# LP5560 Programmable LED Driver with Single-Wire Interface

**Check for Samples: LP5560**

## FEATURES

- **Programmable blinking sequence with current rise and fall time control**
- **Default blinking sequence for simple systems without programming capabilities**
- **Single-wire interface**
- **Constant current high side output driver**
- **Ultra-small solution size**
  - **No external components**
  - **0.891 mm (max.) x 0.891 mm (max.) x 0.6 mm micro SMD package with 0.4 mm pitch**
- **Very low headroom voltage (40 mV typ.)**
- **Adjustable output current from 2.8 mA to 19.5 mA**
- **Wide input-voltage range: 2.7V to 5.5V**

## APPLICATIONS

- **Indicator LEDs in cell phones and other portable devices**

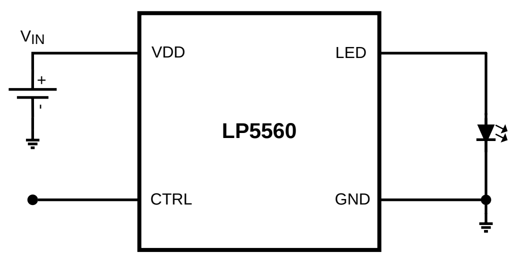
## DESCRIPTION

The LP5560 is a programmable LED driver that can generate a variety of blinking sequences with up to three pulses of different length per sequence. Blinking sequences can be programmed through a single-wire interface. Programmable parameters include on and off times as well as rise and fall times. A default sequence is programmed into LP5560 to enable use of the device in simple systems without programming capabilities.

Very low headroom voltage eliminates the need for a boost converter. Indicator LEDs can be driven directly from the battery. Small package size, combined with zero external components, minimizes the solution size.

The LP5560 is available in a tiny 4-bump micro SMD package with 0.4 mm pitch.

### Typical Application Circuit




### Connection Diagram

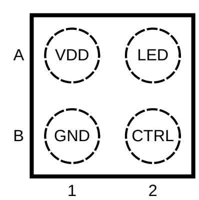



**Figure 1. Top View**

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### Table 1. PIN DESCRIPTIONS

| Pin | Name | Type [(1)] | Description |
|---|---|---|---|
| A1 | VDD | P | Power supply pin |
| A2 | LED | A | Current source output |
| B1 | GND | G | Ground |
| B2 | CTRL | DI | Single-wire interface input |

(1) A: Analog Pin D: Digital Pin G: Ground Pin P: Power Pin I: Input Pin

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

## Absolute Maximum Ratings [(1)] [(2)]

| | |
|---|---|
| Voltage on VDD pin | −0.3V to +6.0V |
| Voltage on other pins (CTRL, LED)[(3)] | −0.3V to VDD +0.3V with 6.0V max |
| Continuous Power Dissipation [(4)] | Internally Limited |
| Junction Temperature ($T_{J\text{-}MAX}$) | 125°C |
| Storage Temperature Range | −65°C to +150°C |
| Maximum Lead Temperature (Reflow soldering, 3 times) [(5)] | 260°C |
| ESD Rating [(6)]<br>Human Body Model<br>Charged Device Model | <br>2.0kV<br>1000V |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the component may occur. Operating Ratings are conditions under which operation of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test conditions, see the Electrical Characteristics tables.
(2) All voltages are with respect to the potential at the GND pins.
(3) Under-voltage lockout (UVLO) shuts down the LED driver with $V_{IN}$ drops to 2.3V (typ.). Power-on reset (POR) trips at $V_{IN}$ = 2.0V (typ.).
(4) Internal thermal shutdown circuitry protects the device from permanent damage. Thermal shutdown engages at $T_J$=160°C (typ.) and disengages at $T_J$=140°C (typ.).
(5) For detailed soldering specifications and information, please refer to *Texas Instruments Application Note AN1112 : Micro SMD Wafer Level Chip Scale Package.*
(6) The Human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. MIL-STD-883 3015.7

## Operating Ratings [(1)] [(2)]

| | |
|---|---|
| Voltage on power pin (VDD) | 2.7V to 5.5V |
| Junction Temperature ($T_J$) Range | −30°C to +125°C |
| Ambient Temperature ($T_A$) Range [(3)] | −30°C to +85°C |

(1) Absolute Maximum Ratings indicate limits beyond which damage to the component may occur. Operating Ratings are conditions under which operation of the device is guaranteed. Operating Ratings do not imply guaranteed performance limits. For guaranteed performance limits and associated test conditions, see the Electrical Characteristics tables.
(2) All voltages are with respect to the potential at the GND pins.
(3) In applications where high power dissipation and/or poor package thermal resistance is present, the maximum ambient temperature may have to be derated. Maximum ambient temperature ($T_{A\text{-}MAX}$) is dependent on the maximum operating junction temperature ($T_{J\text{-}MAX\text{-}OP}$ = 125°C), the maximum power dissipation of the device in the application ($P_{D\text{-}MAX}$), and the junction-to ambient thermal resistance of the part/package in the application ($\theta_{JA}$), as given by the following equation: $T_{A\text{-}MAX} = T_{J\text{-}MAX\text{-}OP} – (\theta_{JA} \times P_{D\text{-}MAX})$.

## Thermal Properties

| | |
|---|---|
| Junction-to-Ambient Thermal Resistance ($\theta_{JA}$), TMD04 Package [(1)] | 120°C/W |

(1) Junction-to-ambient thermal resistance is highly application and board-layout dependent. In applications where high maximum power dissipation exists, special care must be paid to thermal dissipation issues in board design.

