MIC2842A

High Efficiency 4 Channel WLED Driver with DAM™ and Single Wire Digital Control

General Description

The MIC2842A is a high efficiency White LED (WLED) driver designed to drive up to four LEDs and greatly extend battery life for portable display backlighting, and keypad backlighting in mobile devices. The MIC2842A architecture provides the highest possible efficiency by eliminating switching losses present in traditional charge pumps or inductive boost circuits. With a typical dropout of 40mV at 20mA, the MIC2842A allows the LEDs to be driven directly from the battery eliminating switching noise and losses present with the use of boost circuitry.

The MIC2842A features Dynamic Average Matching™ (DAM™) which is specifically designed to provide optimum matching across all WLEDs. The four channels are matched better than ±1.5% typical, ensuring uniform display illumination under all conditions. The LED brightness is preset by an external resistor and can be dimmed using a single-wire digital control. The digital interface 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; full brightness mode or battery saving mode for a total of 49 brightness steps.

The MIC2842A is available in the 2mm x 2mm 10-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

- **High Efficiency (no Voltage Boost losses)**
- Dynamic Average Matching™ (DAM™)
- Single wire digital control
- Input voltage range: 3.0V to 5.5V
- Dropout of 40mV at 20mA
- Matching better than ±1.5% (typical)
- Current accuracy better than ±1.5% (typical)
- Maintains proper regulation regardless of how many channels are utilized
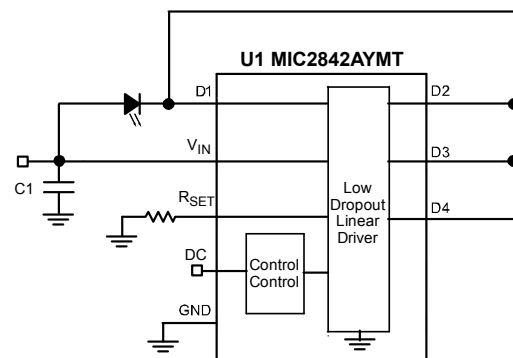- Available in a 10-pin 2mm x 2mm Thin MLF® package

Applications

- Mobile handsets
- Handset LCD backlighting
- Handset keypad backlighting
- Camera flash (see MIC2843A datasheet)
- Digital cameras
- Portable media/MP3 players
- Portable navigation devices (GPS)
- Portable application

Typical Application
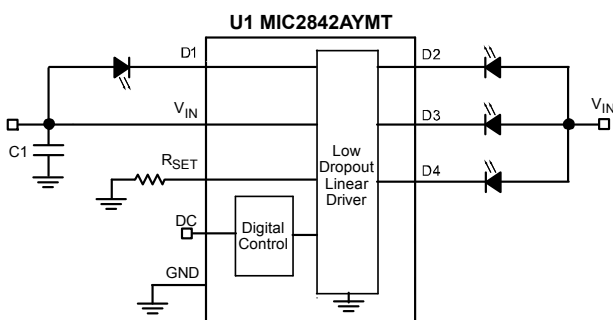
LCD Display Backlight with Four WLEDs

High Current Flash Driver

DAM and Dynamic Average Matching is a trademark of Micrel, Inc.
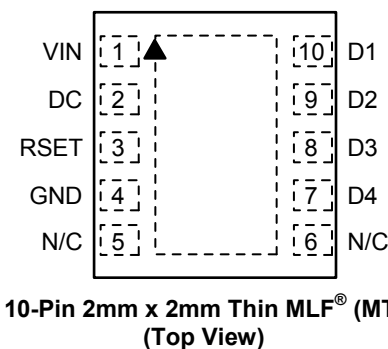MLF and *Micro*LeadFrame are registered trademark Amkor Technology Inc.

Ordering Information

Part Number	Mark Code[1]	Temperature Range	Package[2]
MIC2842AYMT	R2Y	–40°C to +125°C	10-Pin 2mm x 2mm Thin MLF®

Note:

1. Thin MLF® ▲ = Pin 1 identifier.

2. Thin MLF® is a GREEN RoHS compliant package. Lead finish is NiPdAu. Mold compound is halogen free.

Pin Configuration

```
VIN   [1]  ▲        [10]  D1
DC    [2]           [9]   D2
RSET  [3]           [8]   D3
GND   [4]           [7]   D4
N/C   [5]           [6]   N/C
```

10-Pin 2mm x 2mm Thin MLF® (MT)
(Top View)

Pin Description

Pin Number	Pin Name	Pin Function
1	VIN	Voltage Input. Connect at least 1µF ceramic capacitor between VIN and GND.
2	DC	Digital control input for linear WLED driver. See Digital Dimming Interface. Do not leave floating.
3	RSET	An internal 1.27V reference sets the nominal maximum WLED current. Example, apply a 20.5kΩ resistor between RSET and GND to set LED current to 20mA at 100% duty cycle.
4	GND	Ground.
5	NC	Not connected internally.
6	NC	Not connected internally.
7	D4	LED4 driver. Connect LED anode to VIN and cathode to this pin.
8	D3	LED3 driver. Connect LED anode to VIN and cathode to this pin.
9	D2	LED2 driver. Connect LED anode to VIN and cathode to this pin.
10	D1	LED1 driver. Connect LED anode to VIN and cathode to this pin.
EPAD	HS PAD	Heat sink pad. Not internally connected. Connect to ground.

