



SSL3252

Photo flash LED driver

Rev. 1 — 7 July 2011

Product data sheet

1. General description

The SSL3252 is a photo flash LED driver designed for battery operated mobile devices such as mobile phones and PDAs. The boost converter delivers high performance and drives a single or dual high brightness LED at up to 500 mA with over 85 % efficiency. The driver can be programmed to operate in Flash mode, Torch mode, Assist light mode, or Indicator mode.

The small silicon size and the high internal switching frequency of 2 MHz minimize the size of the application and make the SSL3252 very suitable for mobile phones where space is limited, and only requiring three external components. System protection has been a very important part of the SSL3252 design, so a time-out function can be programmed to prevent overstressing the LED, and the driver itself is protected from overheating.

2. Features and benefits

- High power single or dual LED output driving up to 500 mA flash current
- Separate indicator LED output of 2.5 mA to 10 mA
- High side current source for main and indicator LEDs
- Output voltage of up to 8.85 V
- Wide input voltage ranging from 2.5 V to 5.5 V
- High efficiency of over 85 % at optimum output current
- Switching frequency of 2 MHz
- Flash mode, Assist light mode, Torch mode and Indicator mode are supported
- Internally timed flash operation up to 850 ms
- I²C-bus, programmable up to 400 kHz
- Strobe signal to avoid I²C latency for the flash
- Direct enable signals for stand-alone operation
- Forward voltage sensing to allow single/dual LED detection
- Soft start/soft stop
- Integrated protection circuits for enhanced system reliability:
 - ◆ Internal time-out
 - ◆ OverTemperature Protection (OTP)
 - ◆ UnderVoltage LockOut (UVLO)
 - ◆ OverVoltage Protection (OVP)
 - ◆ Short-circuit protection
- Inductor peak current limit and broken coil detection
- Low device shut-down current of less than 1 μA
- Small WLCSP12 package with 500 μm bump pitch



3. Applications

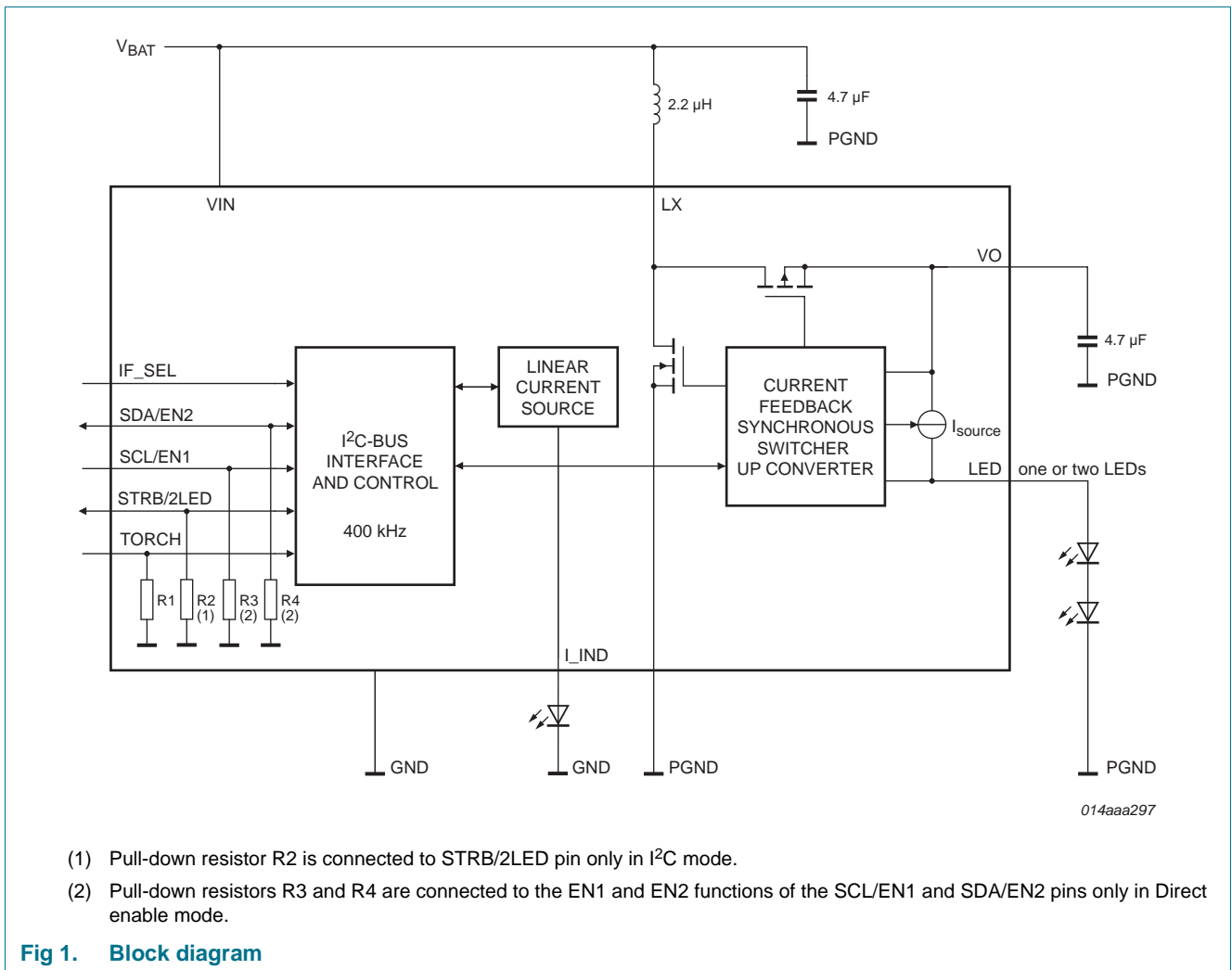
- Photo flash LED driver for mobile phones and digital cameras
- White LED driver for battery powered portable devices

4. Ordering information

Table 1. Ordering information

| Type number | Package | | Version |
|--------------|---------|---|-----------|
| | Name | Description | |
| SSL3252UK/C2 | WLCSP12 | wafer level chip-size package; 12 bumps; 1.58 × 2.06 × 0.6 mm | SSL3252UK |

5. Block diagram



6. Pinning information

6.1 Pinning

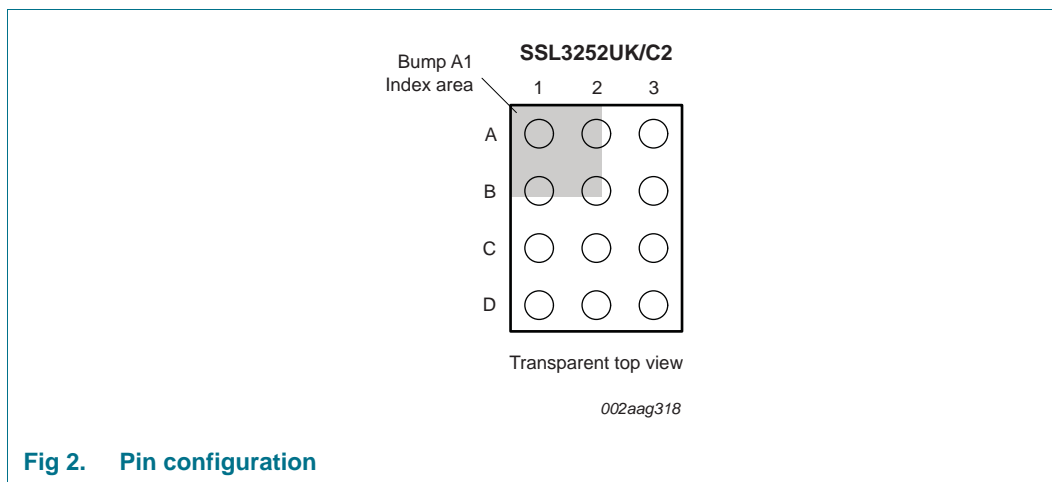


Fig 2. Pin configuration

6.2 Pin description

Table 2. Pin description

| Symbol | Pin | Type | Description |
|-----------|-----|--------------------|---|
| PGND | A1 | ground | power ground |
| GND | A2 | ground | signal ground |
| VIN | A3 | input | input voltage |
| LX | B1 | analog input | inductor connection |
| TORCH | B2 | input | Torch mode activate |
| I_IND | B3 | analog output | indicator LED current source |
| VO | C1 | analog output | output voltage |
| STRB/2LED | C2 | input/output (I/O) | strobe signal input to trigger flash in I ² C mode; 2LED signal output in Direct enable mode (open-drain) |
| IF_SEL | C3 | input | interface select; choose between Direct enable mode or I ² C mode |
| LED | D1 | analog output | main LED current source |
| SDA/EN2 | D2 | input/output (I/O) | serial data line in I ² C mode / enable 2 in Direct enable mode |
| SCL/EN1 | D3 | input | serial clock line in I ² C mode / enable 1 in Direct enable mode. |

7. Functional description

7.1 Introduction

The SSL3252 is a boost converter intended to drive either a single high power flash LED or two high power flash LEDs in series. The LED current is controlled by the output voltage of the boost converter and the integrated linear current source. The SSL3252 has two interface modes and six operational modes. The interface mode is selected by the interface select pin IF_SEL. Depending on the Interface mode selected, the device can either be controlled by an I²C-bus interface, or external enable lines.

The interface modes are:

- I²C mode
- Direct enable mode

The operational modes are:

- Standby mode
- Shut-down mode
- Flash mode
- Torch mode
- Assist light mode
- Indicator mode

In all LED modes, to ensure a constant switching frequency, the regulated converter employs Pulse Width Modulation (PWM).

In applications where the required LED voltage is lower than the applied input voltage, the converter switches to linear mode. The excess voltage difference between the required LED voltage and input voltage is now compensated by increasing the voltage over the linear current source and therefore on the LED pin.

Apart from the main LED(s), a separate indicator LED can be driven from the SSL3252. This is driven by a linear current source circuit that operates independent of the switch mode converter for the main LED(s).

