STOD14

700 mA dual DC-DC converter for powering AMOLED displays

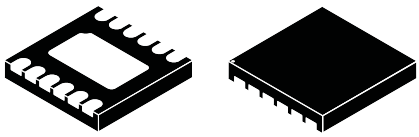
Datasheet — production data

Features

- Step-down and inverter converters
- Operating input voltage range from 6 V to 13 V
- Synchronous rectification for both converters
- 700 mA output current
- Fixed positive voltage 4.6 V
- Programmable negative voltage by S_{WIRE} from - 2.4 V to - 6.0 V
- Typical efficiency 85%
- PWM mode controller @ 1.6 MHz switching frequency
- Enable pin for shutdown mode
- Low quiescent current in shutdown mode
- Soft-start with inrush current protection
- Short-circuit protection on positive output
- Overtemperature protection
- Temperature range - 40 °C to 85 °C
- True shutdown mode
- Fast output discharge after shutdown
- Package DFN 4x4 mm 12 leads 0.75 mm height, 0.5 mm pitch

Applications

- Digital photo frames
- Ultra mobile PCs
- Mobile Internet devices
- Digital still cameras / camcorders
- Portable media players / DVD players



DFN12L (4 x 4 mm)

Description

The STOD14 is a dual channel DC-DC converter driver for medium-sized AMOLED display panels. It integrates a step-down and an inverting converter in a compact IC design. The excellent efficiency makes it particularly suitable for battery operated products. The high frequency operation allows the value and size of external components to be reduced.

The positive output voltage is fixed at 4.6 V with very high current capability and is generated using a buck converter. The negative output is programmable by an external MCU through a dedicated pin which implements single-wire protocol, with values from - 2.4 to - 6.0 V.

Soft-start with controlled inrush current limit, load disconnect and thermal shutdown are integrated functions of the device.

Table 1. Device summary

Order code	Positive voltage	Negative voltage	Package	Packaging
STOD14PUR	4.6 V	- 2.4 V to - 6.0 V	DFN12L (4 x 4 mm)	3000 parts per reel