Absolute Maximum Ratings[1]

Main Input Voltage (V_{IN}) .... –0.3V to +6V
Enable Input Voltage (V_{END}) .... –0.3V to +6V
LED Driver Voltage (V_{D1-D4}) .... –0.3V to +6V
Power Dissipation ....Internally Limited
Lead Temperature (soldering, 10sec.)......................260°C
Storage Temperature (T_s) ....–65°C to +150°C
ESD Rating[3]... ESD Sensitive

Operating Ratings[2]

Supply Voltage (V_{IN})..................................... +3.0V to +5.5V
Enable Input Voltage (V_{DC}) .... 0V to V_{IN}
LED Driver Voltage (V_{D1-D4}) .... 0V to V_{IN}
Junction Temperature (T_J) ....–40°C to +125°C
Junction Thermal Resistance
   2mm x 2mm Thin MLF® (θ_{JA})............................90°C/W

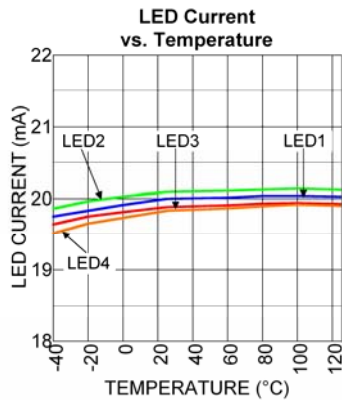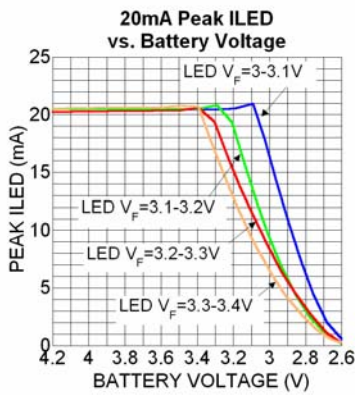## Electrical Characteristics

WLED Linear Drivers
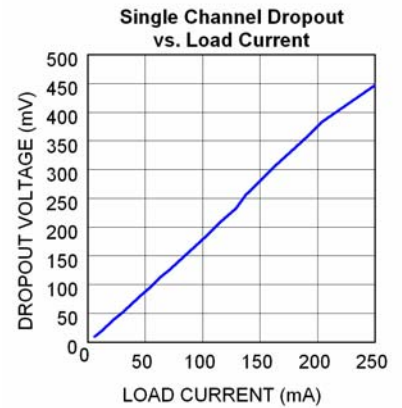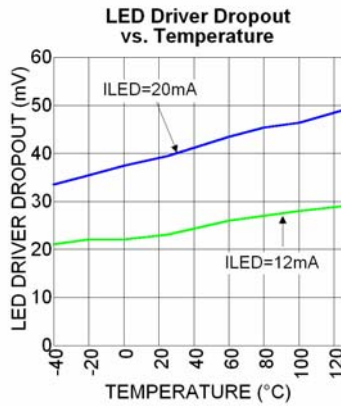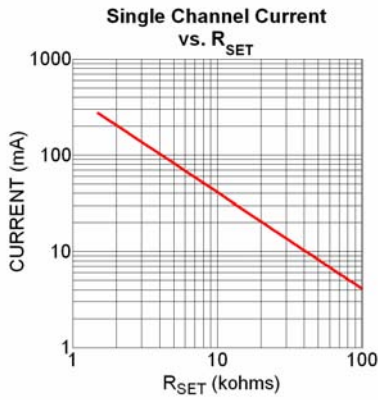
$V_{IN} = V_{DC} = 3.8V$, $R_{SET} = 20.5k\Omega$; $V_{D1-D4} = 0.6V$; $T_J = 25°C$, **bold** values indicate $-40°C \leq T_J \leq 125°C$; unless noted.

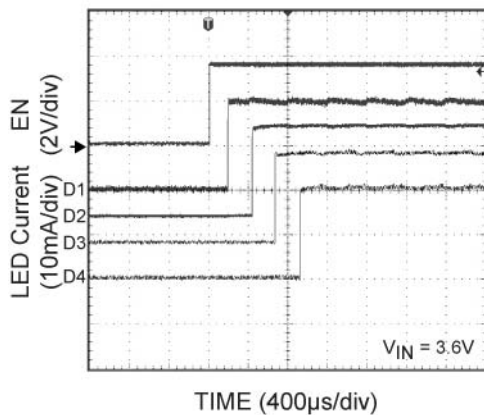| Parameter	Conditions	Min	Typ	Max	Units
Current Accuracy[4]			1.5		%
Matching[5]			1.5	3.6	%
Drop-out	Where I_{LED} = 90% of LED current seen at $V_{DROPNOM}$ = 0.6V, 100% brightness level		40	**80**	mV
Ground/Supply Bias Current	I_{OUT} = 20mA		1.4	1.8	mA
Shutdown Current (current source leakage)	V_{DC} = 0V > 1260µs		0.01	1	µA
Digital Dimming					
DC Input Voltage (V_{DC})	Logic Low			**0.2**	V
	Logic High	**1.2**			V
Enable Input Current	V_{DC} = 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	2		32	µs
t_{DELAY}	Time DC pin must remain high before a mode change can occur	100			µs
t_{PROG_SETUP}	First down edge must occur in this window during presetting brightness	5		75	µs
t_{START_UP}	Delay from DC is high to start up	140			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. Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5kΩ in series with 100pF.

