



## MIC2860-D

### High Efficiency 2 Channel WLED Driver with Single Wire Digital Control

#### General Description

The MIC2860-2D is a high efficiency White LED (WLED) driver designed to drive two WLEDs and greatly extend battery life for portable display backlighting, and keypad backlighting in low cost mobile devices. The MIC2860-2D architecture provides the highest possible efficiency by eliminating switching losses present in traditional charge pumps or inductive boost circuits. It features a typical dropout of 52mV at 30.2mA per channel. This allows the WLEDs to be driven directly from the battery eliminating switching noise and losses present with the use of boost circuitry.

The two channels have better than  $\pm 0.5\%$  matching, which ensures uniform display illumination under all conditions. The WLEDs brightness is externally preset by a resistor and dimmed using a single wire digital control signal. The MIC2860-2D single wire digital interface accepts digital programming pulses providing 32 dimming steps.

The MIC2860-2D is available in Thin SOT-23 and SC-70 six pin packages with a junction temperature range of  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

Datasheets and support documentation can be found on Micrel's web site at: [www.micrel.com](http://www.micrel.com).

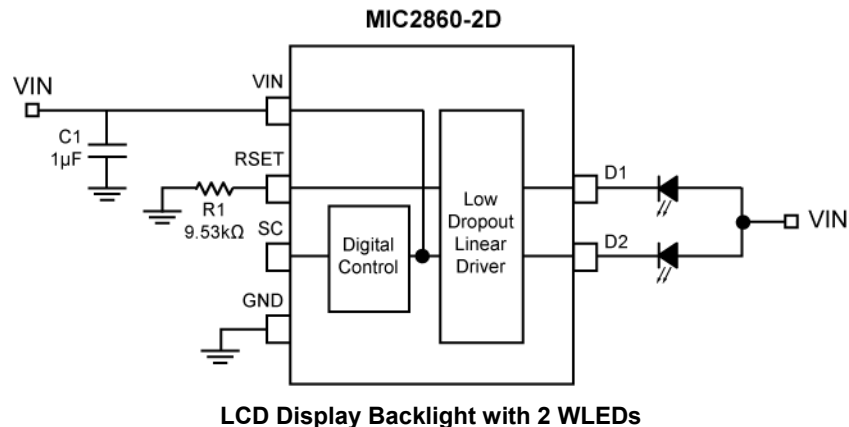
#### Features

- High Efficiency (no switching losses)
- No charge pumps
- 2 WLED driver channels
- Single wire digital control
- Input voltage range: 3.0V to 5.5V
- WLED driver dropout of 52mV at 30.2mA
- Matching better than  $\pm 0.5\%$  (typical)
- Current Accuracy better than  $\pm 1.0\%$  (typical)
- Available in Thin SOT-23 and SC-70 6 pin packages

#### Applications

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

#### Typical Application



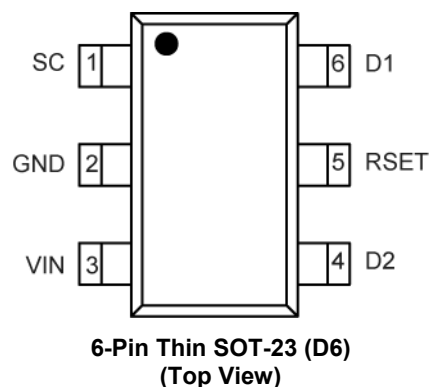
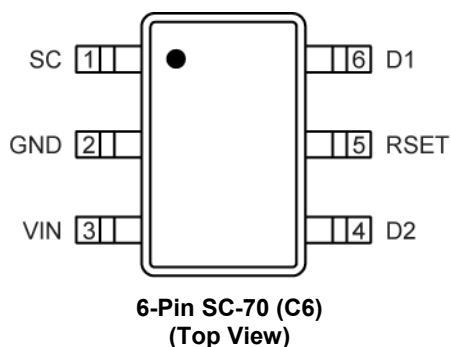
## Ordering Information

| Part Number   | Mark Code <sup>(1)</sup> | Temperature Range | Package <sup>(2)</sup> |
|---------------|--------------------------|-------------------|------------------------|
| MIC2860-2DYC6 | <u>62</u> D              | -40°C to +85°C    | 6-Pin SC-70            |
| MIC2860-2DYD6 | <u>602</u> D             | -40°C to +85°C    | 6-Pin Thin SOT-23      |

### Note:

- Under bar symbol (   ) may not be to scale.
- Package is GREEN RoHS compliant. Lead finish is NiPdAu. Mold compound is halogen free.