Contents

1 Schematic

Figure 1. Application schematic

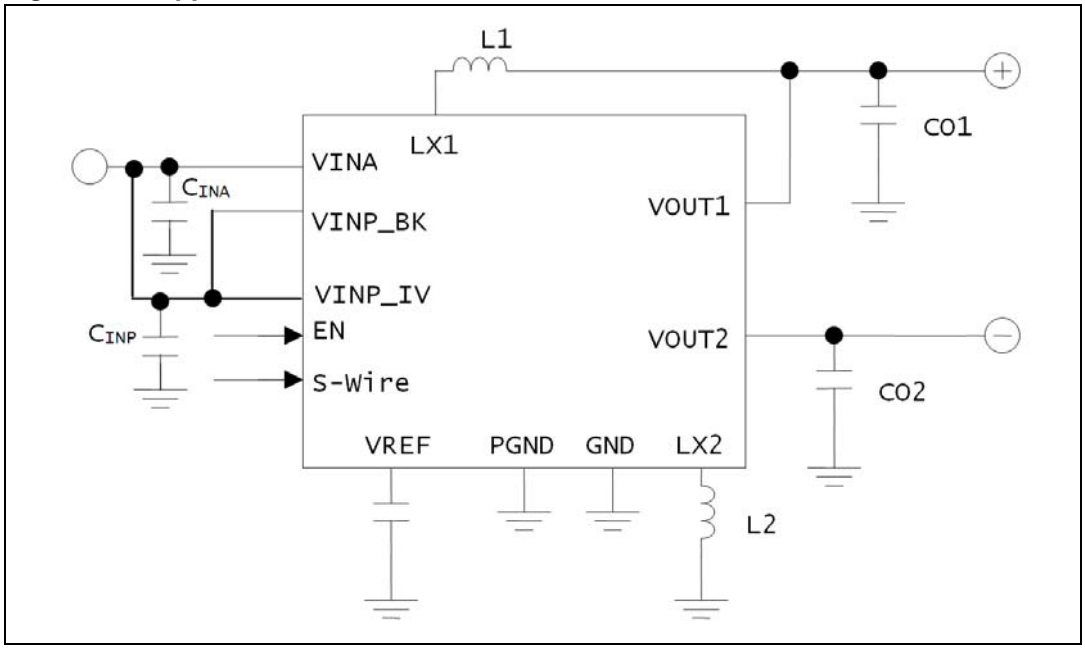


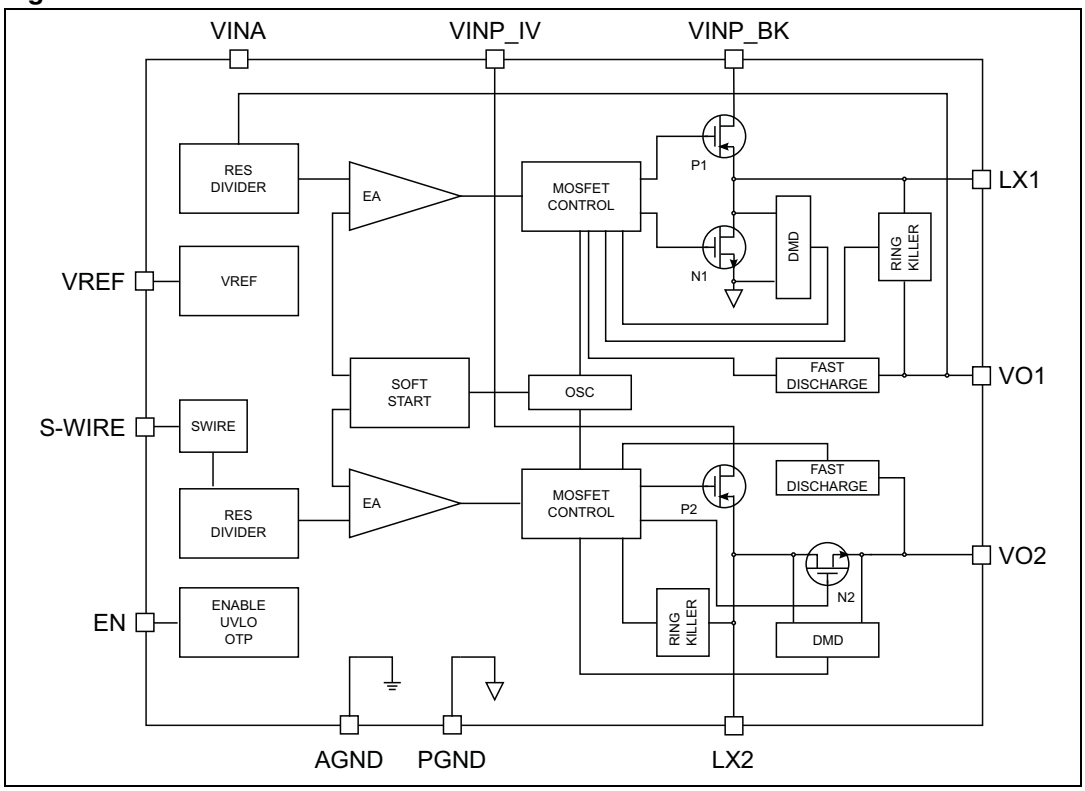
Table 2. Typical external components

Description	Manufacturer	Part number	Value	Size	Ratings
L_1	Coilcraft	LPS4012-472MLB	4.7 µH	4 x 4 x 1.2	1.6 A / 1.8 A (1)
L_2	Coilcraft	LPS4012-472MLB	4.7 µH	4 x 4 x 1.2	1.6 A / 1.8 A (1)
C_{INA}	Murata	GRM21BR61C106KE15L	10 µF	0805	X5R, 16 V
C_{INP}	Murata	2x GRM21BR61C106KE15L	2x 10 µF (2)	0805	X5R, 16 V
C_{O1}	Murata	2x GRM21BR61C106KE15L	2x 10 µF	0805	X5R, 16 V
C_{O2}	Murata	2x GRM21BR61C106KE15L	2x 10 µF	0805	X5R, 16 V
C_{REF}	Murata	GRM185R60J105KE26D	1.0 µF	0603	X5R, 6.3 V

1. I_{SAT} 10% drop / 30% drop.
2. Doubled C_{INP} useful at low temperatures.

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

Figure 2. Block schematic



2 Pin configuration

Figure 3. Pin configuration (top view)

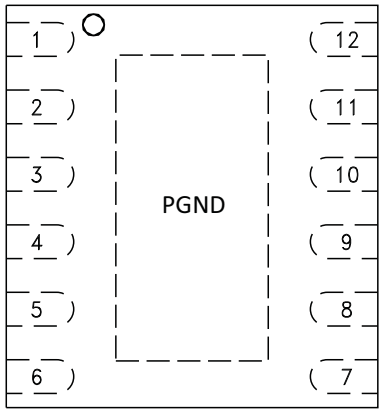


Table 3. Pin description

Symbol	Pin	Description
V_{O2}	1	Inverting converter output voltage (negative)
LX2	2	Switching node of the inverting converter
V_{inIV}	3	Power input supply voltage for inverting converter
V_{inBK}	4	Power input supply voltage for step-down converter
LX1	5	Switching node of the step-down converter
PGND	6	Power ground pin
V_{O1}	7	Step-down converter output voltage (positive)
AGND	8	Signal ground pin. This pin must be connected to power ground pin
S_{WIRE}	9	$S\text{-}_{WIRE}$ pin
V_{inA}	10	Analog input supply voltage
EN	11	Enable control pin. ON = HIGH. When pulled low, puts the device into shutdown mode
V_{REF}	12	Voltage reference output. Connect 1 µF bypass capacitor between this pin and AGND
EXPOSED PAD		Exposed pad must be connected to AGND and PGND in the PCB layout in order to guarantee proper operation of the device.

3 Maximum ratings

Table 4. Absolute maximum ratings

Symbol	Parameter	Value	Unit
VinA, VinIV, VinBK	DC supply voltage	- 0.3 to 13.5	V
EN, S_{WIRE}	Enable pin, $S\text{-}_{WIRE}$ pin	- 0.3 to 4.6	V
ILx2	Inverting converter switching current	Internally limited	A
Lx2	Inverting converter switching node	- 6.5 to VINP +0.3	V
VO2	Inverting converter output voltage	- 6.0 to GND +0.3	V
VO1	Step-down converter output voltage	- 0.3 to 6	V
Lx1	Step-down converter switching node	- 0.3 to VINP +0.3	V
ILx1	Step-down converter switching current	Internally limited	A
VREF	Reference voltage	- 0.3 to 3	V
PD	Power dissipation	Internally limited	mW
T_{STG}	Storage temperature range	- 65 to 150	°C
T_J	Maximum junction temperature	150	°C
ESD	Human body model ESD protection	2	kV

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_{thJA}	Thermal resistance junction-ambient (1)	33	°C/W
R_{thJC}	Thermal resistance junction-case (FR-4 PCB)	1.64	°C/W

1. The package is mounted on a 4-layer (2S2P) JEDEC board as per JESD51-7 and JESD51-5.

4 Electrical characteristics

T_A = 25 °C, V_{INA} = V_{INP} = 9.0 V, $I_{O1,2}$ = 150 mA, C_{IN} = 10 µF, $C_{O1,2}$ = 22 µF, C_{REF} = 1 µF, L1 = 4.7 µH, L2 = 4.7 µH, V_{EN} = High, V_{O1} = 4.6 V, V_{O2} = - 4.9 V, unless otherwise specified.