4. As determined by average current of all channels in use and all channels loaded.

5. The current through each LED meets the stated limits from the average current of all LEDs.
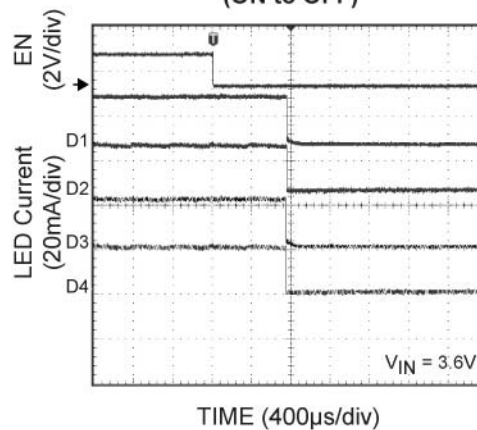
Typical Characteristics

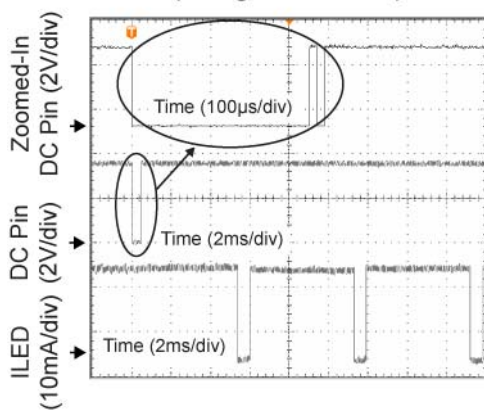**Single Channel Current vs. R_{SET}**

LED Driver Dropout vs. Temperature

Single Channel Dropout vs. Load Current

20mA Peak ILED vs. Battery Voltage

12mA Peak ILED vs. Battery Voltage

LED Current Matching vs. Temperature

LED Current vs. Temperature

Average LED Current vs. Brightness Level (30mA Peak)

Average LED Current vs. Brightness Level (20mA Peak)

Average LED Current vs. Brightness Level (5mA Peak)

Functional Characteristics

Turn On Synchronization (OFF to ON)

EN (2V/div)

LED Current (10mA/div)

D1
D2
D3
D4

$V_{IN} = 3.6V$

TIME (400µs/div)

Turn On Synchronization (ON to OFF)

EN (2V/div)

LED Current (20mA/div)

D1
D2
D3
D4

$V_{IN} = 3.6V$

TIME (400µs/div)

Step Down (1 Brightness Level)

Zoomed-In DC Pin (2V/div)

Time (100µs/div)

DC Pin (2V/div)

Time (2ms/div)

ILED (10mA/div)

Time (2ms/div)

Step Up (1 Brightness Level)

Zoomed-In DC Pin (2V/div)

Time (100µs/div)

DC Pin (2V/div)

Time (2ms/div)

ILED (10mA/div)

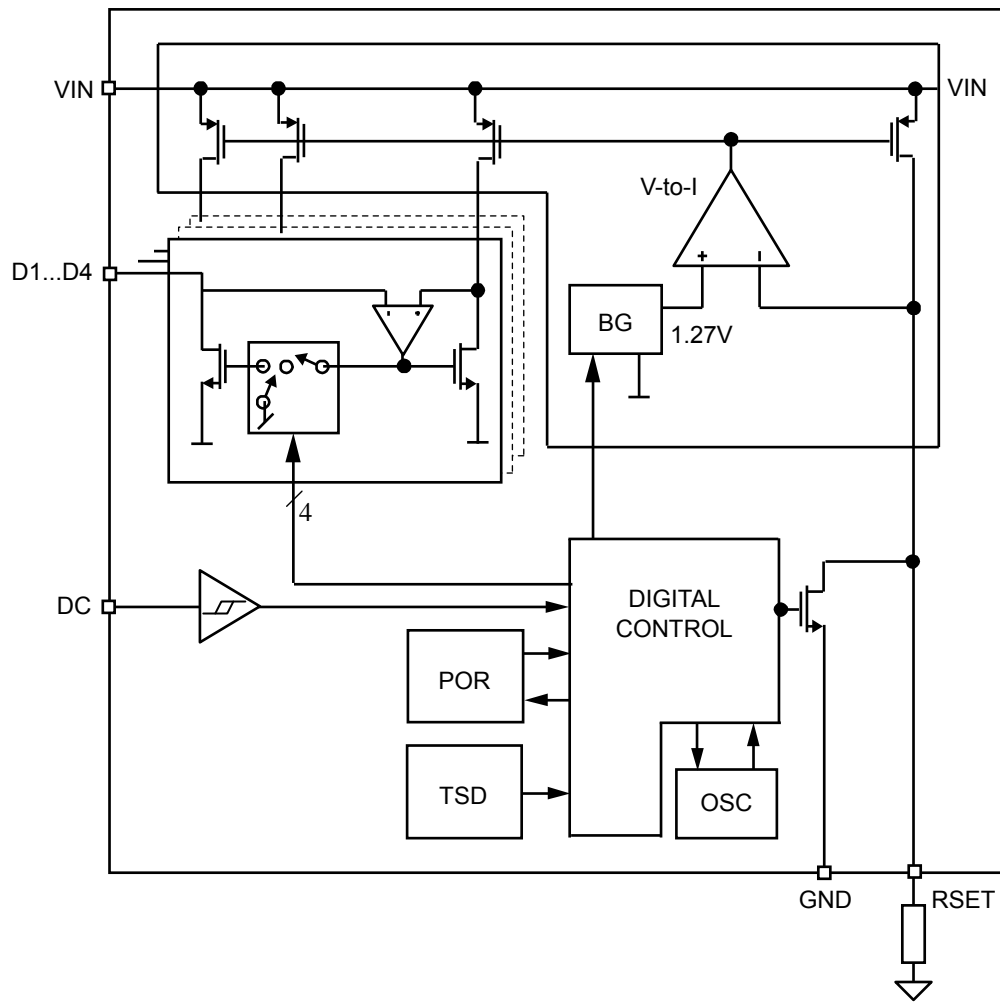Time (2ms/div)
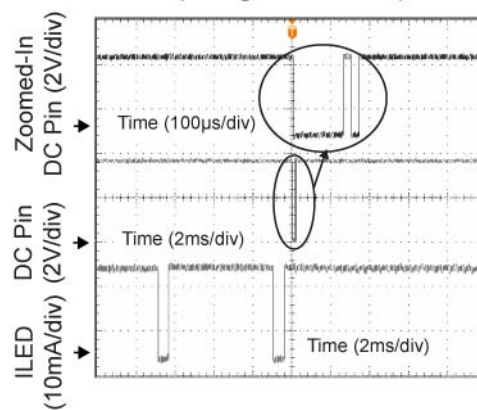
Functional Diagram