## Pin Configuration



## Pin Description

| Pin Number<br>MIC2860-2D | Pin Name | Pin Function   |
|--------------------------|----------|--|
| 1                        | SC       | Serial Control Digital input. Do not leave floating.   |
| 2                        | GND      | Ground.  |
| 3                        | VIN      | Voltage Input. Connect at least 1 $\mu$ F ceramic capacitor between VIN and GND.   |
| 4                        | D2       | LED2 driver. Connect LED anode to VIN and cathode to this pin. Do not leave floating. <sup>(1)</sup>   |
| 5                        | RSET     | Connect an external resistor from this pin to GND to set the maximum LED current. Example, apply a 9.53k $\Omega$ resistor between RSET and GND to set LED current to 30mA at 100% duty cycle. |
| 6                        | D1       | LED1 driver. Connect LED anode to VIN and cathode to this pin. Do not leave floating. <sup>(1)</sup>   |

**Note 1.** When driving only 1 LED, connect D1 and D2 in parallel to the LED cathode and adjust the RSET resistor for half the desired output.

**Absolute Maximum Ratings<sup>(1)</sup>**

|                                      |                    |
|--------------------------------------|--------------------|
| Main Input Voltage ( $V_{IN}$ )      | -0.3V to +6V       |
| Enable Input Voltage ( $V_{SC}$ )    | -0.3V to $V_{IN}$  |
| LED Driver Voltage ( $V_{D1, D2}$ )  | -0.3V to $V_{IN}$  |
| Power Dissipation                    | Internally Limited |
| Lead Temperature (soldering, 10sec.) | 260°C              |
| Storage Temperature ( $T_s$ )        | -65°C to +150°C    |
| ESD Rating <sup>(3)</sup>            | ESD Sensitive      |

**Operating Ratings<sup>(2)</sup>**

|                                     |                 |
|-------------------------------------|-----------------|
| Supply Voltage ( $V_{IN}$ )         | +3.0V to +5.5V  |
| Enable Input Voltage ( $V_{SC}$ )   | 0V to $V_{IN}$  |
| LED Driver Voltage ( $V_{D1, D2}$ ) | 0V to $V_{IN}$  |
| Junction Temperature ( $T_J$ )      | -40°C to +125°C |
| Junction Thermal Resistance         |                 |
| SC-70 ( $\theta_{JA}$ )             | 256 °C /W       |
| SOT-23 ( $\theta_{JA}$ )            | 177 °C /W       |

**Electrical Characteristics**

$V_{IN} = V_{SC} = 3.6V$ ,  $C_{IN} = 1\mu F$ ,  $R_{SET} = 9.53k\Omega$ ;  $V_{D1, D2} = 0.6V$ ;  $T_J = 25^\circ C$ , **bold** values indicate  $-40^\circ C \leq T_J \leq 85^\circ C$ ; unless noted.

| Parameter                                 | Conditions   | Min          | Typ       | Max          | Units   |
|---|--|--------------|-----------|--------------|---------|
| Current Accuracy <sup>(4)</sup>           |  | <b>27.18</b> | 30.2      | <b>33.22</b> | mA      |
| Matching <sup>(5)</sup>                   |  |              | $\pm 0.5$ | $\pm 3$      | %       |
| Drop-out ( $V_{D1, D2}$ )                 | Where $I_{LED} = 90\%$ of LED current seen at $V_{DROPNOM} = 0.6V$ , 100% brightness level |              | 52        | <b>125</b>   | mV      |
| Ground/Supply Bias Current                | $I_{OUT} = 30.2mA$   |              | 0.7       | <b>1.5</b>   | mA      |
| Shutdown Current (current source leakage) | $V_{SC} = 0V > 500\mu s$   |              | 0.01      | 1            | $\mu A$ |