Table 6. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{IN}	Operating input voltage range	T_A = - 40 to 85 °C	6		13	V
UVLO_H	Undervoltage lockout HIGH	V_{INA} rising, T_A = -40 to 85 °C		5	5.2	V
UVLO_L	Undervoltage lockout LOW	V_{INA} falling, T_A = -40 to 85 °C	4.6	4.8		V
I_V_I	Input current	No load condition (I_V_I = I_{INA} + I_{INP})		30		mA
I_{Q_SH}	Shutdown current	V_{EN} = GND, (I_{Q_SH} = I_{INA} + I_{INP})			5	µA
V_{EN} H	Enable HIGH threshold	V_{INA} = 6 V to 13 V, T_A = -40 to 85 °C	1.2			V
V_{EN} L	Enable LOW threshold	V_{INA} = 6 V to 13 V, T_A = -40 to 85 °C			0.4	V
I_{EN}	Enable input current	V_{EN} = V_{IN}			1	µA
F_{SW}	Frequency	PWM mode, T_A = -40 to 85 °C	1.44	1.6	1.76	MHz
$D1_{MAX}$	Step-down maximum duty cycle	No load		90		%
$D2_{MAX}$	Inverting maximum duty cycle	No load		90		%
η	Total system efficiency	$I_{O1,2}$ = 10 to 150 mA V_{O1}=4.6 V, V_{O2}=-4.9 V	see figure			%
		$I_{O1,2}$ =150 to 700 mA V_{O1}=4.6 V, V_{O2}=-4.9 V		85		%
V_{REF}	Voltage reference	I_{REF} = 10 µA	1.198	1.211	1.222	V
I_{REF}	Voltage reference current capability	At V_{REF} = V_{REF} – 1.5%	100			µA
Step-down converter section						
V_{O1}	Output voltage	V_{INA}=6 V to 13 V, I_{O1}=5 mA to 700 mA, T_A=-40 °C to 85 °C	4.55	4.6	4.65	V
$\Delta V_{O1\ SL}$	Static line regulation (1)	V_{INA}=6 V to 13 V, I_{O1}=5 mA I_{O2} no load; T_A=-40 °C to 85 °C		0.5		%
		V_{INA}=6 V to 13 V, I_{O1}=700 mA I_{O2} no load, T_A=-40 °C to 85 °C		0.5		
ΔV_{O1}	Static load regulation (2)	I_{O1}=5 to 700 mA, I_{O2} no load, V_{INA}=6 V; T_A=-40 °C to 85 °C		1		%
		I_{O1}=5 to 700 mA, I_{O2} no load, V_{INA}=13 V; T_A=-40 °C to 85 °C		1		
I_{O1}	Maximum step-down output current	V_I=6 V to 13 V	700			mA

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$I\text{-}L_{1MAX}$	Inductor peak current	V_{O1} below 10% of nominal value	1.2			A
$R_{DSON}P1$		T_A = -40 to 85 °C		0.2	0.5	Ω
$R_{DSON}N1$		T_A = -40 to 85 °C		0.18	0.5	Ω
Inverting converter section						
V_{O2}	Output negative voltage range	41 discrete values with 100 mV steps set by S_{WIRE} pin	-6.0		-2.4	V
	Default value	Default output voltage		-4.9		V
	Accuracy	Output voltage variation on the nominal value	-1.4		+1.4	%
$\Delta V_{O2\ SL}$	Static line regulation (3)	V_{INA}=6 V to 13 V, I_{O2}=5 mA I_{O1} no load; T_A=-40 °C to 85 °C		1		%
		V_{INA}=6 V to 13 V, I_{O2}=700 mA I_{O1} no load, T_A=-40 °C to 85 °C		1		
ΔV_{O2}	Static load regulation (4)	I_{O2}=5 to 700 mA, I_{O1} no load, V_{INA}=6 V; T_A=-40 °C to 85 °C		1		%
		I_{O2}=5 to 700 mA, I_{O1} no load, V_{INA}=13 V; T_A=-40 °C to 85 °C		1		
I_{O2}	Maximum inverting output current	V_{INA}=6 V to 13 V	-700			mA
$I\text{-}L_{2MAX}$	Inductor peak current	V_{O2} below 10% of nominal value			-2.0	A
$R_{DSON}P2$		T_A = -40 to 85 °C		0.17	0.5	Ω
$R_{DSON}N2$		T_A = -40 to 85 °C		0.16	0.5	Ω
Thermal shutdown						
OTP	Overtemperature protection			150		°C
OTP_{HYST}	Overtemperature protection hysteresis			15		°C
Discharge resistor						
R_{DIS}	Discharge resistor value			300		Ω
T_{DIS}	Discharge time	No load, from 90% to 10%		15		ms

1. [(VO1MAX - VO1MIN) / (VO1 @ 25 °C and VINA,P = 6 V)] x 100.
2. [(VO1MAX - VO1MIN) / (VO1 @ 25 °C and IO1 = 5 mA)] x 100.
3. [(VO2MAX - VO2MIN) / (VO2 @ 25 °C and VINA,P = 6 V)] x 100.
4. [(VO2MAX - VO2MIN) / (VO2 @ 25 °C and IO2 = 5 mA)] x 100.

5 Typical performance characteristics

Figure 4. Total system efficiency @ 25 °C, (L1 = L2 = LPS4012-472MLB)

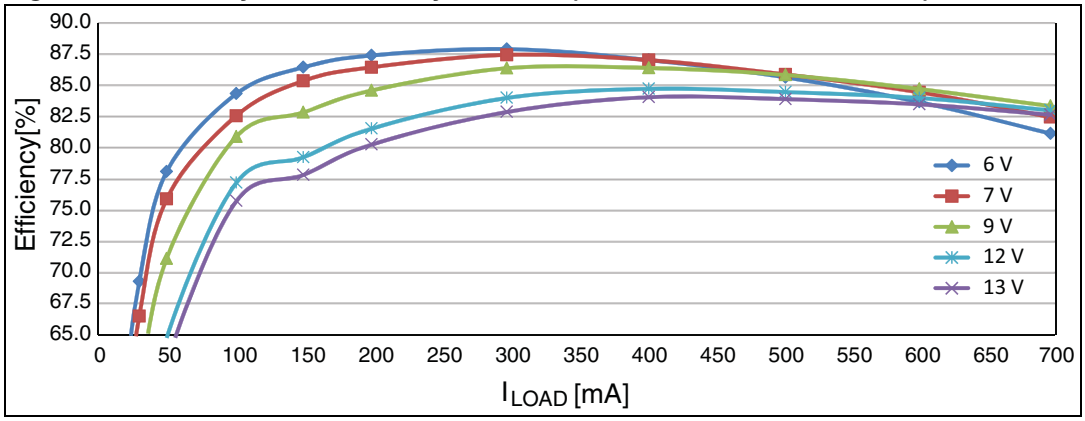
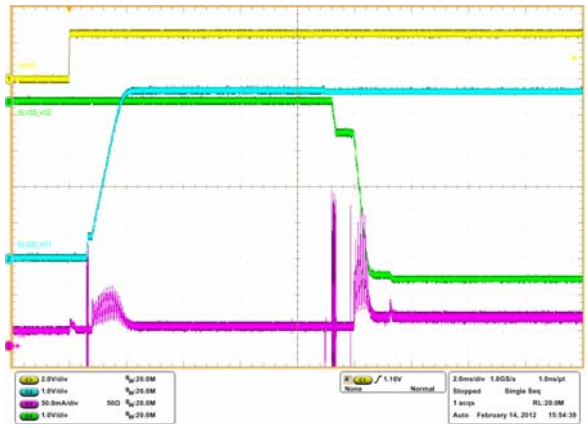
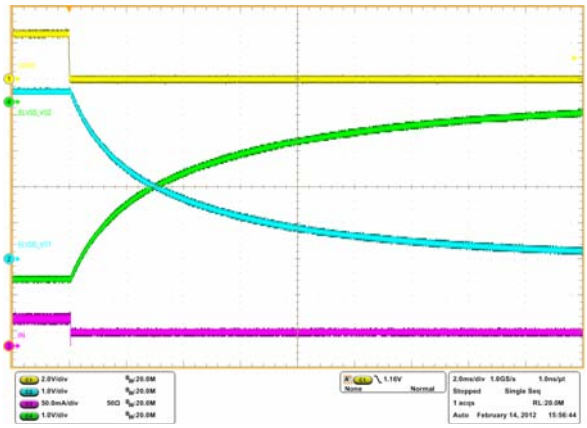


