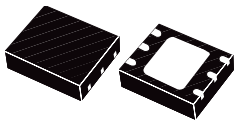
# ST1S03

## 1.5 A, 1.5 MHz adjustable, step-down switching regulator

**Datasheet - production data**



**DFN6D (3 x 3 mm)**

## Features

- Step-down current mode PWM (1.5 MHz) DC-DC converter
- 2% DC output voltage tolerance
- Internal soft-start for STARTUP current limitation and power on delay of 50 - 100 µs
- Typical efficiency: > 70% over all operating conditions
- 1.5 A output current capability
- Not switching quiescent current: max 2.5 mA over temperature range
- Switch $V_{DS}$: max. 350 mV at $I_{SW}$ = 750 mA
- Uses tiny capacitors and inductors
- Available in DFN6D 3 x 3 mm package with exposed pad

## Description

The ST1S03 is a step-down DC-DC converter optimized for powering a low voltage digital core in HDD applications and, generally, to replace the high current linear solution when the power dissipation may cause a high heating of the application environment. It provides up to 1.5 A over an input voltage range of 3 V to 16 V. A high switching frequency (1.5 MHz) allows the use of tiny surface-mount components: as well as the resistor divider to set the output voltage value, only an inductor, a Schottky diode and two capacitors are required. Besides, a low output ripple is guaranteed by the current mode PWM topology and by the use of low ESR SMD ceramic capacitors. The device is thermal protected and current limited to prevent damages due to an accidental short-circuit. The ST1S03 device is available in a DFN6D package.

**Table 1. Device summary**

| Order code | Package | Packaging |
|---|---|---|
| ST1S03PUR | DFN6D (3 x 3 mm) | Tape and reel |

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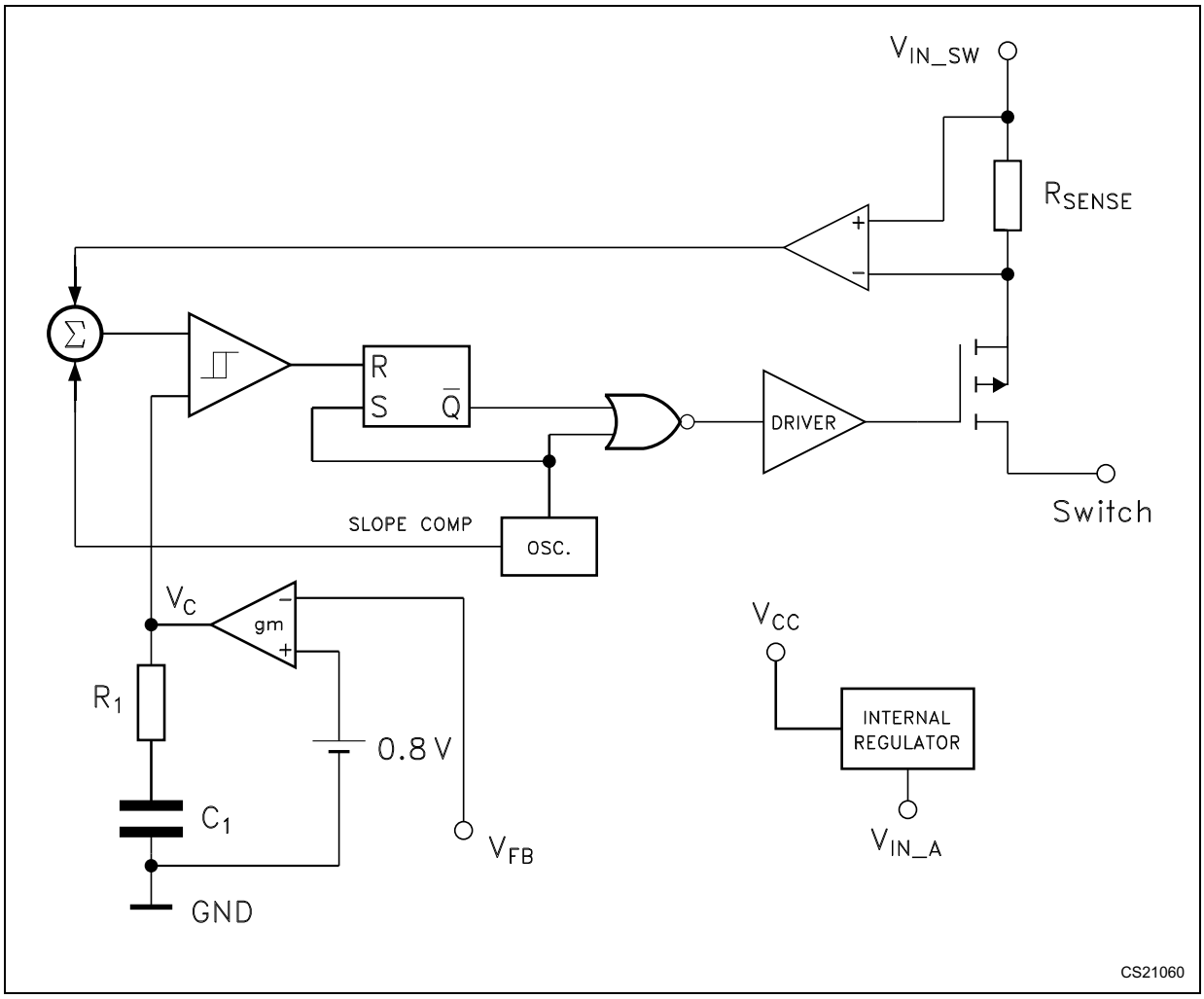
# 1 Diagram