## Electrical Characteristics (1) (2)

Limits in standard typeface are for $T_A$ = 25°C. Limits in **boldface** type apply over the operating ambient temperature range (−30°C < $T_A$ < +85°C). Unless otherwise specified: $V_{IN}$ = 3.6V, CTRL = 3.6V, $V_{LED}$ = 3.1V.

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $I_{SD}$ | Shutdown Supply Current | CTRL = 0V | | 0.4 | **0.75** | µA |
| $I_Q$ | Quiescent Supply Current | $I_{LED}$ = 0 mA | | 25 | **30** | |
| $I_{LED}$ | LED Output current | ISET = 0 | **2.26** | 2.8 | **3.34** | mA |
| | | ISET = 1 (default) | **4.61** | 5.3 | **5.99** | |
| | | ISET = 2 | **6.78** | 7.8 | **8.82** | |
| | | ISET = 3 | **8.87** | 10.2 | **11.53** | |
| | | ISET = 4 | **10.96** | 12.6 | **14.24** | |
| | | ISET = 5 | **13.50** | 15.0 | **16.50** | |
| | | ISET = 6 | **15.05** | 17.3 | **19.55** | |
| | | ISET = 7 | **16.96** | 19.5 | **22.04** | |
| $\Delta I_{LED}\%/\Delta V_{IN}$ | Line regulation | 2.7V ≤ $V_{IN}$ ≤ 4.5V, $I_{DX}$ = 5.3 mA, Vf = 2.5V | **−3%** | | **3%** | %/1V |
| $\Delta I_{LED}\%/\Delta V_{LED}$ (3) | Load regulation | 1.7V ≤ $V_{LED}$ ≤ 3.4V, $I_{LED}$ = 5.3 mA | | 0.6 | | |
| $V_{HR}$ | Headroom Voltage (4) | $I_{LED}$ = 5.3 mA | | 40 | **100** | mV |
| | | $I_{LED}$ = 19.5 mA | | 40 | | |
| $V_{IH}$ | Logic Input High level | $V_{IN}$ = 2.7V to 5.5V | **1.1** | | | V |
| $V_{IL}$ | Logic Input Low level | $V_{IN}$ = 2.7V to 5.5V | | | **0.6** | V |
| $I_{CTRL}$ | CTRL pin leakage current | CTRL = 1.8V | | | **400** | nA |
| T_cycle_H | LED On time | adjustable (5) | 13.2 | | 3009.6 | ms |
| T_cycle_L | LED OFF time | adjustable (5) | 26.4 | | 6019.2 | |
| T rise | LED current rise time (6) | adjustable (5) | 0 | | 1584 | |
| T fall | LED current fall time (6) | adjustable (5) | 0 | | 1584 | |
| Fade resolution | Rise/fall time resolution | (5) | | 105.6 | | |

(1) All voltages are with respect to the potential at the GND pins.
(2) Min and Max limits are guaranteed by design, test, or statistical analysis. Typical numbers are not guaranteed, but do represent the most likely norm.
(3) $I_{LED}$ = LED output current, $V_{LED}$ = LED forward voltage.
(4) For LED output pin, headroom voltage is defined as the voltage across the internal current source when the LED current has dropped 10% from the value measured at VIN – 0.5V. If headroom voltage requirement is not met, LED current regulation will be compromised.
(5) Guaranteed by design.
(6) LED current ramp up and ramp down uses a combined PWM / current adjustment.

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## Single-Wire Interface Timing Characteristics (7)

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| $T_{C\_ON}$ | Command pulse on time | (1) | 15 | | | µs |
| $T_{C\_OFF}$ | Command pulse off time | (1) | 30 | | | |
| $T_{T\_ON}$ | Minimum training pulse on time (2) | (1) | 200 | | | |
| $T_{T\_OFF}$ | Minimum training pulse off time (3) | (1) | 200 | | | |
| $T_{CAL}$ | Calibration pulse length | (1) | 0.35 | | 8 | ms |
| $T_{ENTER}$ | Command entering period | (1) | 500 | | | µs |
| $T_{ENTER}+T_{BLANK}$ | Command entering period + Blank period | (1) | | | 1500 | |

(7) Min and Max limits are guaranteed by design, test, or statistical analysis. Typical numbers are not guaranteed, but do represent the most likely norm.
(1) Guaranteed by design.
(2) All CTRL signal high times between calibration pulse and training end are considered as training pulse on times.
(3) All CTRL signal low times between calibration pulse and training end are considered as training pulse off times.