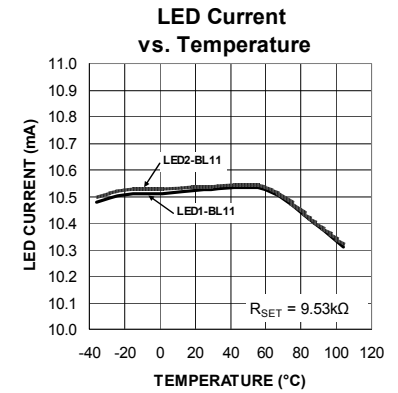
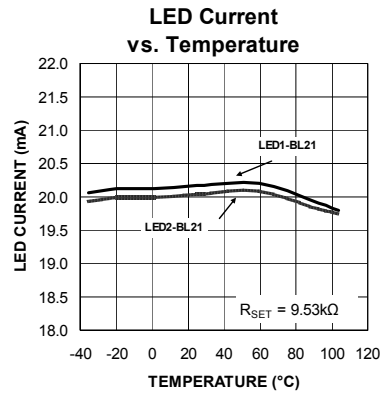
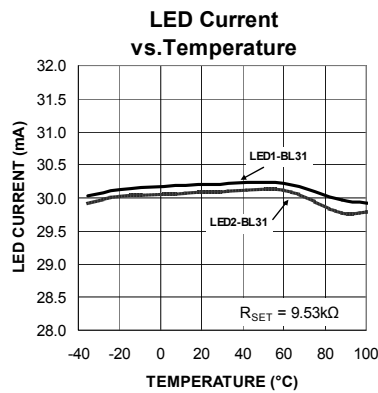
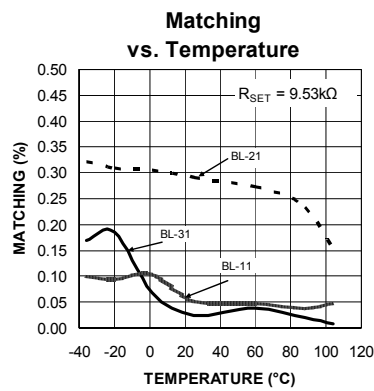
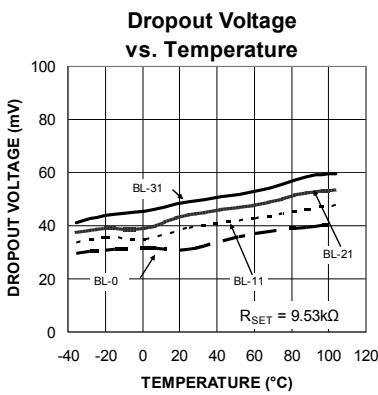
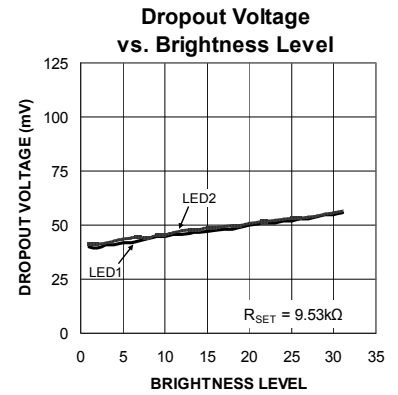
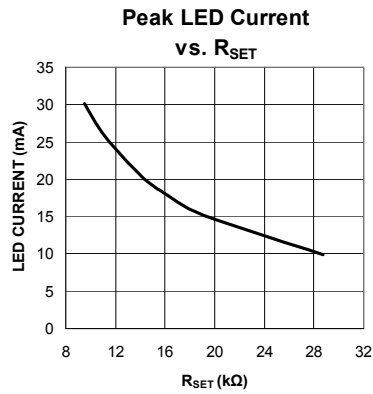
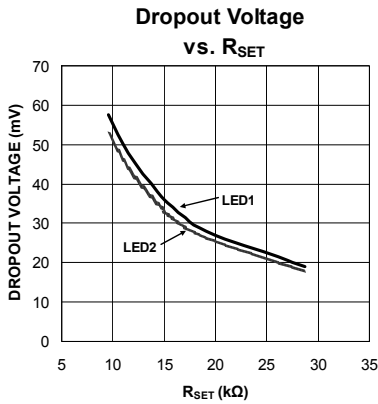
**Digital Dimming**

|                                    |  |            |      |            |         |
|------------------------------------|--|------------|------|------------|---------|
| $V_{SC}$ Input Voltage             | Logic Low  |            |      | <b>0.4</b> | V       |
|                                    | Logic High   | <b>1.4</b> |      |            | V       |
| $V_{SC}$ Enable Input Current      | $V_{SC} = 1.2V$  |            | 0.01 | 1          | $\mu A$ |
| $t_{SHUTDOWN}$                     | Time SC pin is low to put into shutdown                |            | 100  | <b>500</b> | $\mu s$ |
| $t_{PROG\_HIGH}$ , $t_{PROG\_LOW}$ | Time for valid SC edge; Ignored if outside limit range | <b>0.3</b> |      | <b>75</b>  | $\mu s$ |
| $t_{START\_UP}$                    | Delay from SC is high to start up                      |            | 33   |            | $\mu s$ |

**Notes:**

- Exceeding the absolute maximum rating may damage the device.
- The device is not guaranteed to function outside its operating rating.
- Devices are ESD sensitive. Handling precautions recommended. Human body model, 1.5k $\Omega$  in series with 100pF.
- As determined by average current of all channels in use and all channels loaded.
- The current through each LED meets the stated limits from the average current of all LEDs.

