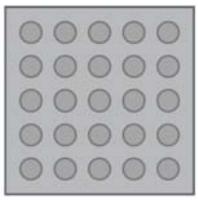
STBCFG01

Switch mode single cell Li+ battery charger with OTG boost, voltage mode fuel gauge and LDO

Datasheet - production data



Flip Chip 25 (2.3 x 2.2 mm)

Features

- High efficiency switching battery charger
  - 2 MHz or 3 MHz switching frequency
  - 1.2 A max. charging current
  - 20 V tolerant input with OVP
  - Programmable input current limitation and dynamic input current limit
  - Battery overvoltage protection
  - Auto-recharge
  - Integrated current sensing resistor
  - USB compatible
- Voltage mode fuel gauge
  - External sensing resistor is not needed
  - Battery swap detection through ID resistor
  - Low battery voltage and low SOC programmable alarms
- 50 mA LDO for system boot in dead battery condition
- USB OTG V_{BUS} generation (500 mA)
  - USB overvoltage protection
  - Programmable battery overcurrent protection
- Automatic 60 mA input pre-bias
- I²C compatible control interface
- Interrupt output pin
- Flip Chip package, 25 bumps (2.3 x 2.2 mm)

Applications

- Mobile phones
- Smart phones

Description

The STBCFG01 is a switching battery charger integrating the necessary functions to charge single cell Li-Ion batteries, monitor the battery charge and generate 5 V to supply USB OTG bus powered devices.

The IC also integrates the LDO regulator to support system boot in dead battery conditions.

The battery charger features a smart input current limit: the maximum input current can be selected through I²C and if the input voltage drops below a programmable threshold, the input current is reduced even if the selected maximum current limit has not been reached yet. The dynamic input current limit can be disabled.

An automatic input pre-bias load makes the device suitable for applications using voltage sources with a minimum external load for the right regulation.

The STBCFG01 also integrates a voltage mode fuel gauge to provide the state of charge evaluation without the current sensing resistor.

Table 1. Device summary

Order code	Package	Packaging
STBCFG01JR	Flip Chip 25 (2.3 x 2.2 mm)	Tape and reel

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1 Application schematic

Figure 1. Application diagram

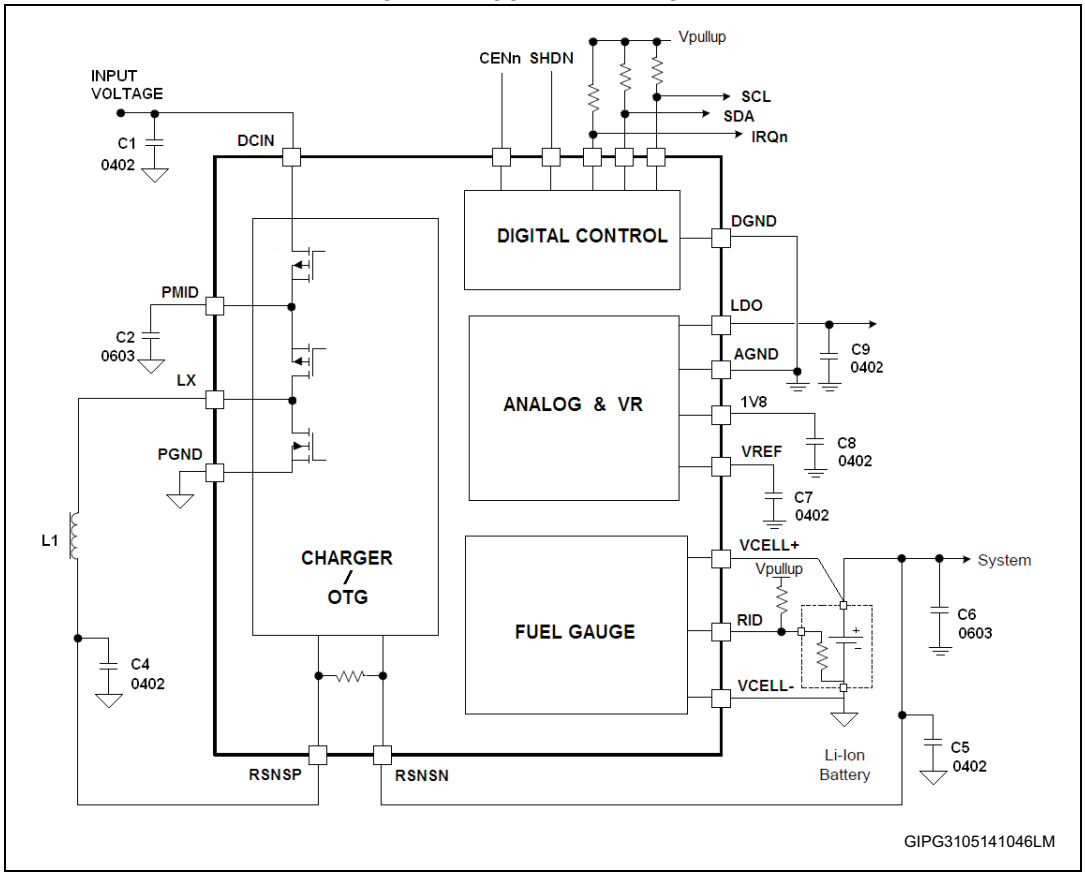


Table 2. Typical external components table

Component name	Size	Value	Supplier	Part number
C1	0603	10µF, 16V	MURATA	GRM188R61C106MA73D
C2	0603	4.7µF, 25V	TDK	C1608X5R1E475K080AC
C3	0402	1µF, 16V	MURATA	GRM155R61C105KA12D
C4	0603	4.7µF, 25V	TDK	C1608X5R1E475K080AC
C5	0603	1µF, 16V	MURATA	GRM185R61C105KE44
C6	0603	10µF, 16V	MURATA	GRM188R61C106MA73D
C7	0603	100nF, 25V	MURATA	GRM188R71H104KA93
C8	0603	1µF, 16V	MURATA	GRM185R61C105KE44
C9	0603	1µF, 16V	MURATA	GRM185R61C105KE44
L1	2.5*2 mm	1µH, 2.2A	TDK	VLS252012ET-1R0N

2 Pin configuration

Figure 2. Pin connections (top view)

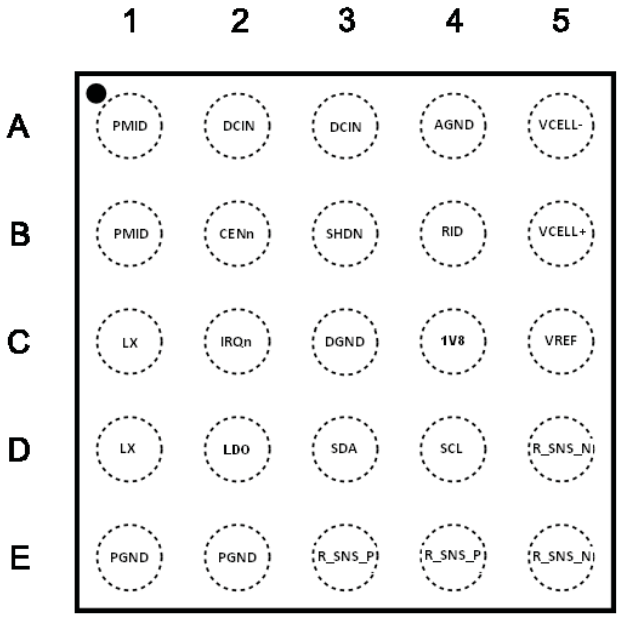


Table 3. Pin description

Symbol	Ball	Pin function	Description
PMID	A1, B1	Power I/O	Reverse blocking MOSFET to high-side connection node
DCIN	A2, A3	Power I/O	Input supply voltage/OTG output
AGND	A4	Analog ground	Analog ground
VCELL-	A5	Analog input	Battery pack negative terminal sense input
CENn	B2	Digital input	Charger enable, active low. Internal 200 kΩ pull-down to GND
SHDN	B3	Digital input	Shutdown input, active high. Internal 200 kΩ pull-down to GND
RID	B4	Analog input	Battery identification resistor connection (for battery detection). An external bias has to be applied
VCELL+	B5	Analog input	Battery pack positive terminal sense input
LX	C1, D1	Power I/O	Switch mode, inductor connection
IRQn	C2	Digital input	Open drain interrupt output, active low
DGND	C3	Digital ground	Digital ground

Table 3. Pin description (continued)

Symbol	Ball	Pin function	Description
1V8	C4	Analog out	1.8 V internal regulator bypass pin. Bypass this pin to GND with a capacitor of 220 nF. Do not connect any load
VREF	C5	Analog out	Reference voltage bypass pin. Do not connect any load
LDO	D2	Analog out	4.85 V LDO output
SDA	D3	Digital I/O	I²C data pin to the baseband, I²C master peripheral
SCL	D4	Digital input	I²C clock pin to the baseband, I²C master peripheral
R_SNS_N	D5, E5	Power I/O	Internal sense resistor, negative terminal
PGND	E1, E2	Power ground	Power ground
R_SNS_P	E3, E4	Power I/O	Internal sense resistor, positive terminal

3 Maximum ratings

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{DCIN}, V_{PMID}	Charger input voltage	-1.5 to +20	V
V_{LX}	Switch mode voltage	-0.3 to +8	V
VCELL+, $R_{\_SNS\_N}$, $R_{\_SNS\_P}$	Battery pin	-0.3 to +6	V
V_{VREF}, V_{V1V8}, V_{CENn}, V_{SHDN}	Low voltage pins	-0.3 to +2.1	V
V_{AMR}	All other pin input voltage	-0.3 to +5.5	V
ESD	Human body model	±2000	V
	Charged device model	±250	V
T_{AMB}	Operating ambient temperature	-30 to +85	°C
T_J	Maximum junction temperature	+125	°C
T_{STG}	Storage temperature	-65 to +150	°C

Note: Absolute maximum ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied.

