STBB3J

2 A, high efficiency single inductor buck-boost DC-DC converter

Datasheet - production data

Flip Chip 20, pitch = 0.4 mm

Features

- Input voltage range from 1.8 V to 5.5 V
- 2 A output current at 3.3 V in buck mode (V_{IN} = 3.6 V to 5.5 V)
- 800 mA output current at 3.3 V in boost mode (V_{IN} 2.0 V)
- Typical efficiency higher than 94%
- ± 2% DC feedback voltage tolerance
- Automatic transition between step-down and boost mode
- Adjustable output voltage from 1.2 V to 5.5 V
- Power save mode (PS) at light load
- 2.0 MHz fixed switching frequency
- Adjustable switching frequency up to 2.4 MHz (by external synchronous square signal)
- Device quiescent current less than 50 µA
- Load disconnect during shutdown
- Shutdown function and soft-start
- Shutdown current < 1 µA
- Available in Flip Chip 20, pitch = 0.4 mm

Applications

- Single cell Li-Ion, two-cell and three-cell alkaline, Ni-MH powered devices
- Memory card supply
- Tablet, smartphones
- Digital cameras

Description

The STBB3J is a fixed frequency, high efficiency, buck-boost DC-DC converter which provides output voltages from 1.2 V to 5.5 V starting from input voltage from 1.8 V to 5.5 V. The device can operate with input voltages higher than, equal to, or lower than the output voltage making the product suitable for cell lithium-Ion applications where the output voltage is within the battery voltage range. The low-$R_{DS(on)}$ N-channel and P-channel MOSFET switches are integrated and contribute to achieve high efficiency. The MODE pin allows the selection between auto mode and forced PWM mode, taking advantage from either lower power consumption or best dynamic performance.The device also includes soft-start control, thermal shutdown, and current limit. The STBB3J is packaged in Flip Chip 20 bumps with 2.5 x 1.75 mm.

Table 1. Device summary

Order code	Part number	Marking	Packing	Output voltage
STBB3JR	STBB3J	BB3	Flip Chip 20	Adjustable

Contents

List of figures

1 Application schematic

Figure 1. Application schematic for adjustable output version

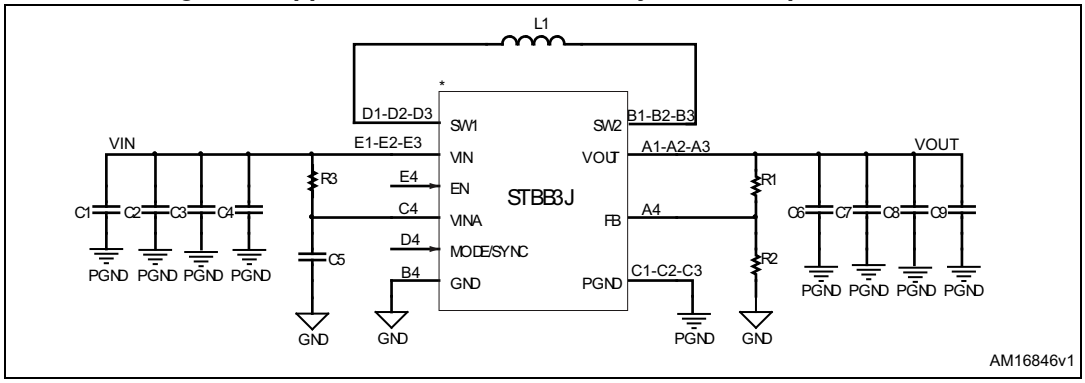


Table 2. Typical external components

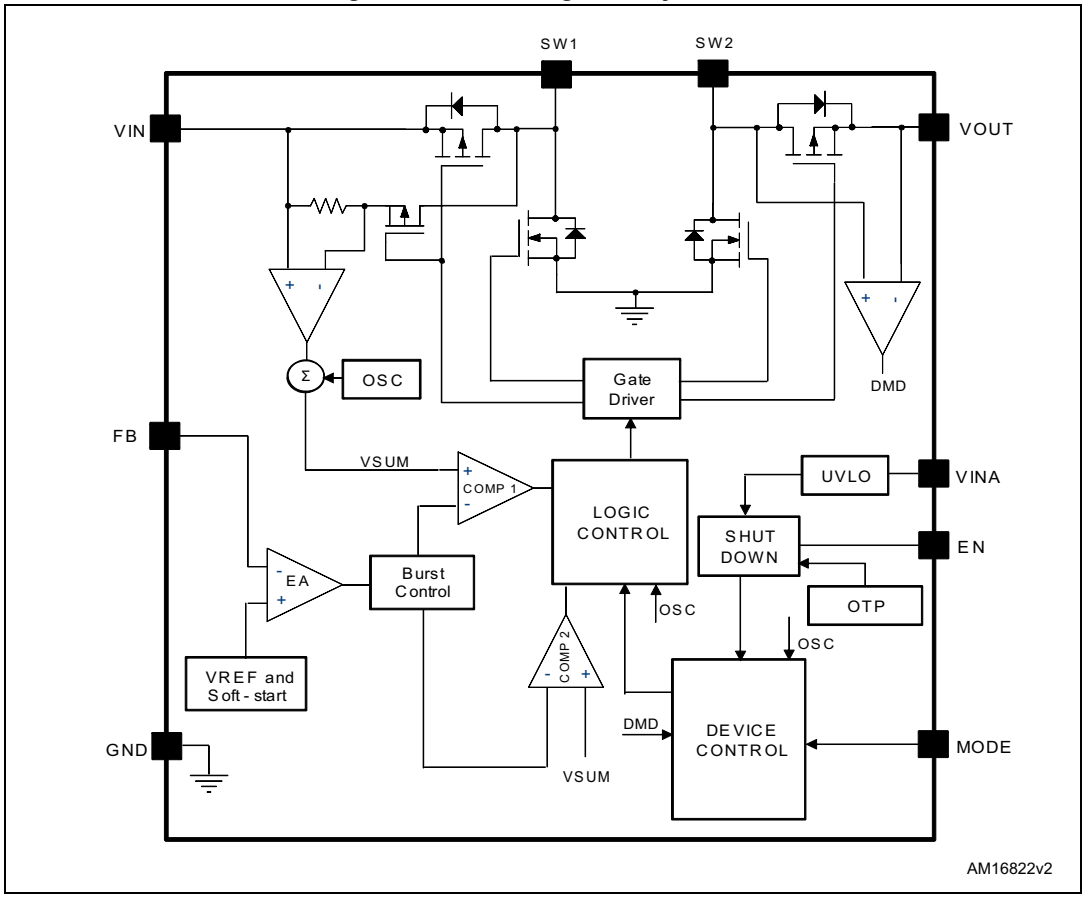
Component	Manufacturer	Part number	Value	Size
C1,C2,C3, C4	Murata	GRM188R60J106ME84	10 µF	0603
C6, C7, C8, C9	TDK-EPC	C1608X5R1A106M		
C5	Murata	TBD	100 nF	0603
	TDK-EPC	C1608X7R1H104K		
L(1)	Coilcraft	XFL4020-152MEB	1.5 µH	4 x 3.2 x 1.5 mm
	TDK-EPC	VLF403215MT-1R5N		4 x 4 x 2 mm
R1	Depending on the output voltage			0603
R2	Depending on the output voltage			0603
R3	-	-	47 Ω	0603

1. Inductor used for the maximum power capability. Optimized choice can be made according to the application conditions (see *Section 8*).