**Figure 1. Schematic diagram**



# 2 Pin configuration

**Figure 2. Pin connections (top view)**

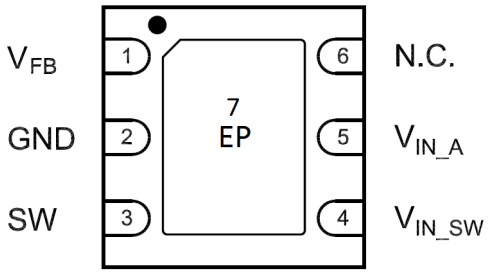



**Table 2. Pin description**

| Pin no. | Symbol | Name and function |
|---|---|---|
| 1 | $V_{FB}$ | Voltage of feedback |
| 2 | GND | System ground |
| 3 | SW | Output of the internal power switch |
| 4 | $V_{IN\_SW}$ | Power supply for the MOSFET switch |
| 5 | $V_{IN\_A}$ | Power supply for the analog circuit |
| 6 | N.C. | Not connected |
| 7 | EP | Exposed pad should be connected to GND |

# 3 Maximum ratings

**Table 3. Absolute maximum ratings**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_{IN\_SW}$ | Positive power supply voltage | -0.3 to 16 | V |
| $V_{IN\_A}$ | Positive power supply voltage | -0.3 to 16 | V |
| SWITCH voltage | Max voltage of output pin | -0.3 to 16 | V |
| $V_{FB}$ | Feedback voltage | 2.5 | V |
| $I_{VFB}$ | Common mode input voltage | ±1 | mA |
| $T_J$ | Max junction temperature | 150 | °C |
| $T_{STG}$ | Storage temperature range | -25 to 150 | °C |
| $T_{LEAD}$ | Lead temperature (soldering) 10 s | 300 | °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 4. Thermal data**

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $R_{thJC}$ | Thermal resistance junction case | 10 | °C/W |
| $R_{thJA}$ | Thermal resistance junction ambient | 55 | °C/W |

# 4 Electrical characteristics

**Table 5. Electrical characteristics** ($V_{IN\_SW}$ = $V_{IN\_A}$ = 5 V, $C_I$ = 4.7 µF, $C_O$ = 22 µF, L1 = 3.3 µH, $T_J$ = 0 to 125 °C, unless otherwise specified. Typical values are referred to 25 °C)

| Symbol | Parameter | Test conditions | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| FB | Feedback voltage | $I_O$ = 100 mA | 784 | 800 | 816 | mV |
| $I_{FB}$ | $V_{FB}$ pin bias current | | | | 600 | nA |
| $I_Q$ | Quiescent current | No switching | | | 2.5 | mA |
| $I_O$ | Output current | $V_{IN}$ = 3 V to 16 V | 1.5 | | | A |
| $I_{MIN}$ | Minimum output current | | 1 | | | mA |
| $\%V_O/\Delta V_{IN}$ | Reference line regulation | $V_{IN}$ = 3 V to 16 V | | 0.032 | 0.06 | $\% V_O/\Delta V_{IN}$ |
| $\%V_O/\Delta I_O$ | Reference load regulation | $I_O$ = 10 mA to 1.2 A | | 0.0014 | 0.003 | $\% V_O$/mA |
| PWM $f_S$ | PWM switching frequency(1) | $V_{FB}$ = 0.8 V, $T_A$ =25 °C | 1.2 | 1.5 | 1.8 | MHz |
| $D_{MAX}$ | Maximum duty cycle | | | 87 | | % |
| $I_{SWL}$ | Switching current limitation | | 1.65 | | | A |
| $V_{DS}$ | Switch $V_{DS}$ | $I_{SW}$ = 750 mA | | 200 | 350 | mV |
| E | Efficiency | $I_O$ = 10 mA to 1.2 A | 70 | | | % |
| $T_{SHDN}$ | Thermal shutdown(1) | | 130 | 150 | | °C |
| $T_{HYS}$ | Thermal shutdown hysteresis(1) | | | 15 | | °C |
| $\Delta V_O/\Delta I_O$ | Load transient response(1) | $I_O$ = 100 mA to 700 mA<br>$t_R = t_F \geq 100$ ns, $T_A$ = 25 °C | -5 | | +5 | $\% V_O$ |
| $\Delta V_O/\Delta I_O$at $I_O$ = short | Short-circuit removal response(1) | $I_O$ = 10 mA to short, $T_A$ = 25 °C | | | +5 | $\% V_O$ |

1. Guaranteed by design, but not tested in production.

# 5 Application notes

The ST1S03 is an adjustable current mode PWM step-down DC-DC converter with an internal 1.5 A power switch, housed in a 6-lead DFN 3 x 3 mm package.

