FAIRCHILD SEMICONDUCTOR®

November 2006

FAN5611/FAN5612/FAN5613/FAN5614 Low-Dropout LED Drivers for White, Blue, or any Color LED

Features

- LED drivers for parallel-connected LEDs (2 to 4)
- Ultra-low voltage drop (< 300mV) to support direct Li-ion applications
- No EMI, no switching noise
- No external components needed for current matching
- Both analog and PWM brightness control
- FAN5611, FAN5613 feature up to 160mA bias current (up to 40mA for each LED)
- FAN5612 features up to 120mA bias current (up to 40mA for each LED)
- FAN5614 features up to 160mA bias current (up to 80mA for each LED)
- Enable/Shutdown control (FAN5612, FAN5613, FAN5614)
- Shutdown current < 1µA
- Small footprint SC-70 and MLP

Applications

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

Description

The FAN5611/12/13/14 low-dropout product family is designed to drive two to four parallel LEDs, providing matched current source bias for all color LEDs. The LED current is set by an external resistor, R_{SET}. The FAN5611/13 supports four parallel LEDs with up to 160mA bias current (up to 40mA per output). The FAN5612 supports three LEDs with up to 120mA bias current (40mA per output). The FAN5614 drives two high-current LEDs (80mA per output). Pin I1 should always be connected to an LED to provide a matched current for any additional LEDs.

The FAN5612/13 and 14 are selected using an ENABLE pin. When the chip is not selected (ENABLE pin is LOW), the supply current drops to less than 1µA.

The FAN5611, FAN5612, and FAN5614 are available in an SC-70 package. The FAN5611 and FAN5613 are available in MLP packages.

Ordering Information

Product Number	Package Type	Order Code
FAN5611	6-Lead SC-70 / 2x2mm 6-Lead MLP	FAN5611S7X / FAN5611MPX
FAN5612	6-Lead SC-70	FAN5612S7X
FAN5613	2x2mm 8-Lead MLP	FAN5613MPX
FAN5614	6-Lead SC-70	FAN5614S7X

