

# AS3649

## 2500mA High Current LED Flash Driver

### 1 General Description

The AS3649 is an inductive high efficient DCDC step up converter with two current sources. The DCDC step up converter operates at a fixed frequency of 4MHz and includes soft startup to allow easy integration into noise sensitive RF systems. The two current sources can operate in flash / torch or video light modes.

The AS3649 includes flash timeout, overvoltage, overtemperature, undervoltage and LED short/open circuit protection functions. A TXMASK/TORCH function reduces the flash current in case of parallel operation to the RF power amplifier and avoids a system shutdown. Alternatively this pin can be used to directly operate the torch light directly. If the TXMask function is not used, it can be used as a hardware torch input (programmable).

A hardware NTC pin can be used to measure the LED temperature with the ADC and to automatically reduce the LED current if a temperature threshold is exceeded.

The AS3649 is controlled by an I<sup>2</sup>C interface and has a hardware reset pin ON. Setting ON=0 resets the AS3649. Interface input voltage levels are 1.8V compliant.

The AS3649 is available in a space-saving WL-CSP package measuring only 2.06x2.02x0.6mm and operates over the -30°C to +85°C temperature range.

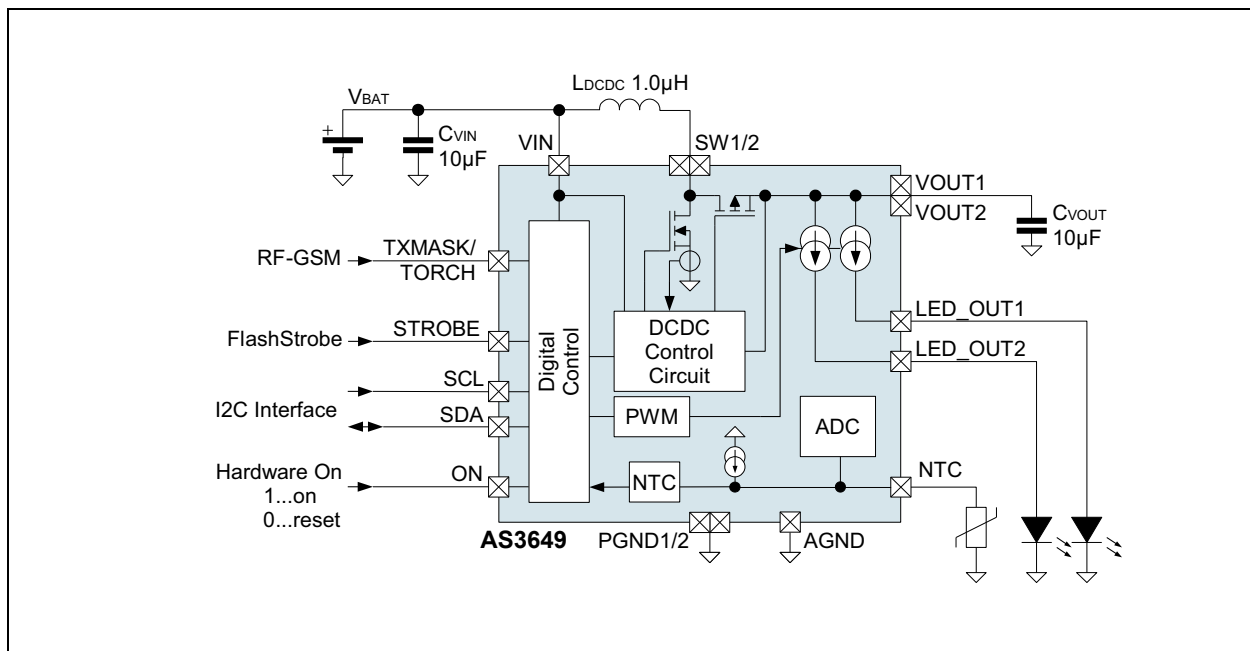
### 2 Key Features

- High efficiency 4MHz fixed frequency DCDC Boost converter with soft start allows small coils
  - Stable even in coil current limit
- LED current adjustable up to 2x1000mA(2x1250mA with current boost) or 2000mA and automatic load balancing for two LEDs
- Automatic current adjustment for low battery voltage
- PWM operation for lower output current for reliable light output of the LED; can run at 31.5kHz to avoid audible noise
- Protection functions:
  - Automatic Flash Timeout timer to protect the LED(s)
  - Overvoltage and undervoltage Protection
  - Overtemperature Protection
  - LED short/open circuit protection
- ADC to measure LED temperature
- NTC to automatically reduce the flash current if the LED temperature is too high (programmable level)
- I<sup>2</sup>C Interface with hardware reset pin
- Available in tiny WL-CSP Package, 16 balls 0.5mm pitch, 2.06x2.02x0.6mm package size

### 3 Applications

Flash/Torch for mobile phones

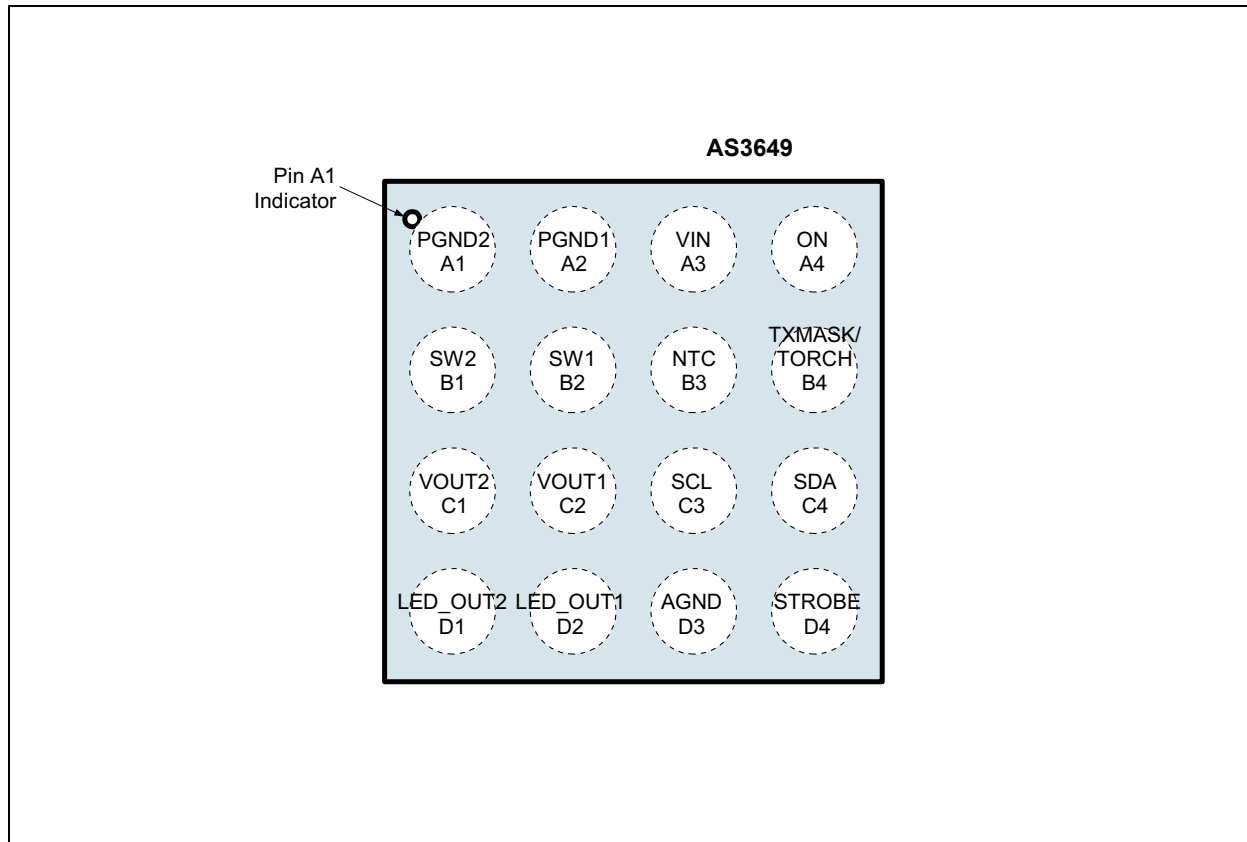
Figure 1. Typical Operating Circuit





## 4 Pin Assignments

Figure 2. Pin Assignments (Top View)



### 4.1 Pin Description

Table 1. Pin Description for AS3649

| Pin Number <sup>1</sup> | Pin Name     | Description   |
|-------------------------|--------------|---|
| A1                      | PGND2        | Power ground; make a short connection between all GND balls   |
| A2                      | PGND1        | Power ground; make a short connection between all GND balls   |
| A3                      | VIN          | Positive supply voltage input - connect to supply and make a short connection to input capacitor CVIN and to coil LDCDC   |
| A4                      | ON           | Hardware reset input; an active low signal resets the registers of AS3649 and enters shutdown (and I <sup>2</sup> C lines SDA and SCL are in high-Z), active high allows to operate the device  |
| B1                      | SW2          | DCDC converter switching node - make a short connection to SW1 / coil LDCDC   |
| B2                      | SW1          | DCDC converter switching node - make a short connection to SW2 / coil LDCDC   |
| B3                      | NTC          | LED temperature sensor input (NTC) for LED overtemperature protection   |
| B4                      | TXMASK/TORCH | Function 1: Connect to RF power amplifier enable signal - reduces currents during flash to avoid a system shutdown due to parallel operation of the RF PA and the flash driver<br>Function 2: Operate torch current level without using the I <sup>2</sup> C interface to operate the torch without need to start a camera processor (if the I <sup>2</sup> C is connected to the camera processor) |
| C1                      | VOUT2        | DCDC converter output capacitor - make a short connection to CVOUT / VOUT1  |
| C2                      | VOUT1        | DCDC converter output capacitor - make a short connection to CVOUT / VOUT2  |



Table 1. Pin Description for AS3649

| Pin Number <sup>1</sup> | Pin Name | Description  |
|-------------------------|----------|--|
| C3                      | SCL      | serial clock input for I <sup>2</sup> C interface  |
| C4                      | SDA      | serial data input/output for I <sup>2</sup> C interface (needs external pullup resistor) |
| D1                      | LED_OUT2 | Flash LED current source   |
| D2                      | LED_OUT1 | Flash LED current source   |
| D3                      | AGND     | Analog ground; make a short connection between all GND balls                             |
| D4                      | STROBE   | Digital input with pulldown to control strobe time for flash function                    |

1. Final pinout subject to change - now only used to count number of pins



## 5 Absolute Maximum Ratings

Stresses beyond those listed in [Table 2](#) may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in [Electrical Characteristics on page 5](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 2. Absolute Maximum Ratings

| Parameter  | Min   | Max             | Units | Comments  |
|--|-------|-----------------|-------|---|
| VIN to GND                                       | -0.3  | +7.0            | V     |   |
| STROBE, TXMASK/TORCH, SCL, SDA, ON, NTC to GND   | -0.3  | VIN + 0.3       | V     | max. +7V  |
| SW1/2, VOUT1/2, LED_OUT1/2 to GND                | -0.3  | +7.0            | V     |   |
| VOUT1/2 to SW1/2                                 | -0.3  |                 | V     | <b>Note:</b> Diode between VOUT1/2 and SW1/2  |
| voltage between AGND, PGND1/2 pins               | 0.0   | 0.0             | V     | short connection required   |
| Input Pin Current without causing latching       | -100  | +100<br>+IIN    | mA    | Norm: EIA/JESD78  |
| <b>Continuous Power Dissipation (TA = +70°C)</b> |       |                 |       |   |
| Continuous power dissipation                     |       | 1470            | mW    | PT at 70°C <sup>1</sup>   |
| Continuous power dissipation derating factor     |       | 20              | mW/°C | PDERATE <sup>2</sup>  |
| <b>Electrostatic Discharge</b>                   |       |                 |       |   |
| ESD HBM  |       | ±2000           | V     | Norm: JEDEC JESD22-A114F  |
| ESD CDM  |       | ±500            | V     | Norm: JEDEC JESD 22-C101E   |
| <b>Temperature Ranges and Storage Conditions</b> |       |                 |       |   |
| Junction to ambient thermal resistance           |       | 50 <sup>3</sup> | °C/W  | For more information about thermal metrics, see application note AN01 Thermal Characteristics |
| Junction Temperature                             |       | +150            | °C    | Internally limited (overtemperature protection), max. 20000s                                  |
| Storage Temperature Range                        | -55   | +125            | °C    |   |
| Humidity   | 5     | 85              | %     | Non condensing  |
| Body Temperature during Soldering                |       | +260            | °C    | according to IPC/JEDEC J-STD-020  |
| Moisture Sensitivity Level (MSL)                 | MSL 1 |                 |       | Represents a max. floor life time of unlimited  |

1. Depending on actual PCB layout and PCB used measured on demoboard; for peak power dissipation during flashing see document 'AS3649 Thermal Measurements'
2. PDERATE derating factor changes the total continuous power dissipation (PT) if the ambient temperature is not 70°C. Therefore for e.g. TAMB=85°C calculate PT at 85°C = PT - PDERATE \* (85°C - 70°C)
3. Measured on AS3649 demoboard.



## 6 Electrical Characteristics

V<sub>VIN</sub> = +2.7V to +4.4V, T<sub>AMB</sub> = -30°C to +85°C, unless otherwise specified. Typical values are at V<sub>VIN</sub> = +3.7V, T<sub>AMB</sub> = +25°C, unless otherwise specified.

Table 3. Electrical Characteristics

| Symbol                              | Parameter  | Condition   | Min        | Typ  | Max               | Unit |
|-------------------------------------|--|---|------------|------|-------------------|------|
| <b>General Operating Conditions</b> |  |   |            |      |                   |      |
| V <sub>VIN</sub>                    | Supply Voltage                                       | Pin VIN   | 2.7        | 3.7  | 4.4               | V    |
| V <sub>VINREDUCED_FUNC</sub>        | Supply Voltage                                       | AS3649 functionally working, but not all parameters fulfilled   | 2.5<br>4.4 |      | 2.7<br>5.5        | V    |
| ISHUTDOWN                           | Shutdown Current                                     | TXMASK/TORCH=L, STROBE=L, ON=L, V <sub>VIN</sub> <3.7V  |            | 1.0  | 2.0               | μA   |
| I <sub>STANBY</sub>                 | Standby Current                                      | Interface active, TXMASK/TORCH=L, STROBE=L<br>V <sub>VIN</sub> <3.7V  |            | 1.0  | 10                | μA   |
| T <sub>AMB</sub>                    | Operating Temperature                                |   | -30        | 25   | 85                | °C   |
| $\eta$                              | Application Efficiency (DCDC and current source)     | L <sub>COIL</sub> =0.6μH@3A, L <sub>ESR</sub> =60mΩ, I <sub>LED_OUT1,2</sub> =2000mA, t <sub>FLASH</sub> <300ms, V <sub>FLED</sub> =3.7V  |            | 83   |                   | %    |
| t <sub>FLASH</sub>                  | Flash Duration                                       | V <sub>VIN</sub> >3.3V, T <sub>AMB</sub> <85°C, I <sub>LED_OUT</sub> <2000mA<br>If T <sub>AMB</sub> or I <sub>LED_OUT</sub> is reduced or V <sub>VIN</sub> is increased, longer flash times are allowed.<br>For longer flash durations, see section <a href="#">Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse</a> on page 15 |            |      | 300               | ms   |
| <b>DCDC Step Up Converter</b>       |  |   |            |      |                   |      |
| V <sub>VOUT</sub>                   | DCDC Boost output Voltage (pin V <sub>OUT1/2</sub> ) |   | 2.8        |      | 5.5               | V    |
| R <sub>PMOS</sub>                   | On-resistance  | DCDC internal PMOS switch   |            | 45   |                   | mΩ   |
| R <sub>NMOS</sub>                   | On-resistance  | DCDC internal NMOS switch   |            | 47   |                   | mΩ   |
| f <sub>CLK</sub>                    | Operating Frequency                                  | All internal timings are derived from this oscillator   | -7.5%      | 4.0  | +7.5%             | MHz  |
| V <sub>VOUT5V</sub>                 | DCDC Boost output Voltage (pin V <sub>OUT1/2</sub> ) | Constant voltage mode operation <a href="#">const_v_mode</a> (see <a href="#">page 30</a> )=1   |            | 5.0  |                   | V    |
| <b>Current Sources</b>              |  |   |            |      |                   |      |
| V <sub>LED</sub>                    | LED forward voltage                                  | Two flash LEDs, I <sub>LED_OUT</sub> <2x1000mA  | 2.8        | 3.32 | 4.0               | V    |
|                                     |  | Single flash LED, I <sub>LED_OUT</sub> <1800mA  | 2.8        | 3.32 | 4.4               | V    |
| I <sub>LED_OUT</sub>                | LED_OUT1/2 current combined                          | V <sub>VIN</sub> >3.3V, coil_peak=11b, L <sub>COIL</sub> =0.6μH@3.4A, L <sub>ESR</sub> =60mΩ, coil SPM3012T-1R0M, t <sub>FLASH</sub> <300ms   |            |      | 2000              | mA   |
|                                     |  | dual flash LED, <a href="#">current_boost</a> =0<br>single flash LED  | 0          |      | 2000              | mA   |
| I <sub>LED_OUT_BOOST</sub>          | LED_OUT1/2 current combined                          | Dual flash LED, <a href="#">current_boost</a> =1  | 0          |      | 2500 <sup>2</sup> | mA   |
| I <sub>LED_OUTΔ</sub>               | LED_OUT1/2 current source accuracy                   | Otherwise   | -7         |      | +7                | %    |
|                                     |  | I <sub>LED_OUT</sub> =500mA...800mA, 0°C<T <sub>J</sub> <100°C  | -5         |      | +5                | %    |
| I <sub>LED_OUT_RAMP</sub>           | LED_OUT1/2 ramp time                                 | Rampup initiated by I <sup>2</sup> C command  |            | 730  |                   | μs   |
|                                     |  | Rampup started by STROBE  |            | 530  |                   | μs   |
|                                     |  | Full range Ramp-down  |            | 500  |                   | μs   |
| I <sub>LED_OUT_RIPPLE</sub>         | LED_OUT current ripple                               | I <sub>LED_OUT</sub> = 1000mA   |            | 40   |                   | mAPP |