Note: All the above components refer to a typical application. Operation of the device is not limited to the choice of these external components.

2 Block diagram

Figure 2. Block diagram adjustable



3 Pin configuration

Figure 3. Pin connection top view

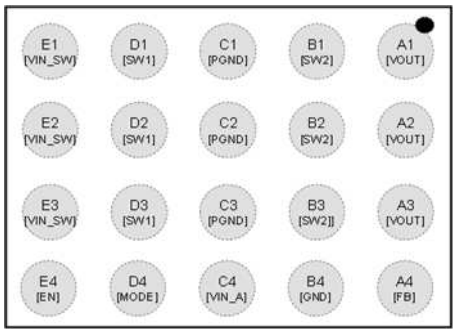


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Figure 4. Pin connection bottom view

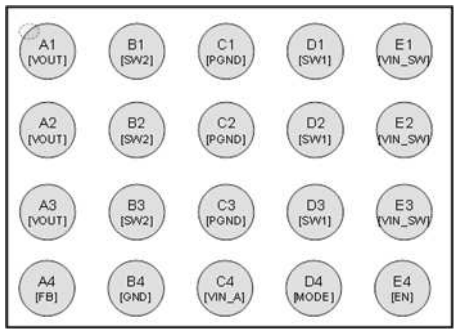

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Table 3. Pin description

Pin name	Pin	Description
VOUT	A1, A2, A3	Output voltage.
SW1	D1, D2, D3	Switch pin - internal switches are connected to this pin. Connect inductor between SW1 to SW2.
PGND	C1, C2, C3	Power ground.
SW2	B1, B2, B3	Switch pin - internal switches are connected to this pin. Connect inductor between SW1 and SW2.
EN	E4	Enable pin. Connect this pin to GND or a voltage lower than 0.4 V to shut down the IC. A voltage higher than 1.2 V is required to enable the IC.
MODE/SYNC	D4	When in normal operation, the MODE pin selects between auto transition mode and fixed frequency PWM mode. If the MODE pin is low, the STBB3J automatically switches between pulse-skipping and standard fixed frequency PWM according to the load level. If the MODE pin is pulled high, the STBB3J works always at fixed frequency. When a square wave is applied, this pin provides the clock signal for oscillator synchronization.
VIN_A	C4	Supply voltage for control stage. Connecting an R-C filter between VIN_A and GND.
VIN_SW	E1, E2, E3	Power input voltage.
GND	B4	Signal ground.
FB	A4	Feedback voltage.

4 Absolute maximum ratings

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
VIN_A, VIN_SW	Supply voltage	-0.3 to 7.0	V
SW1,SW2	Switching nodes	-0.3 to 7.0	V
VOUT	Output voltage	-0.3 to 7.0	V
MODE, EN	Logic pins	-0.3 to 7.0	V
FB	Feedback pin for adjustable version	-0.3 to 1.5	V
ESD	Human body model	± 2000	V
T_{AMB}	Operating ambient temperature	-40 to 85	°C
T_J	Maximum operating junction temperature	150	°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
$R_{th(JA)}$	Thermal resistance junction-ambient	84	°C/W

5 Electrical characteristics

V_{IN} = V_{INA} = V_{EN} = 3.6 V, V_{OUT} = 3.3 V, C_{IN} = 4x10 µF, C_{OUT} = 4 x 10 µF, R_{INA} = 47 Ohm, C_{INA} = 100 nF, L = 1.5 µH, T_A = - 40 °C to 85 °C (unless otherwise specified; typical values are referred to T_A = 25 °C).

Table 6. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
General section						
V_{IN}	Input voltage range		1.8		5.5	V
	Minimum input voltage for the startup	I_{OUT} = 600 mA, mode = V_{IN}		1.8	1.9	V
V_{UVLO}	Undervoltage lockout threshold	V_{INA} rising, I_{OUT} = 100 mA MODE = $V_{IN;}$	1.5	1.6	1.7	V
		V_{INA} falling; I_{OUT} = 100 mA V_{MODE} = $V_{IN;}$	1.4	1.5	1.6	
I_q	Quiescent current V_{IN} and V_{INA}	I_{OUT} = 0 A V_{MODE} = GND			50	µA
I_{SHDN}	Shutdown current	V_{EN} = GND		0.1	1	µA
V_{FB}	Feedback voltage	V_{IN} from 1.8 to 5.5 V	490	500	510	mV
f_{SW}	Switching frequency	T_A = 25 °C	1.8	2	2.2	MHz
	Frequency range for external synchronization		1.6		2.4	
I_{OUT}	Continuous output current (1)	V_{IN} from 1.8 to 5.5 V	600			mA
I_{SWL}	Switch current limitation	T_A = 25 °C	2.8	3	3.65	A
I_{PK}	Switch current limitation		2.3	2.5	2.7	A
I_{PS-PWM}	PS to PWM transition			730		mA
	PWM to PS transition			680		
Output voltage						
V_{OUT}	Output voltage range		1.2		5.5	V
$\%\Delta_{OUT}$	Maximum load regulation	V_{IN} = 2.5 to 5.5 V, V_{MODE} = V_{IN}	-1.5		+1.5	%
		V_{IN} = 2.5 to 5.5 V, V_{MODE} = GND suitable output current to keep PS operation	-3		+3	%
$\%V_{OUT}$	Maximum load regulation	I_{LOAD} = from 10 mA to 800 mA		± 0.5		%
V_{OPP-PS}	Peak-to-peak ripple in PS mode	I_{OUT} = 100 mA		100		mV
I_{LKFB}	FB pin leakage current	V_{FB} = 1.5 V			1	µA
Control stage						
V_{IL}	Low-level input voltage (EN, MODE pins)				0.4	V

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IH}	High-level input voltage (EN, MODE pins)		1.2			V
I_{LK-I}	Input leakage current (EN, MODE pins)	$V_{EN} = V_{MODE} = 5.5$ V		0.01	1	µA
T_{ON}	Turn on-time(2)	V_{EN} from low to high, $I_{OUT} = 10$ mA		260	300	µs
Power switches						
$R_{DS(on)}$	P-channel on-resistance			100	300	mΩ
	N-channel on-resistance			100	300	mΩ
I_{LKG-P}	P-channel leakage current	$V_{IN} = V_{OUT} = 5.5$ V; $V_{EN} = 0$			1	µA
I_{LKG-N}	N-channel leakage current	$V_{SW1} = V_{SW2} = 5.5$ V; $V_{EN} = 0$			1	µA

1. Not tested in production. This value is guaranteed by correlation with $R_{DS(on)}$, peak current limit and operating input voltage.
2. Not tested in production.