Table 1. Ordering Information

Typical Applications

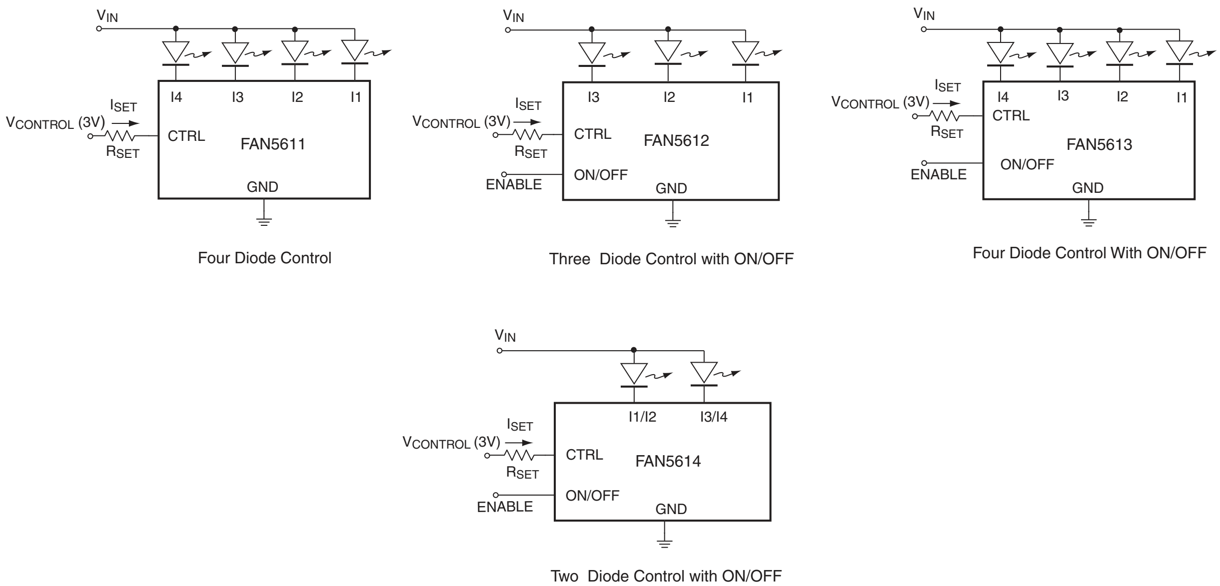


Figure 1. Typical Applications for FAN5611, FAN5612, FAN5613, FAN5614

Pin Assignments

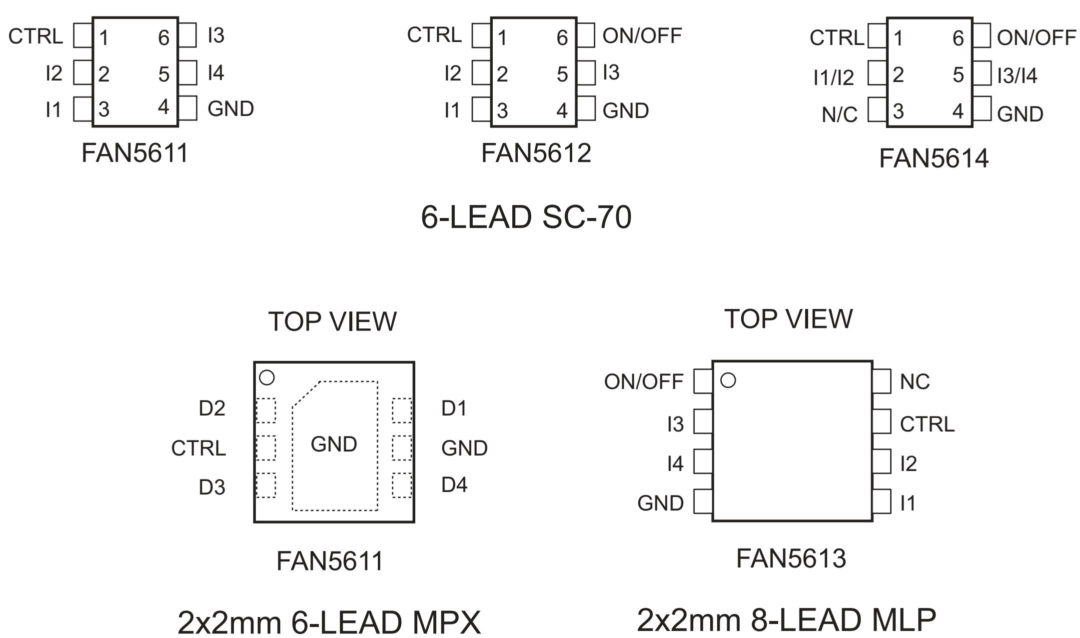


Figure 2. Pin Assignments for FAN5611, FAN5612, FAN5613, FAN5614

Pin Descriptions

Pin #	Name				Description
	FAN5611	FAN5612	FAN5613	FAN5614	
1	CTRL	CTRL		CTRL	Sets LED Current (see Operational Descripton)
			ON/OFF		Chip ON/OFF/Disable
2	I2	I2			Connect to Cathode of LED
			I3		Connect to Cathode of LED
				I1/I2	
3	I1	I1			Connect to Cathode of LED
			I4		Connect to Cathode of LED
				N/C	No Connection
4	GND	GND	GND	GND	Ground
5	I4				Connect to Cathode of LED
		I3			Connect to Cathode of LED
			I1		Connect to Cathode of LED
				I3/I4	Connect to Cathode of LED
6	I3				Connect to Cathode of LED
		ON/OFF		ON/OFF	Chip ON/OFF/Disable
			I2		Connect to Cathode of LED
7			CTRL		Sets LED Current (see Operational Descripton)
8			NC		No Connection

Table 2. Pin Descriptions

Notes:
1. The DAP of FAN 5611MPX can be tied to the GND pin or left floating. For better power dissipation, tie to GND.

Absolute Maximum Ratings

The “Absolute Maximum Ratings” are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings. The “Recommended Operating Conditions” table defines the conditions for actual device operation.

Parameter		Min.	Max.	Unit
V_{I1}, V_{I2}, V_{I3}, V_{I4} and ENABLE Voltage to GND		-0.3	6.0	V
CTRL Voltage to GND		-0.3	3.0	
Power Dissipated by package at T_A = 85°C	6-Lead SC70		190	mW
	6, 8-Lead MLP		700	
I1, I2, I3, I4 Steady State Current	FAN5611/12/13		40	mA
I1/I2, I3/I4 Steady State Current	FAN5614		80	
Lead Temperature (Soldering 10 seconds)			300	°C
Junction Temperature			150	°C
Storage Temperature		-55	150	°C
Electrostatic Discharge Protection (ESD) Level (1)	HBM	4		kV
	CDM	1		

Table 3. Absolute Maximum Ratings

Recommended Operating Conditions

Parameter		Min.	Typ.	Max.	Unit
LED Cathode Voltage	FAN5611, FAN5612, FAN5613	0.3	0.5	1.0	V
	FAN5614	0.15			
Ambient Temperature		-40	25	85	°C

Table 4. Recommended Operating Conditions

Notes:

2. Using Mil Std. 883E, method 3015.7 (Human Body Model) and EIA/JESD22C101-A (Charge Device Model).

DC Electrical Characteristics

V_{IN} = 3.3V to 5.5V, ENABLE = V_{IN}, T_A = 25°C unless otherwise noted.