It's a complete 1.5 A switching regulator with its internal compensation eliminating an additional component.

The constant frequency, current mode, PWM architecture and stable operation with ceramic capacitors results in a low, predictable output ripple. However, in order to keep the output regulated, the devices goes in pulse skipping mode when a very light load is required.

To clamp the error amplifier reference voltage, a soft-start control block generating a voltage ramp has been implemented. Besides an on-chip power on reset of 50 = 100 µs ensures the proper operation when switching on the power supply. Other circuits fitted to the device protection are the thermal shutdown blocks which turn off the regulator when the junction temperature exceeds 150 °C typically and the cycle-by-cycle current limiting that provides protection against shorted outputs.

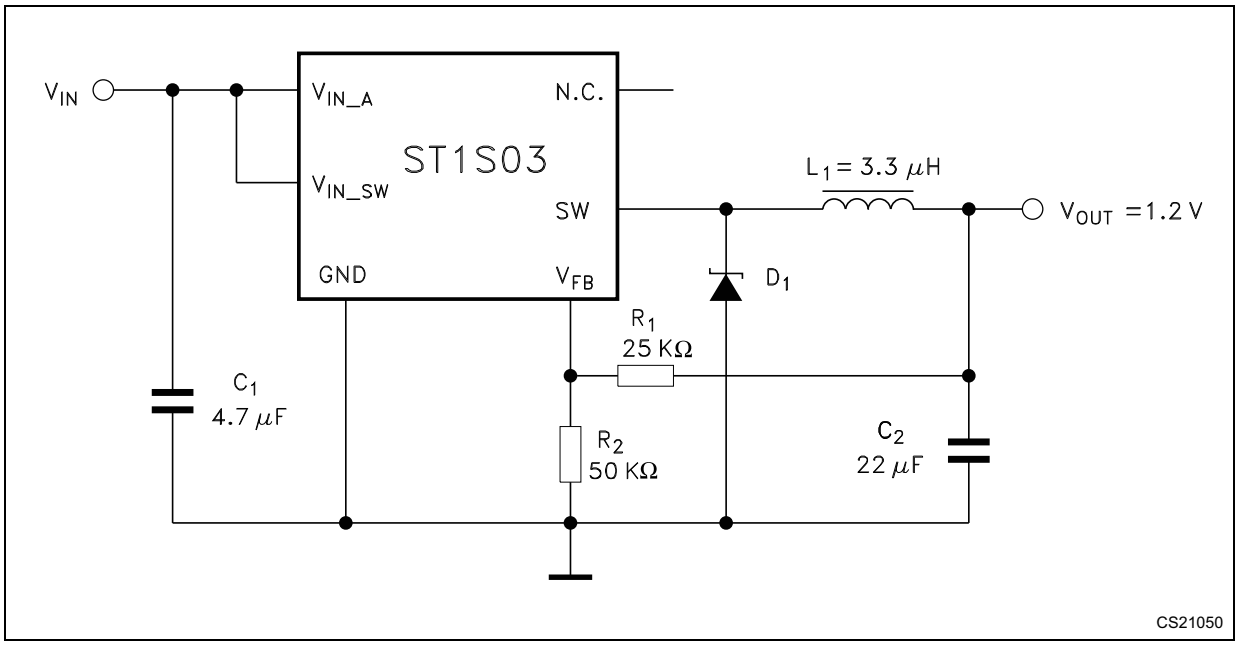
Being the ST1S03 an adjustable regulator, the output voltage is determined by an external resistor divider. The desired value is given by the following equation:

$$V_O = V_{FB} [1 + R1 / R2]$$

To make the device working, only other four external components are required: a Schottky diode, an inductor and two capacitors. The chosen inductor must be able to not saturate at the peak current level. Besides, its value can be selected keeping in account that a large inductor value increases the efficiency at a low output current and reduces an output voltage ripple, while a smaller inductor can be chosen when it is important to reduce the package size and the total cost of the application. Finally, the ST1S03 device has been designed to work properly with the X5R or X7R SMD ceramic capacitors both at the input and at the output. This kind of capacitors, thanks to their very low series resistance (ESR), minimize the output voltage ripple. Other low ESR capacitors can be used according to the need of the application without invalidating the right functioning of the device. Due to the high switching frequency and peak current, it is important to optimize the application environment reducing the length of the PCB traces and placing all the external components near the device.

# 6 Typical application

**Figure 3. Application circuits**



# 7 Typical performance characteristics

(L1 = 3.3 µH, $C_I$ = 4.7 µF, $C_O$ = 22 µF, unless otherwise specified).