6 Typical performance characteristics

Table 7. Table of graphs

Parameter	Test conditions	Ref.
Efficiency	vs. output current (power save enabled, V_{IN} = 1.8 V, 3.6 V, 5.5 V/V_{OUT} = 3.3 V)	*Figure 4*
	vs. output current (power save disabled, V_{IN} = 1.8 V, 3.6 V, 5.5 V/V_{OUT} = 3.3 V)	*Figure 5*
	vs. output current (PWM/auto mode), V_{IN} = 1.8 V, V_{OUT} = 3.3 V	*Figure 6*
	vs. output current (PWM/auto mode), V_{IN} = 3.6 V, V_{OUT} = 3.3 V	*Figure 7*
	vs. output current (PWM/auto mode), V_{IN} = 5.5 V, V_{OUT} = 3.3 V	*Figure 8*
Maximum output current	vs. input voltage (V_{OUT} = 3.3 V, V_{OUT} = 5.0 V)	*Figure 9*
Waveforms	Line transient response (V_{IN} = 3.0 V to 3.6 V, V_{OUT} = 3.3 V, I_{OUT} = 300 mA)	*Figure 10*
	Line transient response (V_{IN} = 3.6 V to 3.0 V, V_{OUT} = 3.3 V, I_{OUT} = 300 mA)	*Figure 11*
	Line transient response (V_{IN} = 3.6 V to 4.0 V, V_{OUT} = 3.3 V, I_{OUT} = 300 mA)	*Figure 12*
	Line transient response (V_{IN} = 4.0 V to 3.6 V, V_{OUT} = 3.3 V, I_{OUT} = 300 mA)	*Figure 13*
	Load transient response V_{IN} = 1.8 V V_{OUT} = 3.3 V, I_{OUT} = 100 to 300 mA	*Figure 14*
	Load transient response V_{IN} = 1.8 V V_{OUT} = 3.3 V, I_{OUT} = 300 to 100 mA	*Figure 15*
	Load transient response V_{IN} = 3.6 V V_{OUT} = 3.3 V, I_{OUT} = 100 to 300 mA	*Figure 16*
	Load transient response V_{IN} = 3.6 V V_{OUT} = 3.3 V, I_{OUT} = 300 to 100 mA	*Figure 17*
	Load transient response V_{IN} = 5.5 V V_{OUT} = 3.3 V, I_{OUT} = 100 to 300 mA	*Figure 18*
	Load transient response V_{IN} = 5.5 V V_{OUT} = 3.3 V, I_{OUT} = 300 to 100 mA	*Figure 19*
	Startup after enable (V_{IN} = 1.8 V, V_{OUT} = 3.3 V, I_{OUT} = 10 mA)	*Figure 20*
	Startup after enable (V_{IN} = 3.6 V, V_{OUT} = 3.3 V, I_{OUT} = 10 mA)	*Figure 21*
	Startup after enable (V_{IN} = 5.5 V, V_{OUT} = 3.3 V, I_{OUT} = 10 mA)	*Figure 22*
Output voltage	vs. output current (V_{OUT} = 3.3 V)	*Figure 23*

Figure 5. Efficiency vs. output current (power save mode enabled V_{OUT} = 3.3 V)

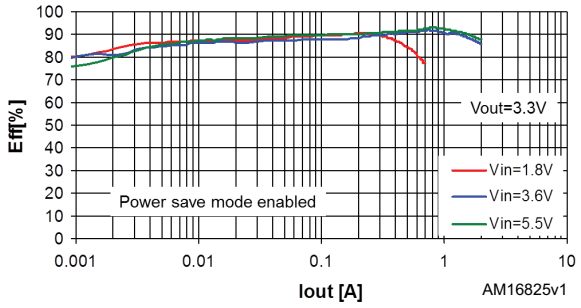


Figure 6. Efficiency vs. output current (power save mode disabled V_{OUT} = 3.3 V)

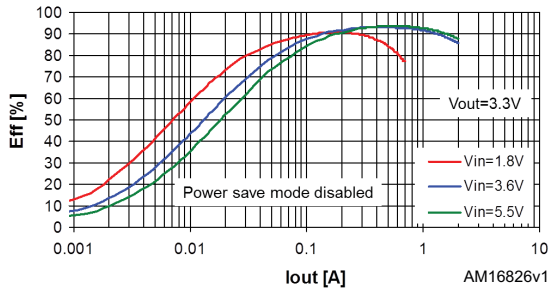


Figure 7. Efficiency vs. output current (PWM/auto mode V_{IN} = 1.8 V)

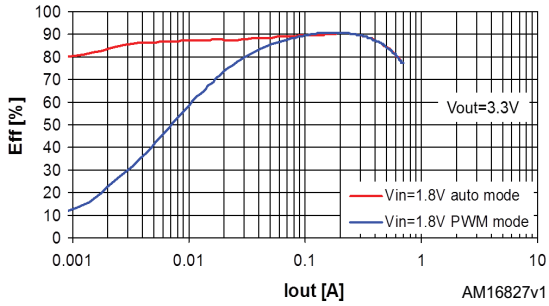


Figure 8. Efficiency vs. output current (PWM/auto mode V_{IN} = 3.6 V)

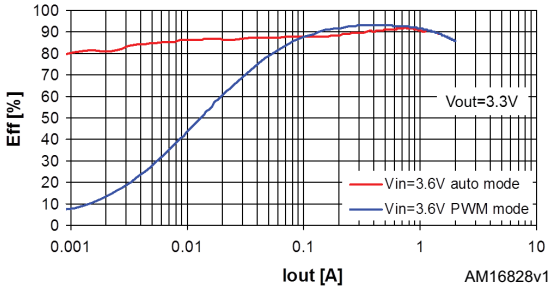


Figure 9. Efficiency vs. output current (PWM/auto mode V_{IN} = 5.0 V)