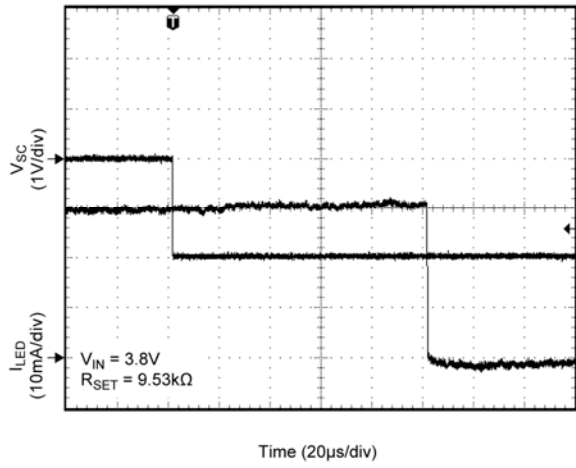
# Typical Characteristics



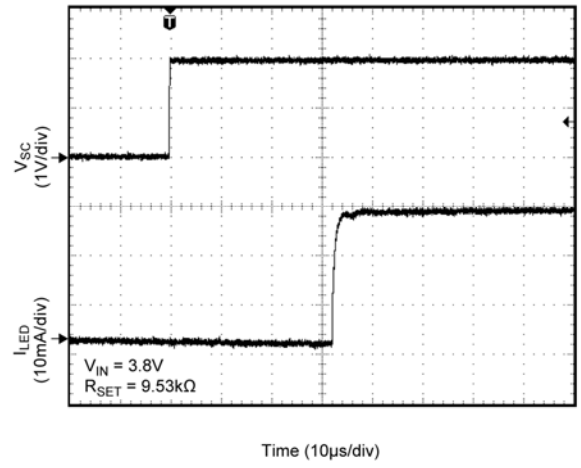
Note: BL = Brightness Level

# Functional Characteristics

### ILED Response to SC Signal Turn-Off Time



### ILED Response to SC Signal Turn-On Time



## Functional Diagram

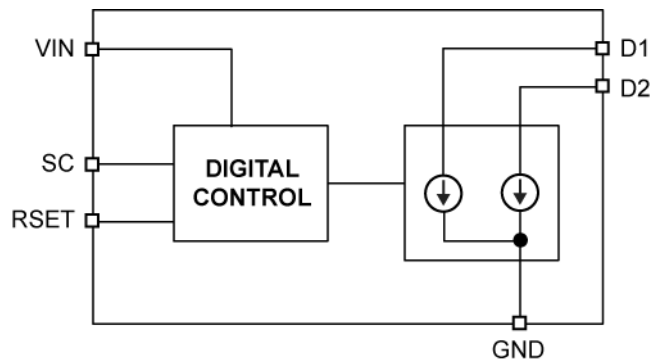


Figure 1. MIC2860-2D Functional Block Diagram

## Functional Description

The MIC2860-2D is a 2 channel WLED driver. The WLED driver is designed to maintain proper current regulation with LED current accuracy of 1.0% while the typical matching between the 2 channels is 0.5% at room temperature. The WLEDs are driven independently from the input supply and will maintain regulation with a dropout of 52mV at 30.2mA. The low dropout of the linear drivers 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 resistor.

### Block Diagram

As shown in Figure 1, the MIC2860-2D consists of 2 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 MIC2860-2D 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. Due to wire inductance a minimum bypass capacitor of 1 $\mu$ F should be placed close to the input ( $V_{IN}$ ) pin and the ground (GND) pin. Refer to the layout recommendations section for details on placing the input capacitor (C1).

### SC

The SC pin is equivalent to the enable pin for the linear drivers on the MIC2860-2D. It can also be used for dimming using a single wire digital interface. See the MIC2860-2D Digital Dimming Interface in the Application Information section for details. Do not leave control pins floating.