7.2 Interface modes

The device is equipped with two interfaces: I²C and Direct enable. Which interface mode is used is defined by the level of the IF_SEL pin. [Table 3](#) describes the interface possibilities.

Table 3. Interface modes

| IF_SEL | Interface mode | Relevant controls |
|--------|-----------------------|----------------------------|
| 1 | I ² C mode | SDA, SCL, STRB/2LED, TORCH |
| 0 | Direct enable mode | EN1, EN2, TORCH |

7.2.1 Using the direct enable control

When the Direct enable mode is used, the device can be switched to the various operational modes using the TORCH, EN1 and EN2 control signals. The definitions of these control signals are given in Table 4. The EN1 and EN2 functions of the SCL/EN1 and SDA/EN2 pins have a higher priority than the pin TORCH. Figure 3 shows all the possible transitions between the various interface modes.

The device is in Shut-down mode when all control pins (IF_SEL, EN1, EN2, TORCH) are LOW.

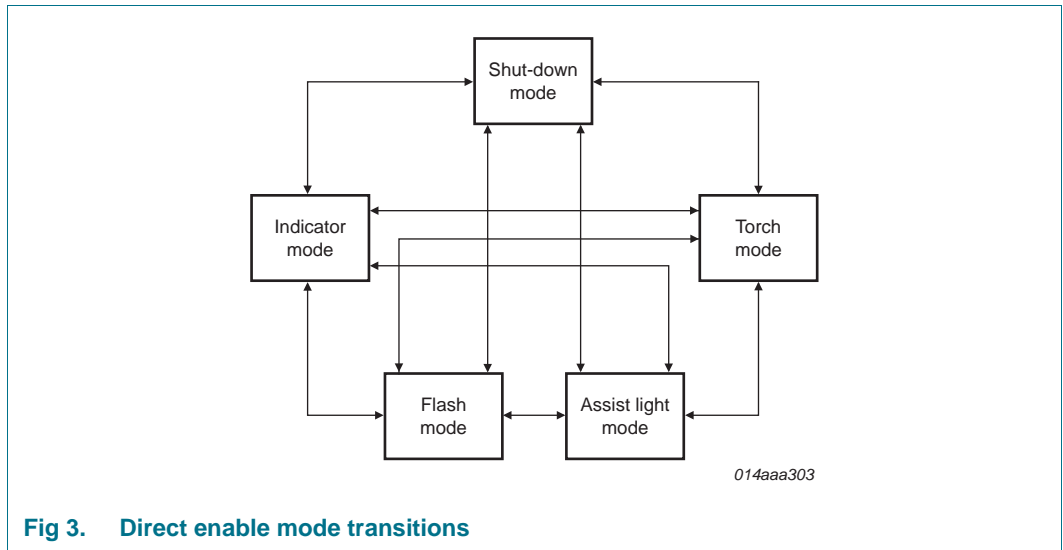


Fig 3. Direct enable mode transitions

Table 4. Direct enable logic definition

| IF_SEL pin | SCL/ EN1 pin | SDA/ EN2 pin | TORCH pin | Mode | Output states |
|------------|--------------|--------------|------------------|--------------|--|
| 0 | 0 | 0 | 0 | Shut-down | Outputs disabled; shut-down current less than 1 μA |
| 0 | 0 | 0 | 1 | Torch | Fixed value; 40 mA dual LEDs; 80 mA single LED |
| 0 | 0 | 1 | X ^[1] | Assist light | Fixed value; 40 mA dual LEDs; 80 mA single LED |
| 0 | 1 | 0 | X ^[1] | Indicator | Fixed value 2.5 mA |
| 0 | 1 | 1 | X ^[1] | Flash | Fixed value; 320 mA dual LEDs; 500 mA single LED |

[1] X = Don't care.

7.2.2 Using the I²C control

Using the I²C interface mode enables additional features and settings as described in the I²C register set Table 6. The definition of the control pins is given in Table 5. Figure 4 shows the typical transitions between the various modes.

The device cannot enter Shut-down mode when in I²C mode. The lowest power consumption can be achieved in Standby mode. When using I²C, the device can still be put in Shut-down mode by first making all control pins LOW (SDA = SCL = TORCH = 0) and then going to Direct enable Shut-down mode by making IF_SEL LOW.

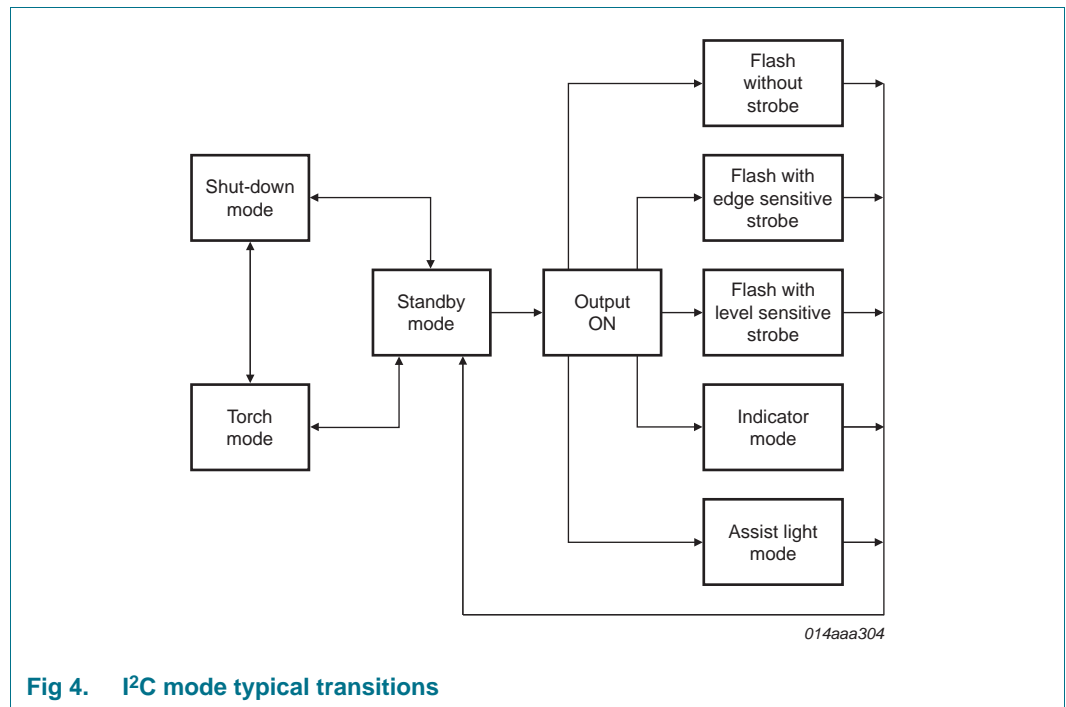


Fig 4. I²C mode typical transitions

Table 5. I²C logic definition

| IF_SEL pin | Torch mode; bit D4; Reg 04h | Output ON; bit D3; Reg 04h | Output mode; bit D1; Reg 04h | Output mode; bit D0; Reg 04h | TORCH pin | Mode | Output states |
|------------|-----------------------------|----------------------------|------------------------------|------------------------------|-----------|--------------|---|
| 1 | X | 0 | X | X | 0 | Standby | Outputs disabled; standby current less than 10 μA |
| 1 | 1 | X | 0 | 0 | 1 | Torch | Depends on the register value; between 20 mA and 160 mA; TORCH signal triggers this mode only if the registers allow it |
| 1 | X | 1 | 1 | 0 | X | Assist light | Depends on the register value; between 20 mA and 160 mA |
| 1 | X | 1 | 0 | 1 | X | Indicator | Depends on the register value; between 2.5 mA and 10 mA |
| 1 | X | 1 | 1 | 1 | X | Flash | Depends on the register value; between 200 mA and 500 mA for a single LED and 200 mA to 400 mA for dual LEDs |

7.3 Operational modes

7.3.1 Shut-down mode

To enter the Shut-down mode, all control pins, IF_SEL, EN1 function of SCL/EN1, EN2 function of SDA/EN2, and TORCH, must be LOW. In this mode, the internal circuitry of the device is turned off to guarantee a shut-down current of less than 1 μ A. The PMOS switch of the converter is conducting, and the NMOS is set to high-impedance. To avoid current leakage into the LED, the current source circuitry for both the main LED and the indicator LED are switched to high-impedance.

7.3.2 Standby mode

The device only enters Standby mode in I²C mode when pin IF_SEL is HIGH and the outputs are not active. In Standby mode, part of the internal circuitry of the device remains on, but the converter is not switching. To avoid current leakage into the LED, the current source circuitry for both the main LED and the indicator LED are switched to high-impedance. In this mode, I²C communication with the device is possible.

7.3.3 Switching between Standby mode and Shut-down mode

When using the I²C interface, the lowest power mode is the Standby mode. To further reduce the power, switching to Direct enable mode allows the device to enter Shut-down mode. When switching to and from the Direct enable interface, the I²C lines have to be switched LOW to avoid that they are interpreted as EN1 and EN2.

When IF_SEL is switched HIGH, the I²C lines may still be LOW. After the SDA lines and the SCL lines have become HIGH, the bus free time has to be respected, as is specified in the I²C-bus timing specifications. I²C communication cannot be started until at least 350 μ s after the IF_SEL line is switched HIGH.

When switching from Standby mode to Shut-down mode, the I²C lines need to be set LOW before the IF_SEL line is set LOW, or at least within 5 μ s after that, to avoid the I²C levels being interpreted as EN1 and EN2, which may cause the LEDs to be lit.