Figure 5. Startup and inrush current



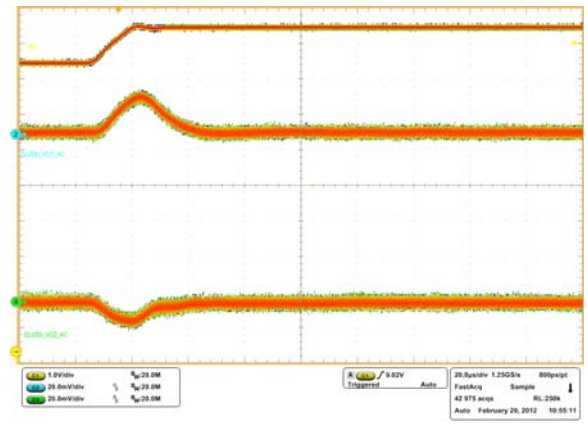
V_{INA} = V_{INP} = 6 V, No load, T_A = 25 °C

Figure 6. Fast discharge



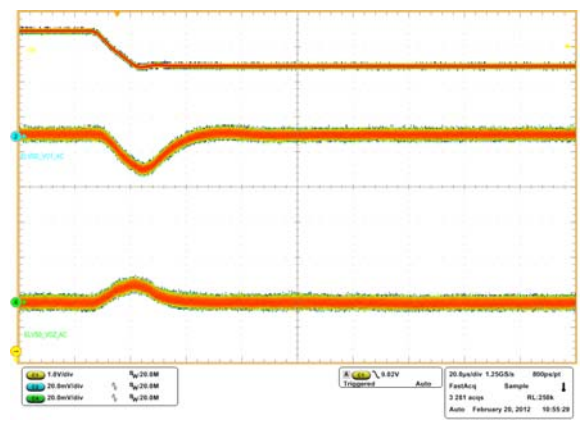
V_{INA} = V_{INP} = 6 V, No load, T_A = 25 °C

Figure 7. Line transient (t_R = 10 µs)



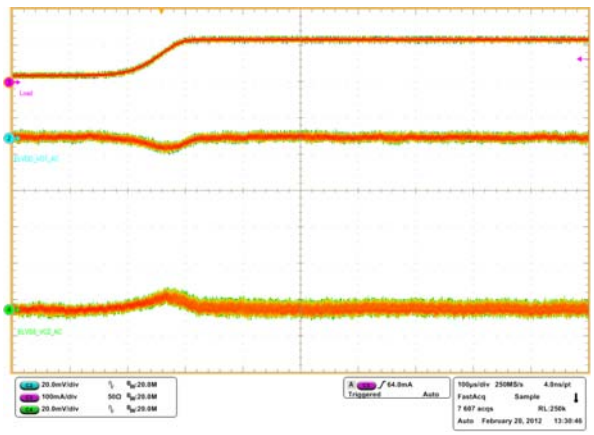
V_{IN} = 8.5 V to 9.5 V, Diff. load 100 mA, t_R = 10 µs

Figure 8. Line transient (t_F = 10 µs)



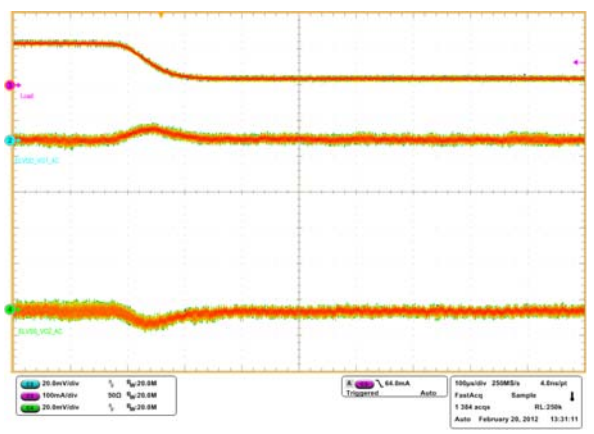
V_{IN} = 9.5 V to 8.5 V, Diff. load 100 mA, t_F = 10 µs

Figure 9. Load transient (t_R = 10 µs)



V_{IN} = 6 V, Diff. load 20 to 120 mA, t_R = 100 µs

Figure 10. Load transient (t_F = 10 µs)



V_{IN} = 6 V, Diff. load 120 to 20 mA, t_F = 100 µs

Figure 11. PSRR (V_{IN} = 9 V + 1 V_{PP} sinewave, single-ended 100 mA load)