Table 5. Thermal data

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance junction-case	TBD	°C/W
R_{thJA}	Thermal resistance junction-ambient	TBD	°C/W

4 Electrical characteristics

T_J = - 30 °C to 85 °C, V_{BAT} = 3.6 V, V_{DCIN} = 5 V unless otherwise specified.

Table 6. Electrical characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
General information						
V_{IN}	DCIN input voltage range		3.78		5.95	V
f_{SW}	Switching frequency	FSW bit = 0		2		MHz
		FSW bit = 1		3		
T_{SD}	Thermal shutdown threshold			165		°C
	Hysteresis			20		
t_{TSD}	Thermal shutdown deglitch time			50		µs
Battery charger						
I_{IN}	Current consumption from DCIN	Charger enabled, switching, V_{BUS_CON} = 5 V		14		mA
		Shutdown, LDO disabled		290	400	µA
		Shutdown, LDO enabled		500	800	µA
I_{BAT}	Current consumption from BAT (including fuel gauge)	On battery power V_{BUS_CON} = 0 V GG_RUN = 0		10	25	µA
		On battery power V_{BUS_CON} = 0 V GG_RUN = 1		32	100	µA
V_{INOVP}	DCIN overvoltage protection	V_{DCIN} rising	6.05	6.3	6.62	V
		V_{DCIN} falling	5.95	6.2	6.51	
V_{INOVP_PB}	Pre-bias overvoltage protection	V_{DCIN} rising		7.0		V
		V_{DCIN} falling		6.9		V
	Pre-bias OVP accuracy		-5		+5	%
V_{INUVLO}	DCIN undervoltage lockout	V_{DCIN} rising		3.6		V
		V_{DCIN} falling		3.5		
	DCIN UVLO accuracy		-5		+5	%
I_{PREB}	Pre-bias current			60		mA

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
t_{PBD}	Pre-bias current enable deglitch time	V_{DCIN} rising over V_{INOVP} but below V_{INOVP_PB}		5		ms
t_{HDO}	Hold-off time	Valid DCIN connection to charging start		200		ms
V_{ASD}	Automatic shutdown threshold	$V_{ASD} = V_{DCIN}-V_{BAT}$, V_{DCIN} rising		130		mV
		$V_{ASD} = V_{DCIN}-V_{BAT}$, V_{DCIN} falling	0	36		mV
t_{ASD}	Automatic shutdown threshold deglitch time			50		µs
I_{INLIM}	DCIN current limit	I_{LIM} configurable by I^2C		90		mA
				476		
				760		
				1140		
V_{DICL}	Dynamic input current limit threshold	DICL configurable by I^2C (4.0 V, 4.25 V, 4.5 V, 4.75 V)	4.0		4.75	V
	DICL accuracy		-3		+3	%
t_{DICL}	DICL activation deglitch time			100		ms
V_{FLOAT}	CV regulation voltage	V_{BUS_CON} = 5 V	3.52		4.78	V
	CV regulation voltage accuracy	V_{BUS_CON} = 5 V	-1		+1	%
V_{FLD}	CC to CV threshold deglitch time			170		ms
V_{RCHG}	Auto-recharge threshold voltage	ARCHG bit = 1		V_{FLOAT}- 0.12		V
	Auto-recharge threshold accuracy	ARCHG bit = 1	-17		+17	%
t_{RCHG}	Auto-recharge threshold deglitch time	ARCHG bit = 1		170		ms
V_{BATOVP}	Battery overvoltage protection	This is got by increasing the battery voltage until BATOVP status register turns on		V_{FLOAT}+ 0.1		V
	Battery OVP accuracy		-10		+10	%
t_{BOVP}	Battery OVP deglitch time			170		ms
I_{TRK}	Trickle charge current	$V_{BAT} < V_{TRK}$		45		mA
	Trickle charge current accuracy		-20		+20	%

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{PRE}	Pre-charge current	$V_{TRK} < V_{BAT} < V_{PRE}$		450		mA
	Pre-charge current accuracy		-10		+10	%
I_{FAST}	Fast charge current	$V_{BAT} > V_{PRE}$	550		1250	mA
	Fast charge current accuracy		-10		10	%
I_{TERM}	Termination current		50		300	mA
	Termination current accuracy		-30		30	%
t_{TERM}	Charge termination deglitch time			170		ms
V_{TRK}	Trickle charge to pre-charge battery voltage threshold			2		V
	V_{TRK} accuracy		-5		+5	%
t_{TPD}	Trickle charge to pre-charge threshold deglitch time			100		ms
V_{PRE}	Pre-charge to fast charge battery voltage threshold			3		V
	V_{PRE} accuracy		-5		+5	%
t_{PFD}	Pre-charge to fast charge threshold deglitch time			170		ms
V_{DETH}	Battery detection high threshold			3		V
V_{DETL}	Battery detection low threshold			2		V
I_{DETSNK}	Sink detection current			-5		mA
t_{DETSRC}	Current source detection time			340		ms
t_{DETSNK}	Current sink detection time			200		ms
R_{ON_HI}	High-side MOSFET on-resistance (including reverse blocking MOFET)			300		mΩ
R_{ON_LOW}	Low-side MOSFET on-resistance			125		mΩ
R_{SNS}	Internal sensing resistor			35	68	mΩ
t_{MAXPRE}	Maximum pre-charge time	Including trickle charge		45		min
t_{MAXCHG}	Maximum fast charge time	including taper charge		360		min
OTG boost regulator						
I_{BQ}	Boost quiescent current	V_{BAT} = 3.7 V, no load		4		mA
V_{BUS}	Output voltage at V_{BUS_CON}		4.75	5	5.25	V

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
I_{VBUS}	Output current capability	V_{BUS} ≥ 4.75 V	500			mA
$V_{BATUVLO}$	Battery undervoltage lock-out	Falling edge		3		V
	Accuracy		-5		+5	%
V_{BUSOVP}	Output overvoltage protection			6		V
	Accuracy		-5		+5	%
$t_{VBUSOVP}$	V_{BUSOVP} deglitch time			30		ms
I_{BATLIM}	Battery average current limitation		350		950	mA
	Accuracy		-10		+10	%
I_{LMAX}	Cycle-by-cycle limitation			1.2		A
Z_0	Output impedance in OFF mode		100			kΩ
LDO output						
V_{LDO}	LDO output voltage	I_{LDO} = 50 mA,		4.85		V
	Accuracy	V_{DCIN} - V_{LDO} > 300 mV	-4		+4	%
I_{LDO}	LDO output current	V_{DCIN} - V_{LDO} > 300 mV	50			mA
I_{SC}	LDO short-circuit current	V_{LDO} ≤ 4 V		75		mA
	Accuracy		-27		+27	%
V_{DO}	LDO dropout voltage	I_{LDO} = 50 mA		150	300	mV
V_{INMIN}	LDO input undervoltage lockout	V_{DCIN} rising		3.6		V
		V_{DCIN} falling		3.5		
	V_{INMIN} accuracy		-5		+5	%
V_{INMAX}	LDO input overvoltage lockout	V_{DCIN} rising		6.3		V
		V_{DCIN} falling		6.2		
	V_{INMAX} accuracy		-5		+5	%
Fuel gauge						
I_{FGQ}	Fuel gauge quiescent current	GG_RUN = 1		25		µA
		GG_RUN = 0		2		

