MIC2845/6

6 Channel High Side Current Source WLED driver with Dual Low I_Q LDOs

General Description

The MIC2845 and MIC2846 are all-in-one integrated circuits designed for driving White LEDs (WLEDs) for display backlighting, camera flash, and other modules in mobile devices. The MIC2845/6 uses 6 channels of current sinks to maintain constant current for up to 6 WLEDs. It features a typical dropout of less than 50mV at 20mA and guarantees less than 100mV over all conditions, thus allowing the WLEDs to be driven directly from the battery without the use of extra capacitors in a large and costly charge pump. The current sinks are accurate up to 95% while the matching between each channel is guaranteed above 96.5% at room temperature. The superior matching of MIC2845/6 insures clear and uniform display brightness under all conditions.

The brightness of WLEDs is be externally preset by a resistor or internally programmed using pulse width modulation (PWM) on the MIC2845 or single-wire digital control on the MIC2846. The PWM brightness control on the MIC2845 will operate down to less than 1% duty cycle for an accurate and a high dynamic brightness range. The MIC2846 dimming features a single-wire digital interface which takes commands from digital programming pulses to change the brightness in a logarithmic scale similar to the eye's perception of brightness. The single-wire digital brightness control is divided into two modes of operation for full brightness mode or battery saving mode for a total of 32 total brightness steps.

The MIC2845/6 also features two independently enabled low quiescent current LDOs. Each LDO offers ±3% accuracy from the nominal voltage over temperature, low dropout voltage (150mV @ 150mA), and low ground current at all load conditions (typically 25µA). Both LDOs can be turned off to draw virtually no current.

The MIC2845/6 are both available in the 2.5mm x 2.5mm 14-pin Thin MLF® leadless package with a junction temperature range of -40°C to +125°C.

Datasheets and support documentation can be found on Micrel's web site at: www.micrel.com.

Features

- Input voltage range: 3.0V to 5.5V

WLED Driver

- Current source dropout of less than 50mV guaranteed at 20mA
- Accuracy better than ±95% (-40°C to +125°C)
- Mismatching lower than ±3.5% (20°C)
- Maintains proper regulation regardless of how many channels are utilized
- Flash LED driver paralleling 6 channels
- Two methods of dimming control
  - MIC2845 – PWM operation to <1% duty cycle
  - MIC2846 – Single wire digital control

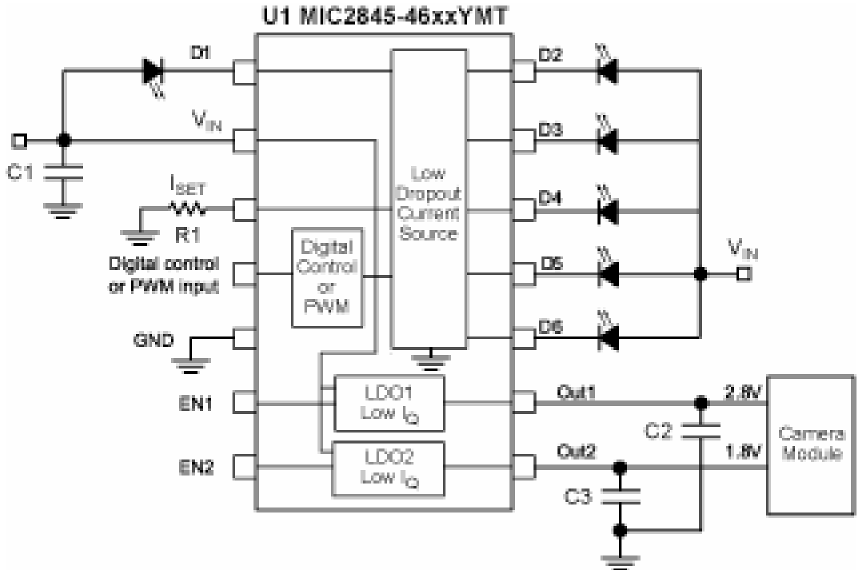
LDOs

- Very low ground current – <25µA each @ 150mA
- Stable with 1µF ceramic output capacitor
- Dropout at 150mV at 150mA
- Thermal shutdown and current limit protection

Applications

- Mobile handsets
- Digital cameras
- Portable media/MP3 players
- Portable navigation devices (GPS)
- Portable applications

Typical Application



Ordering Information

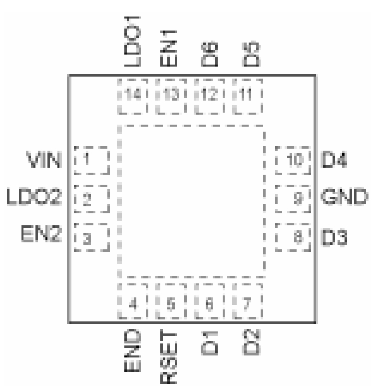
Part Number	LDO1 Output Voltage	LDO2 Output Voltage	Mark Code	Temperature Range	Package
MIC2845-MFYMT	2.8V	1.5V	YNMF	–40°C to +125°C	14-Pin 2.5x2.5 MLF®
MIC2845-MGYMT	2.8V	1.8V	YNMG	–40°C to +125°C	14-Pin 2.5x2.5 MLF®
MIC2846-MFYMT	2.8V	1.5V	YPMF	–40°C to +125°C	14-Pin 2.5x2.5 MLF®
MIC2846-MGYMT	2.8V	1.8V	YPMG	–40°C to +125°C	14-Pin 2.5x2.5 MLF®

Note:

1. Output voltage range of each LDO is 1.0V to 3.3V in 50mV steps. Contact Micrel Marketing for other voltage options.

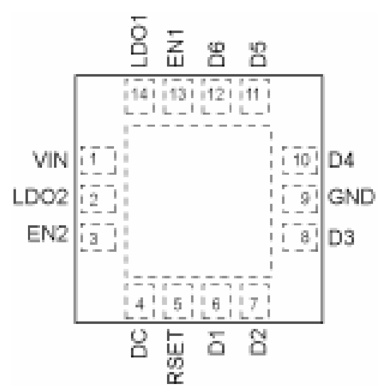
Pin Configuration

MIC2845



2.5mm x 2.5mm Thin MLF®
(Top View)

MIC2846



2.5mm x 2.5mm Thin MLF®
(Top View)

Pin Description

Pin Number MIC2845	Pin Number MIC2846	Pin Name	Pin Function
1	1	VIN	Voltage Input. Connect at least 1µF ceramic capacitor between V_{IN} and GND.
2	2	LDO2	Output of LDO2. Connect at least 1µF ceramic output capacitor.
3	3	EN2	Enable Input for LDO2. Active High Input. Logic High = On; Logic Low = Off; Do not leave floating.
4	-	END	Enable high side current source. This pin can be used as a PWM input for dimming of WLEDs. Do not leave floating.
-	4	DC	Digital control input for high side current source. See Digital Dimming Interface. Do not leave floating.
5	5	R_{SET}	An internal 1.27V reference sets the nominal maximum WLED current. Example, apply a 20.5kΩ resistor between R_{SET} and GND to set LED current to 20mA at 100% duty cycle.
6	6	D1	LED1 current sink input. Connect LED anode to VIN and cathode to this pin.
7	7	D2	LED2 current sink input. Connect LED anode to VIN and cathode to this pin.
8	8	D3	LED3 current sink input. Connect LED anode to VIN and cathode to this pin.
9	9	GND	Ground.
10	10	D4	LED4 current sink input. Connect LED anode to VIN and cathode to this pin.
11	11	D5	LED5 current sink input. Connect LED anode to VIN and cathode to this pin.
12	12	D6	LED6 current sink input. Connect LED anode to VIN and cathode to this pin.
13	13	EN1	Enable Input for LDO1. Active High Input. Logic High = On; Logic Low = Off; Do not leave floating.
14	14	LDO1	Output of LDO1. Connect a 1µF ceramic output capacitor.

Absolute Maximum Ratings[1]

Main Input Voltage (V_{IN}) .... -0.3V to +6V
Enable/DC Input Voltage .... -0.3V to +6V
Current Source Voltage ………………………..-0.3V to +6V
Power Dissipation………………………..Internally Limited[3]
Lead Temperature (soldering, 10sec.)....................... 260°C
Storage Temperature (T_s) ....-65°C to +150°C
ESD Rating[4].. 2kV

Operating Ratings[2]

Supply Voltage (V_{IN})................................... +3.0V to +5.5V
Enable Input Voltage ($V_{EN1/2}$,V_{DC},V_{END}) .... 0V to V_{IN}
Current Source Voltage (V_{D1-6}) .... 0V to V_{IN}
Junction Temperature (T_J) ....–40°C to +125°C
Junction Thermal Resistance
MLF® (θ_{JA})..60°C/W

Electrical Characteristics

Linear Regulators

V_{IN} = V_{EN1} = V_{EN2} = 3.8V, V_{DC} (2846) V_{END} (2845) = 0V; $C_{OUT1/2}$ = 2.2µF, $I_{OUT1/2}$ = 100µA;
T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ 125°C; unless noted.

Parameter	Conditions	Min	Typ	Max	Units
Output Voltage Accuracy	Variation from nominal V_{OUT}	-2 -3		+2 +3	% %
V_{IN} Line Regulation			0.02	0.3	%/V
Load Regulation	I_{OUT} = 100µA to 150mA		6	10	mV
Dropout Voltage	V_{OUT} > = 3.0V; I_{OUT} = 150mA		150	330	mV
Ground Pin Current	I_{OUT} = 100µA to 150mA		25	40	µA
Ground Pin Current in Shutdown	V_{EN} ≤ 0.2V, T_J < 85C		0.05	1.0	µA
Ripple Rejection	f = up to 1kHz; C_{OUT} = 2.2µF		65		dB
Current Limit	V_{OUT} = 0V	200	300	550	mA
Output Voltage Noise	C_{OUT} = 2.2µF, 10Hz to 100kHz		58		□V_{RMS}

Enable Inputs (EN1, 2)

Enable Input Voltage	Logic Low			0.2	V
	Logic High	1.2			V
Enable Hysterisis			25		mV
Enable Input Current	$V_{EN1/2}$ ≥ 1.0V		0.01	1	µA
Turn-on Time	C_{OUT} = 2.2µF; 90% of V_{OUT}		50	100	µs

Notes:

1. Exceeding the absolute maximum rating may damage the device.
2. The device is not guaranteed to function outside its operating rating.
3. The maximum allowable power dissipation of any T_A (ambient temperature) is $P_{D(max)} = T_{J(max)} – T_A) / \theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.
4. Devices are ESD sensitive. Handling precautions recommended. Human body model: 1.5kΩ in series with 100pF.