Table 3. Electrical Characteristics (Continued)

| Symbol  | Parameter   | Condition   | Min   | Typ         | Max        | Unit         |                |
|---|---|---|---|-------------|------------|--------------|----------------|
| VILED_COMP  | LED_OUT current source voltage compliance   | Minimum voltage between pin VOUT1/2 and LED_OUT1/2 for operation of the current source with <code>current_boost=0</code>                    |   | 230         |            | mV           |                |
| VILED_COMP_BOOST  |   | VILED_COMP with <code>current_boost=1</code>  |   | 290         |            | mV           |                |
| LLED_CONNECTION   | LED connection inductance   | Represents a maximum connection length of 10cm (LED connection and ground return path)  |   |             | 100        | nH           |                |
| <b>Protection and Fault Detection Functions (see page 12)</b> |   |   |   |             |            |              |                |
| VVOUTMAX  | VVOUT overvoltage protection  | DCDC Converter Overvoltage Protection   | 5.0   | 5.3         | 5.6        | V            |                |
| ILIMIT  | Current Limit for coil LDCDC (Pin SW) measured at 25% PWM duty cycle <sup>3</sup><br><br>maximum 40000s lifetime operation in overcurrent limit | <code>coil_peak=00b</code>  | 2.25  | 2.5         | 2.75       | A            |                |
|   |   | <code>coil_peak=01b</code>  | 2.61  | 2.9         | 3.19       |              |                |
|   |   | Default value<br><code>coil_peak (see page 23)=10b</code>   | 3.0   | 3.3         | 3.63       |              |                |
|   |   | <code>coil_peak=11b</code>  | 3.3   | 3.7         | 4.1        |              |                |
| VLEDSHORT   | Flash LED short circuit detection voltage   | Voltage measured between pins LED_OUT1,2 and GND  |   | 1.2         |            | V            |                |
| TOVTEMP   | Overtemperature Protection  | Junction temperature  |   | 144         |            | °C           |                |
| TOVTEMPHYS T  | Overtemperature Hysteresis  |   |   | 5           |            | °C           |                |
| tFLASHTIMEOUT   | Flash Timeout Timer   | Can be adjusted with register <code>flash_timeout</code> (page 26)  | 4   |             | 1124       | ms           |                |
|   |   | Accuracy  | -7.5  |             | +7.5       | %            |                |
| VVULO   | Undervoltage Lockout  | Falling VVIN  | 2.25  | 2.4         | 2.5        | V            |                |
|   |   | Rising VVIN   | VVULO+0.05                                  | VVULO+0.1   | VVULO+0.15 | V            |                |
| VIN_LOW_VOLTAGE   | Battery Low Voltage Protection  | Defined by <code>vin_low_v</code> - see <a href="#">Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse on page 15</a> | -2.5%                                       | 3.0-3.47    | +2.5%      | V            |                |
| <b>Protection and Fault Detection Functions - NTC</b>         |   |   |   |             |            |              |                |
| INTC  | NTC Current Source  | Adjustable by <code>ntc_current</code> (page 25) in 40µA steps  | Range                                       | 40          |            | 600          | µA             |
|   |   |   | $\Delta I$ - accuracy<br>$V(NTC) \leq 1.7V$ | -7          |            | +7           | % <sup>4</sup> |
|   |   |   |   | -5          |            | +5           | µA             |
| VNTC_TH   | Threshold for overtemperature   | If <code>ntc_on</code> (page 25)=1 and the voltage on NTC drops below VNTC_TH, any flash/torch or pwm operation of LED_OUT is stopped       |   | 1.0         |            | V            |                |
| <b>ADC</b>  |   |   |   |             |            |              |                |
| Resolution  |   |   |   | 10          |            | bits         |                |
| Range   | ADC input range; channel selected by <code>adc_channel</code> (page 27)   | ADC Code  | 0   |             | full scale |              |                |
|   |   | NTC   | 0.0   |             | 2.2        | V            |                |
|   |   | VIN   | 0.0   |             | 5.5        | V            |                |
|   |   | TJUNC (AS3649 junction temperature)   |   | see Table 6 |            | °C           |                |
| Accuracy  | ADC measurement accuracy  | NTC   | -1.5  |             | +1.5       | % full scale |                |
|   |   | TJUNC (-30°C...150°C)   | -8  |             | +8         | °C           |                |
|   |   | TJUNC (0°C...85°C)  | -5  |             | +5         | °C           |                |



Table 3. Electrical Characteristics (Continued)

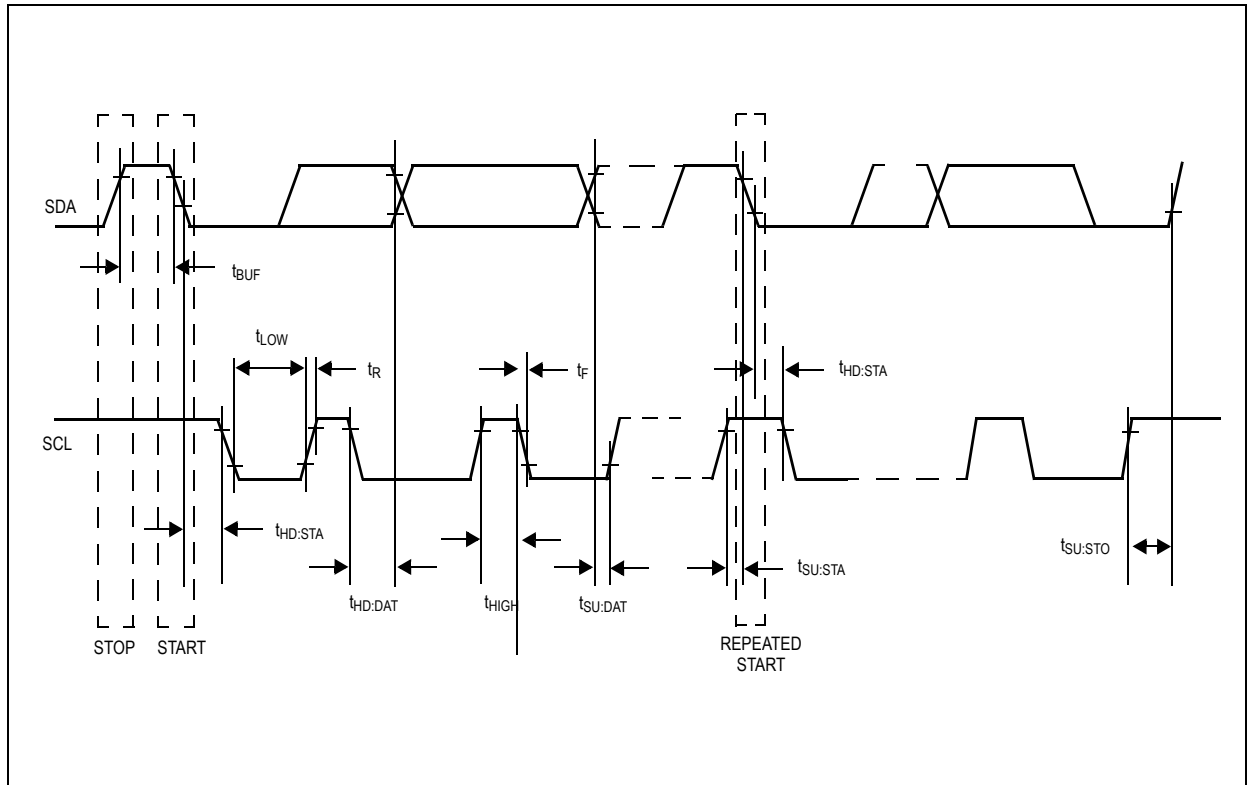
| Symbol  | Parameter   | Condition  | Min                    | Typ | Max              | Unit |
|---|---|--|------------------------|-----|------------------|------|
| <b>Digital Interface</b>                                    |   |  |                        |     |                  |      |
| V <sub>IH</sub>   | High Level Input Voltage                          | Pins ON, SCL, SDA.<br>and TXMASK/TORCH                   | 1.26                   |     | V <sub>VIN</sub> | V    |
| V <sub>IL</sub>   | Low Level Input Voltage                           |  | 0.0                    |     | 0.54             | V    |
| V <sub>IHFLASH</sub>  | High Level Input Voltage                          | Pin STROBE.  | 0.84                   |     | V <sub>VIN</sub> | V    |
| V <sub>ILFLASH</sub>  | Low Level Input Voltage                           |  | 0.0                    |     | 0.54             | V    |
| V <sub>OL</sub>   | Low Level Output Voltage                          | Pin SDA, I <sub>OL</sub> =3mA                            |                        |     | 0.3              | V    |
| I <sub>LEAK</sub>   | Leakage current                                   | Pins ON, SCL, SDA  | -1.0                   | 0.0 | +1.0             | μA   |
| I <sub>PD</sub>   | Pulldown current to GND <sup>5</sup>              | Pins STROBE and TXMASK/TORCH                             |                        | 36  |                  | μA   |
| t <sub>DEBTORCH</sub>                                       | TORCH debounce time                               |  | 6.3                    | 9   | 11.7             | ms   |
| t <sub>DEBTXMASK</sub>                                      | TXMASK debounce timer                             |  |                        | 1.5 |                  | μs   |
| <b>I<sup>2</sup>C mode timings - see Figure 3 on page 8</b> |   |  |                        |     |                  |      |
| f <sub>SCLK</sub>   | SCL Clock Frequency                               |  | 0                      |     | 400              | kHz  |
| t <sub>BUF</sub>  | Bus Free Time Between a STOP and START Condition  |  | 1.3                    |     |                  | μs   |
| t <sub>HD:STA</sub>   | Hold Time (Repeated) START Condition <sup>6</sup> |  | 0.6                    |     |                  | μs   |
| t <sub>LOW</sub>  | LOW Period of SCL Clock                           |  | 1.3                    |     |                  | μs   |
| t <sub>HIGH</sub>   | HIGH Period of SCL Clock                          |  | 0.6                    |     |                  | μs   |
| t <sub>SU:STA</sub>   | Setup Time for a Repeated START Condition         |  | 0.6                    |     |                  | μs   |
| t <sub>HD:DAT</sub>   | Data Hold Time <sup>7</sup>                       |  | 0                      |     | 0.9              | μs   |
| t <sub>SU:DAT</sub>   | Data Setup Time <sup>8</sup>                      |  | 100                    |     |                  | ns   |
| t <sub>R</sub>  | Rise Time of Both SDA and SCL Signals             |  | 20 + 0.1C <sub>B</sub> |     | 300              | ns   |
| t <sub>F</sub>  | Fall Time of Both SDA and SCL Signals             |  | 20 + 0.1C <sub>B</sub> |     | 300              | ns   |
| t <sub>SU:STO</sub>   | Setup Time for STOP Condition                     |  | 0.6                    |     |                  | μs   |
| C <sub>B</sub>  | Capacitive Load for Each Bus Line                 | C <sub>B</sub> — total capacitance of one bus line in pF |                        |     | 400              | pF   |
| C <sub>I/O</sub>  | I/O Capacitance (SDA, SCL)                        |  |                        |     | 10               | pF   |

1. To improve efficiency at low output currents, the active part of the internal switching transistor PMOS is reduced in size to 1/5 its original size. This reduces the current required to drive the PMOS transistor and therefore improves overall efficiency at low output currents.
2. The maximum current driving capability depends on supply voltage V<sub>VIN</sub>, LED forward voltage and coil peak current limit.
3. Due to slope compensation of the current limit, I<sub>LIMIT</sub> changes with duty cycle - see Figure 16 on page 11.
4. Accuracy defined in % of current setting and in absolute value (μA), accuracy values have to be added together
5. A pulldown current of 36μA is equal to a pulldown resistor of 42kΩ at 1.5V
6. After this period, the first clock pulse is generated
7. A device must internally provide a hold time of at least 300ns for the SDA signal (referred to the V<sub>IHMIN</sub> of the SCL signal) to bridge the undefined region of the falling edge of SCL.
8. A fast-mode device can be used in a standard-mode system, but the requirement t<sub>SU:DAT</sub> = to 250ns must then be met. This is automatically the case if the device does not stretch the LOW period of the SCL signal. If such a device does stretch the LOW period of the SCL signal, it must output the next data bit to the SDA line t<sub>R</sub> max + t<sub>SU:DAT</sub> = 1000 + 250 = 1250ns before the SCL line is released.



## 6.1 Timing Diagrams

Figure 3. I<sup>2</sup>C mode Timing Diagram







## 7 Typical Operating Characteristics

$V_{IN} = 3.7V$ ,  $T_A = +25^\circ C$  (unless otherwise specified)

Figure 4. DCDC Efficiency vs.  $V_{VIN}$

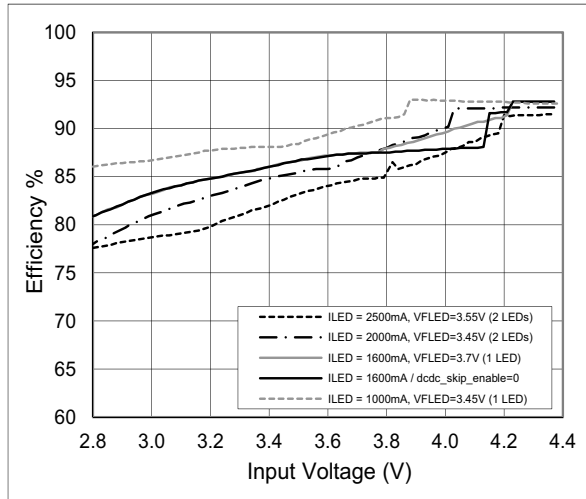


Figure 5. Application Efficiency ( $P_{LED}/P_{VIN}$ ) vs.  $V_{VIN}$

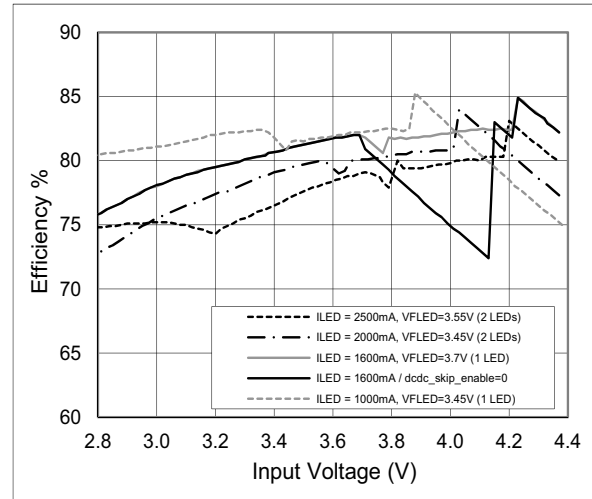


Figure 6. Battery Current vs.  $V_{VIN}$

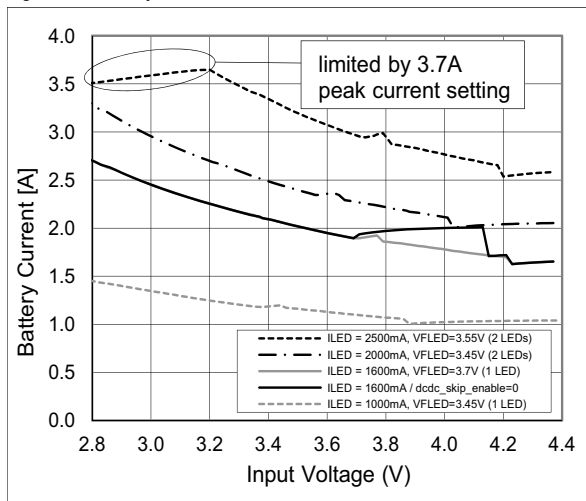


Figure 7. Efficiency at low currents (298mA/100mA)

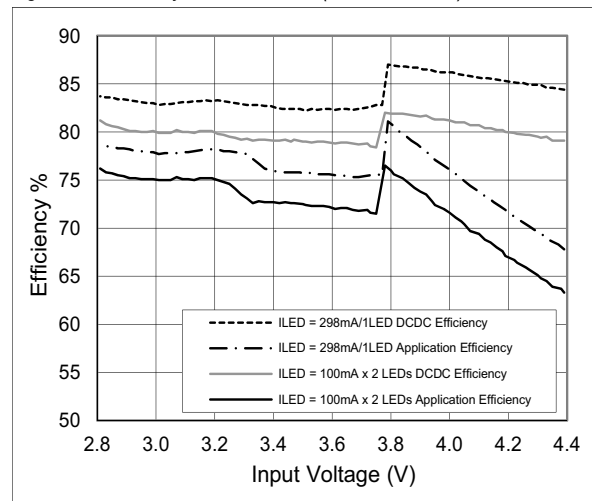


Figure 8. I<sub>LED</sub> Startup (I<sub>LED\_OUT</sub>=1.0A)

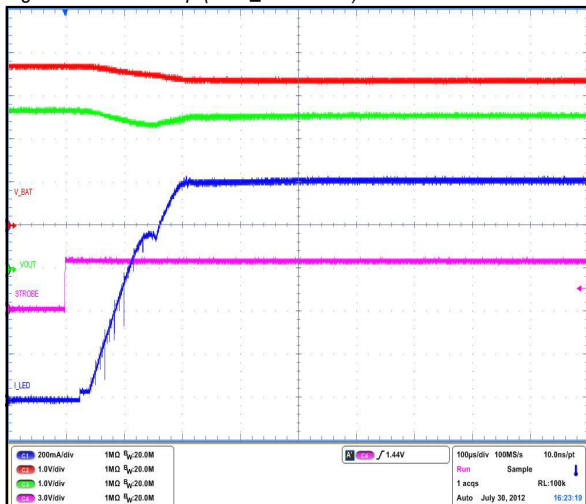


Figure 9. I<sub>VIN</sub>, I<sub>LED</sub> Startup (I<sub>LED\_OUT</sub>=800mA)