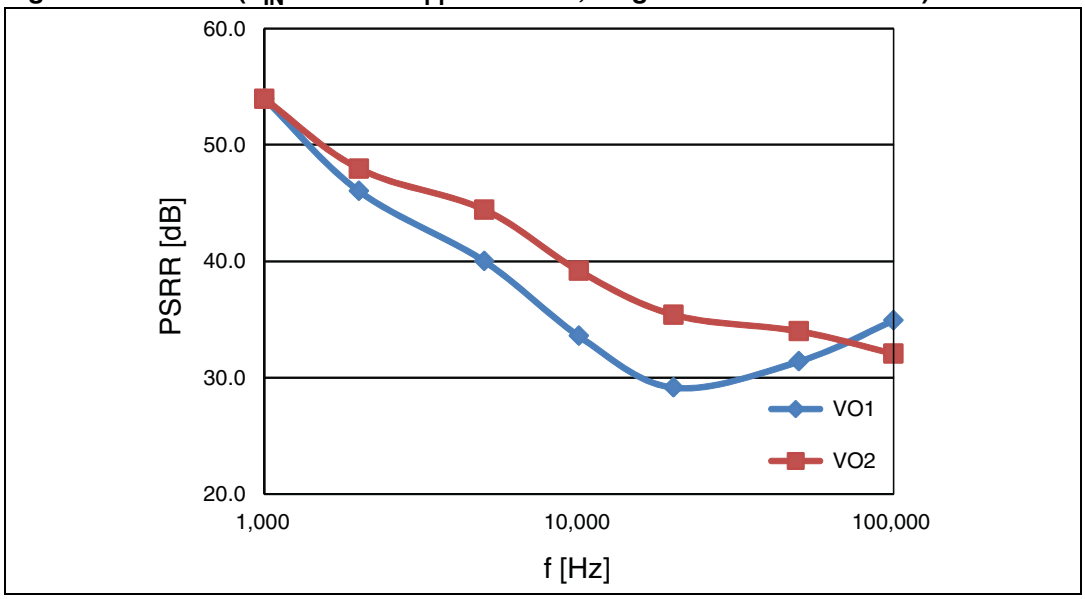


Table 7. PSRR

f [Hz]	PSRR_VO1 [dB]	PSRR_VO2 [dB]
10	> 60	> 60
100	> 60	> 60
1 000	54	54
2 000	46	48
5 000	40	44
10 000	34	39
20 000	29	35
50 000	31	34
100 000	35	32

6 Application Information

6.1 Inductor selection

The inductor is the key passive component for switching converters.

For the step-down converter an inductance between 3.3 µH and 6.8 µH is recommended. For the inverting stage the suggested inductance ranges from 3.3 µH to 4.7 µH.

It is very important to select a proper inductor according to the maximum current the inductor can handle in order to avoid saturation. The peak current for the step-down and the inverting can be calculated with the following formulas:

Equation 1

$$I_{PEAK\_BUCK} = \frac{V_{O1} \cdot (1 - V_{O1} / V_{IN})}{2 \cdot f_s \cdot L_1} + I_O$$

Equation 2

$$I_{PEAK\_INV} = \frac{V_{IN} \cdot V_{O2}}{2 \cdot f_s \cdot L_2 (V_{O2} - V_{IN})} + \frac{I_O (V_{IN} - V_{O2})}{\eta_2 \cdot V_{IN}}$$

where

V_{O1} is step-down output voltage

V_{O2} is inverting output voltage including sign

I_O is output current for both DC-DC converters

V_{IN} is input voltage; use minimum of operating voltage

f_s is switching frequency; use the minimum value of 1.44 MHz for worst case

η_2 is inverter efficiency; typ. 85%

L1 is buck inductor value; including tolerance

L2 is inverter inductor value; including tolerance.

6.2 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 get stable operation for the switching converters.

6.3 Recommended PCB layout

The STOD14 is a high frequency power switching device so it requires a proper PCB layout in order to obtain the necessary stability and optimize line/load regulation and output voltage ripple. Analog input (V_{INA}) and power input (V_{INP}) must be kept separated and connected together at the C_{IN} pad only. The input capacitor must be as close as possible to the IC. To minimize the ground noise, a common ground node for power ground and a different one for analog ground must be used. The exposed pad is connected to AGND through vias.

Figure 12. Top layer and top silkscreen (top view)

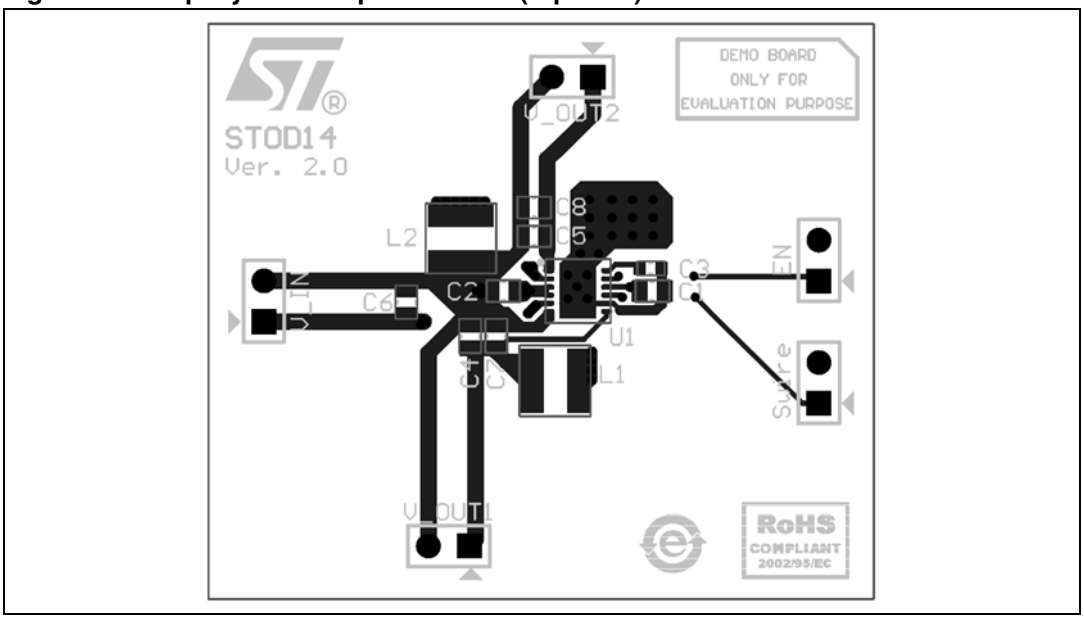
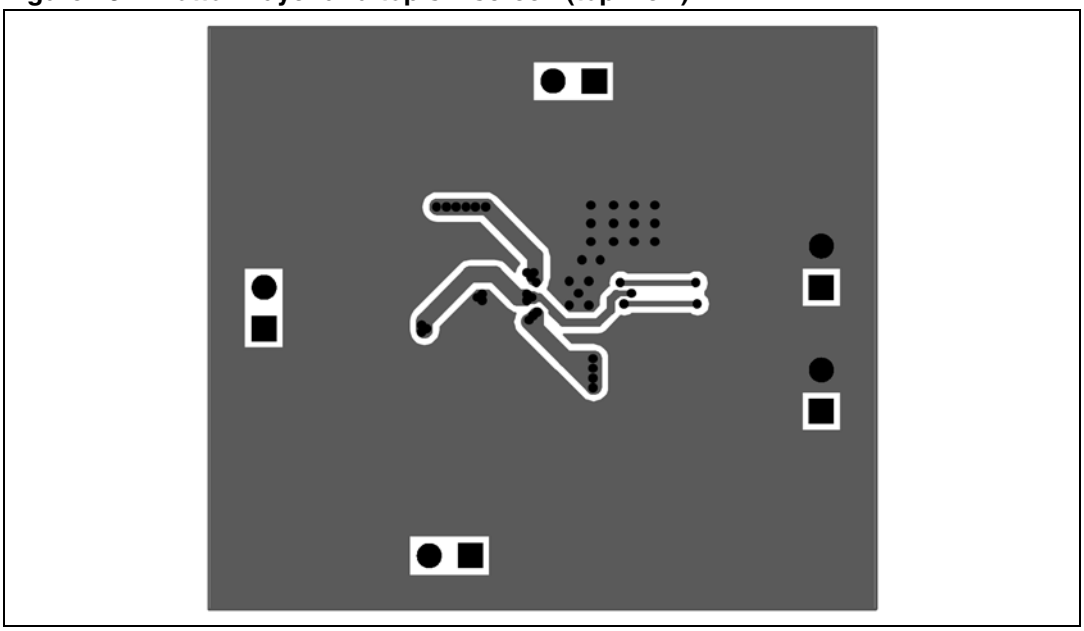