Figure 1. MIC2842A Functional Block Diagram

Functional Description

The MIC2842A is a four channel linear WLED driver. The WLED driver is designed to maintain proper current regulation with LED current accuracy of 1.5%, and typical matching of 1.5% across the four channels. The WLEDs are driven independently from the input supply and will maintain regulation with a dropout of 40mV at 20mA. The low dropout allows the WLEDs to be driven directly from the battery voltage and eliminates the need for large and inefficient charge pumps. The maximum WLED current for each channel is set via an external R_{SET} resistor. If dimming is desired the MIC2842A is controlled by a single-wire digital interface.

Block Diagram

As shown in Figure 1, the MIC2842A consists of 4 current mirrors set to copy a master current determined by R_{SET}. The linear drivers have a designated control block for enabling and dimming of the WLEDs. The MIC2842A dimming is controlled by an internal Digital Control Interface.

V_{IN}

The input supply (V_{IN}) provides power to the linear drivers and the control circuitry. The V_{IN} operating range is 3V to 5.5V. A bypass capacitor of 1µF 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).

DC

The DC pin is used to enable and control dimming of the linear drivers on the MIC2842A. See the MIC2842A Digital Dimming Interface in the Application Information section for details. Pulling the DC pin low for more than 1260µs puts the MIC2842A into a low Iq sleep mode. The DC pin cannot be left floating; a floating enable pin may cause an indeterminate state on the outputs. A 200kΩ pull down resistor is recommended.

R_{SET}

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

$$I_{LED} (mA) = 410 * ADC / R_{SET} (k\Omega) \qquad (1)$$

ADC is the average duty cycle of the LED current controlled by the single-wire digital dimming. See Table 1 for ADC values. When the device is fully on the average duty cycle equals 100% (ADC=1). A plot of I_{LED} versus R_{SET} at 100% duty cycle is shown in Figure 2.
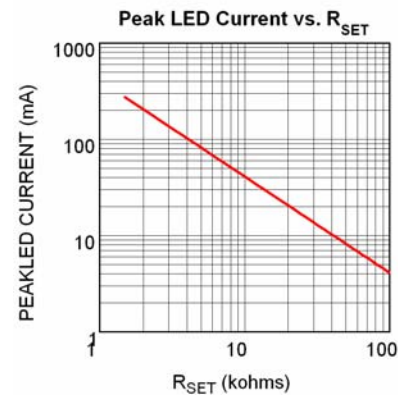

Figure 2. Peak LED Current vs. R_{SET}

D1-D4

The D1 through D4 pins are the linear driver inputs for WLED 1 through 4, respectively. When operating with less than four WLEDs, leave the unused D pins unconnected. The linear drivers are extremely versatile in that they may be used in any combination, for example D1 thru D4 leaving D3 unconnected or paralleled for higher current applications.

GND

The ground pin is the ground path for the linear drivers. The current loop for the ground should be as small as possible. The ground of the input capacitor 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

Brightness Level (0 - 48)	Average Duty Cycle (%)	Average I_{LED} (mA)	I_{PEAK} (mA)
0	100	12	
1	80	9.6	
2	60	7.2	
3	48.33	5.8	
4	36.67	4.4	
5	29.17	3.5	
6	21.67	2.6	
7	16.67	2	**60% of I_{PEAK}**
8	11.67	1.4	**R_{SET} = 20.5kΩ**
9	9.17	1.1	**I_{PEAK} = 12mA**
10	6.67	0.8	
11	5	0.6	
12	3.33	0.4	
13	2.5	0.3	
14	1.67	0.2	
15	0.83	0.1	
16	0	0	**0**
17	0.83	0.1	**60% of I_{PEAK}**
18	0.83	0.17	
19	1.25	0.25	
20	1.67	0.33	
21	2.08	0.42	
22	2.5	0.5	
23	2.92	0.58	
24	3.33	0.67	
25	4.17	0.83	
26	5	1	
27	5.83	1.17	
28	6.67	1.33	
29	7.92	1.58	
30	9.17	1.83	
31	10.42	2.08	
32	11.67	2.33	**100% of I_{PEAK}**
33	14.17	2.83	**R_{SET} = 20.5kΩ**
34	16.67	3.33	**I_{PEAK} = 20mA**
35	19.17	3.83	
36	21.67	4.33	
37	25.42	5.08	
38	29.17	5.83	
39	32.92	6.58	
40	36.67	7.33	
41	42.5	8.5	
42	48.33	9.67	
43	54.17	10.83	
44	60	12	
45	70	14	
46	80	16	
47	90	18	
48	100	20	

Table 1. Digital Interface Brightness Level Table

Dynamic Average Matching (DAM™)