**Figure 4. Load voltage feedback vs. temp.**

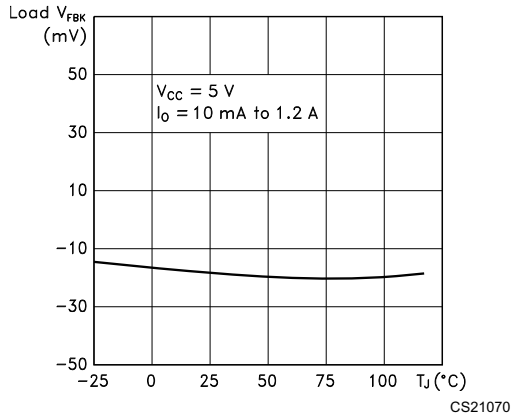



**Figure 5. Voltage feedback vs. temperature**

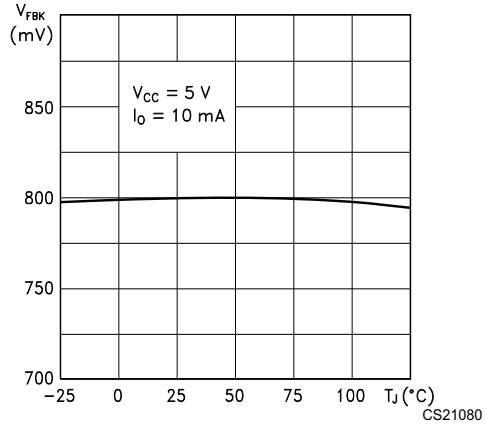



**Figure 6. Line output voltage regulation vs. temperature**

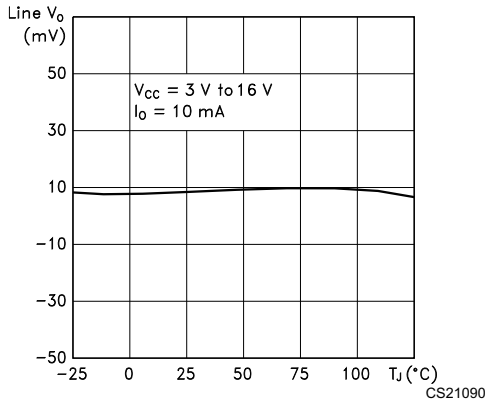



**Figure 7. Line voltage feedback vs. temperature**

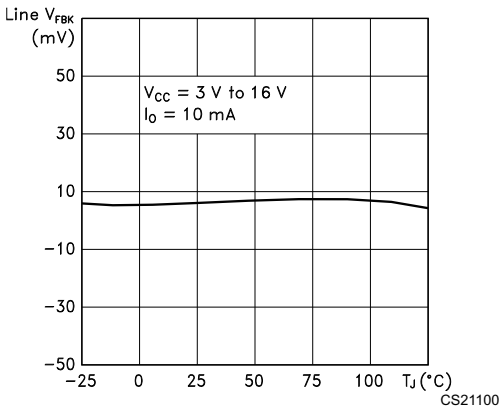



**Figure 8. Voltage feedback vs. output current**

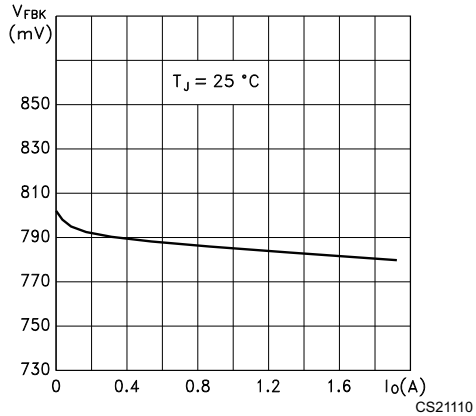



**Figure 9. PWM Switching frequency vs. temp.**

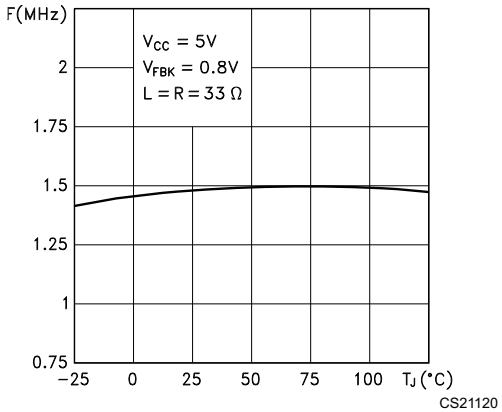