Parameter		Conditions	Min.	Typ.	Max.	Units
Current Gain	FAN5611/12/13	I_{SET} = 100µA V_{SAT} = 300mV	140	200	260	
	FAN5614	I_{SET} = 100µA V_{SAT} = 150mV				
LED Current (Per Diode)	FAN5611/12/13	V_{SAT} = 300mV I_{SET} = 100µA		20		mA
	FAN5614	V_{SAT} = 150mV I_{SET} = 100µA				
LED to LED Current Matching	FAN5611/12/13	V_{SAT} = 300mV I_{SET} = 100µA T_A = -40°C to 85°C	-3		3	%
	FAN5614	V_{SAT} = 150mV I_{SET} = 100µA T_A = -40°C to 85°C				
Peak Efficiency		V_{IN} = 3V		90		%
Current in OFF Mode (I_{SET} and I_I)		V_{EN} = 0V			1	µA
Minimum ENABLE "ON Voltage"[2] (FAN5612, FAN5613, FAN5614)		I_{SET} = 150µA			2.8	V
Maximum ENABLE "OFF Voltage"[2] (FAN5612, FAN5613 FAN5614)			0.5			V

Table 5. DC Electrical Characteristics

Notes:

3. ENABLE "ON" is V_{EN} where I_{I1}>20mA @ V_{I1}=0.3V, while ENABLE "OFF" is V_{EN} where I_{I1}<1µA @ V_{I1}>0.3V.

Typical Performance Characteristics

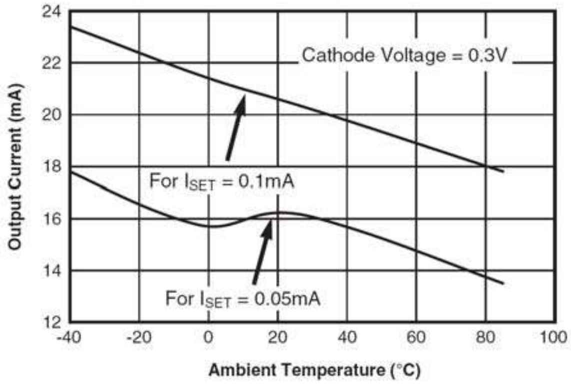


Figure 3. FAN5611/12/13
Output Current vs. Temerature

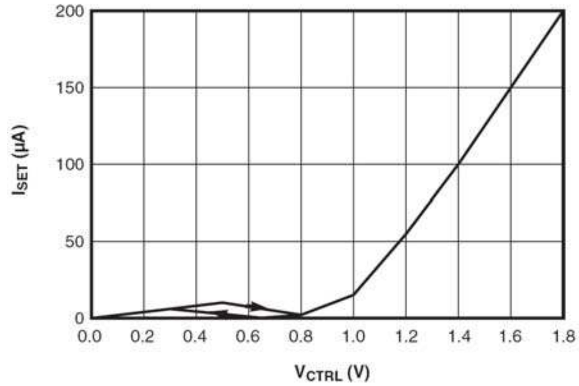


Figure 4. I_{SET} vs. V_{CTRL}

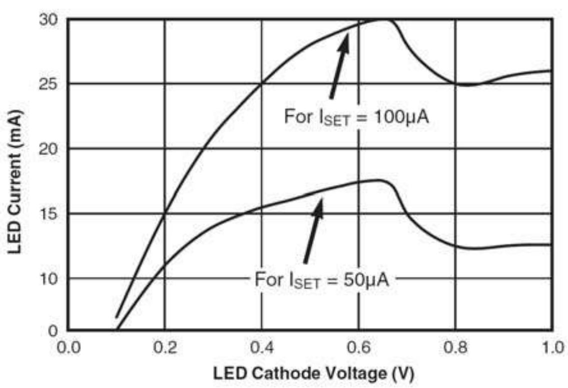


Figure 5. FAN5611/12/13
LED Current vs. LED Cathode Voltage

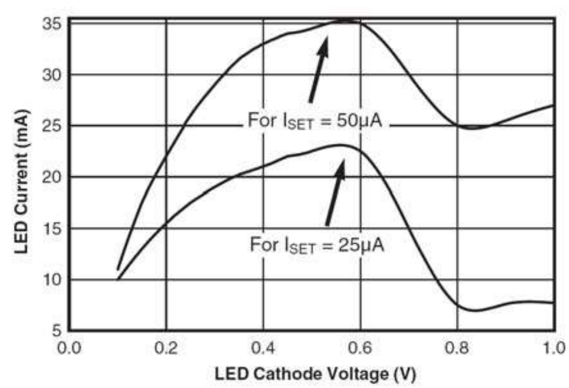


Figure 6. FAN5614
LED Current vs. LED Cathode Voltage

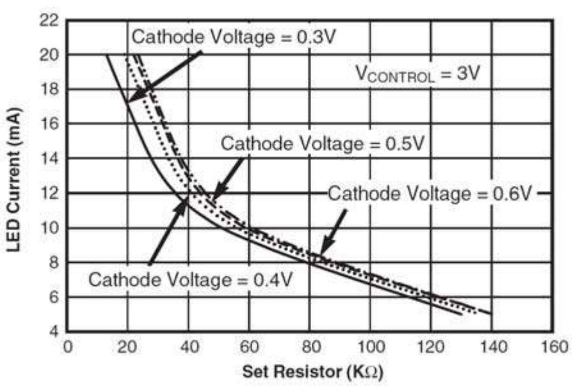


Figure 7. FAN5611/12/13
LED Current vs. Set Resistor

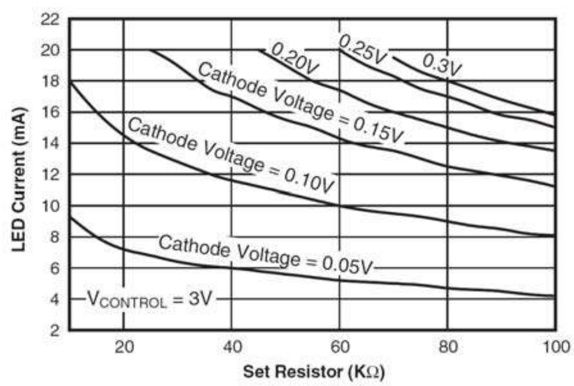


Figure 8. FAN5614 LED Current vs. Set Resistor

Typical Performance Characteristics (Continued)

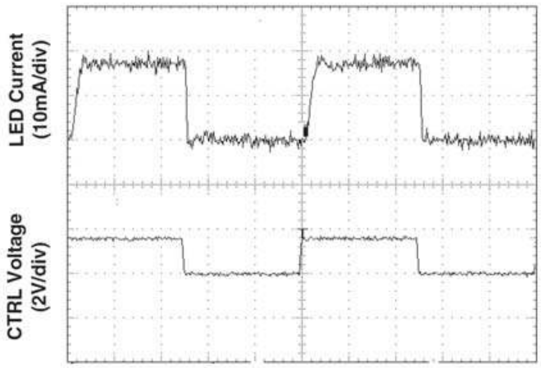


**Figure 9. FAN5611/12/13/14
Control Voltage Transient Response**