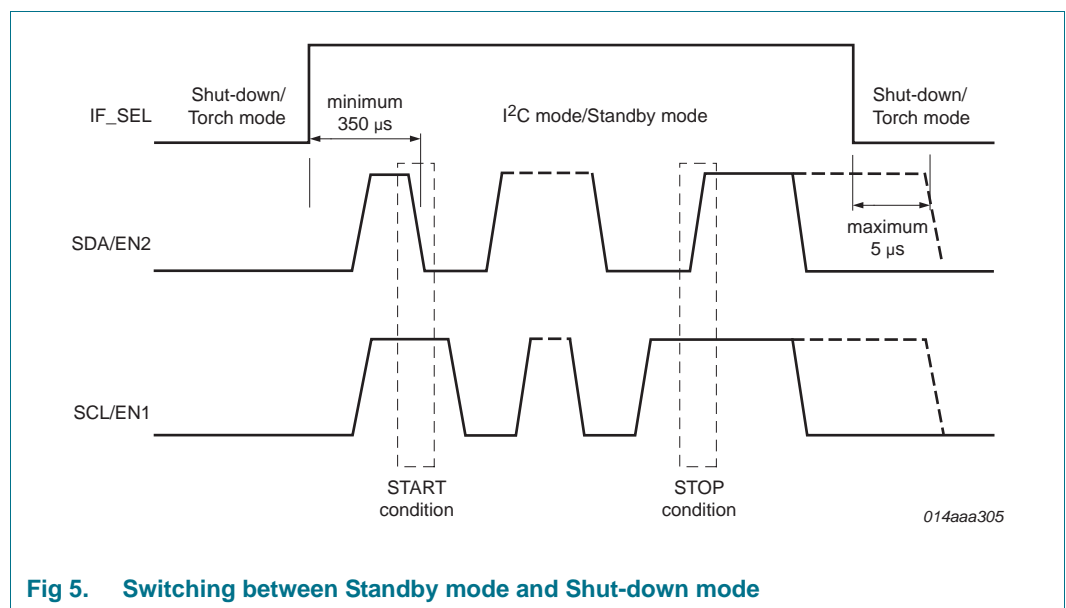


Fig 5. Switching between Standby mode and Shut-down mode

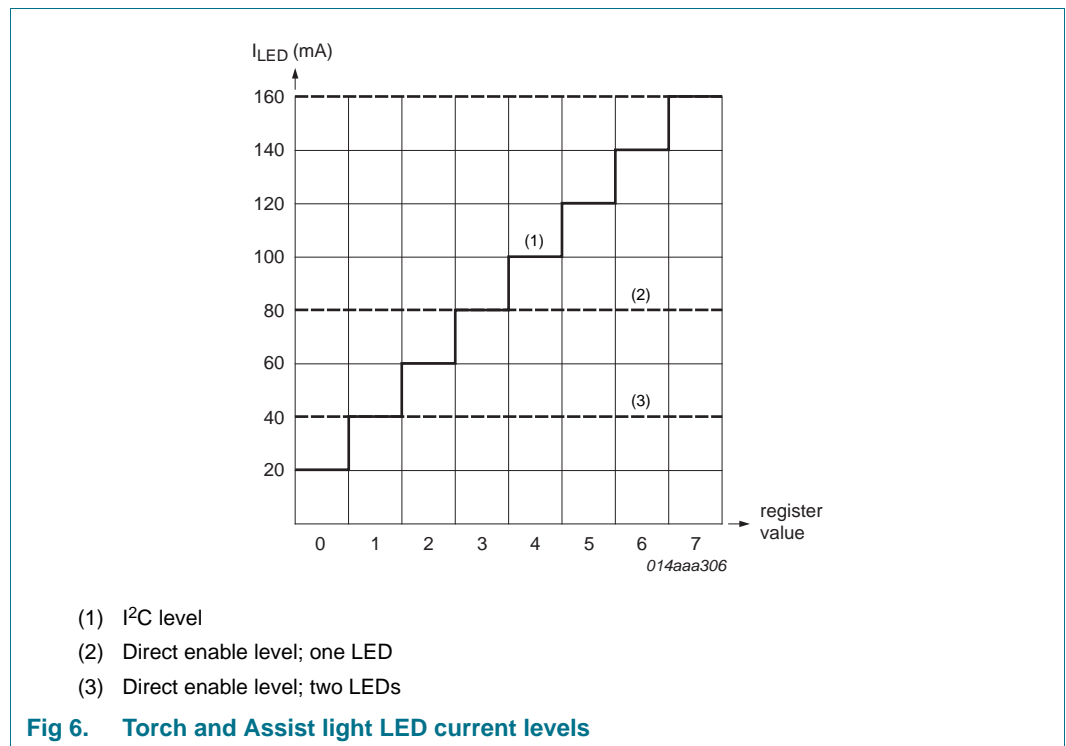
7.3.4 Torch mode

The Torch mode allows the main LED to be switched on at a lower LED current setting without timing limitations. Torch mode can be selected by connecting pin TORCH to HIGH. Pin TORCH is a debounced input. This allows the pin to be directly connected to a mechanical switch. The debouncing circuit is active during both the LOW-to-HIGH and the HIGH-to-LOW transitions. It uses a time constant of typically 9 ms. The main LEDs will light to the set torch current level. The TORCH pin has an internal 350 kΩ pull-down resistor.

In I²C mode, the LED current is defined by bits D[2:0] in the current set register. The torch current can be set between 20 mA and 160 mA. The same bits are also used for Assist light mode. For details see [Table 5](#) and [Figure 4](#).

When using the Direct enable mode, the default torch current values are used. When only one LED is used, the torch current will be set to a default level of 80 mA. For two LEDs this value is 40 mA. The EN1 and EN2 signals have higher priority than the TORCH pin signal. For details see [Table 4](#) and [Figure 3](#).

[Figure 6](#) shows the current register setting for the torch.



7.3.5 Assist light mode

The Assist light mode allows the main LED to be switched on at a lower LED current setting, without any timing limitations. The Assist light mode can be selected in both I²C and Direct enable modes.

In I²C mode, the LED current is defined by bits D[2:0] in the current set register. The Assist light current value can be set between 20 mA and 160 mA. The same bits are also used for Torch mode. Entering Assist light mode is possible if bits D[1:0] from the control register are set to 10 and bit D3 from the same register is set to 1.

When using the Direct enable mode, the default Assist light current values are used. When only one LED is used, the Assist light current will be set to a default level of 80 mA. For two LEDs this value is 40 mA. The state of the EN1 function of the SCL/EN1 pin must be LOW and the state of the EN2 function of the SDA/EN2 pin HIGH to enter Assist light mode (see Table 4). Figure 6 shows the current register setting for the Assist light.

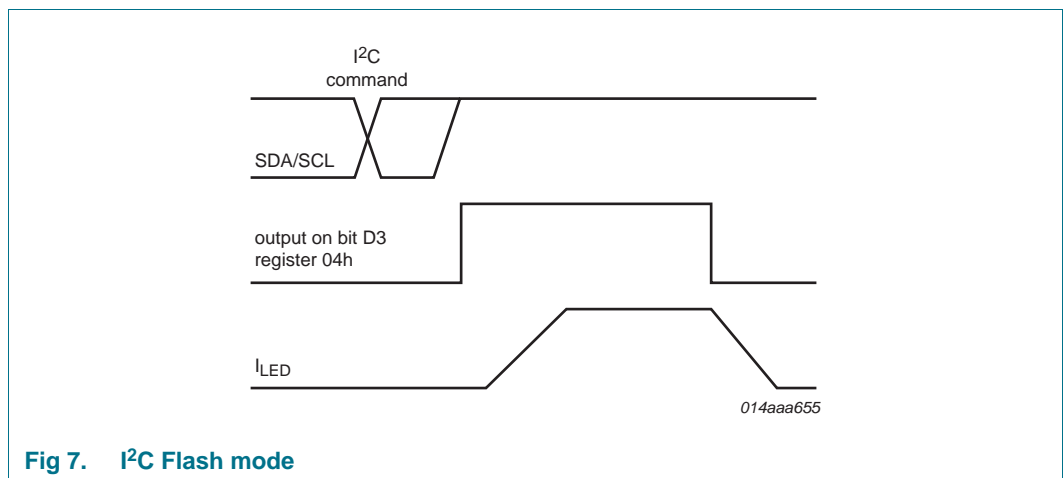
7.3.6 Flash mode

The Flash mode allows the main LEDs to be used at high current settings. The Flash mode current can be set to up to 500 mA in both the I²C mode and Direct enable mode.

In I²C mode, the current is defined by bits D[7:4] in the current set register. When two LEDs are used and the register is set for more than 400 mA, the maximum current is clipped to 400 mA. Generating the Flash mode can be done in the following three ways:

- software controlled
- edge sensitive strobe
- level sensitive strobe

When using the I²C software controlled flash, the bits in the control register D[1:0] = 11, D2 = 0 and D3 = 1 must be set and the timing of the flash is determined by the value of the bits D[3:0] in the indicator/timer register. Figure 7 shows the software controlled flash operation.



The strobe signal coming directly from the host, or camera processor, can be used to avoid I²C latency for the flash. To select Strobe flash mode, bit D2 in the control register must be set to 1. In I²C mode the STRB function of the STRB/2LED pin has an internal

pull-down resistor of 350 kΩ, and can be either level sensitive or edge sensitive, depending on the value of the bit D5 in the control register (0 = edge sensitive, 1 = level sensitive).

When using the level sensitive strobe, the flash operates as long as the strobe signal is active, or until the time limit set by the ‘flash timer’ bits in the indicator/timer register is reached. This will generate time-out fault. [Figure 8](#) shows the level sensitive strobe flash operation.

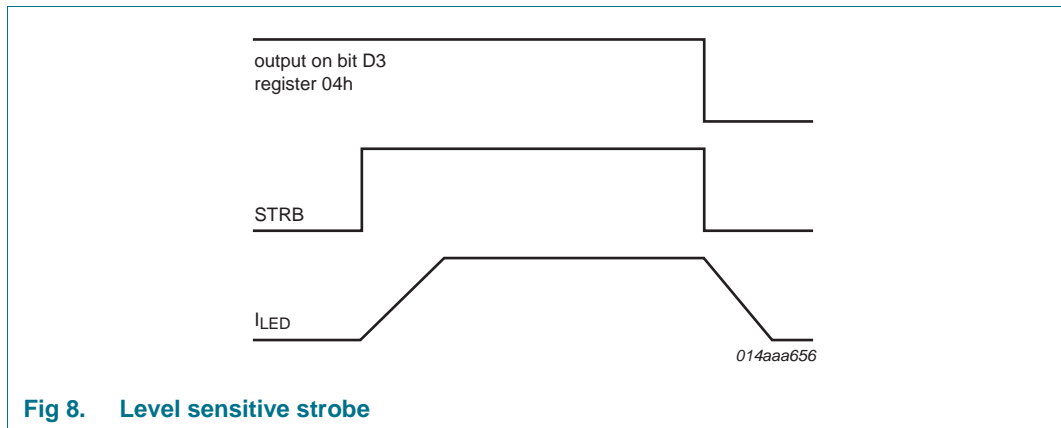


Fig 8. Level sensitive strobe

When the edge sensitive strobe signal is used, the flash is activated at the positive edge of the STRB function of the STRB/2LED pin, and the flash operation time will be defined from the timer register value. [Figure 9](#) shows the edge sensitive strobe flash operation.