### $R_{SET}$

The  $R_{SET}$  pin is used by connecting an  $R_{SET}$  resistor to ground to set the peak current of the linear drivers. The maximum LED current set by the  $R_{SET}$  resistor is shown in the table below:

| $R_{SET}$ (k $\Omega$ ) | $I_{LED}$ (mA) |
|-------------------------|----------------|
| 9.53                    | 30.2           |
| 11.5                    | 25.0           |
| 14.3                    | 20.1           |
| 15.8                    | 18.2           |
| 19.1                    | 15.1           |
| 28.7                    | 10.0           |

Table 1. Maximum LED Current vs.  $R_{SET}$  Resistor Values

A plot of maximum  $I_{LED}$  versus  $R_{SET}$  is shown in Figure 2.

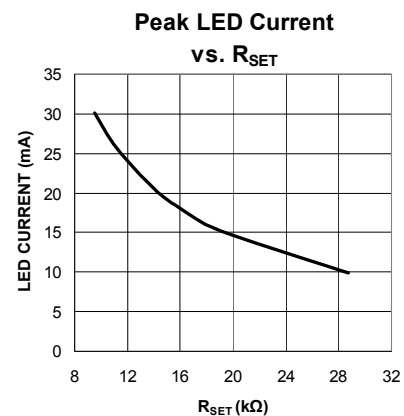


Figure 2. Peak LED current vs.  $R_{SET}$

**D1, D2**

The D1 and D2 pins are the linear driver inputs for WLED 1 and 2 respectively. Connect the anodes of the WLEDs to  $V_{IN}$  and each cathode of the WLEDs to D1 and D2. When operating with a single WLED, D1 and D2 should be connected to the WLED cathode to parallel the outputs for improved dropout performance. Paralleling these pins can also be done to drive a higher current through a single WLED. Do not leave these pins floating

**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

### Digital Dimming Interface

| Brightness Level (0 - 31) | I <sub>LED</sub> (mA)<br>R <sub>SET</sub> =14.3kΩ | I <sub>LED</sub> (mA)<br>R <sub>SET</sub> =19.1kΩ | % of Max. Current |
|---------------------------|---|---|-------------------|
| 31                        | 20.1  | 15.1  | 100               |
| 30                        | 19.4  | 14.6  | 96.7              |
| 29                        | 18.8  | 14.1  | 93.7              |
| 28                        | 18.2  | 13.6  | 90.4              |
| 27                        | 17.5  | 13.1  | 87.1              |
| 26                        | 16.8  | 12.6  | 83.8              |
| 25                        | 16.2  | 12.2  | 80.8              |
| 24                        | 15.6  | 11.7  | 77.5              |
| 23                        | 14.9  | 11.2  | 74.2              |
| 22                        | 14.2  | 10.7  | 70.9              |
| 21                        | 13.6  | 10.2  | 67.9              |
| 20                        | 13.0  | 9.7   | 64.6              |
| 19                        | 12.3  | 9.2   | 61.3              |
| 18                        | 11.6  | 8.7   | 57.9              |
| 17                        | 11.0  | 8.3   | 55.0              |
| 16                        | 10.4  | 7.8   | 51.7              |
| 15                        | 9.7   | 7.3   | 48.3              |
| 14                        | 9.1   | 6.8   | 45.0              |
| 13                        | 8.5   | 6.4   | 42.1              |
| 12                        | 7.8   | 5.8   | 38.7              |
| 11                        | 7.1   | 5.3   | 35.4              |
| 10                        | 6.5   | 4.8   | 32.1              |
| 9                         | 5.9   | 4.4   | 29.1              |
| 8                         | 5.2   | 3.9   | 25.8              |
| 7                         | 4.5   | 3.4   | 22.5              |
| 6                         | 3.9   | 2.9   | 19.2              |
| 5                         | 3.3   | 2.4   | 16.2              |
| 4                         | 2.6   | 1.9   | 12.9              |
| 3                         | 1.9   | 1.4   | 9.6               |
| 2                         | 1.3   | 0.9   | 6.3               |
| 1                         | 0.7   | 0.5   | 3.3               |
| 0                         | 0.3   | 0.2   | 1.7               |

**Table 2. Digital Interface Brightness Level Table**

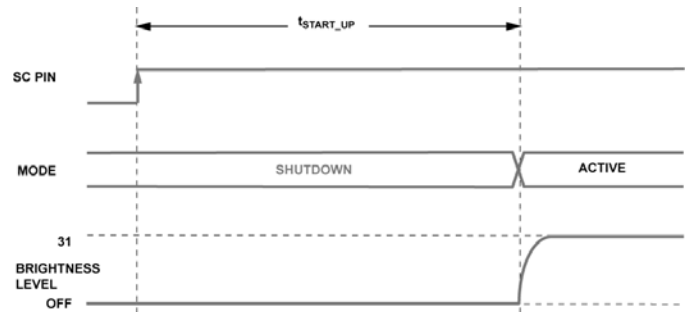
The MIC2860-2D incorporates an easy to use single wire, serial programming interface that allows users to set WLED brightness up to 32 different levels as shown in Table 2. To calculate the brightness level for other R<sub>SET</sub> values, multiply the percentage of max current values by the maximum LED current set by the R<sub>SET</sub> resistor value from table 1.