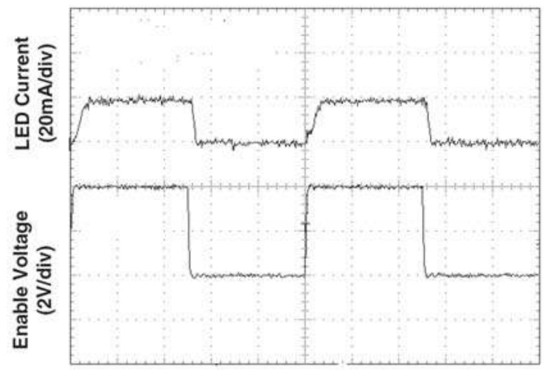


**Figure 10. FAN5612/13/14
Enable Voltage Transient Response**

Application Information

Operational Descripton

The regulated current through each LED is a multiplication of the I_{SET} current. The I_{SET} value is determined by the R_{SET} value. The I_{SET} value can be calculated as:

$I_{SET} = I_{LED}$ / Current Gain

Reference Figure 4, the I_{SET} vs. V_{CTRL} graph, to estimate V_{CTRL}. The value of R_{SET} is calculated according to the formula:

$R_{SET} = (V_{CONTROL} - V_{CTRL}) / I_{SET}$

For example, with $V_{CONTROL}$ = 3V, a 10mA current limit through the LED results in I_{SET} = 50µA. That translates to an approximate value of 1.2V for V_{CTRL}, shown in Figure 4. The resulting R_{SET} value that maintains 10mA regulation is 36kΩ.

The LED intensity can be adjusted by varying the duty cycle of a square wave applied to the enable pin. Frequency greater than 100Hz is best to avoid a "flickering" effect. The maximum operation frequency is 10MHz.

Efficiency Considerations

The FAN561X driver's low-dropout architecture can significantly improve the efficiency compared to using simple ballast resistors. The system efficiency, defined as the ratio between the LEDs' power and the input supplied power, can be calculated as:

$$\text{Efficiency} = (V_{IN} - V_{CATHODE}) / V_{IN}$$

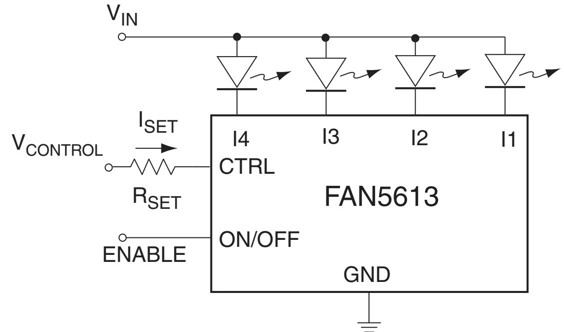
The lower the $V_{CATHODE}$, the higher the system efficiency. Efficiency can be further improved by using a higher V_{IN} with more LEDs, as shown in Example 3.