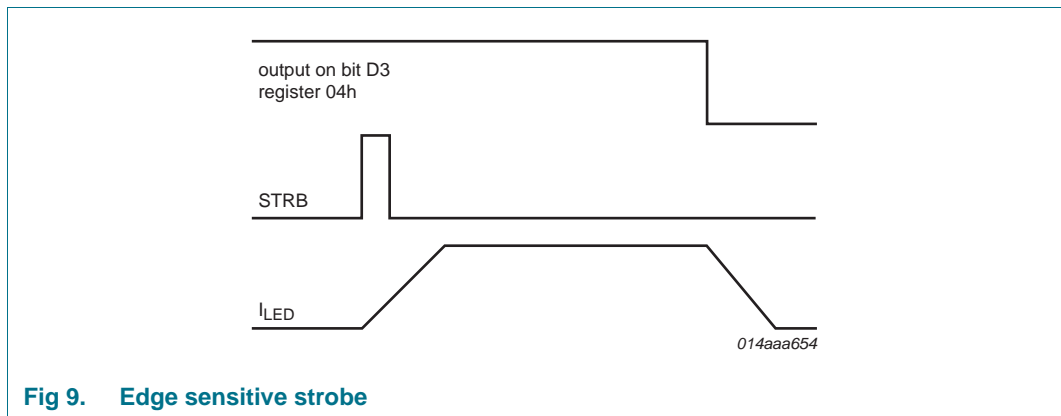
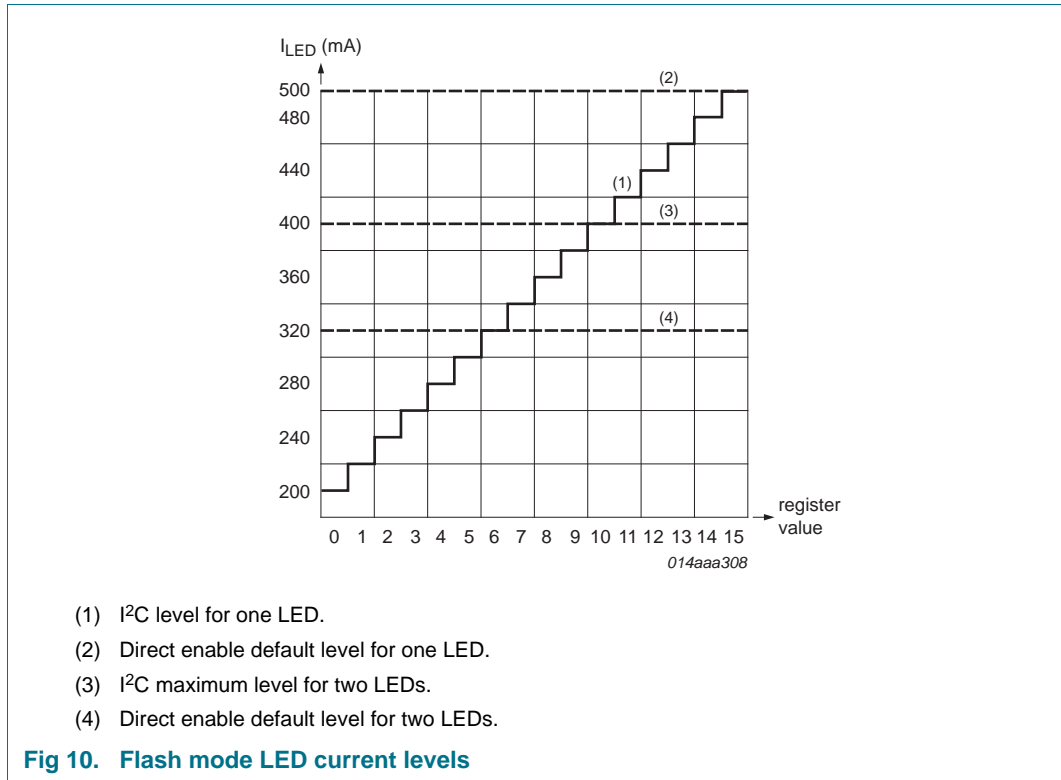


Fig 9. Edge sensitive strobe

After the flash pulse in all three flash modes, the output ON bit is automatically cleared.

In Direct enable mode, the flash current will be set to a default level. When only one LED is used, the flash current will be set to a default level of 500 mA. For two LEDs, this value is 320 mA. Entering Flash mode in Direct enable mode can be done by switching the level to HIGH on both the EN1 and EN2 functions of the SCL/EN1 and SDA/EN2 pins ([Table 4](#)). The LED will stay lit in Flash mode for as long as the enable pins are set to Flash mode, but limited to a maximum of 850 ms by the time-out timer. [Figure 10](#) shows the current levels for the flash in both the I²C and the Direct enable use case. More details on flash timing are given in [Section 7.4.1](#).



7.3.7 Indicator

The indicator LED is connected between the dedicated indicator LED current output pin (I_IND) and GND. Internally, a linear current source controls the indicator LED current to the required current level.

In I²C interface mode, the indicator LED current can be set between 2.5 mA and 10 mA by bits D[7:6] of the indicator/timer register.

When using the Direct enable mode, the indicator current is set to a default level of 2.5 mA.

[Figure 11](#) shows the LED current levels for the indicator in both the I²C and the Direct enable use case.

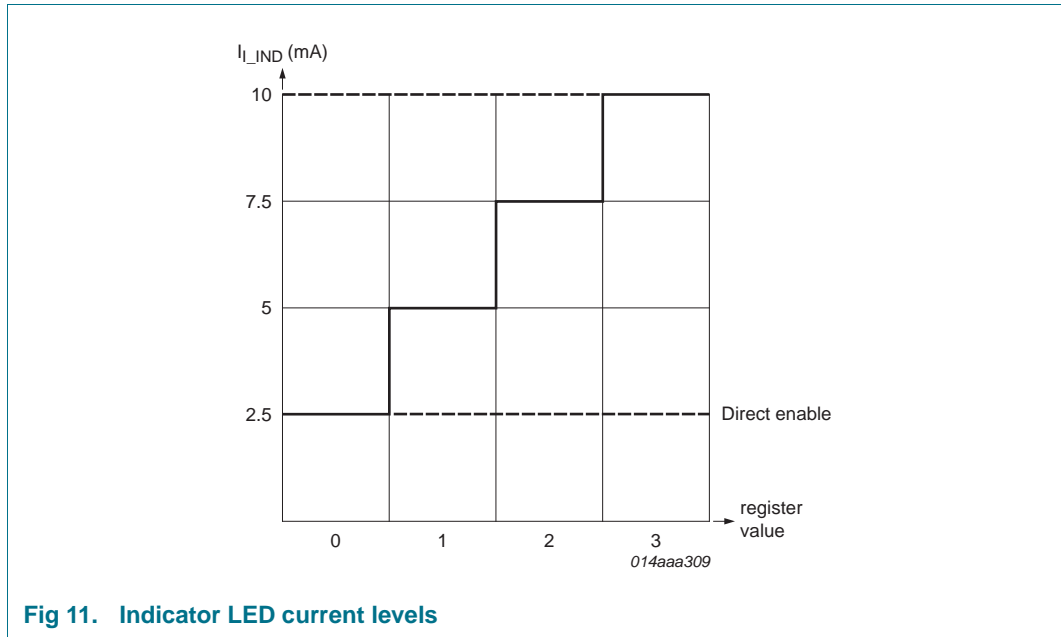


Fig 11. Indicator LED current levels

7.4 Protection circuits

There are several integrated protection circuits that protect the device and the application against defects. Some of the protection circuits trigger the corresponding bit in the fault and info register. In I²C mode, the external logic can read out the status of the protection circuits to determine what fault has occurred, and decide on the proper action to take. In Direct enable mode, the status register cannot be read out, but the protection circuits are still functional. In I²C mode the faults are cleared automatically by reading the fault and info register. In Direct enable mode the faults are cleared when the EN1 function of SCL/EN1, EN2 function of SCL/EN2 and TORCH pins are set to LOW.

7.4.1 Time-out protection

A time-out protection function is used to avoid main LED overloading during flash. The timer is started when the Flash mode is activated by the software, or by hardware strobe signals in I²C mode, or by the signals EN1 and EN2 in Direct enable mode.

The time-out protection is active in I²C level sensitive strobe Flash and Direct enable modes. When using I²C level sensitive strobe Flash mode the time-out protection is triggered when the STRB signal is active longer than the time set by the 'flash timer' bits in indicator/timer register. In Direct enable mode, the default time limit is used as a trigger for this protection. If the EN1/EN2 signals are active (HIGH) longer than the default limit of 850 ms, the time-out protection is triggered. In case of a time-out fault the IC will stop switching and go into Fault mode. The fault and info register is set accordingly to flag a fault condition.

7.4.2 Overtemperature protection

If the chip temperature exceeds its limit (T_{otp} , see [Table 9](#)), the SSL3252 will stop switching and enter Fault mode.

When an overtemperature situation is encountered, the fault and info register is set accordingly to flag a fault condition. If the chip temperature drops below the $T_{\text{otp(hys)}}$ level and the fault register is cleared, the SSL3252 can operate normally.

