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The technical content of this austriamicrosystems datasheet is still valid.

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AS3647/47B

1600mA High Current LED Flash Driver



1 General Description

The AS3647/47B is an inductive high efficient DCDC step up converter with two current sinks. 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 sinks can operate in flash / torch / assist (=video) light modes.

The AS3647/47B includes flash timeout, overvoltage, overtemperature, undervoltage and LED short 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.

The AS3647/47B is controlled by an I²C interface and has a hardware automatic shutdown if SCL=0 for 100ms. Therefore no additional enable input is required for shutting down of the device once the system shuts down.

The AS3647/47B is available in a space-saving WL-CSP package measuring only 2.25x1.5x0.6mm (AS3647B: 2.25x1.5x0.5mm) and operates over the -30°C to +85°C temperature range.

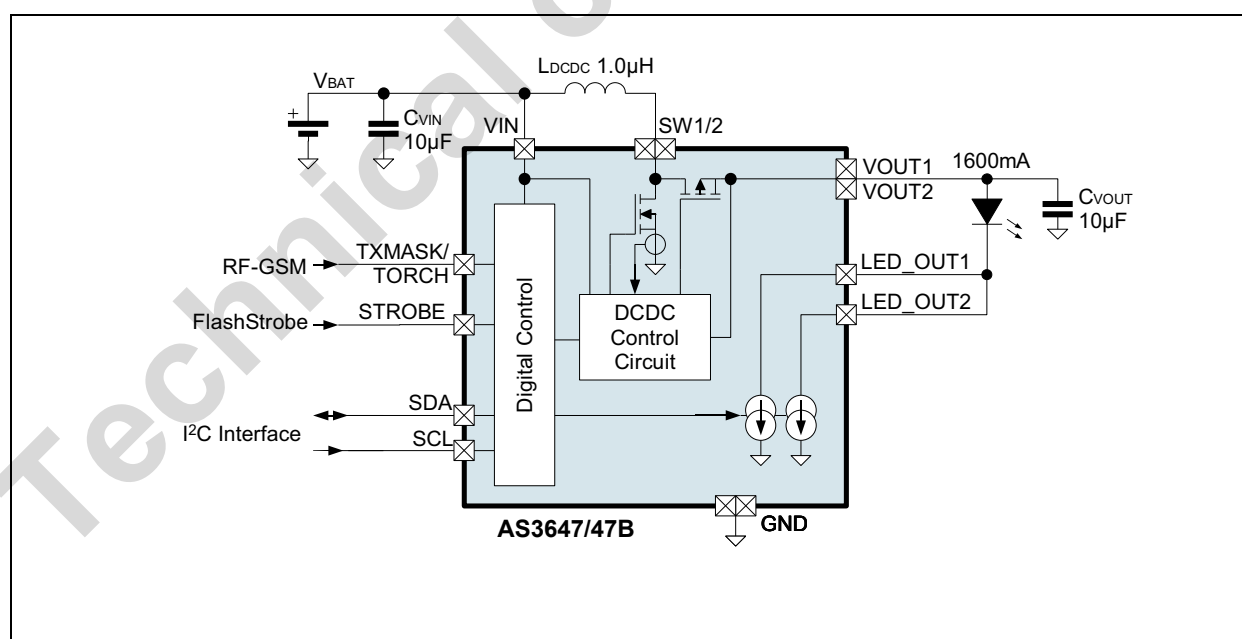
2 Key Features

- 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 1600mA
- Automatic current adjustment for low battery voltage
- PWM operation for lower output current for reliable light output of the LED; running at 31.25kHz 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
- I²C Interface with automatic shutdown
- 5V constant voltage mode operation
- Available in tiny WL-CSP Packages, 13 balls 0.5mm pitch 2.25x1.5x0.6mm, 15 balls 0.4mm pitch 2.25x1.5x0.5mm package size

3 Applications

Flash/torch/videolight for smartphones, feature-phones, tablets, DSCs, DVCs

Figure 1. Typical Operating Circuit



4 Pinout

Pin Assignment

Figure 2. Pin Assignments (Top View) AS3647

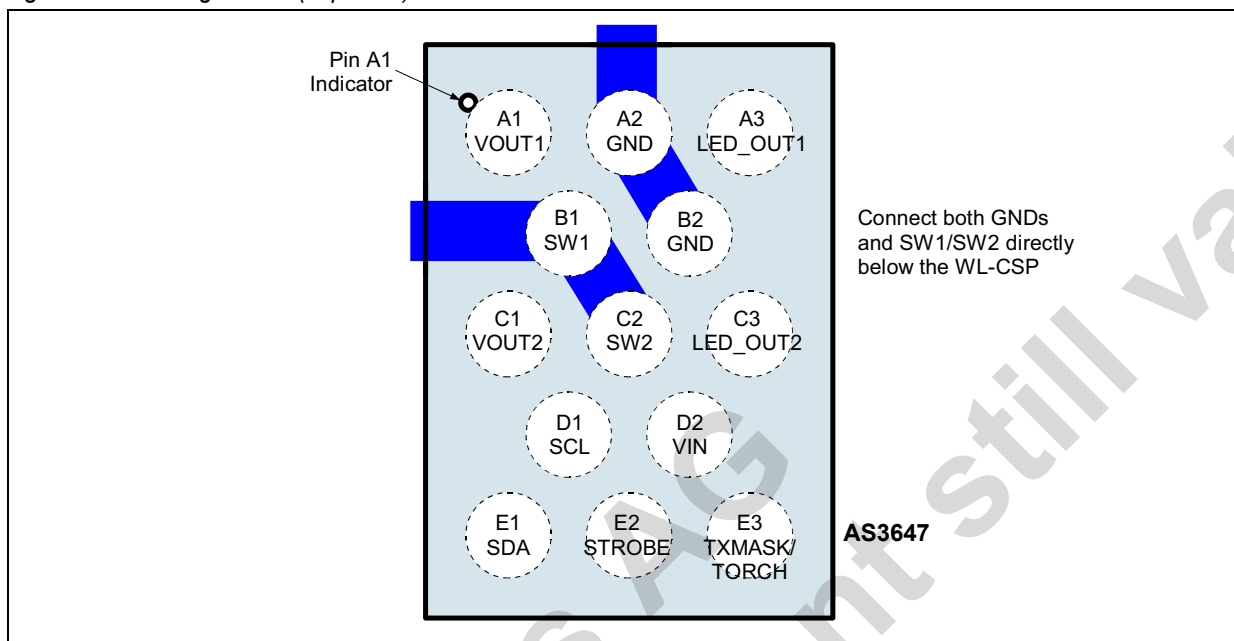
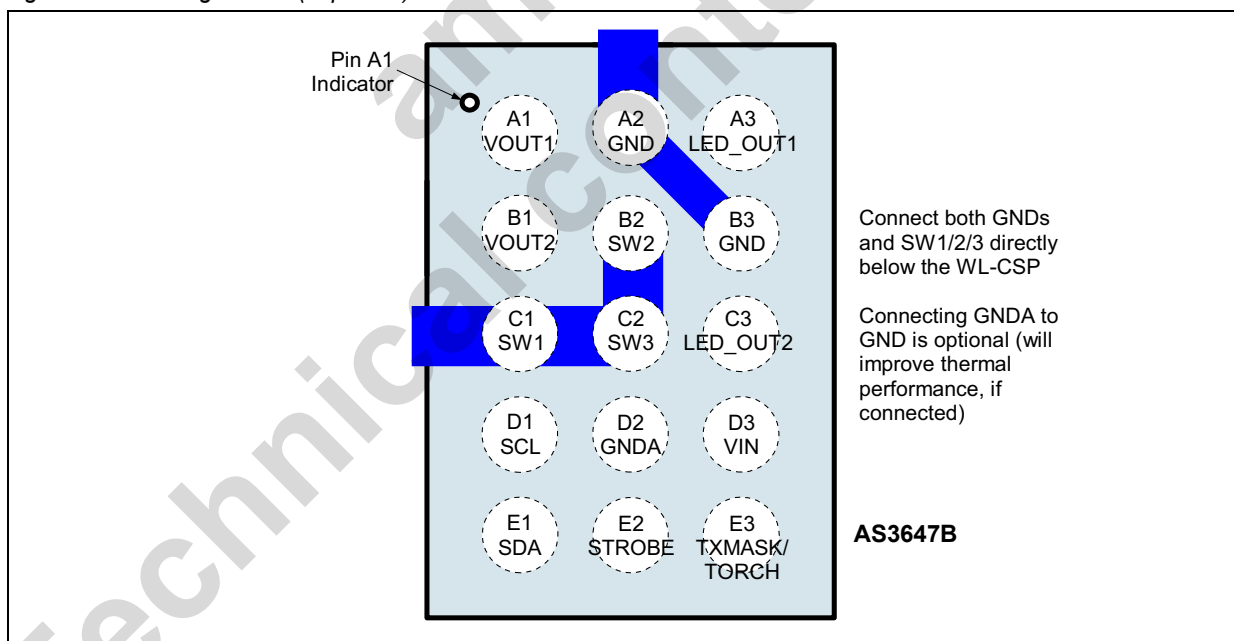


Figure 3. Pin Assignments (Top View) AS3647B



Pin Description

Table 1. Pin Description for AS3647

| Pin Number | Pin Name | Description |
|------------|------------------|---|
| A1 | VOUT1 | DCDC converter output capacitor - make a short connection to Cvout / VOUT2 |
| A2 | GND | Power and analog ground; make a short connection between both balls |
| A3 | LED_OUT1 | Flash LED current sink |
| B1 | SW1 | DCDC converter switching node - make a short connection to SW2 / coil LDCDC |
| B2 | GND | Power and analog ground; make a short connection between both balls |
| C1 | VOUT2 | DCDC converter output capacitor - make a short connection to Cvout / VOUT1 |
| C2 | SW2 | DCDC converter switching node - make a short connection to SW1 /coil LDCDC |
| C3 | LED_OUT2 | Flash LED current sink |
| D1 | SCL | serial clock input for I ² C interface |
| D2 | VIN | Positive supply voltage input - connect to supply and make a short connection to input capacitor CvIN and to coil LDCDC |
| E1 | SDA | serial data input/output for I ² C interface (needs external pullup resistor) |
| E2 | STROBE | Digital input with pulldown to control strobe time for flash function |
| E3 | 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 Function 2: Operate torch current level without using the I ² C interface to operate the torch without need to start a camera processor (if the I ² C is connected to the camera processor) |

Table 2. Pin Description for AS3647B

| Pin Number | Pin Name | Description |
|------------|----------|---|
| A1 | VOUT1 | DCDC converter output capacitor - make a short connection to Cvout / VOUT2 |
| A2 | GND | Power ground; make a short connection between both balls |
| A3 | LED_OUT1 | Flash LED current sink |
| B1 | VOUT2 | DCDC converter output capacitor - make a short connection to Cvout / VOUT1 |
| B2 | SW2 | DCDC converter switching node - make a short connection to SW1 /coil LDCDC |
| B3 | GND | Power ground; make a short connection between both balls |
| C1 | SW1 | DCDC converter switching node - make a short connection to SW2 / coil LDCDC |
| C2 | SW3 | DCDC converter switching node - make a short connection to SW3 /coil LDCDC |
| C3 | LED_OUT2 | Flash LED current sink |
| D1 | SCL | serial clock input for I ² C interface |
| D2 | GNDA | Analog ground - internally connected to GND ball A2; for improving thermal performance connect to ground plane (optional) |
| D3 | VIN | Positive supply voltage input - connect to supply and make a short connection to input capacitor CvIN and to coil LDCDC |
| E1 | SDA | serial data input/output for I ² C interface (needs external pullup resistor) |

Table 2. Pin Description for AS3647B

| Pin Number | Pin Name | Description |
|------------|------------------|--|
| E2 | STROBE | Digital input with pulldown to control strobe time for flash function |
| E3 | TXMASK/ TORCH | <p>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</p> <p>Function 2: Operate torch current level without using the I²C interface to operate the torch without need to start a camera processor (if the I²C is connected to the camera processor)</p> |

5 Absolute Maximum Ratings

Stresses beyond those listed in [Table 3](#) 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 [Table 4](#), “[Electrical Characteristics](#),” on [page 6](#) is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Table 3. Absolute Maximum Ratings

| Parameter | Min | Max | Units | Comments |
|---|------|--------------------------|-------|---|
| VIN to GND | -0.3 | +7.0 | V | |
| STROBE, TXMASK/TORCH, SCL, SDA to GND | -0.3 | VIN + 0.3 | V | max. +7V |
| SW1/2/3, VOUT1/2, LED_OUT1/2 to GND | -0.3 | +7.0 | V | |
| VOUT1/2 to SW1/2/3 | -0.3 | | V | Note: Diode between VOUT1/2 and SW1/2/3 |
| voltage between 2xGND, GNDA pins | 0.0 | 0.0 | V | short connection recommended |
| Input Pin Current without causing latchup | -100 | +100 +I _{IN} | mA | Norm: EIA/JESD78 |
| Continuous Power Dissipation (T_A = +70°C) | | | | |
| Continuous power dissipation | | 1230 | mW | P _T at 70°C ¹ |
| Continuous power dissipation derating factor | | 16.7 | mW/°C | P _{DERATE} ² |
| Electrostatic Discharge | | | | |
| ESD HBM pins LED_OUT1/2 ³ | | ±8000 | V | Norm: JEDEC JESD22-A114F |
| ESD HBM | | ±2000 | V | |
| ESD CDM | | ±500 | V | Norm: JEDEC JESD 22-C101E |
| ESD MM | | ±100 | V | Norm: JEDEC JESD 22-A115-B |
| Temperature Ranges and Storage Conditions | | | | |
| Junction to ambient thermal resistance | | 60 ⁴ | °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 'AS3647/47B Thermal Measurements'
2. P_{DERATE} derating factor changes the total continuous power dissipation (P_T) if the ambient temperature is not 70°C. Therefore for e.g. T_{AMB}=85°C calculate P_T at 85°C = P_T - P_{DERATE} * (85°C - 70°C)
3. Pins LED_OUT1 connected to LED_OUT2 and capacitor C_{VOUT} connected to VOUT1/2 and GND; both GND pins connected together
4. Measured on AS3647/47B Demoboard.

