

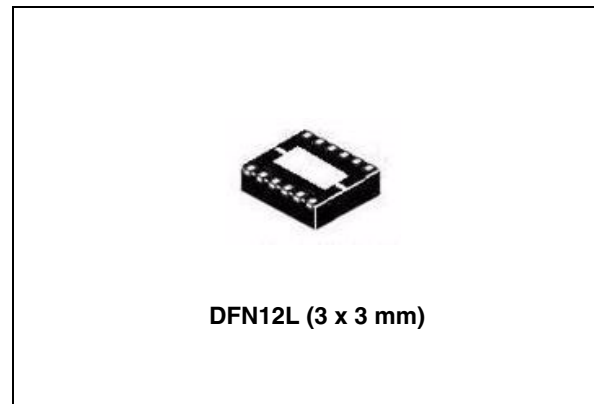
## Dual DC-DC converter for powering AMOLED display

### Features

- Step-up and inverter converters
- Operating input voltage range from 2.5 V to 4.5 V
- Synchronous rectification for both DC-DC converters
- 150 mA maximum output current
- 4.6 V fixed positive output voltage
- Programmable negative voltage by S-wire from - 2.3 V to - 5.9 V
- Typical efficiency: 85 %
- Pulse skipping mode in light load condition ( $I_O < 10$  mA)
- 1.6 MHz PWM mode control switching frequency ( $I_O > 10$  mA)
- Enable pin for shutdown mode
- Low quiescent current: < 1  $\mu$ A in shutdown mode
- Soft-start with inrush current protection
- Over temperature protection
- Temperature range: -40 °C to 85 °C
- True shutdown mode
- Fast outputs discharge circuit after shutdown
- Package: DFN 12 leads - (3 x 3 mm)

### Applications

- Active matrix organic LED power supply (AMOLED)
- Mobile phones



- PDAs
- Camcorders and digital still cameras

### Description

The STOD02 is a dual DC-DC converter meant to power AMOLED displays. It integrates a step up and an inverting DC-DC converter making it particularly suitable for battery operated products, where the major concern is the overall system efficiency. STOD02 works in pulse skipping mode during low load condition and in PWM-mode (at 1.6 MHz) for medium/high load condition. The high frequency allows reducing the value and number of external components just to 6 components needed. The enable pin allows turning off the device so reducing the current consumption to less than 1  $\mu$ A. The negative output voltage can be programmed by an MCU through a dedicated pin which implements single-wire protocol. Soft-start with controlled inrush current limit and thermal shutdown are integrated functions of the device.

**Table 1. Device summary**

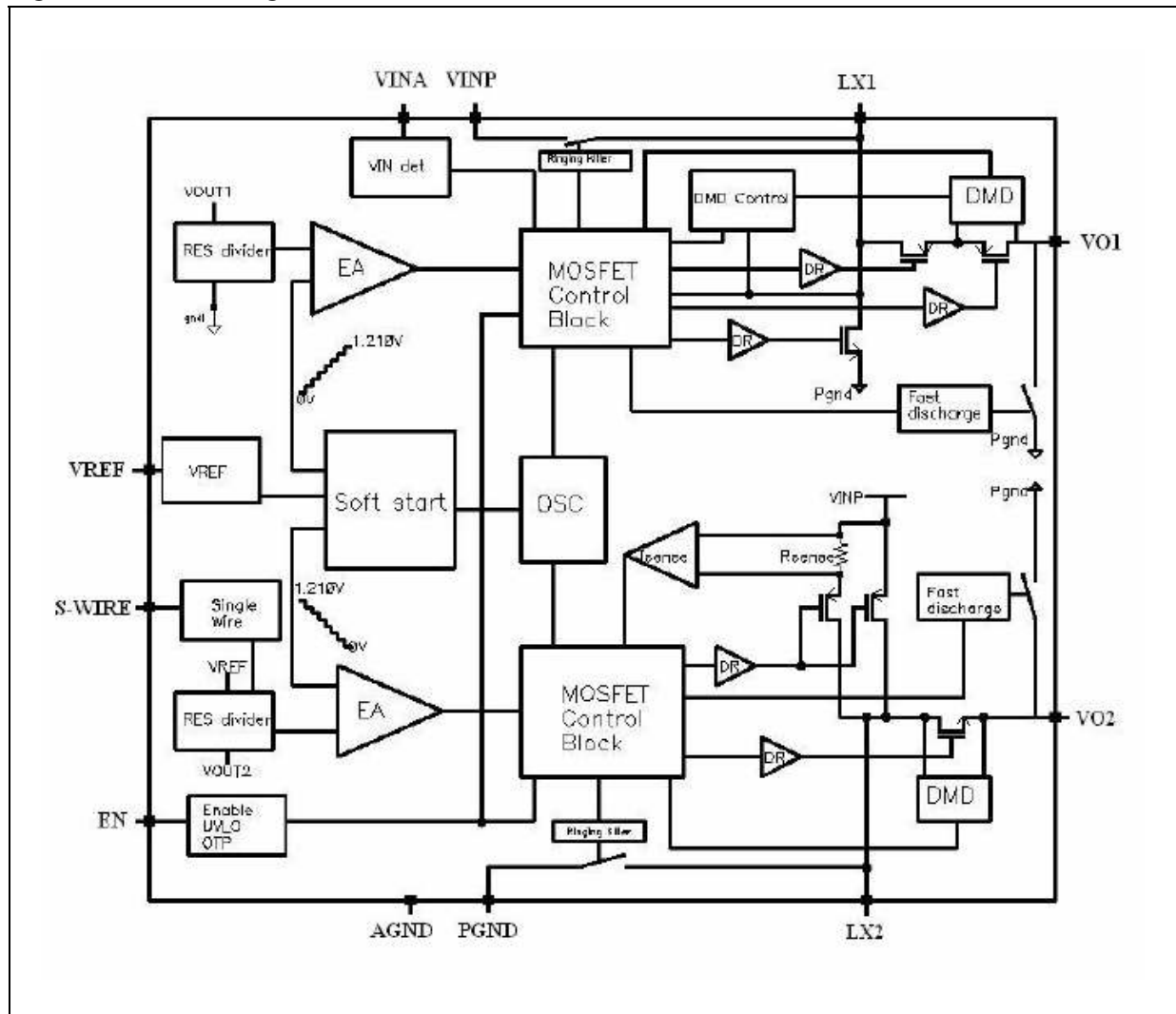
Order code	Package	Packaging
STOD02PUR	DFN12L (3 x 3 x 0.8 mm)	3000 parts per reel
STOD02TPUR	DFN12L (3 x 3 x 0.6 mm)	3000 parts per reel

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# 1 Diagram

Figure 1. Block diagram



## 2 Pin configuration

Figure 2. Pin connections (top view)