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
UVLO	Fuel gauge undervoltage lock-out	Rising edge	2.0	2.6	2.7	V
	Hysteresis			100		mV
f_{OSC}	Internal time base frequency			512		kHz
	Time base accuracy			1		%
t_{STRB}	ADC conversion strobe			4		s
t_{SWAP}	Battery swap deglitch time			1		s
V_{BATERR}	V_{BAT} measurement error		-0.5		+0.5	%
V_{BATRES}	V_{BAT} measurement resolution	OCV reading		2.69		mV
V_{BATRNG}	V_{BAT} measurement range		2.5		5.5	V
V_{RIDTH}	RID threshold		1.2	1.25	1.3	V
	Hysteresis			0.130		V
I²C compatible interface						
V_{IH}	High level input voltage		1.3			V
V_{IL}	Low level input voltage				0.6	V
V_{OL}	Low level output voltage at 10 mA sink current for open drain I/O				0.3	V
C_{IO}	I/O pin capacitance				10	pF
f_{SCL}	SCL clock frequency				400	kHz
t_{LOW}	Minimum clock low period		1.3			µs
t_{HIGH}	Minimum clock high period		600			ns
t_F	SDA and SCL fall time				300	ns
t_{HOLD_STA}	Start condition hold time		600			ns
t_{SU_STA}	Start condition set-up time		600			ns
t_{SU_DAT}	Data set-up time		100			ns
t_{HOLD_DAT}	Data hold time		0			µs
t_{SU_STO}	Stop condition set-up time		600			ns
t_{BUF}	Minimum delay between operations		1.3			µs
Digital interface						
V_{IH}	Input high threshold		1.3			V

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
V_{IL}	Input low threshold				0.6	V
V_{OL}	Output low threshold				0.3	V
I_{IN_IO}	I/O pin input current		-10		+10	µA

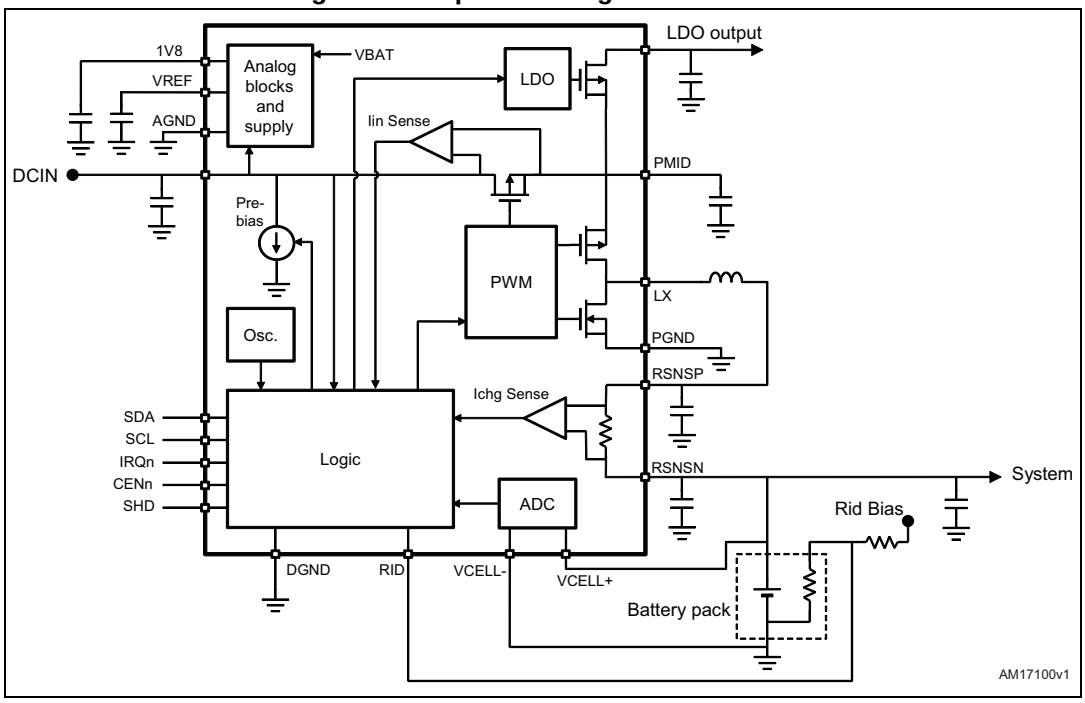
Note: Dropout voltage is the input-to-output voltage difference at which the output voltage is 100 mV below its nominal value.

5 Operation description

5.1 Battery charger

The STBCFG01 integrates a high efficiency battery charger of 1.2 A implementing the CC/CV charging algorithm for single cell Li-Ion battery powered applications. The switching frequency can be either 2 MHz or 3 MHz, according to platform noise requirements, and the inductor value is 1 µH. The charging current sensing resistor is integrated.

Figure 3. Simplified charger architecture



When the battery is deeply discharged (VCELL+ < V_{TRK}, V_{TRK} = 2 V) the device is in trickle charge mode and charges the battery in linear mode with a low current (I_{TRK} = 45 mA) up to the trickle charge threshold.

As soon as the battery voltage enters the pre-charge range (V_{TRK} < VCELL+ < V_{PRE}, V_{PRE} = 3 V) the device starts the switch mode charging and increases the charging current up to the pre-charge current level (I_{PRE}) to make the system voltage rise quickly up to a level which allows the system to wake up.

The typical value for the pre-charge current is 450 mA but this value can be decreased to 100 mA through the I²C compatible interface.

A 45 minute (typ.) safety timer is active during both trickle charge and pre-charge.

When the battery voltage is above the pre-charge threshold, the STBCFG01 enters fast charge mode and increases the charging current up to I_{FAST} value. The fast charge current can be programmed through the I²C compatible interface between 550 mA and 1.2 A in 100 mA steps.

A soft-start function makes the battery current increase smoothly when the charging current changes.

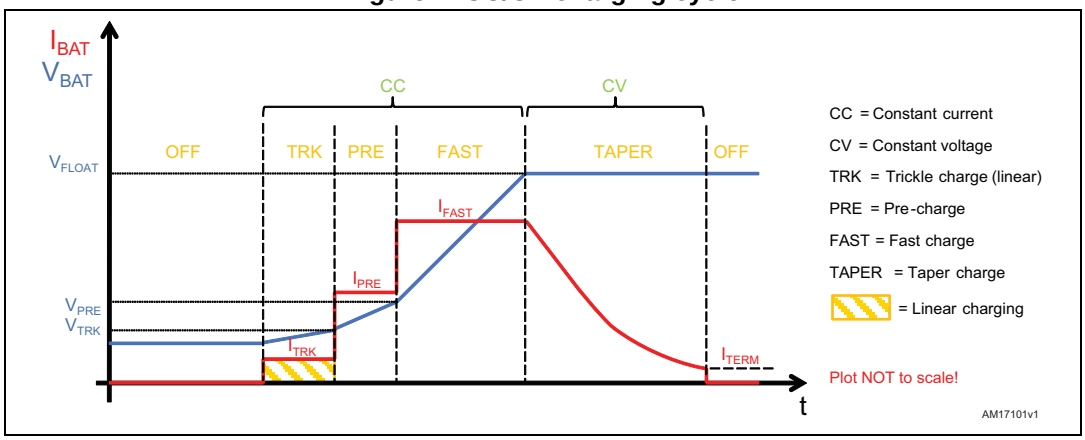
The constant voltage mode enters when the battery voltage reaches the programmable floating voltage threshold (V_{FLOAT}, 3.60 V to 4.70 V in 20 mV steps).

In constant voltage mode, the charging current tapers down the termination current threshold and then the charging process stops. The termination current is programmable from 50 mA to 300 mA in 25 mA steps.

A 360 minute (typ.) safety timer is active when the fast charge starts.

The charger can be disabled pulling high the charger enable input (CENn) and is automatically stopped in automatic shutdown conditions (ASD, V_{DCIN} - V_{BAT} < V_{ASD}).

Figure 4. CC/CV charging cycle



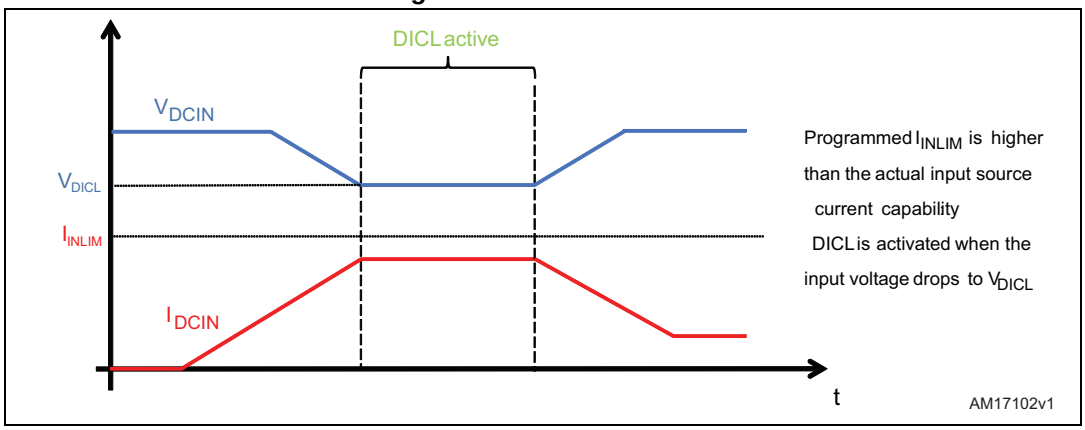
5.1.1 Input current limit

The STBCFG01 implements a programmable input current limitation to prevent the battery charger from exceeding DCIN voltage source current capability. The current limit can be programmed through I²C to the following maximum values: 100 mA, 500 mA, 800 mA, 1.2 A. A “no limit” option is also available.