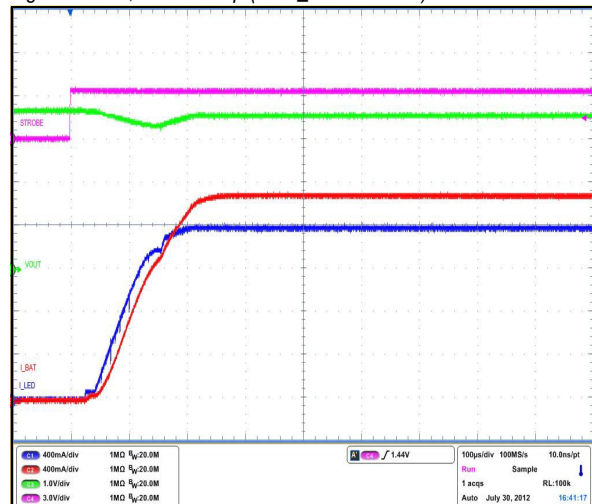




Figure 10. ILED vs. VVIN

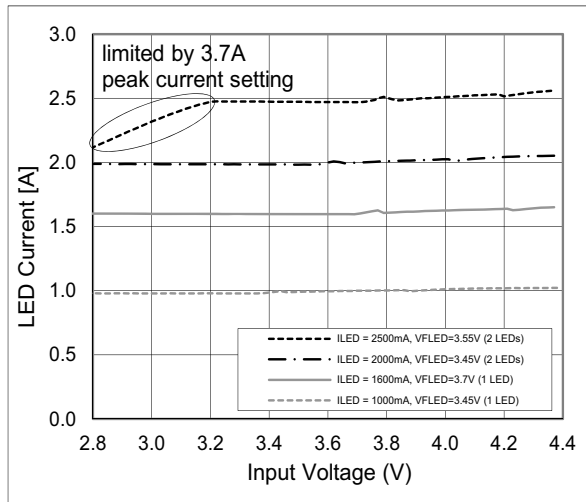


Figure 11. VOUT / ILED\_OUT ripple, ILED\_OUT = 2x1.0A

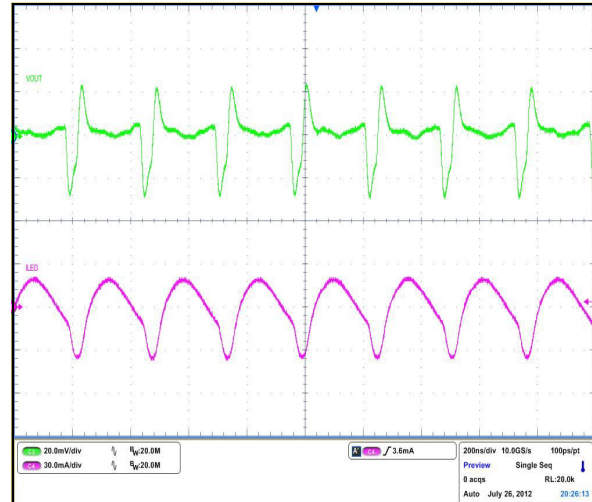


Figure 12. Diagnostic Pulse Operation

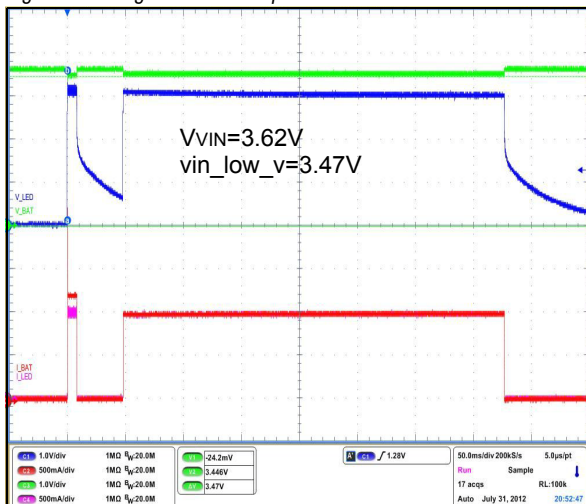


Figure 13. TxMask operation waveform (ILED, IVIN)

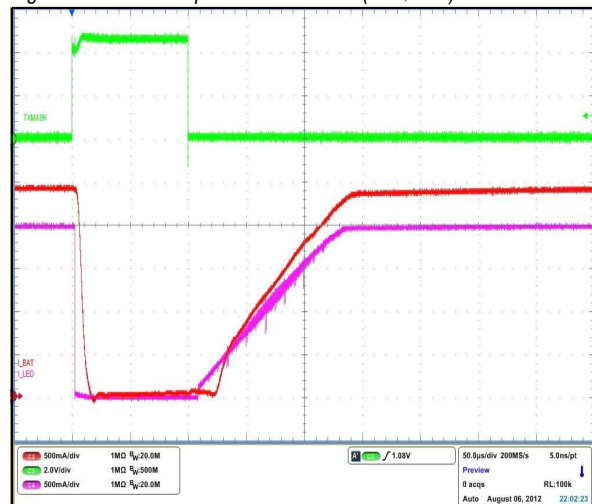


Figure 14. Timeout Timer

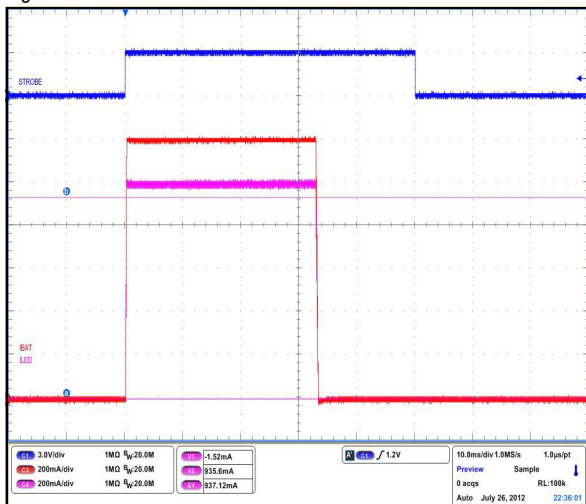
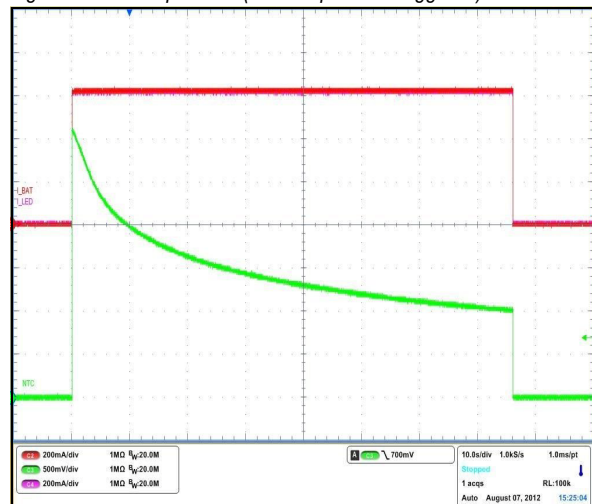


Figure 15. NTC operation (overtemperature triggered)





## 8 Detailed Description

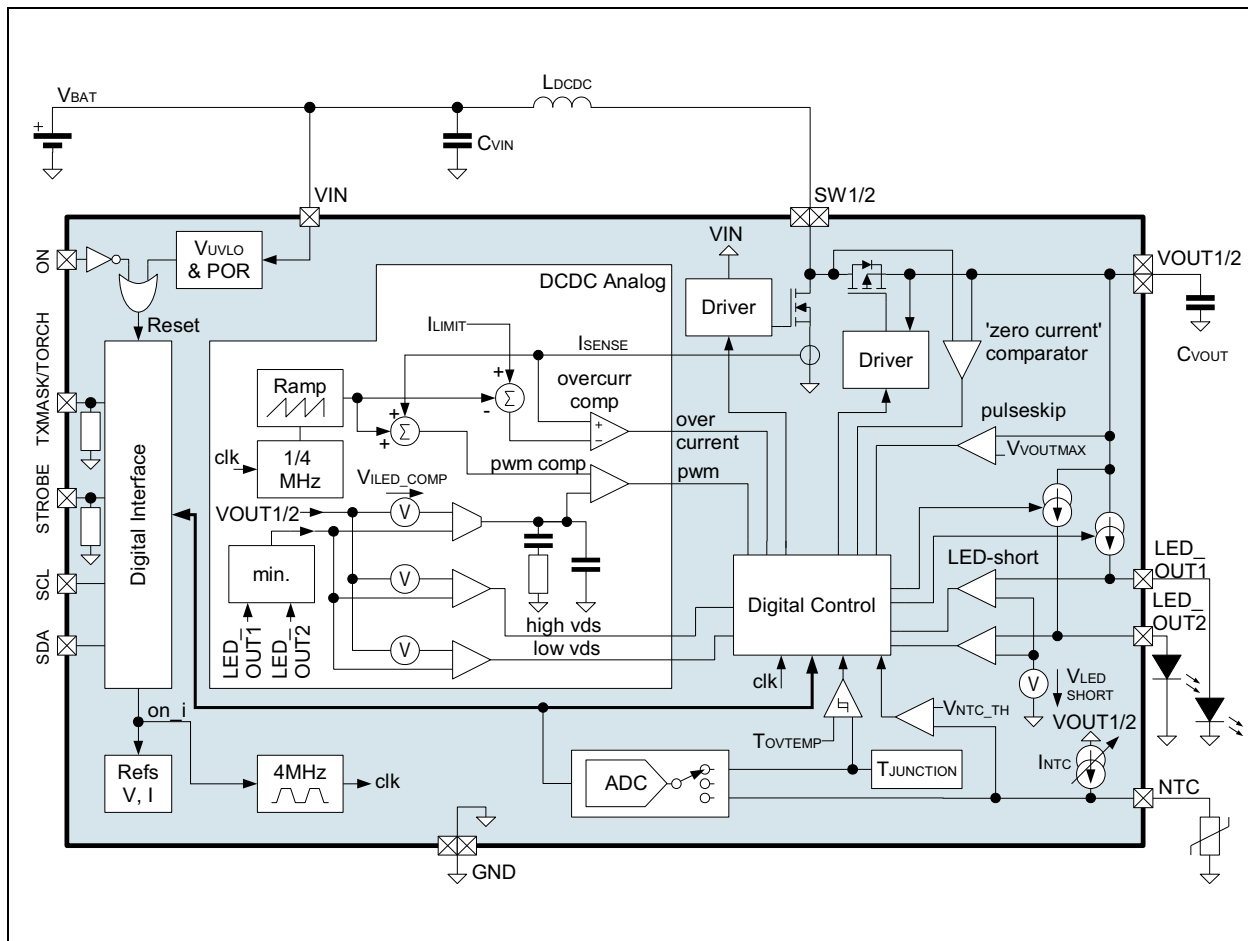
The AS3649 is a high performance DCDC step up converter with internal PMOS and NMOS switches. Its output is connected to one or two flash LEDs<sup>1</sup> with two internal current sources and hardware LED temperature protection using an external NTC. The device is controlled by the pins SDA and SCL in I<sup>2</sup>C mode and includes a hardware reset input ON.

The actual operating mode like standby, torch light, indicator or flash mode, can then be chosen by the interface. If not in standby mode, the device automatically enters shutdown and resets all registers by setting pin ON=0.

The AS3649 includes a fixed frequency DCDC step-up with accurate startup control. Together with the current source (on LED\_OUT1/2) it includes several protection and safety functions.

### 8.1 Internal Circuit Diagram

Figure 16. Internal Circuit Diagram



### 8.2 Softstart / Soft ramp down

During startup and ramp down the LED current is smoothly ramped up and ramped down. If the DCDC converter goes out of regulation (measured by monitoring the voltage across the current sources), the ramp up is temporarily stopped in order for the DCDC to return to regulation<sup>2</sup>.

1. If two LEDs are connected, it is possible to operate each of the two LEDs individually as the LED current can be selected individually.
2. The actual value of the LED current setting can be readout by the register `led_current_actual` (see page 31) to allow the camera processor to adopt to the actual operating conditions.



### 8.3 4/1MHz Operating Mode Switching and Pulse Skipping

If `freq_switch_on` (see page 29)=1 and if `led_current1`>=40h<sup>3</sup> or `led_current2`>=40h<sup>3</sup> and `current_boost`=0, the DCDC converter always operates in PWM mode (exception: PFM mode is allowed during startup) to reduce EMI in EMI sensitive systems. For high duty cycles close to 100% on-time (maximum duty cycle) of the PMOS, the DCDC converter can switch into a 1MHz operating mode and maximum duty cycle to improve efficiency for this load condition<sup>4</sup>. The DCDC converter returns back to its normal 4MHz operating frequency when load or supply conditions change. Due to this switching between two fixed frequencies the noise spectrum of the system is exactly defined and predictable. If improved efficiency is required, the fixed switching between 4MHz / 1MHz can be disabled by `freq_switch_on` (see page 29)=0. In this case pulseskip will be used.

The modes are selected according to Table 4:

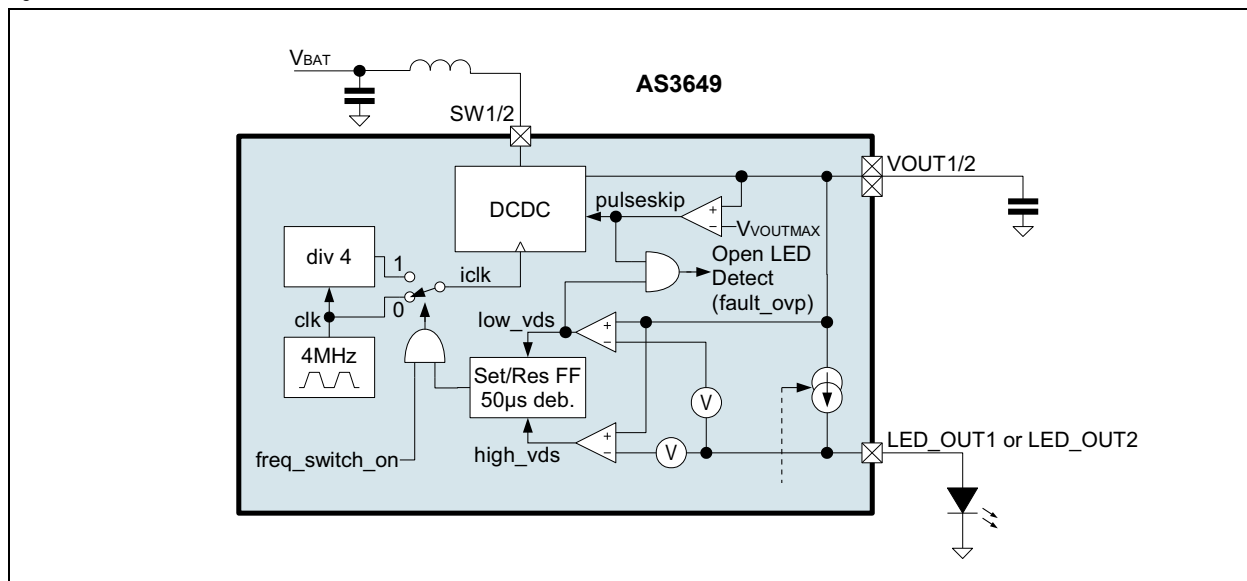
Table 4. 4/1MHz switching and pulseskip operating modes

| <code>freq_switch_on</code> | <code>dcdc_skip_enable</code> | <code>led_current1</code> >=40h or <code>led_current2</code> >=40h | <code>led_current1</code> <40h and <code>led_current2</code> <40h |
|-----------------------------|-------------------------------|--|---|
| 0                           | 0                             | 4MHz forced PWM operation (no 1MHz operation, no pulseskip)        |   |
| 0                           | 1                             | 4MHz, pulse skipping allowed, no 1MHz operation                    |   |
| 1                           | 0                             | 4MHz/1MHz forced PWM operation, pulseskip not allowed <sup>1</sup> | 4MHz forced PWM operation (no 1MHz operation, no pulseskip)       |
| 1                           | 1                             |  | 4MHz, pulse skipping allowed, no 1MHz operation                   |

1. If `current_boost`=1, `freq_switch_on` is set to '0'.

The internal circuit for switching between these two frequencies is shown in Figure 17 (for simplicity only a single current source is shown):

Figure 17. Internal circuit of 4MHz/1MHz selection



**Note:** If the voltage on VOUT1/2 exceeds VVOUTMAX, the DCDC will always skip pulses to limit the output voltage.

### 8.4 Protection and Fault Detection Functions

The protection functions protect the AS3649 and the LED(s) against physical damage. In most cases a `Fault` register bit is set, which can be readout by the I<sup>2</sup>C interface. The fault bits are automatically cleared by a I<sup>2</sup>C readout of the fault register. Additionally the DCDC is stopped and the current sources are disabled<sup>5</sup> by resetting `mode_setting`=00<sup>6</sup> and `txmask_torch_mode`=00.

3. Set register `dcdc_skip_enable` (see page 28)=1 if 4MHz forced operation shall be used below this LED current.
4. Efficiency compared to a 4MHz only DCDC converter forced to operate with minimum duty cycle.



### 8.4.1 Overvoltage Protection

In case of no or a broken LED(s) at the pin LED\_OUT1/2 and an enabled DCDC converter, the voltage on VOUT1/2 rises until it reaches VVOUTMAX (overvoltage condition) and the voltage across the current source is below low\_vds<sup>7</sup>, the DCDC converter is stopped, the current sources are disabled and the bit `fault_ovp` (see page 29)<sup>8</sup> is set<sup>9</sup>. In a dual LED configuration for the AS3649, if a single open LED is detected, this LED is disabled, `fault_ovp` is set and the device continues operation with the other LED.

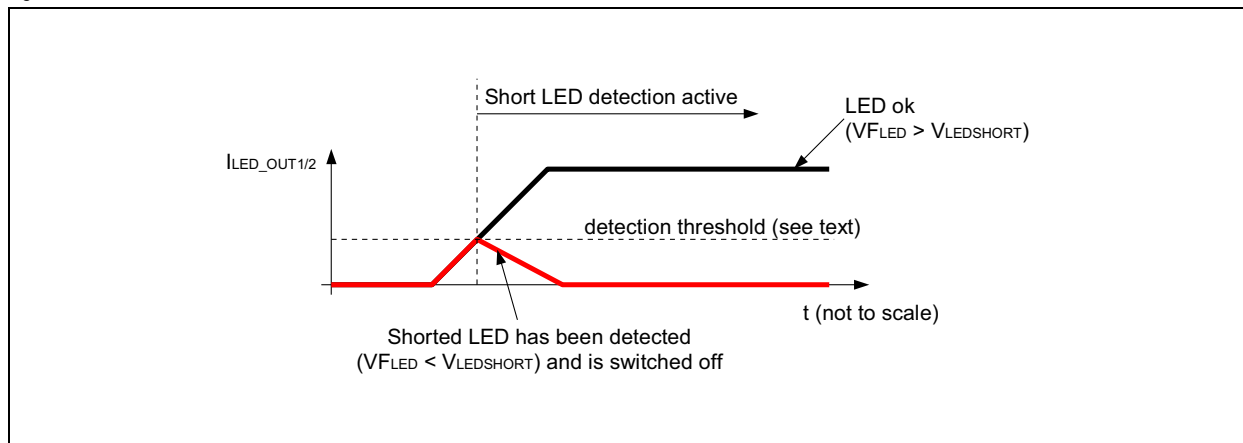
**Note:** In PWM operating mode (`mode_setting=01b`), open LED detection is disabled (and `fault_ovp` is not set). The output voltage will nevertheless be kept below VVOUTMAX.