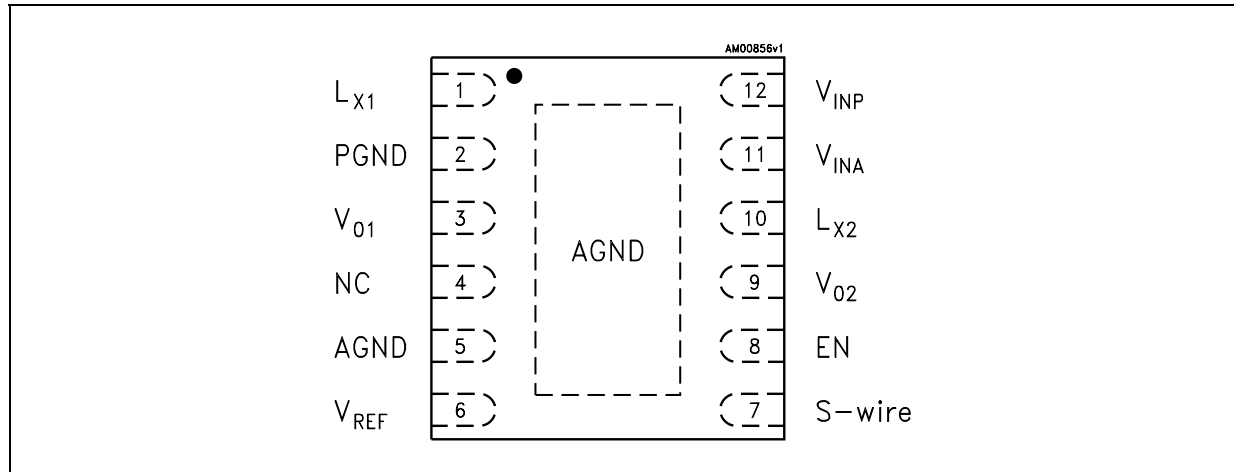


Table 2. Pin description

Pin n°	Symbol	Description
1	L <sub>X1</sub>	Switching node of the step up converter
2	PGND	Power ground pin
3	V <sub>O1</sub>	Step up converter output voltage
4	NC	Not connected
5	AGND	Signal ground pin. This pin must be connected to power ground pin
6	V <sub>REF</sub>	External voltage reference
7	S-wire	Negative voltage setting pin, uses S-wire protocol
8	EN	Enable control pin. ON = V <sub>I</sub> . When pulled low, the device goes in shutdown mode
9	V <sub>O2</sub>	Inverting converter output voltage
10	L <sub>X2</sub>	Switching node of the inverting converter
11	V <sub>INA</sub>	Analog input supply voltage
12	V <sub>INP</sub>	Power input supply voltage
	exposed pad	Internally connected to AGND. 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 3. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
$V_{INA}, V_{INP}$	DC supply voltage	-0.3 to 6	V
EN,S-wire	Enable pin, S-wire pin	-0.3 to 6	V
$I_{LX2}$	Inverting converter's switching current	Internally limited	A
$L_{X2}$	Inverting converter switching node	-10 to $V_{INP}+0.3$	V
$V_{O2}$	Inverting converter output voltage	-10 to GND+0.3	V
$V_{O1}$	Step-up converter output voltage	-0.3 to 6	V
$L_{X1}$	Step-up converter switching node	-0.3 to $V_{O1}+0.3$	V
$I_{LX1}$	Step up converter's switching current	Internally limited	A
$V_{REF}$	Reference voltage	-0.3 to 3	V
$P_D$	Power dissipation	Internally limited	mW
$T_{st}$	Storage temperature range	-65 to 150	°C
$T_J$	Maximum junction temperature	150	°C
ESD	ESD protection HBM	2	kV

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

**Table 4. Thermal data**

Symbol	Parameter	Value	Unit
$R_{thJA}$	Thermal resistance junction-ambient referred to FR-4 PCB	49.1	°C/W
$R_{thJC}$	Thermal resistance junction-case	4.216	°C/W

# 4 Application

Figure 3. Typical application circuit

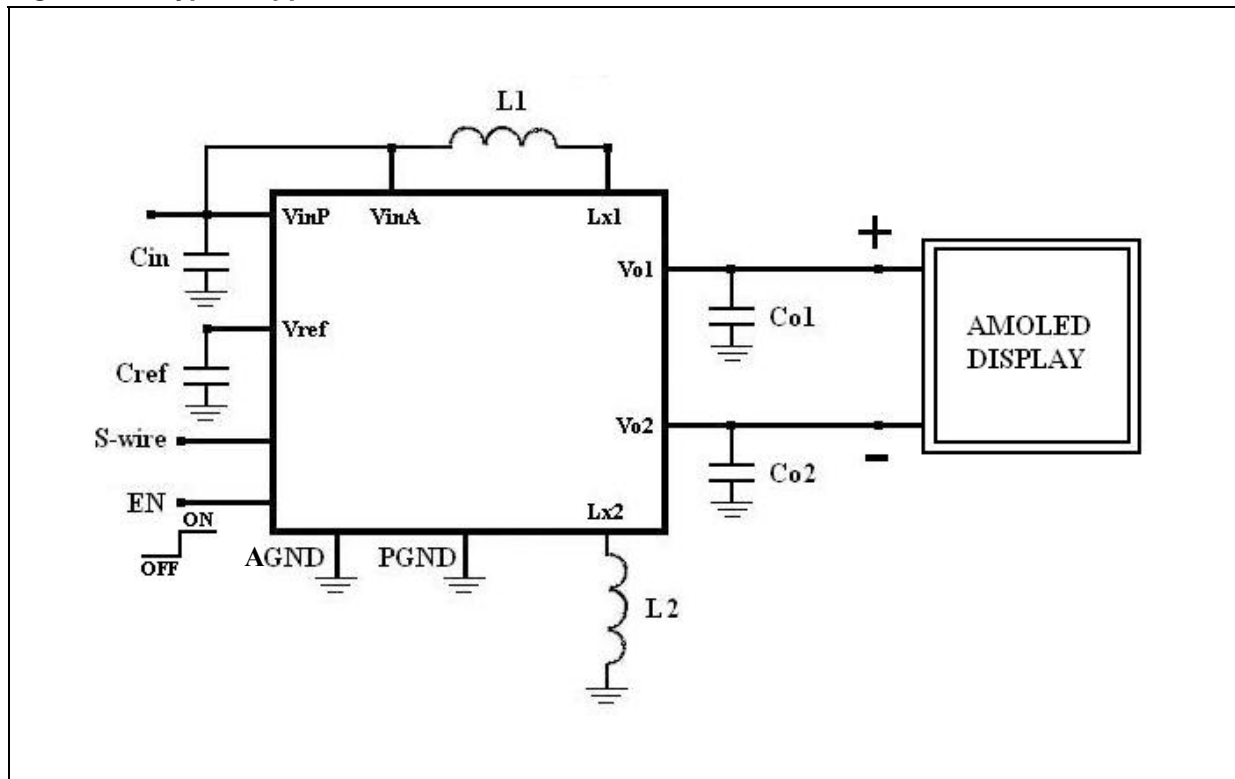


Table 5. Typical external components

Symbol	Parameter	Min.	Typ.	Max.	Unit
$L_1$	Inductor		4.7		$\mu H$
$L_2$	Inductor		4.7		$\mu H$
$C_{IN}$	Ceramic capacitor SMD		4.7		$\mu F$
$C_{01}, C_{02}$	Ceramic capacitor SMD		4.7		$\mu F$
$C_{ref}$	Ceramic capacitor SMD		1		$\mu F$

## 5 Electrical characteristics

$T_J = 25\text{ }^\circ\text{C}$ ,  $V_{INA} = V_{INP} = 3.7\text{ V}$ ,  $I_{O1,2} = 30\text{ mA}$ ,  $C_1 = 4.7\text{ }\mu\text{F}$ ,  $C_{O1,2} = 4.7\text{ }\mu\text{F}$ ,  $C_{REF} = 1\text{ }\mu\text{F}$ ,  $L_1 = 4.7\text{ }\mu\text{H}$ ,  $L_2 = 4.7\text{ }\mu\text{H}$ ,  $V_{EN} = V_{INA} = V_{INP}$ ,  $V_{O1} = 4.6\text{ V}$ ,  $V_{O2} = -4.9\text{ V}$  unless otherwise specified.

**Table 6. Electrical characteristics**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
<b>General section</b>						
$V_{IN}$	Operating input voltage range	$V_{O1}=4.6\text{V}$ , $T_J = -40\text{ to }85\text{ }^\circ\text{C}$	2.5		4.5	V
UVLO_H	Under voltage lockout HIGH	$V_{INA}$ rising, $T_J = -40\text{ to }85\text{ }^\circ\text{C}$		2.40	2.50	V
UVLO_L	Under voltage lockout LOW	$V_{INA}$ falling, $T_J = -40\text{ to }85\text{ }^\circ\text{C}$	2.30	2.35		V
$I_{V_I}$	Input current	No Load condition ( $I_{V_I} = I_{INA} + I_{INP}$ )		1	1.5	mA
$I_S$	Shutdown current	$V_{EN} = \text{GND}$ , ( $I_S = I_{INA} + I_{INP}$ )			1	$\mu\text{A}$
$V_{EN\ H}$	Enable high threshold	$V_{INA} = 2.5\text{V to }4.5\text{V}$ , $T_J = -40\text{ to }85\text{ }^\circ\text{C}$	1.2			V
$V_{EN\ L}$	Enable low threshold	$V_{INA} = 2.5\text{V to }4.5\text{V}$ , $T_J = -40\text{ to }85\text{ }^\circ\text{C}$			0.4	
$I_{EN}$	Enable input current	$V_{EN} = V_I$			1	$\mu\text{A}$
$F_{SW}$	Frequency	PWM mode, $T_J = -40\text{ to }85\text{ }^\circ\text{C}$	1.35	1.6	1.85	MHz
$D1_{MAX}$	Step-up maximum duty cycle			90		%
$D2_{MAX}$	Inverting maximum duty cycle			90		%
$\eta$	Total system efficiency	$I_{O1,2}=10\text{ to }30\text{mA}$ , $V_{O1}=4.6\text{V}$ , $V_{O2}=-4.9\text{V}$		80		%
		$I_{O1,2}=30\text{ to }150\text{mA}$ , $V_{O1}=4.6\text{V}$ , $V_{O2}=-4.9\text{V}$		85		
$V_{REF}$	Voltage reference	$I_{REF}=10\mu\text{A}$	1.196	1.209	1.222	V
$I_{REF}$	Voltage reference current capability	At $V_{REF} = V_{REF} - 1.5\%$	100			$\mu\text{A}$
<b>Step-up converter section</b>						
$V_{O1}$	Line/Load maximum output voltage variation	$V_{INA}=2.5\text{V to }4.5\text{V}$ , $I_{O1}=5\text{mA to }100\text{mA}$	4.55	4.6	4.65	V
$\Delta V_{O1\ SL}$	Static line regulation <sup>(1)</sup>	$V_{INA}=2.5\text{V to }4.5\text{V}$ , $I_{O1}=5\text{mA}$ , $I_{O2}$ no load; $T_J=-40\text{ }^\circ\text{C to }85\text{ }^\circ\text{C}$		0.5		%
		$V_{INA}=2.5\text{V to }4.5\text{V}$ , $I_{O1}=100\text{mA}$ , $I_{O2}$ no load, $T_J=-40\text{ }^\circ\text{C to }85\text{ }^\circ\text{C}$		0.5		
$\Delta V_{O1\ LT}$	Line transient	$V_{INA}=3.5\text{V to }3.0\text{V}$ , $I_{O1}=100\text{mA}$ $T_J=-40\text{ }^\circ\text{C to }85\text{ }^\circ\text{C}$ , $T_R=T_F=50\mu\text{s}$ output voltage variation with respect to nominal $V_{O1}$		-12		mV