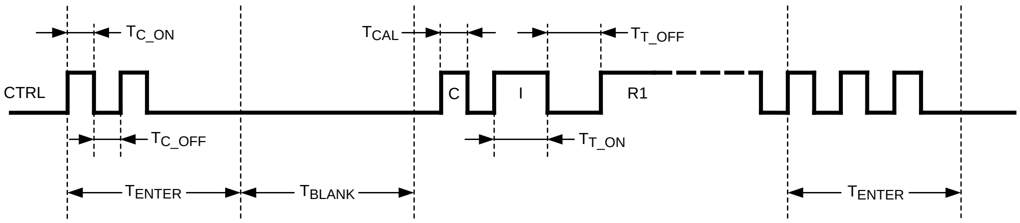
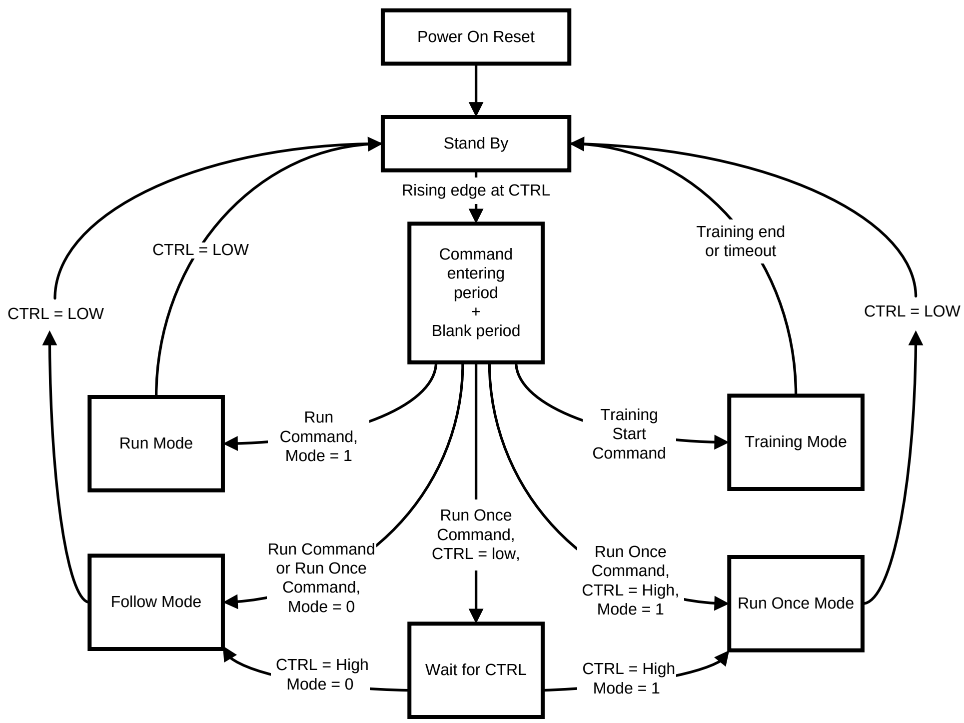



**Figure 2. Interface Timing**

## Operating Modes




**POWER-ON RESET** When input voltage is applied to VDD pin device goes through Power On Reset (POR). During POR defaults are set into control registers.

**STANDBY:** After POR device goes to standby. This is the low-power mode when all the internal blocks are shut down.

**COMMAND ENTERING PERIOD + BLANK PERIOD:** Rising edge of the CTRL signal activates the circuit and starts a command entering period. During the command entering period all rising edges are counted. After command entering period there is a blank period when no rising edges are allowed.

**RUN:** If mode bit is “1” (run mode), and run command has been detected, device goes into run mode. In run mode the LP5560 generates the programmed blinking sequence.

**FOLLOW MODE:** If mode bit is “0” (follow mode), and run command or run once command has been detected, the LP5560 goes into follow mode. In follow mode LED stays on as long as CTRL pin is held high.

**RUN ONCE MODE:** If run once command has been detected, and mode bit is “1” (run mode), the device goes into run once mode. In run once mode the LP5560 generates the programmed blinking sequence once. CTRL must be high as long as blinking sequence is running.

**TRAINING:** If training start command has been detected device goes into training mode. In training mode a new blinking sequence can be programmed into the device.

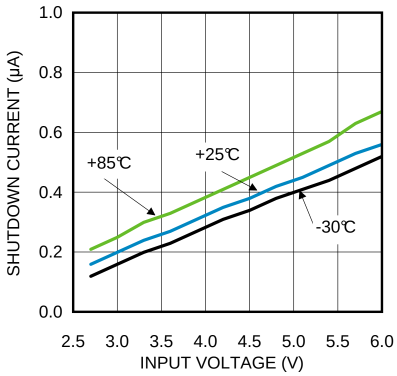


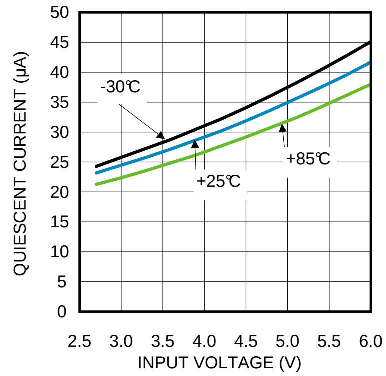
## Typical Performance Characteristics

$T_J$ = 25°C. Unless otherwise noted, typical performance characteristics apply to the LP5560 Typical Application Circuit with: $V_{IN}$ = 3.6V, $R_{ISET}$ = 24 kΩ, $C_{IN}$ = 100 nF.