**Figure 10. Quiescent current vs. temperature**

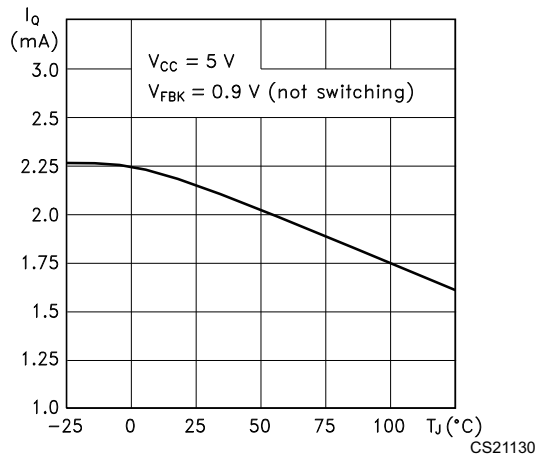



**Figure 11. Quiescent current vs. input voltage**

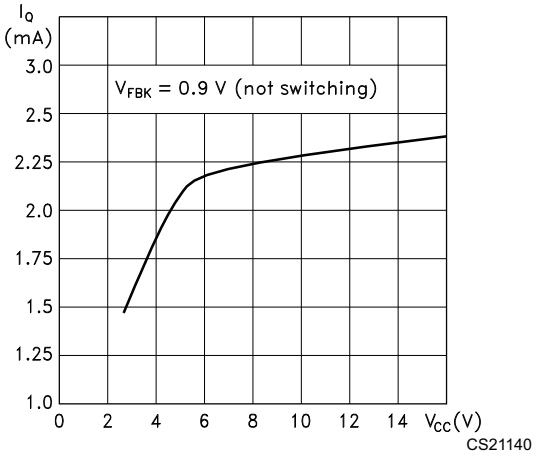



**Figure 12. Minimum operating voltage vs. output voltage**

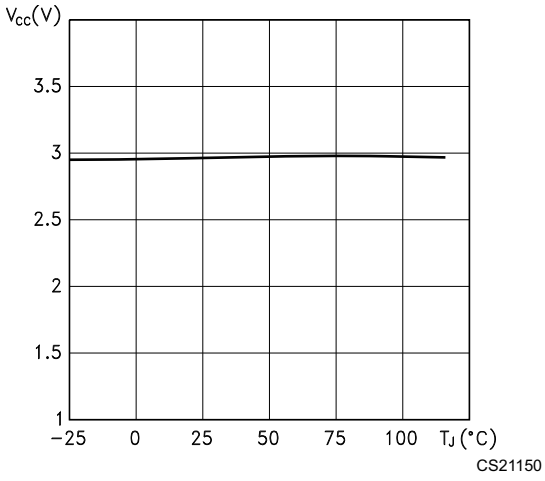



**Figure 13. Efficiency vs. temperature**

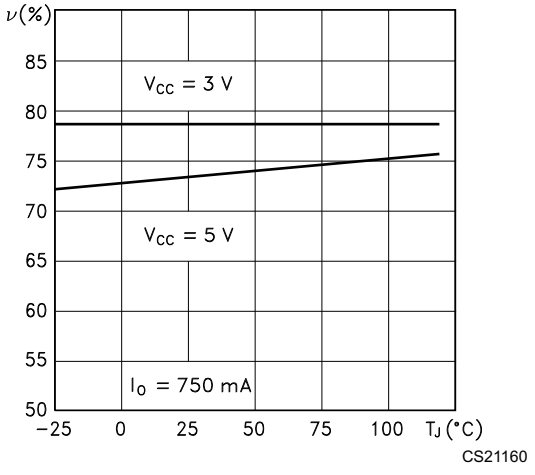



**Figure 14. Efficiency vs. output current**

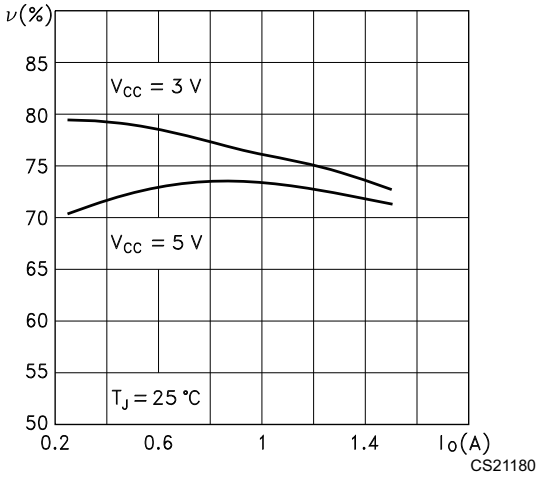



**Figure 15. Switch $V_{DS}$ vs. temperature**

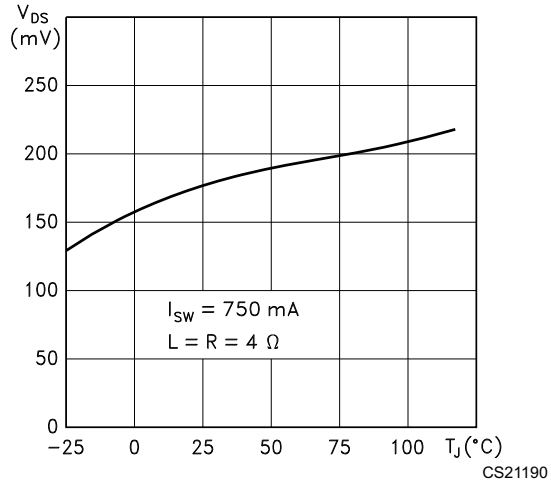


**Figure 16. Switch RDS-ON vs. temperature**

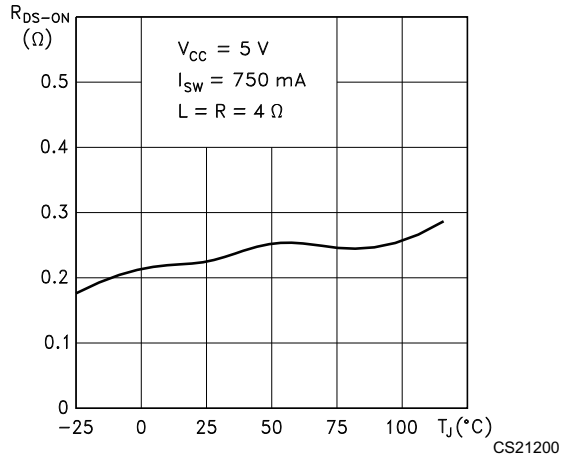