Table 6. Electrical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$\Delta V_{O1}$	Static load regulation <sup>(2)</sup>	$I_{O1}=5$ to 100mA, $I_{O2}$ no load, $V_{INA}=2.5V$ ; $T_J=-40^\circ C$ to $85^\circ C$		+ 1		%
		$I_{O1}=5$ to 100mA, $I_{O2}$ no load, $V_{INA}=4.5V$ ; $T_J=-40^\circ C$ to $85^\circ C$		+ 1		
$\Delta V_{O1t}$	Load transient regulation	$I_{O1}=3$ to 30mA and $I_{O1}=30$ to 3mA, $T_R=T_F=30\mu s$ , output voltage variation with respect to nominal $V_{O1}$		$\pm 30$		mV
		$I_{O1}=10$ to 100mA and $I_{O1}=100$ to 10mA, $T_R=T_F=30\mu s$ , output voltage variation with respect to nominal $V_{O1}$		$\pm 35$		
$\Delta V_{O1}$	Ripple output voltage range (peak to peak)	$I_{O1}=5$ to 100mA; 0.5Vpp pulse signal applied to $V_I$ at 200Hz; TDMA Noise			20	mV
$I_{O1}$	Maximum Step-up output current	$V_I=2.9V$ to 5.5V	150			mA
I-L1MAX	$I_{peak}$ current	$V_{O1}$ below 10% of nominal value	0.9			A
$R_{DSONP1}$		$T_J = -40$ to $85^\circ C$		0.8	1.0	$\Omega$
$R_{DSONN1}$		$T_J = -40$ to $85^\circ C$		0.5	1.0	$\Omega$
<b>Inverting converter section</b>						
$V_{O2}$	Output negative voltage range	10 different values set by S-wire pin (see <a href="#">Table 9</a> )	-2.3		-5.9	V
$V_{O2}$ def.	$V_{O2}$ default value	Default output voltage	-4.80	-4.9	-5.00	V
$V_{O2}$ Toll.	$V_{O2}$ tolerance	Output voltage variation with respect to nominal $V_O$ selected		$\pm 2$		%
$\Delta V_{O2}$	Static line regulation <sup>(3)</sup>	$V_{INA}=2.5V$ to 4.5V, $I_{O2}=5mA$ , $I_{O1}$ no load; $T_J=-40^\circ C$ to $85^\circ C$		+ 1		%
		$V_{INA}=2.5V$ to 4.5V, $I_{O2}=100mA$ , $I_{O1}$ no load, $T_J=-40^\circ C$ to $85^\circ C$		+ 1		%
$\Delta V_{O1LT}$	Line transient	$V_{INA}=3.5V$ to 3.0V, $I_{O2}=100mA$ $T_J=-40^\circ C$ to $85^\circ C$ , $T_R=T_F=50\mu s$ output voltage variation with respect to nominal $V_{O2}$		+30		mV
$\Delta V_{O2}$	Static load regulation <sup>(4)</sup>	$I_{O2}=5$ to 100mA, $I_{O1}$ no load, $V_{INA}=2.5V$ ; $T_J=-40^\circ C$ to $85^\circ C$		+ 1		%
		$I_{O2}=5$ to 100mA, $I_{O1}$ no load, $V_{INA}=4.5V$ ; $T_J=-40^\circ C$ to $85^\circ C$		+ 1		
$\Delta V_{O2t}$	Load transient regulation	$I_{O2}=3$ to 30mA and $I_{O2}=30$ to 3mA, $T_R=T_F=30\mu s$ , output voltage variation with respect to nominal $V_{O2}$		$\pm 40$	$\pm 80$	mV
$\Delta V_{O2e}$	Load transient regulation HC	$I_{O2}=10$ to 100mA and $I_{O2}=100$ to 10mA, $T_R=T_F=30\mu s$		$\pm 30$	$\pm 50$	mV



Table 6. Electrical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$\Delta V_{O2}$	Ripple output voltage range	$I_{O2}=5$ to 100mA 0.5Vpp pulse signal applied to $V_1$ at 200Hz; TDMA Noise			25	mV
$I_{O2s}$	Maximum inverting output current	$V_{INA}=2.5V$ to 2.9V			-120	mA
$I_{O2}$	Maximum inverting output current	$V_{INA}=2.9V$ to 4.5V			-150	mA
$I-L_{2MAX}$	$I_{peak}$ current	$V_{O2}$ below 10% of value set by S-wire		-1.2	-1.1	A
$R_{DSONP2}$		$T_J = -40$ to 85°C		0.4	2.0	$\Omega$
$R_{DSONN2}$		$T_J = -40$ to 85°C		0.4	1.0	$\Omega$
<b>Thermal shutdown</b>						
OTP	Over temperature protection			140		°C
OTP <sub>HYST</sub>	Over temperature protection hysteresis			15		°C
<b>Discharge resistor</b>						
$R_{DIS}$	Discharge resistor value			600		$\Omega$
$T_{DIS}$	Discharge time			6		ms

1.  $[(V_{O1MAX} - V_{O1MIN}) / (V_{O1} \text{ at } 25^\circ\text{C and } V_{INA} = 2.5 \text{ V})] \times 100$
2.  $[(V_{O1MAX} - V_{O1MIN}) / (V_{O1} \text{ at } 25^\circ\text{C and } I_{O1} = 5 \text{ mA})] \times 100$
3.  $[(V_{O2MAX} - V_{O2MIN}) / (V_{O2} \text{ at } 25^\circ\text{C and } V_{INA} = 2.5 \text{ V})] \times 100$
4.  $[(V_{O2MAX} - V_{O2MIN}) / (V_{O2} \text{ at } 25^\circ\text{C and } I_{O2} = 5 \text{ mA})] \times 100$