6 Electrical Characteristics

$V_{VIN} = +2.7V$ to $+4.4V$, $T_{AMB} = -30^{\circ}C$ to $+85^{\circ}C$, unless otherwise specified. Typical values are at $V_{VIN} = +3.7V$, $T_{AMB} = +25^{\circ}C$, unless otherwise specified.

Table 4. Electrical Characteristics

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|---|--|---|------------|-----|------------|-------------|
| General Operating Conditions | | | | | | |
| V_{VIN} | Supply Voltage | pin VIN | 2.7 | 3.7 | 4.4 | V |
| $V_{VINREDUCE_D_FUNC}$ | Supply Voltage | AS3647/47B functionally working, but not all parameters fulfilled | 2.5 4.4 | | 2.7 5.5 | V |
| ISHUTDOWN | Shutdown Current | TXMASK/TORCH=L, SCL=SDA=0V, $V_{VIN}<3.7V$ | | 0.6 | 2.0 | μA |
| ISTANBY | Standby Current | interface active, TXMASK/TORCH=L, $V_{VIN}<3.7V^1$ | | 1.0 | 10 | μA |
| T_{AMB} | Operating Temperature | | -30 | 25 | 85 | $^{\circ}C$ |
| Eta | Application Efficiency (DCDC and current sink) | $L_{COIL}=0.6\mu H@3A$, $L_{ESR}=60m\Omega$, $LED_OUT_{1,2}=1300mA^2$, $t_{FLASH}<300ms$ | | 84 | | % |
| DCDC Step Up Converter | | | | | | |
| V_{VOUT} | DCDC Boost output Voltage (pin VOUT1/2) | | 2.8 | | 5.5 | V |
| V_{VOUT5V} | DCDC Boost output Voltage (pin VOUT1/2) | constant voltage mode operation const_v_mode (see page 25)=1 | | 5.0 | | V |
| RPMOS | On-resistance | DCDC internal PMOS switch | | 70 | | $m\Omega$ |
| RNMOS | On-resistance | DCDC internal NMOS switch | | 70 | | $m\Omega$ |
| fCLK | Operating Frequency | All internal timings are derived from this oscillator | -7.5% | 4.0 | +7.5% | MHz |
| Current Sinks | | | | | | |
| V_{LED} | LED forward voltage | single LED at 1600mA | 2.8 | 3.5 | 4.2 | V |
| I_{LED_OUT} | LED_OUT1/2 current sinks output combined | single LED | 0 | | 1600 | mA |
| $I_{LED_OUT\Delta}$ | LED_OUT1/2 current sink accuracy | $I_{LED_OUT}\geq 800mA$ or $I_{LED_OUT}<500mA$ $0^{\circ}C < T_J < 100^{\circ}C$ | -7 | | +7 | % |
| | | $500mA < I_{LED_OUT} < 800mA$, $0^{\circ}C < T_J < 100^{\circ}C$ | -5 | | +5 | % |
| $I_{LED_OUT_RAMP}$ | LED_OUT1/2 ramp time | Ramp-up During startup | | 250 | 1000 | μs |
| | | Ramp-down | | 500 | 1000 | μs |
| $I_{LED_OUT_RIPPLE}$ | LED_OUT current ripple | $I_{LED_OUT} = 1000mA$, $BW=20MHz$ | | 20 | | mAPP |
| V_{ILED_COMP} | LED_OUT current sink voltage compliance | Minimum voltage between pin LED_OUT1/2 and GND for operation of the current sink | | 325 | | mV |
| V_{HIGH_VDS} | Comparator High VDS | low vds and high vds comparator - see 4MHz/1MHz Operating Mode Switching on page 13 | | 900 | | mV |
| V_{LOW_VDS} | Comparator Low VDS | | | 320 | | |
| $I_{LEAK_LED_OUT}$ | LED_OUT1/2 Leakage Current | Pins LED_OUT1 and LED_OUT2 | -1.0 | 0.0 | +1.0 | μA |
| Protection and Fault Detection Functions (see page 13) | | | | | | |

Table 4. Electrical Characteristics (Continued)

| Symbol | Parameter | Condition | Min | Typ | Max | Unit | |
|---|---|---|-----------------------------|-----------|------------|------|------|
| 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 40% PWM duty cycle ³ maximum 40000s lifetime operation in overcurrent limit | coil_peak=00b | 1.8 | 2.0 | 2.23 | A | |
| | | coil_peak=01b | 2.25 | 2.5 | 2.78 | | |
| | | default value | coil_peak (see page 24)=10b | 2.7 | 3.0 | | 3.34 |
| | | coil_peak=11b | 3.15 | 3.5 | 3.9 | | |
| VLEDSHORT | Flash LED short circuit detection voltage | Voltage measured between pins VOUT1,2 and LED_OUT1,2 | | 1.0 | | V | |
| TOVTEMP | Overtemperature Protection | Junction temperature | | 144 | | °C | |
| TOVTEMPHYST | Overtemperature Hysteresis | | | 5 | | °C | |
| tFLASHTIMEOUT | Flash Timeout Timer | Can be adjusted with register flash_timeout (page 26) | 2 | | 1280 | ms | |
| | | accuracy | -7.5 | | +7.5 | % | |
| VUVLO | Undervoltage Lockout | Falling VVIN | 2.25 | 2.4 | 2.5 | V | |
| | | Rising VVIN | VUVLO+0.05 | VUVLO+0.1 | VUVLO+0.15 | V | |
| Digital Interface | | | | | | | |
| VIH | High Level Input Voltage | Pins SCL, SDA. Pin TXMASK/TORCH in external torch mode (ext_torch_on=10) | 1.26 | | VVIN | V | |
| VIL | Low Level Input Voltage | | 0.0 | | 0.54 | V | |
| VIHFLASH | High Level Input Voltage | Pin STROBE. Pin TXMASK/TORCH for TxMask mode | 0.7 | | VVIN | V | |
| VILFLASH | Low Level Input Voltage | (ext_torch_on=01) ⁴ | 0.0 | | 0.54 | V | |
| VOL | Low Level Output Voltage | pin SDA, IoL=3mA | | | 0.3 | V | |
| I _{LEAK} | Leakage current | Pins SCL, SDA | -1.0 | 0.0 | +1.0 | µA | |
| I _{PD} | Pulldown current to GND ⁵ | Pins TORCH, STROBE and TXMASK/TORCH | | 36 | | µA | |
| tDEBTORCH | TORCH debounce time | | 6.3 | 9 | 11.7 | ms | |
| tTIMEOUT | SCL timeout | In indicator, assist or flash mode, if SCL is low longer than this timeout, the AS3647/47B automatically enters shutdown mode | 35 | | 100 | ms | |
| I²C mode timings - see Figure 4 on page 9 | | | | | | | |
| fSCLK | SCL Clock Frequency | | 1/ tTIMEOUT | | 400 | kHz | |
| t _{BUF} | Bus Free Time Between a STOP and START Condition | | 1.3 | | | µs | |

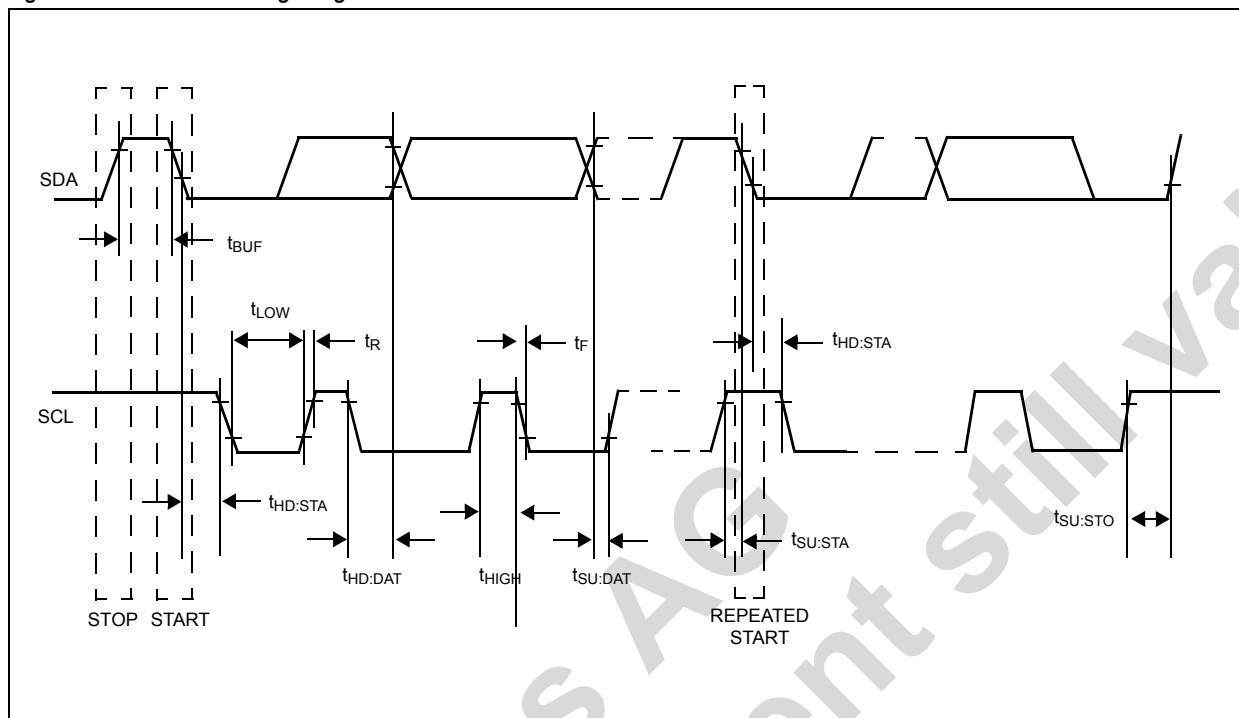
Table 4. Electrical Characteristics (Continued)

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|--------------|---|---|---------------|-----|-----|---------|
| $t_{HD:STA}$ | Hold Time (Repeated) START Condition ⁶ | | 0.6 | | | μs |
| t_{LOW} | LOW Period of SCL Clock | | 1.3 | | | μs |
| t_{HIGH} | HIGH Period of SCL Clock | | 0.6 | | | μs |
| $t_{SU:STA}$ | Setup Time for a Repeated START Condition | | 0.6 | | | μs |
| $t_{HD:DAT}$ | Data Hold Time ⁷ | | 0 | | 0.9 | μs |
| $t_{SU:DAT}$ | Data Setup Time ⁸ | | 100 | | | ns |
| t_R | Rise Time of Both SDA and SCL Signals | | $20 + 0.1C_B$ | | 300 | ns |
| t_F | Fall Time of Both SDA and SCL Signals | | $20 + 0.1C_B$ | | 300 | ns |
| $t_{SU:STO}$ | Setup Time for STOP Condition | | 0.6 | | | μs |
| C_B | Capacitive Load for Each Bus Line | C_B — total capacitance of one bus line in pF | | | 400 | pF |
| $C_{I/O}$ | I/O Capacitance (SDA, SCL) | | | | 10 | pF |

1. For $V_{BAT}=4.5V$, $SCL=1.8V$, $SDA=1.8V$ maximum I_{STANBY} is $<16\mu A$.
2. 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.
3. Due to slope compensation of the current limit, I_{LIMIT} changes with duty cycle - see [Figure 17 on page 12](#).
4. The logic input levels V_{IH} and V_{IL} allow for 1.2V or 1.8V supplied driving circuit
5. A pulldown current of $36\mu A$ is equal to a pulldown resistor of $42k\Omega$ 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_{IHMIN} 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 $t_{SU:DAT} =$ 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 $t_R \max + t_{SU:DAT} = 1000 + 250 = 1250ns$ before the SCL line is released.

Timing Diagrams

Figure 4. I²C mode Timing Diagram



7 Typical Operating Characteristics

$V_{IN} = 3.7V$, $T_A = +25^\circ C$ (unless otherwise specified), LED: Osram Phaser 2 ($V_{FLED} = 3.8V$ at 1A)

Figure 5. DCDC Efficiency vs. V_{IN}

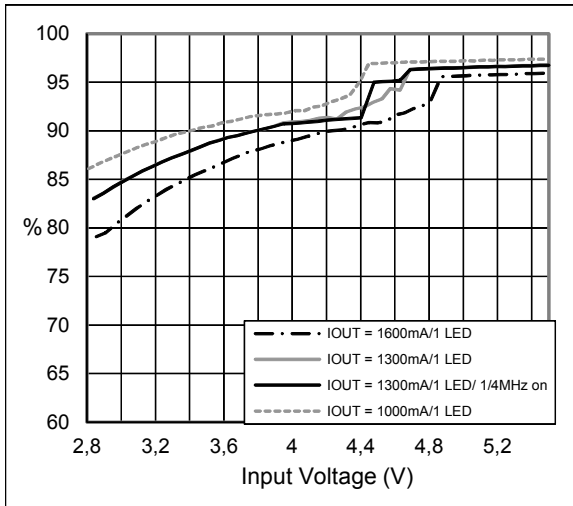


Figure 6. Application Efficiency (P_{LED}/P_{VIN}) vs. V_{IN}

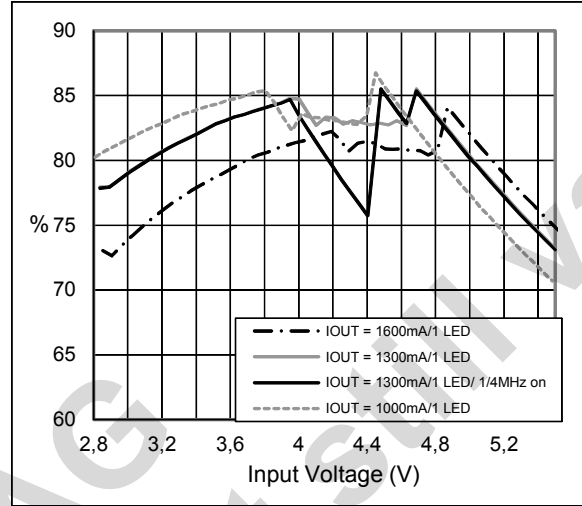


Figure 7. Battery Current vs. V_{IN}

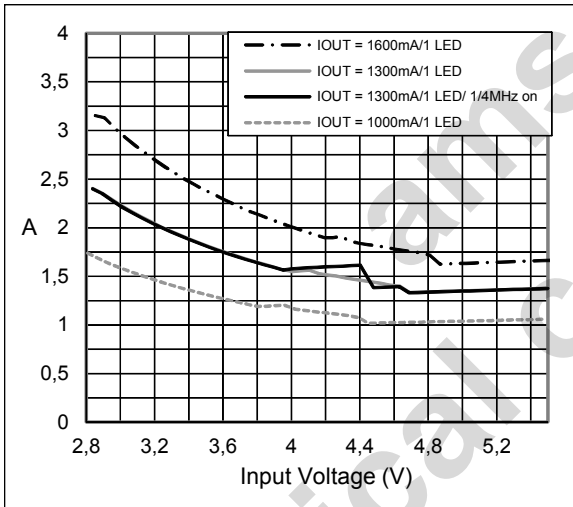


Figure 8. Efficiency at low currents (300mA)