**Figure 17. Switch current limitation vs. temperature**

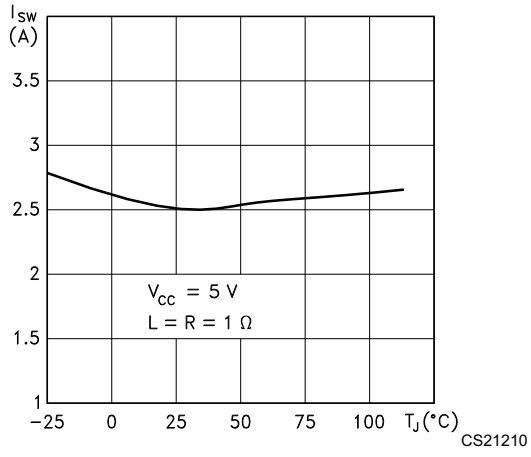
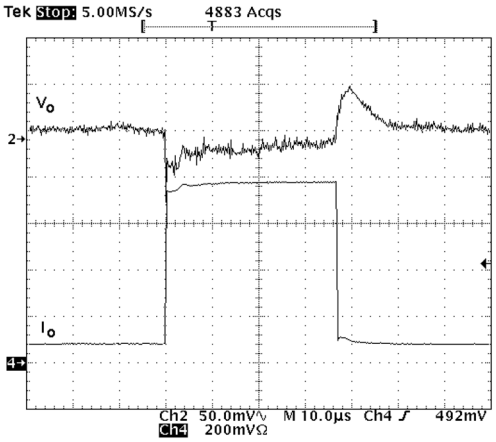
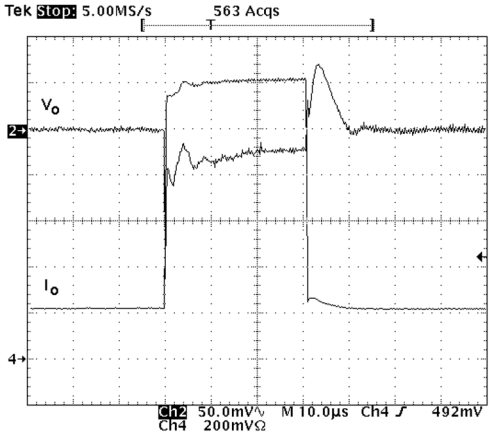



**Figure 18. Load transient response**



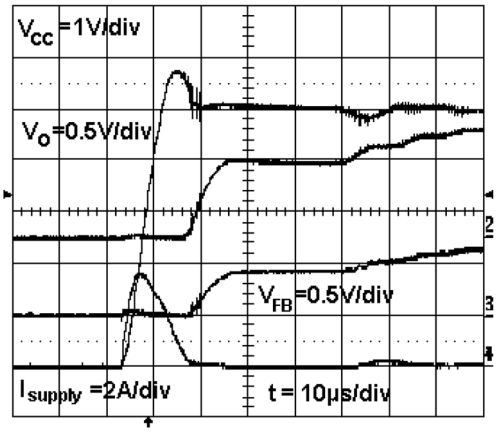

$V_{CC}$ = 5 V, $I_O$ = 100 mA to 780 mA, $C_I$ = 4.7 µF, $C_O$ = 22 µF, L = 3.3 µH, $T_{ON}$ = 38 µs, $T_J$ = 25 °C

**Figure 19. Load transient response**



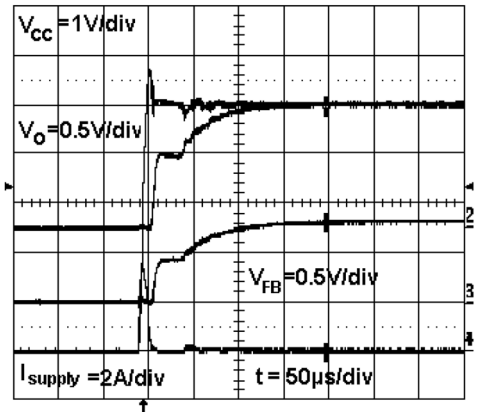

$V_{CC}$ = 5 V, $I_O$ = 200 mA to 1.2 A, $C_I$ = 4.7 µF, $C_O$ = 22 µF, L = 3.3 µH, $T_{ON}$ = 38 µs, $T_J$ = 25 °C