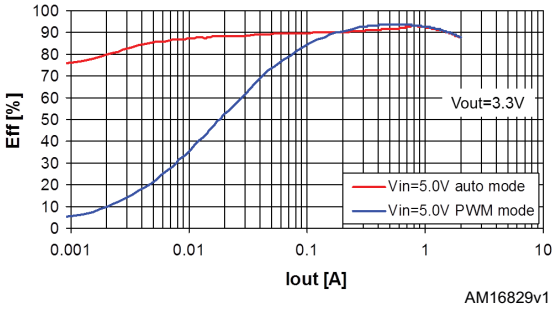


Figure 10. Maximum output current vs. input voltage

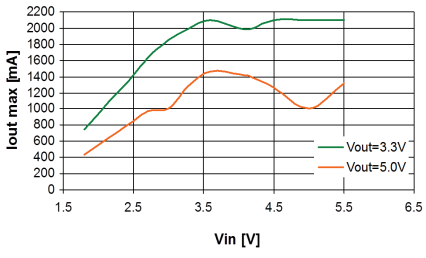
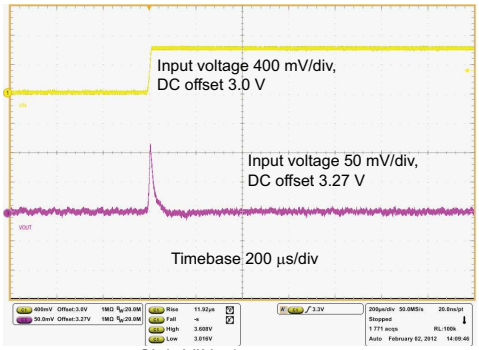
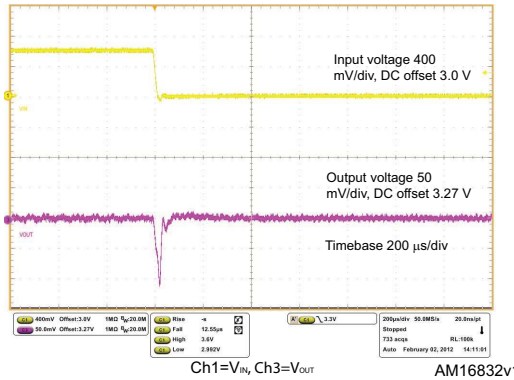