Application Notes

The ultra-low voltage drop across the FAN561X series of LED drivers allows the devices to drive white, blue, and other color LEDs in a wide range of input voltages. The driver can be used in many applications. Although only the FAN5613 is shown in all three examples, any of the FAN561X-series LED drivers can be used in the applications presented, due to their similar operation.

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 drivers low voltage drop, only 3.4V in V_{IN} is needed for the full 20mA LED current. At 3.1V, there is 5mA typical current available for the LEDs. The single cell Li-ion is utilized in 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.



- $V_{DROP} < 0.3V$
- $V_{F\ (at\ 20mA)} < 3.1V$ (Low V_F)
- $V_{IN\ (at\ 20mA)} = V_{DROP} + V_F = 3.4V$
- $V_{IN\ (at\ 5mA\ Typical)} \sim 3.1V$

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

Key advantages:

- No boost circuit is needed for the LCD or keyboard backlight.
- Drivers are directly connected to a Li-ion battery.
- No EMI, no switching noise, no boost efficiency lost, no capacitor, and 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 3.2V 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, which can be utilized. Due to the ultra-low voltage drop of the FAN561X series of LED drivers to drive high-V_F white or blue LEDs, the V_{IN} needs to be only 300mV higher than the highest V_F in the circuit.

- $V_{DROP} < 0.3V$
- $V_{F\ (at\ 20mA)} < 3.3V$ to 4.0V (High V_F)
- $V_{IN\ (at\ 20mA)} = V_{DROP} + V_F = 3.6V$ to 4.3V
- $V_{IN\ (at\ 5mA\ Typical)} \sim 3.3V$

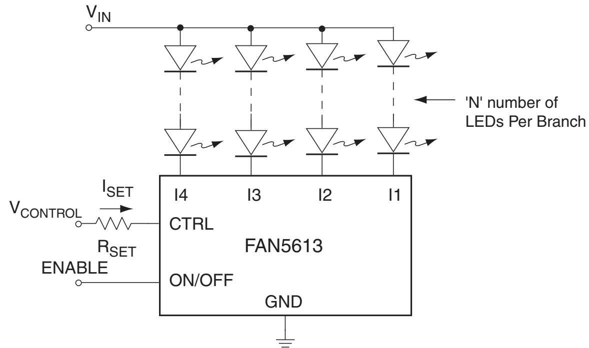
where V_{IN} = existing bus = 3.3V to 4.3V.

Key advantages:

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

Example 3: Drive white, blue, red, amber LEDs string

Assuming a boost circuit or existing voltage bus, the FAN561X series of LED drivers can be used to drive a whole string of LEDs with flexible brightness control via analog and/or PWM. .



– $V_{DROP} < 0.3V$
– V_{IN_MIN} = N ¥ $V_F + V_{DROP}$
– V_{IN_MAX} = N ¥ V_F + 5.5V

where V_{IN} = existing bus, boost voltage.

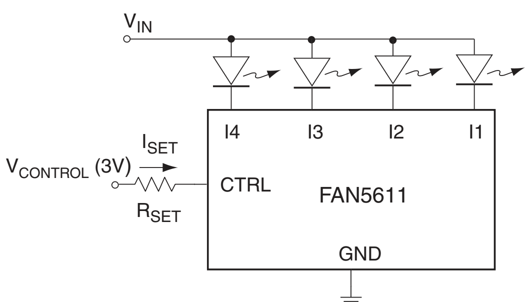
Key advantage:

- No need for current matching resistors and discrete transistor for brightness control.

LED Brightness Control

All of the FAN561X LED drivers feature analog and PWM controls to give designers flexible brightness control. These control methods can be applied to the circuit in two different ways to provide more flexibility than other solutions. To determine the value of R_{SET}, use the I_{SET} vs. V_{CTRL} graph in Figure 4.

1. FAN5611

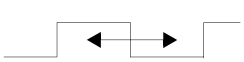


- Analog

Set $V_{CONTROL}$ and R_{SET} for LED current using:

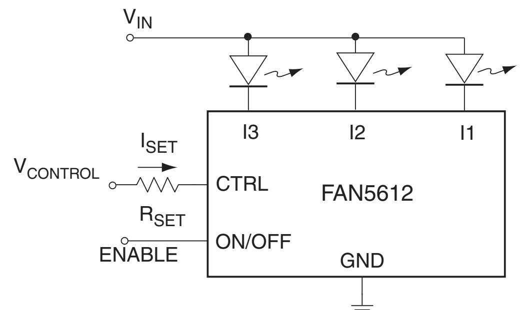
$$I_{LED} = \frac{200 \times (V_{CONTROL} - V_{CTRL})}{R_{SET}}$$

- PWM

$V_{CONTROL}$ = PWM 

– Amplitude sets maximum LED current.
– Pulse width controls between 0 and maximum.