### 8.4.2 Short Circuit Protection

After the startup of the DCDC converter, the voltage on LED\_OUT1/2 is continuously monitored and compared against VLED<sub>SHORT</sub> if the LED current is above 27.5mA (`current_boost=0`), 34.3mA (`current_boost=1`)<sup>10, 11</sup> (see Figure 18). If the voltage on the LED ( $V_{LED} = LED\_OUT1/2$ ) stays below VLED<sub>SHORT</sub>, the DCDC is stopped (as a shorted LED is assumed), the current sources are disabled and the bit `fault_led_short` (see page 29) is set. In a dual LED configuration for the AS3649, if a single shorted LED is detected, this LED is disabled, `fault_led_short` is set and the device continues operation with the other LED.

**Note:** In PWM operating mode (`mode_setting=01b`), short circuit protection is disabled.

Figure 18. Short LED Detection



### 8.4.3 Overtemperature Protection

The junction temperature of the AS3649 is continuously monitored. If the temperature exceeds T<sub>OVTEMP</sub>, the DCDC is stopped, the current sources are disabled (instantaneous) and the bit `fault_overtemp` (see page 29) is set (but the operating mode `mode_setting` is not changed). The driver is automatically re-enabled<sup>12</sup> once the junction temperature drops below T<sub>OVTEMP</sub>-T<sub>OVTEMPHYS</sub>.

### 8.4.4 TXMASK event occurred

If during flash, TXMASK current reduction is enabled (see TXMASK on page 15, configured by `txmask_torch_mode=01`) and a TXMASK event happened (pin TXMASK/TORCH=1), the fault register bit `fault_txmask` (see page 28) is set.

5. Applies for all faults except TXMASK event occurred
6. Except for TXMASK event occurred and Overtemperature Protection
7. If overvoltage is reached, but none of the low\_vds comparator(s) triggers, VOUT1/2 is still regulated below VVOUTMAX.
8. In indicator or low current PWM mode (`mode_setting` (see page 26)=01) the register `fault_ovp` is not set under an overvoltage conditions. The output voltage is nevertheless kept below VVOUTMAX.
9. In constant voltage mode (5V generation, register bit `const_v_mode=1`) this fault is disabled.
10. To avoid errors in short LED detection for LEDs with a high leakage current
11. The LED short circuit protection is disabled in indicator mode (or low current mode using PWM) (`mode_setting` on page 26=01b)
12. In constant voltage mode (`const_v_mode=1`) the DCDC will not be automatically re-enabled.



### 8.4.5 Flash Timeout

If the flash is started a timeout timer is started in parallel. If the flash duration defined by the STROBE input (`strobe_on=1` and `strobe_type=1`, see [Figure 25 on page 18](#)) exceeds `tFLASHTIMEOUT` (adjustable by register `flash_timeout` (see [page 26](#))), the DCDC is stopped and the flash current sources (on pin LED\_OUT1/2) are disabled (ramping down) and `fault_timeout` is set.

If the flash duration is defined by the timeout timer itself (`strobe_on = 0`, see [Figure 23 on page 17](#)), the register `fault_timeout` is set after the flash has been finished.

### 8.4.6 Supply Undervoltage Protection

If the voltage on the pin VIN (=battery voltage) is or falls below `VUVLO`, the AS3649 is kept in shutdown state and all registers are set to their default state.

### 8.4.7 NTC - Flash LED Overtemperature Protection

The `ntc_on` (see [page 25](#))=1, the flash LED is protected by the AS3649 using an internal comparator connected to NTC and an current source controlled by `ntc_current` (see [page 25](#)) (`VNTC_TH`, `INTC` as shown in [Figure 16, "Internal Circuit Diagram," on page 11](#)); once it is triggered, the DCDC is stopped, the current sources are disabled (instantaneous) and the bit `fault_ntc` (see [page 28](#)) is set.

As the external NTC cannot measure the LED temperature in real time during a high current flash pulse (the duration from heating up of the LED until the NTC recognizes a too hot LED is usually too long), it is advisable to measure the LED temperature before the flash pulse (with the [ADC](#) (see [page 19](#)) and `ntc_current` (see [page 25](#))) and judge how much current can be driven through the LED (to be estimated depending on LED heat sink and is usually specified by the LED manufacturer).

## 8.5 Operating Mode and Currents

The output currents and operating mode currents are selected according to the following table:

Table 5. Operating Mode and Current Settings

| AS3649 Configuration   |              |   |   | Operating Mode and Currents  |   |  |
|--|--------------|---|---|--|---|--|
| ON, SCL, SDA   | TXMASK/TORCH | STROBE  | mode setting (see <a href="#">page 26</a> ) | Condition  | Mode  | LED_OUT1/2 Output current  |
| ON=0   | X            | X   | X   | X  | Shutdown<br>All registers are reset to their default values                         | 0  |
| ON=1; I <sup>2</sup> C commands are accepted on pins SCL and SDA | X            | X   | 00  | <code>txmask_torch_mode</code> (see <a href="#">page 23</a> ) not 10                       | standby   | 0  |
|  | 0            | X   |   | <code>txmask_torch_mode</code> = 10  |   |  |
|  | 1            | X   |   | <code>txmask_torch_mode</code> = 10  | external torch mode   | LED current is defined by the 6LSB <sup>1</sup> bits of <code>led_current1</code> and <code>led_current2</code>  |
|  | X            | X   | 01  |  | indicator mode or low current pwm mode <sup>2</sup>                                 | LED current is defined by the 6LSB bits (bits 5...0) of <code>led_current1</code> and <code>led_current2</code> pwm modulated defined by register <code>inct_pwm</code> (31.5kHz: 1/16...4/16) or 7.9kHz: 1/64...3/64) |
|  | X            | X   | 10  |  | torch light mode  | LED current is defined by the 6LSB <sup>2</sup> bits (5...0) of <code>led_current1</code> and <code>led_current2</code>  |
|  | X            | X   | 11  | <code>strobe_on</code> (see <a href="#">page 28</a> ) = 0                                  | flash mode;   | LED current is defined by <code>led_current1</code> and <code>led_current2</code> - the current can be reduced during flash, see <a href="#">Flash Current Reductions</a> below  |
|  | X            | 0->1  |   | <code>strobe_on</code> = 1 and <code>strobe_type</code> (see <a href="#">page 28</a> ) = 0 | flash duration defined by <code>flash_timeout</code> (see <a href="#">page 26</a> ) |  |
| X  | 1            | <code>strobe_on</code> = 1 and <code>strobe_type</code> = 1 |   | flash duration defined by STROBE input; timeout defined by <code>flash_timeout</code>      |   |  |



1. The MSB bit of this register not used to protect the LED; therefore the maximum torch light current =  $1/4 * \text{the maximum flash current}$
2. The low current mode is a general purpose PWM mode to drive less current through the LED in average, but keep the actual pulsed current in a range where the light output from the LED is still specified. As only the 6 LSBs of `led_current1` and `led_current2` is used the maximum current is limited to  $1/4$  of the maximum flash current.

Always keep `led_current1`  $\geq$  `led_current2`.

### 8.5.1 Flash Current Reductions

#### TXMASK.

Usually the flash current is defined by the register `led_current1` and `led_current2`. If the TXMASK/TORCH input is used and (configured by `txmask_torch_mode=01`), the flash current is reduced to `flash_txmask_current` if TXMASK/TORCH=1.

#### Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse.

Due to the high load of the flash driver and the ESR of the battery (especially critical at low temperatures), the voltage on the battery drops. If the voltage drops below the reset threshold, the system would reset. To prevent this condition the AS3649 monitors the battery voltage and keeps it above `vin_low_v` as follows:

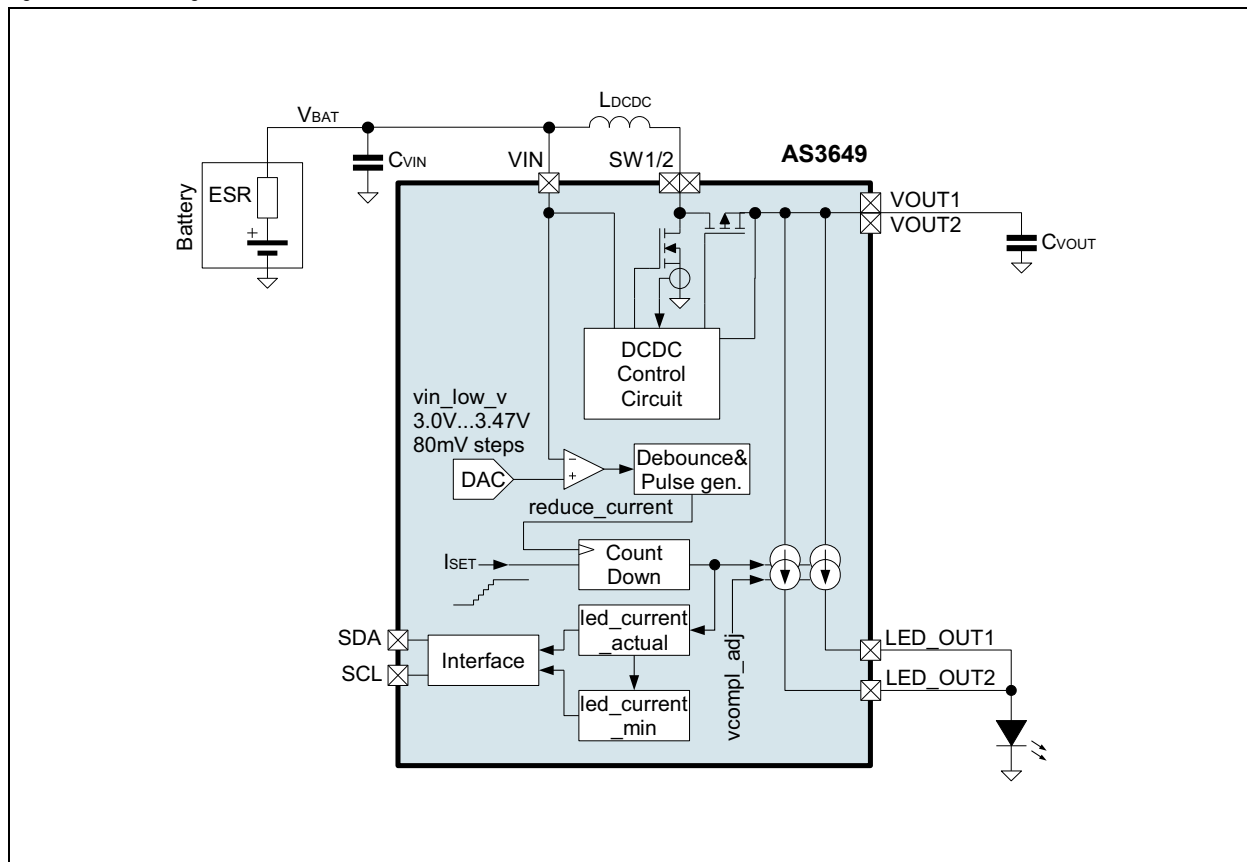
If the voltage on VIN before the flash is below `vin_low_v`, the DCDC is not started at all. Otherwise during flash, if the voltage on VIN drops below the threshold defined by `vin_low_v`, the flash current is reduced (or ramping of the current is stopped during flash current startup) and `status_uvlo` is set. The timing for the reduction of the current is  $2\mu\text{s}/\text{LSB}$  current change.

During the flash pulse the actual used current can be readout by the register `led_current_actual`.

After the flash pulse the minimum current can be readout by the register `led_current_min` - this allows to adjust the camera sensitivity (gain or iso-settings) for the subsequent flash pulse (e.g. when using a pre-flash and a main flash pulse).

The internal circuit for low voltage current reductions are shown in [Figure 19](#):

Figure 19. Low Voltage Current Reduction Internal Circuit

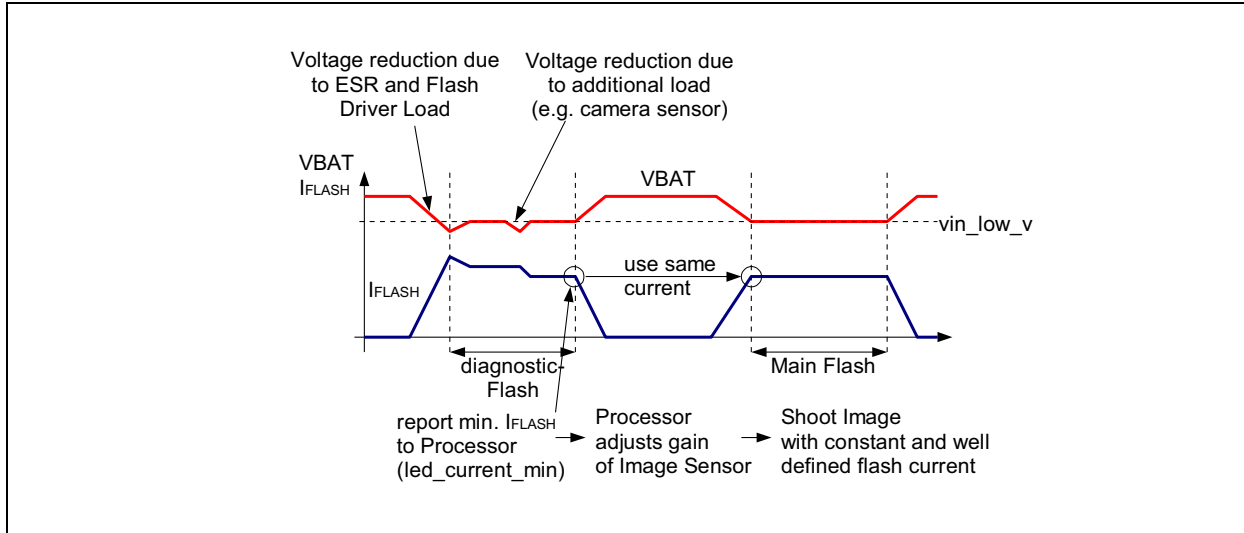




A mobile phone camera flash system can trigger a diagnostic flash and a main-flash:

The diagnostic flash is initiated by the processor. After this diagnostic flash, the determined maximum flash current can be read back through the I<sup>2</sup>C interface from register `led_current_min` (see page 30) and used for the setting for the main flash. Therefore the current in the main-flash is constant and additionally the camera system can use this current for picture quality adjustments - the waveforms for this concept are shown in Figure 20:

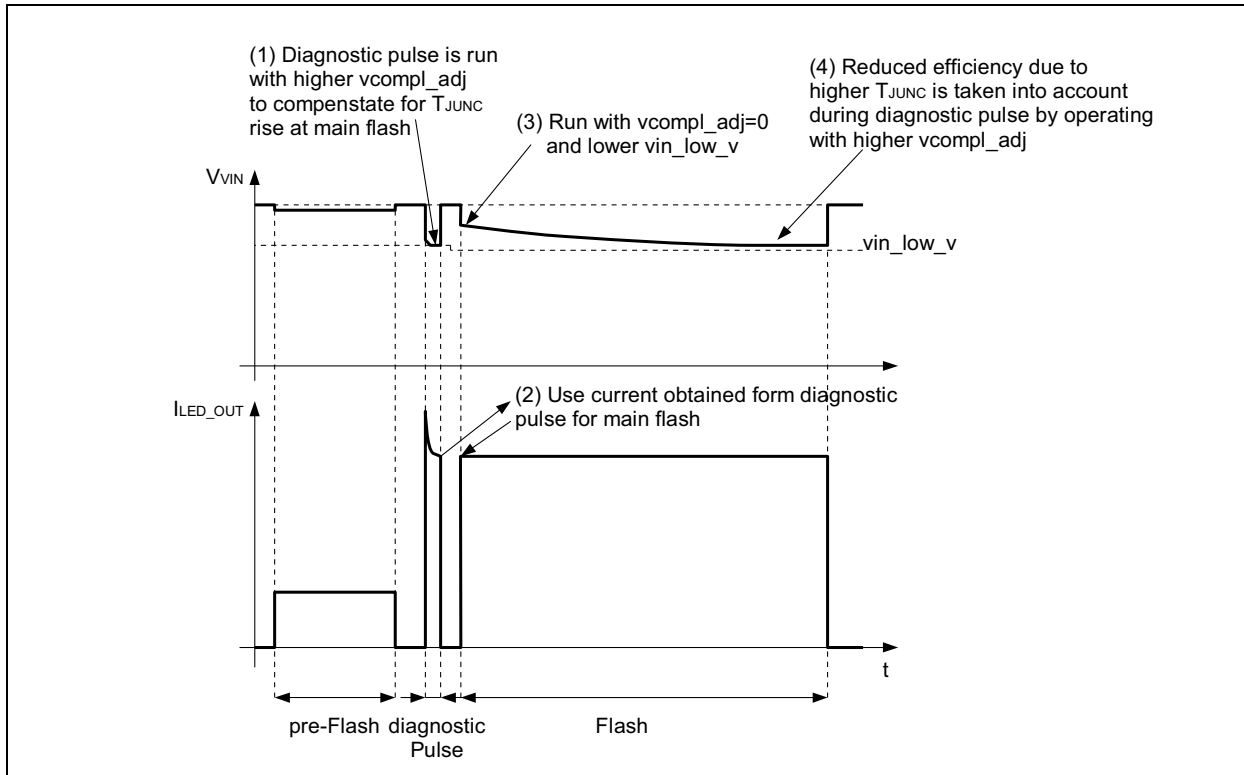
Figure 20. Low Voltage Current Reduction Waveform with Diagnostic-Flash and Main-Flash Phase



### Short Diagnostic Pulse.

If the diagnostic flash should be short (e.g. 4ms) it is recommended to operate this diagnostic flash at a different `vcompl_adj` (see page 27) and higher `vin_low_v` (see page 24) settings compared to the main flash as shown in Figure 21:

Figure 21. Low Voltage Current Reduction Waveform with Short Diagnostic-Flash and Main-Flash Phase







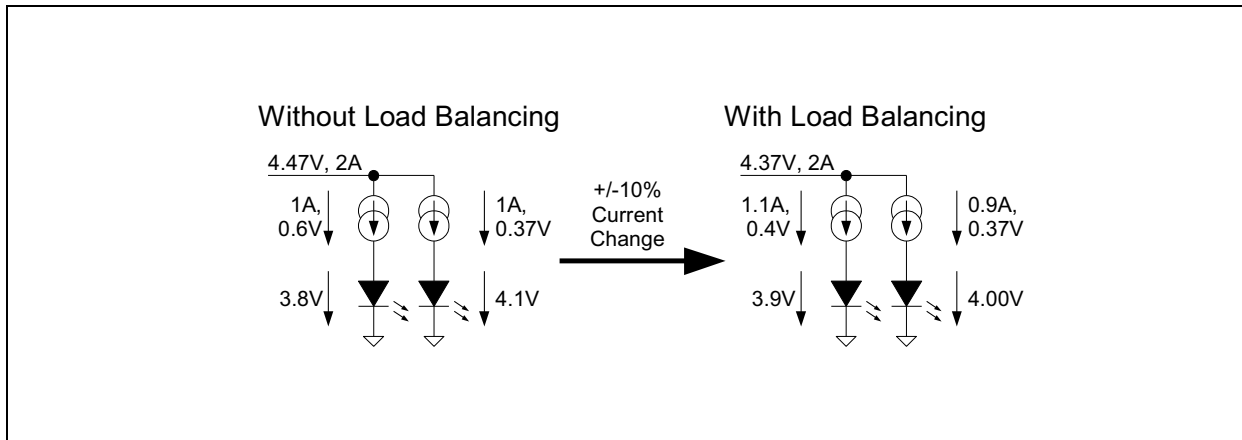
The AS3649 efficiency reduction during main flash can be compensated during a short diagnostic flash by adjusting `vcompl_adj` as shown in Figure 21. Reducing `vin_low_v` during main flash additionally takes into account a longer time constant of the battery for high loads and allows a very short diagnostic pulse (only 4ms).