Figure 11. Line transient response @ V_{IN} = 3 V to 3.6 V



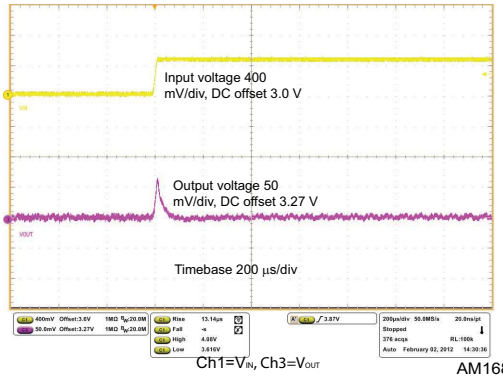
Ch1=VIN, Ch3=VOUT AM16831v1

Figure 12. Line transient response @ V_{IN} = 3.6 V to 3 V



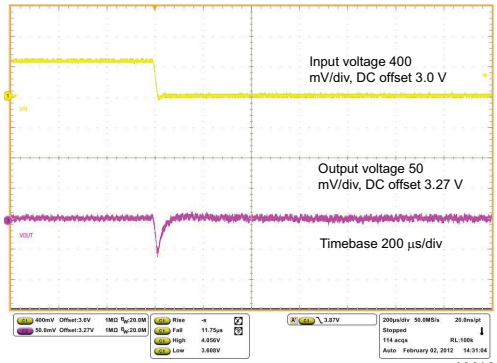
Ch1=V_{IN}, Ch3=V_{OUT} AM16832v1

Figure 13. Line transient response @ V_{IN} = 3.6 V to 4 V



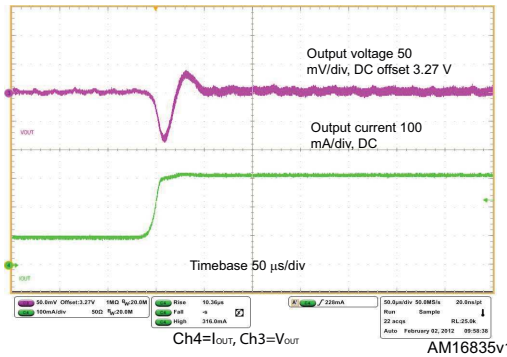
Ch1=V_{IN}, Ch3=V_{OUT} AM16833v1

Figure 14. Line transient response @ V_{IN} = 4 V to 3.6 V



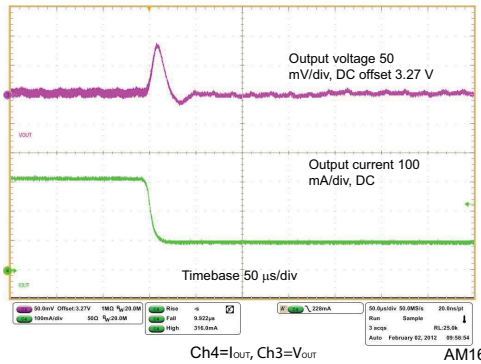
Ch1=V_{IN}, Ch3=V_{OUT} AM16834v1

Figure 15. Load transient response @ V_{IN}=1.8 V, I_{OUT} = 100 to 300 mA



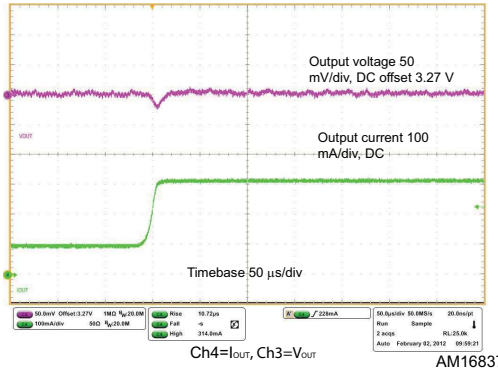
Ch4=I_{OUT}, Ch3=V_{OUT} AM16835v1

Figure 16. Load transient response @ V_{IN}=1.8 V, I_{OUT} = 300 mA to 100 mA



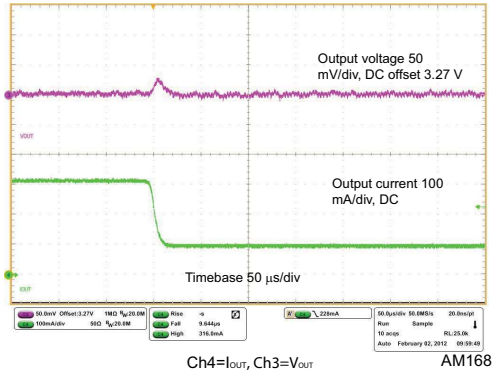
Ch4=I_{OUT}, Ch3=V_{OUT} AM16836v1

Figure 17. Load transient response @ V_{IN}=3.6 V, I_{OUT} = 100 to 300 mA



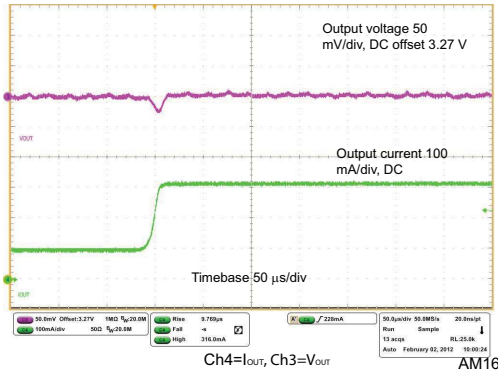
Ch4=I_{OUT}, Ch3=V_{OUT} AM16837v1

Figure 18. Load transient response @ V_{IN}=3.6 V, I_{OUT} = 300 mA to 100 mA



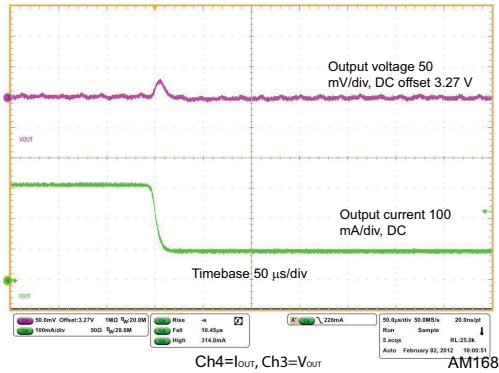
Ch4=I_{OUT}, Ch3=V_{OUT} AM16838v1

Figure 19. Load transient response @ V_{IN}=5.5 V, I_{OUT} = 100 to 300 mA



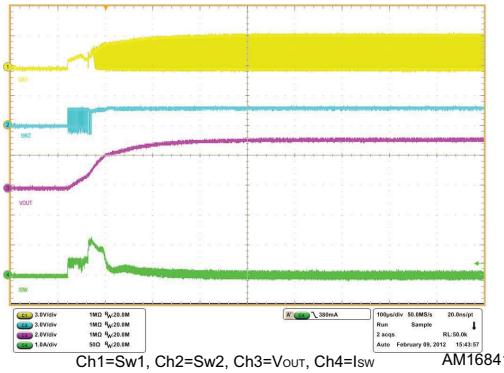
Ch4=I_{OUT}, Ch3=V_{OUT} AM16839v1

Figure 20. Load transient response @ V_{IN}=5.5 V, I_{OUT} = 300 to 100 mA



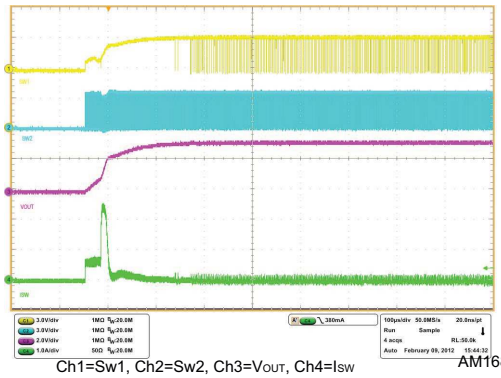
Ch4=I_{OUT}, Ch3=V_{OUT} AM16840v1

Figure 21. Startup after enable @ V_{IN}=1.8 V



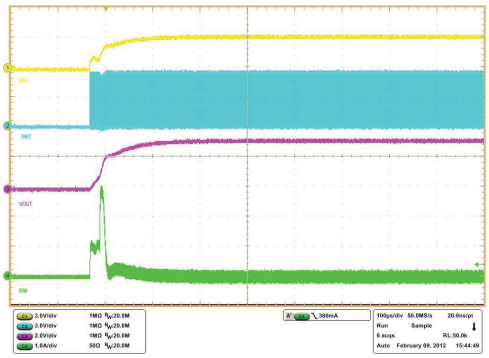
Ch1=Sw1, Ch2=Sw2, Ch3=V_{OUT}, Ch4=I_{SW} AM16841v1

Figure 22. Startup after enable @ V_{IN}=3.6 V



Ch1=Sw1, Ch2=Sw2, Ch3=V_{OUT}, Ch4=I_{SW} AM16842v1

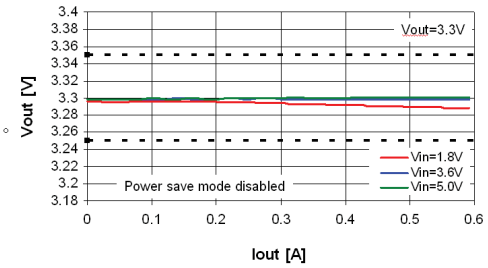
Figure 23. Startup after enable @ V_{IN}=5.5 V



Ch1=Sw1, Ch2=Sw2, Ch3=V_{OUT}, Ch4=Isw

AM16843v1

Figure 24. Output voltage vs. output current



AM16844v1

7 General description

The STBB3J is a high efficiency dual mode buck-boost switch mode converter. Thanks to the 4 internal switches, 2 P-channels and 2 N-channels, it is able to deliver a well-regulated output voltage using a variable input voltage which can be higher than, equal to, or lower than the desired output voltage. This solves most of the power supply problems that circuit designers face when dealing with battery-powered equipment.

The controller uses a peak current mode technique in order to obtain good stability in all possible conditions of input voltage, output voltage and output current. In addition, the peak inductor current is monitored to avoid saturation of the coil.

The STBB3J can work in two different modes: PWM mode or power save mode. Top-class line and load transients are achieved thanks to a feed-forward technique and due to the innovative control method specifically designed to optimize the performances in the buck-boost region where input voltage is very close to the output voltage.

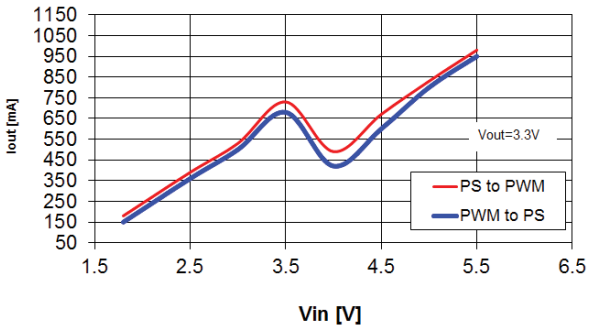
The STBB3J is self-protected from short-circuit and overtemperature. Undervoltage lockout and soft-start guarantee proper operation during startup.