5.1.2 Dynamic input current limit (DICL)

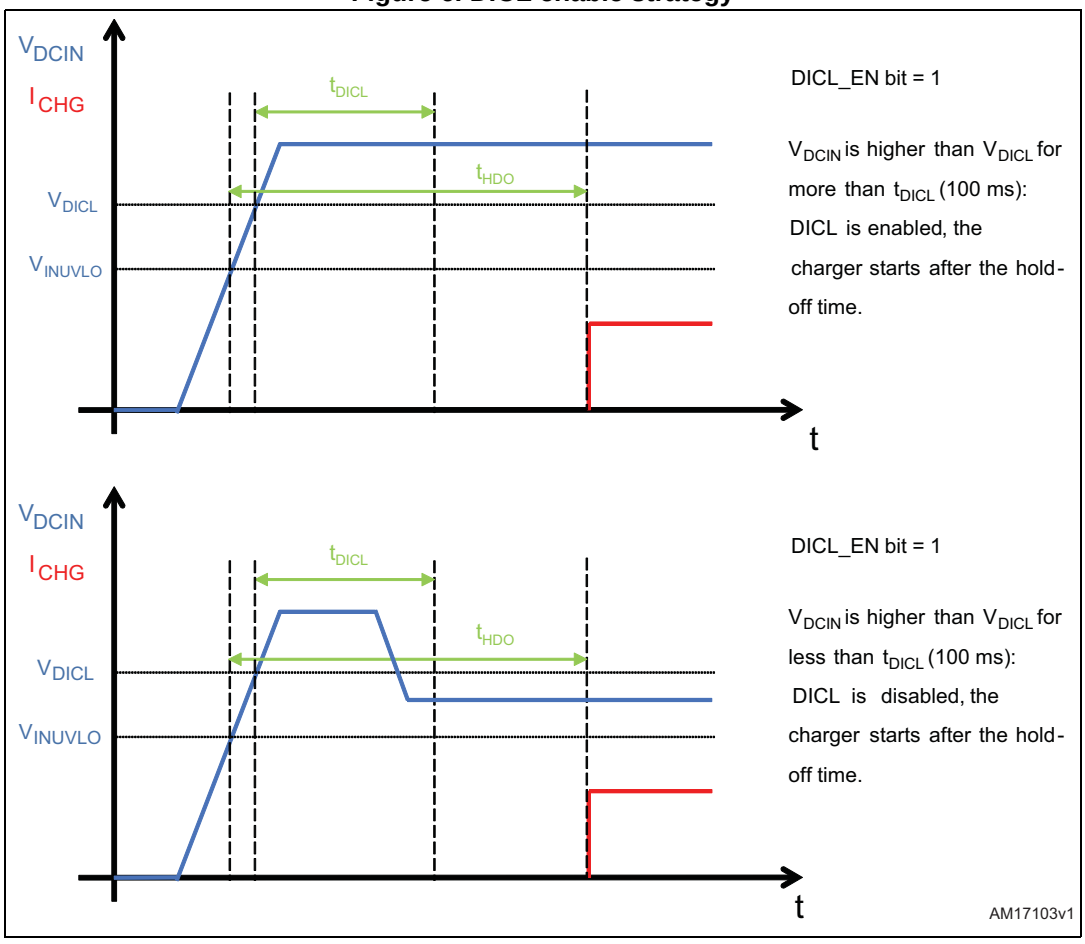
Independently from the chosen input current limit, a dynamic input current limit loop can also be enabled through the I²C compatible interface (DICL_en bit). When DICL is active, an analog loop limits the input current when the input voltage drops to a programmable threshold (V_{DICL} = 4.0 V to 4.75 V in 250 mV steps).

Figure 5. DICL activation



When a valid input source is connected to DCIN, DICL is enabled only if the input voltage is higher than V_{DICL} for a deglitch time (t_{DICL} = 100 ms). The user can check the enabling status of DICL function reading DICL status bit. Once DICL is enabled it can be disabled through DICL_en bit.

Figure 6. DICL enable strategy



5.1.3 Automatic recharge

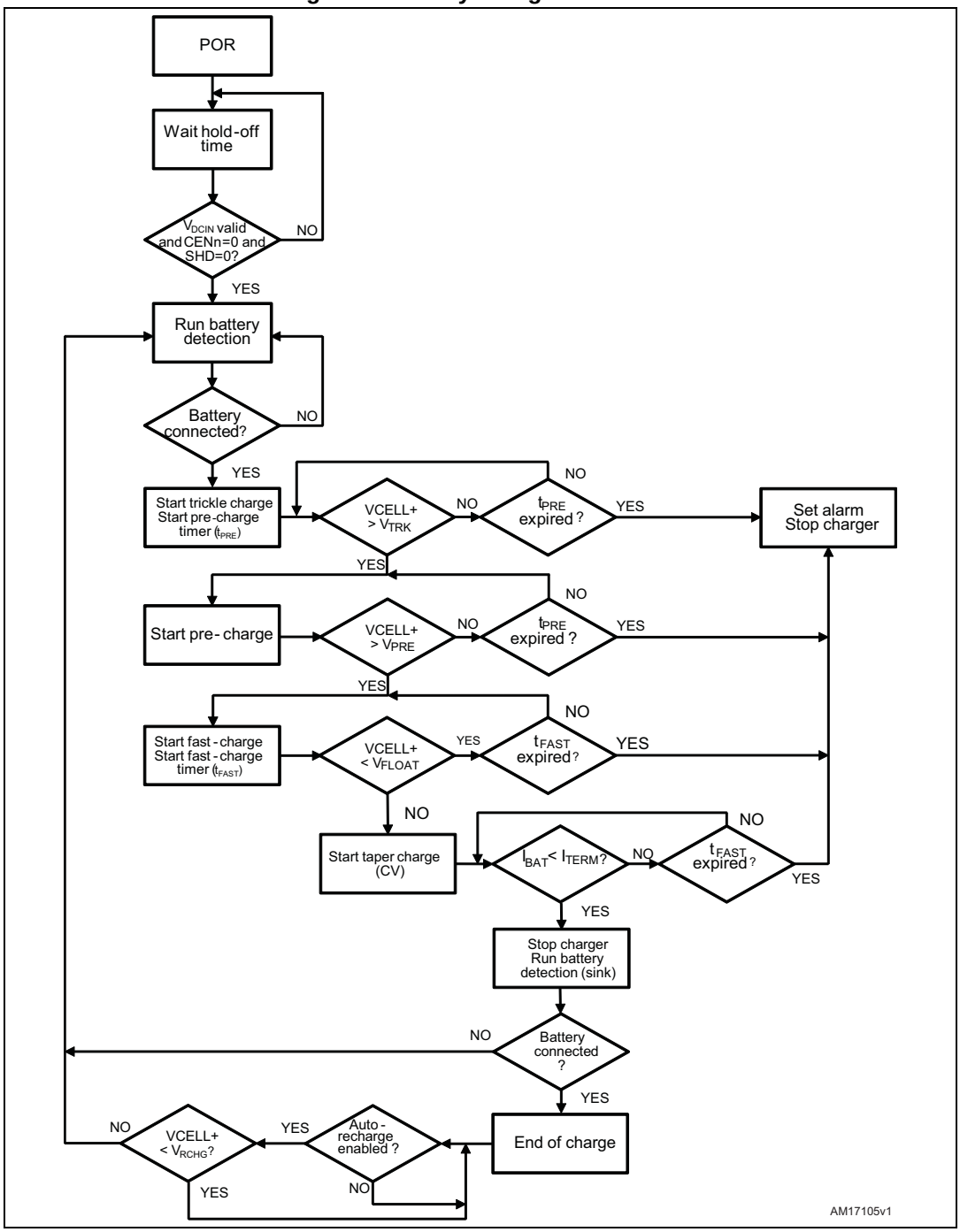
When the charging cycle is over, the device keeps monitoring the battery voltage: if the voltage drops below the auto-recharge threshold (V_{RCHG} = V_{FLOAT} - 120 mV), a new charging cycle starts to keep the battery at maximum capacity. The automatic recharge function can be disabled through I²C.

5.1.4 Battery detection

The battery charger IC features a battery detection function to check if a battery is inserted before starting the charging cycle and to make sure that charging termination is not triggered because of a battery disconnection.