Using the ams AG linux software driver it is possible to calculate the maximum flash duration for a given operating condition (additionally using `T_JUNCTION` measured through the AS3649 ADC).

### 8.5.2 Load Balancing

To improve the efficiency of the AS3649 for LEDs with unmatched forward voltage and reduce the internal power dissipation of the AS3649, set the bit `load_balance_on=1`. This bit can change the currents through the LEDs by up to +/-15% to match the forward voltage of the LED better as shown in Figure 22:

Figure 22. Load Balancing



## 8.6 Flash Strobe Timings

The flash timing are defined as follows:

- Flash duration defined by register `flash_timeout` and flash is started immediately when this mode is selected by the I<sup>2</sup>C command (see Figure 23):  
set `strobe_on=0`, start the flash by setting `mode_setting=11b`
- Flash duration defined by register `flash_timeout` and flash started with a rising edge on pin STROBE (see Figure 24):  
set `strobe_on=1` and `strobe_type=0`
- Flash start and timing defined by the pin STROBE; the flash duration is limited by the timeout timer defined by `flash_timeout` (see Figure 25 and Figure 26):  
set `strobe_on=1` and `strobe_type=1`

Figure 23. AS3649 Flash Duration Defined by `flash_timeout` Without Using STROBE Input

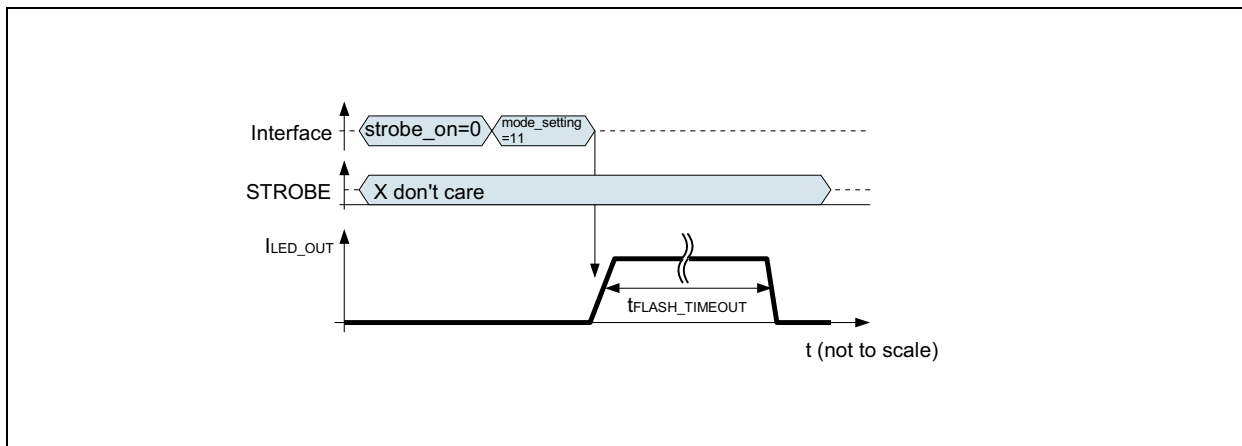




Figure 24. AS3649 Flash Duration Defined by *flash\_timeout*, Starting Flash with STROBE Rising Edge

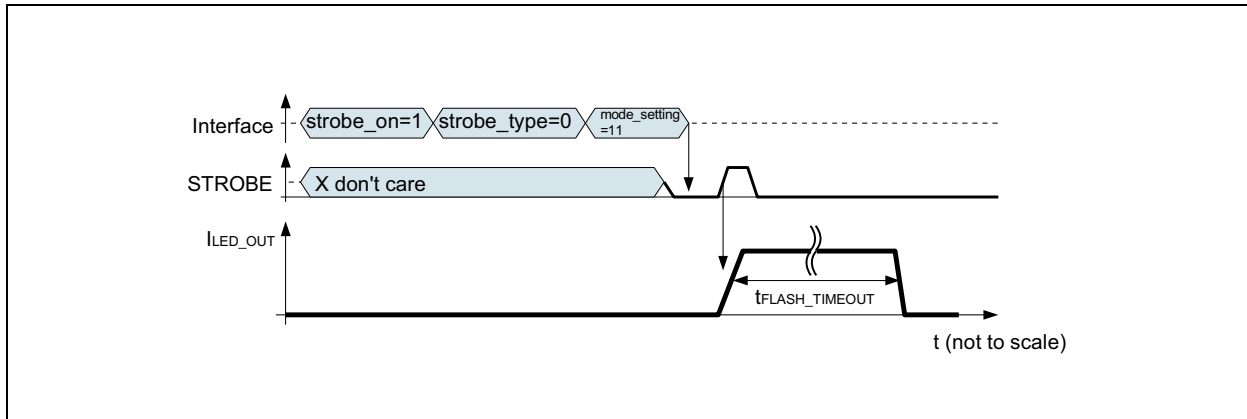


Figure 25. AS3649 Flash Duration and Start Defined by STROBE, Limited by *flash\_timeout*; Timer Not Expired

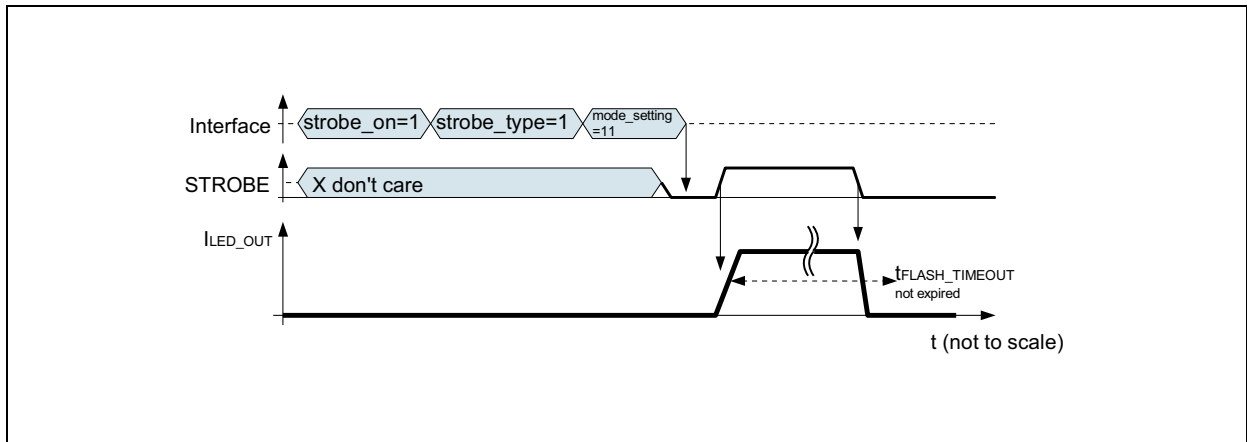
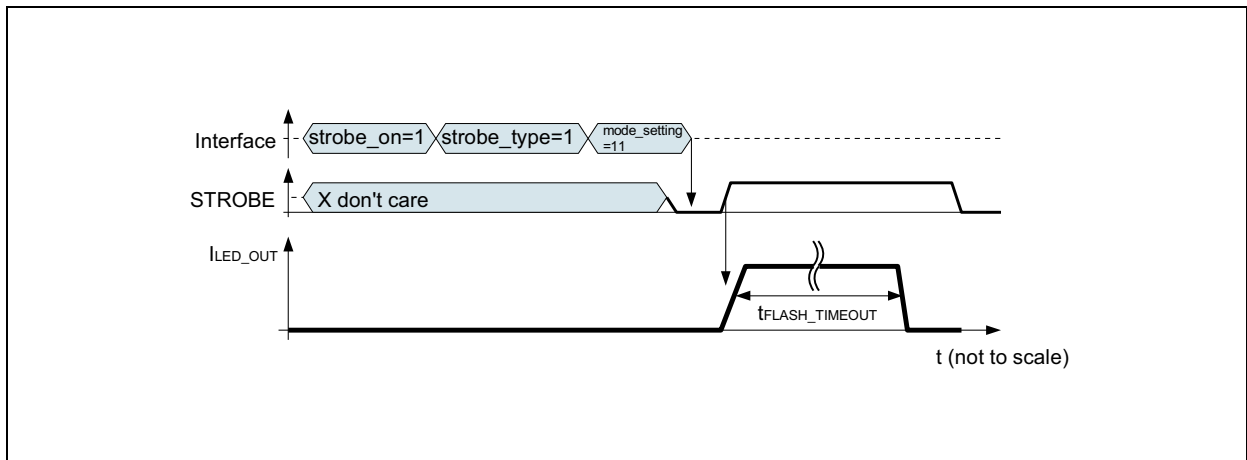


Figure 26. AS3649 Flash Duration and Start Defined by STROBE, Limited by *flash\_timeout*; Timer Expired





## 8.7 ADC

The internal ADC is used to monitor LED temperature and DIE temperature. To operate the ADC, set the `adc_channel` (see page 27) and start the conversion by `adc_convert`. When `adc_convert` returns to '0' the result is available in register `adc_result` (see page 30) (Bits 9...7) and `adc_result_lsbs` (Bits 1...0).

The DIE junction temperature measurement returns the value according to Table 6:

Table 6. Junction Temperature Measurement ADC result

| Junction Temperature - °C | ADC Return Value (10bit) |
|---------------------------|--------------------------|
| -30                       | 352                      |
| -20                       | 343                      |
| -10                       | 334                      |
| 0                         | 325                      |
| 10                        | 316                      |
| 20                        | 306                      |
| 30                        | 297                      |
| 40                        | 287                      |
| 50                        | 278                      |
| 60                        | 268                      |
| 70                        | 259                      |
| 80                        | 249                      |
| 90                        | 239                      |
| 100                       | 229                      |
| 110                       | 219                      |
| 120                       | 209                      |
| 130                       | 199                      |
| 140                       | 189                      |
| 150                       | 179                      |

## 8.8 I<sup>2</sup>C Serial Data Bus

The AS3649 supports the I<sup>2</sup>C bus protocol. A device that sends data onto the bus is defined as a transmitter and a device receiving data as a receiver. The device that controls the message is called a master. The devices that are controlled by the master are referred to as slaves. A master device that generates the serial clock (SCL), controls the bus access, and generates the START and STOP conditions must control the bus. The AS3649 operates as a slave on the I<sup>2</sup>C bus. Within the bus specifications a standard mode (100kHz maximum clock rate) and a fast mode (400kHz maximum clock rate) are defined. The AS3649 works in both modes. Connections to the bus are made through the open-drain I/O lines SDA and SCL.

The following bus protocol has been defined (Figure 27):

- Data transfer may be initiated only when the bus is not busy.
- During data transfer, the data line must remain stable whenever the clock line is HIGH. Changes in the data line while the clock line is HIGH are interpreted as control signals.

Accordingly, the following bus conditions have been defined:

**Bus Not Busy.** Both data and clock lines remain HIGH.

**Start Data Transfer.** A change in the state of the data line, from HIGH to LOW, while the clock is HIGH, defines a START condition.

**Stop Data Transfer.** A change in the state of the data line, from LOW to HIGH, while the clock line is HIGH, defines the STOP condition.



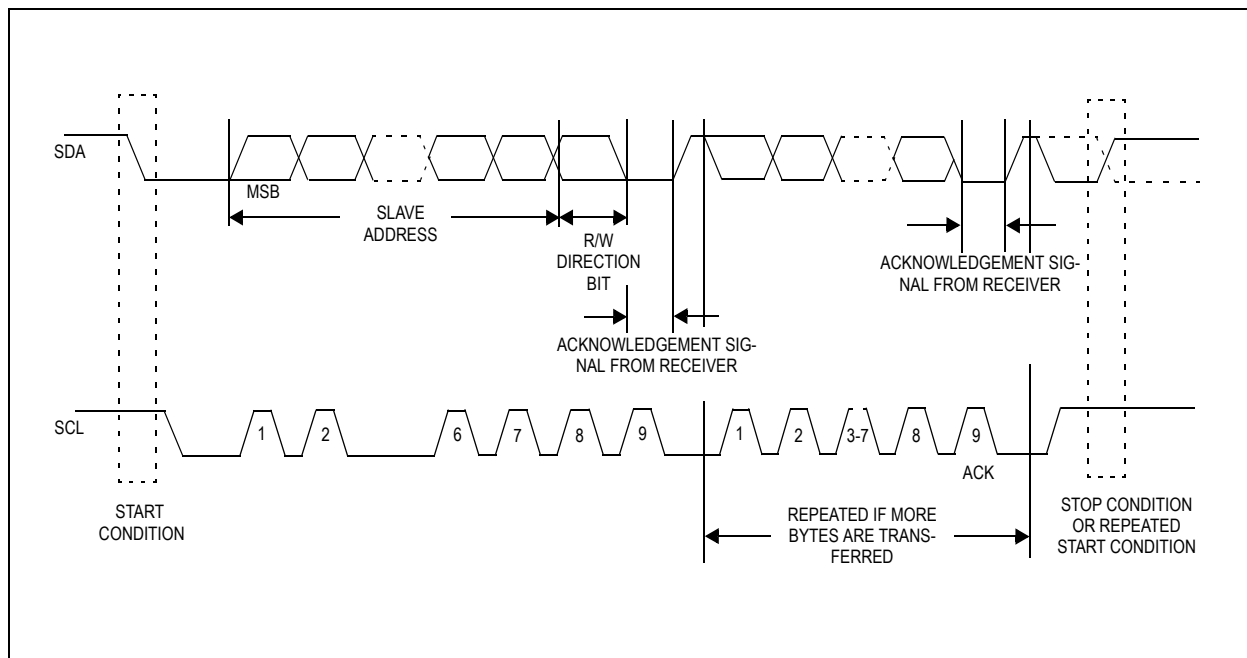
**Data Valid.** The state of the data line represents valid data when, after a START condition, the data line is stable for the duration of the HIGH period of the clock signal. The data on the line must be changed during the LOW period of the clock signal. There is one clock pulse per bit of data.

Each data transfer is initiated with a START condition and terminated with a STOP condition. The number of data bytes transferred between START and STOP conditions are not limited, and are determined by the master device. The information is transferred byte-wise and each receiver acknowledges with a ninth bit.

**Acknowledge.** Each receiving device, when addressed, is obliged to generate an acknowledge after the reception of each byte. The master device must generate an extra clock pulse that is associated with this acknowledge bit.

A device that acknowledges must pull down the SDA line during the acknowledge clock pulse in such a way that the SDA line is stable LOW during the HIGH period of the acknowledge-related clock pulse. Of course, setup and hold times must be taken into account. A master must signal an end of data to the slave by not generating an acknowledge bit on the last byte that has been clocked out of the slave. In this case, the slave must leave the data line HIGH to enable the master to generate the STOP condition.

Figure 27. Data Transfer on I<sup>2</sup>C Serial Bus



Depending upon the state of the R/W bit, two types of data transfer are possible:

1. **Data transfer from a master transmitter to a slave receiver.** The first byte transmitted by the master is the slave address. Next follows a number of data bytes. The slave returns an acknowledge bit after each received byte. Data is transferred with the most significant bit (MSB) first.
2. **Data transfer from a slave transmitter to a master receiver.** The master transmits the first byte (the slave address). The slave then returns an acknowledge bit, followed by the slave transmitting a number of data bytes. The master returns an acknowledge bit after all received bytes other than the last byte. At the end of the last received byte, a "not acknowledge" is returned. The master device generates all of the serial clock pulses and the START and STOP conditions. A transfer is ended with a STOP condition or with a repeated START condition. Since a repeated START condition is also the beginning of the next serial transfer, the bus is not released. Data is transferred with the most significant bit (MSB) first.

The AS3649 can operate in the following two modes:

1. **Slave Receiver Mode (Write Mode):** Serial data and clock are received through SDA and SCL. After each byte is received an acknowledge bit is transmitted. START and STOP conditions are recognized as the beginning and end of a serial transfer. Address recognition is performed by hardware after reception of the slave address and direction bit (see Figure 28). The slave address byte is the first byte received after the master generates the START condition. The slave address byte contains the 7-bit AS3649 address, which is 0110000, followed by the direction bit (R/W), which, for a write, is 0.<sup>13</sup> After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. After the AS3649 acknowledges the slave address + write bit, the master transmits a



register address to the AS3649. This sets the register pointer on the AS3649. The master may then transmit zero or more bytes of data, with the AS3649 acknowledging each byte received. The address pointer will increment after each data byte is transferred. The master generates a STOP condition to terminate the data write.

2. **Slave Transmitter Mode (Read Mode):** The first byte is received and handled as in the slave receiver mode. However, in this mode, the direction bit indicates that the transfer direction is reversed. Serial data is transmitted on SDA by the AS3649 while the serial clock is input on SCL. START and STOP conditions are recognized as the beginning and end of a serial transfer (Figure 29 and Figure 30). The slave address byte is the first byte received after the master generates a START condition. The slave address byte contains the 7-bit AS3649 address, which is 0110000, followed by the direction bit (R/W), which, for a read, is 1.<sup>14</sup> After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. The AS3649 then begins to transmit data starting with the register address pointed to by the register pointer. If the register pointer is not written to before the initiation of a read mode the first address that is read is the last one stored in the register pointer. The AS3649 must receive a “not acknowledge” to end a read.