7.4.3 Overvoltage protection

If the output voltage (V_{O}) exceeds its limit ($V_{\text{O(ovp)}}$, see [Table 9](#)), the SSL3252 will stop switching and enter Fault mode. Overvoltage protection will be triggered when there is no LED connected to LED pin (open), or no capacitor connected to VO pin (open).

If the overvoltage protection is triggered, the fault and info register is set accordingly to flag a fault condition.

7.4.4 Short-circuit protection

The output is short-circuit protected to avoid device and battery overloading. If the LED is shorted to GND (voltage on LED drops below 1.2 V) due to a main LED, or application failure, the SSL3252 will stop switching and enter Fault mode.

If the short-circuit protection is triggered, the fault and info register is set accordingly to flag a fault condition.

7.4.5 Broken coil detection

To avoid device and battery overloading from high peak currents, the device is equipped with broken coil peak current protection. This protection will be triggered when the core of the coil is broken and the inductance of the coil drops below 800 nH ($\pm 25\%$). The broken coil detection is done at the beginning of the ramp-up of the LED current. In case of broken coil detection, the SSL3252 will stop switching and go in Fault mode.

If the broken coil protection is triggered, the fault and info register is set accordingly to flag a fault condition.

7.4.6 Indicator output protection

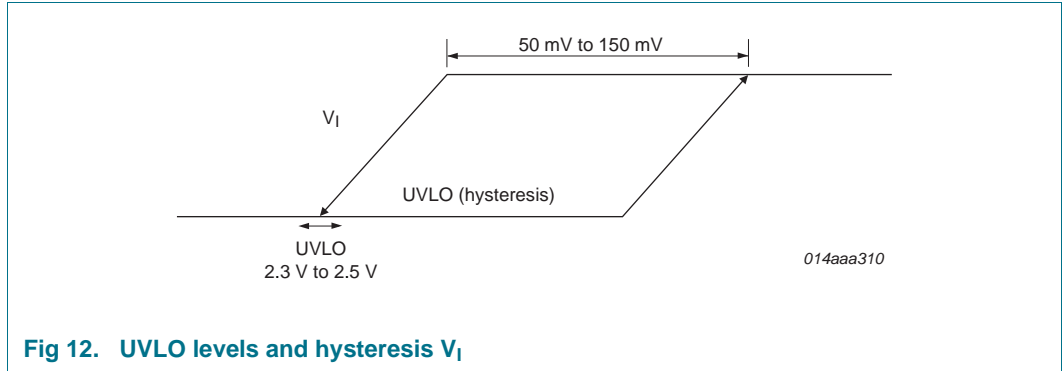
The I_IND output is short-circuit and open-circuit protected to detect the fault condition. In case I_IND is shorted ($V_{\text{I_IND}}$ is less than 1.2 V) to GND or open (I_IND current is lower than 1.25 mA), the SSL3252 will only stop the indicator LED current source. The rest of the device will remain functional.

If the indicator output protection is triggered, the fault and info register is set accordingly to flag a fault condition.

7.4.7 Undervoltage lockout

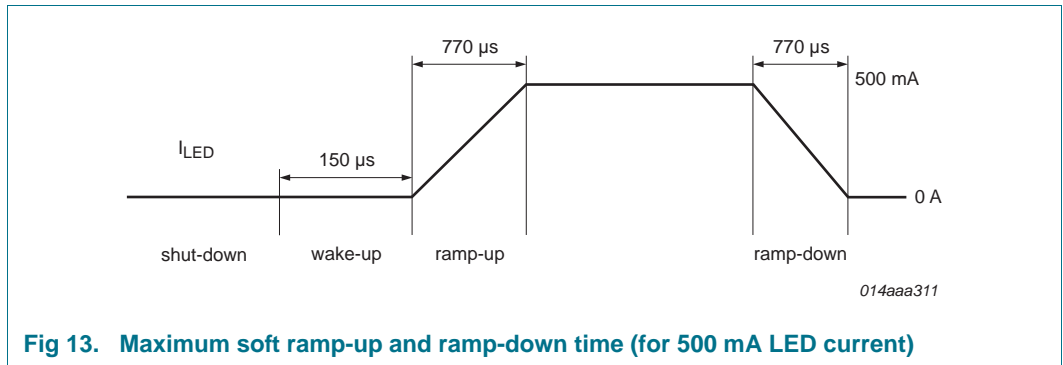
As a result of a low input voltage, the input voltage can drop too low to guarantee normal operation. When the input voltage has dropped below the undervoltage lockout level, the device switches to Fault mode stopping the switching completely. Start-up in I²C mode is only possible by crossing the start-up level ($V_{\text{I(UVLO)}} + V_{\text{hys(UVLO)}}$) and if the TORCH pin is LOW, see [Table 9](#). Start-up in Direct enable mode is only possible by crossing the start-up level and if EN1 function of SCL/EN1, EN2 function of SDA/EN2 and TORCH pins are

LOW. Recovering from this error results in the reset of all register settings. This protection cannot be read out in the status register. [Figure 12](#) shows the UVLO and trigger points and hysteresis.



7.5 Soft ramp-up/ramp-down of LED current

The device is equipped with a soft ramp-up/ramp-down circuit to avoid battery overloading. When entering the Torch mode, Assist light mode or Flash mode, when switching back to Standby mode or Shut-down mode, or just going from one current mode to another (e.g., Torch mode to Flash mode), the soft start circuit will slowly increase or decrease the output current until the required LED current has been reached. The maximum total ramp-up time will be 1 ms including the 150 μ s wake-up time for going from 0 mA to the maximum current of 500 mA and the maximum ramp-down time of 770 μ s for going from 500 mA to 0 mA. The ramp-up/ramp-down time depends on the LED current setting.



7.6 Peak current limit

The device is equipped with a peak current limit function to avoid saturation of the inductor. This circuit limits the peak inductor currents to the value set in the control register (04h bits D[7:6]). In Direct enable mode the default current limit value is 1.75 A. No protection is activated.

7.7 Start-up sequence

When I²C mode is selected (IF_SEL is HIGH) and the voltage on the VIN pin is rising to a level higher than the Power-On Reset (POR) value (POR level is typically 2.0 V) all registers are set to their reset state. After the registers are set, the device enters Standby mode and waits for I²C commands.

If the Direct enable mode is selected (IF_SEL is low), POR is detected, and pins EN1 function of SCL/EN1, EN2 function of SDA/EN2, and TORCH are set to LOW, the device will stay in Shut-down mode. When activity is detected on one of the control pins (EN1 function of SCL/EN1, EN2 function of SDA/EN2 or TORCH), the SSL3252 will start to operate using the default settings. When the activity ends (all control pins are LOW) the device will go back to Shut-down mode.

7.8 LED detection

There is an internal circuit integrated into the SSL3252, which is capable of detecting the number of LEDs connected in series to the LED output, and automatically selecting the right default current settings. The number of LEDs is detected every time the LED is ramping up. At an LED current of 80 mA the voltage at the LED output is compared to the reference level of 4.35 V plus the offset set by bits D[5:4] in the indicator/timer register. If the measured voltage is higher than the reference level, this is interpreted as two LEDs connected in series at the LED pin and the device changes all current settings to the dual LED default value. If the voltage is lower than the reference level, the single LED current settings are selected.

In I²C mode, bit D3 in the fault and info register is set according to the detected amount of LEDs. In Direct enable mode, the 2LED function of the STRB/2LED pin is used to indicate the number of detected LEDs. The STRB/2LED pin is an open-drain output pin in Direct enable mode with a maximum sink current of 1 mA. The 2LED function of the STRB/2LED pin will only signal the number of LEDs in Flash mode. The signal on the 2LED function of the STRB/2LED pin will be active during the flash period from the moment of the detection (80 mA LED current) until the moment the LED current is back to 0 mA. In all other operating modes, the 2LED function of the STRB/2LED pin will be high-impedance.

In I²C mode, LED detection can be disabled by setting bit D3 in the current set register to 0. In this case, the number of LEDs can only be set via the I²C-bus by writing the required value to bit 3 from the fault and info register, which results in the corresponding default currents being set.

When operating in Assist light mode or Torch mode and with the LED detection enabled, the LED output will always first ramp-up to 80 mA and then ramp-up or ramp-down to the value set by the current register.

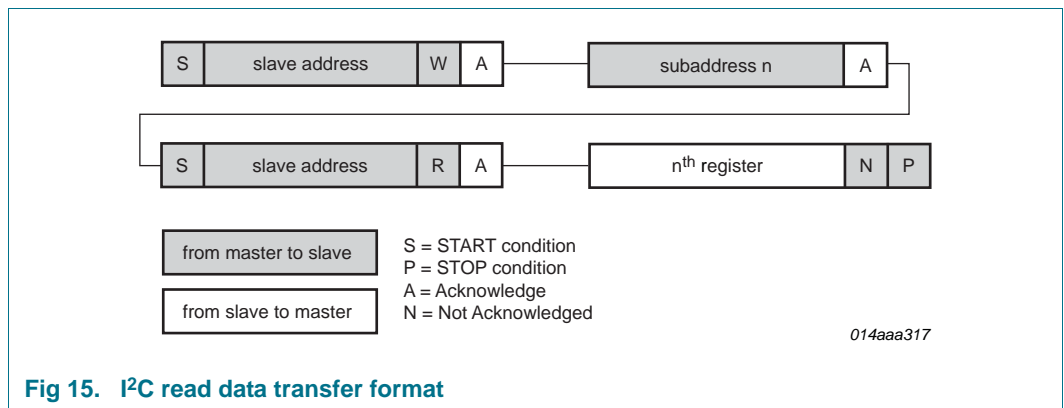
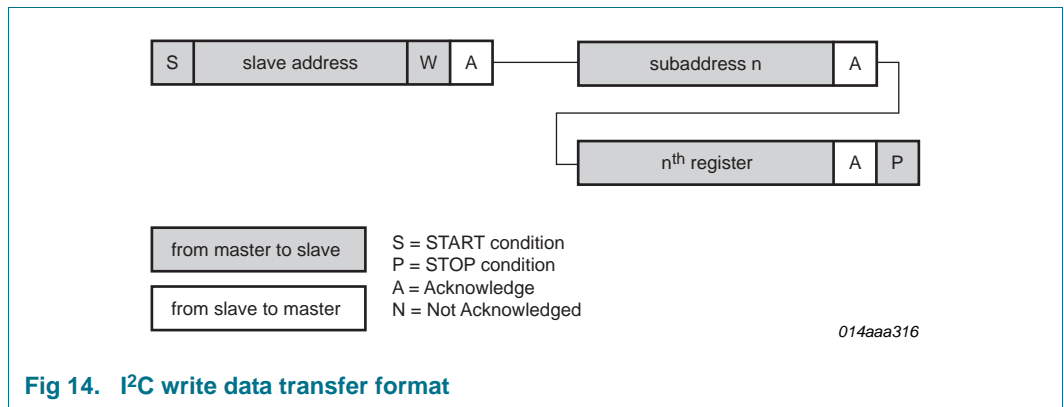
7.9 I²C-bus protocol

The I²C interface is a 2-wire serial interface developed by NXP Semiconductors to communicate between different ICs or modules. The two wires are a Serial Data line (SDA) and a Serial Clock Line (SCL). Both lines must be connected to a positive supply via a pull-up resistor when connected to the output stages of a device. Data transfer may only be initiated when the bus is not busy. The SSL3252 I²C-bus characteristic is the 400 kbit/s Fast-mode I²C-bus from the I²C-bus specification.