WLED Current Sinks

V_{IN} = V_{DC} (2846) V_{END} (2845) = 3.8V, V_{EN1} = V_{EN2} = 0V; R_{SET} = 20.5kΩ; V_{DROP} = 0.6V;
T_J = 25°C, **bold** values indicate –40°C ≤ T_J ≤ 125°C; unless noted.

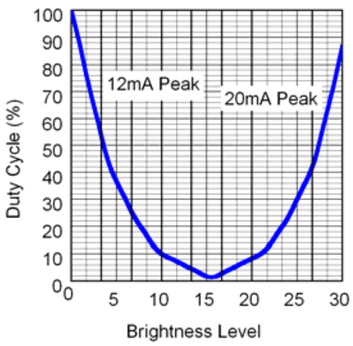
Parameter	Conditions	Min	Typ	Max	Units
Current Accuracy(5)	$V_{DROPNOM}$ = 0.6V	-5		+5	%
Matching(6)	$V_{DROPNOM}$ = 0.6V	-3.6 -5.5		+3.6 +5.5	% %
Drop-out	Where I_{LED} = 90% of LED current seen at $V_{DROPNOM}$ = 0.6V, 100% brightness level		50	100	mV
Ground/Supply Bias Current	I_{OUT} = 20mA		1.0		mA
Shutdown Current (current source leakage)	V_{END} = 0V or V_{DC} = 0V > 1260µs, $V_{ENLDO1,2}$ = 0V		0.01	1	µA
MIC2845- PWM Dimming					
Enable Input Voltage V_{END}	Logic Low			0.2	V
	Logic High	1.2			V
Enable Input Current	V_{IH} ≥ 1.0V		0.01	1	µA
Minimum Pulse Width			10		µs
Current Source Delay (50% levels)	Shutdown to on(5) Standby to on; V_{DROP} = 0.1V Standby to on; V_{DROP} = 0.6V On to Standby; V_{DROP} = 0.1V On to Standby; V_{DROP} = 0.6V R_{SET} = 20.5k		125 1 0.5 1 1		µs µs µs µs µs
Current Source Transient Time (10%-90%)	T_{RISE}, V_{DROP} = 0.1V T_{RISE}, V_{DROP} = 0.6V T_{FALL}; V_{DROP} = 0.1V T_{FALL}, V_{DROP} = 0.6V		1 1 0.3 0.3		µs µs µs µs
Stand-by to shutdown time	V_{END} = 0V	20	TBD	40	ms
MIC2846- Digital Dimming					
V_{DC} Input Voltage V_{DC}	Logic Low			0.2	V
	Logic High	1.2			V
VDC Enable Input Current	V_{IH} ≥ 1.2V		0.01	1	µA
$t_{SHUTDOWN}$	Time DC pin is low to put into shutdown	1260			µs
t_{MODE_UP}	Time DC pin is low to change to Count Up Mode	100		160	µs
t_{MODE_DOWN}	Time DC pin is low to change to Count Down Mode	420		500	µs
t_{PROG_HIGH}, t_{PROG_LOW}	Time for valid edge count; Ignored if outside limit range	1		32	µs
t_{DELAY}	Time DC pin must remain high before a mode change can occur	140			µs
t_{PROG_SETUP}	First down edge must occur in this window during presetting brightness	35		50	µs
t_{START_UP}	Delay from DC is high to start up	140			µs

Notes:

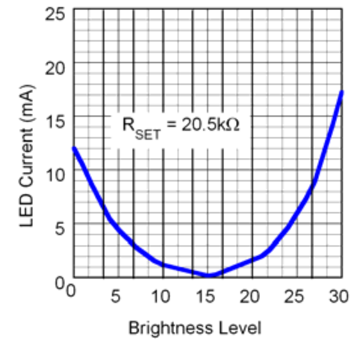
5. As determined by average current of all channels in use and all channels loaded.
6. The current through each LED meet the stated limits from the average current of all LEDs.
7. Maximum differential in forward voltage anticipated from the LED with the highest forward voltage to the LED with the lowest forward voltage at nominal current.
8. Current accuracy guaranteed for V_{DROP} current source 100mV to V_{IN}-1.2V.
9. Dropout voltage is defined as the input-output differential at which the output voltage drops 2% below its nominal value measured at 1V differential.

Typical Characteristics (Current Sink)

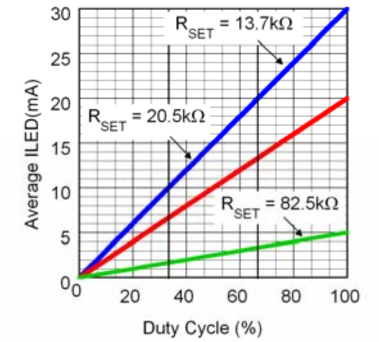
Duty Cycle vs. Brightness Level



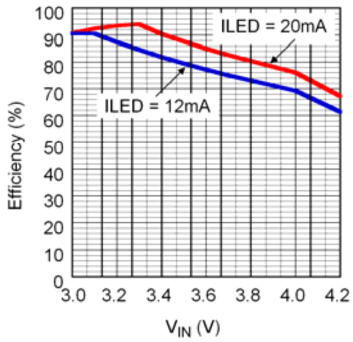
Average LED Current vs. Brightness Level



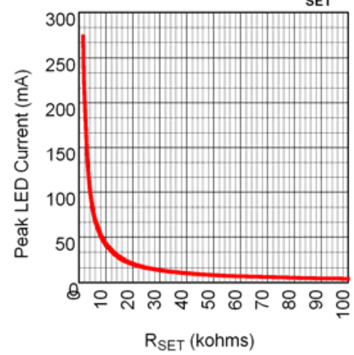
Average ILED vs. Duty Cycle



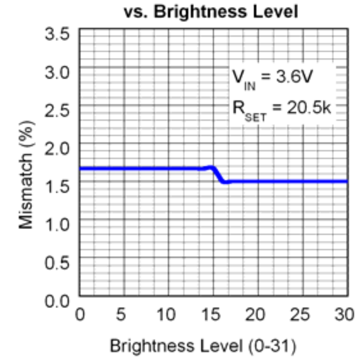
Current Sink Efficiency



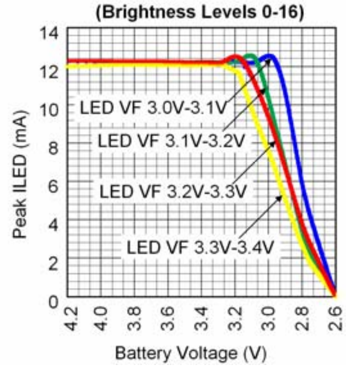
Peak LED Current vs. R_{SET}



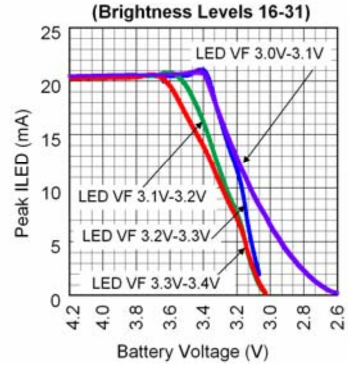
LED Mismatch vs. Brightness Level



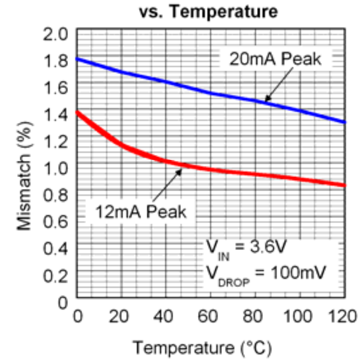
12mA Peak ILED vs. V_{IN} (Brightness Levels 0-16)



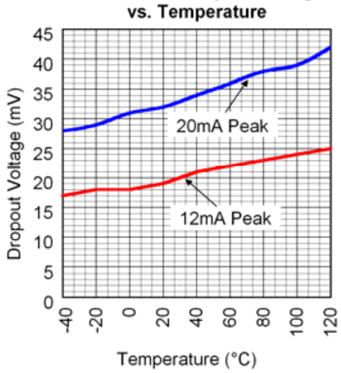
20mA Peak ILED vs. V_{IN} (Brightness Levels 16-31)



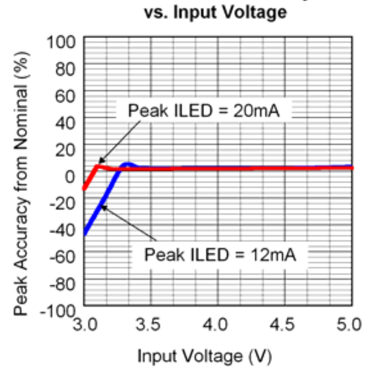
LED Mismatch vs. Temperature



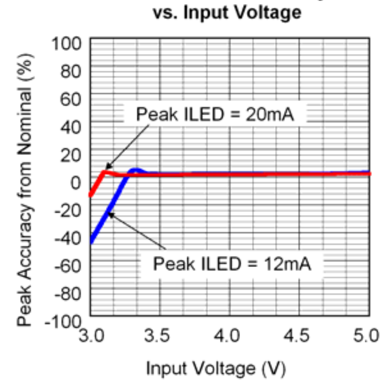
Current Sink Dropout Voltage vs. Temperature