Figure 13. Bottom layer and top silkscreen (top view)



7 Detailed description

The STOD14 is a high efficiency dual DC-DC converter which integrates a step-down and inverting power stage suitable for supplying AMOLED panels.

Thanks to the high level of integration it needs only 6 external components to operate and it achieves very high efficiency using a synchronous rectification technique for both the DC-DC converters.

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

The STOD14 avoids battery leakage thanks to the true-shutdown feature and it is self protected from overtemperature. Undervoltage lockout and soft-start guarantee proper operation during startup.

7.1 Mode of operation

To guarantee the minimal output voltage ripple, the device works just in continuous conduction mode (CCM). In this mode, reverse current pulses flowing back to the power supply can appear, especially at low load.

7.2 Enable pin

The device operates when the Enable pin is set high. If the Enable pin is set low, the device stops switching, and all the internal blocks are turned off. In addition, the internal switches are in an OFF state so the load is electrically disconnected from the input. This avoids unwanted current leakage from the input to the load.

When the EN is pulled high, the P1 switch is turned on for 100 µs. In normal operation, during this time, apart of a small drop due to parasitic resistance, V_{O1} reaches V_{IN}. After 100 µs, if V_{O1} stays below V_{IN}, the P1 is turned off and stays off until a new pulse is applied to EN. This mechanism avoids the device starting if a short-circuit is present on V_{O1}.

7.3 Soft-start and inrush current limiting

As a first step, the C_{O1} capacitor is charged, the P1 switch implements a current limiting technique in order to keep the charge current below 400 mA. This avoids battery overloading during startup.

After VO1 reaches VINP voltage level, the P1 switch is fully turned on and the soft-start procedure for the step-down is started.

After around 2 ms the soft-start for the inverting is started. The positive and negative voltage is under regulation around 6 ms after the Enable pin is asserted high.

7.4 Startup sequence

After the Enable pin is pulled high, or after a suitable voltage is applied to V_{INP}, V_{INA} and the Enable pin, the device begins the startup phase. The positive and negative voltages are

under regulation about 10 ms after the Enable pin is asserted high. The short-circuit protection is designed to prevent overload, performing a dynamic current limitation on both output pins. At light load condition (up to 150 mA), the load can be connected during the startup phase. At medium/high load condition (above 150 mA), the proper sequence needs the startup phase to be entirely completed before connecting a load.

7.5 Fast discharge

When the device goes into shutdown mode and LX1 and LX2 stop switching, the discharge switch between V_{O1} and V_{IN} and the switch between V_{O2} and GND turn on and discharge the positive and the negative output voltages. After output voltages are discharged to zero, the switches turn off and the outputs stay in high impedance state.

7.6 Undervoltage lockout

The undervoltage lockout function avoids improper operation of the device when the input voltage is not high enough. When the input voltage is below the UVLO threshold, the device is in shutdown mode. The hysteresis avoids unstable operation at input voltage levels close to the UVLO threshold.

7.7 Overtemperature protection

An internal temperature sensor continuously monitors the IC junction temperature. If the temperature exceeds the specified value (see *Table 5*) the device stops operating. As soon as the temperature falls below the threshold (including hysteresis), normal operation is restored.

7.8 Short-circuit startup detection (SSD)

During device soft-start on positive output, an internal comparator checks load condition to detect eventual panel damage. In such case soft-start is stopped and the device is parked in power-off. To reset the normal functionality (assuming that the anomalous load condition was removed), it is necessary to restart the converter by an enable transient.

If no damage is detected during soft-start on the positive output, the startup procedure follows with negative output soft-start to reach, at the end, normal outputs functionality and voltages.

7.9 Overload protection (OLP)

Output current is internally limited. An overload condition, as a short-circuit between the two outputs or between each output and GND, produces the device power-off. To reset normal functionality (assuming that the short condition was removed), it is necessary to restart the converter by an enable transient.

7.10 Short-circuit protection (SCP)

When short-circuit occurs, the device is able to detect the voltage difference between V_{IN} and V_{OUT}. Overshoots are limited, decreasing the inductor current. After that, the output

stages of the device are turned off. This status is maintained avoiding current flowing to the load. A new enable transition is needed to restart the device. The short-circuit protection is active during startup.

7.11 S-$_{WIRE}$ protocol description

Protocol to digitally communicate over a single cable with single-wire components.

Features and benefits

- Fully digital signal
- No handshake needed
- Protection against glitches and spikes though an internal low-pass filter acting on both rising and falling edges
- Uses a single-wire (plus analog ground) to accomplish both communication and power control transmission
- Simple design with an interface protocol that supplies control and signaling over a single-wire connection to set the output voltages.

S-$_{WIRE}$ protocol

- Single-wire protocol uses conventional CMOS/TTL logic levels (maximum 0.6 V for logic “zero” and a minimum 1.2 V for the logic “one”) with operation specified over a supply voltage range of 2.5 V to 4.5 V
- Both master (MCU) and slave (this device) are configured to permit bit sequential data to flow only in one direction at a time; master initiates and controls the device
- Data is bit-sequential with a START bit and a STOP bit
- Signal is transferred in real time
- System clock is not required; each single-wire pulse is self-clocked by the oscillator integrated in the master and asserted valid within a frequency range of 250 kHz (maximum).