2. FAN5612

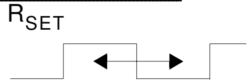


- Analog

Set $V_{CONTROL}$ and R_{SET} for LED current using:

- PWM - 1

$$I_{LED} = \frac{200 \times (V_{CONTROL} - V_{CTRL})}{R_{SET}}$$

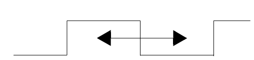
$V_{CONTROL}$ = PWM 

– Amplitude sets maximum LED current.
– Pulse width controls between 0 and maximum.

- PWM - 2

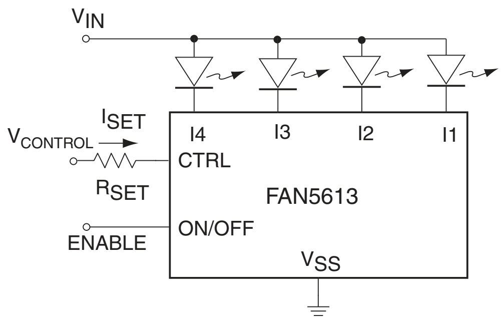
Set $V_{CONTROL}$ and R_{SET} for maximum LED current using:

$$I_{LED} \sim 200 \times I_{SET}$$

ON/OFF = PWM 

– Amplitude has no effect on current.
– Pulse width controls between 0 and maximum.

3. FAN5613

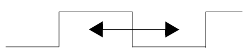


- Analog

Set $V_{CONTROL}$ and R_{SET} for LED current using:

$$I_{LED} = \frac{200 \times (V_{CONTROL} - V_{CTRL})}{R_{SET}}$$

- PWM - 1

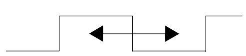
$V_{CONTROL}$ = PWM 

– Amplitude sets maximum LED current.
– Pulse width controls between 0 and maximum.

- PWM - 2

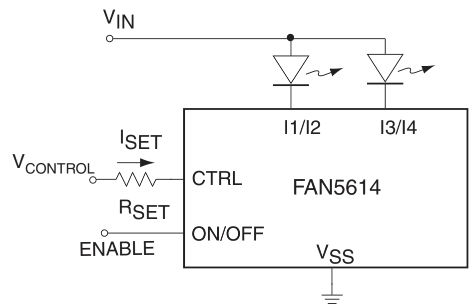
Set $V_{CONTROL}$ and R_{SET} for maximum LED current using:

$$I_{LED} \sim 200 \times I_{SET}$$

ON/OFF = PWM 

– Amplitude has no effect on current.
– Pulse width controls between 0 and maximum.

4. FAN5614

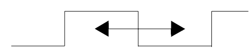


- Analog

Set $V_{CONTROL}$ and R_{SET} for LED current using:

$$I_{LED} = \frac{200 \times (V_{CONTROL} - V_{CTRL})}{R_{SET}}$$

- PWM - 1

$V_{CONTROL}$ = PWM 

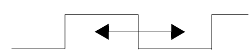
– Amplitude sets maximum LED current.
– Pulse width controls between 0 and maximum.

- PWM - 2

Set $V_{CONTROL}$ and R_{SET} for maximum LED current using:

$$I_{LED} \sim 200 \times I_{SET}$$

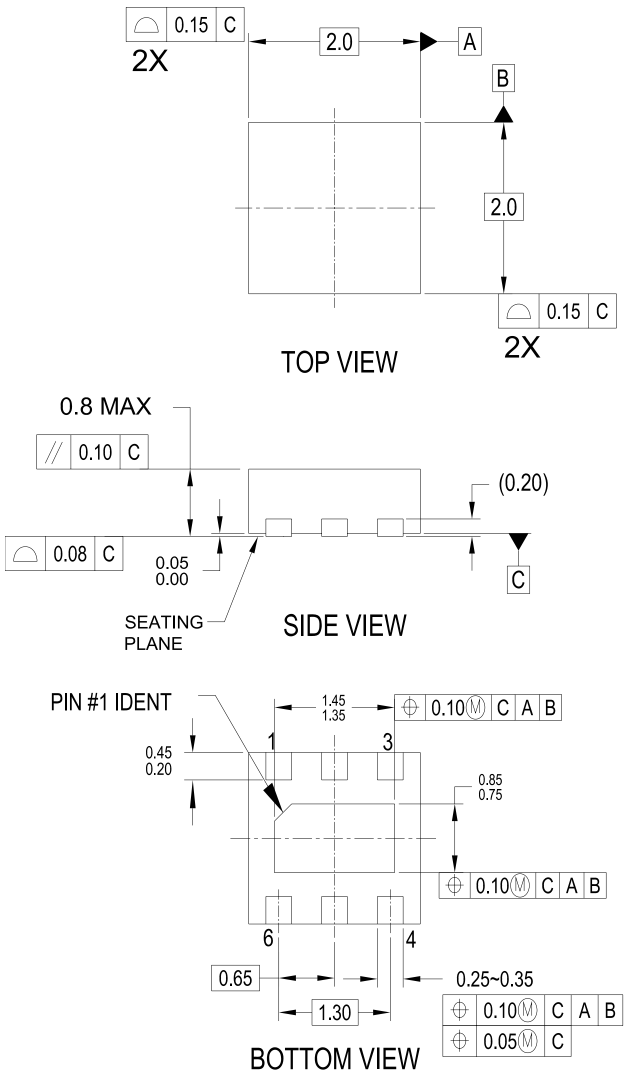
$$I_{LED} = \frac{200 \times (V_{CONTROL} - V_{CTRL})}{R_{SET}}$$