LED Current Accuracy vs. Input Voltage

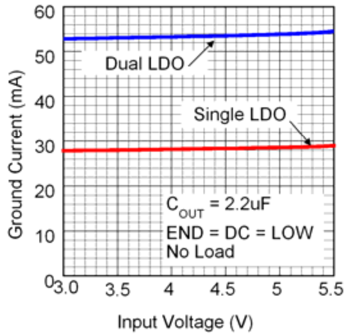


LED Current Accuracy vs. Input Voltage

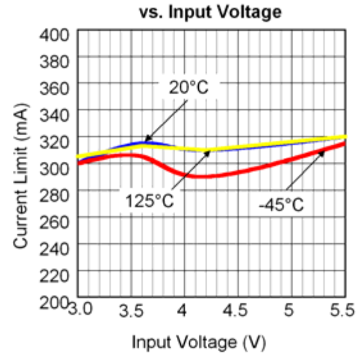


Typical Characteristics (LDO)

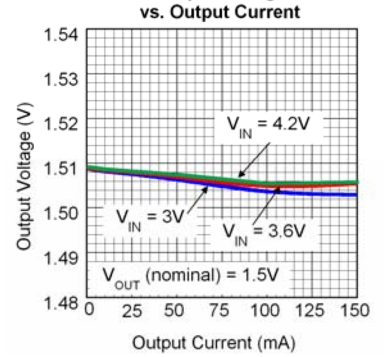
Ground Current vs. Input Voltage



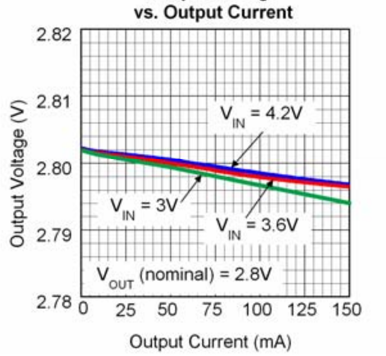
Current Limit vs. Input Voltage



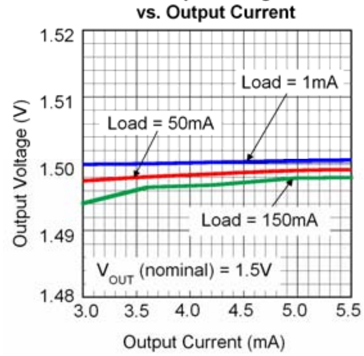
Output Voltage vs. Output Current



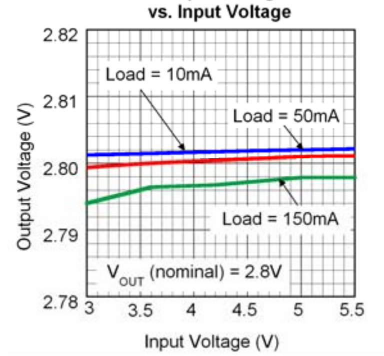
Output Voltage vs. Output Current



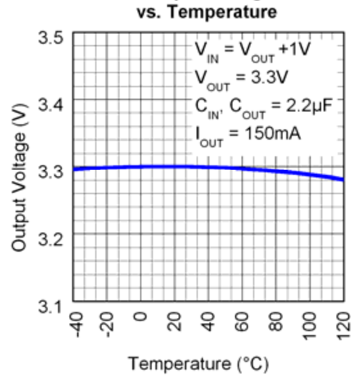
Output Voltage vs. Output Current



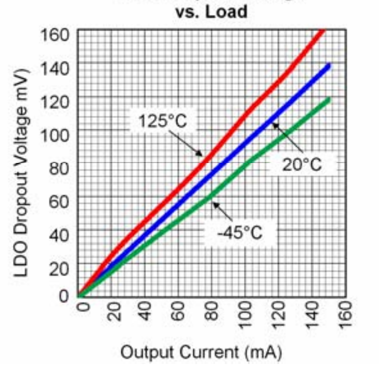
Output Voltage vs. Input Voltage



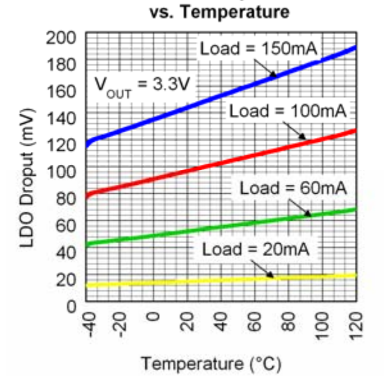
Output Voltage vs. Temperature



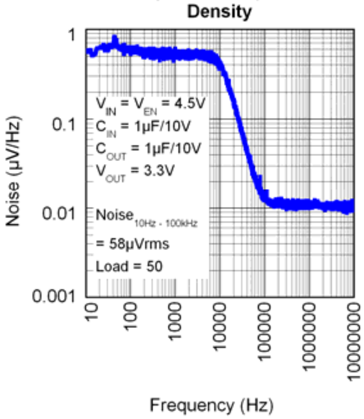
LDO Dropout Voltage vs. Load



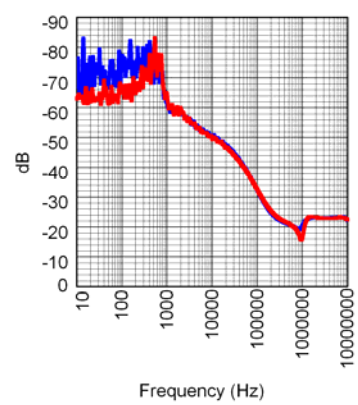
LDO Dropout vs. Temperature



Output Noise Spectral Density

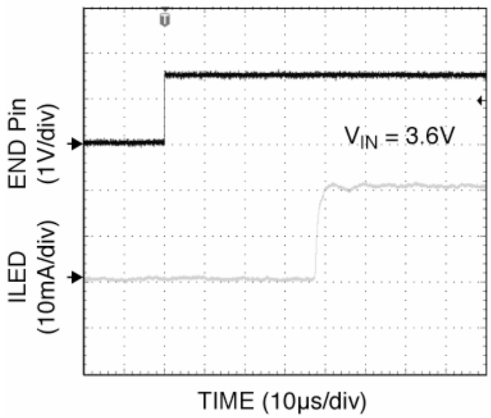


PSRR

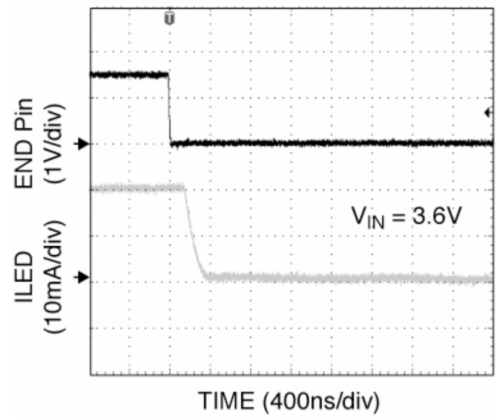


Functional Characteristics (Current Sink)

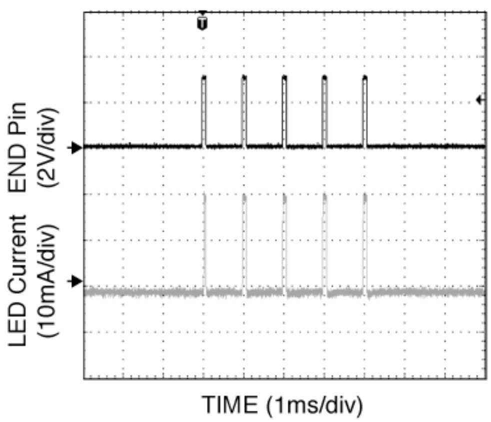
MIC2845 LED Response to END Signal Turning ON



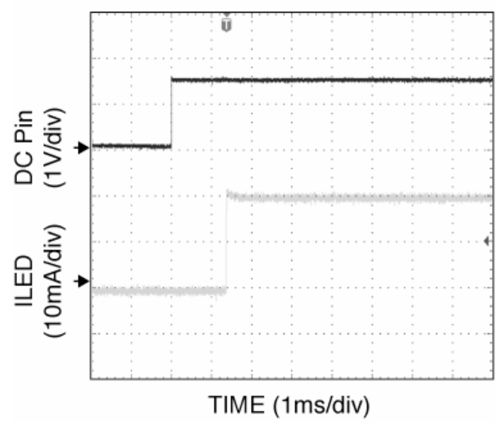
MIC2845 LED Response to END Signal Turning OFF



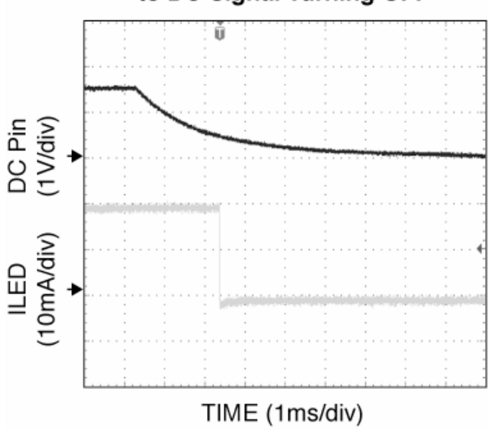
MIC2845 LED Startup into 10% Duty Cycle



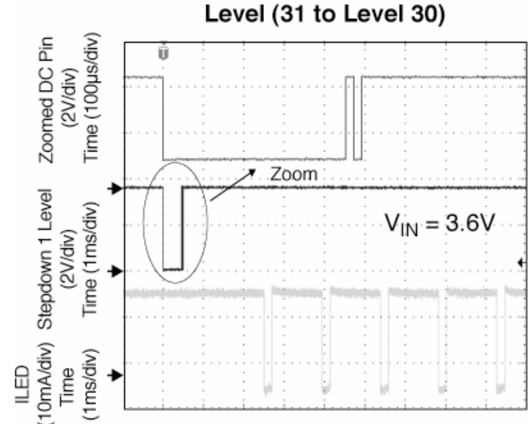
MIC2846 ILED Response to DC Signal Turning ON