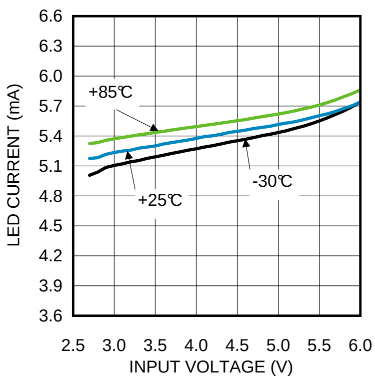
**Standby Current vs $V_{IN}$**



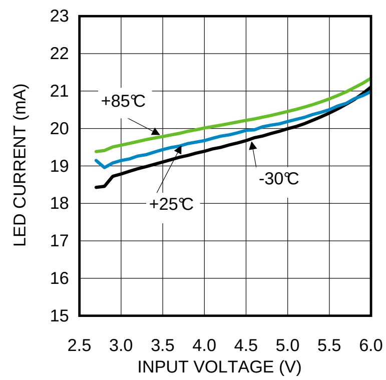

**Quiescent Current vs $V_{IN}$**



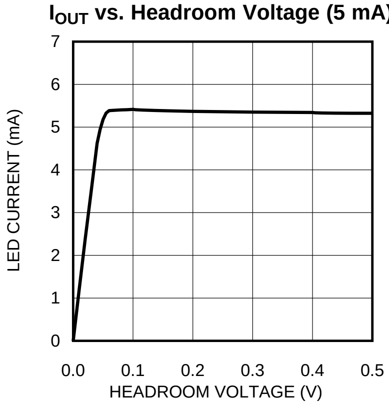

**LED Current vs Input Voltage (5 mA)**



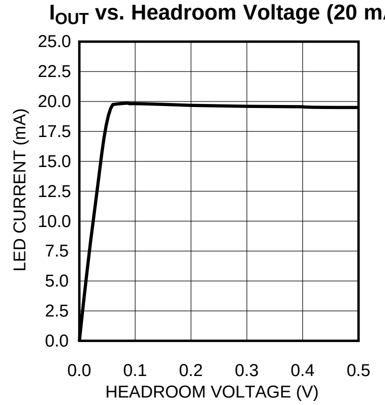

**LED Current vs Input Voltage (20 mA)**




**$I_{OUT}$ vs. Headroom Voltage (5 mA)**




**$I_{OUT}$ vs. Headroom Voltage (20 mA)**

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## Application Information

The LP5560is a programmable LED driver with a single-wire interface. It is designed to drive a single indicator LED with different blinking sequences. Up to three pulses with different on and off times can be programmed into the device. LED current rise and fall times can also be independently controlled. Blinking sequence is stored into volatile memory, thus removing input voltage $V_{IN}$ resets the memory into default state.

High-side LED driver has a very low headroom voltage requirement and can drive most indicator LEDs directly from battery voltage. A single CTRL pin is used to control the device on and off and to change settings of the device. A default blinking sequence is programmed into the device to enable use of the devices in simply applications without programming capabilities.

## LED DRIVER HEADROOM VOLTAGE

Current source is connected internally between the VDD and LED output pins. The voltage across the current source, ($V_{VDD} - V_{LED}$), is referred to as headroom voltage ($V_{HR}$). The current source requires a sufficient amount of headroom voltage to be present across it in order to regulate the output current properly. LP5560's headroom voltage requirement is 40 mV (typ.) and does not depend on the current setting.

## SINGLE-WIRE INTERFACE

The LP5560 has one digital control input (CTRL). Threshold levels of CTRL input are fixed to support control from low-voltage controller. The CTRL signal is used to control the mode of the circuit. Rising edge of the CTRL signal activates the circuit and starts a command entering period. During the command entering period all rising edges are counted. After command entering period there is a blank period when no rising edges are allowed. If there are any rising edges during the blank period, they are not detected. User must take care not to start the training sequence before the blank period has elapsed, or the training sequence will be corrupted.

If CTRL is left high after command entering period, the consequent command is performed right after the blank period. In case of run once command, CTRL pin can be set low after the command entering period, and execution of the command starts once CTRL pin is pulled high after blank period.

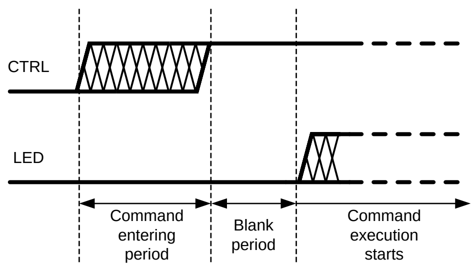


**Figure 3. Single-Wire Interface Command**

The LP5560 has four different commands. Each command depends on the number of rising edges during command entering period. If there are more than 4 rising edges during command entering period, the command is ignored. Note that even in this case the blank period needs to elapse before next command can be given.

| Command | Number of Rising Edges During Command Entering Period |
|---|---|
| Run | 1 |
| Training start | 2 |
| Training end | 3 |
| Run once | 4 |

### *Run Command*

One rising edge of CTRL signal within the command entering period is interpreted as Run command. The CTRL pin must be kept high during blank period. If the CTRL pin is pulled low during the command entering period or the blank period, the device goes to Standby. In run mode (mode bit = 1) a blinking sequence is started right after the blank period, and it is repeated as long as the CTRL signal is kept high. When the CTRL signal is set low the device goes into Standby mode (Figure 4).

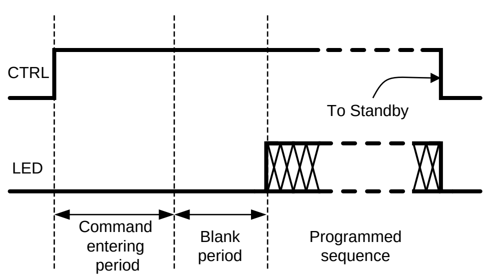


**Figure 4. Run Mode**

 

In Follow mode (mode bit = 0) LED is turned on right after the Blank period, and it stays on as long as CTRL is kept high. When the CTRL signal is set low, LED is turned off, and the device goes into Standby mode (Figure 5).

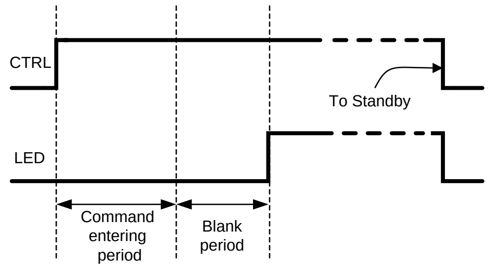


**Figure 5. Follow Mode**

### *Training Start Command*

Two rising edges of the CTRL signal within the command entering period is interpreted as a Training Start command. The Training Start command starts the training sequence. Different blinking sequences can be trained into the device in Training mode. Training mode is described in more details in TRAINING MODE.