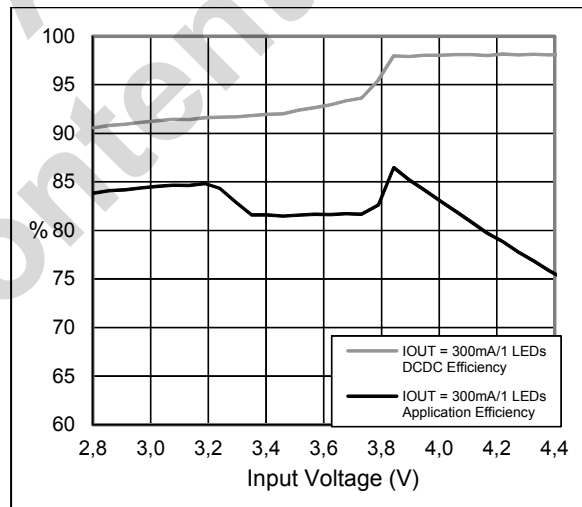


Figure 9. ILED Startup ($I_{LED_OUT} = 1.0A$)

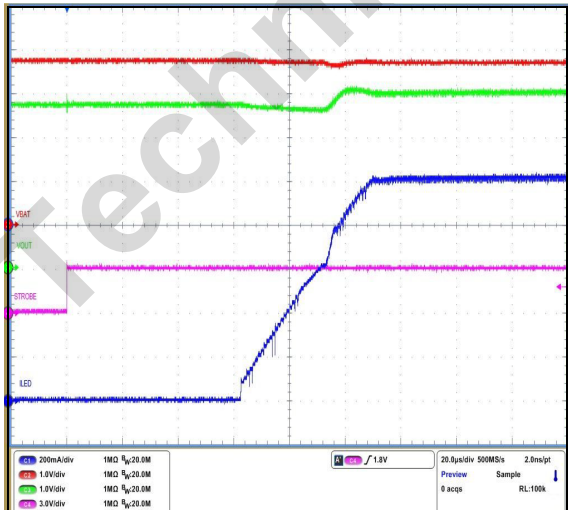


Figure 10. I_{VIN} , ILED Startup ($I_{LED_OUT} = 800mA$)

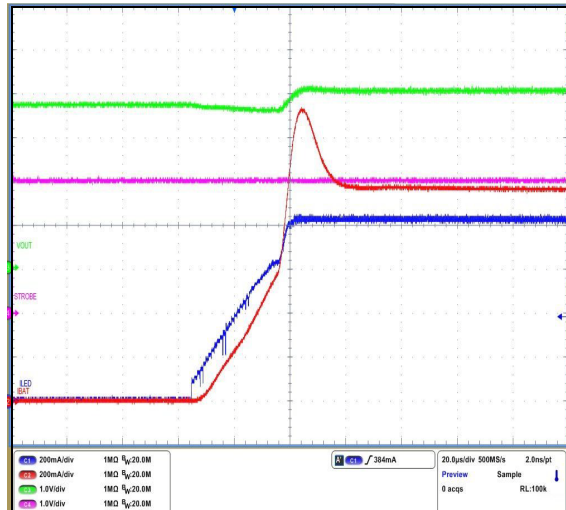


Figure 11. ILED Startup (ILED_OUT=60mA)

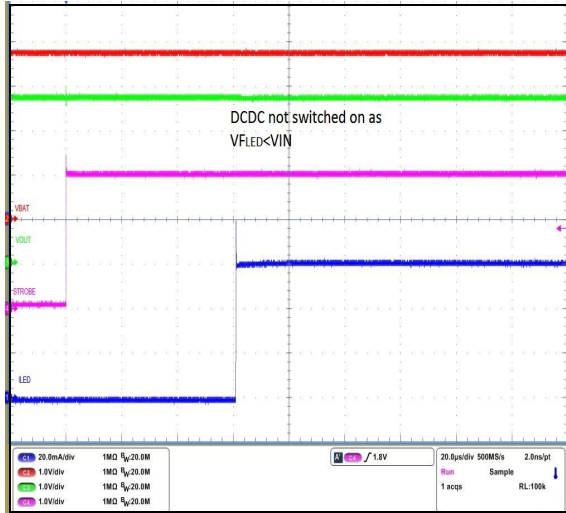


Figure 12. VOUT / ILED_OUT ripple, ILED_OUT = 1.0A

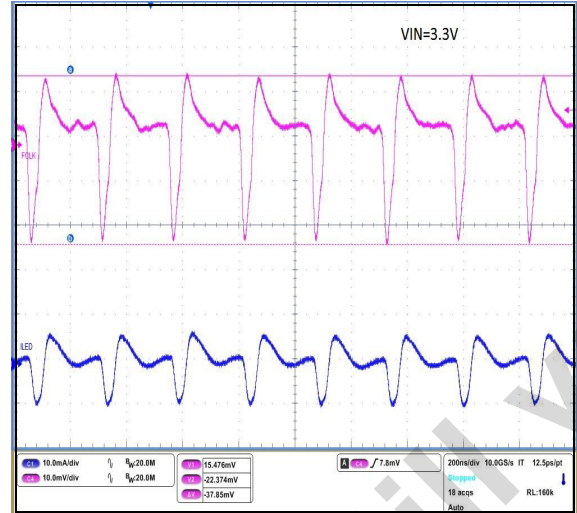


Figure 13. ILED Rampdown (ILED_OUT=1.0A)

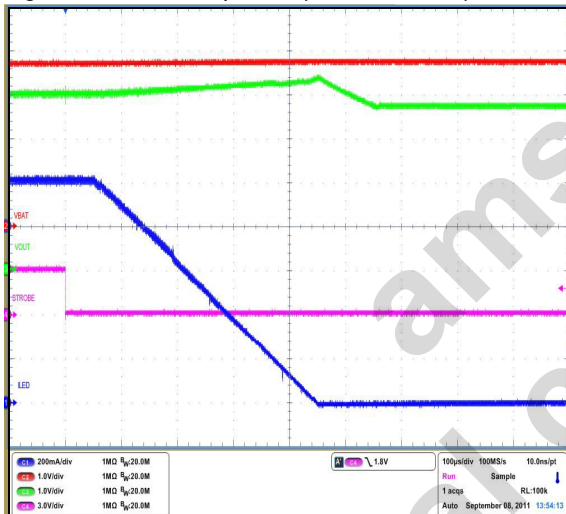


Figure 14. ILED_OUT vs. TAMB

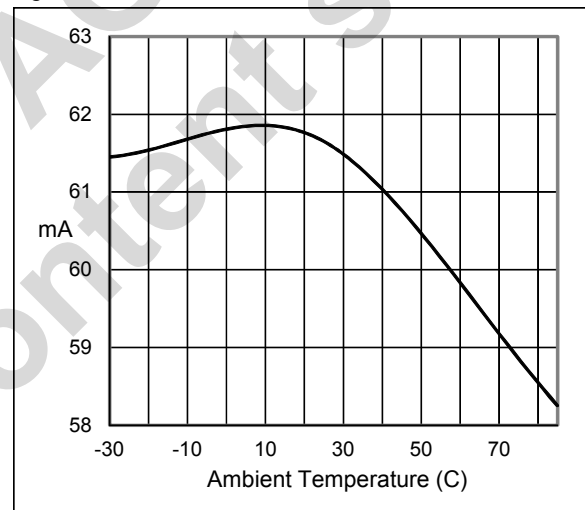


Figure 15. Oscillator frequency fCLK vs. TAMB

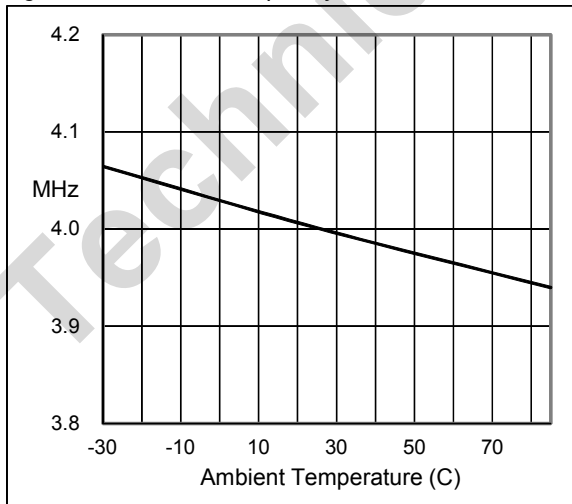
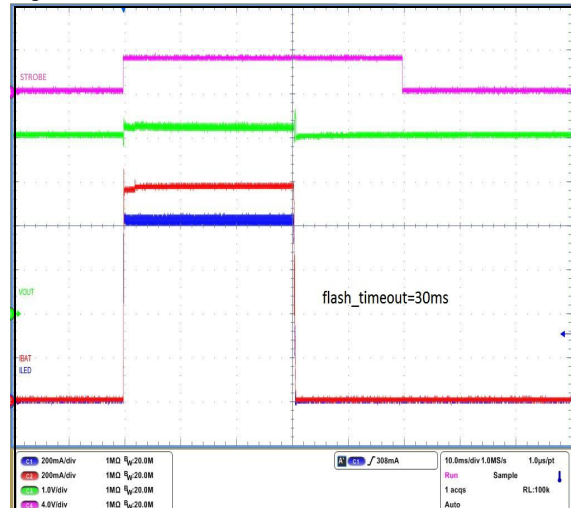


Figure 16. Flash Timeout



8 Detailed Description

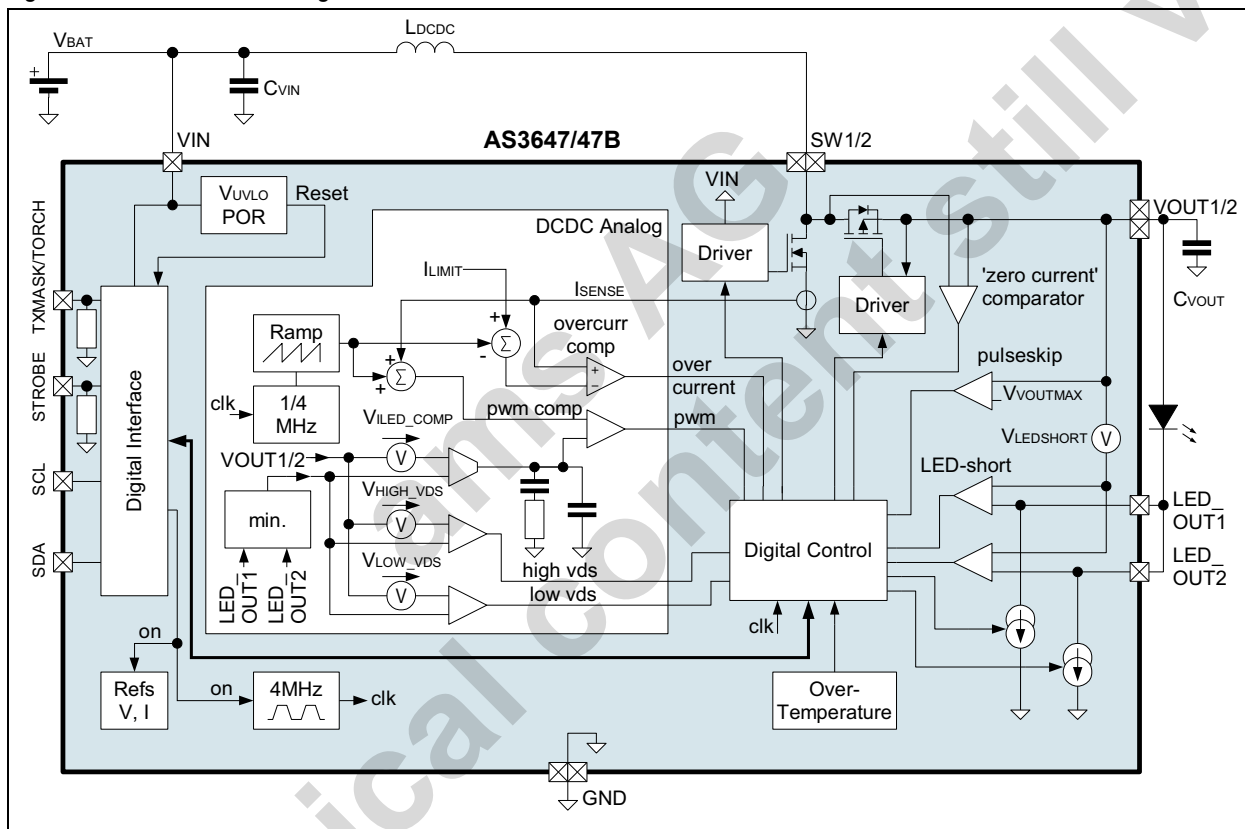
The AS3647/47B is a high performance DCDC step up converter with internal PMOS and NMOS switches. Its output is connected to one flash LED with an internal current sink. The device is controlled by the pins SDA and SCL in I²C mode.