**Figure 20. Startup transient**




$V_{CC}$ = 5 V, $T_J$ = 25 °C

**Figure 21. Startup transient**




$V_{CC}$ = 5 V, $T_J$ = 25 °C

# 8 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 22. DFN6D (3 x 3 mm) package outline**

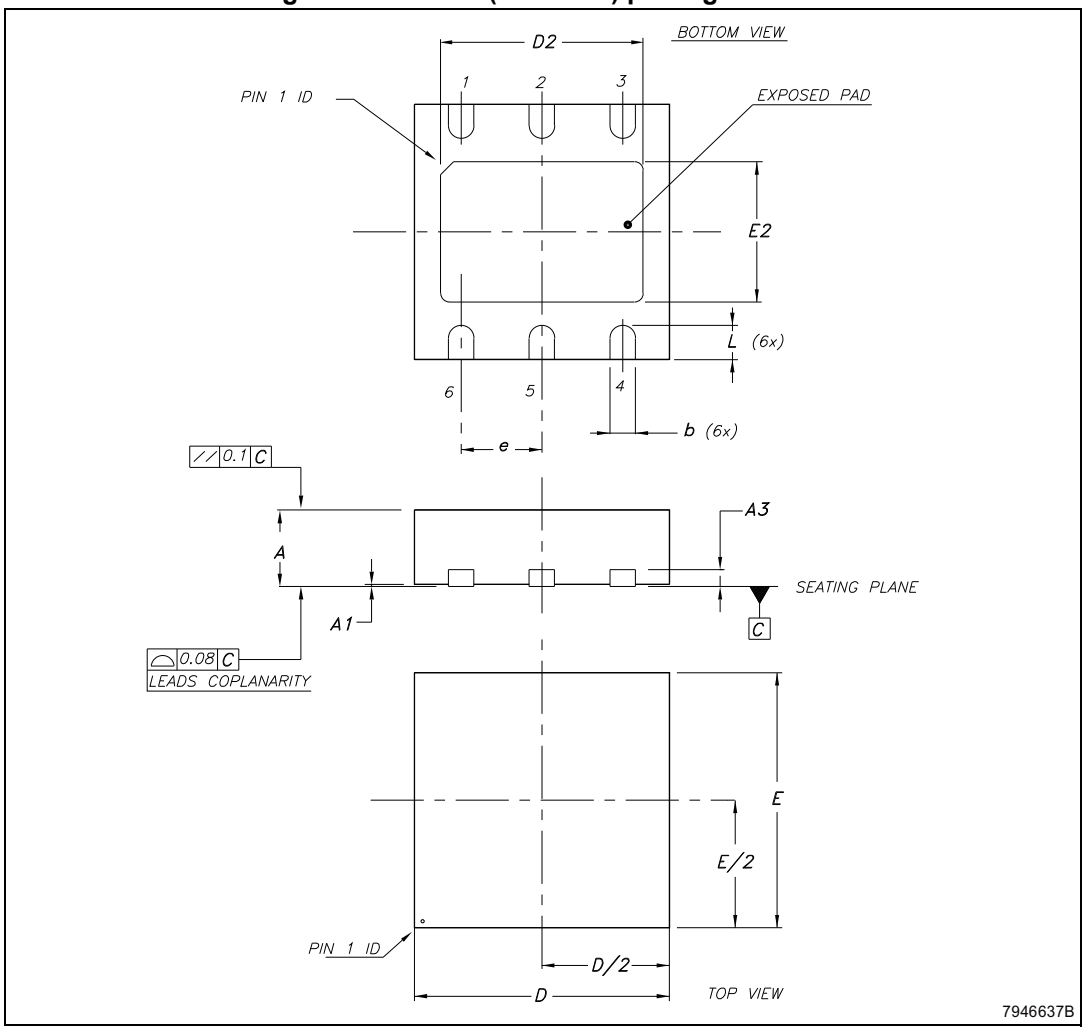
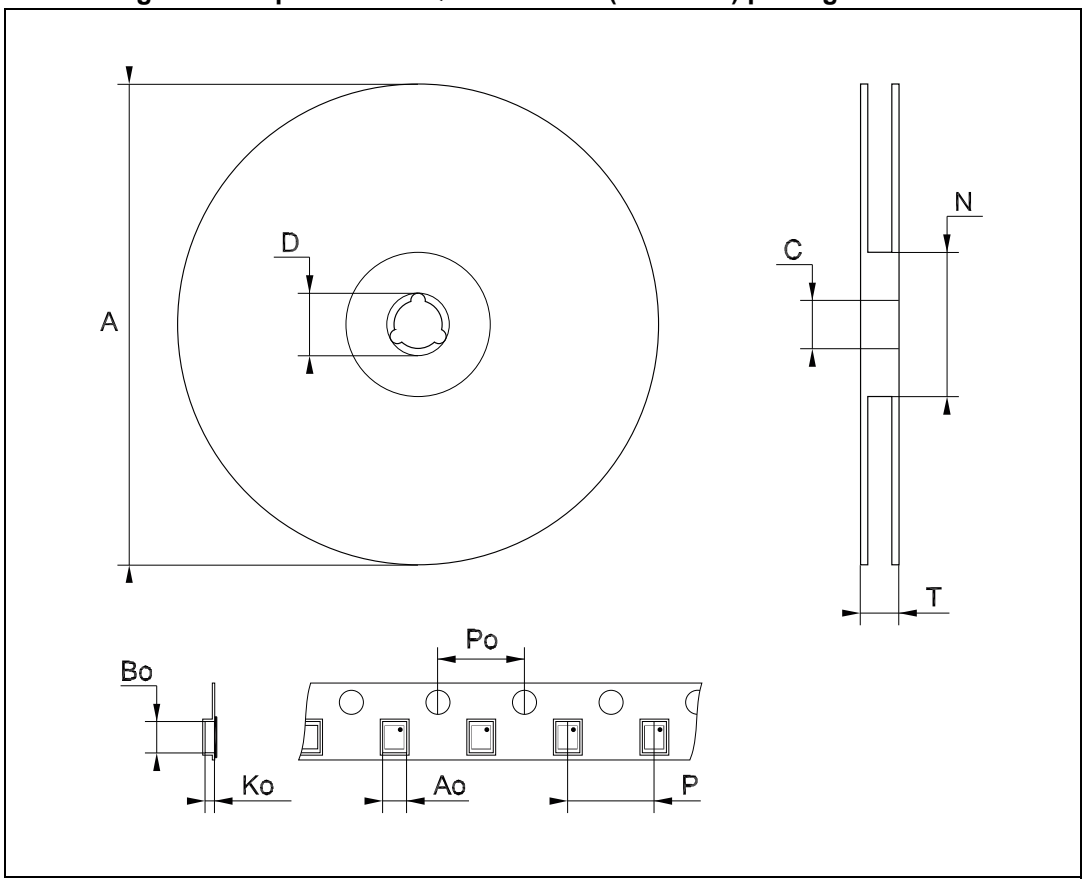



