

# DC6M60xX6 family

6 MHz, 650 mA, ultra small DC-to-DC buck converter

Rev. 2 — 29 January 2013

Product data sheet

## 1. Product profile

### 1.1 General description

The DC6M60xX6 family consists of highly efficient 6 MHz, 650 mA step-down DC-to-DC converters. The devices convert input voltages between 2.3 V and 5.5 V to fixed output voltages of 1.2 V, 1.5 V, 1.8 V or 2.85 V.

The devices of DC6M60xX6 family are optimized for battery-driven applications. Their high efficiency of up to 95 % enables an extended battery life in all portable designs. Buck operation at a switching frequency of 6 MHz allows using only a small low-cost 470 nH coil and two capacitors. Besides working with standard chip inductors, the DC6M60xX6 family devices also support Printed-Circuit Board (PCB) coils and air coils.

Product versions with and without automatic mode selection between Pulse Frequency Modulation (PFM) and Pulse Width Modulation (PWM) are available. Optionally the devices can be switched to forced PWM mode.

### 1.2 Features and benefits

- Efficiency up to 95 %
- Extremely low output ripple in PWM and PFM mode
- $\pm 2$  % total DC output voltage accuracy
- Soft start function for limiting inrush current
- Short circuit and over-temperature protection
- Integrated flyback diode
- Enable input operates with an active HIGH or with a clock signal
- Optional power good indicator output (XSHUTDOWN version)
- Wafer-Level Chip-Size Package (WLCSP) with 0.4 mm pitch

### 1.3 Applications

- |                               |                                 |
|-------------------------------|---------------------------------|
| ■ Smartphones                 | ■ Tablet PCs                    |
| ■ Mobile handsets             | ■ Mobile Internet Devices (MID) |
| ■ Digital Still Cameras (DSC) | ■ Portable Media Players (PMP)  |

### 1.4 Quick reference data

- |   |   |
|---|---|
| ■ $I_O = 650$ mA (max)                                  | ■ Switching frequency $f_{\text{clk(PWM)}} = 6$ MHz |
| ■ $V_O = 1.2$ V, 1.5 V, 1.8 V or 2.85 V                 | ■ $V_I = 2.3$ V to 5.5 V                            |
| ■ Supply current $I_{CC} = 0.2$ $\mu$ A in standby mode |   |



2. Pinning information

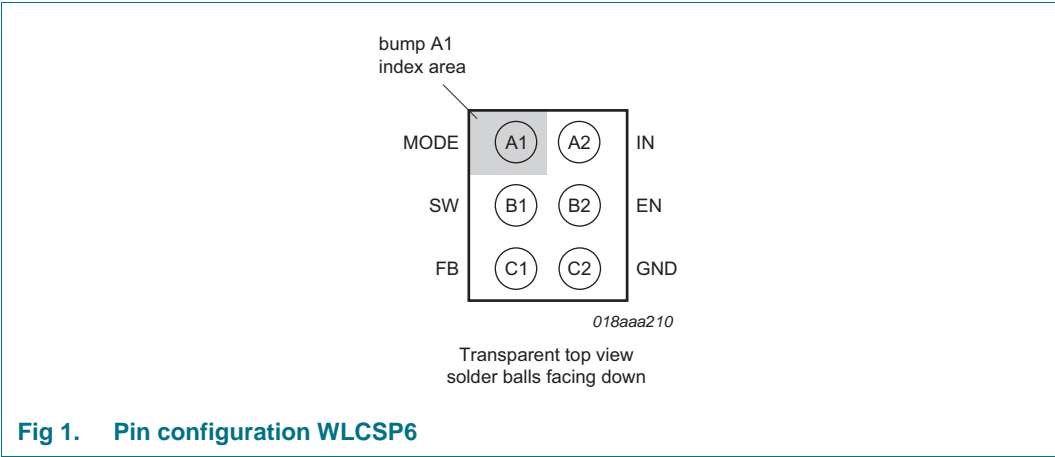


Fig 1. Pin configuration WLCSP6

Table 1. Pin description

Symbol	Pin	Description
MODE <a href="#">[1]</a>	A1	voltage select/mode select/XSHUTDOWN
IN	A2	supply input voltage
SW	B1	output voltage switch regulator
EN	B2	enable
FB	C1	control feedback
GND	C2	ground

[1] Mode function depends on the chosen version of the buck converter as listed in [Table 3](#).