### *Training End Command*

Three rising edges of CTRL signal within the command entering period is interpreted as a Training End command. Training End is used to stop the training sequence.

### *Run Once Command*

Four rising edges of CTRL signal within the command entering period is interpreted as a Run Once command. A programmed blinking sequence is performed once after the Run Once command. If CTRL is kept high after the command entering period, the programmed blinking sequence starts right after the blank period has elapsed (Figure 6). The CTRL signal must stay high as long as the programmed blinking sequence is executed. If CTRL is set low during execution of the blinking sequence, the device goes to standby, and execution of the blinking sequence is stopped.

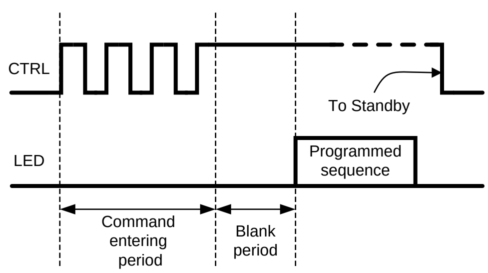


**Figure 6. Run Once Command**

If the CTRL signal is low after the command entering period, a blinking sequence is executed once the CTRL is set high (Figure 7).

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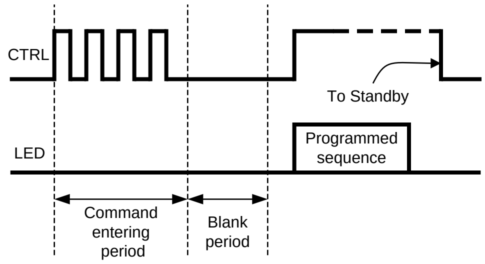


**Figure 7. Delayed Run Once Command**

If the device is in Follow mode (mode bit is “0”), the run once command turns LED on, and it is kept on as long as CTRL is held high.

## TRAINING MODE

Figure 12 shows an example of the full training sequence with 3 pulses. Training mode starts with a training start command. The training start command is followed by blank time during which no rising edges are allowed. Blank time is followed by calibration pulse. Calibration pulse length ($T_{CAL}$) defines the speed of the training sequence and can vary from 300 µs to 10 ms. During parameter settings register values are incremented at a speed defined by $T_{CAL}$. For example, if calibration pulse length is 1 ms and current setting pulse length is 3.3 ms, the current setting value is 3 (current set register is incremented 3 times). If parameter setting pulse is shorter than calibration, the pulse setting is 0.

The next rising edge after the calibration pulse starts the LED driver current setting (I). The LED driver current is recorded once CTRL is pulled low. Note that there are “empty” low times before and after current setting pulse. For the following pulses both CTRL high and CTRL low times are used to set the parameters. Next , CTRL high time defines LED current rise time setting for pulse 1 (R1). When R1 setting is started, Mode bit is set to “0”. This sets the LP5560 into Follow mode. Mode bit is set to “1” after the first off time has been saved into the register. This means that at least one full pulse needs to be trained into memory to set the device into Run mode.

CTRL low time after R1 defines the LED on time for pulse 1 (ON1). CTRL high time after ON1 sets the LED current fall time (F1). CTRL low time after F1 sets pulse 1 off time (OFF1). Once the rising edge of CTRL is detected after first off-time setting, mode bit is set to “1” (Run mode), and number of pulses register (NOP[1:0]) is set to 1. This indicates that one full pulse has been trained into memory.

Rise-, on-, fall- and off-times for pulses 2 and 3 are set the same way as for pulse 1. Note that NOP register is always incremented after OFFx time setting. This means that all pulse parameters (rise-, on-, fall- and off-time) need to be trained for each pulse make it valid. The training sequence ends with the Training End command.

### *Ending the Training Sequence*

The training end command can be given at any time of the training sequence except during blank time. Outcome of the training sequence depends on the place of the Training End command. If the Training End command is given after any of the off-time setting (OFF1, OFF2 or OFF3), mode bits are set to “1”, and corresponding number of pulses are stored into memory. If the Training End command is given after any of the other pulse parameters (Rx, ONx or Fx), that pulse is ignored. For example, if the Taining End command is given after ON2, pulse 2 is ignored, and the blinking sequence will include only pulse 1.

### *Reset to Default*

If the Training End command is given right after the Training Start command, the LP5560 is reset back to factory defaults (Figure 8). In this case the mode bit is set to "1" (Run mode) with the factory-set default blinking sequence.



 

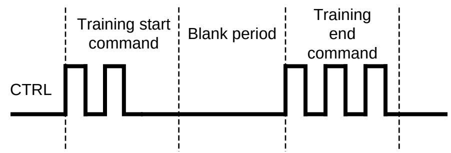


**Figure 8. Reset to Default**

### *Changing LED Current*

The LP5560 allows the LED output current to be changed without the need to reprogram the previously programmed blinking sequence. This is done by giving the Training End command after current setting (Figure 9). In this case only the current setting changes. If a blinking sequence was programmed into the LP5560, it remains unchanged. If mode bit was "0" (Follow mode) before the training sequence, it remains "0".

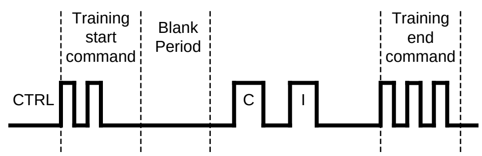


**Figure 9. Current Programming Sequence**

### *Entering Follow Mode*

The Mode bit can be set to "0" (Follow mode) in two ways. If the Training end command is given after calibration, the pulse mode bit is set to "0" (Follow mode), and the previously set LED output current setting remains unchanged (Figure 10).