MIC2846 ILED Response to DC Signal Turning OFF

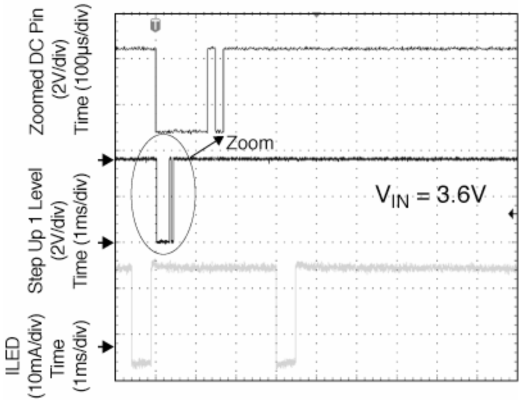


MIC2846 Step Down 1 Brightness Level (31 to Level 30)

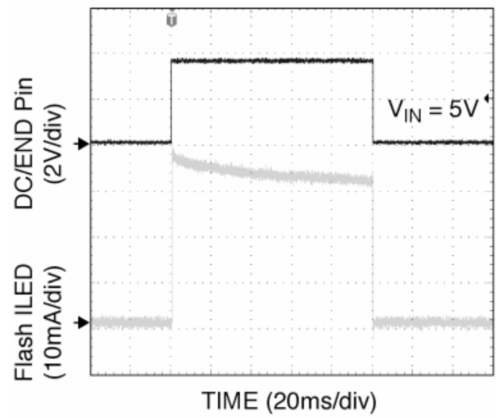


Functional Characteristics (Current Sink)

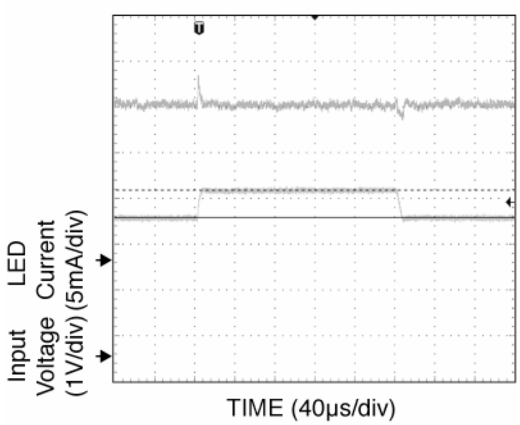
MIC2846 Step Up 1 Brightness Level (30 to Level 31)



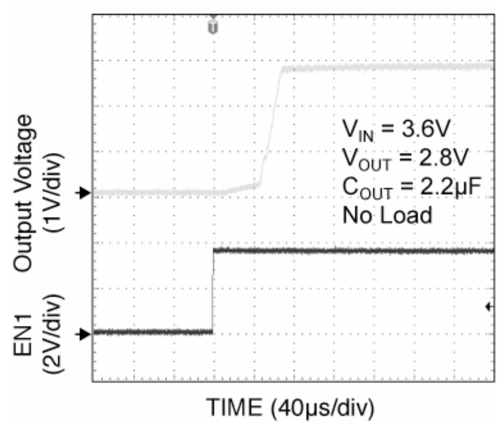
MIC2845/6 Flash LED with 6 Channels Paralled



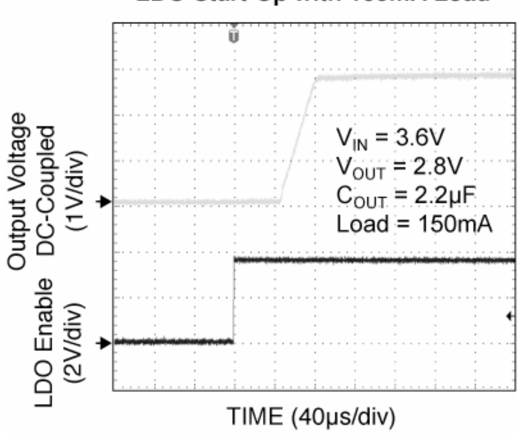
Line Transient from 3.6V to 4.2V



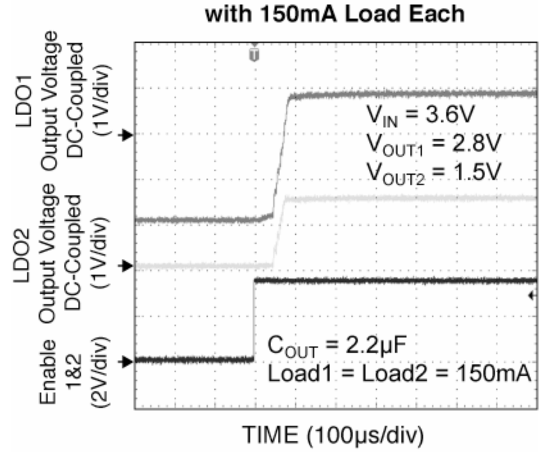
LDO Start-Up with No Load



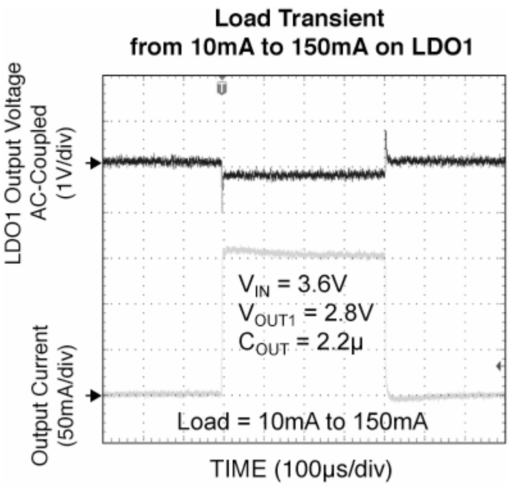
LDO Start-Up with 150mA Load

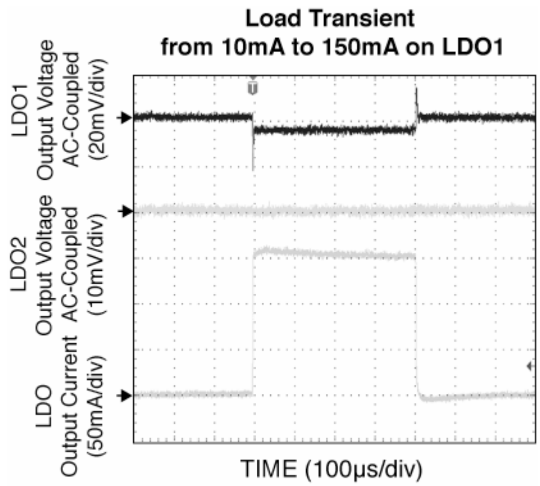


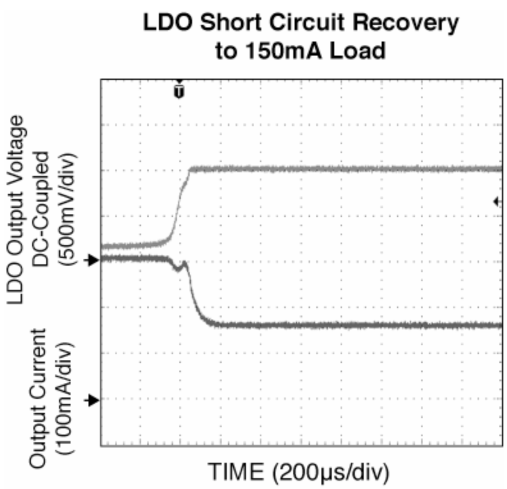
Dual LDO Start-Up with 150mA Load Each



Functional Characteristics (Current Sink)