Input voltage and ground connections are split into power and signal pins. This allows reduction of internal disturbances when the 4 internal switches are working. The switch bridge is connected between the V_{IN} and PGND pins while all logic blocks are connected between V_{INA} and GND.

7.1 Dual mode operation

The STBB3J works in PWM mode or in power save mode (PS) according to the different status of the MODE pin. If the MODE pin is pulled high the device works in PWM only. In this case the device operates at 2 MHz fixed frequency pulse width modulation (PWM mode) in all line/load conditions. In this condition, the STBB3J provides the best dynamic performance. If the MODE pin is pulled low, at low average current the STBB3J enters PS mode allowing very low power consumption and therefore obtaining very good efficiency event at light load. When the average current increases, the device automatically switches to PWM mode in order to deliver the power needed by the load. In PS mode the STBB3J implements a burst mode operation: if the output voltage increases above its nominal value the device stops switching; as soon the V_{OUT} falls below the nominal value the device restarts switching with a programmed average current higher than the one needed by the load. *Figure 25* shows PS mode operation areas vs. output current in typical application conditions.

Figure 25. Auto mode vs. output current



7.2 External synchronization

The STBB3J implements the external synchronization function. If an external clock signal is applied to the MODE/SYN pin with a frequency between 1.6 MHz and 2.4 MHz and with proper low/high levels, the device automatically is in PWM mode and the external clock is used as switching oscillator.

7.3 Enable pin

The device turns on when the EN pin is pulled high. If the EN pin is low the device stops switching and all the internal blocks are turned off. In this condition the current drawn from V_{IN}/V_{INA} is below 1 µA in the whole temperature range. In addition the internal switches are in off-state so the load is electrically disconnected from the input; this avoids unwanted current leakage from the input to the load.

7.4 Protection features

The STBB3J implements different types of protection features

7.4.1 Soft-start and short-circuit

After the EN pin is pulled high, or after a suitable voltage is applied to V_{IN}, V_{INA} and EN, the device initiates the startup phase. The average current limit is gradually increased while the output voltage increases. As soon as the output voltage reaches 1.0 V, the average current limit is set to its nominal value.

7.4.2 Undervoltage lockout

The undervoltage lockout function prevents improper operation of the STBB3J when the input voltage is not high enough. When the input voltage is below the VUVLO threshold, the device is in shutdown mode. The hysteresis of 100 mV prevents unstable operation when the input voltage is close to the UVLO threshold.

7.4.3 Overtemperature protection

An internal temperature sensor continuously monitors the IC junction temperature. If the IC temperature exceeds 160 °C (typ.), the device stops operating. As soon as the temperature falls below 140 °C (typ.), normal operation is restored.

8 Application information

8.1 Programming the output voltage

The external resistor divider must be connected between V_{OUT} and GND and the middle point of the divider must be connected to FB.

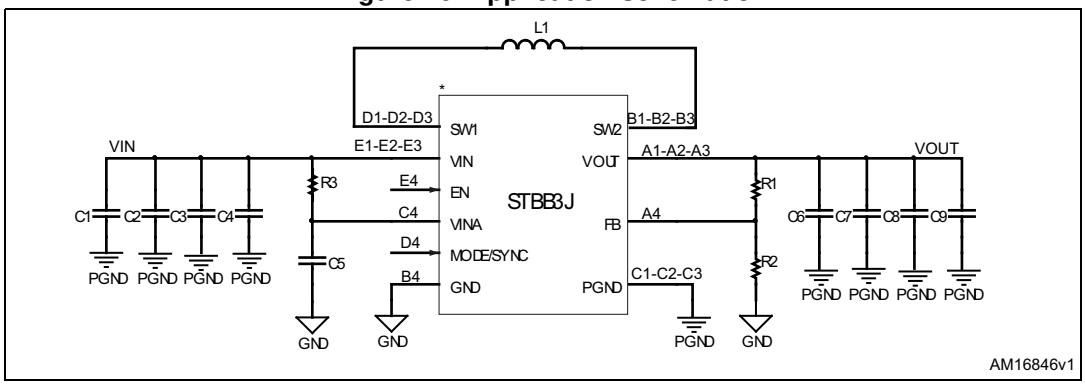
The value of the resistor R1, connected between V_{OUT} and FB, is function of the output voltage and can be calculated using the equation 1:

Equation 1

$$R1 = R2 \times \left(\frac{V_{OUT}}{V_{FB}} - 1\right)$$

The value for the resistor R2, placed between FB and GND must be selected in function of the FB pin leakage current and the V_{OUT} accuracy.

Figure 26. Application schematic



8.2 Inductor selection

The inductor is the key passive component for switching converters. With a buck-boost device, the inductor selection must take into consideration the following two conditions in which the converter works:

- as buck region at the maximum input voltage
- as boost region at the minimum input voltage

Two critical inductance values are then obtained according to the following formulas:

Equation 2

$$L_{MIN\_BUCK} = \frac{V_{OUT} \times (V_{IN\_MAX} - V_{OUT})}{V_{IN\_MAX} \times f_S \times \Delta I_L}$$

Equation 3

$$L_{MIN\_BOOST} = \frac{V_{IN\_MIN} \times (V_{OUT} - V_{IN\_MIN})}{V_{OUT} \times f_S \times \Delta I_L}$$

where f_S is the minimum value of the switching frequency and ΔI_L is the inductor ripple current. The amplitude of the inductor ripple current is typically set between 20% and 40% of the maximum inductor current. To guarantee an inductor ripple current always lower than the selected value ΔI_L, the higher value between L_{MIN_BUCK} and L_{MIN_BOOST} have to be chosen.

In addition to the inductance value, also the maximum current which the inductor can handle must be calculated in order to avoid saturation.

Equation 4

$$I_{PEAK\_BUCK} = \frac{I_{OUT}}{\eta} + \frac{V_{OUT} \times (V_{IN\_MAX} - V_{OUT})}{2 \times V_{IN\_MAX} \times f_S \times L}$$

Equation 5

$$I_{PEAK\_BOOST} = \left(\frac{V_{OUT} \times I_{OUT}}{\eta \times V_{IN\_MIN}}\right) + \frac{V_{IN\_MIN} \times (V_{OUT} - V_{IN\_MIN})}{2 \times V_{OUT} \times f_S \times L}$$

where η is the estimated efficiency. The maximum of the two values above must be considered when selecting the inductor.

8.3 Input and output capacitor selection

It is recommended to use ceramic capacitors with low ESR as input and output capacitors in order to filter any disturbance present in the input line and to obtain stable operation.

Minimum values of 10 µF for both capacitors, C_{IN} and $C_{OUT,}$ are needed to achieve good behavior of the device. The input capacitor must be placed as close as possible to the device.

An R-C filter is added to VINA pin (R3-C5 *Figure 26*) to assure a clean input voltage to the internal logic block.