The Dynamic Average Matching™ architecture multiplexes four voltage references to provide highly accurate LED current and channel matching. The MIC2842A achieves industry leading LED channel matching of 1.5% across the entire dimming range.
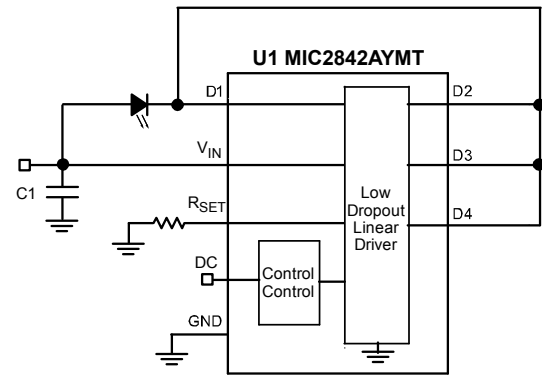
High Current Parallel Operation

Figure 3. High Current LED Driver Circuit

The linear drivers are independent of each other and can be used individually or paralleled in any combination for higher current applications. A single WLED can be driven with all 4 linear drivers by connecting D1 through D4 in parallel to the cathode of the WLED as shown in Figure 3. This will generate a current 4 times the individual channel current and can be used for higher current WLEDs such as those used in flash or torch applications.

Digital Dimming

The MIC2842A utilizes an internal dynamic pulse width to generate an average duty cycle for each brightness level. By varying the duty cycle the average current achieves 49 logarithmically spaced brightness levels. This generates a brightness scale similar to the perception of brightness seen by the "human eye." Figure 4 shows the LED current at different brightness levels. When dimming, the D1 through D4 pins are 60° out of phase from each other to reduce electromagnetic interference. The MIC2842A uses an internal frequency of approximately 700Hz to dim the WLEDs. With the period of approximately 1.43ms, the 60° phase shift equates to a timing offset of 238μs. As shown in Figure 5, brightness level 32 was selected to show the phase shift across the channels.
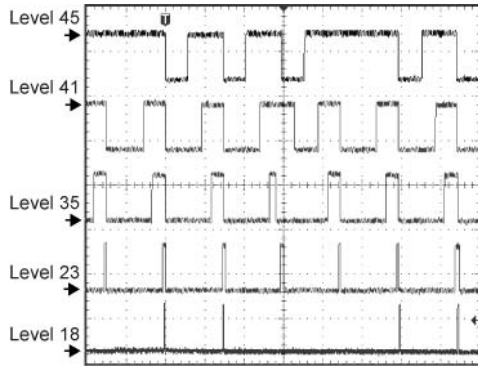
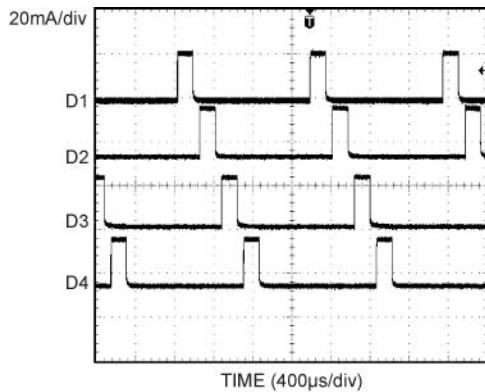**Figure 4. LED Current with Brightness Level Change**

Figure 5. LED Current 60° Phase Shift

Digital Dimming Interface

The MIC2842A incorporates an easy to use single-wire, serial programming interface that allows users to set LED brightness up to 49 different levels, as shown in the table1.

Brightness levels 0 through 15 are logarithmically spaced with a peak current equal to 60% of the current programmed by R_{SET}. Brightness level 16 is provided for applications that want to "fade to black" with no current flowing through the LEDs. Brightness Level 17 has the same duty cycle as level 18, but the peak current is only 60% of the current set by R_{SET}; therefore, the average current is 0.1mA. Brightness levels 18 through 48 are also logarithmically spaced, but the peak current is equal to 100% of the current determined by R_{SET}. Refer to Table 1 for the translation from brightness level to average LED duty cycle and current. The MIC2842A 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 LEDs can be turned on at any particular brightness level.

Start Up

Assuming the MIC2842A has been off for a long time and no presetting brightness command is issued (presetting is discussed in a later section), the MIC2842A will start-up in its default mode approximately 140µs (t_{START_UP}) after a logic level high is applied to the DC pin, shown in Figure 6. In the default mode the LEDs are turned on at the maximum brightness level of 48. Each falling edge 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.
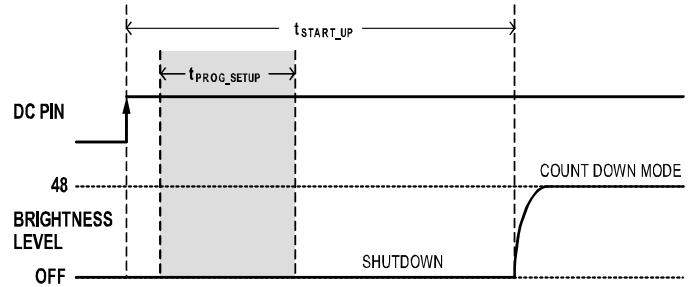

Figure 6. Typical Start-Up Timing

Shutdown

Whenever the DC input pin is pulled low for a period greater than or equal to $t_{SHUTDOWN}$ (1260µs), the MIC2842A will be shutdown as shown in Figure 7.