If the battery is not detected when the input voltage is valid, the device keeps running the detection sequence until a battery is inserted. The battery detection result is reported by DET_ok bit. If the battery detection function or RID comparator detects a battery disconnection, BAT_Fail interrupt is generated. See the battery detection algorithm flowchart for more details.

Figure 7. Battery charger flowchart



5.1.5 Battery overvoltage protection

If the battery voltage exceeds the battery overvoltage protection threshold (V_{BATOVP} = V_{FLOAT} + 100 mV) for more than t_{BOVP}, the charging cycle stops and an alarm is generated. The battery overvoltage protection is active only when the charger is enabled. The charger automatically restarts when the battery voltage falls below the battery overvoltage protection threshold.

5.2 OTG boost

The STBCFG01's internal bridge can be used in boost configuration to generate USB OTG V_{BUS} voltage (5 V, 500 mA).

OTG boost generator can be enabled setting the dedicated I²C enable bit (OTG_en) according to the following conditions:

- $V_{DCIN} < V_{INUVLO}$
- CENn = high
- VCELL+ > $V_{BATUVLO}$

OTG boost operation is automatically stopped if the battery voltage falls below $V_{BATUVLO}$ or if CENn is pulled low during operation.

The device also features an output overvoltage protection which turns off OTG boost if the output voltage rises above V_{BUSOVP}. If the overvoltage lasts for more than $t_{VBUSOVP}$, OTG boost is disabled and an alarm is generated.

Together with the standard cycle-by-cycle current limit for the inductor peak current, the STBCFG01 also implements an average battery current limitation to avoid excessive battery voltage drop during peaks in system current consumption. When the average boost input current reaches the programmed limit (I_{BATLIM} = 350 mA, 450 mA, 550 mA, 950 mA), OTG boost is disabled and an alarm is generated.

5.3 LDO regulator

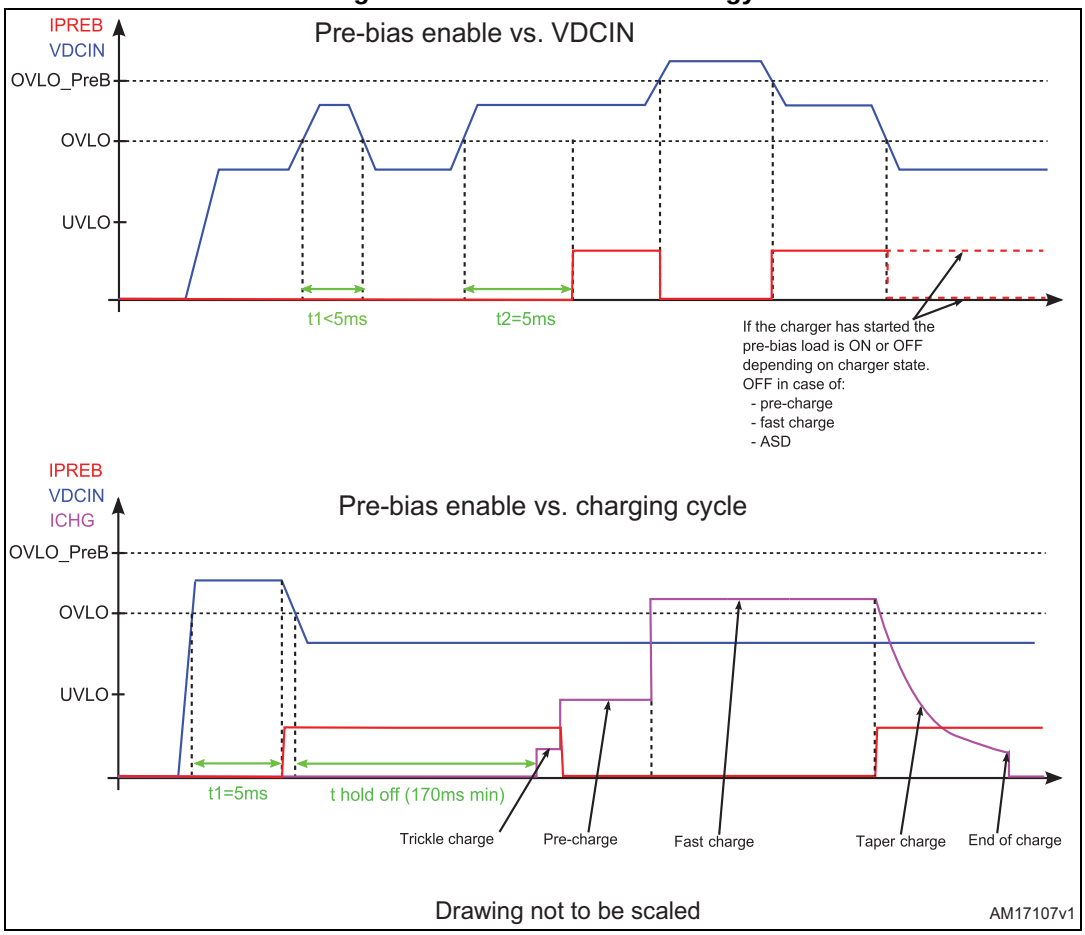
The STBCFG01 integrates a 4.85 V, 50 mA LDO regulator which is active when DCIN voltage is higher than V_{INMIN} and lower then V_{INMAX}. LDO is also active when the battery is not connected and in OTG mode, while it is turned off in automatic shutdown conditions (V_{DCIN} - VCELL+ < V_{ASD}). LDO function can be disabled through I²C and its output is protected against short-circuit.

5.4 Pre-bias

In order to allow proper functionality with input sources not integrating the necessary minimum load to provide a valid voltage, the STBCFG01 integrates an automatic pre-bias circuit: if the input voltage (V_{DCIN}) is above the input OVP threshold but lower than the pre-bias OVP threshold ($V_{INOVP} < V_{DCIN} < V_{INOVP\_PB}$) a pre-bias current is applied to DCIN to attempt reducing the input voltage down to a valid level. During the charging cycle, if the pre-bias current has been activated, it is kept on only during trickle charge and taper charge. The pre-bias current is also turned off in automatic shutdown conditions (ASD).

The pre-bias current is active only if the input voltage is in the activation range for at least t_{PBD} (5 ms typ.). The pre-bias function can be disabled through I²C.

Figure 8. Pre-bias enable strategy



5.5 Fuel gauge

The voltage mode fuel gauge provides the accurate information about the state of the Lithium-Ion battery. Battery voltage is constantly monitored to evaluate the state of charge of battery and open circuit voltage.

At power-up, the fuel gauge algorithm uses the voltage reading to provide a first evaluation of SOC based on battery modeling data. The evolution of voltage is then used to track the changes of SOC of battery while cycling. The external software driver performs the temperature compensation.

Initial accuracy depends on the state of the battery. When the fuel gauge is activated the battery is supposed to be in fully relaxed state. If the battery is not fully relaxed the initial error in the evaluation of the state of charge is high but converges to lower values while the battery is being used.

The fuel gauge block can be adapted to different batteries. Programmable parameters are used to tailor the algorithm to each battery model.

In order to keep the optimal performance and avoid losing information learned during battery cycling, the user is supposed to save data contained in the device's volatile memory when power is removed. The same data has to be restored at power-up.

The STBCFG01 also provides programmable alarms to notify low battery voltage and low SOC conditions.

5.5.1 Operating mode

At start-up and when the battery voltage is below UVLO threshold, the fuel gauge is in standby mode. This block is activated when the battery voltage is above UVLO and GG_RUN bit has been set through I²C. When the fuel gauge is in standby mode, all register values are frozen and the algorithm doesn't run. In active mode, a voltage reading is acquired every 4 seconds (t_{STRB}).

5.5.2 Battery connection

When a battery is connected, the device wakes up and attempts reading the battery voltage before high current loads can change the open circuit voltage. The charging process is inhibited until the battery voltage reading is completed. If the battery voltage is too low, the charger is not inhibited to allow the battery to be charged up to a stable voltage and avoid oscillations.

5.5.3 Low battery alarms

The voltage mode fuel gauge provides low SOC and low battery voltage alarms, which are notified to the host through the active low open drain interrupt register (IRQn). Both of alarms can be disabled clearing ALRM_en bit in FG_Mode register.

Low battery voltage threshold and low SOC threshold can be changed writing ALARM_Voltage and ALARM_SOC registers. The default thresholds are 3.00 V battery voltage and 1% SOC.

When a low battery voltage condition or a low SOC condition is detected and alarms are enabled, the corresponding bit in FG_CTRL register is set (ALRM_VBAT or ALRM_SOC) and IRQn output is pulled low.

ALRM_VBAT and ALRM_SOC bits have to be cleared by the host to release the interrupt pin (if no other interrupt is active in the device).

If the alarm is cleared while the alarm condition is still true, the device doesn't generate another interrupt: the alarm condition has to disappear and be detected again in order to generate another interrupt.