## 6 S-wire protocol

Figure 4. S-wire protocol

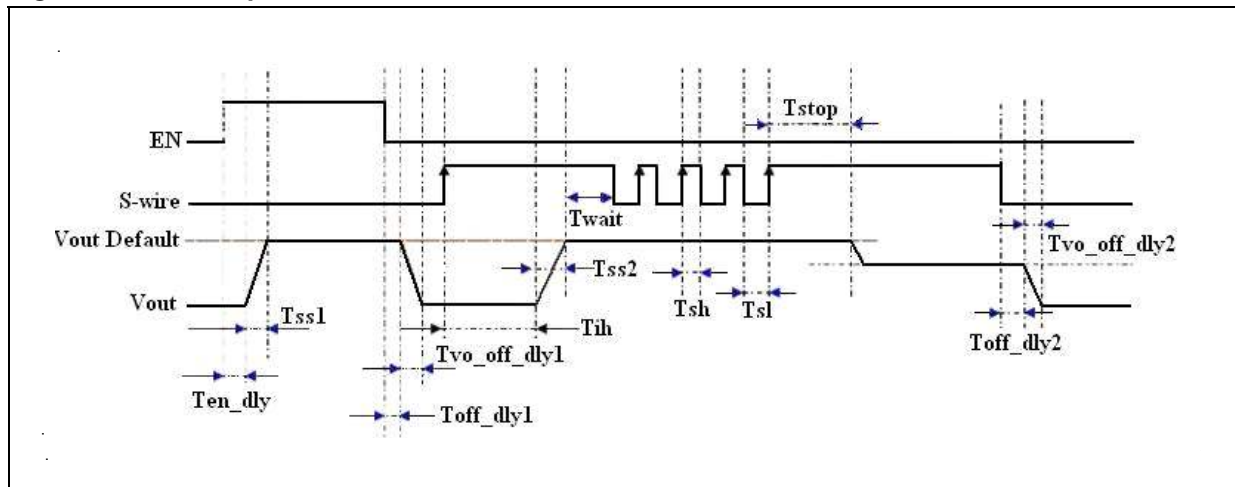


Table 7. Time

Rating	Symbol	Min.	Typ.	Max.	Unit
Enable high delay time	T <sub>en_dly</sub>		300		μs
Soft-start delay	T <sub>ss1</sub>		2		ms
Turn-off delay	T <sub>off_dly1</sub>		50		μs
V <sub>O</sub> turn-off delay	T <sub>vo_off_dly1</sub>		12		ms
S-Wire initial time	T <sub>ih</sub>		300	400	μs
Soft-start time by S-wire enable	T <sub>ss2</sub>		2	3	ms
S-Wire High	T <sub>sh</sub>	2	20	45	μs
S-Wire Low	T <sub>sl</sub>	2	20	75	μs
S-Wire signal stop indicate time	T <sub>stop</sub>	300		400	μs
V <sub>O</sub> turn-off delay by S-Wire	T <sub>vo_off_dly2</sub>		12	related to load	ms
Twait after data	T <sub>wait</sub>		0	10	μs
S-Wire turn-off detection time	T <sub>off_dly2</sub>	300		400	μs

Figure 5. Waveform

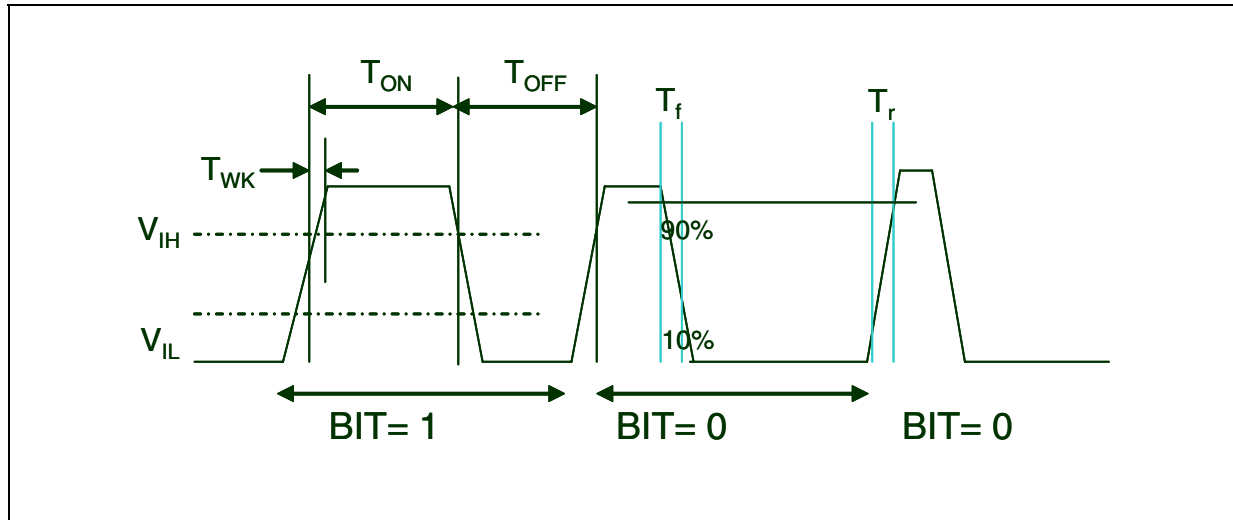


Table 8. Time

Rating	Symbol	Min.	Typ.	Max.	Unit
Rising input high threshold voltage level	$V_{IH}$	1.2		$V_{INA}$	V
Falling input high threshold voltage level	$V_{IL}$	0		0.6	V
Pull down resistor	$R_{S-WIRE}$		150		$k\Omega$
Wake up delay	$T_{WK}$			1	$\mu s$
S-Wire rising time	$T_r$			200	ns
S-Wire falling time	$T_f$			200	ns
Clocked s-wire high	$T_{ON}$	2		45	$\mu s$
S-wire low	$T_{OFF}$	2		75	$\mu s$
Input S-Wire frequency	$F_{S-WIRE}$			400	kHz

Table 9. Inverting output voltages

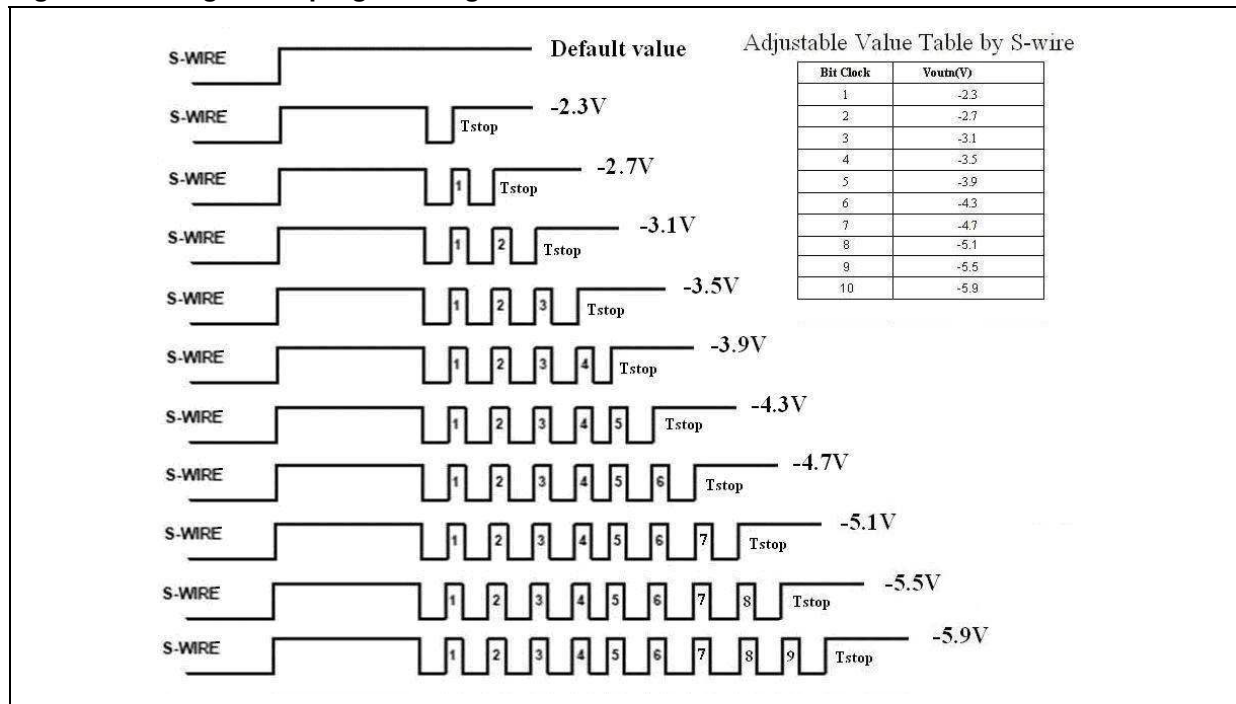
Bit clock	$V_{O2}$ (V)
1	-2.3
2	-2.7
3	-3.1
4	-3.5
5	-3.9
6	-4.3
7	-4.7
8	-5.1
9	-5.5
10	-5.9

**Table 10. Enable and s-wire pin settings**

Enable	S-wire	Action
0	0	Device off
0	1	Output set by S-Wire
1	0	Default value output (- 4.9 V)
1	1	Default value output (- 4.9 V)