### 3. Ordering information

DC6M60xX6 family is available with different modes or output voltages and can be supplied upon request and acceptance from NXP Semiconductors. For more details, see [Section 19](#).

**Table 2. Ordering information**

Type number	Package		
	Name	Description	Version
DC6M60xX6 family	WLCSP6	wafer-level chip-size package; 6 bumps (3 × 2) <a href="#">[1]</a>	-

[1] Size 1.36 × 0.96 × 0.47 mm

#### 3.1 Ordering options

**Table 3. Ordering options for DC6M601X6 and DC6M603X6 [\[1\]](#)**

Type number	Mode option	Nominal output voltage (V <sub>O(nom)</sub> )
DC6M601X6/12S	select automatic PWM/PFM or forced PWM mode	1.2 V
DC6M601X6/15S	select automatic PWM/PFM or forced PWM mode	1.5 V
DC6M601X6/18S	select automatic PWM/PFM or forced PWM mode	1.8 V
DC6M601X6/285S	select automatic PWM/PFM or forced PWM mode	2.85 V
DC6M603X6/12A	power good (XSHUTDOWN) output; automatic PWM/PFM mode	1.2 V
DC6M603X6/15A	power good (XSHUTDOWN) output; automatic PWM/PFM mode	1.5 V
DC6M603X6/18A	power good (XSHUTDOWN) output; automatic PWM/PFM mode	1.8 V

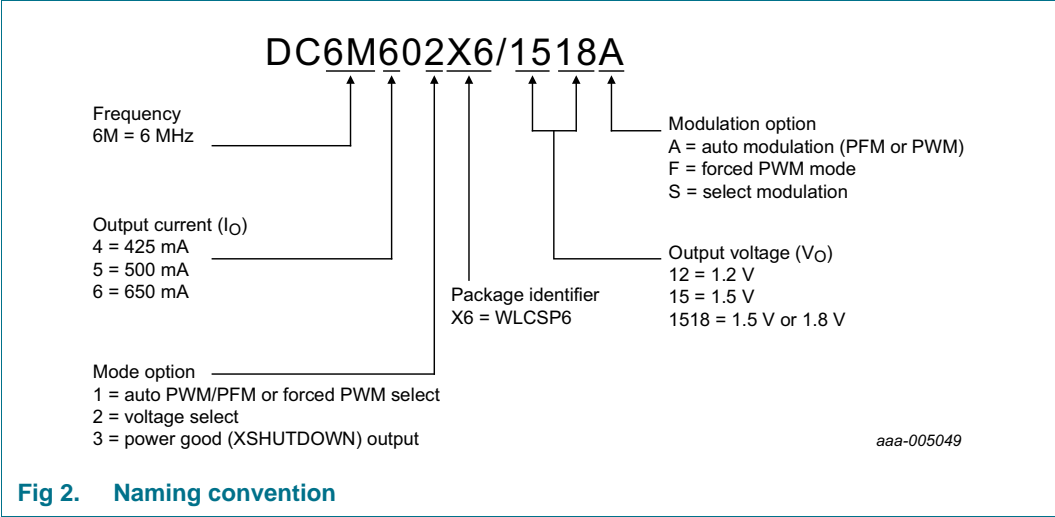
[1] For detail information about options see [Section 5](#), about functional selection see [Section 5.6](#).