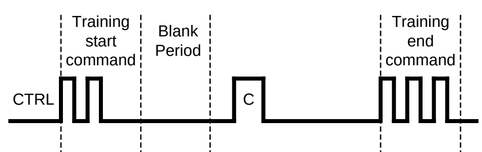


**Figure 10. Entering Follow Mode**

If the Training End command is given after R1, ON1 or F1 modes, bits are set to "0" (follow mode), and new current setting is stored to the current register (Figure 11). If the Training End command is given after F1, CTRL low time before training end command needs to be less than Minimum training pulse off time (200 µs). Otherwise off-time OFF1 will be set to minimum value, and pulse 1 will be stored into memory.

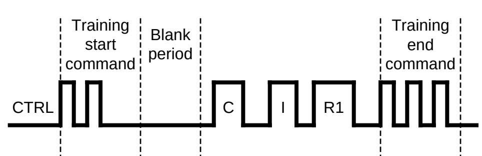


**Figure 11. Entering Follow Mode with New Current Setting**

### *Timeout*

If during training CTRL stays constant for more than 127 * $T_{CAL}$ time, this is interpreted as timeout. For example, if calibration pulse length $T_{CAL}$ is 1ms, timeout time is 127 ms. Timeout ends the training sequence. Timeout is considered as a “false” training, and it is a good practice to always give a complete training sequence after timeout to ensure correct data is stored into memory.

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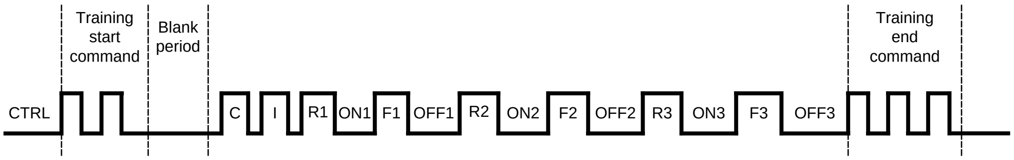


**Figure 12. Full Training Sequence**

## LED OUTPUT CURRENT SETTING

The LED output current can be set from 2.8 mA to 19.5 mA in 7 steps. Duration of the current setting pulse (I) defines the current setting.

| Current Setting | LED Current (mA) |
|---|---|
| 0 | 2.8 |
| 1 | 5.3 default |
| 2 | 7.8 |
| 3 | 10.2 |
| 4 | 12.6 |
| 5 | 15.0 |
| 6 | 17.3 |
| 7 | 19.5 |

## RISE/FALL TIME SETTING

Rise and fall times of each pulse can be programmed independently. Rise and fall times can be set from 0 to 1584 ms with 105.6 ms steps. Rise and fall times are generated using a combined PWM and current control. Ramp has 32 PWM steps. For the first 8 steps LED current is decreased to 12.5%. For the remaining steps current is set to 100%. Each step is 3.3 ms long. This result in a minimum ramp time of 3.3 ms * 32 = 105.6 ms. When ramp time is increased, each PWM step is done multiple times. When setting rise and fall times, they are always rounded down. For example, if calibration pulse length is 1 ms, and rise time setting pulse is 2.9 ms, rise time is set to 2 which is 211.2 ms. Rise and fall times can be set to zero by giving a pulse that is shorter than a calibration pulse.

| Ramp setting | Ramp time (ms) |
|---|---|
| 0 | 0 |
| 1 | 105.6 |
| 2 | 211.2 |
| 3 | 316.8 |
| 4 | 422.4 |
| 5 | 528 default |
| 6 | 633.6 |
| 7 | 739.2 |
| 8 | 844.8 |
| 9 | 950.4 |
| 10 | 1056 |
| 11 | 1161.6 |
| 12 | 1267.2 |
| 13 | 1372.8 |
| 14 | 1478.4 |
| 15 | 1584 |

PRODUCT PREVIEW

## LED ON-TIME SETTING

LED on-time has a 5-bit control. On-time can be controlled from 13.2 ms to 3009.6 ms in 31 steps. Step size is not constant to increase resolution on shorter ON times. With longer on-times the step size is increased as well. The table below shows the available on-times:

| Setting | LED On time (ms) |
|---|---|
| 0 | 13.2 |
| 1 | 26.4 |
| 2 | 52.8 |
| 3 | 105.6 |
| 4 | 158.4 |
| 5 | 211.2 |
| 6 | 264 |
| 7 | 316.8 |
| 8 | 369.6 |
| 9 | 435.6 |
| 10 | 501.6 default |
| 11 | 594 |
| 12 | 699.6 |
| 13 | 805.2 |
| 14 | 910.8 |
| 15 | 1016.4 |
| 16 | 1122 |
| 17 | 1227.6 |
| 18 | 1353 |
| 19 | 1478.4 |
| 20 | 1603.8 |
| 21 | 1729.2 |
| 22 | 1854.6 |
| 23 | 1980 |
| 24 | 2105.4 |
| 25 | 2230.8 |
| 26 | 2356.2 |
| 27 | 2481.6 |
| 28 | 2613.6 |
| 29 | 2745.6 |
| 30 | 2877.6 |
| 31 | 3009.6 |

PRODUCT PREVIEW

## LED OFF-TIME SETTING

LED off-time has also a 5-bit control. Off-time can be controlled from 26.4 ms to 6019.2 ms in 31 steps. Off-time is always twice as long as on-time with the same setting.