*Note: Enable pin must be set to GND while using S-wire function.*

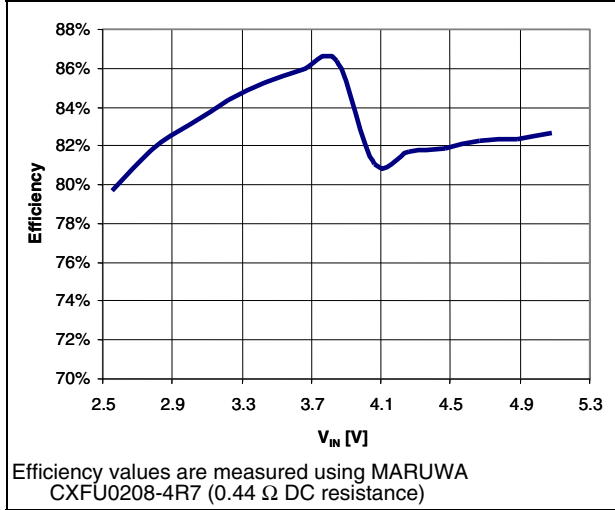
**Figure 6. Single wire programming**



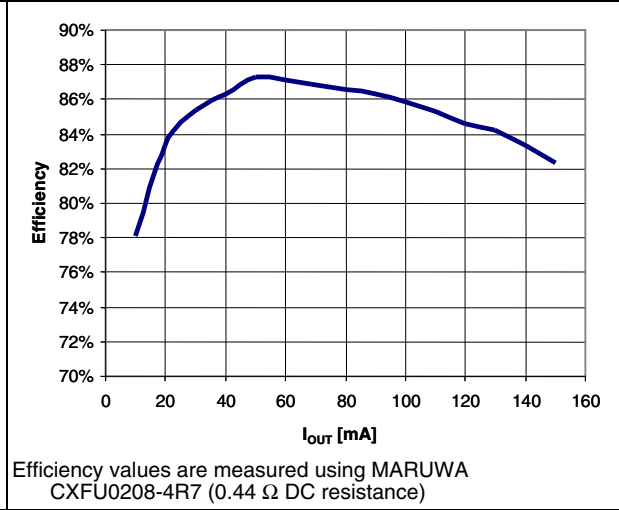
# 7 Typical performance characteristics

$C_1 = C_{O1,2} = 4.7 \mu\text{F}$ ,  $C_{\text{REF}} = 1 \mu\text{F}$ ,  $L_1 = L_2 = 4.7 \mu\text{H}$ ,  $T_J = 25 \text{ }^\circ\text{C}$

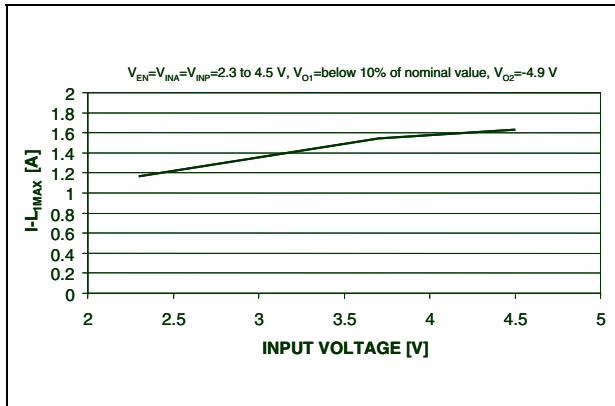
**Figure 7. Efficiency vs. input voltage**



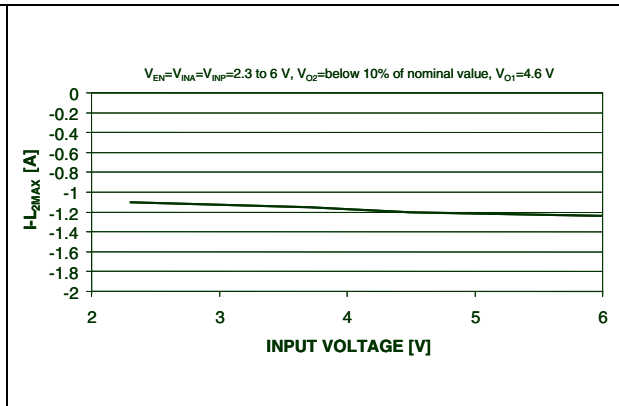
**Figure 8. Efficiency vs. output current**



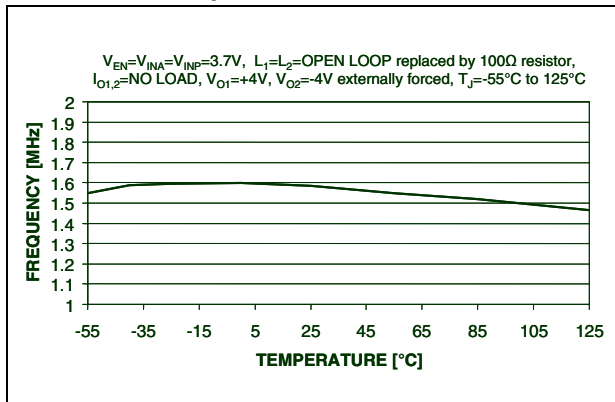
**Figure 9. Step-up inductor peak current vs. input voltage**