At power-up or when the fuel gauge is reset, fuel gauge alarms are enabled and alarms are generated after the first OCV reading and SOC estimation (if the alarm condition is true).

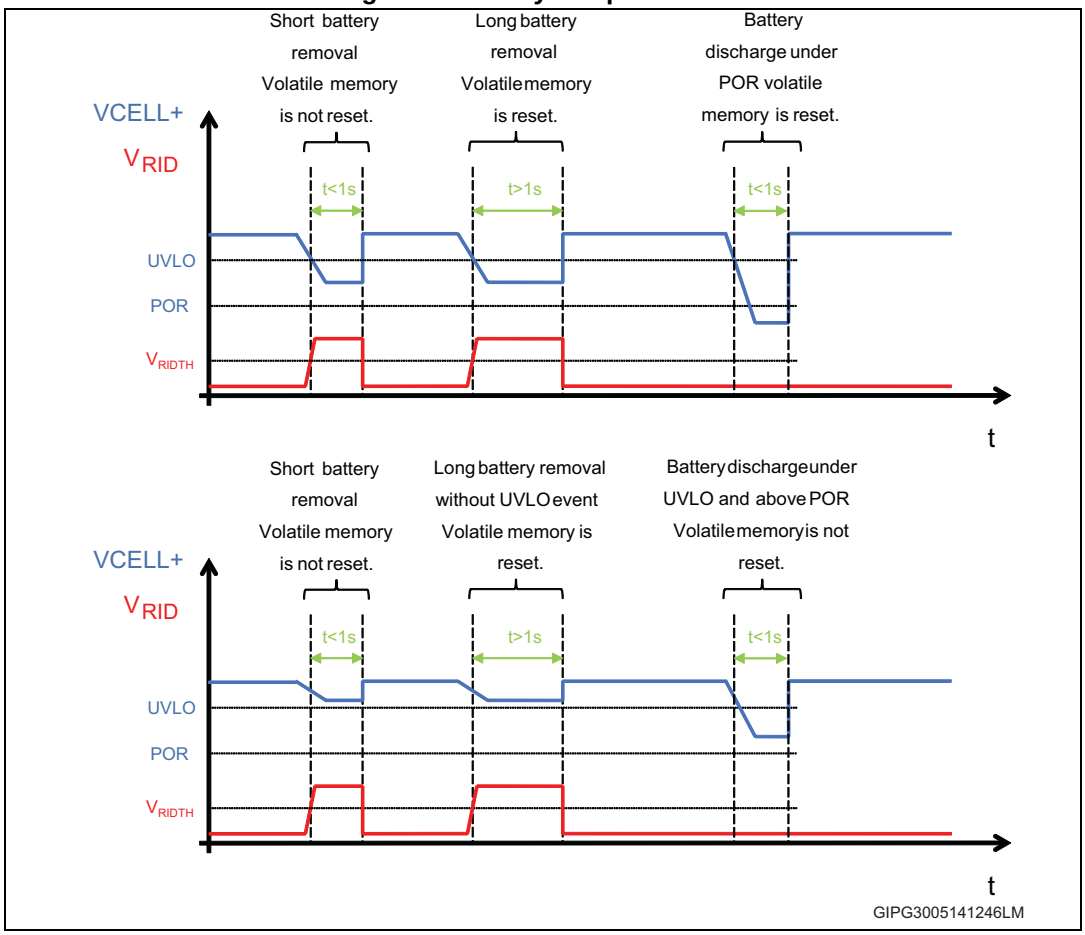
5.5.4 Battery swap

When the battery is removed from the system, the fuel gauge is reset to avoid providing wrong battery information if a different battery is inserted.

In order to detect battery disconnection, the STBCFG01 monitors both the battery voltage (VCELL+) and the voltage on RID pin connected to the battery identification resistor.

All volatile memory information is always lost when the battery voltage falls below POR threshold.

Figure 9. Battery swap detection



5.6 Thermal shutdown

In any working condition, if the die temperature reaches the thermal shutdown threshold (T_{SD} = 165 °C typ.) the device enters shutdown mode: the bridge and LDO output turn off. The fuel gauge keeps working normally. The operation is automatically restored when the temperature falls back into the valid range. Safety timers are reset when a thermal shutdown is triggered.

5.7 Shutdown mode

When SHDN pin is tied high the device enters shutdown mode. In this mode, the switching converter turns off and it cannot be used neither in charging mode nor OTG boost mode. LDO and fuel gauge functionality are not affected by SHDN pin.

5.8 Watchdog

A watchdog timer function can be enabled to reset the programmable register values to power-on reset values if no I²C acknowledgments are generated for more than 45 seconds. This function is normally disabled.

5.9 Alarms

The STBCFG01 provides an open drain active low interrupt output (IRQn) to notify the application processor about abnormal operating conditions or generic events. The following register types check the status of alarms and control the device:

- Interrupt enable
- Interrupt latch

The interrupt enable registers enable the propagation of alarms to the interrupt pin (IRQn). The interrupt is generated (IRQn pulled low) on a rising edge of the interrupt latch bits (assuming that the corresponding enable bit has been set).

The interrupt latch registers show the alarm conditions, which generate the interrupt. Although the alarm condition is no longer active, once each latch register bit is set, it stays high until the register is updated. Interrupt latch registers are updated by writing 0 to their bits: if the alarm condition is still active the bit is kept to 1 (new interrupt is not generated); if the alarm condition is no more active the bit is cleared. This update method assures that no further rising edge on the latch bit is generated for alarms which have already been signaled before the update operation. In order to release IRQn line after an interrupt generated by the charger/OTG, the host processor has to write 0 to IRQ_CLR bit in CHG_Cfg2 register and then back 1. The fuel gauge generated alarms share the same enable bit (ALRM_en) as described in *Section 5.5.3*.

The following conditions generate an interrupt signal:

- DCIN UVLO
- DCIN OVP
- ASD condition
- Pre-charge timer expiration
- Fast charge timer expiration
- Watchdog timer expiration
- Battery overvoltage protection (charger)
- End of charge
- Battery undervoltage lockout (OTG boost)
- V_{BUS} overvoltage protection (OTG boost)
- Average current limit reached (OTG boost, I_{BATLIM})
- OTG output short-circuit; thermal shutdown
- Low battery voltage (fuel gauge)
- Low SOC (fuel gauge)

6 I²C compatible interface registers

The STBCFG01 can be monitored and controlled using the I²C compatible communication interface. The 7-bit device slave address is 1110001_{BIN}.

Table 7 shows the register map.

Table 7. Register map

Name	Address	POR value	R/W
Fuel gauge			
FG_Mode	00h	19h	R/W
FG_CTRL	01h	15h	R/W
SOC	02h-03h	0000h	R/W
VBAT	08h-09h	0000h	R
OCV	0Dh-0Eh	0000h	R
VM_CNF	11h-12h	0141h	R/W
ALARM_SOC	13h	02h	R/W
ALARM_Voltage	14h	AAh	R/W
REG_ID	18h	14h	R
RAM0…RAM15	20h…2Fh	-	R/W
OCV_ADJ	30h…3Fh	-	R/W
LUT	5Dh…8Ch	-	R/W
Charger/OTG			
CHG_Cfg1	90h	00h	R/W
CHG_Cfg2	91h	62h	R/W
CHG_Cfg3	92h	61h	R/W
CHG_Cfg4	93h	4Fh	R/W
CHG_Cfg5_OTG_Status	94h	06h	R/W
CHG_Status1	95h	00h	R
CHG_Status2	96h	C0h	R
Int_Enable_1	97h	00h	R/W
Int_Enable_2	98h	00h	R/W
Int_Latch_1	99h	00h	R/W
Int_Latch_2	9Ah	00h	R/W

6.1 Fuel gauge registers

Table 8. Fuel gauge mode register (address: 00h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
-	OTG_en	LPM_dis	GG_RUN	ALRM_en	-	-	-	19h	R/W

ALRM_en: fuel gauge alarm enable

- 0: disabled
- 1: enabled (default)

GG_RUN: fuel gauge operative mode

- 0: standby (default). Registers are frozen, fuel gauge in standby
- 1: running

LPM_dis: low power mode disable (set this bit to program battery charger/OTG configuration registers and enable OTG function when USB input is not plugged and GG_RUN = 0)

- 0: low power mode enabled (default)
- 1: low power mode disabled

OTG_en: OTG boost enable bit

- 0: disabled (default)
- 1: enabled

Table 9. FG_CTRL register (address: 01h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
-	ALRM_VBAT	ALRM_SOC	POR_Det	BAT_Fail	-		IODATA	15h	R/W

IODATA: IRQn pin status

Read:

- 0: IRQn pin is low
- 1: IRQn pin is high

Write:

- 0: forces IRQn pin low
- 1: IRQn pin is driven by interrupt logic

BAT_Fail: battery removal or battery UVLO detection bit. Write 0 to clear

- 0: battery connected
- 1: battery removed or UVLO

POR_Det: power-on reset detection bit. Write 1 to force a soft reset (self-clearing)

- 0: no POR event occurred
- 1: POR event occurred

ALRM_SOC: low SOC alarm

- 0: SOC OK
- 1: low SOC

Note: Write this bit to 0 to clear the alarm. If the alarm condition is still active a new alarm is triggered only on the following rising edge of the alarm condition (the alarm condition has to disappear and then appear again).