For example with R<sub>SET</sub> = 19.1kΩ, the max current (brightness level = 31) is 15.1mA and brightness level 20 would equate to 15.1mA x 0.646 = 9.7mA.

Brightness levels are linearly spaced with a maximum current equal to 100% of the current set by R<sub>SET</sub>. The MIC2860-2D is designed to receive programming pulses to decrease brightness from the initial start up default (level 1 maximum current). Once the brightness change signal is received, the SC 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.

#### Start Up

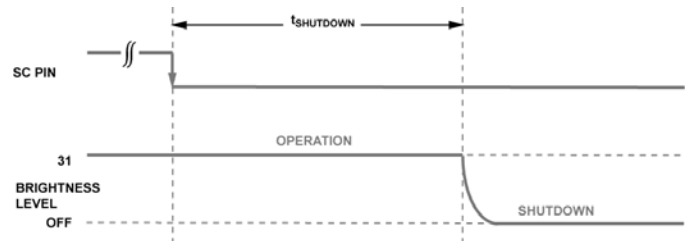
Assuming the MIC2860-2D has been off for a long time, the MIC2860-2D will start-up in its default mode approximately 33μs (t<sub>START\_UP</sub>) after a logic level high is applied to the SC pin. In the default mode the WLEDs are turned on at the maximum brightness (level 31). Each falling edge will cause the default brightness level to decrease by one.



**Figure 3. Typical Start-Up Timing**

#### Shutdown

When the SC input pin is pulled low for a period greater than or equal to t<sub>SHUTDOWN</sub> (500μs), the MIC2860-2D will turn off the current sinks as shown in Figure 4.



**Figure 4. 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 MIC2860-2D prior to shutdown will be erased and upon a following startup signal the WLEDs will be turned on at maximum brightness (level 31).

#### Programming the Brightness Level

MIC2860-2D is designed to start driving the WLEDs



33 $\mu$ s ( $t_{START\_UP}$ ) after the SC pin is first pulled high at the maximum brightness level 1. After start up, the internal control logic is ready to decrease the WLED brightness upon receiving programming pulses (positive edges applied to SC pin). The brightness level can be decreased one level by applying a single programming pulse as shown in Figure 5. Brightness settings can be quickly changed by sending programming pulses one after each other. Each programming pulse has a high ( $t_{PROG\_HIGH}$ ) and a low ( $t_{PROG\_LOW}$ ) pulse width that must be between 0.3 $\mu$ s to 75 $\mu$ s.

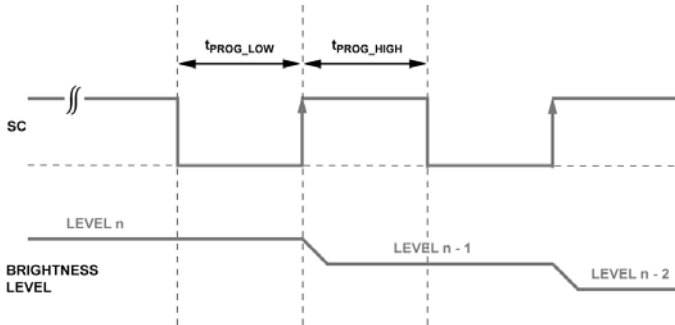


Figure 5. Brightness Programming Pulses

Multiple brightness levels can be changed as shown in Figure 6. When issuing multiple brightness level adjustments to the SC pin, ensure both  $t_{PROG\_LOW}$  and  $t_{PROG\_HIGH}$  are within 0.3 $\mu$ s and 75 $\mu$ s.

