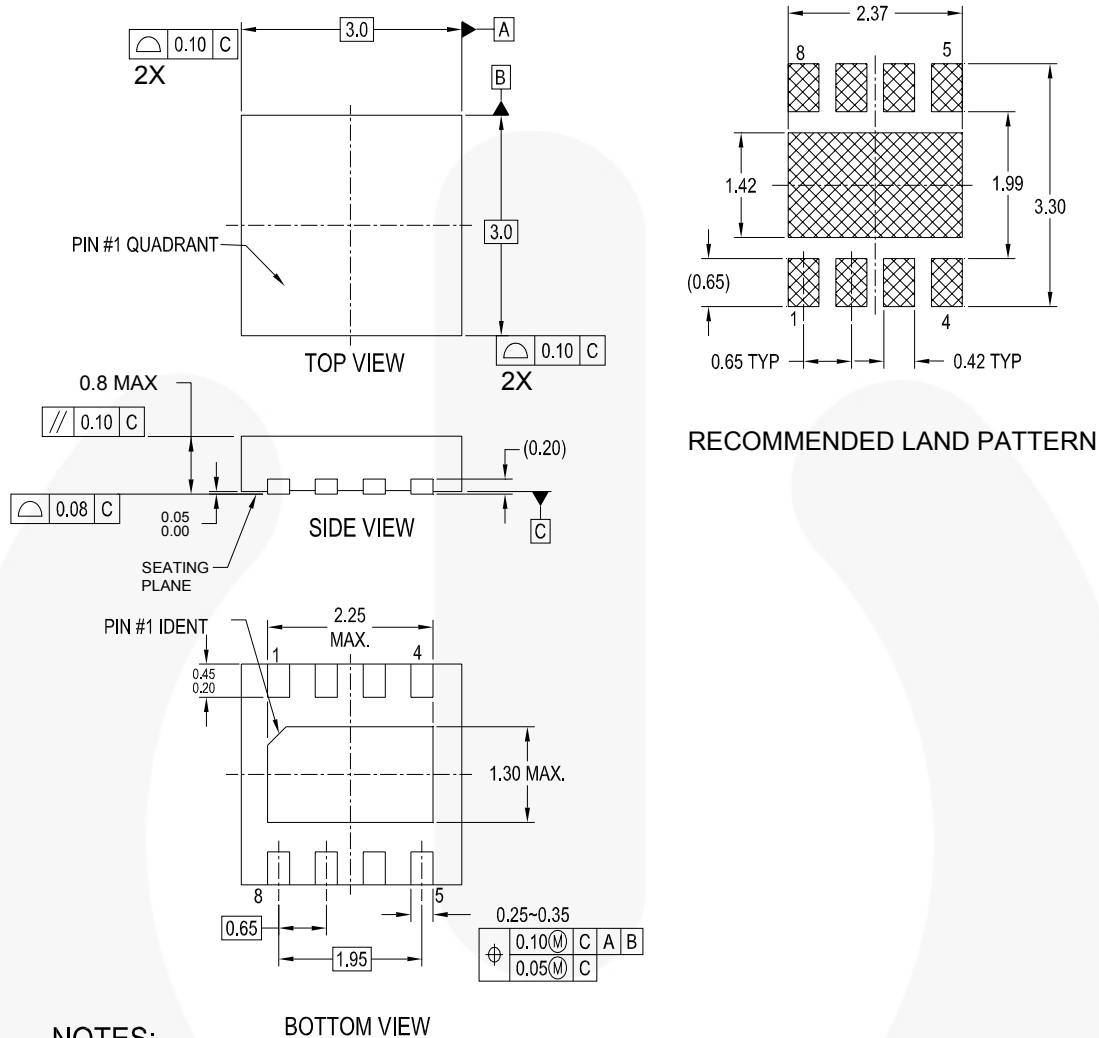
**Figure 13. Drive High  $V_F$  White or Blue LEDs from Existing Bus from 4.0V to 5.5V**

- $V_{DROD} \sim 0.35V$  (5)
  - $V_F$  (at 20mA) = 3.3V to 4.0V (High  $V_F$ ) (6)
  - $V_{IN}$  (at 20mA)  $\geq V_{DROD} + V_F = 4.35V$  (max.) (7)
- where  $V_{IN}$  = existing bus = 5V.

#### Key Advantages:

- No boost circuit needed for LCD or keyboard backlight
- Driver utilizes the existing bus
- Low voltage drop provides the full 20mA LED current at the lowest possible voltage level

## Physical Dimensions



### NOTES:

- A. CONFORMS TO JEDEC REGISTRATION MO-229, VARIATION VEEC, DATED 11/2001
- B. DIMENSIONS ARE IN MILLIMETERS.
- C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994
- D. FILENAME: MKT-MLP08Drev2

**Figure 14. 3x3mm, 8-Lead, Molded Leadless Package**

### Note:

6. Center pad, P1, may be left floating or be connected to GND (Pin 8). The center pad **must not** be used as an alternative GND connection to Pin 8.

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|                                      |  | SuperSOT <sup>™</sup> .8               |                                    |

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