| Setting | LED Off time (ms) |
|---|---|
| 0 | 26.4 |
| 1 | 52.8 |
| 2 | 105.6 |
| 3 | 211.2 |
| 4 | 316.8 |
| 5 | 422.4 |

| Setting | LED Off time (ms) |
|---|---|
| 6 | 528 |
| 7 | 633.6 |
| 8 | 739.2 |
| 9 | 871.2 |
| 10 | 1003.2 |
| 11 | 1188 |
| 12 | 1399.2 |
| 13 | 1610.4 default |
| 14 | 1821.6 |
| 15 | 2032.8 |
| 16 | 2244 |
| 17 | 2455.2 |
| 18 | 2706 |
| 19 | 2956.8 |
| 20 | 3207.6 |
| 21 | 3458.4 |
| 22 | 3709.2 |
| 23 | 3960 |
| 24 | 4210.8 |
| 25 | 4461.6 |
| 26 | 4712.4 |
| 27 | 4963.2 |
| 28 | 5227.2 |
| 29 | 5491.2 |
| 30 | 5755.2 |
| 31 | 6019.2 |

## DEFAULT SEQUENCE

A default blinking sequence is programmed into the LP5560 to enable the use of the device in simple systems without programming capabilities. Default sequence has a single pulse with following parameters:

| |
|---|
| I = 5.3 mA |
| R1 = 528 ms |
| ON1 = 501.6 ms |
| F1 = 528 ms |
| OFF1 = 1610.4 ms |

## CONTROL REGISTERS

Control registers are shown only for reference. There is no direct way to write or read these registers. Register values are set in the Training mode as described earlier in the document.

<table>
<tr><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td colspan="4">F1[3:0]</td><td colspan="4">R1[3:0]</td></tr>
<tr><td>MODE</td><td colspan="2">NOP[1:0]</td><td colspan="5">ON1[4:0]</td></tr>
<tr><td colspan="3">I_LED[2:0]</td><td colspan="5">OFF1[4:0]</td></tr>
<tr><td colspan="4">F2[3:0]</td><td colspan="4">R2[3:0]</td></tr>
<tr><td colspan="3">n/a</td><td colspan="5">ON2[4:0]</td></tr>
<tr><td colspan="3">n/a</td><td colspan="5">OFF2[4:0]</td></tr>
<tr><td colspan="4">F3[3:0]</td><td colspan="4">R3[3:0]</td></tr>
</table>

PRODUCT PREVIEW

| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|
| n/a | | | ON3[4:0] | | | | |
| n/a | | | OFF3[4:0] | | | | |

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Samples (Requires Login) |
|---|---|---|---|---|---|---|---|---|---|
| LP5560TME/NOPB | ACTIVE | DSBGA | YFQ | 4 | 250 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | |
| LP5560TMX/NOPB | ACTIVE | DSBGA | YFQ | 4 | 3000 | Green (RoHS & no Sb/Br) | SNAGCU | Level-1-260C-UNLIM | |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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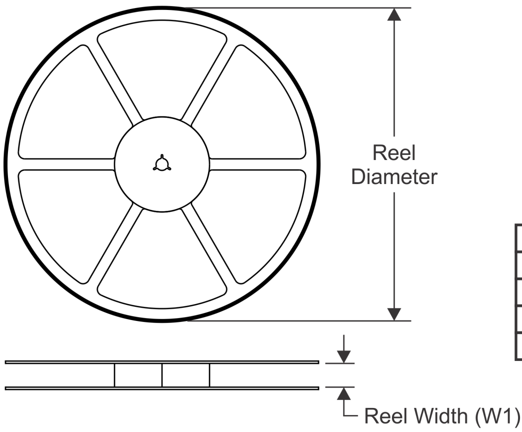
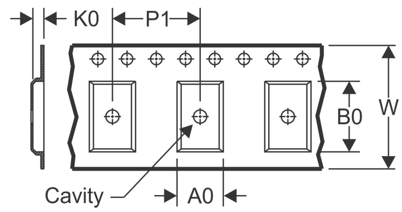
## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

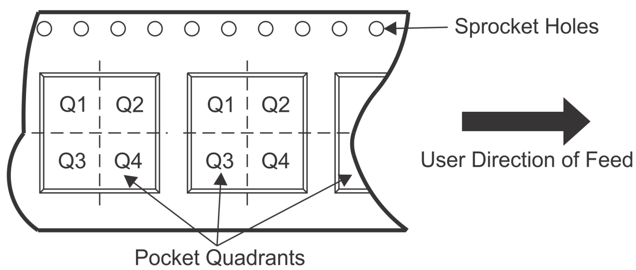



**TAPE DIMENSIONS**




| | |
|---|---|
| A0 | Dimension designed to accommodate the component width |
| B0 | Dimension designed to accommodate the component length |
| K0 | Dimension designed to accommodate the component thickness |
| W | Overall width of the carrier tape |
| P1 | Pitch between successive cavity centers |