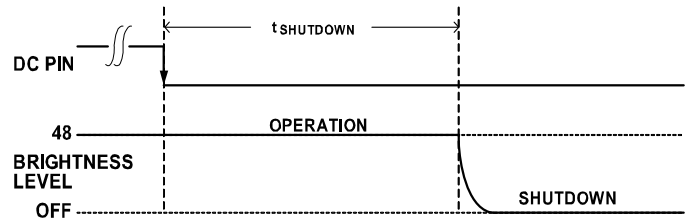**Figure 7. Shutdown Timing**

Once the device is shutdown, the control circuit supply is disabled and the LEDs are turned off, drawing only 0.01µA. Brightness level information stored in the MIC2842A prior to shutdown will be erased.

Count Up Mode/Count Down Mode

The mode of MIC2842A can be in either Count Up Mode or Count Down Mode. The Count Down/Up 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 MIC2842A 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 8. The device will remain in

Count Up Mode until its mode is changed to Count Down Mode or by disabling the MIC2842A to reset the mode back to default.
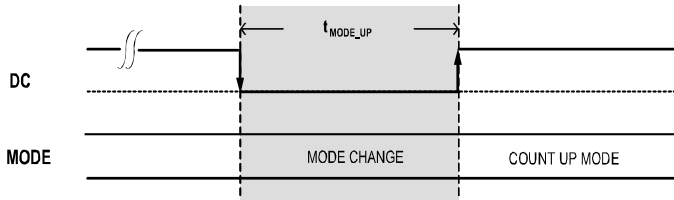

Figure 8. Mode Change to Count Up

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 9. Now the internal circuitry will remain in Count Down Mode until changed to Count Up as described previously.
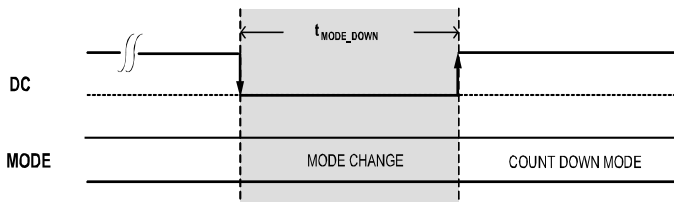

Figure 9. Mode Change to Count Down

Programming the Brightness Level

MIC2842A is designed to start driving the LEDs 140µs (t_{START_UP}) after the DC pin is first pulled high at the maximum brightness level of 48. After start up, the internal control logic is ready to decrease the LED brightness upon receiving programming pulses (negative edges applied to DC pin). Since MIC2842A starts in Count Down Mode, the brightness level can be decreased without a mode change by applying two programming pulses, as shown in Figure 10. Note that the extra pulse is needed to decrease brightness because the first edge is ignored. Anytime the first falling edge occurs later 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 2µs to 32µs. The MIC2842A will remember the brightness level and mode it was changed to. For proper operation, ensure that the DC pin remains high for at least t_{DELAY} (140µs) before issuing a mode change command.
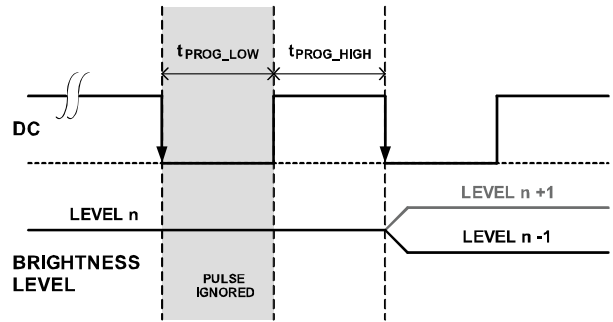
Figure 10. Brightness Programming Pulses

Multiple brightness levels can be set as shown in Figure 11. When issuing multiple brightness level adjustments to the DC pin, ensure both t_{PROG_LOW} and t_{PROG_HIGH} are within 2µs to 32µs.

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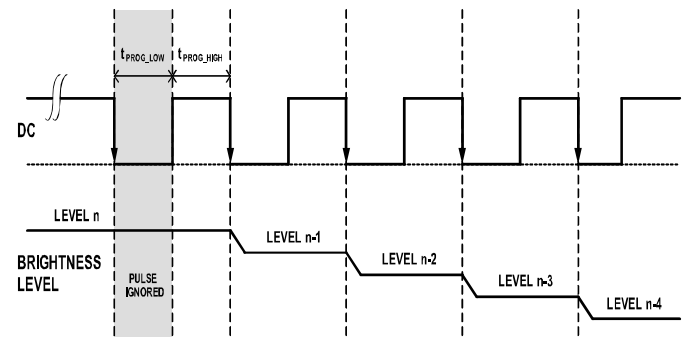

Figure 11. Decreasing Brightness Several Levels

As mentioned, MIC2842A can be programmed to set LED drive current to produce one of 49 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.

Counter Roll-Over

The MIC2842A internal up/down counter contains registers from 0 to 48 (49 levels). When the brightness level is at 0 and a programming pulse forces the brightness to step down, then the counter will roll-over to level 48. This is illustrated in Figure 12.
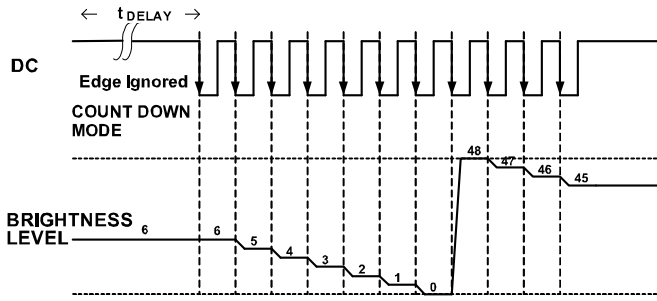
Figure 12. Down Counter Roll-Over