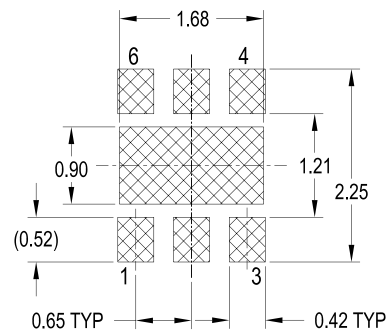
ON/OFF = PWM 

– Amplitude has no effect on current.
– Pulse width controls between 0 and maximum.

Mechanical Dimensions

2x2mm 6-Lead MLP





RECOMMENDED LAND PATTERN

NOTES:

A. NON-CONFORMS TO JEDEC REGISTRATION,

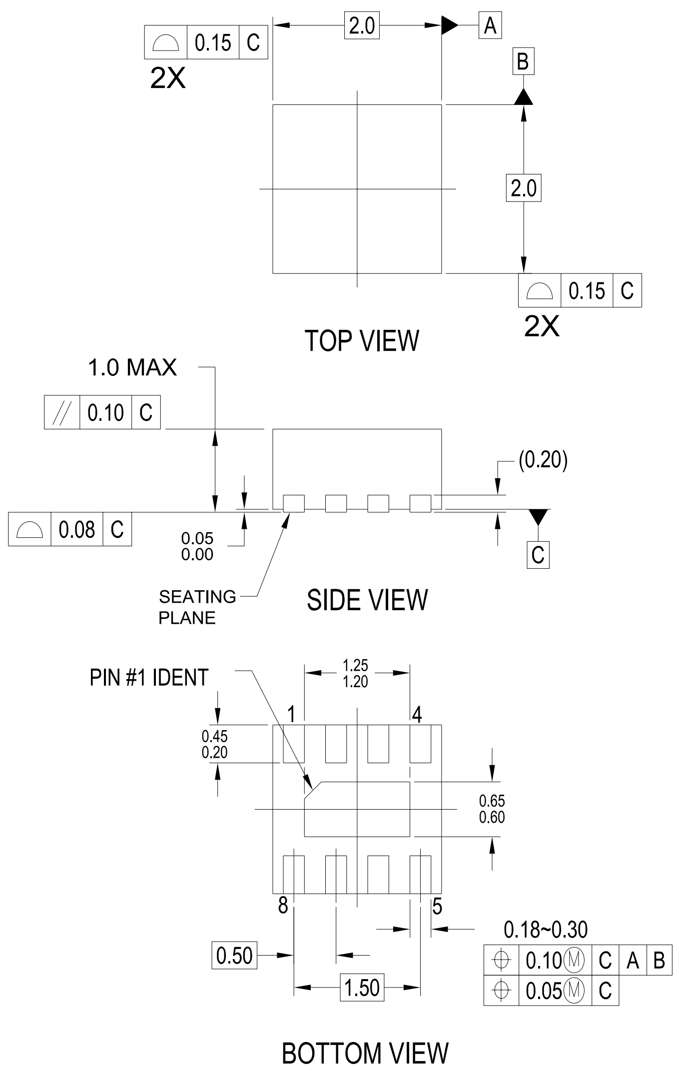
B. DIMENSIONS ARE IN MILLIMETERS.

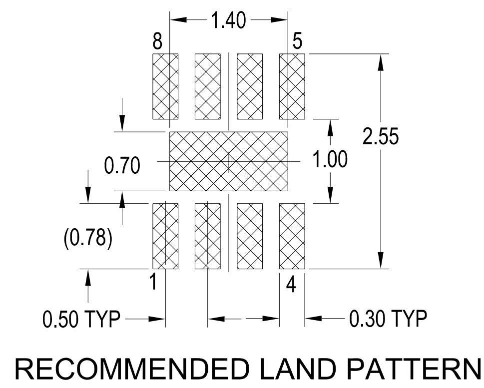
C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994

MLP06KrevA

Mechanical Dimensions

2x2mm 8-Lead MLP





NOTES:

A. CONFORMS TO JEDEC REGISTRATION MO-229, VARIATION VCCD-3, DATED 11/2001

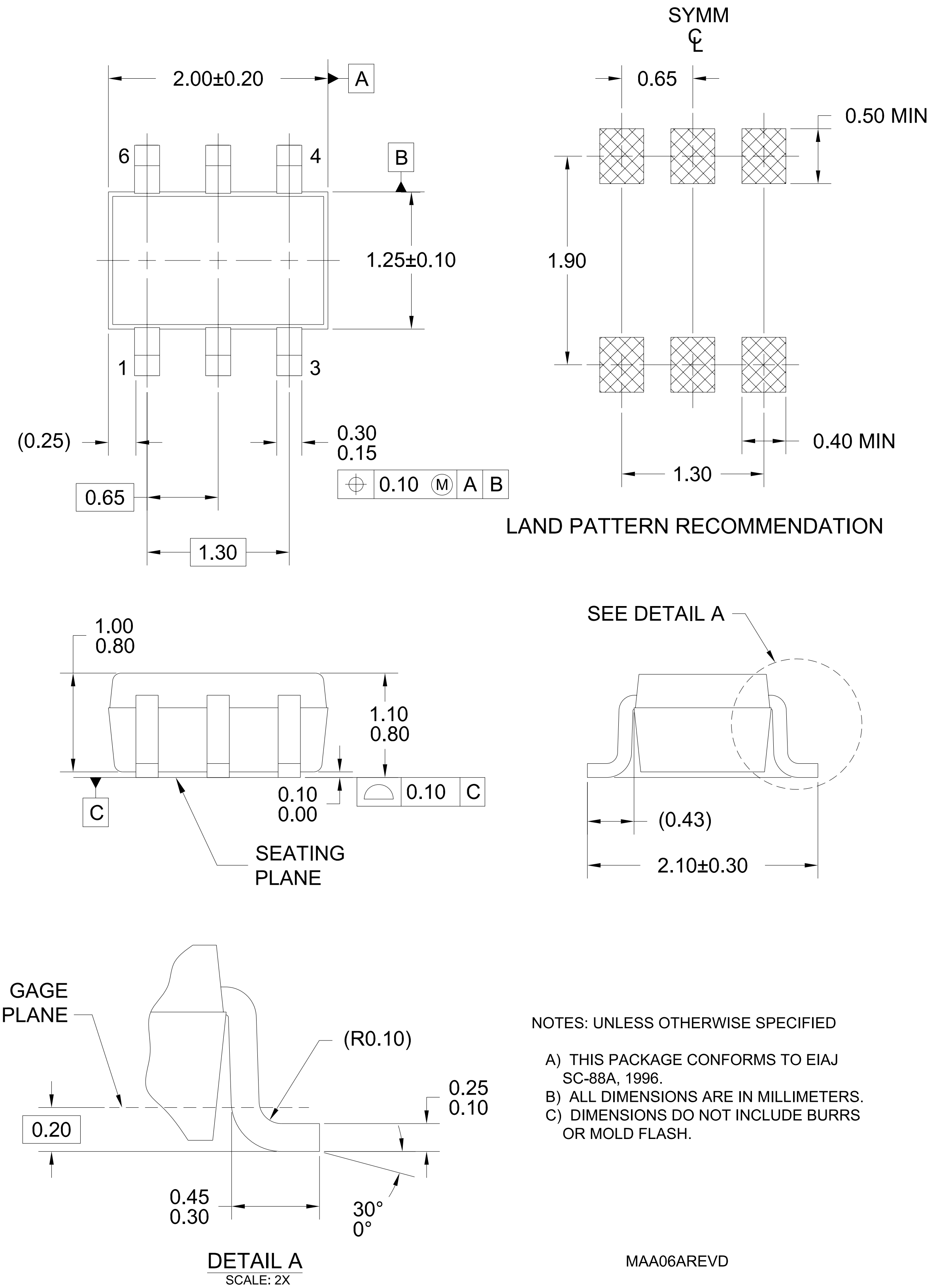
B. DIMENSIONS ARE IN MILLIMETERS.

C. DIMENSIONS AND TOLERANCES PER ASME Y14.5M, 1994

MLP08CrevB

Mechanical Dimensions

6-Lead SC-70 Package



NOTES: UNLESS OTHERWISE SPECIFIED

A) THIS PACKAGE CONFORMS TO EIAJ SC-88A, 1996.
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DOME™	ImpliedDisconnect™	Power247™	SuperSOT™-6	
EcoSPARK™	IntelliMAX™	PowerEdge™	SuperSOT™-8	
E^2CMOS™	ISOPLANAR™	PowerSaver™	SyncFET™	
EnSigna™	LittleFET™	PowerTrench®	TCM™	
FACT™	MICROCOUPLER™	QFET®	TinyBoost™	
FAST®	MicroFET™	QS™	TinyBuck™	
FASTr™	MicroPak™	QT Optoelectronics™	TinyPWM™	
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As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user.

2. A critical component is any component of 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.

PRODUCT STATUS DEFINITIONS

Definition of Terms

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.

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