The actual operating mode like standby, assist light, indicator or flash mode, can then be chosen by the interface. If not in standby mode, the device automatically enters shutdown mode by keeping SCL low for more than t_{TIMEOUT}^1 .

The AS3647/47B includes a fixed frequency DCDC step-up with accurate startup control. Together with the current sink (on LED_OUT1/2) it includes several protection and safety functions.

Internal Circuit Diagram

Figure 17. Internal circuit Diagram



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 sinks), the ramp up is temporarily stopped in order for the DCDC to return to regulation².

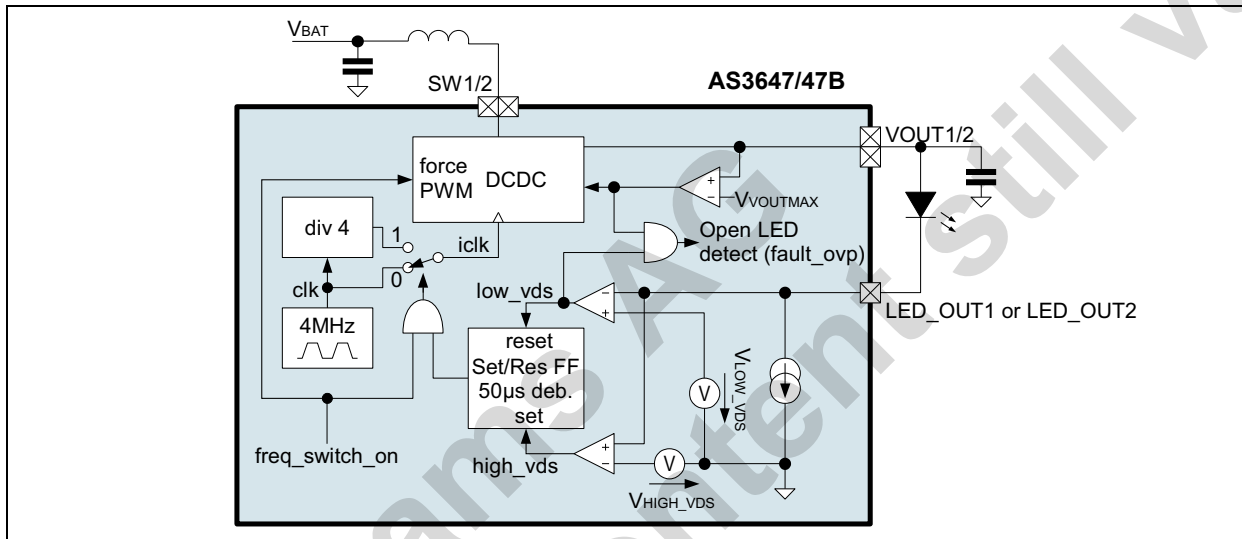
1. Following registers are reset to their default value if the timeout expires: `out_on=0`, `ext_torch_on=00`, `mode_setting=00`, `const_v_mode=0`.
2. The actual value of the LED current setting can be readout by the register `led_current_actual` (see page 28) to allow the camera processor to adopt to the actual operating conditions.

4MHz/1MHz Operating Mode Switching

If `freq_switch_on` (see page 28)=1 and in flash and assist light mode (indicator mode or low current mode using PWM mode -see `mode_setting` (page 26) - always will use pulseskip) if `led_current`>=40h, the DCDC converter always operates in PWM mode (exception: PFM mode is allowed during startup) to reduce EMI in EMI sensitive systems. For flash and assist light mode and 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 condition³. 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 1MHz / 4MHz can be disabled by `freq_switch_on` (see page 28)=0. In this case pulseskip will be used.

The internal circuit for switching between these two frequencies is shown in Figure 18:

Figure 18. Internal circuit of 4MHz/1Mhz selection



Note: For simplicity Figure 18 shows only a single current sink.

Protection and Fault Detection Functions

The protection functions protect the AS3647/47B and the LED(s) against physical damage. In most cases a `Fault` register bit is set, which can be readout by the I²C interface. The fault bits are automatically cleared by a I²C readout of the fault register. Additionally the DCDC is stopped and the current sinks are disabled⁴ by resetting `out_on`=0, `mode_setting`=00 and `ext_torch_on`=00.

Overvoltage Protection

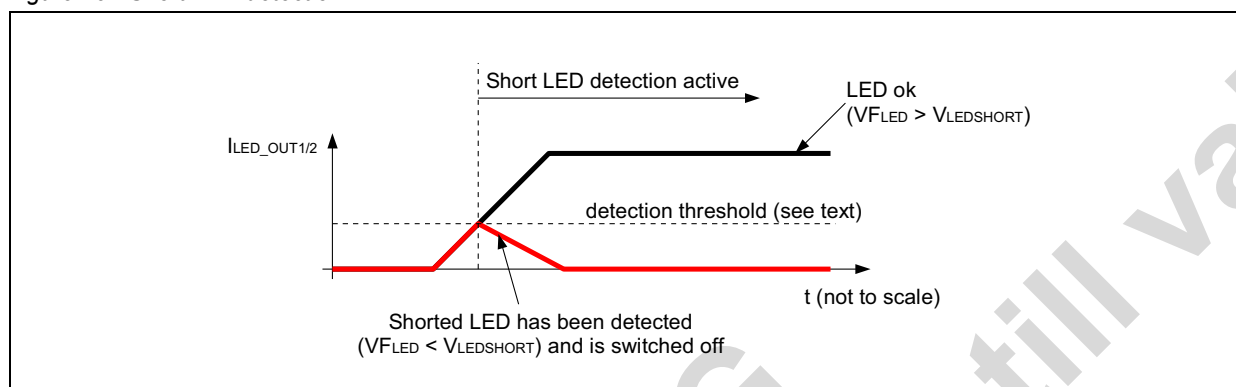
In case of no or a broken LED(s) at the pin LED_OUT1/2 and an enabled DCDC converter, the voltage on VOUT1/2 rises until it reaches $V_{VOUTMAX}$ (overvoltage condition) and the voltage across the current source is below low_vds ⁵, the DCDC converter is stopped, the current sources are disabled and the bit `fault_ovp` (see page 27) is set⁶.

3. Efficiency compared to a 4MHz only DCDC converter forced to operate with minimum duty cycle.
4. Applies for all faults except `TXMASK event occurred`
5. If overvoltage is reached, but none of the `low_vds` comparator(s) triggers, VOUT1/2 is still regulated below $V_{VOUTMAX}$.
6. In constant voltage mode (5V generation, register bit `const_v_mode`=1) this fault is disabled.

Short Circuit Protection

After the startup of the DCDC converter, the voltage on LED_OUT1/2 is continuously monitored and compared against $V_{LED\text{SHORT}}$ if the LED current is above 25mA⁷ (see Figure 19). If the voltage across the LED ($V_{FLED} = V_{OUT1/2} - V_{LED_OUT1/2}$) stays below $V_{LED\text{SHORT}}$, the DCDC is stopped (as a shorted LED is assumed), the current sinks are disabled and the bit `fault_led_short` (see page 27) is set.

Figure 19. Short LED detection



Overtemperature Protection

The junction temperature of the AS3647/47B is continuously monitored. If the temperature exceeds T_{OVTEMP} , the DCDC is stopped, the current sinks are disabled (instantaneous) and the bit `fault_overtemp` (see page 27) is set. The driver is automatically re-enabled⁸ once the junction temperature drops below $T_{OVTEMP} - T_{OVTEMPHYST}$.

TXMASK event occurred

If during flash, TXMASK current reduction is enabled (see TXMASK on page 16, configured by `ext_torch_on=01`) and a TXMASK event happened (pin TXMASK/TORCH=1), the fault register bit `fault_txmask` (see page 27) is set.

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 26 on page 19) exceeds $t_{FLASH\text{TIMEOUT}}$ (adjustable by register `flash_timeout` (see page 26)), the DCDC is stopped and the flash current sinks (on pin LED_OUT1/2) are disabled and `fault_timeout` is set.

If the flash duration is defined by the timeout timer itself (`strobe_on = 0`, see Figure 24 on page 19), the register `fault_timeout` is set after the flash has been finished.

Supply undervoltage Protection

If the voltage on the pin VIN (=battery voltage) is or falls below V_{UVLO} , the AS3647/47B is kept in shutdown state and all registers are set to their default state.

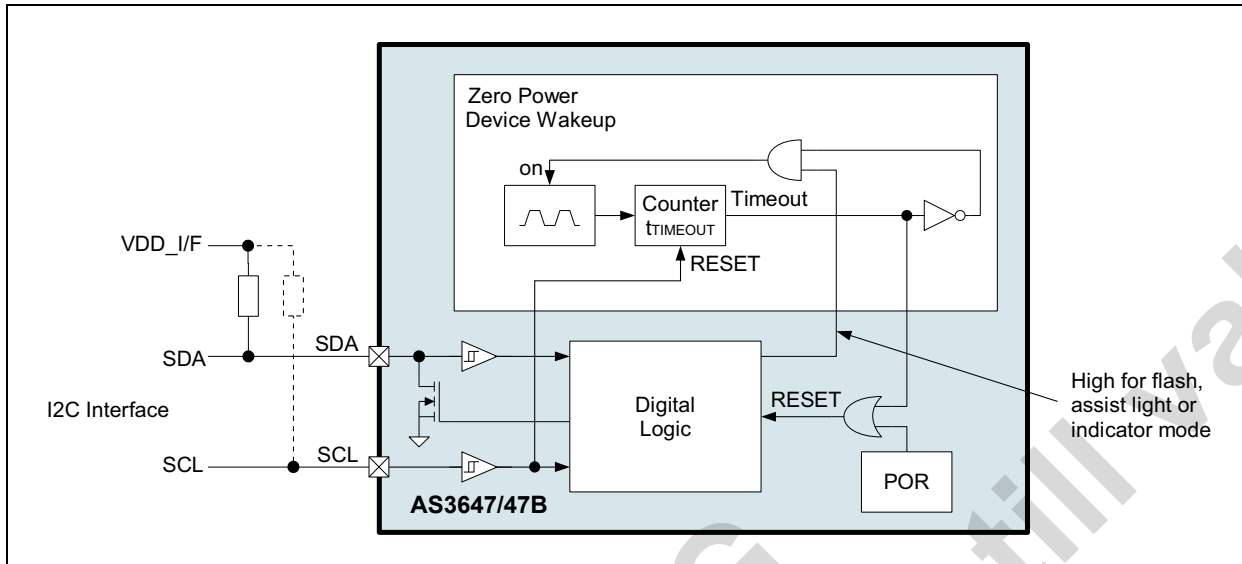
Wakeup Circuit - Power off detection

In flash, assist light and indicator mode (register `mode_setting` (page 26)=01, 10 or 11) and `out_on` (page 26)=1, if SCL is L for more than t_{TIMEOUT} , shutdown mode is automatically entered. This feature automatically detects a power-off of the controlling circuit driving SCL and SDA ($V_{DD_I/F}$ goes to 0V e.g. due to a low power condition of the driving circuit) - the internal circuit is shown in Figure 20:

7. To avoid errors in short LED detection for LEDs with a high leakage current

8. In constant voltage mode (`const_v_mode=1`) the DCDC will not be automatically re-enabled.

Figure 20. Device Shutdown and Wakeup



In shutdown mode once pin SCL goes high for the first time, the internal counter shown in Figure 20 is immediately reset thus releasing the internal RESET (assuming VIN is above VUVLO) signal and allows instant communication on the I²C bus. Therefore no additional action is required to leave the shutdown mode and start I²C communication.

Purpose of this circuit

The purpose of this circuit is an additional security mechanism.

Assume the user programmed torch or indicator operation (there is no timeout for these operating modes) and the battery slowly drops below the undervoltage limit of the system. The processor would get a reset by the PMIC and the LDO operating VDD_I/F is switched off, but the processor might not have been able to switch-off the torch/indicator operation of the AS3647/47B. Due to the implemented security mechanism the AS3647/47B detects a power off of VDD_I/F and automatically enters shutdown.

Current consumption in standby/shutdown mode

The AS3647/47B is designed to draw minimum current in standby and shutdown mode. There is a small difference in current consumption between these two operating modes (typ. 300nA) only due to the internal level shifters (see the schmitt trigger input buffers connected to SCL and SDA in Figure 20) for shifting up the voltage on SCL/SDA (VDD_I/F e.g. 1.8V) to the supply voltage on VIN (e.g. 3.7V). If the AS3647/47B is driven with digital levels close to 0V/VIN, the current consumption for standby mode is identical to shutdown mode.

Operating Mode and Currents

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

Table 5. Operating Mode and current settings

| AS3647/47B configuration | | | | | operating mode and currents | | |
|-----------------------------------|-------|--------|----------------------------|----------------------|--|---|---------------------------|
| SCL and SDA | TORCH | STROBE | mode setting (see page 26) | out_on (see page 26) | Condition | Mode | LED_OUT1/2 output current |
| SCL low for tTIMEOUT ¹ | X | X | X | X | if previous operating mode was indicator, assist light or flash mode | shutdown all registers are reset to their default values | 0 |

Table 5. Operating Mode and current settings (Continued)

| AS3647/47B configuration | | | | | operating mode and currents | | |
|--|-------|-----------------------------------|----------------------------|----------------------|--|---|--|
| SCL and SDA | TORCH | STROBE | mode setting (see page 26) | out_on (see page 26) | Condition | Mode | LED_OUT1/2 output current |
| I ² C commands are accepted | X | X | 10, 01 or 11 | 0 | | standby | 0 |
| | X | X | 00 | X | ext_torch_on (see page 24) not 10 | | |
| | 0 | X | | | ext_torch_on = 10 | | |
| | 1 | X | | | ext_torch_on = 10 | external torch mode | LED current is defined by the 7LSB ² bits of led_current |
| | X | X | 01 | 1 | | indicator mode or low current pwm mode ³ | LED current is defined by the 6LSB bits (bits 5...0) of led_current pwm modulated with 31.25kHz defined by register inct_pwm (1/16...4/16) |
| | X | X | 10 | 1 | | assist light mode | LED current is defined by the 7LSB ² bits (6...0) of led_current |
| | X | X | 11 | 1 | strobe_on (see page 27) = 0 | flash mode; | LED current is defined by led_current - the current can be reduced during flash, see Flash Current Reductions below |
| | X | 0->1 | | | strobe_on = 1 and strobe_type (see page 27) = 0 | flash duration defined by flash_timeout (see page 26) | |
| X | 1 | strobe_on = 1 and strobe_type = 1 | | | flash duration defined by STROBE input; timeout defined by flash_timeout | | |

1. SCL low for tTIMEOUT and operating mode is indicator, assist or flash mode then shutdown mode is entered.
2. The MSB bit of this register not used to protect the LED; therefore the maximum assist / torch light current = half the maximum flash current
3. 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_current are used the maximum current is limited to 1/4 of the maximum flash current.