Similarly, when the counter mode is set to Count Up and a programming pulse forces the brightness level to step up from level 48, then the counter will roll-over to level 0 as illustrated in Figure 13.
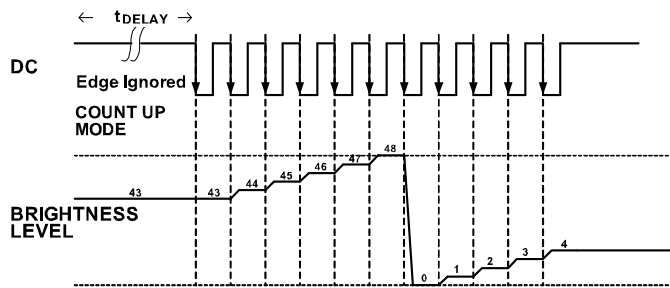

Figure 13. Up Counter Roll-Over

One-Step Brightness Changes

The "One-Step" brightness change procedure relieves the user from keeping track of the MIC2842A'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.
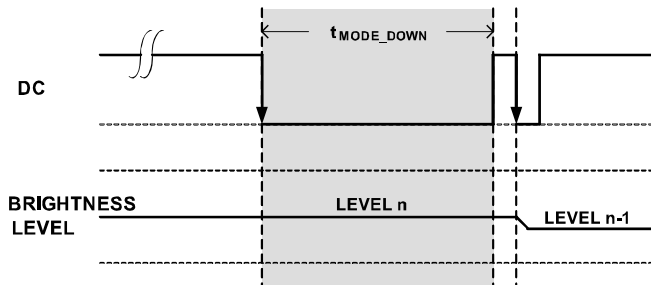
Figure 14. One-Step Brightness Decrease

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} (2µs to 32µs) as shown in Figure 14. 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}

(2µs to 32µs). Figure 15 illustrates the proper timing for execution of a One-Step Brightness Increase.
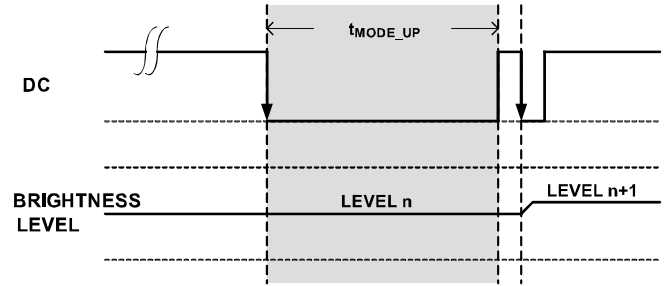
Figure 15. One-Step Brightness Increase

Presetting Brightness

Presetting the brightness will allow the MIC2842A start-up at any brightness level (0 to 48). The MIC2842A does not turn on the linear LED driver until the 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 5µs to 75µs after the DC pin is first pulled high. The 70µs timeframe between 5µs and 75µs is the t_{PROG_SETUP} period. The first presetting pulse edge must occur somewhere between the timeframe of 5µs to 75µs, otherwise the MIC2842A may continue to start up at the full (default) brightness level.
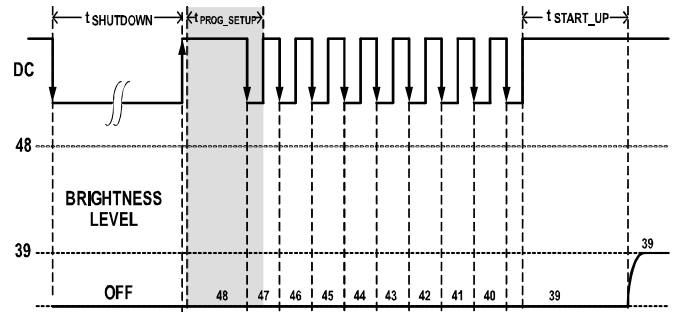

Figure 16. Presetting Timing

Figure 16 shows the correct presetting sequence to set the MIC2842A brightness to level 39 prior to start up. Notice that when using the presetting feature the first programming pulse is not 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 2µs to 32µs.)

Typical Application
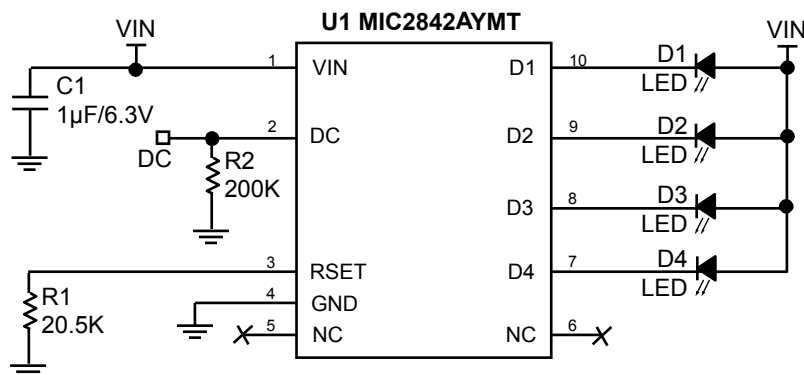
Bill of Materials

Item	Part Number	Manufacturer	Description	Qty.
C1	C1608X5R0J105K	TDK[1]	Ceramic Capacitor, 1µF, 6.3V, X5R, Size 0603	1
	06036D105KAT2A	AVX[2]		
	GRM188R60J105KE19D	Murata[3]		
	VJ0603G225KXYAT	Vishay[4]		
D1 – D4	SWTS1007	Seoul Semiconductor[5]	WLED	4
	99-116UNC	EverLight[6]		
R1	CRCW060320K5F5EA	Vishay[4]	Resistor, 20.5k, 1%, 1/16W, Size 0603	1
R2	CRCW06032003FKEA	Vishay[4]	Resistor, 200k, 1%, 1/16W, Size 0603	1
U1	**MIC2842AYMT**	**Micrel, Inc.[7]**	**High Efficiency 4 Channel WLED Driver with Single Wire Digital Control**	**1**