**Figure 10. Inverting inductor peak current vs. input voltage**



**Figure 11. PWM step-up frequency vs. temperature**



**Figure 12. PWM inverting frequency vs. temperature**

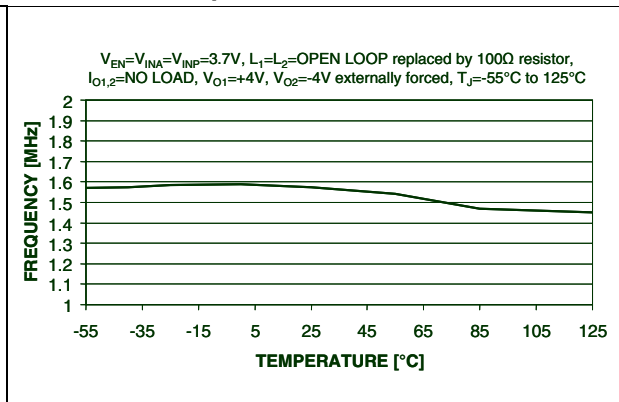


Figure 13. Quiescent current vs. temperature

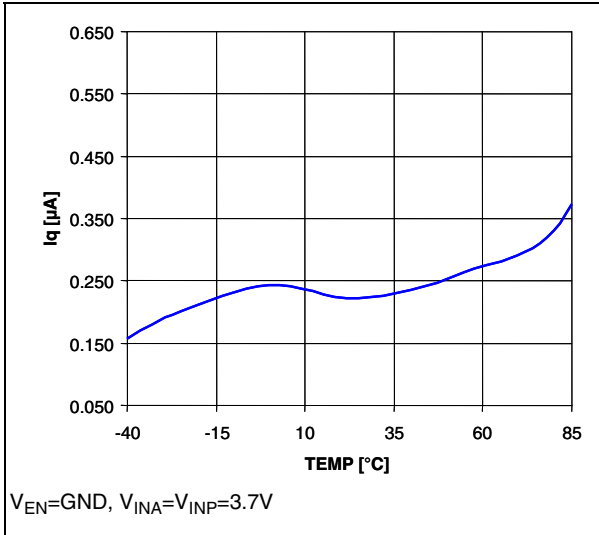


Figure 14. Input current vs. temperature

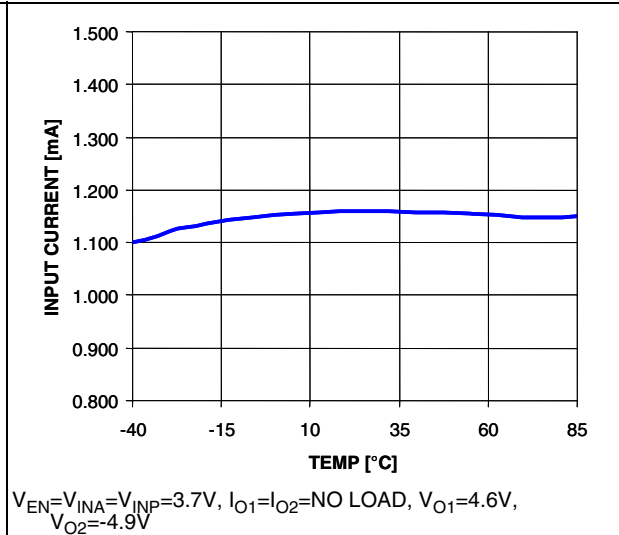


Figure 15. Step-up line transient regulation

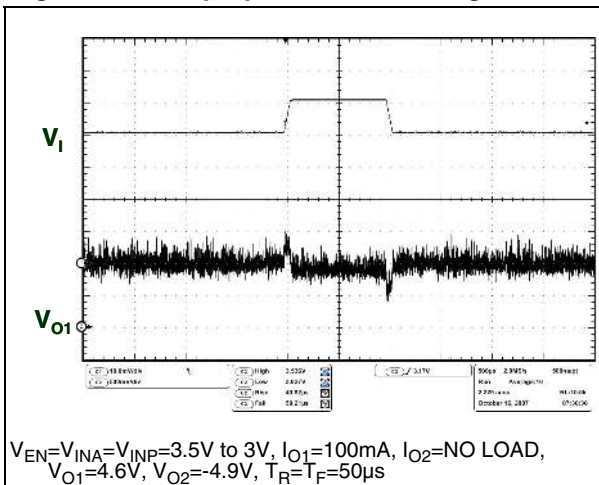


Figure 16. Inverting line transient regulation

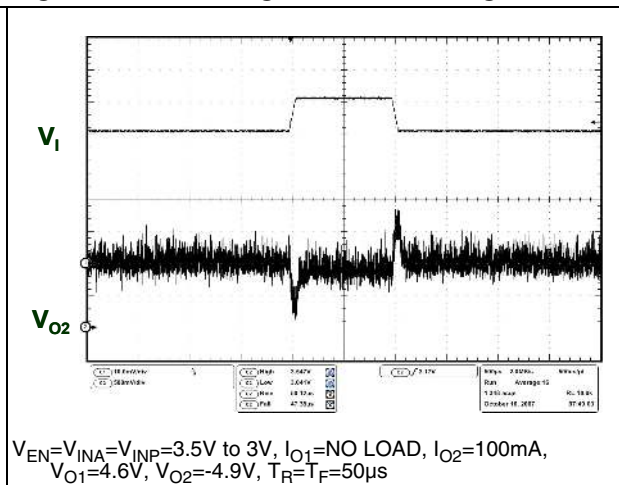


Figure 17. Step-up load transient regulation

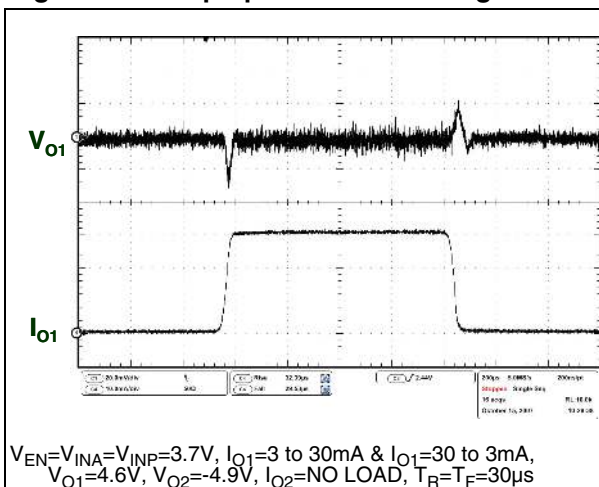


Figure 18. Inverting load transient regulation

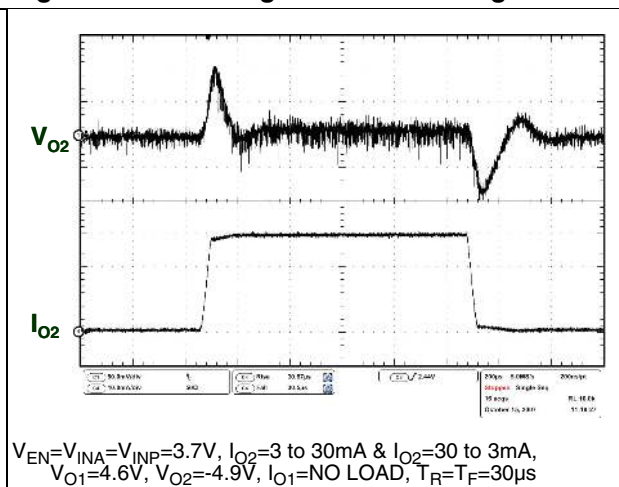
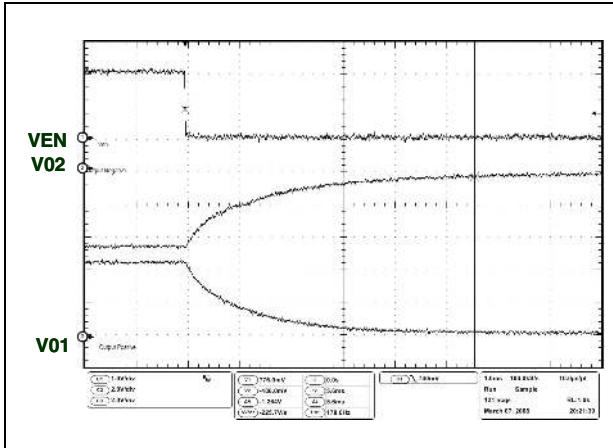


Figure 19. Fast discharge



# 8 Demonstration board

Figure 20. Suggested demonstration board schematic (top layer view)

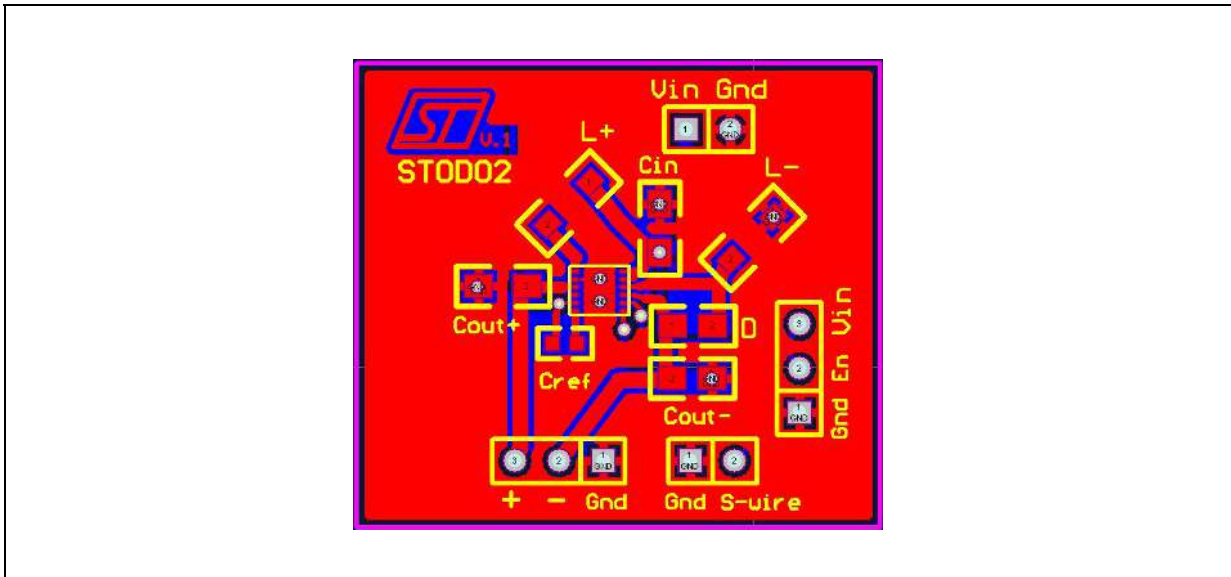
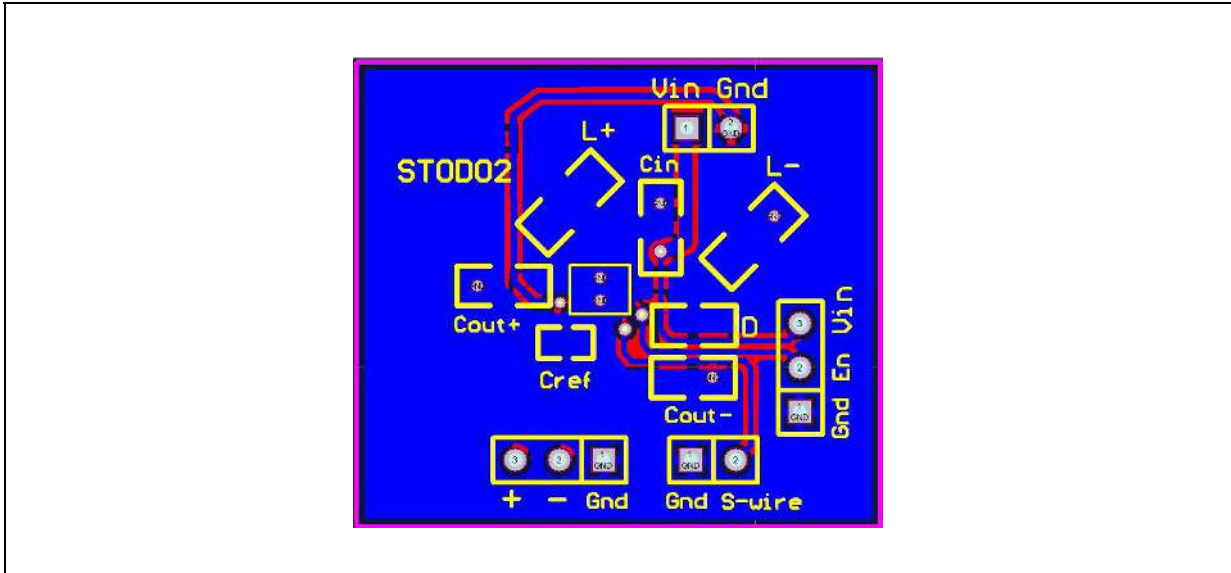