Flash Current Reductions

TXMASK

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

Current Reduction by VIN measurements in Flash Mode

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 of the system would reset. To prevent this condition the AS3647/47B monitors the battery voltage and keeps it above vin_low_v_run as follows:

Before a flash is started the voltage on VIN is measured. If the voltage is below the setting of vin_low_v the fault_uvlo (see page 27) is set and the flash is disabled (driver stays in shutdown) if vin_low_v_shutdown=1. The flash current is reduced to flash_txmask_current if vin_low_v_shutdown=0.

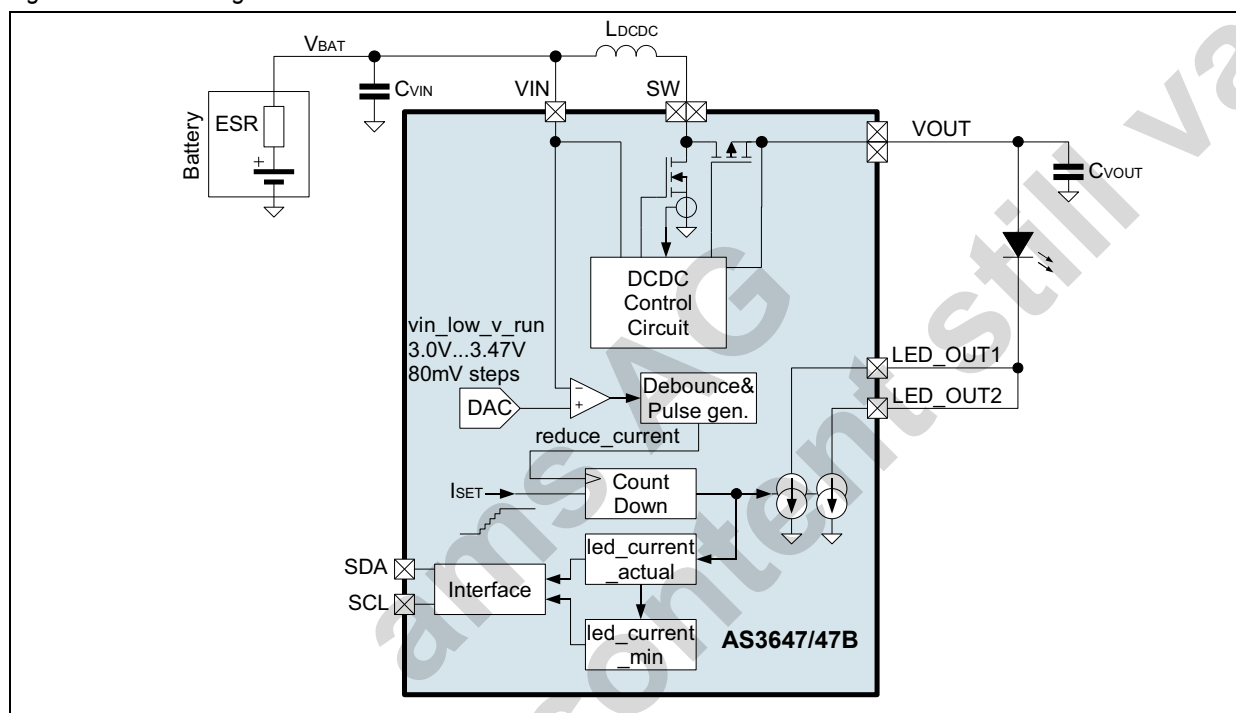
During flash, if the voltage on VIN drops below the threshold defined by `vin_low_v_run`, the flash current is reduced (or ramping of the current is stopped during flash current startup) and `fault_uvlo` is set. The timing for the reduction of the current is $8\mu\text{s}/\text{LSB}$ current change.

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 21](#):

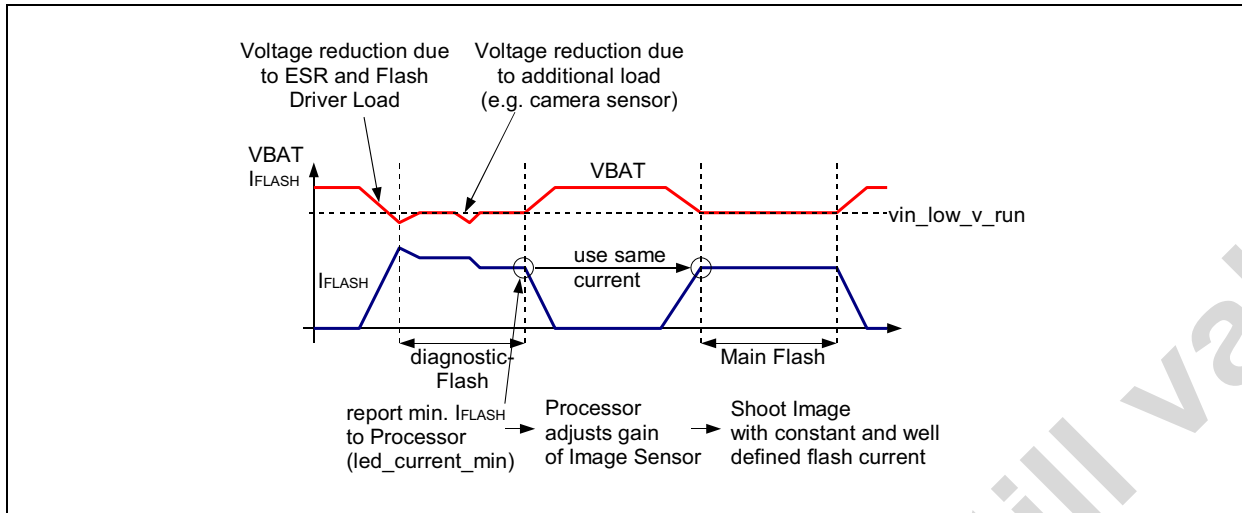
Figure 21. Low Voltage current Reduction Internal Circuit



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

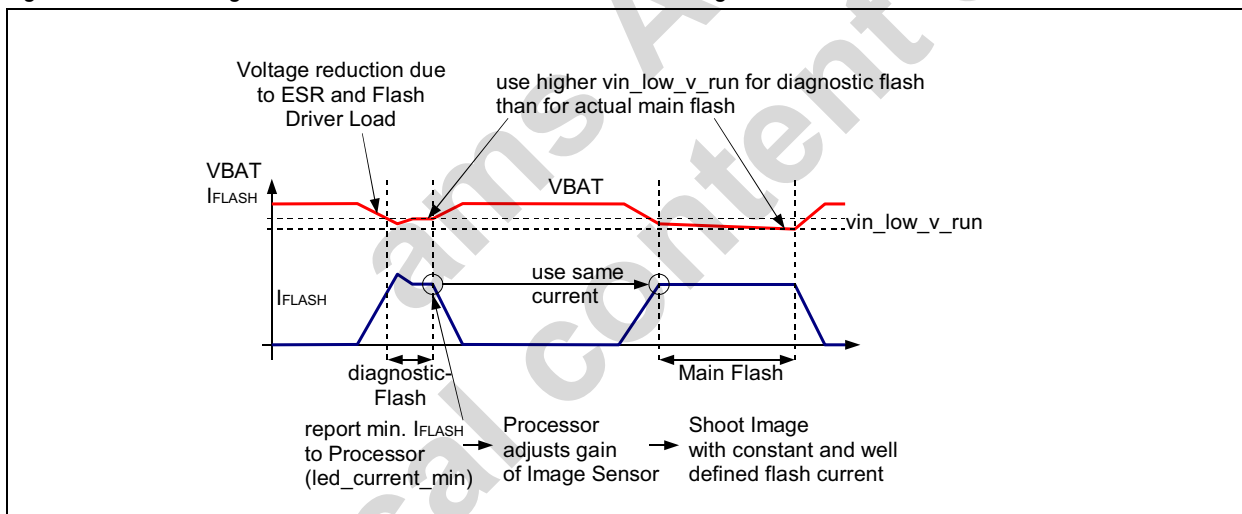
The diagnostic flash is initiated by the processor. After this diagnostic flash, the determined maximum flash current can be read back through the I²C interface from register `led_current_min` (see [page 28](#)) and used for the setting for the main flash. Therefore the current in the main-flash is constant and additionally the camera system can use this current for picture quality adjustments - the waveforms for this concept are shown in [Figure 22](#):

Figure 22. Low Voltage current Reduction Waveform with diagnostic-Flash and Main-Flash Phase



If the diagnostic flash should be short (e.g. 10ms) it is recommended to operate this diagnostic flash at slightly higher `vin_low_v_run` setting compared to the main flash as shown in Figure 23:

Figure 23. Low Voltage current Reduction Waveform with short diagnostic-Flash and Main-Flash Phase



The different settings for `vin_low_v_run` allow a constant main flash current without dropping VIN below `vin_low_v_run`.

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 I²C command (see Figure 24):
set `strobe_on` = 0, start the flash by setting `out_on` = 1
- Flash duration defined by register `flash_timeout` and flash started with a rising edge on pin STROBE (see Figure 25):
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 26 and Figure 34):
set `strobe_on` = 1 and `strobe_type` = 1

Figure 24. AS3647/47B flash duration defined by *flash_timeout* without using STROBE input

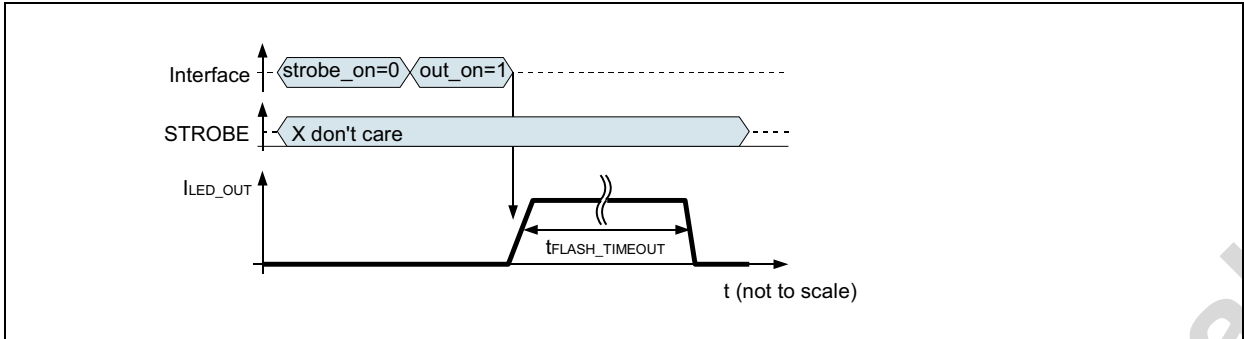


Figure 25. AS3647/47B flash duration defined by *flash_timeout*, starting flash with STROBE rising edge

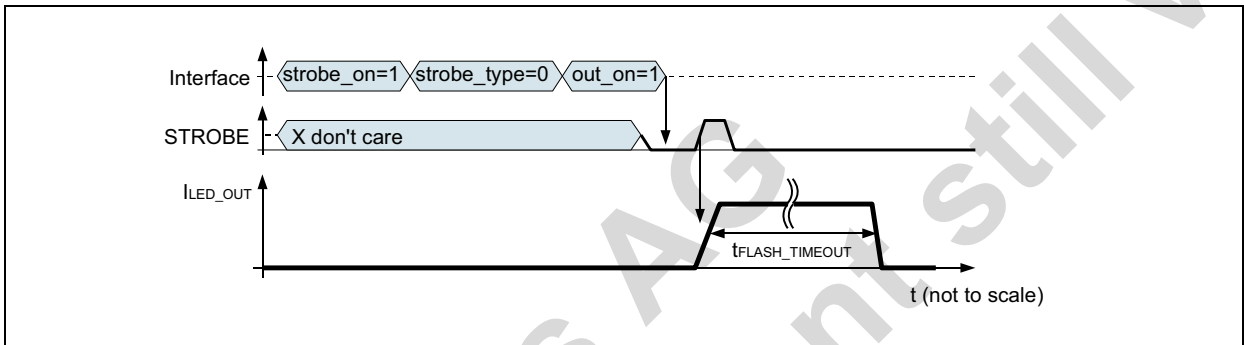


Figure 26. AS3647/47B flash duration and start defined by STROBE, limited by *flash_timeout*; timer not expired