ALRM_VBAT: low battery voltage alarm

- 0: battery voltage above threshold
- 1: low battery voltage

Note: Write this bit to 0 to clear the alarm. If the alarm condition is still active a new alarm is triggered only on the following rising edge of the alarm condition (the alarm condition has to disappear and then appear again).

Table 10. SOC register LSB (register address: 02h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
SOC[7:0]								00h	R/W

Table 11. SOC register MSB (register address: 03h)

b15	B14	b13	b12	b11	b10	b9	b8	POR	R/W
SOC[1:8]								00h	R/W

SOC register LSb: 1/512% SOC

Table 12. VBAT register LSB (register address: 08h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
VBAT[7:0]								00h	R

Table 13. VBAT register MSB (register address: 09h)

b15	B14	b13	b12	b11	b10	b9	b8	POR	R/W
Reserved					VBAT[10:8]			00h	R

VBAT register LSb: 2.69 mV

Table 14. OCV register LSB (register address: 0Dh)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
OCV[7:0]								00h	R

Table 15. OCV register MSB (register address: 0Eh)

b15	B14	b13	b12	b11	b10	b9	b8	POR	R/W
Reserved			OCV[12:8]					00h	R

OCV register LSb: 0.67 mV

Table 16. VM_CNF register LSB (register address: 11h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
VM_CNF[7:0]								41h	R/W

Table 17. VM_CNF register MSB (register address: 12h)

b15	B14	b13	b12	b11	b10	b9	b8	POR	R/W
VM_CNF[15:8]								01h	R

Table 18. ALARM_SOC register (address: 13h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
ALARM_SOC								02h	R/W

ALARM_SOC register LSb: 0.5%

Table 19. ALARM_Voltage register (address: 14h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
ALARM_Voltage								AAh	R/W

ALARM_Voltage register LSb: 21.49 mV

6.2 Charger/OTG/LDO registers

Table 20. CHG_Cfg1 register

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
ITERM				IPRE	IFAST			40h	R/W

IFAST: fast charge current

- Offset: 550 mA
- LSb: 100 mA
- Range: 550 mA to 1250 mA
- Default: 550 mA (000)

IPRE: pre-charge current:

- 0: 450 mA (default)
- 1:100 mA

ITERM: termination current

- Offset: 50 mA
- LSb: 25 mA
- Range: 50 mA to 300 mA
- Default: 150 mA (0100)
- Values 1011 through 1111: reserved

Table 21. CHG_Cfg2 register (address: 91h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
IRQ_CLR	ARCHG	VFLOAT						C0h	R/W

VFLOAT: floating voltage

- Offset: 3.52 V
- LSb: 20 mV
- Range: 3.52 V to 4.78 V
- Default: 3.52 V (000000)

ARCHG: automatic recharge enable

- 0: disabled
- 1: enabled (default)

IRQ_CLR: clear interrupt latch

- 0: clear interrupt latch
- 1: propagate interrupt (default)

Table 22. CHG_Cfg3 register (address: 92h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
IBATLIM		VDICL		DICL_en	Iin_lim			61h	R/W

Iin_lim**:** input current limit (DCIN)

- 000: max.100 mA
- 001: max.
- 500 mA (default)
- 010: max. 800 mA
- 011: max. 1.2 A
- 100: no limit
- Values 101 through 111: reserved

DICL_en**:** dynamic input current limit enable

- 0: disabled (default)
- 1: enabled

VDICL**:** dynamic input current limit threshold

- 00: 4.00 V
- 01: 4.25 V
- 10: 4.50 V (default)
- 11: 4.75 V

IBATLIM**:** OTG average battery current limit

- 00: 350 mA
- 01: 450 mA (default)
- 10: 550 mA
- 11: 950 mA

Table 23. CHG_Cfg4 register format (register address: 93h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
RID_STAT	LDO_en	LDO_UVLO_th	WD	PreB_en	THRML	TFAST	TPRE	4Fh	R/W

TPRE**:** pre-charge timer enable

- 0: disabled
- 1: enabled (default)

TFAST**:** fast charge timer enable

- 0: disabled
- 1: enabled (default)

THRML**:** thermal loop enable (this bit can be masked through OTP)

- 0: disabled
- 1: enabled (default)

PreB_en**:** pre-bias function enable

- 0: disabled
- 1: enabled (default)

WD: watchdog timer function enable

- 0: disabled (default)
- 1: enabled

LDO_UVLO_th**:** LDO UVLO threshold

- 0: 3.6 V rising, 3.5 V falling (default)
- 1: 4.75 V rising, 4.65 V falling

LDO_en**:** LDO output enable

- 0: LDO output disabled
- 1: LDO output enabled (default)

RID_STAT: RID status (read only)

- 0: RID connected
- 1: RID disconnected

Table 24. CHG_Cfg5_OTG_Status register format (register address: 94h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
BST_SH	BST_status			-	DICHG_adj	FSW	CHG_rst	06h	R/W

Note: b0, b1, b2 are R/W; b4, b5, b6, b7 are read status bit only.

CHG_rst: charger reset, all charger registers to POR value. Self-clearing.

- 0: no action (default)
- 1: reset charger

FSW**:** switching frequency. The switching frequency can be changed only when the device doesn't switch. SHDN input should be pulled high before modifying this setting.

- 0: 2 MHz
- 1: 3 MHz (default)

DICHG_adj**:** dynamic charging current adjustment enable (for soft-current transitions)

- 0: disabled
- 1: enabled (default)

BST_status**:** OTG boost status

- 000: idle
- 001: wait soft-start
- 010: linear soft-start
- 011: switching soft-start
- 100: frequency ramp-up
- 101: OTG_run
- 110: PMOS-off
- 111: shutdown

BST_SH**:** OTG boost output short at beginning

- 0: no short detected (default)
- 1: short detected

Table 25. CHG_Status1 register format (register address: 95h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
CHG_status					PreB_st	PreB	Alarm	00h	R

Alarm**:** alarm state

- 0: no alarm is active
- 1: alarm condition detected

PreB**:** pre-bias current activation

- 0: pre-bias current has not been activated
- 1: pre-bias current has been activated ($V_{INOVP} < V_{DCIN} < V_{INOVP\_PB}$ for more than t_{PBD})

PreB_st**:** pre-bias current sink status

- 0: pre-bias current sink is currently off
- 1: pre-bias current sink is currently on

CHG_status**:** charger status

- 00000: idle
- 00001: trickle charge
- 00010: pre-charge
- 00011: fast charge
- 00100: taper charge (constant voltage)
- 00101: charge done (termination)
- 00110: boost on
- 00111: shutdown
- 01000: battery detection running

Table 26. CHG_Status2 register format (register address: 96h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
-	-	-	-	-	DET_ok	DET_run	DICL	C0h	R

DICL**:** dynamic input current limit activation

- 0: not active
- 1: active

DET_run**:** charger battery detection status

- 0: battery detection doesn’t run
- 1: battery detection runs

DET_Fail: charger battery detection result

- 0: battery connected
- 1: battery not connected

Table 27. Int_Enable_1 register format (register address: 97h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
EOC	Bat_OVP	WD	Fast_TMR	Pre_TMR	ASD	IN_OVP	IN_UVLO	00h	R/W

For all bits:

- Write 1 to propagate the event to IRQn
- Write 0 to mask the event (default)

IN_UVLO**:** charger input voltage UVLO

IN_OVP**:** charger input voltage OVP

ASD**:** automatic shutdown condition

Pre_TMR**:** pre-charge timer expiration

Fast_TMR**:** fast charge timer expiration

WD**:** watchdog timer expiration

Bat_OVP**:** battery overvoltage protection

EOC**:** end of charge (termination current reached)

Table 28. Int_Enable_2 register format (register address: 98h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
BAT_Fail	CHG_ON	-	OTG_short	Ibat_Lim	VBus_OVP	TSHDN	Bat_UVLO	00h	R/W

For all bits:

- Write 1 to propagate the event to IRQn
- Write 0 to mask the event (default)

Bat_UVLO**:** battery UVLO (OTG)

TSHDN**:** thermal shutdown

VBus_OVP**:** OTG boost output OVP

Ibat_Lim**:** OTG battery average current limit

OTG_short**:** OTG output short-circuit

CHG_ON: charging started

BAT_Fail: battery fail

Table 29. Int_Latch_1 register format (register address: 99h)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
EOC	Bat_OVP	WD	Fast_TMR	Pre_TMR	ASD	IN_OVP	IN_UVLO	00h	R/W

Note: This register is cleared upon read operation.