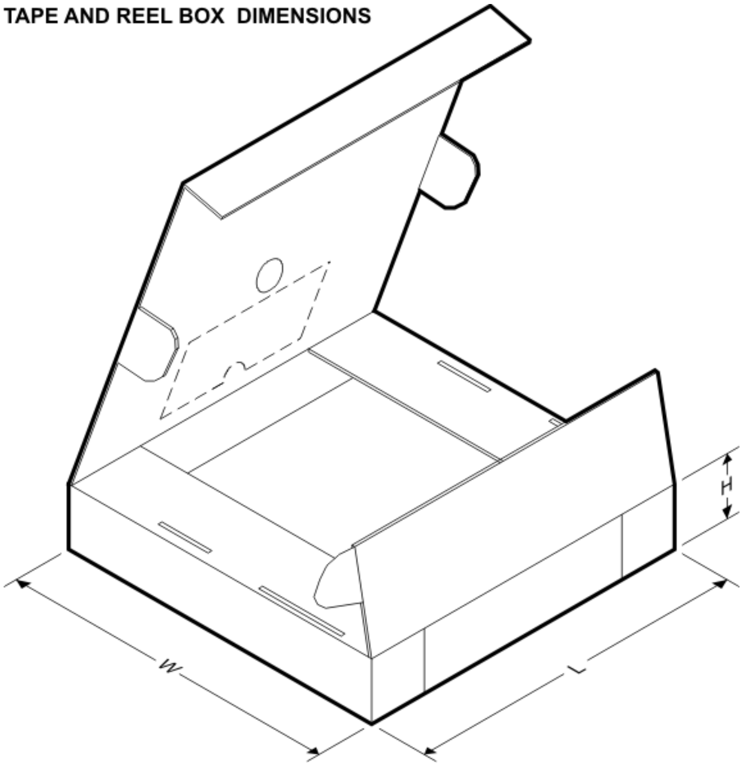
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LP5560TME/NOPB | DSBGA | YFQ | 4 | 250 | 178.0 | 8.4 | 0.92 | 0.99 | 0.7 | 4.0 | 8.0 | Q1 |
| LP5560TMX/NOPB | DSBGA | YFQ | 4 | 3000 | 178.0 | 8.4 | 0.92 | 0.99 | 0.7 | 4.0 | 8.0 | Q1 |

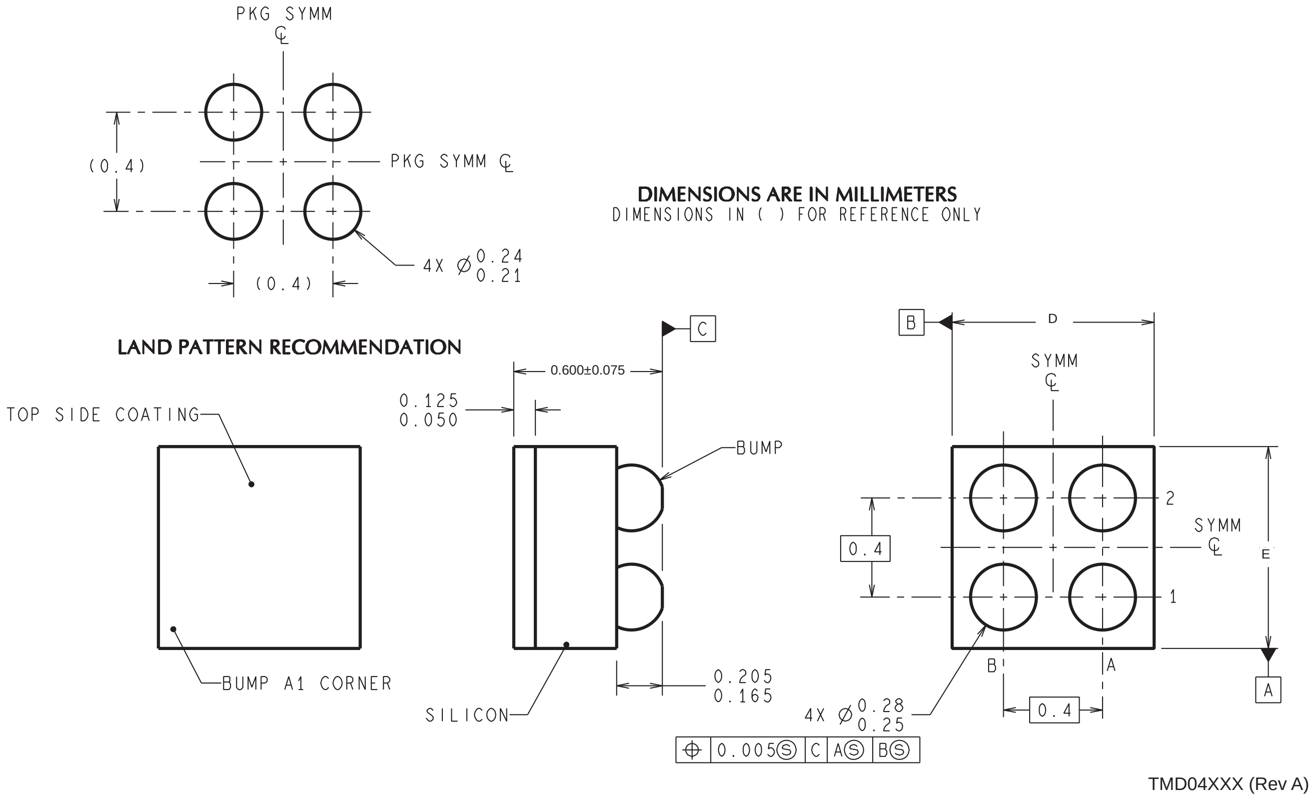
## TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LP5560TME/NOPB | DSBGA | YFQ | 4 | 250 | 210.0 | 185.0 | 35.0 |
| LP5560TMX/NOPB | DSBGA | YFQ | 4 | 3000 | 210.0 | 185.0 | 35.0 |

# YFQ0004




D: Max = 0.916 mm, Min =0.856 mm

E: Max = 0.916 mm, Min =0.856 mm

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NOTES: A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.

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