Figure 28. Data Write - Slave Receiver Mode

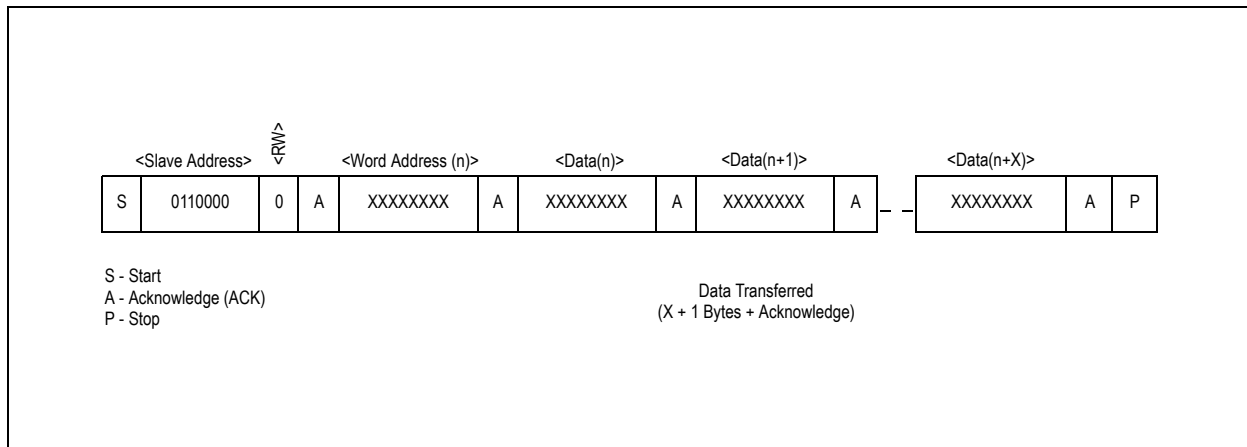
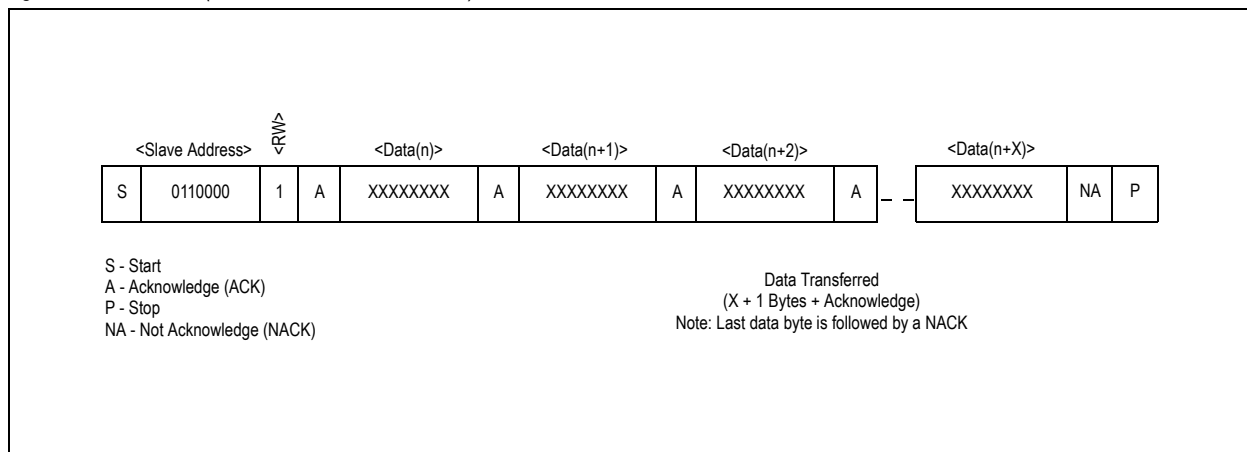


Figure 29. Data Read (from Current Pointer Location) - Slave Transmitter Mode

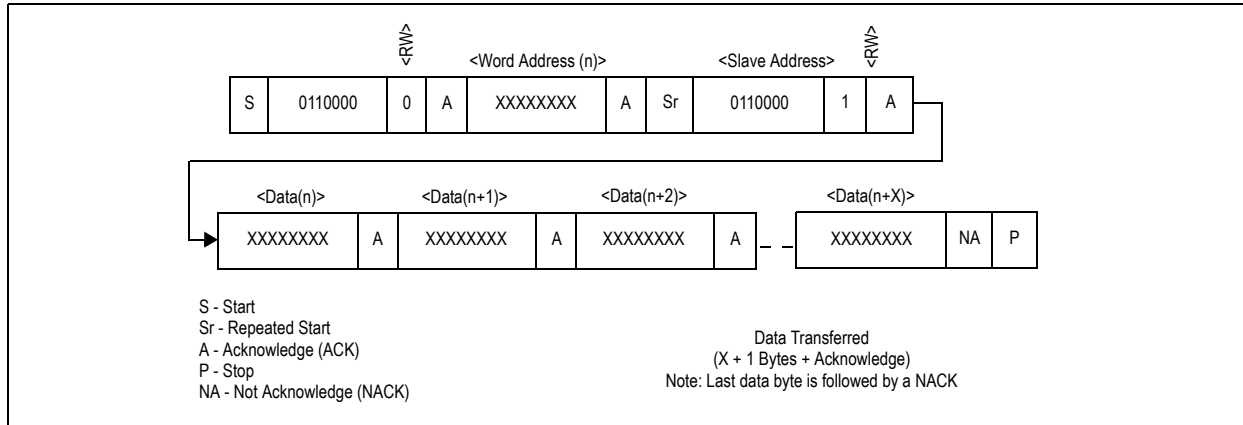


13. The address for writing to the AS3649 is 60h = 01100000b

14. The address for read mode from the AS3649 is 61h = 01100001b



Figure 30. Data Read (Write Pointer, Then Read) - Slave Receive and Transmit



## 8.9 Register Description

Table 7. *ChipID Register*

| Addr: 0                      |          | ChipID Register |        |  |
|------------------------------|----------|-----------------|--------|--|
| This register has a fixed ID |          |                 |        |  |
| Bit                          | Bit Name | Default         | Access | Description  |
| 2:0                          | version  | Xh              | R      | AS3649 chip version number   |
| 7:3                          | fixed_id | 11000b          | R      | This is a fixed identification (e.g. to verify the I <sup>2</sup> C communication) |

Table 8. *Current Set LED1 Register*

| Addr: 1                               |   | Current Set LED1 Register |        |   |   |
|---------------------------------------|---|---------------------------|--------|---|---|
| This register defines design versions |   |                           |        |   |   |
| Bit                                   | Bit Name  | Default                   | Access | Description   |   |
| 7:0                                   | led_current1  | 9Ch                       | R/W    | Define the current on pin LED_OUT1;<br>torch mode uses bits 5:0 of this current setting (max. 1/4 of full current setting)<br>indicator or low current pwm mode uses only 5:0 of this current setting (max. 1/4 of full current setting)<br><b>Note:</b> Always keep <code>led_current1</code> >= <code>led_current2</code> |   |
|                                       |   |                           |        | 0h  | 0mA   |
|                                       |   |                           |        | 1h  | 7.8mA   |
|                                       |   |                           |        | 2h  | 11.7mA  |
|                                       |   |                           |        | ...   | ...   |
|                                       |   |                           |        | 3Fh   | 250mA (maximum current for torch light mode, indicator or low current pwm mode, <code>mode_setting=01</code> or <code>10</code> ) |
|                                       |   |                           |        | ...   | ...   |
|                                       |   |                           |        | 7Fh   | 500mA   |
|                                       |   |                           |        | ...   | ...   |
|                                       |   |                           |        | 9Ch   | 613.3mA - default setting   |
|                                       |   |                           |        | ...   | ...   |
|                                       |   |                           |        | FEh   | 996mA (1245mA <sup>1</sup> if <code>current_boost=1</code> )  |
| FFh                                   | 1000mA (1250mA <sup>1</sup> if <code>current_boost=1</code> ) |                           |        |   |   |

1. Only use `current_boost=1` for currents > 1000mA (code >= CCh)



Table 9. Current Set LED2 Register

| Addr: 2                               |              | Current Set LED2 Register |        |   |   |
|---------------------------------------|--------------|---------------------------|--------|---|---|
| This register defines design versions |              |                           |        |   |   |
| Bit                                   | Bit Name     | Default                   | Access | Description   |   |
| 7:0                                   | led_current2 | 9Ch                       | R/W    | Define the current on pin LED_OUT2;<br>torch mode uses bits 5:0 of this current setting (max. 1/4 of full current setting)<br>indicator or low current pwm mode uses only 5:0 of this current setting (max. 1/4 of full current setting)<br><b>Note:</b> Always keep <code>led_current1</code> >= <code>led_current2</code> |   |
|                                       |              |                           |        | 0h  | 0mA   |
|                                       |              |                           |        | 1h  | 7.8mA   |
|                                       |              |                           |        | 2h  | 11.7mA  |
|                                       |              |                           |        | ...   | ...   |
|                                       |              |                           |        | 3Fh   | 250mA (maximum current for torch light mode, indicator or low current pwm mode, <code>mode_setting=01</code> or <code>10</code> ) |
|                                       |              |                           |        | ...   | ...   |
|                                       |              |                           |        | 7Fh   | 500mA   |
|                                       |              |                           |        | ...   | ...   |
|                                       |              |                           |        | 9Ch   | 613.3mA - default setting   |
|                                       |              |                           |        | ...   | ...   |
|                                       |              |                           |        | FEh   | 996mA (1245mA <sup>1</sup> if <code>current_boost=1</code> )  |
|                                       |              |                           |        | FFh   | 1000mA (1250mA <sup>1</sup> if <code>current_boost=1</code> )   |

1. Only use `current_boost=1` for currents > 1000mA (code >= CCh)

Table 10. TXMask Register

| Addr: 3   |                   | TXMask Register |        |   |   |
|---|-------------------|-----------------|--------|---|---|
| This register defines the TXMask settings and coil peak current |                   |                 |        |   |   |
| Bit   | Bit Name          | Default         | Access | Description   |   |
| 1:0   | txmask_torch_mode | 00              | R/W    | Defines operating mode for input pin TXMASK/TORCH   |   |
|   |                   |                 |        | 00  | pin has no effect   |
|   |                   |                 |        | 01  | txmask-mode: during flash if TXMASK/TORCH=1, the LED current is set to <code>flash_txmask_current</code> - (see TXMASK on page 15)  |
|   |                   |                 |        | 10  | external torch mode: if TXMASK/TORCH=1 and <code>mode_setting=00</code> , the AS3649 is set into external torch mode (LED current is defined by the 6LSB <sup>1</sup> bits of <code>led_current1</code> and <code>led_current2</code> ) |
|   |                   |                 |        | 11  | don't use   |
| 3:2   | coil_peak         | 10              | R/W    | Defines the maximum coil current (parameter ILIMIT) |   |
|   |                   |                 |        | 00  | ILIMIT = 2.5A   |
|   |                   |                 |        | 01  | ILIMIT = 2.9A   |
|   |                   |                 |        | 10  | ILIMIT = 3.3A   |
|   |                   |                 |        | 11  | ILIMIT = 3.7A   |



Table 10. TXMask Register (Continued)

| Addr: 3   |                                   | TXMask Register |        |  |  |
|---|-----------------------------------|-----------------|--------|--|--|
| This register defines the TXMask settings and coil peak current |                                   |                 |        |  |  |
| Bit   | Bit Name                          | Default         | Access | Description  |  |
| 7:4   | flash_txmask_current <sup>2</sup> | 6h              | R/W    | Define the current on pin LED_OUT1 and LED_OUT2 (each current source) in flash mode if txmask_torch_mode=01 and TXMASK/TORCH=1 |  |
|   |                                   |                 |        | 0h   | 0mA  |
|   |                                   |                 |        | 1h   | 31mA (39mA if current_boost=1)             |
|   |                                   |                 |        | 2h   | 63mA (78mA if current_boost=1)             |
|   |                                   |                 |        | 3h   | 94mA (118mA if current_boost=1)            |
|   |                                   |                 |        | 4h   | 125mA (157mA if current_boost=1)           |
|   |                                   |                 |        | 5h   | 157mA (196mA if current_boost=1)           |
|   |                                   |                 |        | 6h   | 188mA (235mA if current_boost=1) - default |
|   |                                   |                 |        | 7h   | 220mA (275mA if current_boost=1)           |
|   |                                   |                 |        | 8h   | 251mA (314mA if current_boost=1)           |
|   |                                   |                 |        | 9h   | 282mA (353mA if current_boost=1)           |
|   |                                   |                 |        | Ah   | 314mA (392mA if current_boost=1)           |
|   |                                   |                 |        | Bh   | 345mA (431mA if current_boost=1)           |
|   |                                   |                 |        | Ch   | 376mA (471mA if current_boost=1)           |
|   |                                   |                 |        | Dh   | 408mA (510mA if current_boost=1)           |
|   |                                   |                 |        | Eh   | 439mA (549mA if current_boost=1)           |
| Fh  | 471mA (588mA if current_boost=1)  |                 |        |  |  |

1. The MSB bit of this register not used to protect the LED; therefore the maximum current = 1/4 the maximum flash current
2. If current\_boost=1, the LED current is increased by 25%.

Table 11. Low Voltage / NTC Register

| Addr: 4  |           | Low Voltage / NTC Register |        |   |                      |
|--|-----------|----------------------------|--------|---|----------------------|
| This register defines the operating mode with low battery voltages |           |                            |        |   |                      |
| Bit  | Bit Name  | Default                    | Access | Description   |                      |
| 2:0  | vin_low_v | 4h                         | R/W    | Voltage level on VIN where current reduction triggers during operation (see Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse on page 15) - only in flash mode; if VIN drops below this voltage during current ramp up, the current ramp up is stopped; during operation the current is decreased until the voltage on VIN rises above this threshold - status_uvlo is set |                      |
|  |           |                            |        | 0h  | function is disabled |
|  |           |                            |        | 1h  | 3.0V                 |
|  |           |                            |        | 2h  | 3.07V                |
|  |           |                            |        | 3h  | 3.14V                |
|  |           |                            |        | 4h  | 3.22V - default      |
|  |           |                            |        | 5h  | 3.3V                 |
|  |           |                            |        | 6h  | 3.38V                |
|  |           |                            |        | 7h  | 3.47V                |





Table 11. Low Voltage / NTC Register (Continued)

| Addr: 4  |             | Low Voltage / NTC Register |        |   |  |
|--|-------------|----------------------------|--------|---|--|
| This register defines the operating mode with low battery voltages |             |                            |        |   |  |
| Bit  | Bit Name    | Default                    | Access | Description   |  |
| 3  | ntc_on      | 0                          | R/W    | Enable overtemperature protection on pin NTC (internal comparator comparing NTC to V <sub>NTC_TH</sub> )  |  |
|  |             |                            |        | 0   | disabled   |
|  |             |                            |        | 1   | enabled  |
| 7:4  | ntc_current | 8h                         | R/W    | Current through the NTC (I <sub>NTC</sub> ); it is enabled once the LED current source (LED_OUT1/2) is operating and ntc_on=1 or the ADC measures the LED temperature (see <a href="#">NTC - Flash LED Overtemperature Protection</a> on page 14) |  |
|  |             |                            |        | 0h  | off;<br>can be used to use an external current to bias the NTC |
|  |             |                            |        | 1h  | 40μA   |
|  |             |                            |        | 2h  | 80μA   |
|  |             |                            |        | 3h  | 120μA  |
|  |             |                            |        | 4h  | 160μA  |
|  |             |                            |        | 5h  | 200μA  |
|  |             |                            |        | 6h  | 240μA  |
|  |             |                            |        | 7h  | 280μA  |
|  |             |                            |        | 8h  | 320μA - default  |
|  |             |                            |        | 9h  | 360μA  |
|  |             |                            |        | Ah  | 400μA  |
|  |             |                            |        | Bh  | 440μA  |
|  |             |                            |        | Ch  | 480μA  |
|  |             |                            |        | Dh  | 520μA  |
| Eh   | 560μA       |                            |        |   |  |
| Fh   | 600μA       |                            |        |   |  |



Table 12. Flash Timer Register

| Addr: 5   |                            | Flash Timer Register |        |  |               |               |
|---|----------------------------|----------------------|--------|--|---------------|---------------|
| This register identifies the flash timer and timeout settings |                            |                      |        |  |               |               |
| Bit   | Bit Name                   | Default              | Access | Description  |               |               |
| 5:0   | flash_timeout <sup>1</sup> | 26h                  | R/W    | Define the duration of the flash timer and timeout timer |               |               |
|   |                            |                      |        | 00h ... 4ms  | 16h ... 92ms  | 2Bh ... 484ms |
|   |                            |                      |        | 01h ... 8ms  | 17h ... 96ms  | 2Ch ... 516ms |
|   |                            |                      |        | 02h ... 12ms   | 18h ... 100ms | 2Dh ... 548ms |
|   |                            |                      |        | 03h ... 16ms   | 19h ... 104ms | 2Eh ... 580ms |
|   |                            |                      |        | 04h ... 20ms   | 1Ah ... 108ms | 2Fh ... 612ms |
|   |                            |                      |        | 05h ... 24ms   | 1Bh ... 112ms | 30h ... 644ms |
|   |                            |                      |        | 06h ... 28ms   | 1Ch ... 116ms | 31h ... 676ms |
|   |                            |                      |        | 07h ... 32ms   | 1Dh ... 120ms | 32h ... 708ms |
|   |                            |                      |        | 08h ... 36ms   | 1Eh ... 124ms | 33h ... 740ms |
|   |                            |                      |        | 09h ... 40ms   | 1Fh ... 128ms | 34h ... 772ms |
|   |                            |                      |        | 0Ah ... 44ms   | 20h ... 132ms | 35h ... 804ms |
|   |                            |                      |        | 0Bh ... 48ms   | 21h ... 164ms | 36h ... 836ms |
|   |                            |                      |        | 0Ch ... 52ms   | 22h ... 196ms | 37h ... 868ms |
|   |                            |                      |        | 0Dh ... 56ms   | 23h ... 228ms | 38h ... 900ms |
|   |                            |                      |        | 0Eh ... 60ms   | 24h ... 260ms | 39h ... 932ms |
|   |                            |                      |        | 0Fh ... 64ms   | 25h ... 292ms | 3Ah ... 964ms |
| 10h ... 68ms  | <b>26h ... 324ms</b>       | 3Bh ... 996ms        |        |  |               |               |
| 11h ... 72ms  | 27h ... 356ms              | 3Ch ... 1028ms       |        |  |               |               |
| 12h ... 76ms  | 28h ... 388ms              | 3Dh ... 1060ms       |        |  |               |               |
| 13h ... 80ms  | 29h ... 420ms              | 3Eh ... 1092ms       |        |  |               |               |
| 14h ... 84ms  | 2Ah ... 452ms              | 3Fh ... 1124ms       |        |  |               |               |
|   |                            |                      |        | 15h ... 88ms   |               |               |