Remark: For more details on the I²C-bus standard, refer to the document *UM10204, "I²C-bus specification and user manual"* (www.nxp.com/documents/user_manual/UM10204.pdf).

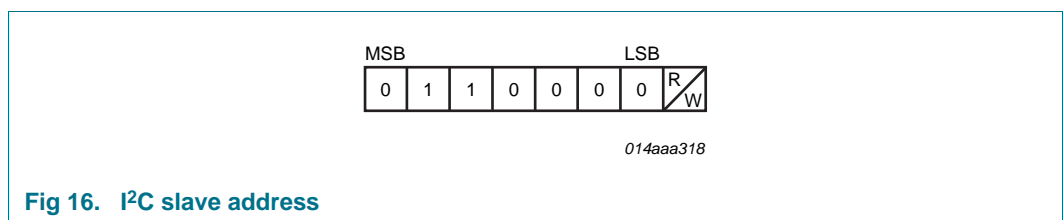
The following text describes the protocols used by the SSL3252 for the read and write sequences. The read sequence may use a repeated START condition during the sequence, to stop the bus being released during the communication. The sequences can be used to read or write only one data byte, or to read or write a sequence of data bytes.

After a START condition, a valid hardware address must be sent to the SSL3252 followed by a subaddress and n data bytes. See [Figure 14](#) and [Figure 15](#) below. For the format and the timing of the START condition (S), the STOP condition (P) and the Acknowledge bit (A), refer to the user manual *UM10204*.



7.9.1 Addressing

Each SSL3252 in an I²C-bus system is activated by sending a valid slave address to the device. The slave address always has to be sent as the first byte after the START condition in the I²C-bus protocol. See [Figure 16](#).



There is one address byte required since 7-bit addresses are used. The last bit of the address byte is the read/write bit and should always be set according to the required operation. This 7-bit address is 0110 000b (30h). The combination with the LSB R/W bit gives a write address of 60h and a read address of 61h.

The second byte sent to the SSL3252 is the subaddress of the specific register.

7.9.2 Data

After the subaddress the data bytes are sent. The definition of the data transfer is given in [Figure 14](#) and [Figure 15](#). After each data byte an acknowledge is given and the subaddress is automatically incremented to the next subaddress.

A description of the data that can be programmed in the registers is given in [Table 6](#).

7.9.3 Register map

Table 6. Description of registers

Legend: * default reset register value.

| Address | Register | Bit | Symbol | Access | Value | Description |
|---------|-----------------|-------------|-------------------|--------|---|--|
| 00h | Design info | 7 to 4 | Man_ID | R | 0100* | Manufacturer ID |
| | | 3 to 0 | Model_ID | R | 0001* | Model ID |
| 01h | Version control | 7 to 4 | Reserved | R | 0000* | Reserved for future use |
| | | 3 to 0 | Design version | R | 0000 | Design version 1 |
| | | | | | 0001 | Design version 2 |
| | | | | | : | : |
| | | | | | 1111 | Design version 16 |
| 02h | Indicator/timer | 7 to 6 | Indicator current | R/W | 00* | Indicator LED current 2.5 mA (default) |
| | | | | | 01 | Indicator LED current 5 mA |
| | | | | | 10 | Indicator LED current 7.5 mA |
| | | | | | 11 | Indicator LED current 10 mA |
| | | | | | | : |
| | 5 to 4 | Vref offset | R/W | 00* | No offset (default) | |
| | | | | 01 | Offset = $V_{ref} + 0.3$ V | |
| | | | | 10 | Offset = $V_{ref} - 0.3$ V | |
| | | | | 11 | Offset = $V_{ref} + 0.6$ V | |
| | 3 to 0 | Flash timer | R/W | 0000 | Software flash timer value 100 ms | |
| | | | | 0001 | Software flash timer value 150 ms | |
| | | | | | : | |
| | | | | 1111* | Software flash timer value 850 ms (default) | |

Table 6. Description of registers ...continued

Legend: * default reset register value.

| Address | Register | Bit | Symbol | Access | Value | Description |
|---------|-----------------------------|--------|---|--------|-------|--|
| 03h | Current set | 7 to 4 | Flash ^[1] | R/W | 0000 | Flash current 200 mA |
| | | | | | 0001 | Flash current 220 mA |
| | | | | | : | : |
| | | | | | 0110* | Flash current 320 mA (default dual LEDs) |
| | | : | : | | | |
| | | 1111 | Flash current 500 mA (default single LED) | | | |
| | | 3 | LED detection enable | R/W | 1* | Enabled number of LED detection (default enabled) |
| | | 2 to 0 | Assist/Torch current | R/W | 000 | Assist/Torch current 20 mA |
| | | | | | 001* | Assist/Torch current 40 mA (default two LEDs) |
| | | | | | : | : |
| | | | | | 011 | Assist/Torch current 80 mA (default one LED) |
| : | : | | | | | |
| 111 | Assist/Torch current 160 mA | | | | | |
| 04h | Control | 7 to 6 | Coil peak | R/W | 00 | Coil peak current limit 1.25 A |
| | | | | | 01 | Coil peak current limit 1.5 A |
| | | | | | 10* | Coil peak current limit 1.75 A (default) |
| | | | | | 11 | Coil peak current limit 2.00 A |
| | | 5 | Strobe signal | R/W | 1* | Strobe signal usage (0 = edge sensitive, 1 = level sensitive) |
| | | 4 | Torch mode | R/W | 1* | Torch mode allowed in Standby mode (1 = allowed) |
| | | 3 | Output ON | R/W | 0* | Turn ON outputs Indicator mode, Assist light mode or Flash mode (1 = ON) |
| | | 2 | Strobe | R/W | 1* | Strobe signal mode (1 = enabled) |
| | | 1 to 0 | Output mode | R/W | 00* | Torch mode (default) |
| | | | | | 01 | Indicator mode |
| | | | | | 10 | Assist light mode |
| 11 | Flash mode | | | | | |
| 05h | Fault and info | 7 | OVP | R | 0* | Overvoltage protection (1 = fault) |
| | | 6 | Short circuit | R | 0* | Short-circuit LED (1 = fault) |
| | | 5 | Over temp | R | 0* | Overtemperature (1 = fault) |
| | | 4 | Timeout | R | 0* | Time-out (1 = fault) |
| | | 3 | Amount LEDs | R/W | - | Amount of LEDs on LED (0 = one LED, 1 = two LEDs) |
| | | 2 | Indicator LED | R | 0* | Short or open circuit on I_IND (1 = fault) |
| | | 1 | Broken coil | R | 0* | Broken coil (1 = fault) |
| | | 0 | Reserved | R | 0* | Reserved for future use |

[1] For register settings above 400 mA and dual LED detected, the output LED current will be limited to 400 mA.

8. Limiting values

Table 7. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

| Symbol | Parameter | Conditions | Min | Max | Unit |
|------------------|---------------------------------|---|------|--------------------|------|
| V_I | input voltage | on pin VIN | -0.5 | +5.5 | V |
| V_{SDA_EN2} | voltage on pin SDA/EN2 | | -0.5 | V_I | V |
| V_{SCL_EN1} | voltage on pin SCL/EN1 | | -0.5 | V_I | V |
| V_{STRB_2LED} | voltage on pin STRB/2LED | | -0.5 | V_I | V |
| V_{IF_SEL} | voltage on pin IF_SEL | | -0.5 | V_I | V |
| V_{TORCH} | voltage on pin TORCH | | -0.5 | V_I | V |
| V_{I_IND} | voltage on pin I_IND | | -0.5 | V_I | V |
| $V_{O(LED)}$ | LED output voltage | pin LED | -0.5 | +10 ^[1] | V |
| V_O | output voltage | pin VO | -0.5 | +10 ^[1] | V |
| V_{LX} | voltage on pin LX | | -0.5 | +10 ^[1] | V |
| P_{tot} | total power dissipation | $T_{amb} = 85\text{ °C}$ | - | 0.8 | W |
| T_j | junction temperature | | -40 | +150 | °C |
| T_{amb} | ambient temperature | | -40 | +85 | °C |
| T_{stg} | storage temperature | IC | -55 | +150 | °C |
| V_{ESD} | electrostatic discharge voltage | human body model according to JESD22-A114-E | - | 2000 | V |
| | | charged-device model according to JESD22-C101-A | - | 500 | V |

[1] Tolerant to the specified maximum voltage while operating. Do not apply voltages externally; this may cause permanent damage to the device.