Figure 21. Suggested demonstration board schematic (bottom layer view)





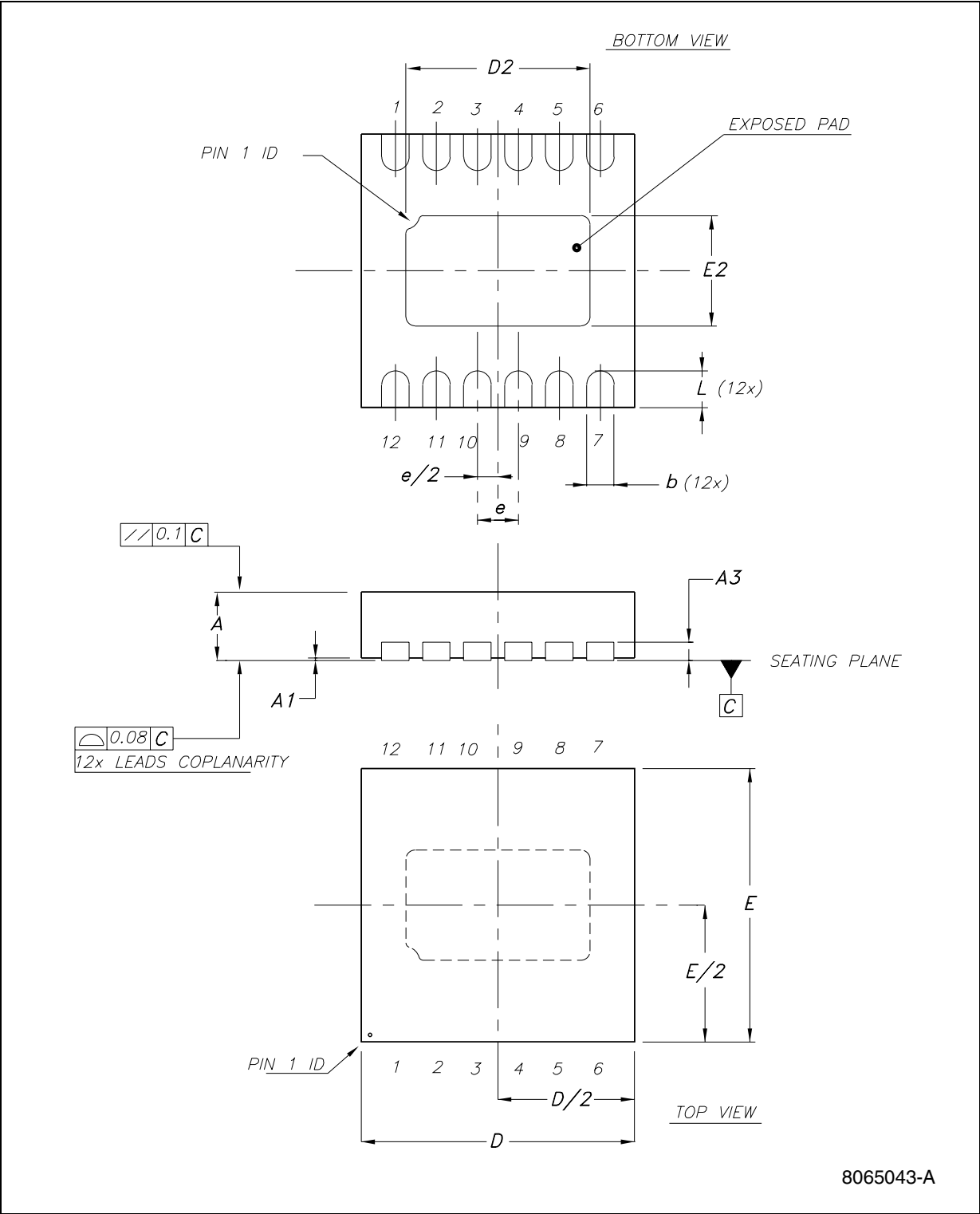
## 9 Package mechanical data

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

**Table 11. DFN12L (3 x 3 x 0.8 mm) mechanical data**

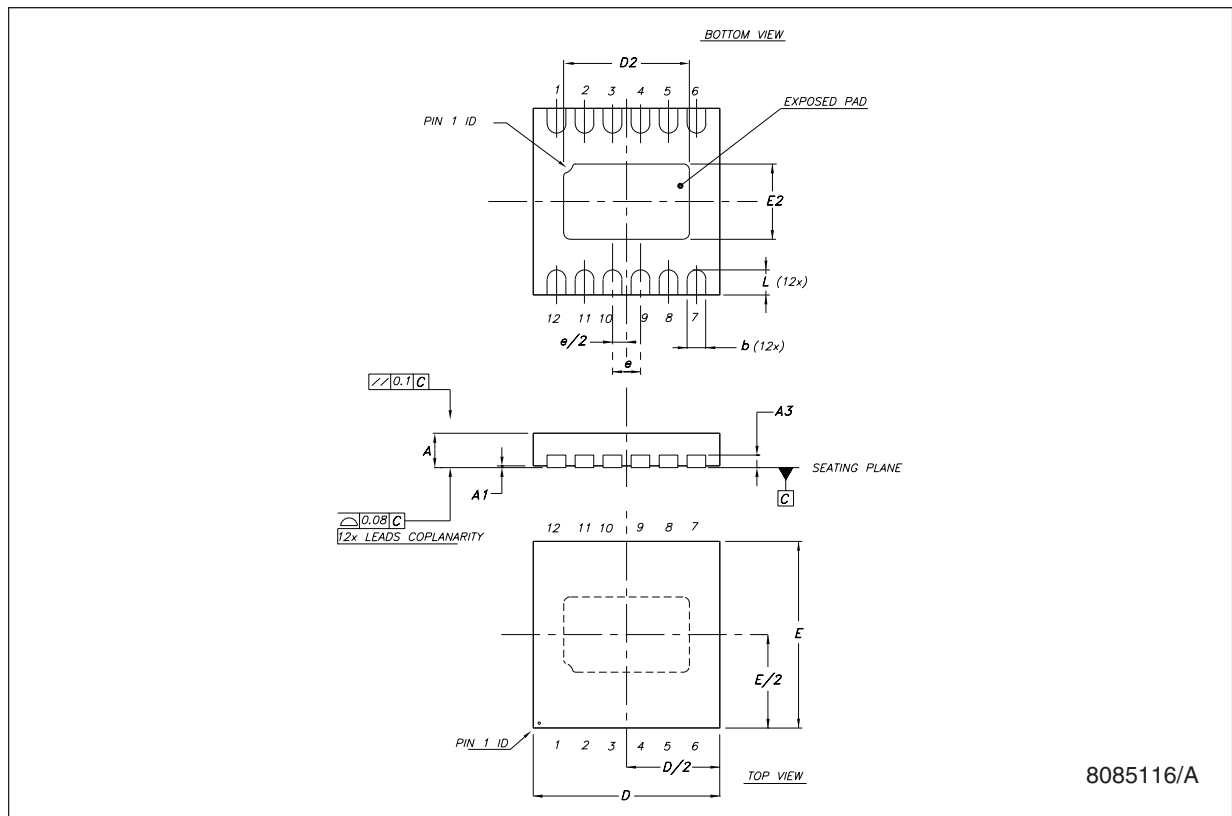
Dim.	mm.		
	Min.	Typ.	Max.
A	0.70	0.75	0.80
A1	0	0.02	0.05
A3		0.20	
b	0.18	0.25	0.30
D	2.85	3	3.15
D2	1.87	2.02	2.12
E	2.85	3	3.15
E2	1.06	1.21	1.31
e		0.45	
L	0.30	0.40	0.50

Figure 22. Drawing dimension DFN12L (3 x 3 x 0.8 mm)