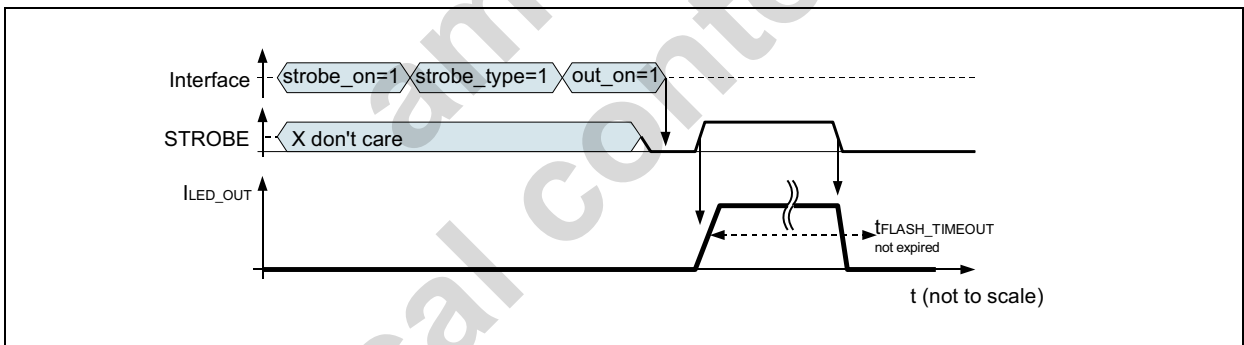
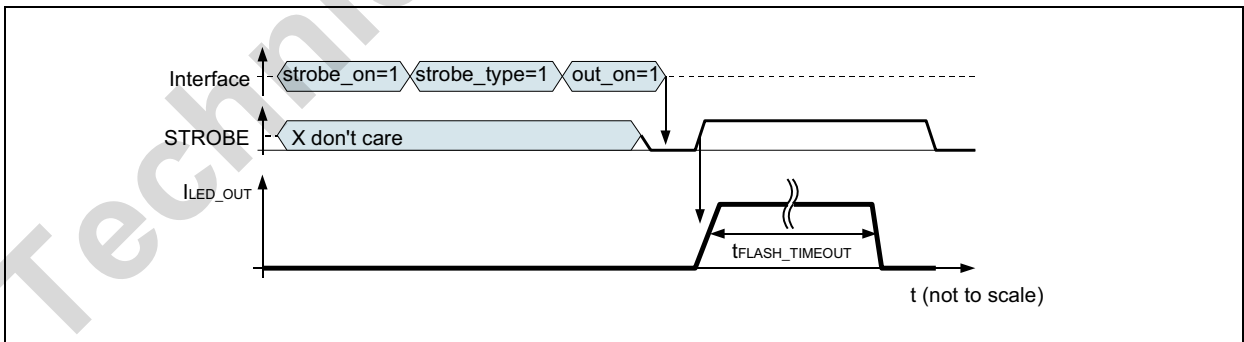


Figure 27. AS3647/47B flash duration and start defined by STROBE, limited by *flash_timeout*; timer expired



I²C Serial Data Bus

The AS3647/47B supports the I²C 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 AS3647/47B operates as a slave on the I²C bus. Within the bus specifications a standard mode (100kHz maximum clock rate) and a fast mode (400kHz maximum clock rate) are defined. The AS3647/47B 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 28):

- 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

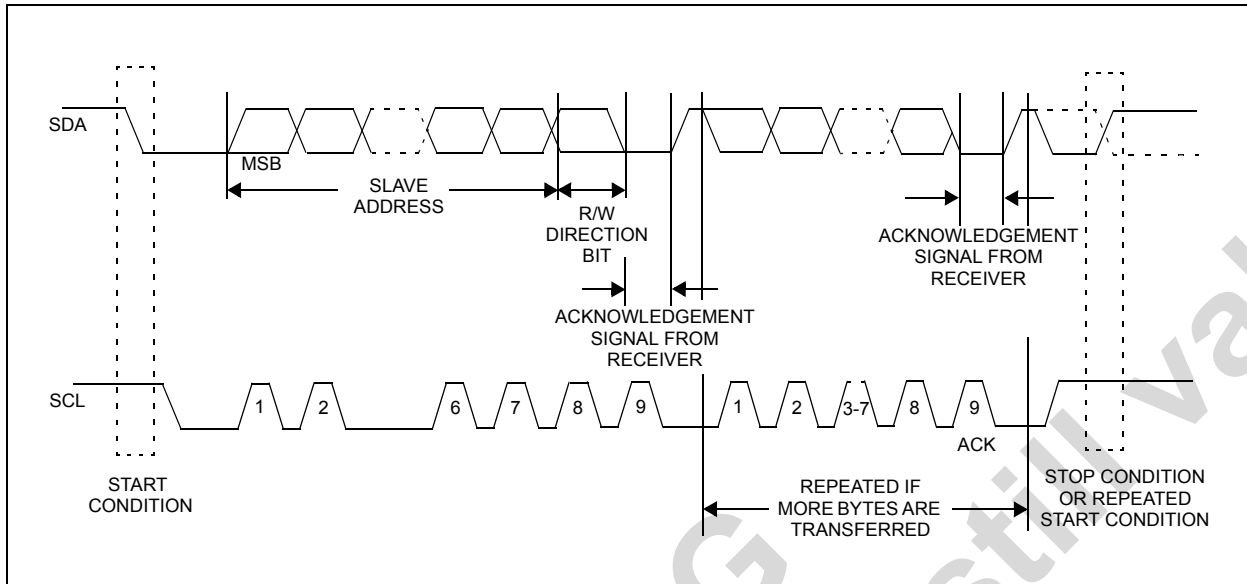
The state of the data line represents valid data when, after a START condition, the data line is stable for the duration of the HIGH period of the clock signal. The data on the line must be changed during the LOW period of the clock signal. There is one clock pulse per bit of data.

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 28. Data Transfer on I²C 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 AS3647/47B 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 29). The slave address byte is the first byte received after the master generates the START condition. The slave address byte contains the 7-bit AS3647/47B address, which is 0110000, followed by the direction bit (R/W), which, for a write, is 0.⁹ After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. After the AS3647/47B acknowledges the slave address + write bit, the master transmits a register address to the AS3647/47B. This sets the register pointer on the AS3647/47B. The master may then transmit zero or more bytes of data, with the AS3647/47B 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 AS3647/47B while the serial clock is input on SCL. START and STOP conditions are recognized as the beginning and end of a serial transfer (Figure 30 and Figure 31). The slave address byte is the first byte received after the master generates a START condition. The slave address byte contains the 7-bit AS3647/47B address, which is 0110000, followed by the direction bit (R/W), which, for a read, is 1.¹⁰ After receiving and decoding the slave address byte the device outputs an acknowledge on the SDA line. The AS3647/47B then begins to transmit data starting with the register address pointed to by the register pointer. If

9. The address for writing to the AS3647/47B is 60h = 01100000b

10. The address for read mode from the AS3647/47B is 61h = 01100001b

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 AS3647/47B must receive a “not acknowledge” to end a read.

Figure 29. Data Write - Slave Receiver Mode

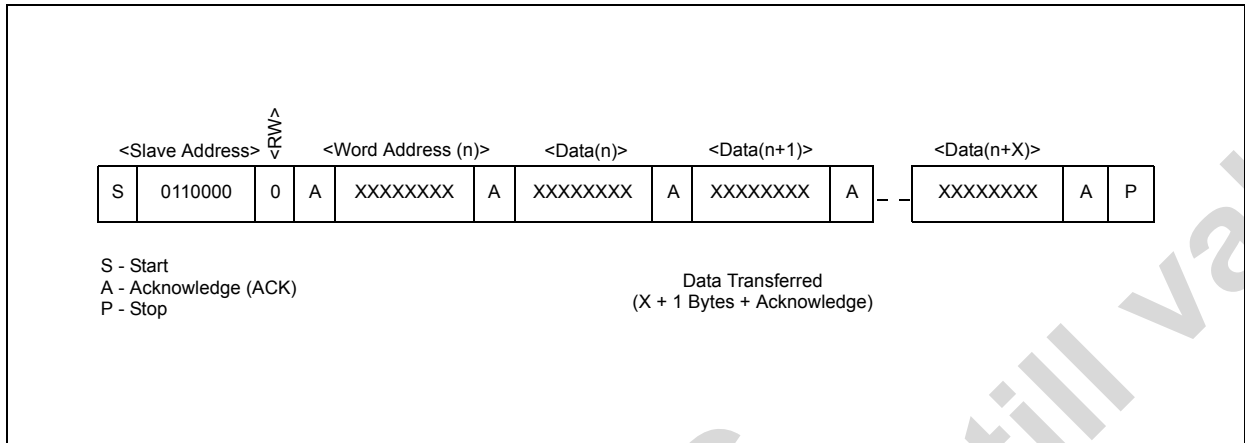


Figure 30. Data Read (from Current Pointer Location) - Slave Transmitter Mode

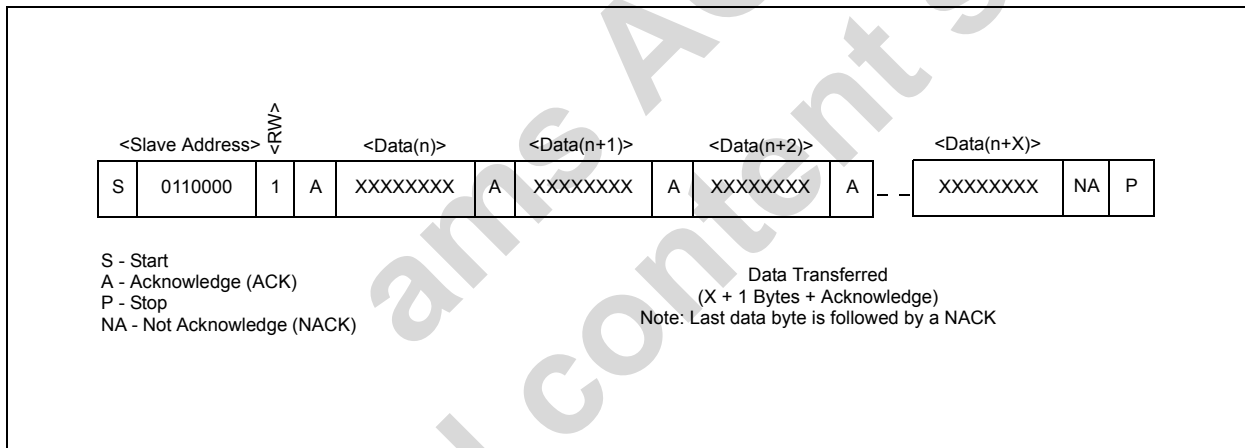
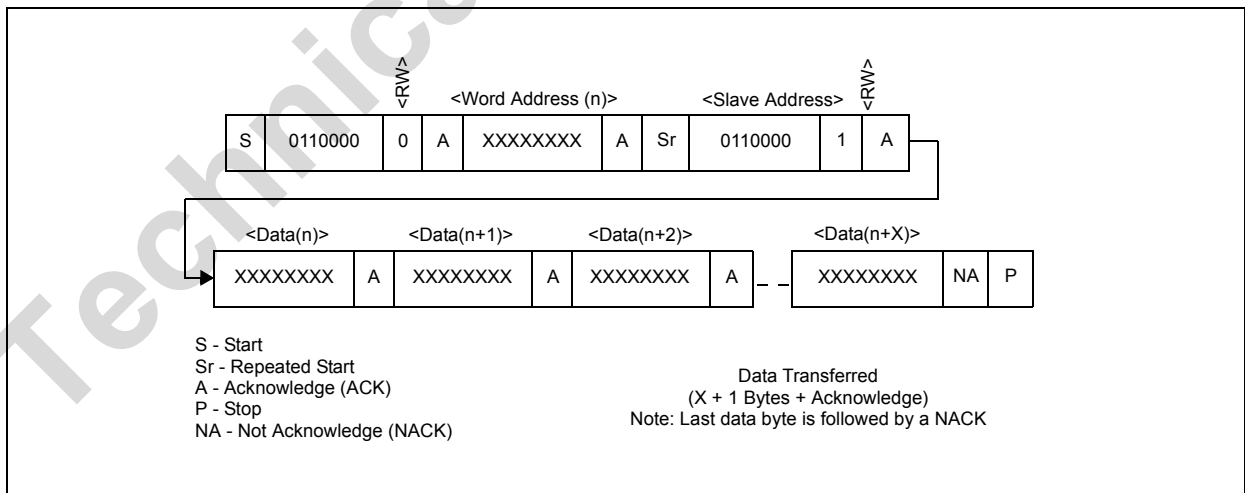


Figure 31. Data Read (Write Pointer, Then Read) - Slave Receive and Transmit



Register Description

Table 6. *ChipID Register*

| Addr: 0 | | ChipID Register | | |
|------------------------------|----------|-----------------|--------|--|
| This register has a fixed ID | | | | |
| Bit | Bit Name | Default | Access | Description |
| 2:0 | version | Xh | R | AS3647/47B chip version number |
| 7:3 | fixed_id | 10110b | R | This is a fixed identification (e.g. to verify the I ² C communication) |

Table 7. *Current Set Register*

| Addr: 1 | | Current Set Register | | | |
|---------------------------------------|-------------|----------------------|--------|--|---|
| This register defines design versions | | | | | |
| Bit | Bit Name | Default | Access | Description | |
| 7:0 | led_current | 9Ch | R/W | Define the current on pin LED_OUT1/2 (combined; each current sink has identical currents) Caution: assist mode uses bits 6:0 of this current setting (max. half of full current setting) indicator or low current pwm mode uses only 5:0 of this current setting (max. 1/4 of full current setting) | |
| | | | | 0h | 0mA |
| | | | | 1h | 6.3mA |
| | | | | 2h | 12.5mA |
| | | | | ... | ... |
| | | | | 3Fh | 393.3mA (maximum current for indicator or low current pwm mode, mode_setting=01) |
| | | | | ... | ... |
| | | | | 7Fh | 796.9mA (maximum current for assist light mode, mode_setting=10) |
| | | | | ... | ... |
| | | | | 9Ch | 979mA - default setting |
| | | | | ... | ... |
| | | | | FEh | 1593.7mA |
| | | | | FFh | 1600mA |

Table 9. TXMask Register

| Addr: 3 | | TXMask Register | | | |
|---|-----------------------------------|-----------------|--------|---|--|
| This register defines the TXMask settings and coil peak current | | | | | |
| Bit | Bit Name | Default | Access | Description | |
| 1:0 | ext_torch_on | 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 flash_txmask_current - (see TXMASK on page 16) |
| | | | | 10 | external torch mode: if TXMASK/TORCH=1 and mode_setting =00, the AS3647/47B is set into external torch mode (LED current is defined by the 7LSB ¹ bits of led_current) |
| | | | | 11 | don't use |
| 3:2 | coil_peak | 10 | R/W | Defines the maximum coil current (parameter ILIMIT) | |
| | | | | 00 | ILIMIT = 2.0A |
| | | | | 01 | ILIMIT = 2.5A |
| | | | | 10 | ILIMIT = 3.0A |
| | | | | 11 | ILIMIT = 3.5A |
| 7:4 | flash_txmask_current ² | 6h | R/W | Define the current on pin LED_OUT1/2 in flash mode if ext_torch_on =01 and TXMASK/TORCH=1 | |
| | | | | 0h | 0mA |
| | | | | 1h | 100mA |
| | | | | 2h | 201mA |
| | | | | 3h | 301mA |
| | | | | 4h | 402mA |
| | | | | 5h | 502mA |
| | | | | 6h | 602mA - default |
| | | | | 7h | 703mA |
| | | | | 8h | 803mA |
| | | | | 9h | 904mA |
| | | | | Ah | 1004mA |
| | | | | Bh | 1104mA |
| | | | | Ch | 1205mA |
| | | | | Dh | 1305mA |
| Eh | 1405mA | | | | |
| Fh | 1506mA | | | | |

1. The MSB bit of this register not used to protect the LED; therefore the maximum current = half the maximum flash current

2.