9. Thermal characteristics

Table 8. Thermal characteristics

| Symbol | Parameter | Conditions | Typ | Unit |
|---------------|---|---|-----|------|
| $R_{th(j-a)}$ | thermal resistance from junction to ambient | mounted on dedicated 4 layer PCB in free air ^[1] | 83 | K/W |

[1] The junction to ambient thermal resistance is dependent on board layout, PCB material application and environmental conditions.

10. Characteristics

Table 9. Characteristics
 $V_I = 2.7\text{ V to }5.5\text{ V}$; $T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ ^[1] | Max | Unit |
|---|---|---|--------------------|--------------------|--------------|---------------|
| General voltage levels | | | | | | |
| V_I | input voltage | pin VIN | 2.7 | - | 5.5 | V |
| $V_{I(\text{extnd})(\text{VIN})}$ | extended input voltage on pin VIN | | ^[2] 2.5 | - | 5.5 | V |
| $V_{I(\text{UVLO})}$ | undervoltage lockout input voltage | V_I falling | 2.3 | 2.4 | 2.5 | V |
| $V_{\text{hys}(\text{UVLO})}$ | undervoltage lockout hysteresis voltage | V_I rising | 50 | 100 | 150 | mV |
| V_{th} | threshold voltage | on pin LED for single and dual LED detection; no offset; register value 00 | 4.25 | 4.35 | 4.45 | V |
| General current levels | | | | | | |
| I_{stb} | standby current | Standby and Fault modes | - | - | 10 | μA |
| I_{sd} | shutdown current | Shut-down mode | - | - | 1 | μA |
| $I_{\text{lmtr}(\text{IM})(\text{LX})}$ | peak current limiter current on pin LX | inductor peak current limiter | | | | |
| | | register value 00 | 1.125 | 1.25 | 1.375 | A |
| | | register value 01 | 1.35 | 1.5 | 1.65 | A |
| | | register value 10 | 1.575 | 1.75 | 1.925 | A |
| | | register value 11 | 1.8 | 2.0 | 2.2 | A |
| High power LED parameters | | | | | | |
| $V_{\text{O(LED)}}$ | LED output voltage | pin LED | 2.8 | - | 8.5 | V |
| | | short-circuit protection level on pin LED | - | - | 1.2 | V |
| V_{hr} | headroom voltage | current source; headroom voltage; $V_{\text{hr}} = V_{\text{O}} - V_{\text{LED}}$; in Boost mode, $V_I = 3.6\text{ V}$ | - | 300 | - | mV |
| I_{LED} | LED current | pin LED; I ² C mode; single LED | 20 | - | 500 | mA |
| | | pin LED; I ² C mode; dual LED | 20 | - | 400 | mA |
| ΔI_{LED} | LED current variation | from 20 mA to 180 mA | - | - | 20 | % |
| | | from 200 mA to 500 mA | - | - | 10 | % |
| $V_{\text{O}(\text{ovp})}$ | overvoltage protection output voltage | pin VO | 9 | 9.5 | 10 | V |
| Indicator LED parameters | | | | | | |
| $I_{\text{I_IND}}$ | current on pin I_IND | IF_SEL = 1 (I ² C mode) | 2.5 | - | 10 | mA |
| | | IF_SEL = 0 (Direct enable mode) | ^[3] - | 2.5 | - | mA |
| | | open-circuit protection level at pin I_IND | - | - | 1.25 | mA |
| $V_{\text{I_IND}}$ | voltage on pin I_IND | | 1.2 | - | $V_I - 0.01$ | V |
| | | short-circuit protection level at pin I_IND | - | - | 1.2 | V |
| $\Delta I_{\text{I_IND}}$ | current variation on pin I_IND | | - | - | 20 | % |

Table 9. Characteristics ...continued $V_I = 2.7\text{ V to }5.5\text{ V}$; $T_{amb} = -40\text{ }^\circ\text{C to }+85\text{ }^\circ\text{C}$, unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ ^[1] | Max | Unit |
|--|--|---|------|--------------------|----------------|------|
| Power MOSFETs | | | | | | |
| R _{DSon} | drain-source on-state resistance | NMOS | - | 240 | - | mΩ |
| | | PMOS | - | 400 | - | mΩ |
| Timing | | | | | | |
| f _{sw} | switching frequency | | 1.85 | 2.0 | 2.15 | MHz |
| t _{to} | time-out time | Flash mode; the absolute value can be set with I ² C | - | 850 | - | ms |
| Δt _{to} | time-out time variation | | - | - | 7.5 | % |
| t _{start(soft)} | soft start time | from Standby mode or Shut-down mode to maximum current on LED (from 0 mA to 500 mA) | - | - | 1000 | μs |
| t _{stop(soft)} | soft stop time | from maximum current on LED (from 500 mA to 0 mA) to Standby mode or Shut-down mode | - | - | 825 | μs |
| I²C interface | | | | | | |
| V _{IL} | LOW-level input voltage | SCL/SDA | 0 | - | 0.54 | V |
| V _{IH} | HIGH-level input voltage | SCL/SDA | 1.26 | - | V _I | V |
| V _{OL} | LOW-level output voltage | LOW on SDA; I _{sink} = 3 mA | 0 | - | 0.4 | V |
| f _{SCL} | SCL clock frequency | | 0 | - | 400 | kHz |
| 2LED function of STRB/2LED | | | | | | |
| V _{OL} | LOW-level output voltage | I _{sink} = 1 mA; LOW state | 0 | - | 0.4 | V |
| I _{OH} | HIGH-level output current | HIGH state | - | - | 1 | μA |
| SCL/EN1, SDA/EN2, IF_SEL, STRB function of STRB/2LED, TORCH | | | | | | |
| V _{IL} | LOW-level input voltage | LOW - digital input voltage | 0 | - | 0.54 | V |
| V _{IH} | HIGH-level input voltage | HIGH - digital input voltage | 1.26 | - | V _I | V |
| R _{pd(int)} | internal pull-down resistance | pins TORCH, STRB function of STRB/2LED (only in I ² C mode), SCL/EN1, SDA/EN2 (only in Direct enable mode) | - | 350 | - | kΩ |
| t _{degl(TORCH)} | deglitch time on pin TORCH | | 6.3 | 9 | 11.7 | ms |
| Temperature | | | | | | |
| T _{otp} | overtemperature protection trip | temperature rising | - | 150 | - | °C |
| T _{otp(hys)} | overtemperature protection trip hysteresis | temperature falling | - | 20 | - | °C |

[1] All typical values are measured at $T_{amb} = 25\text{ }^\circ\text{C}$ and $V_I = 3.6\text{ V}$.

[2] When operating in extended input voltage range, the device will be fully functional but has a reduced performance specification on certain parameters. An extended input voltage range is entered when the input voltage is dropping below 2.7 V, assuming the device is not in undervoltage lockout mode.

[3] When operating in Direct enable mode, the device will apply a default current setting. See [Section 7.3](#) for details. The pin IF_SEL should then be connected to GND.

11. Application information

11.1 Input capacitor

For good input voltage decoupling, a low ESR ceramic capacitor is highly recommended. A 4.7 μF (X5R/X7R) 6.3 V is the minimum recommended value. Since the input capacitor is supplying the input ripple current, a larger capacitor will improve both the transient behavior of the regulator and the EMI behavior of the power supply. Taking capacitor DC bias and temperature de-rating specifications into account, a 10 μF (X5R/X7R) is preferred. Although increasing component count, a smaller capacitor of 100 nF (X5R/X7R) placed in parallel to the input capacitor will also improve EMI behavior.

11.2 Output capacitor

The output capacitor supplies the current into the main LED, while the inductor is being charged, and it also ensures loop stability. The minimum capacitance for stable loop operation would be 4.7 μF , but taking capacitor DC bias and temperature de-rating specifications into account, a low ESR ceramic capacitor of 10 μF (X5R/X7R) is highly recommended. A higher value of capacitance will improve output current ripple, while maintaining loop stability. Typically the SSL3252 overvoltage limit on pin VO is at 9.5 V, and the rated voltage of the output capacitor should be at least 10 V.

11.3 Inductor

The device has been designed to operate well with inductance values between 1.5 μH and 3.3 μH , in order to optimize for solution size. In a typical high current dual flash LED application a 2.2 μH inductance is recommended. The inductor's saturation current should be greater than or equal to the inductor peak current limiter current, which is a typical 1.75 A. During normal operation, it is recommended to keep the inductor peak current below this value. The copper losses and magnetic hysteresis losses in the inductor also contribute to the total system losses.

11.4 PCB layout

It is essential to have a good circuit layout in order to maximize efficiency and minimize EMI disturbance. The circuit topology uses an inductor, which is often seen as a main source of EMI disturbance, but any loop of wire carrying a current is essentially an electromagnet, whose field strength is proportional to the current. Careful circuit layout is therefore very important, keeping loop areas small and minimizing the magnetic flux. Due to the way a boost converter operates, there are two power states. One state when the internal NMOS switch is ON, and one when the NMOS switch is OFF. During each state there will be a current loop made by the power components that are conducting. The input and output capacitors must be arranged in such a way on the SSL3252 that during each of the two states the current loop is conducting in the same direction. This prevents phase reversal of the magnetic field, and reduces radiated EMI. The current loop area should be kept small by placing the power components as close as possible to the SSL3252. Use ground planes to keep the loop areas to a minimum.

Priority should be given for the output capacitor to be positioned as close as possible to the VO and PGND nodes of the SSL3252. Since large currents will flow from input capacitor to the inductor and not to the VIN pin of the SSL3252, it is wise to locate the input capacitor near the inductor. The VIN pin should be star-connected to the positive pad of the input capacitor.

PGND and GND of the SSL3252 should be directly connected to each other. Place the ground connection of the output capacitor as close as possible to the PGND pin of the SSL3252.

The preferred minimum trace width for the high current width is 15 mm/A.