Functional Diagram

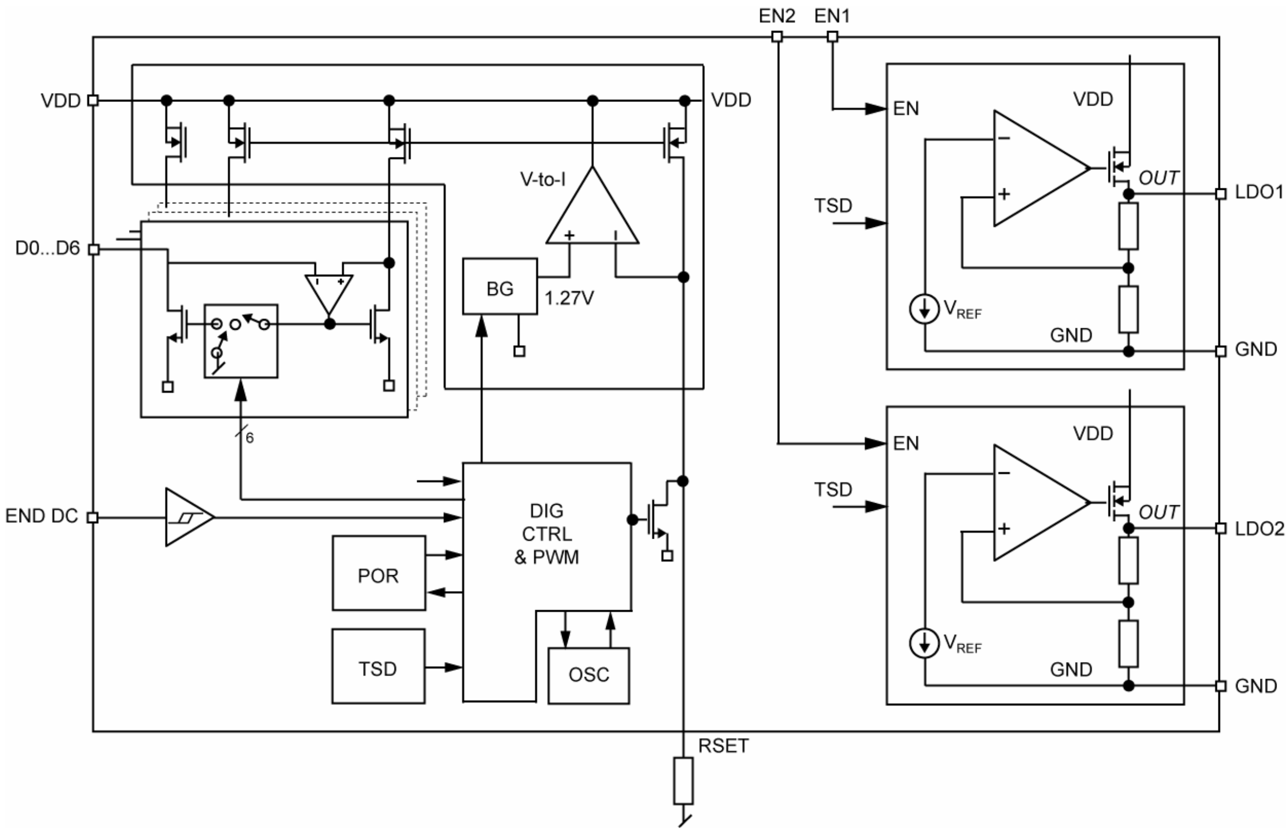


Figure 1. MIC2845 and MIC2846 Functional Block Diagram

Functional Description

The MIC2845/6 is a 6 channels WLED driver with dual 150mA LDOs. The WLED driver is designed to maintain proper current regulation with LED current accuracy of 95% while the minimum matching between the 6 channels to be 96.5% at room temperature. The WLEDs are driven independently from the input supply and will maintain regulation with a dropout of 50mV at 20mA. The low dropout of the current sinks allows the WLEDs to be driven directly from the input voltage and eliminates the need for large and inefficient charge pumps. If desired, multiple channels can be combined to drive a single WLED at a higher current for an intense light output. The combined method generates an extremely bright light suited for camera flash applications. The maximum WLED current for each channel is set via an external resistor. If dimming is desired the MIC2845 can dim via a PWM signal while the MIC2846 is controlled by a single-wire digital interface. Both dimming controls will be discussed in detail in the following sections.

The MIC2845/6 has two LDOs with a dropout voltage of 150mV at 150mA and consume 25µA of current in operation. Each LDO has a dedicated enable pin, which can reduce operating current down to 0.01µA in shutdown. Both linear regulators are stable with just 1µF of output capacitance.

Block Diagram

As shown in Figure 1, the MIC2845/6 consists of 2 LDOs and 6 current mirrors set to copy a master current determined by R_{SET}. The current sinks have a designated control block for enabling and dimming of the WLEDs. The MIC2845 is controlled by the PWM control block that receives PWM signals for dimming. The MIC2846 dimming is controlled by an internal Digital Control Interface. The LDOs each have their own control block and are independent of the current sinks. In each LDO block, there are internal feedback resistors, an error amplifier, a PFET transistor and a control circuit for enabling.

V_{IN}

The input supply (V_{IN}) provides power to the LDOs, the current sinks and the control circuitry. The V_{IN} operating range is 3V to 5.5V. Due to wire inductance a minimum of 1µF/6.3V bypass capacitor should be placed close to input (VIN) pin and the ground (GND) pin. Refer to the layout recommendations section for details on placing the input capacitor (C1).

LDO1/LDO2

The output pins for LDO one and LDO two are labeled LDO1 and LDO2, respectively. A minimum of 1µF bypass capacitor should be placed as close as possible to the output pin of each LDO. Refer to the layout recommendations section for details on placing the output capacitor (C2, C3) of the LDOs.

EN1/EN2

A logic high signal on the enable pin activates the LDO output voltage of the device. A logic low signal on the enable pin deactivates the output and reduces supply current to 0.01µA. EN1 controls LDO1 and EN2 controls LDO2. MIC2845/6 LDOs feature built-in soft-start circuitry that reduces in-rush current and prevents the output voltage from overshooting at start up. Do not leave floating.

END (MIC2845 Only)

The END pin is equivalent to the enable pin for the current sinks on the MIC2845. It can also be used for dimming using a PWM signal. See the MIC2845 PWM Dimming Interface in the Application Information section for details.

DC (MIC2846 Only)

The DC pin is equivalent to the enable pin for the current sinks on the MIC2846. It can also be used for dimming using a single-wire digital interface. See the MIC2846 Digital Dimming Interface in the Application Information section for details.

R_{SET}

The R_{SET} pin is used by connecting a R_{SET} resistor to ground to set the peak current of the current sinks. The average LED current can be calculated by the equation (1) below:

$$I_{LED}\,(mA) = 410 * D / R_{SET}\,(k\Omega) \quad (1)$$

D is the duty cycle of the LED current during PWM dimming (MIC2845) or single-wire digital dimming (MIC2846). When the device is fully on the duty cycle equals 100% (D = 1). A plot of I_{LED} versus R_{SET} at 100% duty cycle is shown in Figure 2.

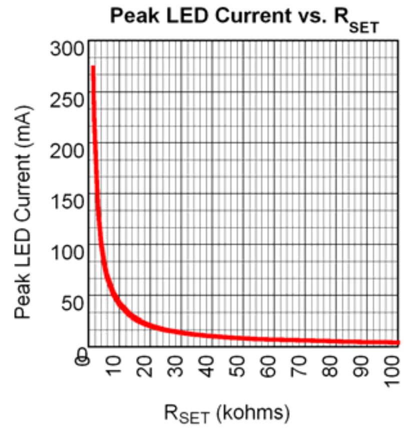


Figure 2. Peak I_{LED} vs. R_{SET}

D1-D6

The D1 through D6 pins are the current sink inputs for WLED 1 through 6, respectively. Connect the anodes of the WLEDs to V_{IN} and each cathode of the WLEDs to D1 through D6. The current sinks are independent of each other. They can be used individually or combined. A single WLED can be driven with all 6 current sinks by connecting D1 through D6 together with the cathode of the WLED. This will generate a current 6 times I_{LED} and can be used for higher current WLEDs such as those used in flash applications. The peak current of each current sink is 80mA at 100% duty cycle due to thermal limitations. With all 6 current sinks, the total current to drive a single flash WLED is 480mA. If the duty cycle is lowered to 10% of 1 second, a WLED can be driven over 1.5A by sinking 250mA on each channel, shown in Figure 3.

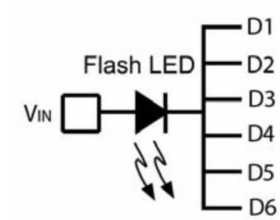


Figure 3. Flash LED Driver Circuit

GND

The ground pin is the ground path for the current sinks as well as the LDOs. The current loop for the ground should be as small as possible. The ground of the input and output capacitors should be routed with low impedance traces to the GND pin and made as short as possible. Refer to the layout recommendations for more details.

Application Information

MIC2845 PWM Dimming Interface

The MIC2845 can receive PWM signals from the END pin for WLED dimming. The frequency of the PWM signal should be between 200Hz – 1kHz and the duty cycle can range from 1% to 100%. Dimming is generated by pulsing the WLEDs on and off in synchronization with the PWM signal. An internal shutdown delay ensures that the internal control circuitry remains active during PWM dimming for optimum performance. Figure 4 through Figure 8 show the WLED current response when a PWM signal is applied to the END pin.

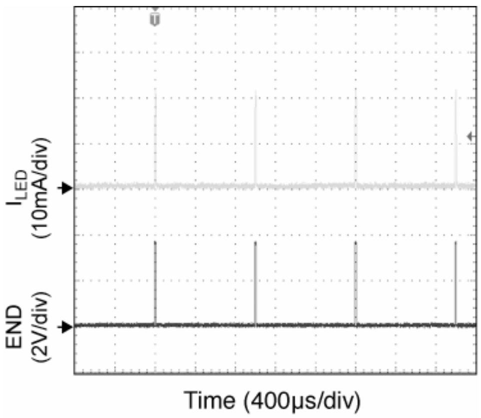


Figure 4. PWM Signal at 1% Duty Cycle

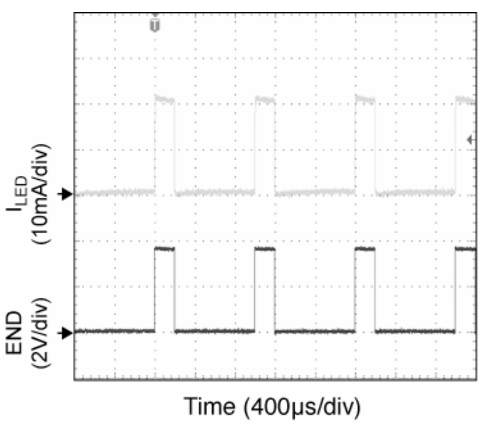


Figure 5. PWM Signal at 20% Duty Cycle

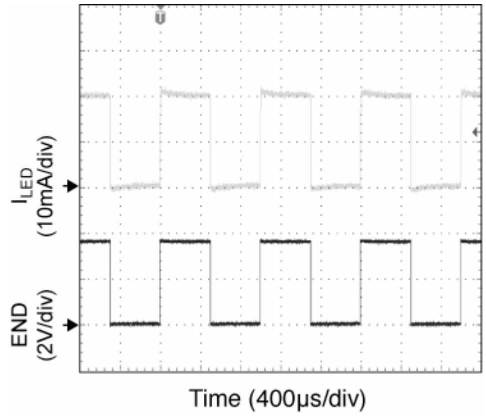


Figure 6. PWM Signal at 50% Duty Cycle

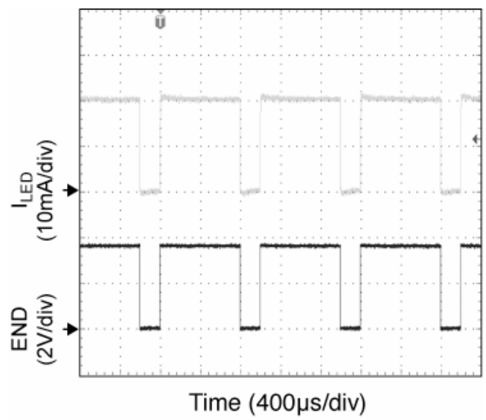


Figure 7. PWM Signal at 80% Duty Cycle

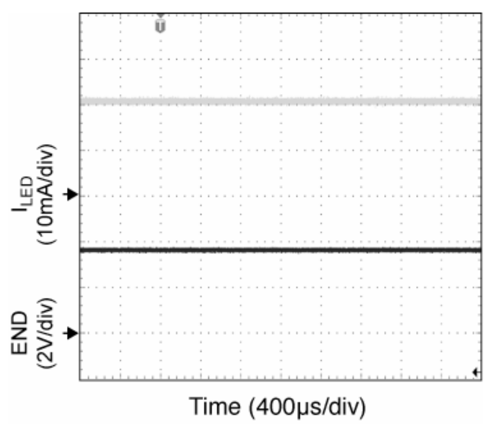


Figure 8. PWM Signal at 100% Duty Cycle

MIC2846 Digital Dimming Interface

The MIC2846 incorporates an easy to use single-wire, serial programming interface that allows users to set WLED brightness up to 32 different levels, as shown in Table 1.