IN_UVLO**:** charger input voltage UVLO

- 0: charger input voltage is above UVLO
- 1: charger input voltage is below UVLO

IN_OVP**:** charger input voltage OVP

- 0: charger input voltage is below OVP
- 1: charger input voltage is above OVP

ASD**:** automatic shutdown condition

- 0: charger input voltage above the automatic shutdown threshold
- 1: charger input voltage below the automatic shutdown threshold

Pre_TMR**:** pre-charge timer expiration (has to be cleared by the host)

- 0: pre-charge timer running
- 1: pre-charge timer expired

Fast_TMR**:** fast charge timer expiration (has to be cleared by the host)

- 0: fast charge timer running
- 1: fast charge timer expired

WD**:** watchdog timer expiration (has to be cleared by the host)

- 0: watchdog timer running
- 1: watchdog timer expired

Bat_OVP**:** battery overvoltage protection

- 0: battery voltage below OVP threshold during charging
- 1: battery voltage above OVP threshold during charging

EOC**:** end of charge (termination current reached)

- 0: termination current not reached
- 1: termination current reached

Table 30. Int_Latch_2 register format (register address: 9Ah)

b7	b6	b5	b4	b3	b2	b1	b0	POR	R/W
BAT_Fail	CHG_ON	TSHDN_LDO	OTG_short	Ibat_Lim	VBus_OVP	TSHDN	Bat_UVLO	00h	R/W

Note: Write 0 to update these register bits.

Bat_UVLO**:** battery UVLO (OTG)

- 0: battery voltage above UVLO threshold during boost operation
- 1: battery voltage below UVLO threshold during boost operation

TSHDN**:** thermal shutdown

- 0: device in normal operation conditions
- 1: device in thermal shutdown

VBus_OVP**:** OTG boost output OVP

- 0: OTG boost output voltage below OVP threshold
- 1: OTG boost output voltage above OVP threshold

Ibat_Lim**:** OTG battery average current limit (has to be cleared by the host)

- 0: average battery current limit not reached during OTG boost operation
- 1: average battery current limit reached during OTG boost operation

OTG_short**:** OTG output short-circuit

- 0: OTG output short-circuit condition not detected
- 1: OTG output short-circuit condition detected

TSHDN_LDO**:** LDO thermal shutdown

- 0: LDO in normal operation conditions
- 1: LDO in thermal shutdown

CHG_ON: charger cycle start

- 0: charging cycle not active
- 1: charging cycle started

BAT_Fail: battery status (from state machine or RID)

- 0: battery connected/good battery
- 1: battery disconnected/not good

7 Package mechanical data

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK is an ST trademark.

Figure 10. Flip Chip 25 (2.3 x 2.2 mm) drawings

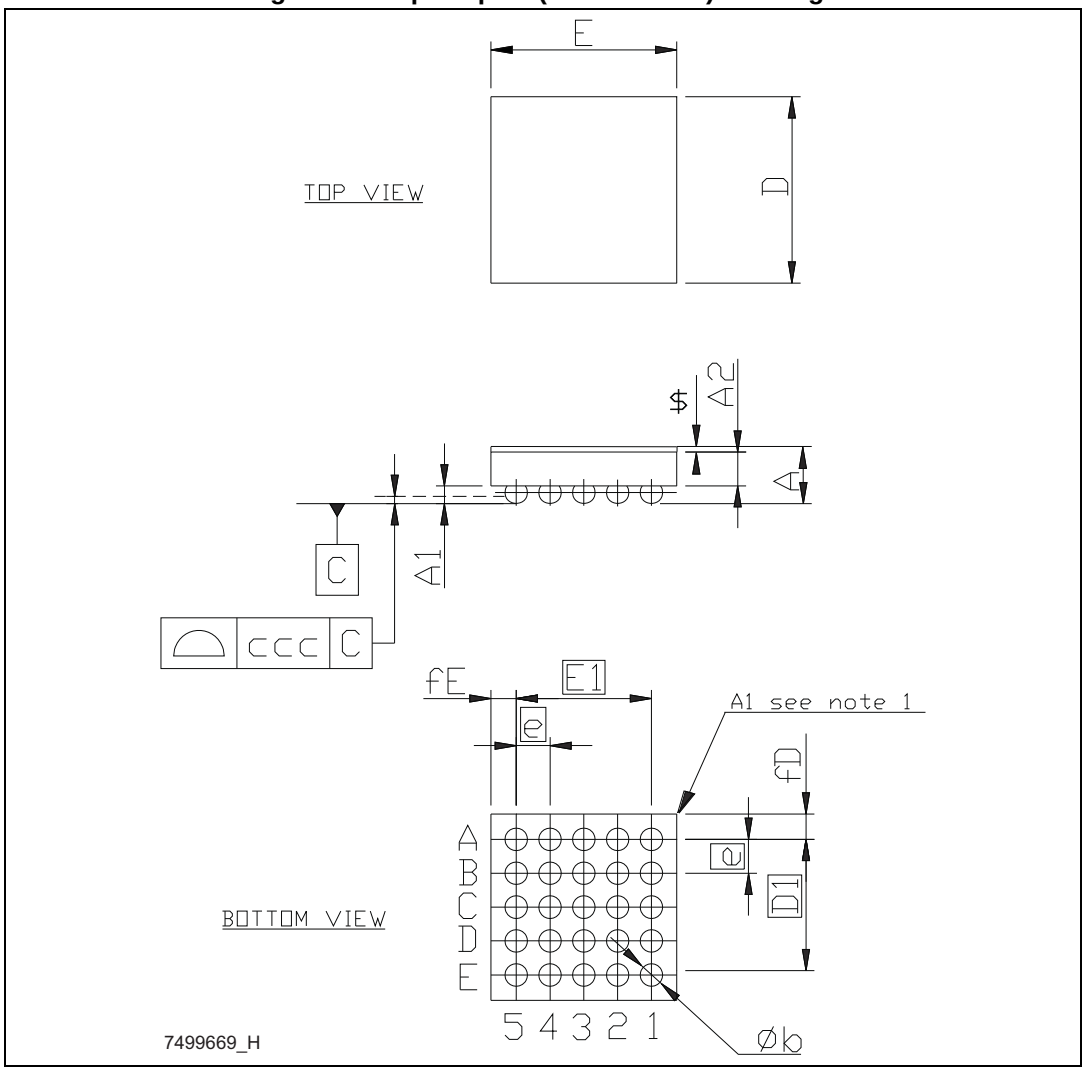
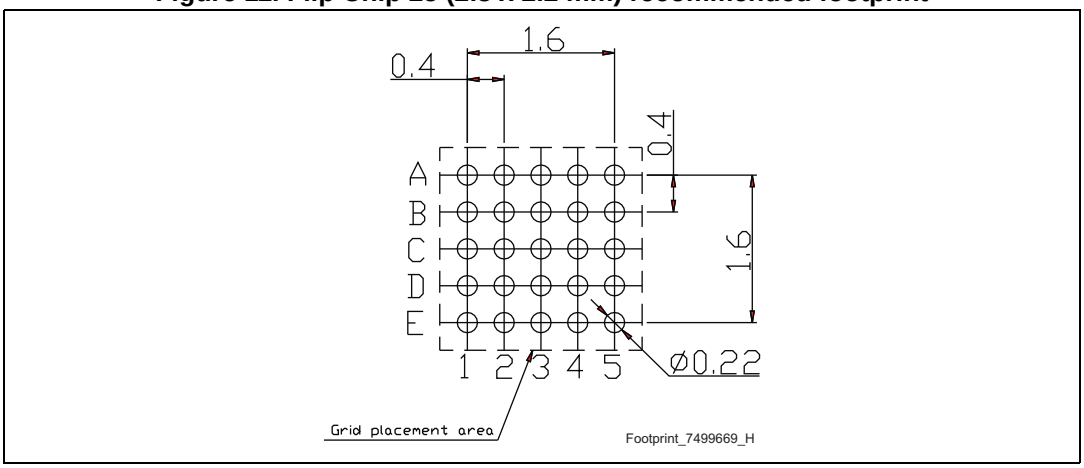


Table 31. Flip Chip 25 (2.3 x 2.2 mm) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	0.495	0.55	0.605
A1	0.17	0.20	0.23
A2	0.275	0.30	0.325
b	0.23	0.26	0.29
D	2.25	2.28	2.31
D1		1.6	
E	2.16	2.19	2.22
E1		1.6	
e		0.4	
fD	0.33	0.34	0.35
fE	0.285	0.295	0.305
ccc		0.075	
$		0.05	

Figure 11. Flip Chip 25 (2.3 x 2.2 mm) recommended footprint



8 Revision history

Table 32. Document revision history

Date	Revision	Changes
10-Jun-2014	1	Initial release.
09-Dec-2014	2	Added *Table 2: Typical external components table*.