12. Package outline

WLCSP12: wafer level chip-size package; 12 bumps; 1.58 x 2.06 x 0.6 mm

SSL3252UK

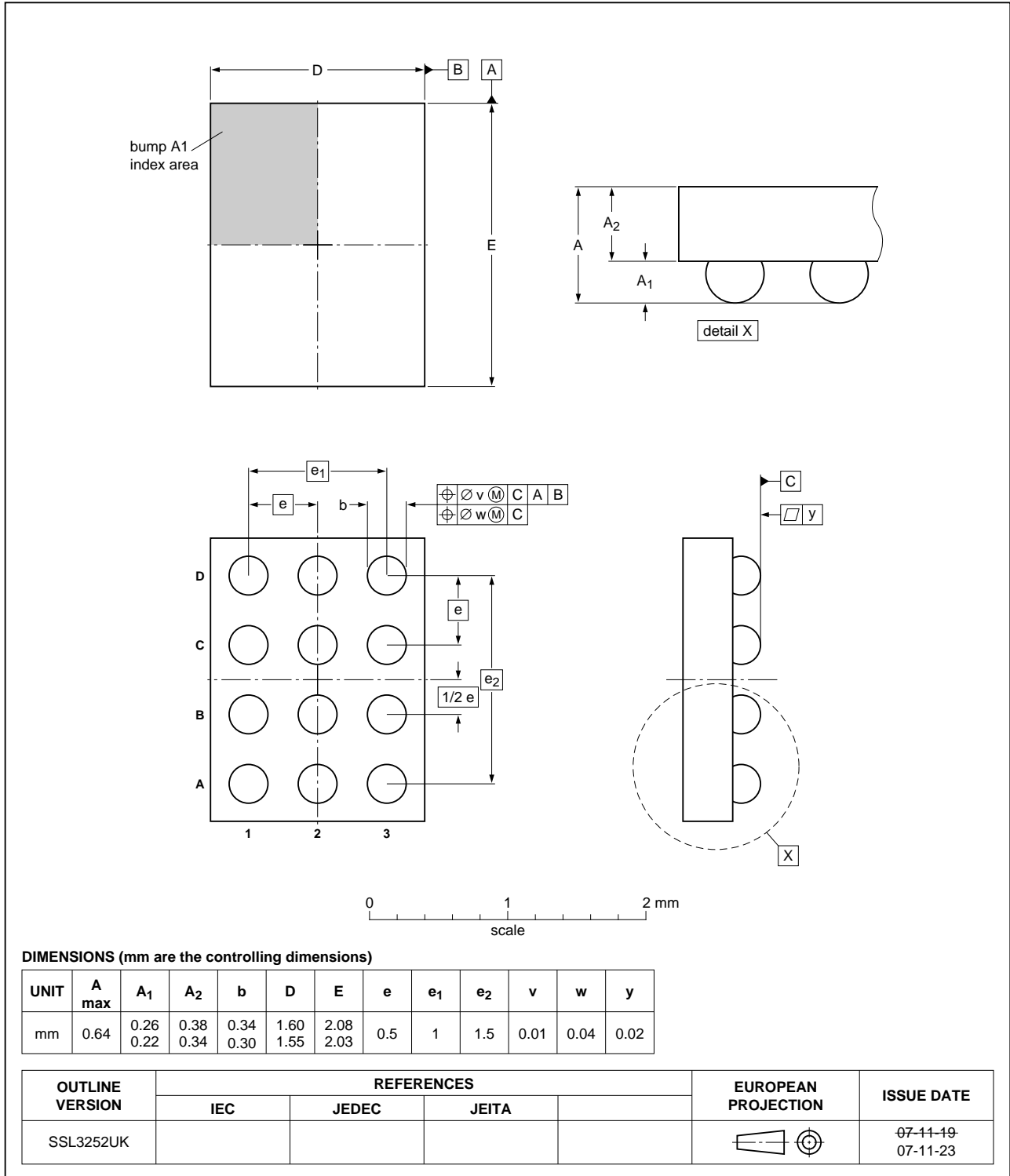


Fig 17. Package outline SSL3252UK (WLCSP12)

13. Soldering of WLCSP packages

13.1 Introduction to soldering WLCSP packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering WLCSP (Wafer Level Chip-Size Packages) can be found in application note AN10439 "Wafer Level Chip Scale Package" and in application note AN10365 "Surface mount reflow soldering description".

Wave soldering is not suitable for this package.

All NXP WLCSP packages are lead-free.

13.2 Board mounting

Board mounting of a WLCSP requires several steps:

1. Solder paste printing on the PCB
2. Component placement with a pick and place machine
3. The reflow soldering itself

13.3 Reflow soldering

Key characteristics in reflow soldering are:

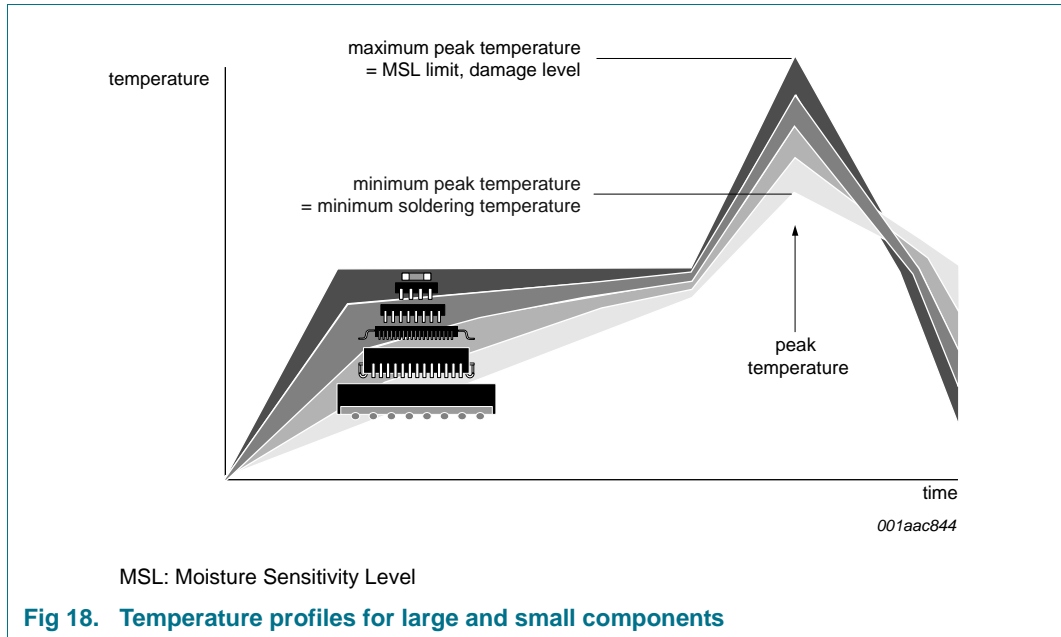
- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 18](#)) than a PbSn process, thus reducing the process window
- Solder paste printing issues, such as smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature), and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic) while being low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 10](#).

Table 10. Lead-free process (from J-STD-020C)

| Package thickness (mm) | Package reflow temperature (°C) | | |
|------------------------|---------------------------------|-------------|--------|
| | Volume (mm ³) | | |
| | < 350 | 350 to 2000 | > 2000 |
| < 1.6 | 260 | 260 | 260 |
| 1.6 to 2.5 | 260 | 250 | 245 |
| > 2.5 | 250 | 245 | 245 |

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 18](#).



For further information on temperature profiles, refer to application note AN10365 “Surface mount reflow soldering description”.

13.3.1 Stand off

The stand off between the substrate and the chip is determined by:

- The amount of printed solder on the substrate
- The size of the solder land on the substrate
- The bump height on the chip

The higher the stand off, the better the stresses are released due to TEC (Thermal Expansion Coefficient) differences between substrate and chip.

13.3.2 Quality of solder joint

A flip-chip joint is considered to be a good joint when the entire solder land has been wetted by the solder from the bump. The surface of the joint should be smooth and the shape symmetrical. The soldered joints on a chip should be uniform. Voids in the bumps after reflow can occur during the reflow process in bumps with high ratio of bump diameter to bump height, i.e. low bumps with large diameter. No failures have been found to be related to these voids. Solder joint inspection after reflow can be done with X-ray to monitor defects such as bridging, open circuits and voids.

13.3.3 Rework

In general, rework is not recommended. By rework we mean the process of removing the chip from the substrate and replacing it with a new chip. If a chip is removed from the substrate, most solder balls of the chip will be damaged. In that case it is recommended not to re-use the chip again.

Device removal can be done when the substrate is heated until it is certain that all solder joints are molten. The chip can then be carefully removed from the substrate without damaging the tracks and solder lands on the substrate. Removing the device must be done using plastic tweezers, because metal tweezers can damage the silicon. The surface of the substrate should be carefully cleaned and all solder and flux residues and/or underfill removed. When a new chip is placed on the substrate, use the flux process instead of solder on the solder lands. Apply flux on the bumps at the chip side as well as on the solder pads on the substrate. Place and align the new chip while viewing with a microscope. To reflow the solder, use the solder profile shown in application note AN10365 "Surface mount reflow soldering description".

13.3.4 Cleaning

Cleaning can be done after reflow soldering.

14. Abbreviations

Table 11. Abbreviations

| Abbreviation | Description |
|--------------|---|
| EMI | ElectroMagnetic Interference |
| ESR | Equivalent Series Resistance |
| IC | Integrated Circuit |
| I/O | Input/Output |
| LED | Light Emitting Diode |
| MOSFET | Metal-Oxide Semiconductor Field-Effect Transistor |
| NMOS | N-type Metal-Oxide Semiconductor |
| PCB | Printed-Circuit Board |
| PDA | Personal Digital Assistant |
| PMOS | P-type Metal-Oxide Semiconductor |
| POR | Power-On Reset |
| PWM | Pulse Width Modulation |
| RF | Radio Frequency |

15. Revision history

Table 12. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|-------------|--------------|--------------------|---------------|------------|
| SSL3252 v.1 | 20110707 | Product data sheet | - | - |

16. Legal information

16.1 Data sheet status

| Document status ^{[1][2]} | Product status ^[3] | Definition |
|-----------------------------------|-------------------------------|---|
| Objective [short] data sheet | Development | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
| Product [short] data sheet | Production | This document contains the product specification. |

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

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