8.4 Layout guidelines

Figure 27. Assembly layer

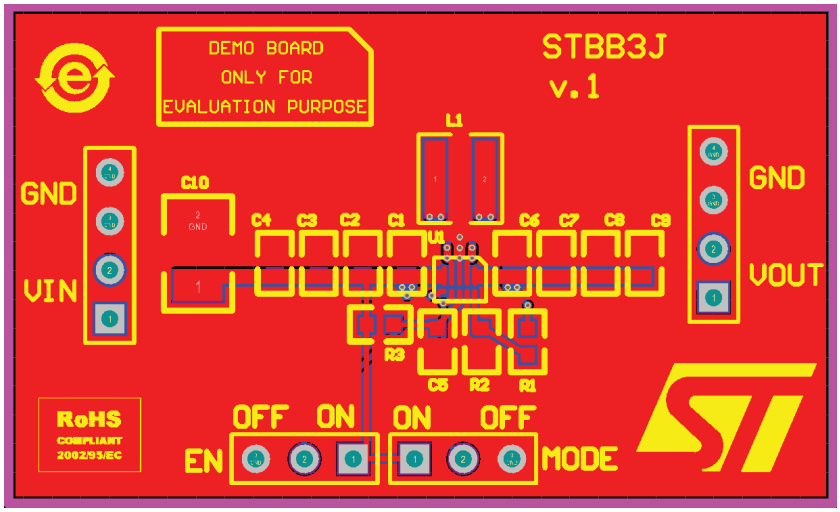


Figure 28. Top layer

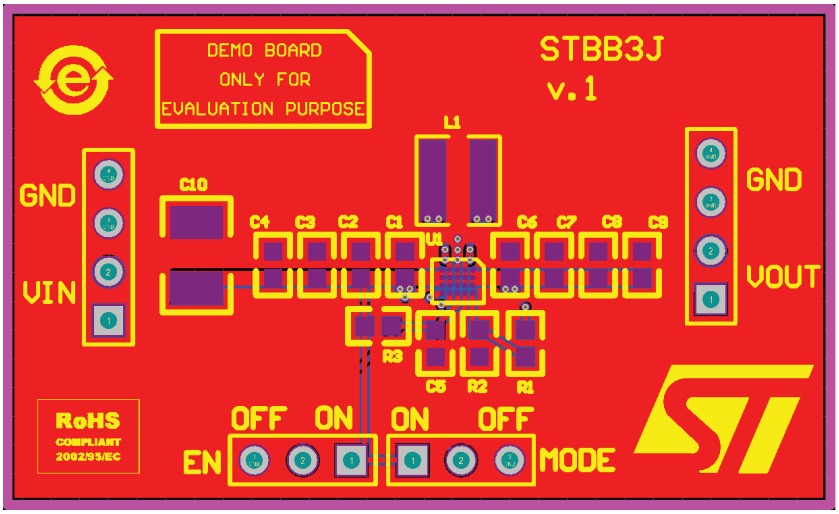
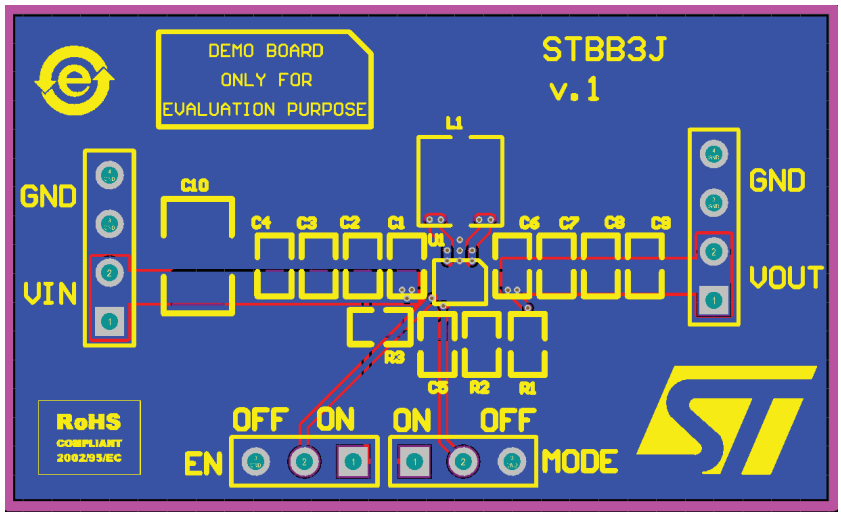


Figure 29. Bottom layer



AM16849v1

9 Package information

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 30. Flip Chip 20 (2.5 x 1.75 mm) outline