1. Internal calculation for codes above 20h: flash timeout [ms] = (flash\_timeout-32) \* 32 + 132 [ms]

Table 13. Control Register

| Addr: 6  |              | Control Register |        |   |  |
|--|--------------|------------------|--------|---|--|
| This register identifies the operating mode and includes an all on/off bit |              |                  |        |   |  |
| Bit  | Bit Name     | Default          | Access | Description   |  |
| 1:0  | mode_setting | 00               | R/W    | Define the AS3649 operating mode - see Table 5, "Operating Mode and Current Settings," on page 14 |  |
|  |              |                  |        | 00  | standby/shutdown or external torch mode if txmask_torch_mode (page 23)=10  |
|  |              |                  |        | 01  | indicator mode (or low current mode using PWM)<br>LED current is defined by the 6LSB <sup>1</sup> bits of led_current1 and led_current2 pwm modulated defined by register inct_pwm (31.5kHz: 1/16...4/16, 7.9kHz: 1/64...3/64) |
|  |              |                  |        | 10  | torch light mode:<br>LED current is defined by the 6LSB <sup>2</sup> bits of led_current1 and led_current2   |
|  |              |                  |        | 11  | flash mode:<br>LED current is defined by led_current1 and led_current2 (mode_setting is automatically cleared after a flash pulse)   |



Table 13. Control Register (Continued)

| Addr: 6  |   | Control Register |        |  |  |
|--|---|------------------|--------|--|--|
| This register identifies the operating mode and includes an all on/off bit |   |                  |        |  |  |
| Bit  | Bit Name  | Default          | Access | Description  |  |
| 3:2  | min_on_increase                                   | 00               | R/W    | Increase min. on time of DCDC converter - use for diagnostic pulse, if <a href="#">freq_switch_on=1</a> .<br>If this register is not 00 and <a href="#">freq_switch_on=1</a> , the DCDC converter will use 4MHz operation forced PWM mode or pass-through mode but will not switch to 1MHz operation |  |
|  |   |                  |        | 00   | 100% - default min. on time                      |
|  |   |                  |        | 01   | 108%   |
|  |   |                  |        | 10   | 131%   |
|  |   |                  |        | 11   | 157%   |
| 4  | force_dcdc_on                                     | 0                | R/W    | Force DCDC operation even in pass-through mode - use for diagnostic pulse, if <a href="#">freq_switch_on=1</a>   |  |
|  |   |                  |        | 0  | DCDC is only enabled when needed; default        |
| 7:5  | vcompl_adj  | 000b             | R/W    | Increase voltage compliance of current source for diagnostic pulses - see <a href="#">Short Diagnostic Pulse on page 16</a>  |  |
|  |   |                  |        | 000  | default - 0mV                                    |
|  |   |                  |        | 001  | 14mV (26mV if <a href="#">current_boost=1</a> )  |
|  |   |                  |        | 010  | 29mV (51mV if <a href="#">current_boost=1</a> )  |
|  |   |                  |        | 011  | 43mV (77mV if <a href="#">current_boost=1</a> )  |
|  |   |                  |        | 100  | 57mV (103mV if <a href="#">current_boost=1</a> ) |
|  |   |                  |        | 101  | 71mV (129mV if <a href="#">current_boost=1</a> ) |
|  |   |                  |        | 110  | 85mV (154mV if <a href="#">current_boost=1</a> ) |
| 111  | 100mV (180mV if <a href="#">current_boost=1</a> ) |                  |        |  |  |

1. The two MSB bits of this register are not used to protect the LED; therefore the maximum indicator (or low current mode using PWM) light current = 1/4 the maximum flash current multiplied by the duty cycle defined by [inct\\_pwm](#)
2. The two MSB bits of this register not used to protect the LED; therefore the maximum torch light current = 1/4 the maximum flash current

Table 14. Strobe Signalling / ADC Register

| Addr: 7  |             | Strobe Signalling / ADC Register |        |                                   |       |
|--|-------------|----------------------------------|--------|-----------------------------------|-------|
| This register defines the flash current reducing and mode for STROBE |             |                                  |        |                                   |       |
| Bit  | Bit Name    | Default                          | Access | Description                       |       |
| 3:0  | adc_channel | 000b                             | R/W    | Select ADC channel for conversion |       |
|  |             |                                  |        | 000                               | NTC   |
|  |             |                                  |        | 001                               | TJUNC |
|  |             |                                  |        | 010                               | VIN   |



Table 14. Strobe Signalling / ADC Register (Continued)

| Addr: 7 |                  | Strobe Signalling / ADC Register                                     |        |  |  |
|---------|------------------|--|--------|--|--|
|         |                  | This register defines the flash current reducing and mode for STROBE |        |  |  |
| Bit     | Bit Name         | Default  | Access | Description  |  |
| 4       | adc_convert      | 0  | R/W    | Start ADC conversion   |  |
|         |                  |  |        | 0  | ADC conversion finished  |
|         |                  |  |        | 1  | Start ADC conversion - once finished the register bit is automatically reset and the result is stored in <code>adc_result</code> |
| 5       | dcdc_skip_enable | 1  | R/W    | Allow pulseskip operation of DCDC - see <a href="#">Table 4 on page 12</a>                               |  |
|         |                  |  |        | 0  | Disabled - force 4MHz (1MHz) operation   |
|         |                  |  |        | 1  | Enabled - can use pulseskip <sup>1</sup>   |
| 6       | strobe_type      | 1  | R/W    | Defines if the STROBE input is edge or level sensitive; see also bit <a href="#">strobe_on (page 28)</a> |  |
|         |                  |  |        | 0  | STROBE input is edge sensitive   |
|         |                  |  |        | 1  | STROBE input is level sensitive  |
| 7       | strobe_on        | 1  | R/W    | Enables the STROBE input   |  |
|         |                  |  |        | 0  | STROBE input disabled  |
|         |                  |  |        | 1  | STROBE input enabled in flash mode   |

1. Exception depending on [freq\\_switch\\_on \(see page 29\)](#) - see [Table 4 on page 12](#)

Table 15. Fault Register

| Addr: 8 |               | Fault Register  |                   |  |                        |
|---------|---------------|---|-------------------|--|------------------------|
|         |               | This register identifies all the different fault conditions and provide information about the LED detection |                   |  |                        |
| Bit     | Bit Name      | Default   | Access            | Description  |                        |
| 0       | status_uvlo   | 0   | R/sC <sup>1</sup> | an undervoltage event has happened - see <a href="#">Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse on page 15</a> |                        |
|         |               |   |                   | 0  | No                     |
|         |               |   |                   | 1  | Yes                    |
| 1       | reserved      | 0   | R                 | reserved - don't use   |                        |
| 2       | fault_ntc     | 0   | R/sC <sup>1</sup> | LED overtemperature detection hit - see <a href="#">NTC - Flash LED Overtemperature Protection on page 14</a>                                |                        |
|         |               |   |                   | 0  | No                     |
|         |               |   |                   | 1  | Yes                    |
| 3       | fault_txmask  | 0   | R/sC <sup>1</sup> | TXMASK/TORCH event triggered during flash - see <a href="#">TXMASK event occurred on page 13</a>   |                        |
|         |               |   |                   | 0  | No                     |
|         |               |   |                   | 1  | Yes                    |
| 4       | fault_timeout | 0   | R/sC <sup>1</sup> | see <a href="#">Flash Timeout on page 14</a>   |                        |
|         |               |   |                   | 0  | No fault               |
|         |               |   |                   | 1  | Flash timeout exceeded |

Table 15. *Fault Register (Continued)*

| Addr: 8   |                 | Fault Register |                   |   |   |
|---|-----------------|----------------|-------------------|---|---|
| This register identifies all the different fault conditions and provide information about the LED detection |                 |                |                   |   |   |
| Bit   | Bit Name        | Default        | Access            | Description   |   |
| 5   | fault_overtemp  | 0              | R/sC <sup>1</sup> | see <a href="#">Overtemperature Protection on page 13</a> |   |
|   |                 |                |                   | 0   | No fault  |
|   |                 |                |                   | 1   | Junction temperature limit has been exceeded    |
| 6   | fault_led_short | 0              | R/sC <sup>1</sup> | see <a href="#">Short Circuit Protection on page 13</a>   |   |
|   |                 |                |                   | 0   | No fault  |
|   |                 |                |                   | 1   | A shorted LED is detected (pin LED_OUT1/2)      |
| 7   | fault_ovp       | 0              | R/sC <sup>1</sup> | see <a href="#">Overvoltage Protection on page 13</a>     |   |
|   |                 |                |                   | 0   | No fault  |
|   |                 |                |                   | 1   | An overvoltage condition is detected (pin VOUT) |

1. R/sC = Read, self clear; after readout the register is automatically cleared

Table 16. *PWM and Indicator Register*

| Addr: 9   |                       | PWM and Indicator Register |        |  |  |
|---|-----------------------|----------------------------|--------|--|--|
| This register defines the PWM mode (e.g. for indicator) and 4/1MHz mode switching |                       |                            |        |  |  |
| Bit   | Bit Name              | Default                    | Access | Description  |  |
| 2:0   | inct_pwm <sup>1</sup> | 00                         | R/W    | Define the AS3649 PWM with 31.5kHz or 7.9kHz operation for indicator or low current mode ( <a href="#">mode_setting=01</a> )   |  |
|   |                       |                            |        | 000  | 1/16 duty cycle / 31.5kHz  |
|   |                       |                            |        | 001  | 2/16 duty cycle / 31.5kHz  |
|   |                       |                            |        | 010  | 3/16 duty cycle / 31.5kHz  |
|   |                       |                            |        | 011  | 4/16 duty cycle / 31.5kHz  |
|   |                       |                            |        | 100  | 1/64 duty cycle / 7.9kHz; needs <a href="#">const_v_mode=1</a> (additional quiescent current)  |
|   |                       |                            |        | 101  | 2/64 duty cycle / 7.9kHz; needs <a href="#">const_v_mode=1</a> (additional quiescent current)  |
|   |                       |                            |        | 110  | 3/64 duty cycle / 7.9kHz; needs <a href="#">const_v_mode=1</a> (additional quiescent current)  |
|   |                       |                            |        | 111  | (4/64 duty cycle / 7.9kHz) - don't use; use 000 setting instead  |
| 3   | freq_switch_on        | 0                          | R/W    | Exact frequency switching between 4MHz/1MHz for operation close to maximum pulsewidth - see <a href="#">Table 4 on page 12</a> |  |
|   |                       |                            |        | 0  | Pulseskip operation is allowed depending on <a href="#">dcdc_skip_enable</a> (see <a href="#">page 28</a> )  |
|   |                       |                            |        | 1  | if <a href="#">led_current1</a> >= 40h or <a href="#">led_current2</a> >= 40h and <a href="#">current_boost</a> = 0, the DCDC is running at 4MHz or 1MHz and pulseskip is disabled - results in improved noise performance |



Table 16. PWM and Indicator Register (Continued)

| Addr: 9   |                 | PWM and Indicator Register |        |  |  |
|---|-----------------|----------------------------|--------|--|--|
| This register defines the PWM mode (e.g. for indicator) and 4/1MHz mode switching |                 |                            |        |  |  |
| Bit   | Bit Name        | Default                    | Access | Description  |  |
| 4   | load_balance_on | 0                          | R/W    | Balance the current sources (up to +/-15% of set current) to improve application efficiency for unmatched LED forward voltages - see Load Balancing on page 17 |  |
|   |                 |                            |        | 0  | disabled   |
|   |                 |                            |        | 1  | enabled  |
| 5   | const_v_mode    | 0                          | R/W    | Enables Constant output voltage mode   |  |
|   |                 |                            |        | 0  | Normal operation defined by <a href="#">mode_setting</a>   |
|   |                 |                            |        | 1  | 5V constant voltage mode on VOUT1/2; LED current can be controlled by registers <a href="#">mode_setting</a> , <a href="#">led_current1</a> and <a href="#">led_current2</a> as in normal operating mode, but the ramping up/down of the current sources is disabled (instantaneous on/off of the LED current) |

- Using 31.5kHz modulation avoids audible noise on the output capacitor CVOUT

Table 17. ADC Result Register

| Addr: Ah   |            | ADC Result Register |        |  |
|--|------------|---------------------|--------|--|
| This register reports the actual set LED current |            |                     |        |  |
| Bit  | Bit Name   | Default             | Access | Description  |
| 7:0  | adc_result | NA                  | R      | Result of ADC conversion for channel <a href="#">adc_channel</a> |

Table 18. ADC Result LSBs Register

| Addr: Bh   |                 | ADC Result LSBs Register |        |  |
|--|-----------------|--------------------------|--------|--|
| This register reports the actual set LED current |                 |                          |        |  |
| Bit  | Bit Name        | Default                  | Access | Description  |
| 1:0  | adc_result_lsbs | NA                       | R      | Result of ADC conversion for channel <a href="#">adc_channel</a> |

Table 19. Minimum LED Current Register

| Addr: Eh  |                                | Minimum LED Current Register |        |   |
|---|--------------------------------|------------------------------|--------|---|
| This register reports the minimum LED current from the last operation cycle |                                |                              |        |   |
| Bit   | Bit Name                       | Default                      | Access | Description   |
| 7:0   | led_current_min <sup>123</sup> | 00h                          | R      | see <a href="#">Current Reduction by VIN Measurements in Flash Mode and Diagnostic Pulse</a> (see page 15) and <a href="#">Figure 20</a> on page 16 |

- Only the current through LED\_OUT1 is reported.
- As the internal change of this register is asynchronous to the readout, it is recommended to readout the register after the flash pulse. The register will store the minimum current through the LED after e.g. a previous flash. This current can be used for a subsequent flash pulse for a safe operating range.
- This register is only set if an actual current reduction happens ([status\\_uvlo](#) (see page 28)=1) otherwise [led\\_current\\_min](#)=0.



Table 20. Actual LED Current Register

| Addr: Fh   |                                  | Actual LED Current Register |        |  |
|--|----------------------------------|-----------------------------|--------|--|
| This register reports the actual set LED current |                                  |                             |        |  |
| Bit  | Bit Name                         | Default                     | Access | Description  |
| 7:0  | led_current_actual <sup>12</sup> | 00h                         | R      | Actual set current through the current source (including all current reductions as described in <a href="#">Flash Current Reductions (see page 15)</a> including LED current ramp up/down) |

1. Only the current through LED\_OUT1 is reported.
2. As the internal change of this register is asynchronous to the readout, it is recommended to readout the register twice and compare the results.

Table 21. Unlock Register Register

| Addr: 80h                             |          | Unlock Register Register |        |   |
|---------------------------------------|----------|--------------------------|--------|---|
| Protection for register Current Boost |          |                          |        |   |
| Bit                                   | Bit Name | Default                  | Access | Description   |
| 7:0                                   | unlock   | NA                       | W      | Write 55h into this register to enable access to register 81h |

Table 22. Current Boost Register

| Addr: 81h                      |                            | Current Boost Register |        |                               |  |
|--------------------------------|----------------------------|------------------------|--------|-------------------------------|--|
| Increase output current by 25% |                            |                        |        |                               |  |
| Bit                            | Bit Name                   | Default                | Access | Description                   |  |
| 0                              | current_boost <sup>1</sup> | 0                      | R/W    | Boost all LED currents by 25% |  |
|                                |                            |                        |        | 0                             | all LED current are as described in the tables |
|                                |                            |                        |        | 1                             | all LED current are increased by 25%           |

1. Write 55h into register [unlock](#) (0x80) to enable access to this register (unlocking is only valid for the next I<sup>2</sup>C access) - required on any write access to this register



## 8.10 Register Map

Table 23. Register Map <sup>1</sup>

| Register Definition     | Addr | Default | Content              |                 |                   |                 |                 |           |                   |                 |
|-------------------------|------|---------|----------------------|-----------------|-------------------|-----------------|-----------------|-----------|-------------------|-----------------|
|                         |      |         | b7                   | b6              | b5                | b4              | b3              | b2        | b1                | b0              |
| ChipID                  | 0    | Cxh     | fixed_id             |                 |                   |                 | version         |           |                   |                 |
| Current Set LED1        | 1    | 9Ch     | led_current1         |                 |                   |                 |                 |           |                   |                 |
| Current Set LED2        | 2    | 9Ch     | led_current2         |                 |                   |                 |                 |           |                   |                 |
| TXMask                  | 3    | 68h     | flash_txmask_current |                 |                   |                 | coil_peak       |           | txmask_torch_mode |                 |
| Low Voltage / NTC       | 4    | 84h     | ntc_current          |                 |                   |                 | ntc_on          | vin_low_v |                   |                 |
| Flash Timer             | 5    | 26h     | flash_timeout        |                 |                   |                 |                 |           |                   |                 |
| Control                 | 6    | 00h     | vcompl_adj           |                 |                   | force_dcdc_on   | min_on_increase |           | mode_setting      |                 |
| Strobe Signalling / ADC | 7    | E0h     | strobe_on            | strobe_type     | ddcdc_skip_enable | adc_convert     | adc_channel     |           |                   |                 |
| Fault                   | 8    | 00h     | fault_ovp            | fault_led_short | fault_overtemp    | fault_timeout   | fault_txmask    | fault_ntc | reserved          | status_uvlo     |
| PWM and Indicator       | 9    | 00h     |                      |                 | const_v_mode      | load_balance_on | freq_switch_on  | inct_pwm  |                   |                 |
| ADC Result              | Ah   | NA      | adc_result           |                 |                   |                 |                 |           |                   |                 |
| ADC Result LSBs         | Bh   | NA      |                      |                 |                   |                 |                 |           |                   | adc_result_lsbs |
| Minimum LED Current     | Eh   | 00h     | led_current_min      |                 |                   |                 |                 |           |                   |                 |
| Actual LED Current      | Fh   | 00h     | led_current_actual   |                 |                   |                 |                 |           |                   |                 |
| Unlock Register         | 80h  | 00h     | unlock               |                 |                   |                 |                 |           |                   |                 |
| Current Boost           | 81h  | 00h     |                      |                 |                   |                 |                 |           |                   | current_boost   |

1. Always write '0' to undefined register bits





## 9 Application Information

### 9.1 External Components

#### 9.1.1 Input Capacitor $C_{VIN}$

Low ESR input capacitors reduce input switching noise and reduce the peak current drawn from the battery. Ceramic capacitors are required for input decoupling and should be located as close to the device as is practical.