Table 10. Low Voltage Register

| Addr: 4 | | Low Voltage Register | | | |
|--|--------------------|----------------------|--------|--|---|
| This register defines the operating mode with low battery voltages | | | | | |
| Bit | Bit Name | Default | Access | Description | |
| 2:0 | vin_low_v_run | 4h | R/W | Voltage level on VIN where current reduction triggers during operation (see Current Reduction by VIN measurements in Flash Mode on page 16) - 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 - fault_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 |
| 5:3 | vin_low_v | 5h | R/W | Voltage level on VIN where driver will change current before startup (only in flash mode) if before startup (out_on set from 0 to 1), the voltage on VIN is below vin_low_v , the current is changed to flash_txmask_current (vin_low_v_shutdown=0) or 0=shutdown (vin_low_v_shutdown=1) and fault_uvlo is set | |
| | | | | 0h | function is disabled |
| | | | | 1h | 3.0V |
| | | | | 2h | 3.07V |
| | | | | 3h | 3.14V |
| | | | | 4h | 3.22V |
| | | | | 5h | 3.3V - default |
| | | | | 6h | 3.38V |
| 6 | vin_low_v_shutdown | 0 | R/W | Enables Shutdown of current reduction under low voltage conditions | |
| | | | | 0 | if before startup (out_on set from 0 to 1), the voltage on VIN is below vin_low_v , the current is changed to flash_txmask_current and fault_uvlo is set |
| 7 | const_v_mode | 0 | R/W | Enables Constant output voltage mode | |
| | | | | 0 | Normal operation defined by mode_setting |
| | | | | 1 | 5V constant voltage mode on VOUT1/2; reset registers mode_setting , out_on and ext_torch_on before setting this bit |

Table 11. Flash Timer Register

| Addr: 5 | | Flash Timer Register | | | |
|---------|---------------|---|--------|--|---|
| | | This register identifies the flash timer and timeout settings | | | |
| Bit | Bit Name | Default | Access | Description | |
| 7:0 | flash_timeout | 23h | R/W | Define the duration of the flash timer and timeout timer | |
| | | | | 0h | 2ms |
| | | | | 1h | 4ms |
| | | | | 2h | 6ms |
| | | | | ... | ... |
| | | | | 23h | 72ms - default |
| | | | | ... | ... |
| | | | | 7Fh | 256ms |
| | | | | 80 | 264ms(now 8 ms LSB steps from here on) ¹ |
| | | | | 81 | 272ms |
| | | | | 82 | 280ms |
| | | | | ... | ... |
| | | | | FEh | 1272ms |
| FFh | 1280ms | | | | |

1. Internal calculation for codes above 80h: flash timeout [ms] = (flash_timeout-127) * 8 + 256 [ms]

Table 12. 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 AS3647/47B operating mode | |
| | | | | 00 | shutdown or external torch mode if ext_torch_on (page 24)=10 |
| | | | | 01 | indicator mode (or low current mode using PWM) LED current is defined by the 6LSB bits of led_current pwm modulated with 31.25kHz defined by register inct_pwm (1/16...4/16) |
| | | | | 10 | assist light mode: LED current is defined by the 7LSB ¹ bits of led_current |
| | | | | 11 | flash mode: LED current is defined by led_current (out_on and mode_setting are automatically cleared after a flash pulse) |
| 2 | reserved | X | R | reserved - don't use, always write 0 | |
| 3 | out_on | 0 | R/W | Enables the output current sinks (pin LED_OUT1/2) | |
| | | | | 0 | outputs disabled |
| | | | | 1 | outputs enabled (out_on and mode_setting are automatically cleared after a flash pulse) |

1. The MSB bit of this register not used to protect the LED; therefore the maximum assist light current = half the maximum flash current

Table 13. *Strobe Signalling Register*

| Addr: 7 | | Strobe Signalling Register | | | |
|--|-------------|----------------------------|--------|--|------------------------------------|
| This register defines the flash current reducing and mode for STROBE | | | | | |
| Bit | Bit Name | Default | Access | Description | |
| 6 | strobe_type | 1 | R/W | Defines if the STROBE input is edge or level sensitive; see also bit strobe_on (page 27) | |
| | | | | 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 |

Table 14. *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 | fault_uvlo | 0 | R/sC ¹ | an undervoltage event has happened - see Current Reduction by VIN measurements in Flash Mode on page 16 | |
| | | | | 0 | No |
| | | | | 1 | Yes |
| 1 | reserved | 0 | R | reserved - don't use | |
| 2 | reserved | 0 | R | reserved - don't use | |
| 3 | fault_txmask | 0 | R/sC ¹ | TXMASK/TORCH event triggered during flash - see TXMASK event occurred on page 14 | |
| | | | | 0 | No |
| | | | | 1 | Yes |
| 4 | fault_timeout | 0 | R/sC ¹ | see Flash Timeout on page 14 | |
| | | | | 0 | No fault |
| | | | | 1 | Flash timeout exceeded |
| 5 | fault_overtemp | 0 | R/sC ¹ | see Overtemperature Protection on page 14 | |
| | | | | 0 | No fault |
| | | | | 1 | Junction temperature limit has been exceeded |
| 6 | fault_led_short | 0 | R/sC ¹ | see Short Circuit Protection on page 14 | |
| | | | | 0 | No fault |
| | | | | 1 | A shorted LED is detected (pin LED_OUT1/2) |
| 7 | fault_ovp | 0 | R/sC ¹ | see Overvoltage Protection on page 13 | |
| | | | | 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 15. *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 | |
| 1:0 | inct_pwm | 00 | R/W | Define the AS3647/47B PWM with 31.25kHz operation for indicator or low current mode (mode_setting=01) | |
| | | | | 00 | 1/16 duty cycle |
| | | | | 01 | 2/16 duty cycle |
| | | | | 10 | 3/16 duty cycle |
| | | | | 4/16 duty cycle | |
| 2 | freq_switch_on | 0 | R/W | Exact frequency switching between 4MHz/1MHz for assist and flash modes for operation close to maximum pulsewidth | |
| | | | | 0 | Pulseskip operation is allowed for all modes - results in better efficiency |
| | | | | 1 In flash and assist light mode (indicator mode or low current mode using PWM always will use pulseskip) if led_current ≥ 40h, the DCDC is running at 4MHz or 1MHz (pulseskip is disabled) - results in improved noise performance; | |

Table 17. *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 ¹² | 00h | R | Minimum current through the current sink (only including all current reductions as described in Current Reduction by VIN measurements in Flash Mode excluding current reductions caused by TXMASK) |

- 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 ([fault_uvlo](#) (see [page 27](#))=1) otherwise [led_current_min](#)=0.

Table 18. *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 ¹ | 00h | R | Actual set current through the current sink (including all current reductions as described in Flash Current Reductions including LED current ramp up/down) |

- As the internal change of this register is asynchronous to the readout, it is recommended to readout the register twice and compare the results.

Register Map

Table 21. Register Map ¹

| Register Definition | Addr | Default | Content | | | | | | | |
|---------------------|------|---------|----------------------|---------------------|----------------|---------------|----------------|---------------|--------------|------------|
| | | | b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 |
| ChipID | 0 | Bxh | fixed_id | | | | | version | | |
| Current Set | 1 | 9Ch | led_current | | | | | | | |
| TXMask | 3 | 68h | flash_txmask_current | | | | coil_peak | | ext_torch_on | |
| Low Voltage | 4 | 2Ch | const_v_mode | vin_low_v_shut_down | vin_low_v | | | vin_low_v_run | | |
| Flash Timer | 5 | 23h | flash_timeout | | | | | | | |
| Control | 6 | 00h | | | | | out_on | reserve_d | mode_setting | |
| Strobe Signalling | 7 | C0h | strobe_on | strobe_type | | | | | | |
| Fault | 8 | 00h | fault_ovp | fault_led_short | fault_overtemp | fault_timeout | fault_txmask | reserve_d | reserve_d | fault_uvlo |
| PWM and Indicator | 9 | 00h | | | | | freq_switch_on | inct_pwm | | |
| Minimum LED Current | Eh | 00h | led_current_min | | | | | | | |
| Actual LED Current | Fh | 00h | led_current_actual | | | | | | | |

1. Always write '0' to undefined register bits (e.g. to bits 4..7 of register 6)

9 Application Information

External Components

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 22. Recommended Input Capacitor

| Part Number | C | TC Code | Rated Voltage | Size | Manufacturer |
|-------------------|---|---------|---------------|------|---|
| GRM188R60J106ME47 | 10 μ >3 μ F@4.5V >2 μ F@5.25V | X5R | 6V3 | 0603 | Murata www.murata.com |
| LMK107BBJ106MA | 10 μ >3 μ F@4.5V | X5R | 6V3 | 0603 | Taiyo Yuden www.t-yuden.com |

If a different input capacitor is chosen, ensure similar ESR value and at least 3 μ 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).

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 23. Recommended Output Capacitor

| Part Number | C | TC Code | Rated Voltage | Size | Manufacturer |
|--------------------------------|--------------------------------------|---------|---------------|---|--|
| GRM219R61A116U | 10 μ F +/-10% >4.2 μ F@5V | X5R | 10V | 0805 | Murata www.murata.com |
| GRM188R60J106ME84 ¹ | 10 μ F +/-20% >4.2 μ F@4V | X5R | 6.3V | 0603 (1.6x0.8x0.85mm max. 0.95mm height) | |

1. Use only for VLED < 3.75V

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

Inductor L_{DCDC}

The fast switching frequency (4MHz) of the AS3647/47B 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}¹¹. The inductor should have very low DC resistance (DCR) to reduce the I²R power losses - high DCR values will reduce efficiency.

Table 24. Recommended Inductor

| Part Number | L | DCR | I _{SATURATION} | Size | Manufacturer |
|---------------|---|----------------|---------------------------------|---|---|
| C3-P1.5R | 1.5μH | 58mΩ | 2.4A@25°C, 2.0A ¹ | 3x3x1.5mm (height is max.) | Mitsumi www.mitsumi.com |
| LQM32PN1R0MG0 | 1.0μH >0.6μH @ 3.0A | 60mΩ | 3.0A ² | 3.2x2.5x0.9 mm max 1.0mm height | Murata www.murata.com |
| LQM2HPN1R0MGC | 1.0μH >0.6μH @ 2.0A | 100mΩ | 1.5A (2.0A) ³ | 2.5x2.0x0.9 mm max 1.00mm height | |
| CIG32W1R0MNE | 1.0μH >0.7μH @ 2.7A >0.6μH @ 3.0A | 60mΩ +/-25% | 3.0A | 3.2x2.5mm max 1.0mm height | Samsung Electro- Mechanics www.sem.samsung.co.kr |
| NRH2412T1R0N | 1.0μH >0.6μH @ 2.5A | 77mΩ | 2.5A ⁴ | 2.4x2.4x1.2 mm (height is max.) | Taiyo Yuden www.t-yuden.com |
| CKP3225N1R0M | 1.0μH >0.6μH @ 3.0A | <60mΩ | 3.0A | 3.2x2.5x0.9 mm max 1.0mm height | |
| MAMK2520T1R0M | 1.0μH >0.6μH @ 2.75A | 45mΩ | 3.0A ⁵ | 2.5x2.0x1.2 mm height is max | |
| MDMK2020T1R0M | 1.0μH >0.6μH @ 2.75A | 56mΩ | 2.55A ⁶ | 2.0x2.0x1.2 mm height is max | |
| MAKK2016T1R0M | 1.0μH >0.6μH @ 2.75A | 65mΩ | 2.0A ⁷ | 2.0x1.6x1.0 mm height is max | |

1. Do not exceed maximum I_{SATURATION} - can be ensured by setting `coil_peak` (will limit LED current)
2. 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)
3. Set current limit to 2A (`coil_peak=00b`) - will limit maximum output current.
Flash cycle limit: 150ms on, 500ms off; repeat maximum 50 times.
4. Set current limit to 2.5A (`coil_peak=01b`) - will limit maximum output current.
5. Set current limit to 3.0A (`coil_peak=10b`) - can limit maximum output current.
6. Set current limit to 2.5A (`coil_peak=01b`) - will limit maximum output current.
7. Set current limit to 2A (`coil_peak=00b`) - will limit maximum output current.