Level (0-31)	LED Duty Cycle (%)	Average I_{LED} (mA)	I_{PEAK} (mA)
0	100	12	60% of $I_{LEDPEAK}$ (12mA for R_{SET} = 20.5k)
1	86	10.32	
2	72	8.6	
3	59	7.1	
4	45.5	5.5	
5	36.5	4.4	
6	29.5	3.5	
7	22.5	2.7	
8	18	2.2	
9	13.5	1.6	
10	9.5	1.1	
11	8	0.96	
12	6	0.72	
13	5	0.6	
14	4	0.48	
15	1.6	0.192	
16	1.6	0.32	100% of $I_{LEDPEAK}$ (20mA for R_{SET} = 20.5k)
17	4	0.8	
18	5	1	
19	6	1.2	
20	8	1.6	
21	9.5	1.9	
22	13.5	2.7	
23	18	3.6	
24	22.5	4.5	
25	29.5	5.9	
26	36.5	7.3	
27	45.5	9.1	
28	59	11.8	
29	72	14.4	
30	86	17.2	
31	100	20	

Table 1. Digital Interface Brightness Level Table

Brightness levels 0-15 is logarithmically spaced with a peak current equal to 60% of the current set by $R_{SET.}$ Brightness levels 16-31 is also logarithmically spaced with a peak current equal to the current determined by $R_{SET.}$ Spacing between each level is in logarithmic scale by design to mimic the sensitivity of the human eye. Refer to Table 1 for the translation from brightness level to LED duty cycle and current. The MIC2846 is designed to receive programming pulses to increase or decrease brightness. Once the brightness change signal is received, the DC pin is simply pulled high to maintain the brightness. This "set and forget" feature relieves processor computing power by eliminating the need to constantly send a PWM signal to the dimming pin. With a digital control interface, brightness levels can also be preset so that WLEDs can be turned on at any particular brightness level.

Start Up

Assuming the MIC2846 has been off for a long time and no presetting brightness command is issued (presetting is discussed in a later section), the MIC2846 will start-up in its default mode approximately 140µs (t_{START_UP}) after a logic level high is applied to the DC pin. In the default mode the WLEDs are turned on at the maximum brightness level of 31. Each falling edges during the t_{PROG_SETUP} period will cause the default brightness level to decrease by one. This is discussed in more detail in the Presetting Brightness section.

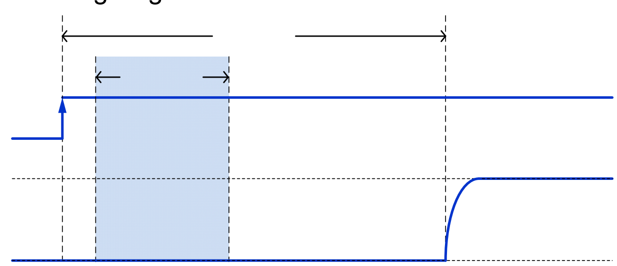


Figure 9. Typical Start-Up Timing

Shutdown

Whenever the DC input pin is pulled low for a period greater than or equal to $t_{SHUTDOWN}$(1260µs), the MIC2846 will be in shutdown, shown in Figure 10.

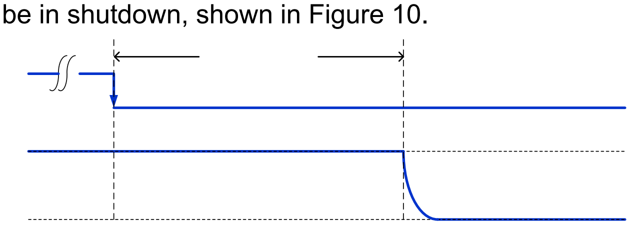


Figure 10. Shutdown Timing

Once the device is shutdown, the control circuit supply is disabled and the WLEDs are turned off, drawing only 0.01µA. Brightness level information stored in the MIC2846 prior to shutdown will be erased.

Count Up Mode/Count Down Mode

The mode of MIC2846 can be in either Count Up Mode or Count Down Mode. The Counting Modes determine what the falling edges of the programming pulses will do to the brightness. In Count Up Mode, subsequent falling edges will increase brightness while in Count Down Mode, subsequent falling edges will decrease brightness. By default, the MIC2846 is in Count Down Mode when first turned on. The counting mode can be changed to Count Up Mode, by pulling the DC pin low for a period equal to t_{MODE_UP} (100µs to 160µs), shown in Figure 11. The device will remain in Count Up Mode until its mode is changed to Count Down Mode or by disabling the MIC2846 to reset the mode back to default.

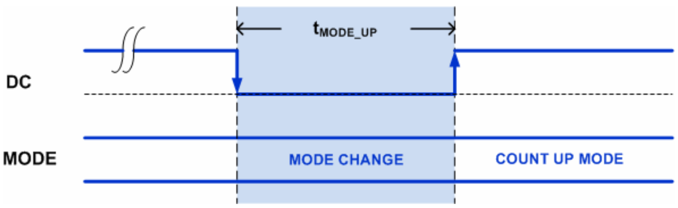


Figure 11. Mode Change to Count Up

To change the mode back to Count Down Mode, pull the DC pin low for a period equal to t_{MODE_DOWN} (420µs to 500µs), shown in Figure 12. Now the internal circuitry will remain in Count Down Mode until changed to Count Up as described previously.

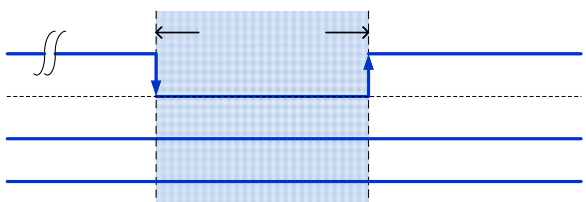


Figure 12. Mode Change to Count Down

Programming the Brightness Level

MIC2846 is designed to start driving the WLEDs 140µs (t_{START_UP}) after the DC pin is first pulled high at the maximum brightness level of 31. After start up, the internal control logic is ready to decrease the WLED brightness upon receiving programming pulses (negative edges applied to DC pin). Since MIC2846 starts in Count Down Mode, the brightness level is decreased one level by applying two programming pulses, as shown in Figure 13. Note that the extra pulse is needed to decrease brightness because the first edge is ignored. Anytime the first falling edge happens greater than 32µs after a Mode Change, it will be ignored. Ignoring the first falling edge is necessary in order that Mode Change (t_{MODE_UP}, t_{MODE_DOWN}) pulses do not result in adjustments to the brightness level. Each programming pulse has a high (t_{PROG_HIGH}) and a low (t_{PROG_LOW}) pulse width that must be between 1µs to 32µs. The MIC2846 will remember the brightness level and mode it was changed to. For proper operation, ensure that the DC pin has remained high for at least t_{DELAY}(140µs) before issuing a mode change command.

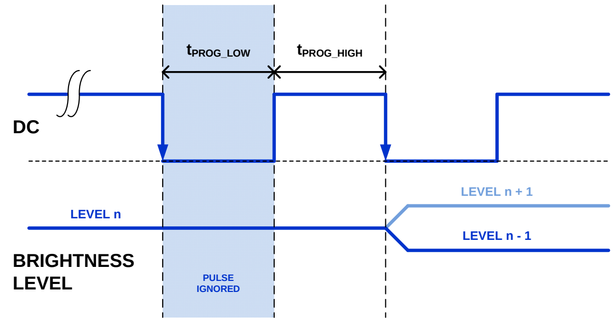


Figure 13. Brightness Programming Pulses

Multiple brightness levels can be changed as shown in Figure 14. When issuing multiple brightness level adjustments to the DC pin, ensure both t_{PROG_LOW} and t_{PROG_HIGH} are within 1µs and 32µs.

To maintain operation at the current brightness level simply maintain a logic level high at the DC pin.

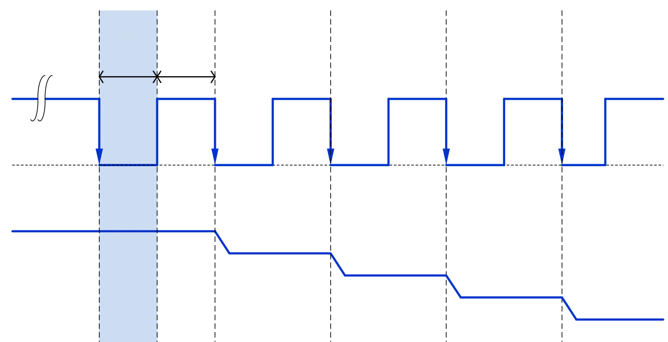


Figure 14. Decreasing Brightness Several Levels

As mentioned, MIC2846 can be programmed to set WLED drive current to produce one of 32 distinct brightness levels. The internal logic keeps track of the brightness level with an Up/Down counter circuit. The following section explains how the brightness counter functions with continued programming edges.