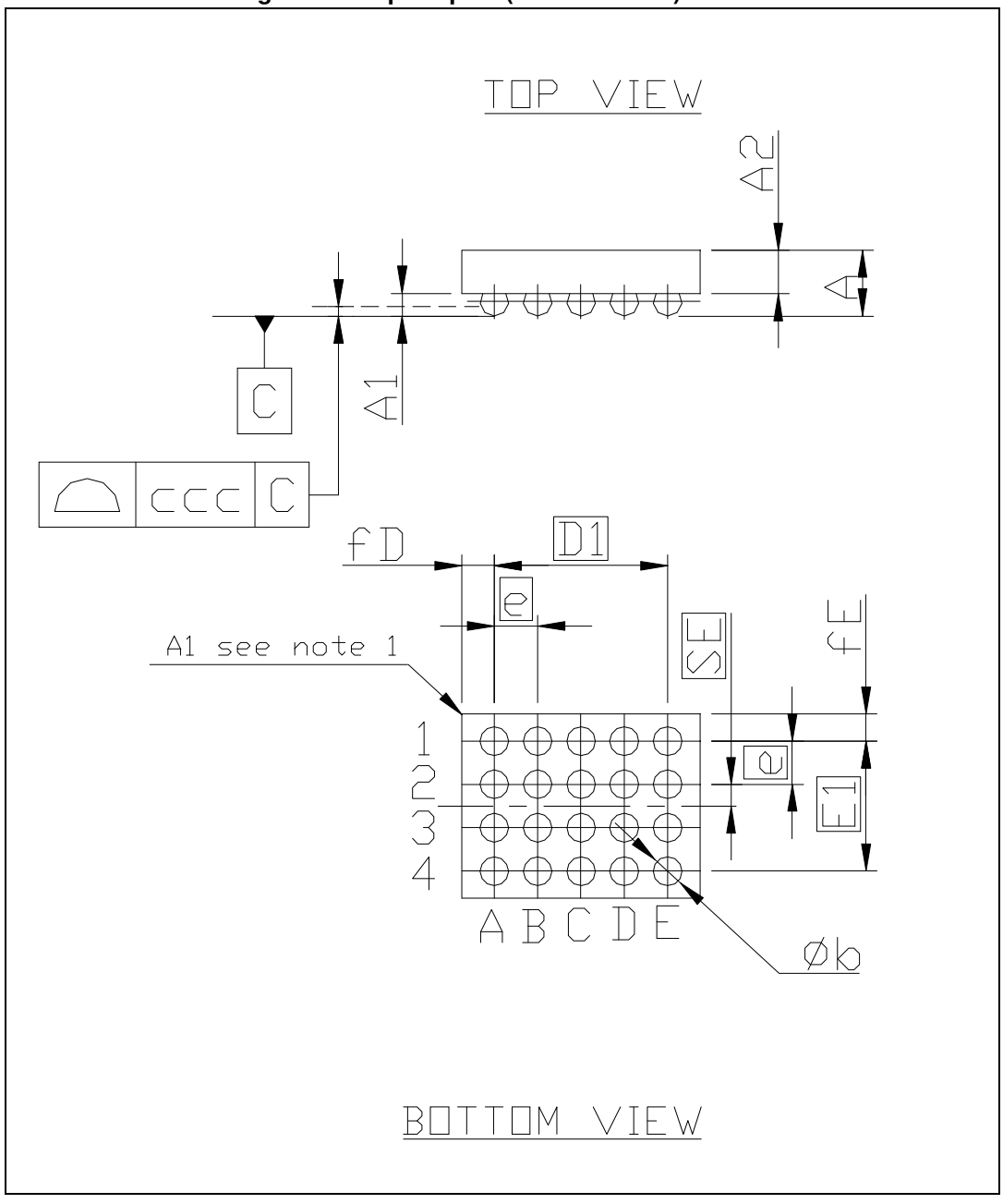


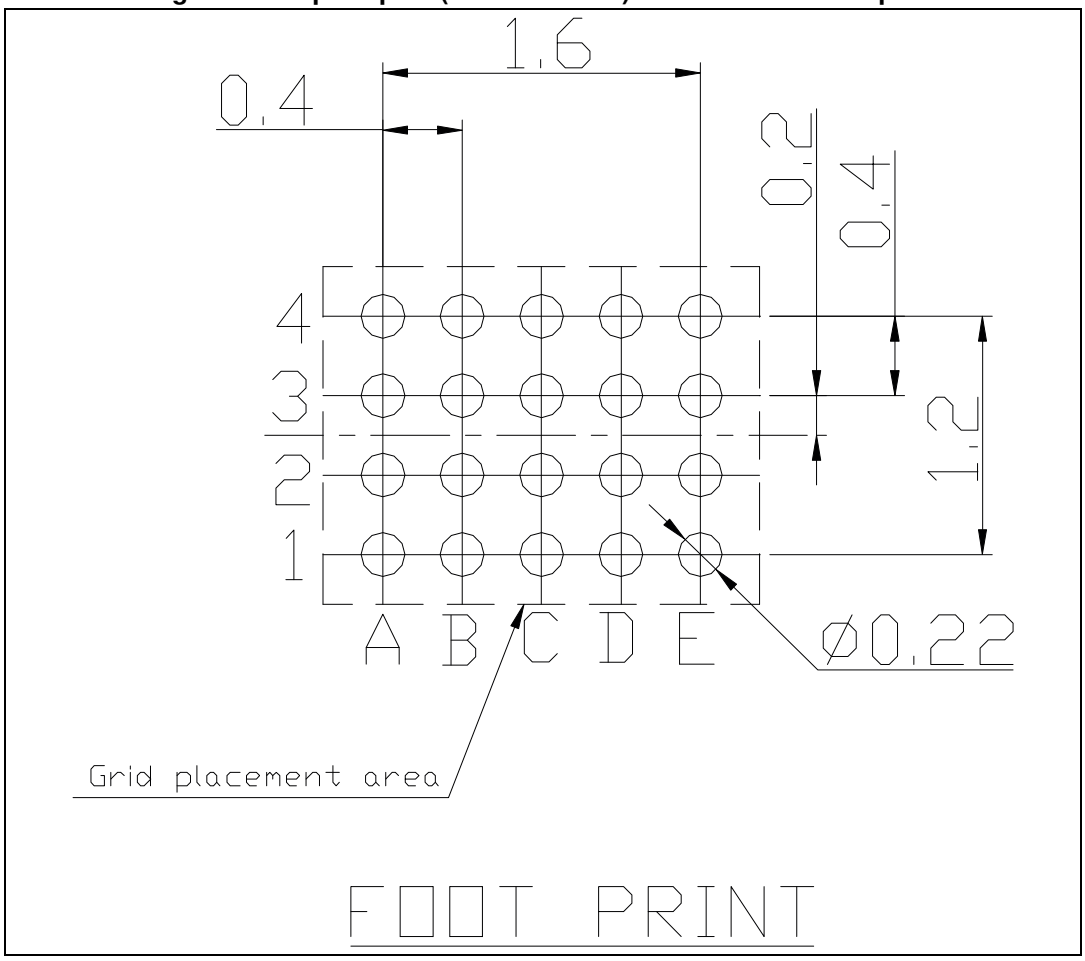
Table 8. Flip Chip 20 (2.5 x 1.75 mm) mechanical data

Dim.	mm		
	Min.	Typ.	Max.
A	0.50	0.55	0.60
A1	0.17	0.20	0.23
A2	0.33	0.35	0.37
b	0.21	0.25	0.29
D	2.485	2.515	2.545
D1		1.6	
E	1.731	1.761	1.791
E1		1.2	
e		0.40	
fD	0.447	0.457	0.467
fE	0.27	0.28	0.29
SE		0.20	
ccc		0.075	

Note: The terminal A1 on the bump side is identified by a distinguishing feature (for instance by a circular “clear area” typically 0.1 mm diameter) and/or a missing bump.

The terminal A1 on the backside of the product is identified by a distinguishing feature (for instance by a circular “clear area” less than 0.5 mm diameter).

Figure 31. Flip Chip 20 (2.5 x 1.75 mm) recommended footprint



10 Revision history

Table 9. Document revision history

Date	Revision	Changes
26-Sep-2013	1	Initial release.
25-Jun-2014	2	Document status promoted from preliminary to production data.
25-Nov-2014	3	Removed footnote from P-channel and N-channel on-resistance parameter in Table 6.
28-Jan-2015	4	Updated I_{SWL} max.value in Table 6.
10-Dec-2015	5	Updated *Figure 1* and *Figure 26*.
11-Dec-2020	6	Updated *Figure 1* and *Figure 2*.
29-Sep-2021	7	Updated I_{LKFB} parameter and max value in Table 6.
06-Dec-2021	8	Updated *Section 8.1*.