S-$_{WIRE}$ basic operations

The negative output voltage levels are selectable within a wide range (steps of 100 mV). The device can be enabled / disabled via S-$_{WIRE}$ in combination with the Enable pin.

7.12 Enable and S-$_{WIRE}$ operation

Both S-$_{WIRE}$ and Enable pins can be used to switch on and off the device. *Table 8* describes functionality for all combinations.

Table 8. EN and S-$_{WIRE}$ operation table

EN	S_{WIRE}	Action
Low	Low	Device off
Low	High	Negative output voltage set by S-$_{WIRE}$
High	Low	Default negative output voltage
High	High	Default negative output voltage

Note: Enable pin must be set to AGND while using the S-$_{WIRE}$ function.

7.13 Programming negative output voltage

Negative output voltage is set through the S-$_{WIRE}$ interface by providing a number of pulses according to the following table.

Table 9. Negative output voltage programming levels

Bit clock	V_{O2} (V)	Bit clock	V_{O2} (V)	Bit clock	V_{O2} (V)	Bit clock	V_{O2} (V)	Bit clock	V_{O2} (V)
1	N/A	11	-5.4	21	-4.4	31	-3.4	41	-2.4
2	N/A	12	-5.3	22	-4.3	32	-3.3		
3	N/A	13	-5.2	23	-4.2	33	-3.2		
4	N/A	14	-5.1	24	-4.1	34	-3.1		
5	-6.0	15	-5.0	25	-4.0	35	-3.0		
6	-5.9	16	-4.9	26	-3.9	36	-2.9		
7	-5.8	17	-4.8	27	-3.8	37	-2.8		
8	-5.7	18	-4.7	28	-3.7	38	-2.7		
9	-5.6	19	-4.6	29	-3.6	39	-2.6		
10	-5.5	20	-4.5	30	-3.5	40	-2.5		

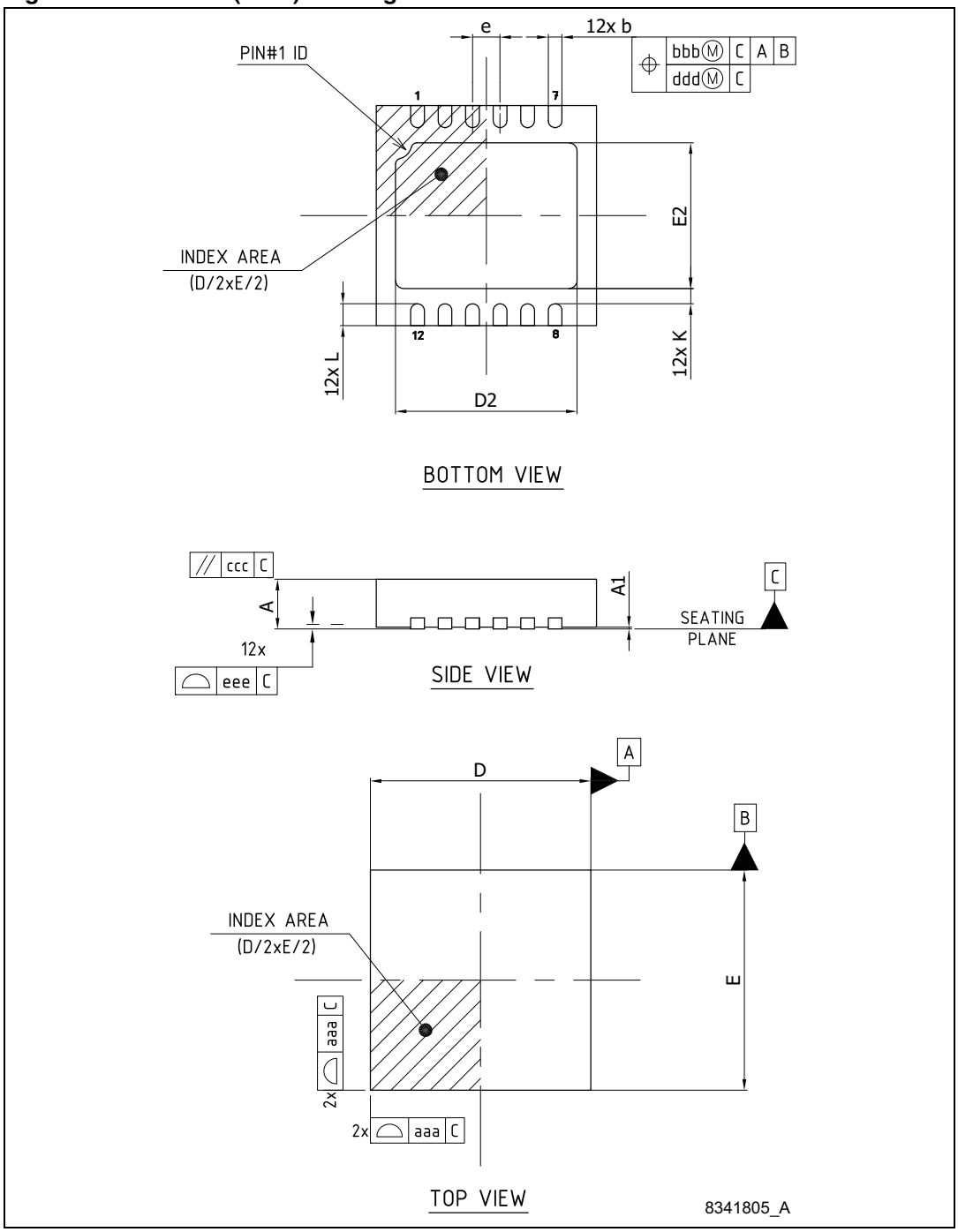
8 Package mechanical data

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.