Notes:

1. TDK: www.tdk.com

2. AVX: www.avx.com

3. Murata: www.murata.com

4. Vishay: www.vishay.com

5. Seoul Semiconductor: www.seoulsemicon.com

6. EverLight: www.everlight.com

7. **Micrel, Inc.: www.micrel.com**

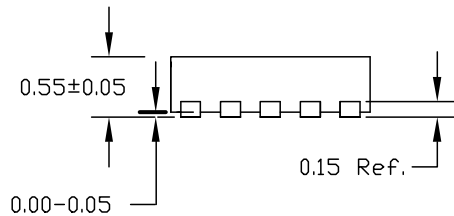# PCB Layout Recommendations
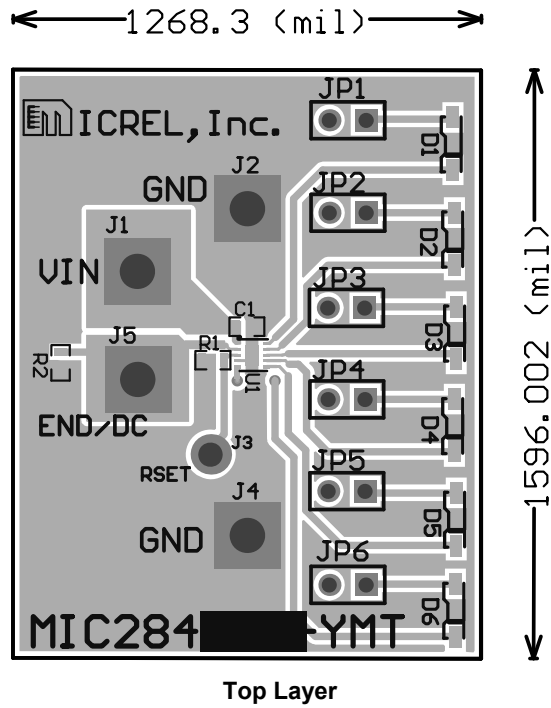
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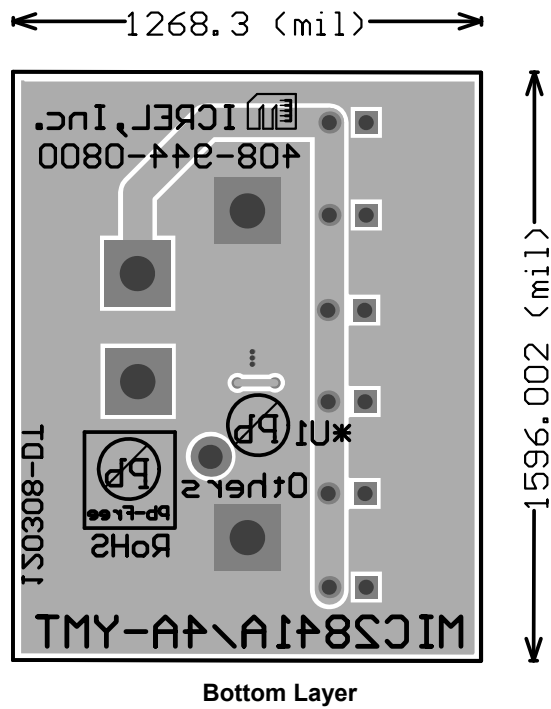
Bottom Layer

Package Information
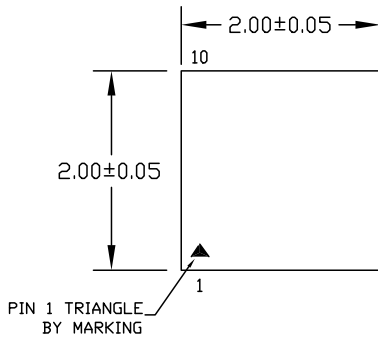
TOP VIEW
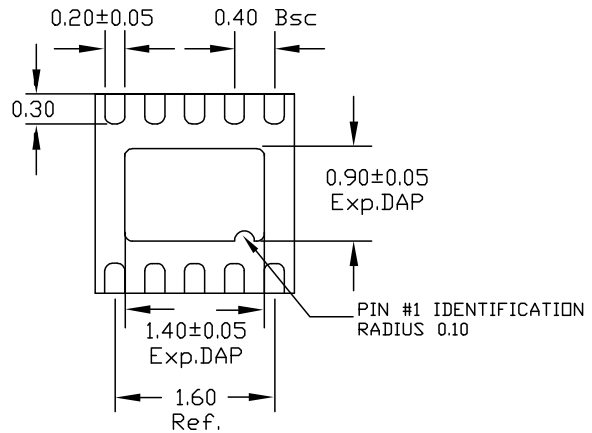
BOTTOM VIEW

NOTE:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. MAX. PACKAGE WARPAGE IS 0.08 mm.
3. MAXIMUM ALLOWABE BURRS IS 0.08 mm IN ALL DIRECTIONS.
4. PIN #1 ID WILL BE LASER MARKED.

SIDE VIEW

10-Pin (2mm x 2mm) Thin MLF® (MT)