One-Step Brightness Changes

The "One-Step" brightness change procedure relieves the user from keeping track of the MIC2846's up/down counter mode. It combines a Mode Change with a programming edge; therefore, regardless of the previous Count Mode, it will change the brightness level by one.

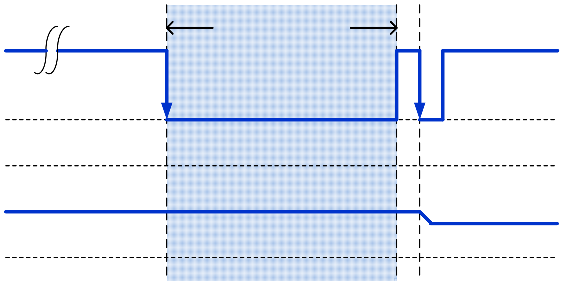


Figure 15. One-Step Brightness Decrease

The One-Step Brightness Decrease method is quite simple. First, the DC pin is pulled low for a period equal to the t_{MODE_DOWN} (420µs to 500µs) and immediately followed by a falling edge within t_{PROG_HIGH} (1µs to 32µs) as shown in Figure 15. This will decrease the brightness level by 1. Similarly a One-Step Brightness Increase can be assured by first generating a DC down pulse whose period is equal to the t_{MODE_UP} (100µs to 160µs) and immediately followed by a falling edge within t_{PROG_HIGH} (1µs to 32µs). Figure 16 illustrates the proper timing for execution of a One-Step Brightness Increase.

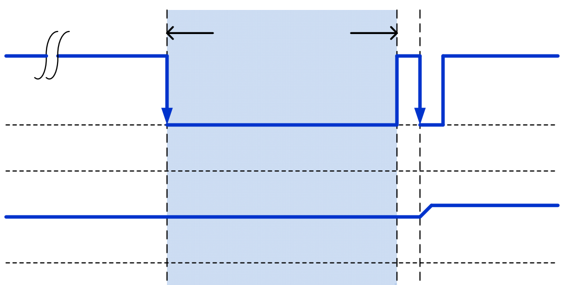


Figure 16. One-Step Brightness Increase

Presetting Brightness

The MIC2846 does not turn on the current sinks until DC pin is kept high for t_{START_UP} (140µs). This grants the user time to preset the brightness level by sending a series of programming edges via the DC pin. The precise timing for the first down edge is between 35µs to 50µs after the DC pin is first pulled high. The 15µs timeframe between 35µs and 50µs is the t_{PROG_SETUP} period. The first presetting pulse edge must occur somewhere between the timeframe of 35µs to 50µs, otherwise the MIC2846 may continue to start up at the full (default) brightness level.

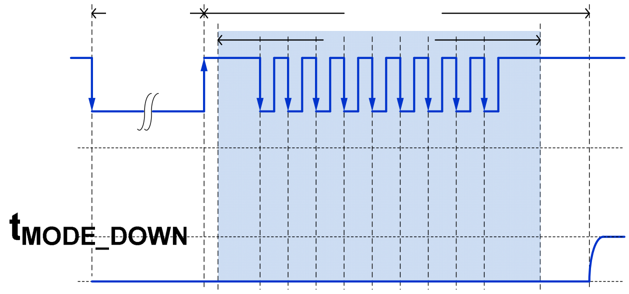


Figure 17. Presetting Timing

Figure 17 shows the correct presetting sequence to set the MIC2846 brightness to level 22 prior to start up. Notice that when using the presetting feature the first programming pulse is <u>not</u> ignored. This is because the counter's default mode is Count Down and a Mode Change cannot be performed in the presetting mode. (Note that the t_{PROG_HIGH} and t_{PROG_LOW} pulse width must still be between 1µs to 32µs`.)

LDO

MIC2845/6 LDOs are low noise 150mA LDOs. The MIC2845/6 LDO regulator is fully protected from damage due to fault conditions, offering linear current limiting and thermal shutdown.

Input Capacitor

The MIC2845/6 LDOs are high-performance, high bandwidth devices. Stability can be maintained using a ceramic input capacitor of 1µF. Low-ESR ceramic capacitors provide optimal performance at a minimum amount of space. Additional high-frequency capacitors, such as small-valued NPO dielectric-type capacitors, help filter out high-frequency noise and are good practice in any noise sensitive circuit. X5R or X7R dielectrics are recommended for the input capacitor. Y5V dielectrics lose most of their capacitance over temperature and are therefore, not recommended.

Output Capacitor

The MIC2845/6 LDOs require an output capacitor of at least 1µF or greater to maintain stability, however, the output capacitor can be increased to 2.2µF to reduce output noise without increasing package size. The design is optimized for use with low-ESR ceramic chip capacitors. High ESR capacitors are not recommended because they may cause high frequency oscillation. X7R/X5R dielectric-type ceramic capacitors are recommended due to their improved temperature performance compared to Z5U and Y5V capacitors. X7R-type capacitors change capacitance by 15% over their operating temperature range and are the most stable type of ceramic capacitors. Z5U and Y5V dielectric capacitors change value by as much as 50% and 60%, respectively, over their operating temperature ranges. To use a ceramic chip capacitor with Y5V dielectric, the value must be much higher than an X7R ceramic capacitor to ensure the same minimum capacitance over the equivalent operating temperature range.

No-Load Stability

Unlike many other voltage regulators, the MIC2845/6 LDOs will remain stable and in regulation with no load. This is especially important in CMOS RAM keep-alive applications.

Thermal Considerations

The MIC2845/6 LDOs are each designed to provide 150mA of continuous current. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. For example if the input voltage is 3.6V, the output voltage is 2.8V, and the output current = 150mA. The actual power dissipation of the regulator circuit can be determined using the equation:

$$P_{LDO1} = (V_{IN} - V_{OUT1})\, I_{OUT} + V_{IN}\, I_{GND}$$

Because this device is CMOS and the ground current (I_{GND}) is typically <100µA over the load range, the power dissipation contributed by the ground current is < 1% and can be ignored for this calculation.

$$P_{LDO1} = (3.6V - 2.8V) \times 150mA$$

$$P_{LDO1} = 0.120W$$

Since there are two LDOs in the same package, the power dissipation must be calculated individually and then summed together to arrive at the total power dissipation.

$$P_{TOTAL} = P_{LDO1} + P_{LDO2}$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance (θ_{JA} = 60°C/W) of the device and the following basic equation:

$$P_{TOTAL(max)} = \left(\frac{T_{J(max)} - T_A}{\theta_{JA}} \right)$$

$T_{J(max)}$ = 125°C, is the maximum junction temperature of the die and $\theta_{JA,}$ is the thermal resistance = 60°C/W.

Substituting P_{TOTAL} for $P_{TOTAL(max)}$ and solving for the ambient operating temperature will give the maximum operating conditions for the regulator circuit.

For example, when operating the MIC2845/6 LDOs (LDO1 = 2.8V and LDO2 = 1.5V) at an input voltage of 3.6V with 150mA load on each, the maximum ambient operating temperature T_A can be determined as follows:

$$P_{LDO1} = (3.6V - 2.8V) \times 150mA = 0.120W$$

$$P_{LDO2} = (3.6V - 1.5V) \times 150mA = 0.315W$$

$$P_{TOTAL} = 0.120W + 0.315W = 0.435W$$

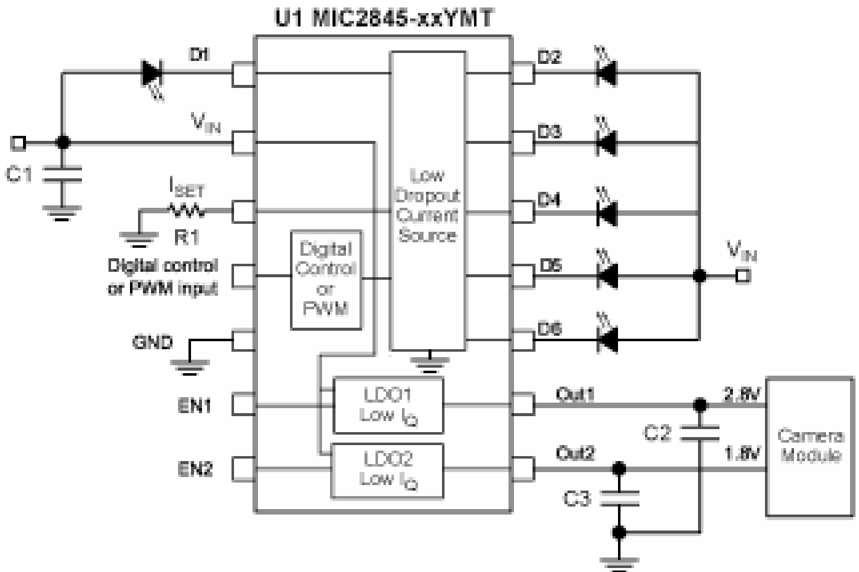
$$= (125°C - T_A)/(60°C/W)$$

$$T_A = 125°C - 0.435W \times 60°C/W$$

$$T_A = 98.9°C$$

Therefore, under the above conditions, the maximum ambient operating temperature of 98.9°C is allowed.