Table 10. DFN12L (4 x 4) mechanical data

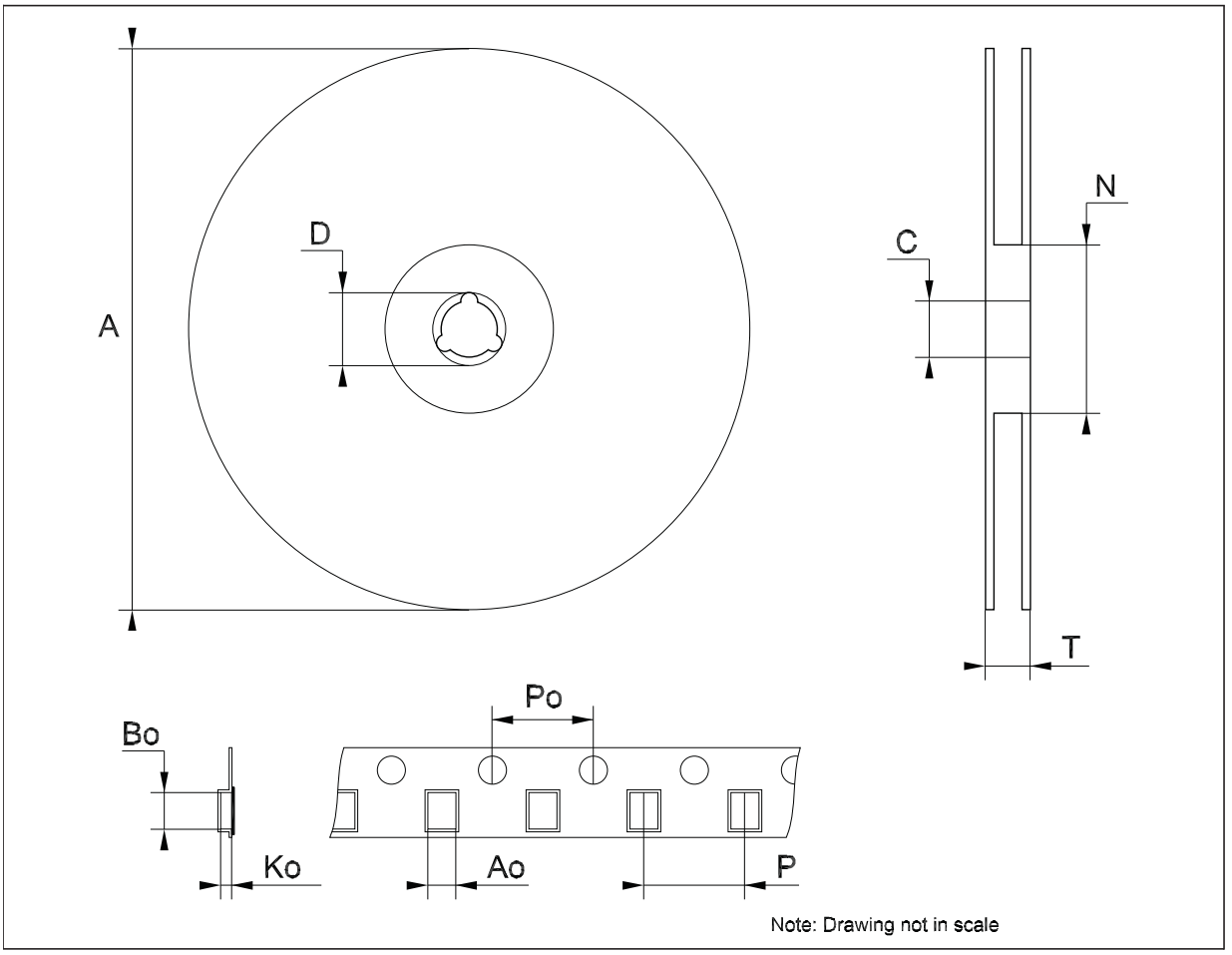
Dim.	mm		
	Min.	Typ.	Max.
A	0.70	0.75	0.80
A1	0	0.02	0.05
b	0.18	0.25	0.30
D		4.0	
D2	3.15	3.30	3.40
E		4.0	
E2	2.50	2.65	2.75
e		0.5	
L	0.30	0.40	0.50

Figure 14. DFN12L (3 x 3) drawing



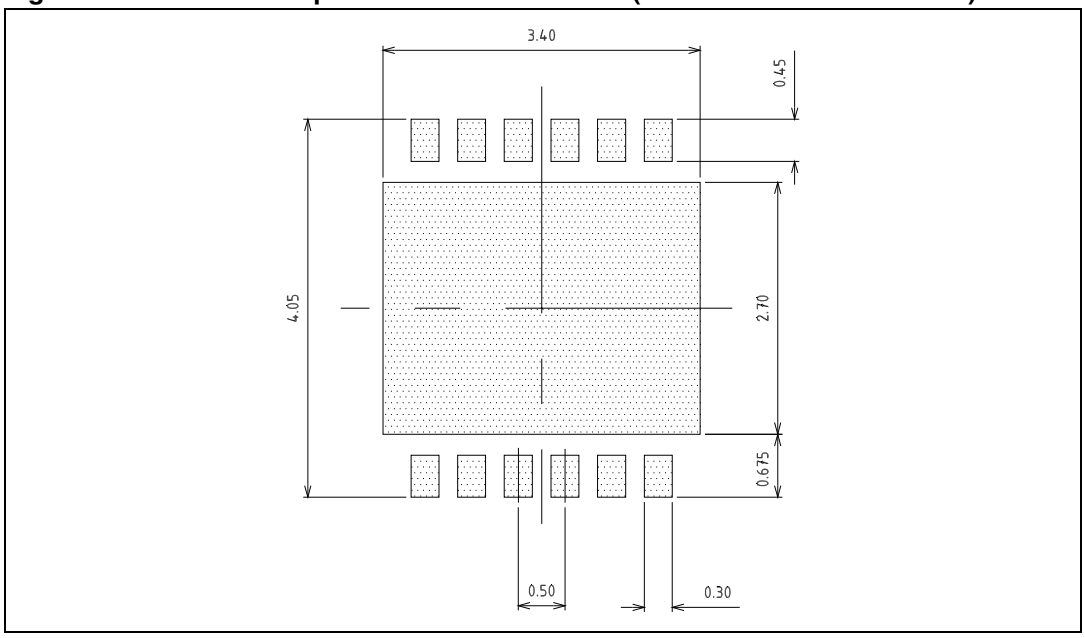
Tape & reel QFNxx/DFNxx (4x4) mechanical data

Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			330			12.992
C	12.8		13.2	0.504		0.519
D	20.2			0.795		
N	99		101	3.898		3.976
T			14.4			0.567
Ao		4.35			0.171	
Bo		4.35			0.171	
Ko		1.1			0.043	
Po		4			0.157	
P		8			0.315	



Note: Drawing not in scale

Figure 15. DFN12L footprint recommended data (dimensions in millimeters)



9 Revision history

Table 11. Document revision history

Date	Revision	Changes
16-Aug-2012	1	Initial release.

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