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

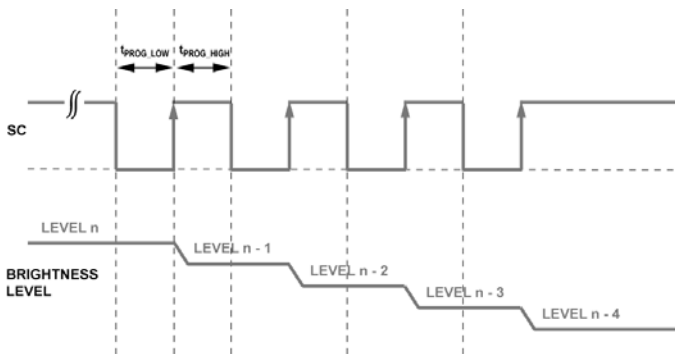


Figure 6. Consecutive Brightness Level Commands

The MIC2860-2D can be programmed to set WLED drive current to produce one of 32 distinct brightness levels. The following section explains how the brightness counter functions with continued programming edges.

**Counter Roll-Over**

The MIC2860-2D internal counter contains registers from 0 to 31 (32 levels). When the brightness level is at 32 (minimum brightness) and a programming pulse forces the brightness to step down, the counter will roll-over to level 31 (maximum brightness). This is illustrated in Figure 7.

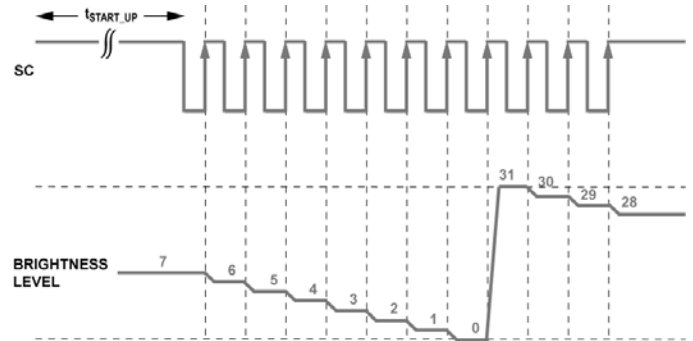
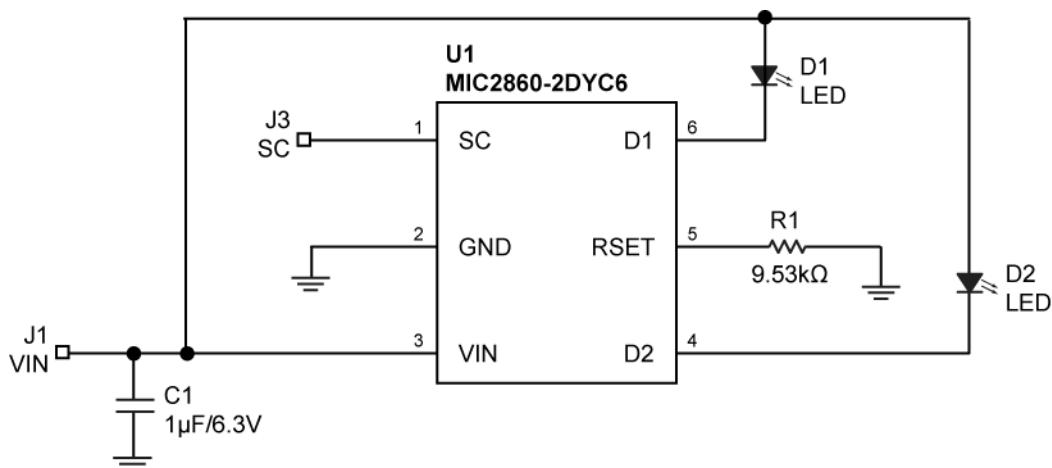


Figure 7. Down Counter Roll-Over

**Input Capacitor**

The MIC2860-2D is a high performance, high bandwidth device. Stability can be maintained using a ceramic input capacitor of 1 $\mu$ F. 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.