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

11. Can be adjusted in I²C mode with register `coil_peak` (see page 24)

PCB Layout Guideline

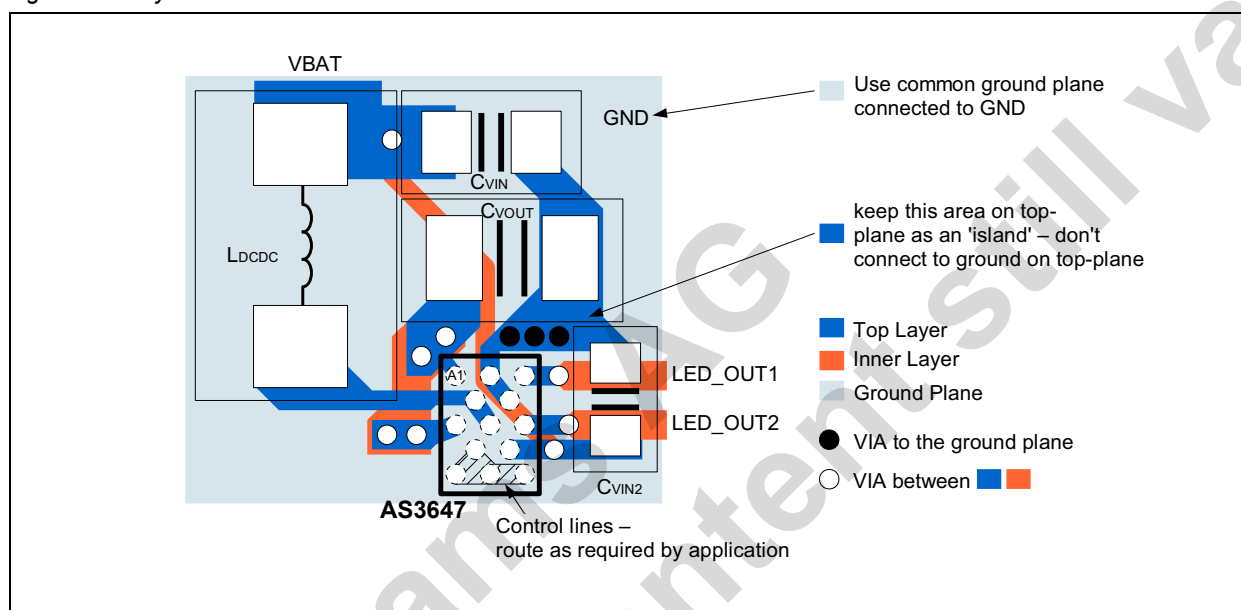
The high speed operation requires proper layout for optimum performance. Route the power traces first and try to minimize the area and wire length of the two high frequency/high current loops:

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 32](#).

Figure 32. Layout recommendation



Note: If component placement rules allow, move all components close to the AS3647/47B to reduce the area and length of Loop1 and Loop2.

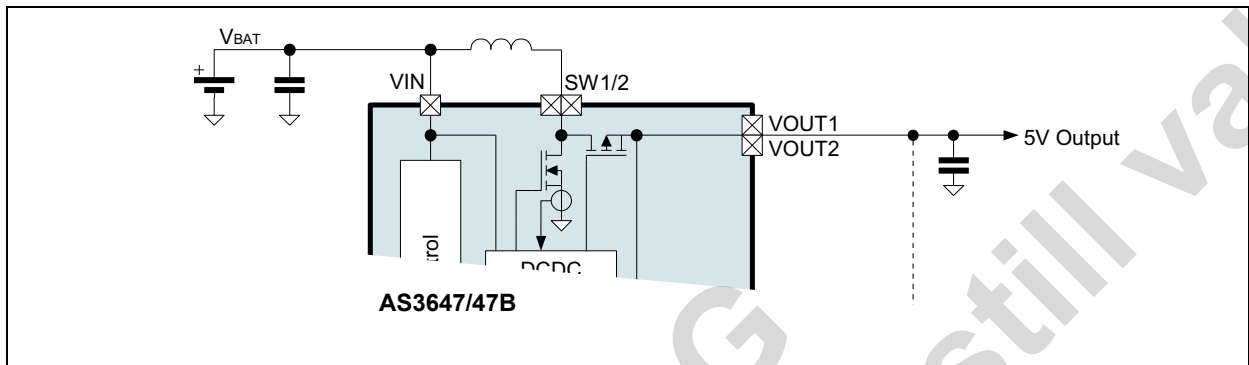
An additional 100nF (e.g. Murata GRM155R61C104, >50nF @ 3V, 0402 size) capacitor CVIN2 in parallel to CVIN is recommended to filter high frequency noise for the power supply of AS3647/47B. This capacitor should be as close as possible to the GND/VIN pins of AS3647/47B.

5V Operating Mode

The AS3647/47B 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 25)=1. In this operating mode, the current sinks are disabled and cannot be switched on (no flash/torch operation is possible).

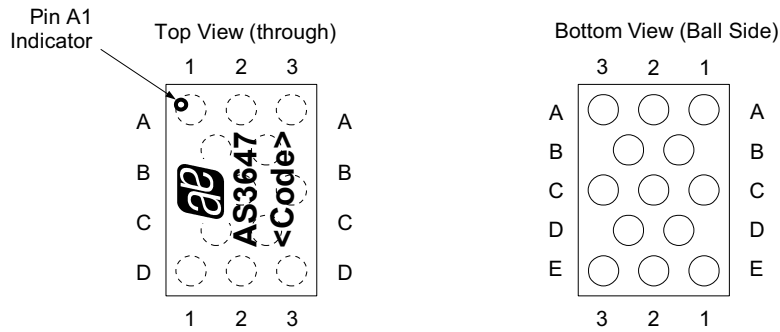
Note: There is always a diode between VIN and VOUT1/2 due to the internal circuit. Therefore VOUT1/2 cannot be completely switched off

Figure 33. 5V Operating Mode



10 Package Drawings and Markings

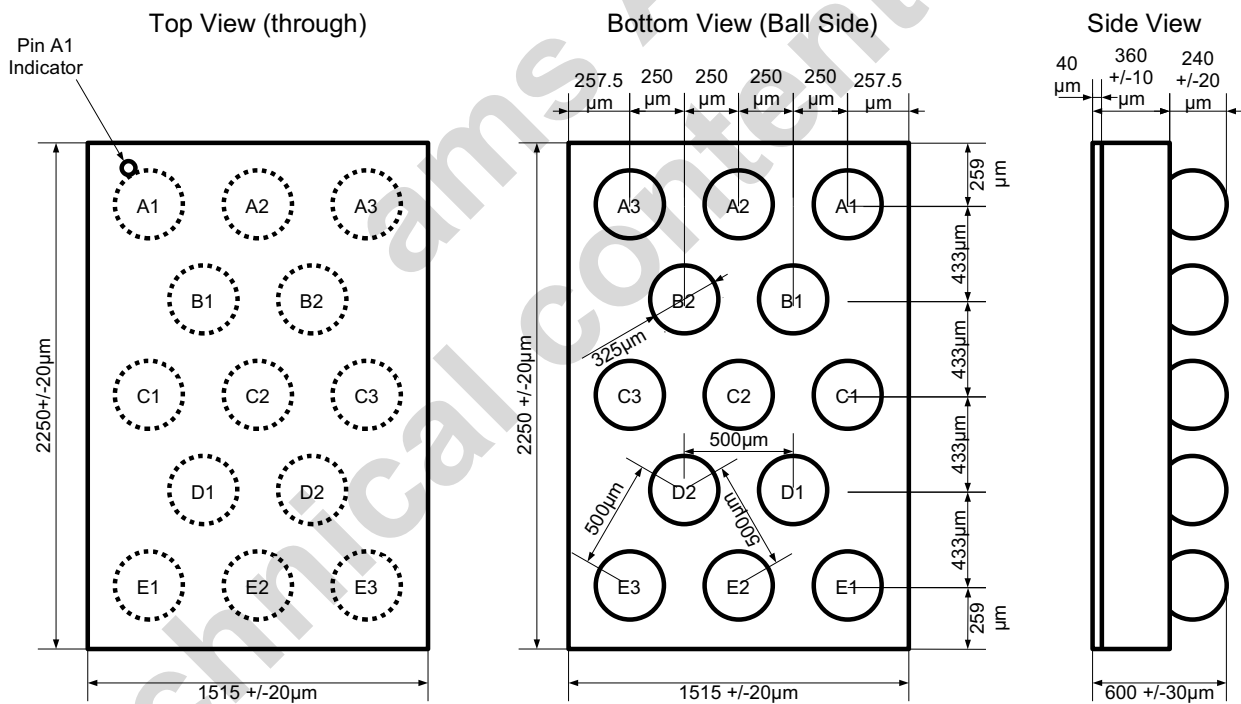
Figure 34. WL-CSP13 Marking AS3647



Note:

- Line 1: austriamicrosystems logo
- Line 2: AS3647
- Line 3: <Code>
Encoded Datecode (4 characters)

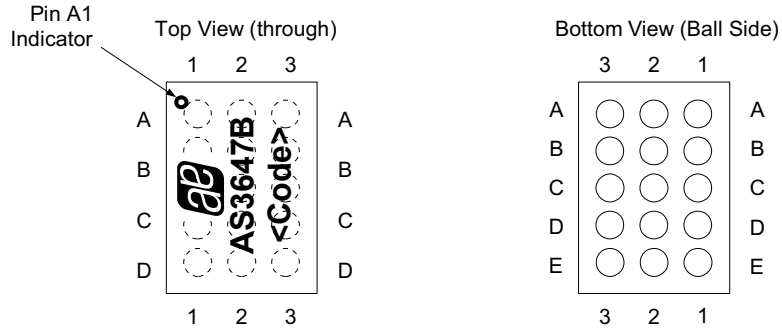
Figure 35. WL-CSP13 Package Dimensions AS3647



The coplanarity of the balls is 40µm.



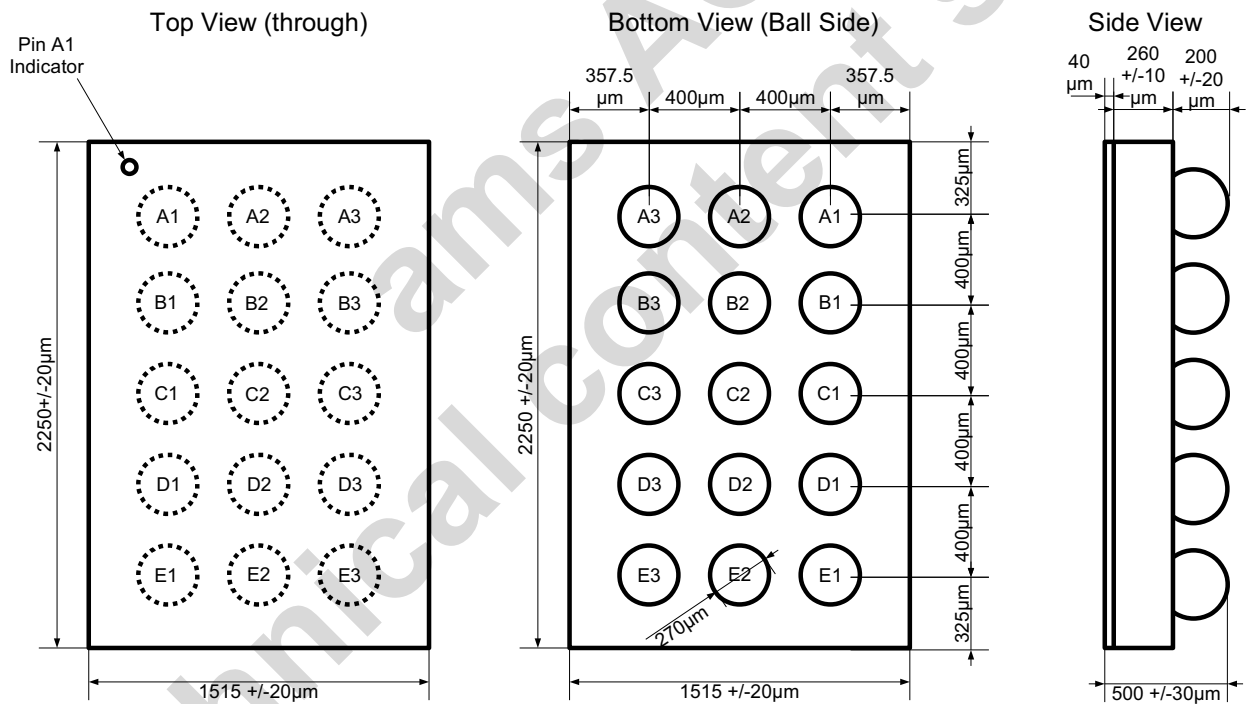
Figure 36. WL-CSP15 Marking AS3647B



Note:

- Line 1: austriamicrosystems logo
- Line 2: AS3647B
- Line 3: <Code>
Encoded Datecode (4 characters)

Figure 37. WL-CSP15 Package Dimensions AS3647B



The coplanarity of the balls is 40 μm.



11 Ordering Information

The devices are available as the standard products shown in [Table 25](#).

Table 25. Ordering Information

| Model | Description | Delivery Form | Package |
|-------------------------------|--------------------------------------|---------------|---|
| AS3647-ZWLT | 1600mA High Current LED Flash Driver | Tape & Reel | 13-pin WL-CSP (2.25x1.5x0.6mm) 0.5mm pitch RoHS compliant / Pb-Free / Green |
| AS3647B- ZWLT ¹ | 1600mA High Current LED Flash Driver | Tape & Reel | 15-pin WL-CSP (2.25x1.5x0.5mm) 0.4mm pitch RoHS compliant / Pb-Free / Green |

1. Check with austriamicrosystems for availability and lead time of AS3647B. AS3647B is only available upon request.

Note: All products are RoHS compliant and austriamicrosystems green.
Buy our products or get free samples online at ICdirect: <http://www.austriamicrosystems.com/ICdirect>

Technical support is found at <http://www.austriamicrosystems.com/Technical-Support>

For further information and requests, please contact us <mailto:sales@austriamicrosystems.com>
or find your local distributor at <http://www.austriamicrosystems.com/distributor>

Note: AS3647/47B-ZWLT

AS3647/47B-

Z Temperature Range: -30°C - 85°C

WL Package: Wafer Level Chip Scale Package (WL-CSP) 2.25x1.5x0.6mm

T Delivery Form: Tape & Reel

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[MPQ4425AGQB-AEC1-Z](#)