Table 24. Recommended Input Capacitor

| Part Number       | C   | TC Code | Rated Voltage | Size | Manufacturer  |
|-------------------|---|---------|---------------|------|---|
| GRM188R60J106ME47 | 10 $\mu$<br>>3 $\mu$ F@4.5V<br>>2 $\mu$ F@5.25V | X5R     | 6V3           | 0603 | Murata<br><a href="http://www.murata.com">www.murata.com</a>        |
| LMK107BBJ106MA    | 10 $\mu$<br>>3 $\mu$ F@4.5V                     | X5R     | 6V3           | 0603 | Taiyo Yuden<br><a href="http://www.t-yuden.com">www.t-yuden.com</a> |

If a different input capacitor is chosen, ensure similar ESR value and at least 3 $\mu$ F capacitance at the maximum input supply voltage. Larger capacitor values (C) may be used without limitations.

Add a smaller capacitor in parallel to the input pin VIN (e.g. Murata GRM155R61C104, >50nF @ 3V, 0402 size).

#### 9.1.2 Output Capacitor $C_{VOUT}$

Low ESR capacitors should be used to minimize VOUT ripple. Multi-layer ceramic capacitors are recommended since they have extremely low ESR and are available in small footprints. The capacitor should be located as close to the device as is practical.

X5R dielectric material is recommended due to their ability to maintain capacitance over wide voltage and temperature range.

Table 25. Recommended Output Capacitor

| Part Number                    | C                                    | TC Code | Rated Voltage | Size   | Manufacturer   |
|--------------------------------|--------------------------------------|---------|---------------|--|--|
| GRM219R61A106ME47              | 10 $\mu$ F +/-10%<br>>4.2 $\mu$ F@5V | X5R     | 10V           | 0805 (2.0x1.25x0.85mm<br>max 1mm height)       | Murata<br><a href="http://www.murata.com">www.murata.com</a> |
| GRM21BR60J226M <sup>1</sup>    | 22 $\mu$ F<br>>4.2 $\mu$ F@4.5V      | X5R     | 6.3V          | 0805<br>(2.0x1.25x1.25mm<br>max. 1.4mm height) |  |
| GRM188R60J106ME84 <sup>2</sup> | 10 $\mu$ F +/-20%<br>>4.2 $\mu$ F@4V | X5R     | 6.3V          | 0603<br>(1.6x0.8x0.85mm<br>max. 0.95mm height) |  |

1. Use only for VLED < 4.1V

2. Use only for VLED < 3.75V

If a different output capacitor is chosen, ensure similar ESR values and at least 4.2 $\mu$ F capacitance at 5V output voltage.



### 9.1.3 Inductor LDCDC

The fast switching frequency (4MHz) of the AS3649 allows for the use of small SMDs for the external inductor. The saturation current  $I_{SATURATION}$  should be chosen to be above the maximum value of  $I_{LIMIT}$ <sup>15</sup>. The inductor should have very low DC resistance (DCR) to reduce the  $I^2R$  power losses - high DCR values will reduce efficiency.

Table 26. Recommended Inductor

| Part Number   | L                                       | DCR            | ISATURATION       | Size                                 | Manufacturer  |
|---------------|---|----------------|-------------------|--------------------------------------|---|
| LQM32PN1R0MG0 | 1.0μH<br>>0.6μH @ 3.0A                  | 60mΩ           | 3.0A <sup>1</sup> | 3.2x2.5x0.9mm<br>max 1.0mm<br>height | Murata<br><a href="http://www.murata.com">www.murata.com</a>                                  |
| SPM4012T-1R0M | 1.0μH +/-20%                            | 38mΩ           | 4.57A             | 4.4x4.1x1.2<br>mm<br>height is max   | TDK<br><a href="http://www.tdk.com">www.tdk.com</a>   |
| SPM3012T-1R0M | 1.0μH +/-20%                            | 57mΩ<br>+/-10% | 3.4A <sup>2</sup> | 3.2x3x1.2<br>mm<br>height is max     |   |
| CIG32W1R0MNE  | 1.0μH<br>>0.7μH @ 2.7A<br>>0.6μH @ 3.0A | 60mΩ<br>+/-25% | 3.0A <sup>4</sup> | 3.2x2.5mm<br>max 1.0mm<br>height     | Samsung Electro-Mechanics<br><a href="http://www.sem.samsung.co.kr">www.sem.samsung.co.kr</a> |
| CKP3225N1R0M  | 1.0μH<br>>0.6μH @ 3.0A                  | <60mΩ          | 3.0A <sup>4</sup> | 3.2x2.5x0.9mm<br>max 1.0mm<br>height | Taiyo Yuden<br><a href="http://www.t-yuden.com">www.t-yuden.com</a>                           |
| NRH2412T1R0N  | 1.0μH<br>>0.6μH @ 2.5A                  | 77mΩ           | 2.5A <sup>3</sup> | 2.4x2.4x1.2mm<br>(height is max.)    |   |
| MAMK2520T1R0M | 1.0μH<br>>0.6μH @ 2.75A                 | 45mΩ           | 3.1A <sup>4</sup> | 2.5x2.0x1.2mm<br>height is max       |   |

- Flash pattern: 200ms/3A, 200ms pause, 200ms/3A, 2s then repeat again (no limit on the number of total cycles)  
Alternative pattern with 1000ms/1.6A, 200ms pause, 200ms/3A, 200ms pause, 200ms/3A, 2s then repeat again. (no limit on the number of total cycles). Use only up to `coil_peak=2.9A` setting
- Inductance changes by -30%, use only up to `coil_peak=3.3A` setting
- Use only for `coil_peak=2.5A` setting.
- Use only up to `coil_peak=2.9A` setting.

If a different inductor is chosen, ensure similar DCR values and at least 0.6μH inductance at  $I_{LIMIT}$ .

### 9.1.4 Thermistor (NTC)

The NTC is used to protect the LED against overheating (hardware protection inside the AS3649, which works without any software - see [NTC - Flash LED Overtemperature Protection on page 14](#)).

The thermistor has to be thermally coupled to the LED (and therefore as close as possible to the LED) and it shall not share the same ground connection as the LED return ground (if they share the same ground connection the high current through the LED will offset the measurement of the NTC).

Table 27. Recommended Thermistors

| Part Number     | Resistance @ 25°C | B-constant 25/50°C | Size | Manufacturer   |
|-----------------|-------------------|--------------------|------|--|
| NCP03WL224E05RL | 220kΩ +/-3%       | 4485K +/-1%        | 0201 | Murata<br><a href="http://www.murata.com">www.murata.com</a> |
| NCP03WL104E05RL | 100kΩ +/-3%       | 4485K +/-1%        |      |  |
| NCP15WF104F03RC | 100kΩ             |                    | 0402 |  |
| NCP15WL683J03RC | 68kΩ              |                    |      |  |

It is recommended to use 220kΩ resistance for a detection threshold of 125°C, 100kΩ for 110°C and 68kΩ for 80°C LED temperature detection threshold.

<sup>15</sup>. Can be adjusted in  $I^2C$  mode with register `coil_peak` (see page 23)



## 9.2 PCB Layout Guideline

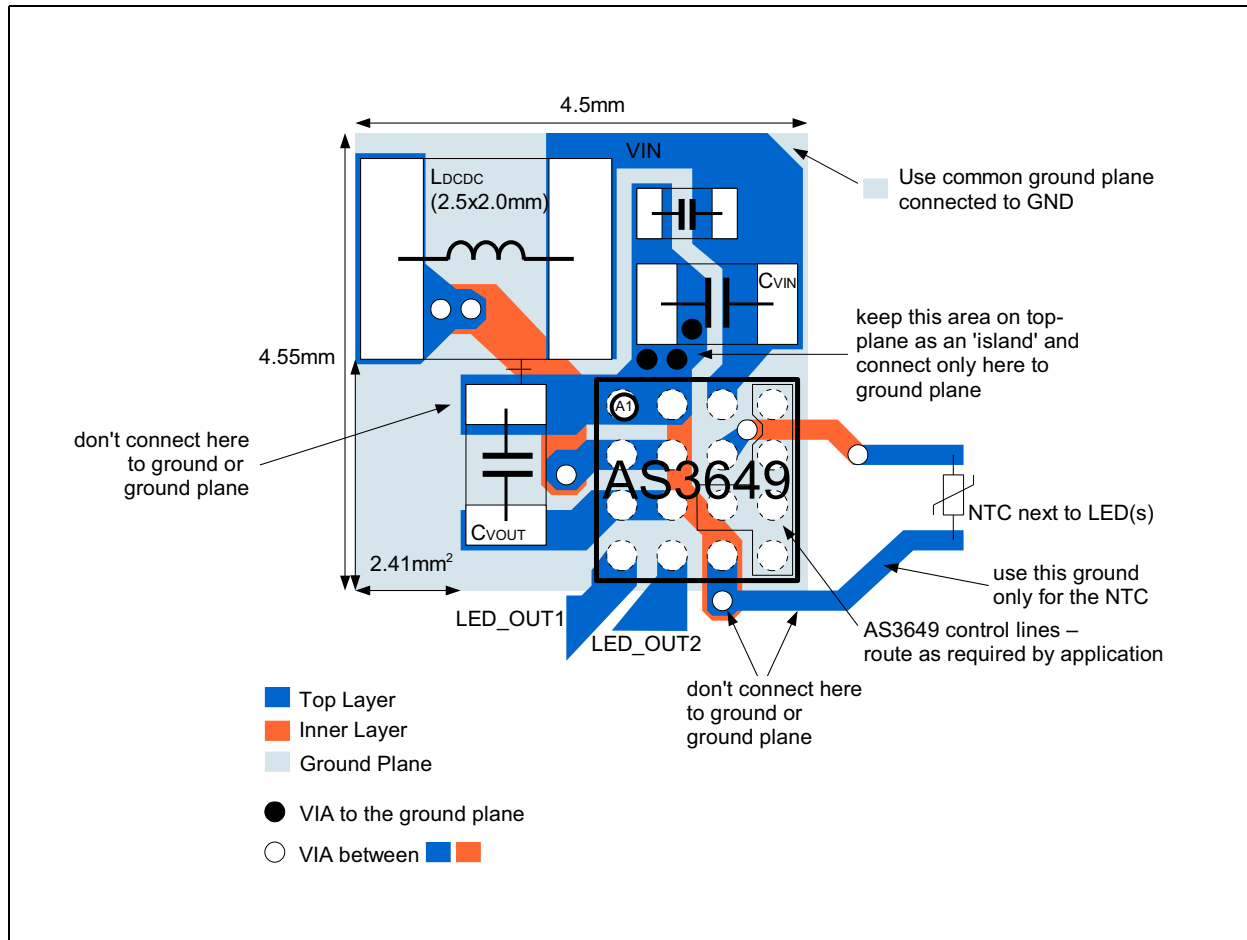
The high speed operation requires proper layout for optimum performance. Route the power traces first and try to minimize the area and wire length of the two high frequency/high current loops:

Loop1: CVIN/CVIN2 - LDCDC - pin SW1/2 - pin GND - CVIN/CVIN2

Loop2: CVIN/CVIN2 - LDCDC - pin SW1/2 - pin VOUT1/2 - CVOUT - pin GND - CVIN/CVIN2

At the pin GND a single via (or more vias, which are closely combined) connects to the common ground plane. This via(s) will isolate the DCDC high frequency currents from the common ground (as most high frequency current will flow between Loop1 and Loop2 and will not pass the ground plane) - see the 'island' in [Figure 31](#).

Figure 31. Layout Recommendation



**Note:** If component placement rules allow, move all components close to the AS3649 to reduce the area and length of Loop1 and Loop2.

It is recommended to use the main ground plane for the LED ground connections (improved thermal performance of the LEDs) - it is recommended to use a separate ground line as shown [Figure 31](#) for the ground connection of the NTC (this avoids errors for the temperature measurement of the LEDs due to the high LED current in the main ground plane).

Keep the LED path (from pin LED\_OUT1/2 to the LED and the ground return path) below 10cm (represents an inductance of less than 100nH).

An additional 100nF (e.g. Murata GRM155R61C104, >50nF @ 3V, 0402 size) capacitor CVIN2 in parallel to CVIN is recommended to filter high frequency noise for the power supply of AS3649. This capacitor should be as close as possible to the AGND/VIN pins of AS3649.

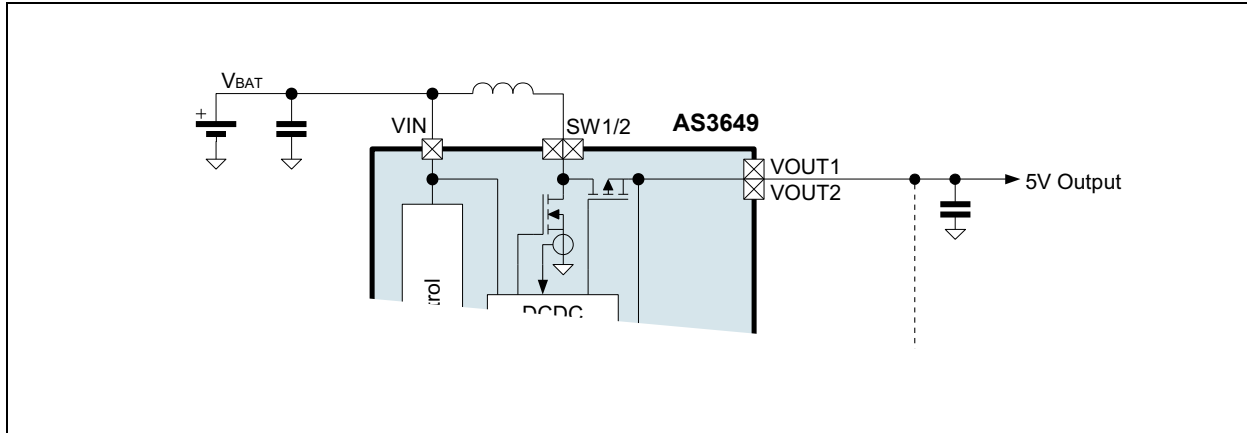


### 9.3 5V Operating Mode

The AS3649 can be used to power a 5V system (e.g. audio amplifier). The operating mode is selected by setting register bit [const\\_v\\_mode](#) (page 30)=1.

**Note:** There is always a diode between VIN and VOUT1/2 due to the internal circuit. Therefore VOUT1/2 cannot be completely switched off

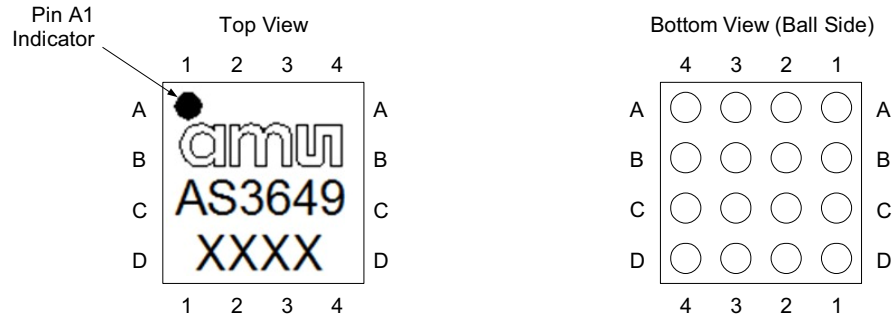
Figure 32. 5V Operating Mode





# 10 Package Drawings and Markings

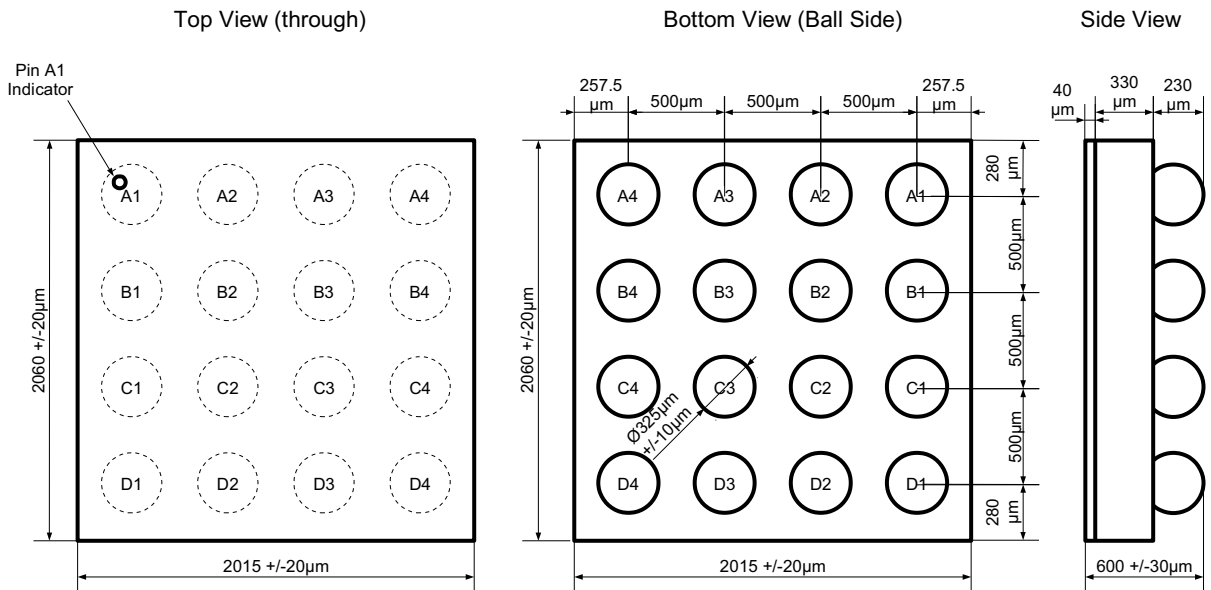
Figure 33. WL-CSP16 Marking



**Note:**

- Line 1: ams AG logo
- Line 2: AS3649
- Line 3: <Code>  
Encoded Datecode (4 characters)

Figure 34. WL-CSP16 Package Dimensions



The coplanarity of the balls is 40µm.





## 11 Ordering Information

The devices are available as the standard products shown in [Table 28](#).

Table 28. Ordering Information

| Ordering Code | Description                          | Delivery Form | Package   |
|---------------|--------------------------------------|---------------|---|
| AS3649-ZWLT   | 2500mA High Current LED Flash Driver | Tape & Reel   | 16-pin WL-CSP<br>(2.06x2.02x0.6mm)<br>0.5mm pitch<br>RoHS compliant / Pb-Free / Green |

Z Temperature Range: -30°C - 85°C

WL Package: Wafer Level Chip Scale Package (WL-CSP) 2.06x2.02x0.6mm

T Delivery Form: Tape & Reel

**Note:** All products are RoHS compliant and ams green.  
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