### MIC2860-2D Typical Application Circuit



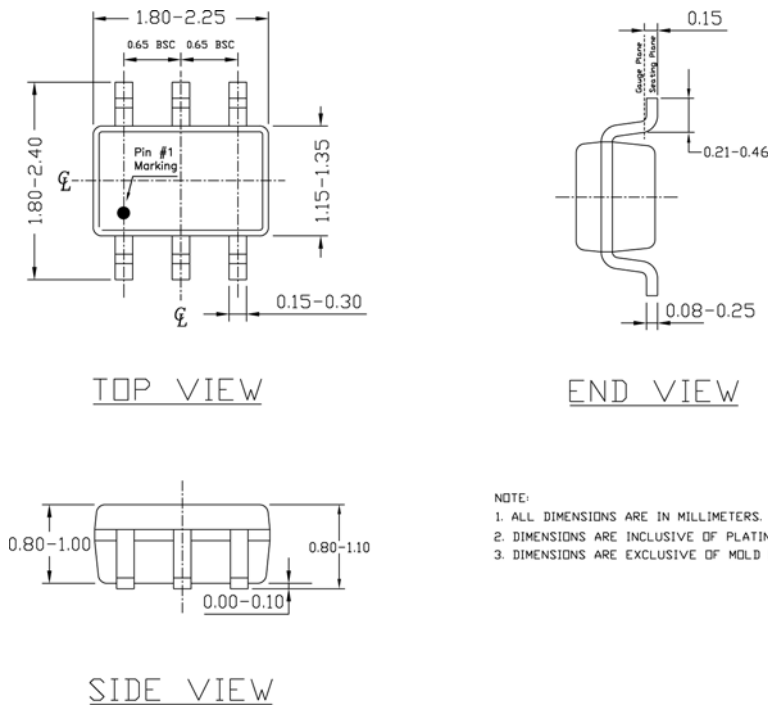
### Bill of Materials

| Item | Part Number     | Manufacturer                | Description                                  | Qty. |
|------|-----------------|-----------------------------|--|------|
| C1   | C1608X5R0J105K  | TDK <sup>(1)</sup>          | 1µF Ceramic Capacitor, 6.3V, X5R, Size 0603  | 1    |
| R1   | CRCW06032052FT1 | Vishay <sup>(2)</sup>       | 9.53kΩ, 1%, Size 0603                        | 1    |
| U1   | MIC2860-2DYC6   | Micrel, Inc. <sup>(3)</sup> | 2 Channel Digital Control Linear WLED Driver | 1    |

**Notes:**

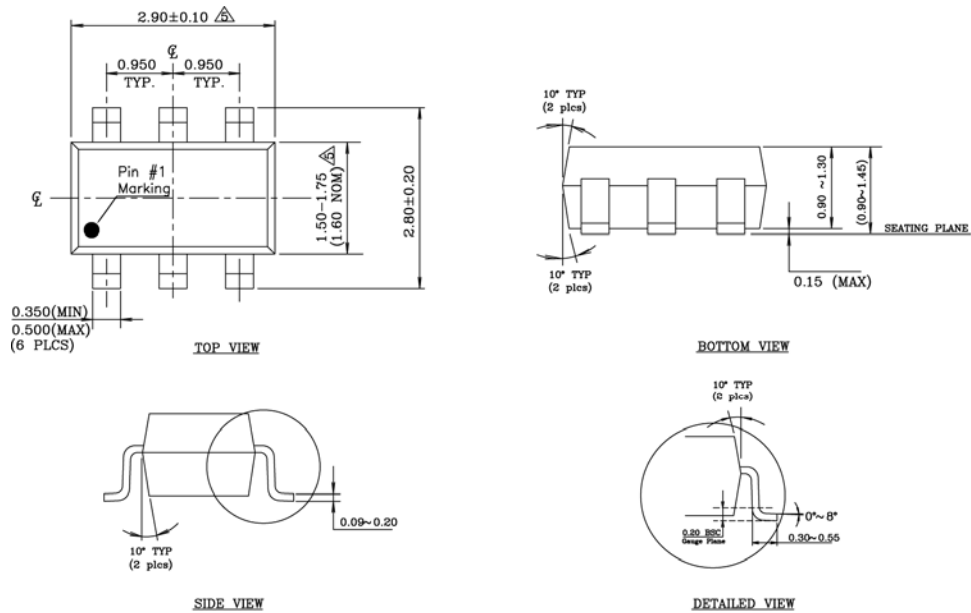
1. TDK: [www.tdk.com](http://www.tdk.com)
2. Vishay: [www.vishay.com](http://www.vishay.com)
3. Micrel, Inc.: [www.micrel.com](http://www.micrel.com)

# Package Information



NOTE:  
 1. ALL DIMENSIONS ARE IN MILLIMETERS.  
 2. DIMENSIONS ARE INCLUSIVE OF PLATING.  
 3. DIMENSIONS ARE EXCLUSIVE OF MOLD FLASH & METAL BURR.

## 6-Pin SC-70 (C6)



NOTE:  
 1. Dimensions and tolerances are as per ANSI Y14.5M, 1982.  
 2. Package surface to be mirror finish.  
 3. Die is facing up for mold. Die is facing down for trim/form, ie. reverse trim/form.  
 4. The footlength measuring is based on the gauge plane method.  
 ⚠ Dimension are exclusive of mold flash & gate burr.

## 6-Pin Thin SOT-23 (D6)

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