**DFN12L (3 x 3 x 0.6 mm) mechanical data**

Dim.	mm.			inch.		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	0.51	0.55	0.60	0.020	0.022	0.024
A1	0	0.02	0.05	0	0.001	0.002
A3		0.20			0.008	
b	0.18	0.25	0.30	0.007	0.010	0.012
D	2.85	3	3.15	0.112	0.118	0.124
D2	1.87	2.02	2.12	0.074	0.080	0.083
E	2.85	3	3.15	0.112	0.118	0.124
E2	1.06	1.21	1.31	0.042	0.048	0.052
e		0.45			0.018	
L	0.30	0.40	0.50	0.012	0.016	0.020



**Tape & reel QFNxx/DFNxx (3x3) 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		3.3			0.130	
Bo		3.3			0.130	
Ko		1.1			0.043	
Po		4			0.157	
P		8			0.315	

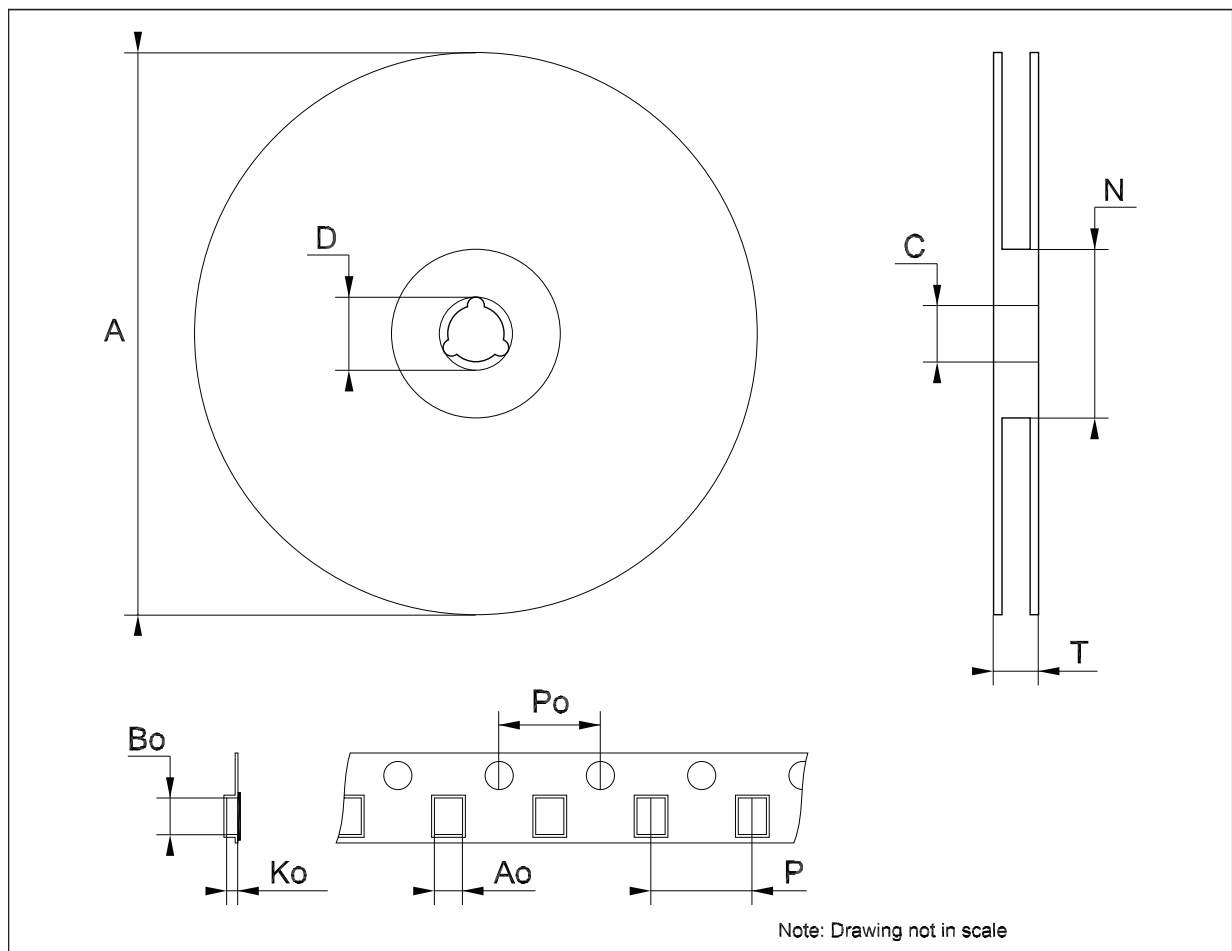
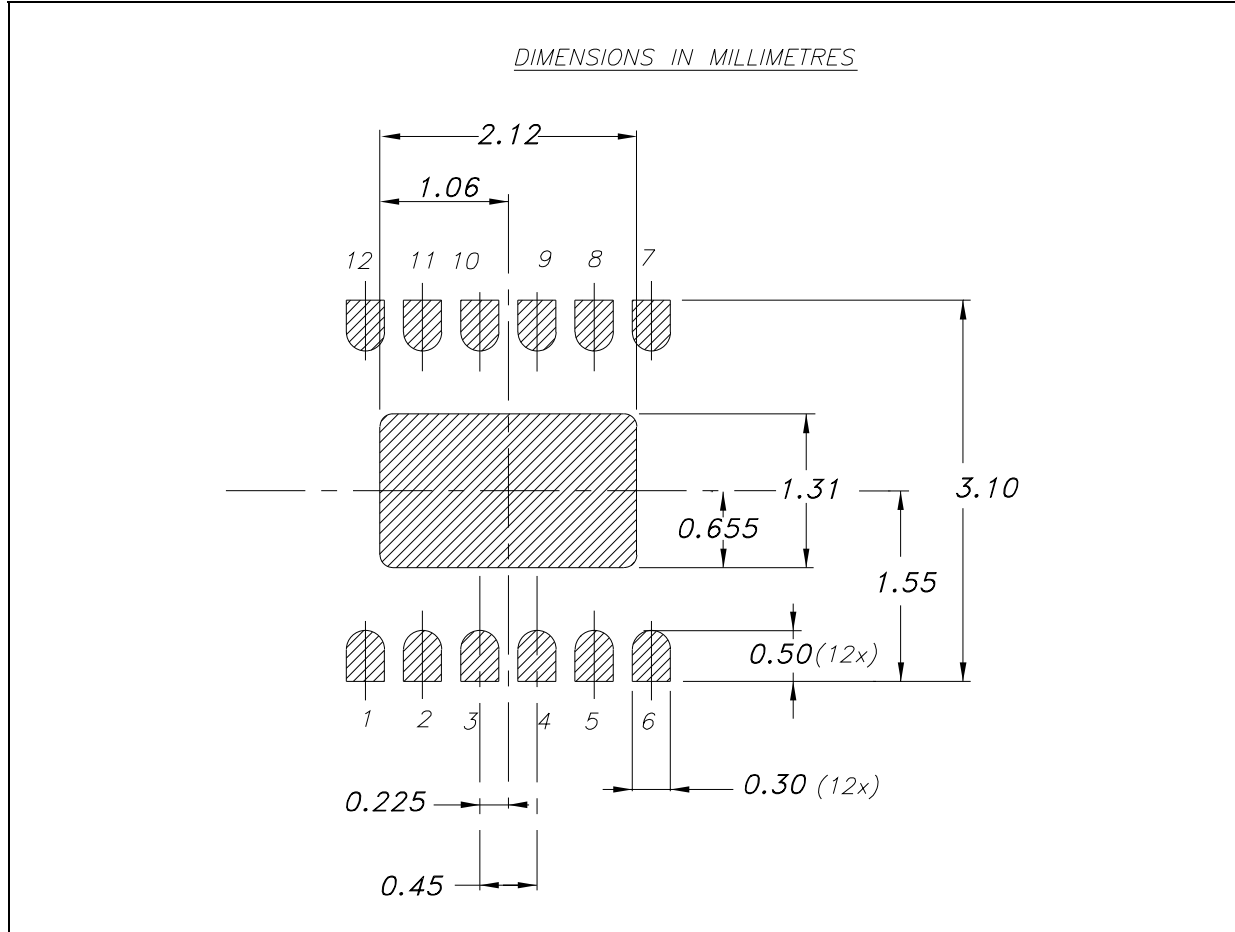


Figure 23. DFN12L (3 x 3 mm) footprint recommended data



## 10 Revision history

**Table 12. Document revision history**

Date	Revision	Changes
05-Dec-2008	1	Initial release.
15-Dec-2008	2	Added: pin description exposed pad <a href="#">Table 2 on page 4</a> .
30-Jun-2009	3	Modified: <a href="#">Table 2 on page 4</a> .

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