MIC2845 Typical Application Circuit



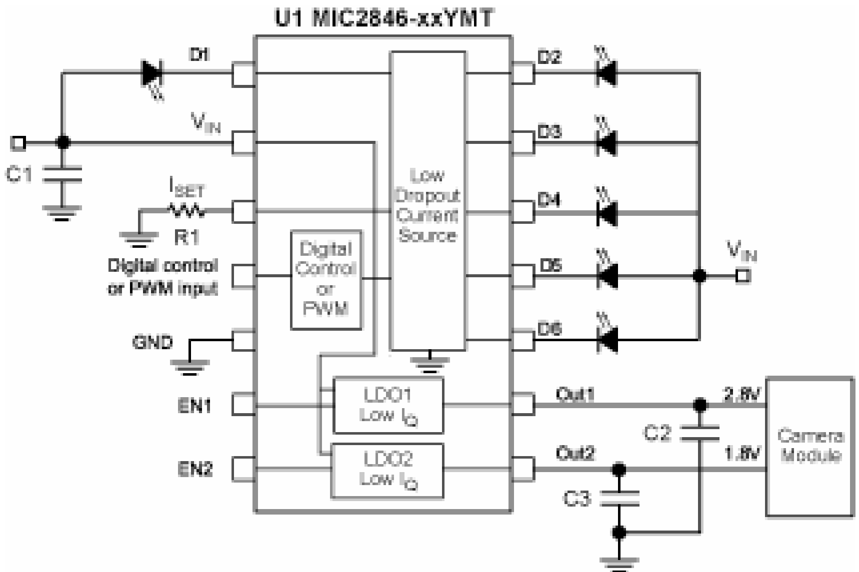
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1, C2, C3	C1608X5R0J105K	TDK(1)	1µF Ceramic Capacitor, 6.3V, X5R, Size 0603	3
R1	CRCW06032052FT1	Vishay(2)	20.5kΩ, 1%, Size 0603	1
U1	**MIC2845-xxYMT**	**Micrel, Inc.(3)**	**6 Channel PWM Controlled Current Sink WLED Driver with Dual LDOs**	**1**

Notes:

1. TDK: www.tdk.com
2. Vishay: www.vishay.com
5. **Micrel, Inc.: www.micrel.com**

MIC2846 Typical Application Circuit



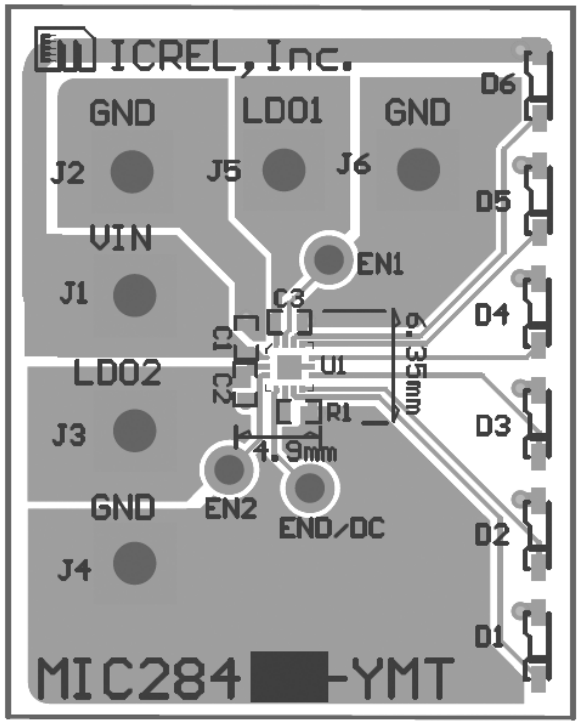
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1, C2, C3	C1608X5R0J105K	TDK[1]	1µF Ceramic Capacitor, 6.3V, X5R, Size 0603	3
R1	CRCW06032052FT1	Vishay[2]	20.5kΩ, 1%, Size 0603	1
U1	**MIC2846-xxYMT**	**Micrel, Inc.[3]**	**6 Channel Digital Controlled Current Sink WLED Driver with Dual LDOs**	**1**

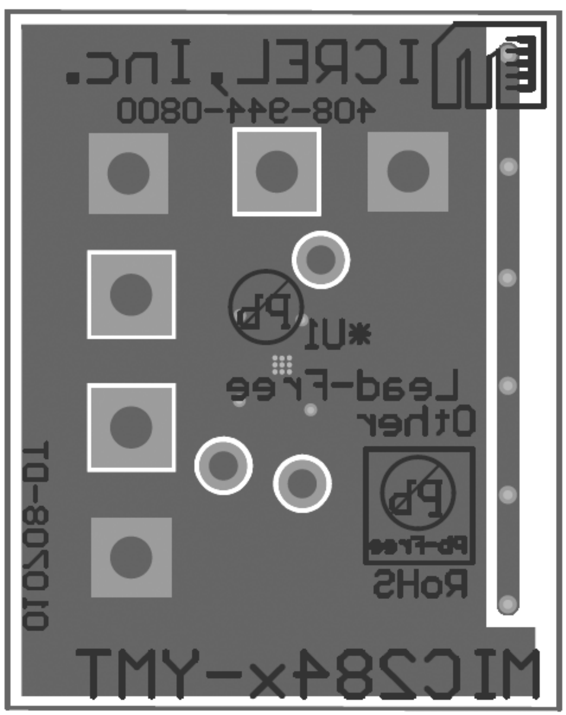
Notes:

1. TDK: www.tdk.com
2. Vishay: www.vishay.com
5. **Micrel, Inc.: www.micrel.com**

PCB Layout Recommendations (Fixed)

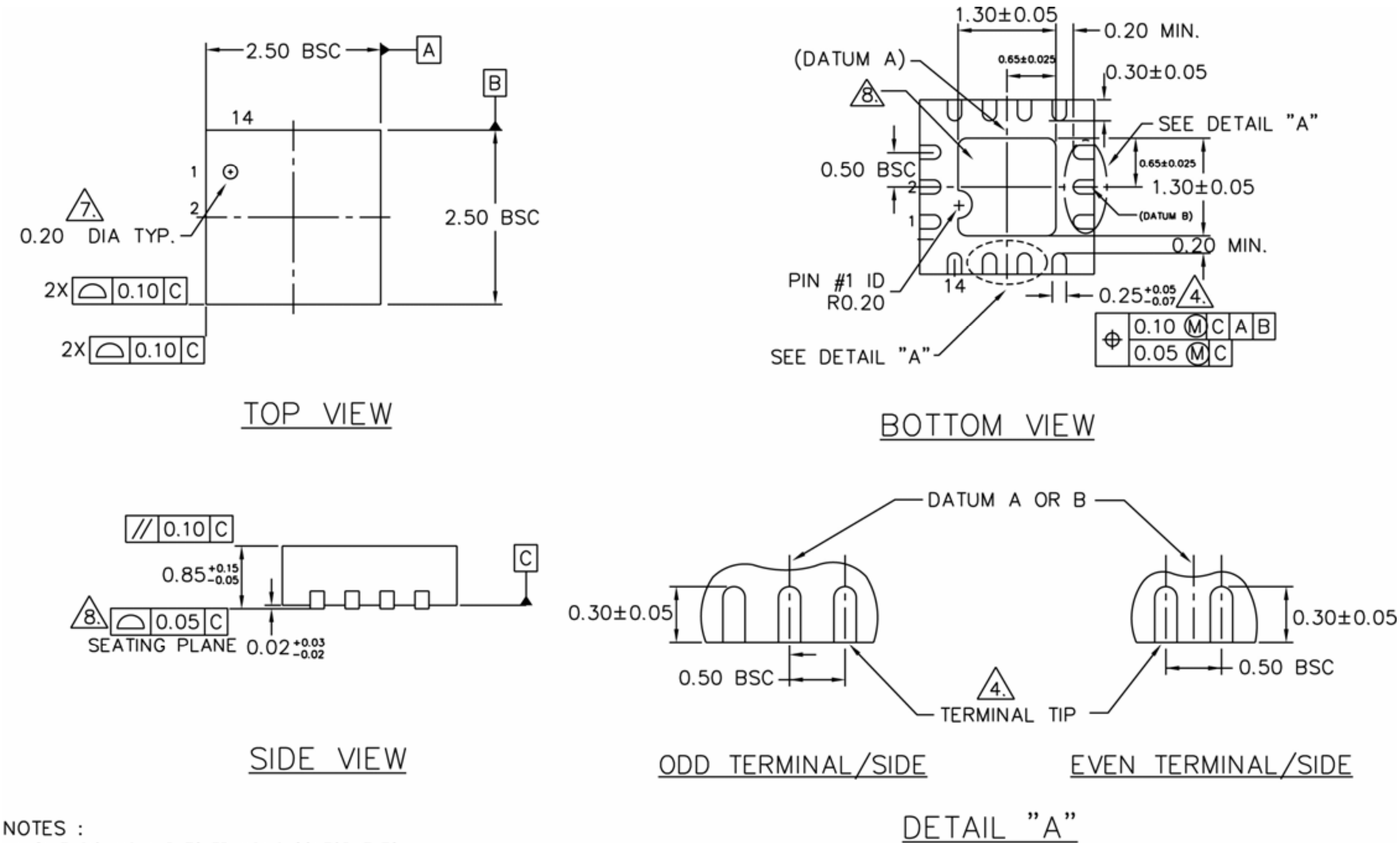


Top Layer



Fixed Bottom Layer

Package Information



NOTES :

1. DIMENSIONING AND TOLERANCING CONFORME TO ASME Y14.5 – 1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS, θ IS IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30mm FROM TERMINAL TIP. IF THE TERMINAL HAS THE OPTIONAL RADIUS ON THE OTHER END OF THE TERMINAL, THE DIMENSION b SHOULD NOT BE MEASURED IN THAT RADIUS AREA.
5. MAX. PACKAGE WARPAGE IS 0.05 mm.
6. MAXIMUM ALLOWABLE BURRS IS 0.076 mm IN ALL DIRECTIONS.
7. PIN #1 ID ON TOP WILL BE LASER MARKED.
8. BILATERAL COPLANARITY ZONE APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.

14-Pin (2.5mm x 2.5mm) Thin MLF® (MT)

MICREL, INC. 2180 FORTUNE DRIVE SAN JOSE, CA 95131 USA
TEL +1 (408) 944-0800 FAX +1 (408) 474-1000 WEB http://www.micrel.com