**Table 6. DFN6D (3 x 3 mm) package mechanical data**

| Symbol | Dimensions (mm) | | | Dimensions (inch) | | |
|---|---|---|---|---|---|---|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | 0.80 | | 1.00 | 0.031 | | 0.039 |
| A1 | 0 | 0.02 | 0.05 | 0 | 0.001 | 0.002 |
| A3 | | 0.20 | | | 0.008 | |
| b | 0.23 | | 0.45 | 0.009 | | 0.018 |
| D | 2.90 | 3.00 | 3.10 | 0.114 | 0.118 | 0.122 |
| D2 | 2.23 | | 2.50 | 0.088 | | 0.098 |
| E | 2.90 | 3.00 | 3.10 | 0.114 | 0.118 | 0.122 |
| E2 | 1.50 | | 1.75 | 0.059 | | 0.069 |
| e | | 0.95 | | | 0.037 | |
| L | 0.30 | 0.40 | 0.50 | 0.012 | 0.016 | 0.020 |

**Figure 23. Tape and reel QFNxx/DFNxx (3 x 3 mm) package outline(1)**




1. Drawing is not in scale.

**Table 7. Tape and reel QFNxx/DFNxx (3 x 3 mm) package mechanical data**

| Symbol | Dimensions (mm) | | | Dimensions (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 | 60 | | | 2.362 | | |
| T | | | 18.4 | | | 0.724 |
| Ao | | 3.3 | | | 0.130 | |
| Bo | | 3.3 | | | 0.130 | |
| Ko | | 1.1 | | | 0.043 | |
| Po | | 4 | | | 0.157 | |
| P | | 8 | | | 0.315 | |

# 9 Revision history

**Table 8. Document revision history**

| Date | Revision | Changes |
|---|---|---|
| 11-Nov-2004 | 1 | First Release. |
| 08-Feb-2005 | 2 | Maturity Change. |
| 03-Mar-2005 | 3 | Mistake on Figure 1, $T_J$ is changed 125 ==> 150°C on Table 3. |
| 13-Jul-2005 | 4 | Add new package SO-8 exposed pad. |
| 29-Mar-2007 | 5 | Package SO-8 removed. |
| 07-Mar-2008 | 6 | Removed: package mechanical data DFN6. |
| 14-Nov-2014 | 7 | Updated *Table 1: Device summary on page 1* (updated Packaging).<br>Updated *Figure 2: Pin connections (top view) on page 4* (replaced by new figure).<br>Updated *Table 2: Pin description on page 4* (added row 7).<br>Updated *Section 8: Package information on page 12* (updated and added titles, updated ECOPACK text, reversed order of *Figure 22* and *Table 6*, *Figure 23* and *Table 7*, updated headings of *Table 6* and *Table 7*).<br>Minor modifications throughout document. |

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