**Table 4. Ordering options for DC6M602X6 [\[1\]](#)**

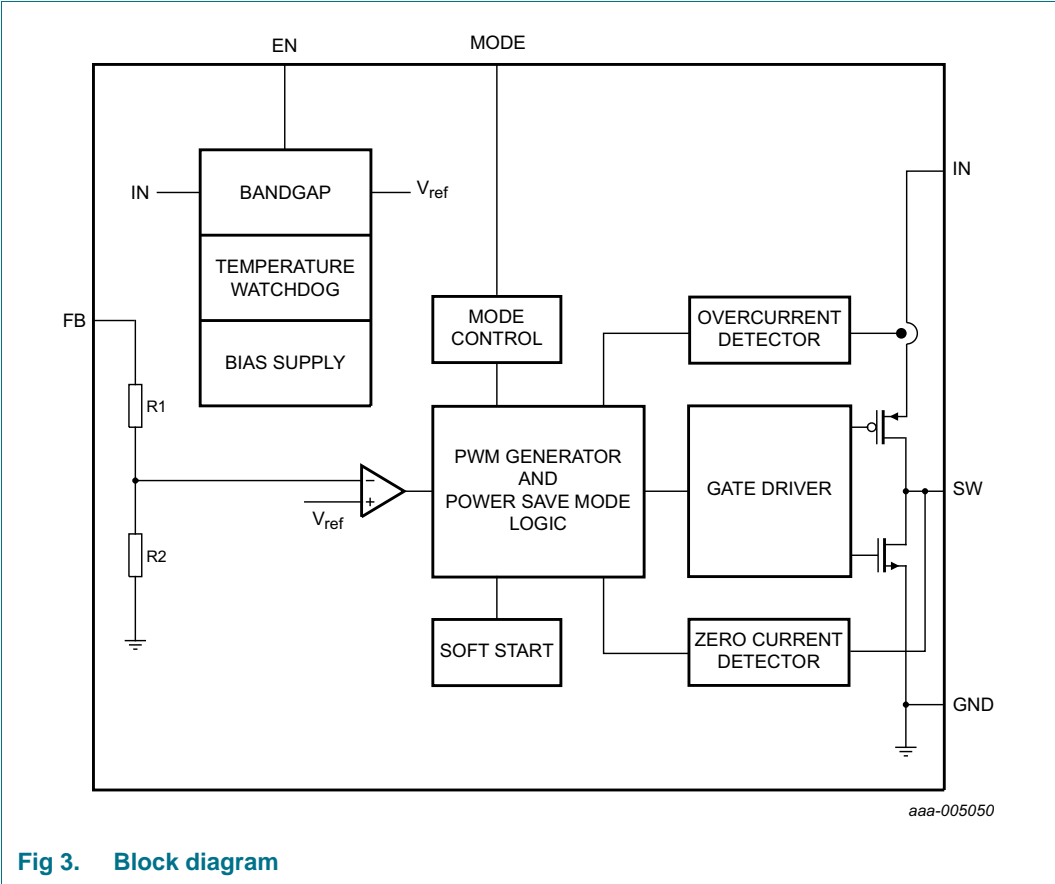
Type number	Mode option	Nominal output voltage (V <sub>O(nom)</sub> )	
		MODE = LOW	MODE = HIGH
DC6M602X6/1215A	output voltage select; automatic PWM/PFM mode	1.2 V	1.5 V
DC6M602X6/1218A	output voltage select; automatic PWM/PFM mode	1.2 V	1.8 V
DC6M602X6/1518A	output voltage select; automatic PWM/PFM mode	1.5 V	1.8 V
DC6M602X6/1215F	output voltage select; forced PWM mode	1.2 V	1.5 V
DC6M602X6/1218F	output voltage select; forced PWM mode	1.2 V	1.8 V
DC6M602X6/1518F	output voltage select; forced PWM mode	1.5 V	1.8 V

[1] For detail information about options see [Section 5](#), about functional selection see [Section 5.6](#).

3.1.1 Naming convention

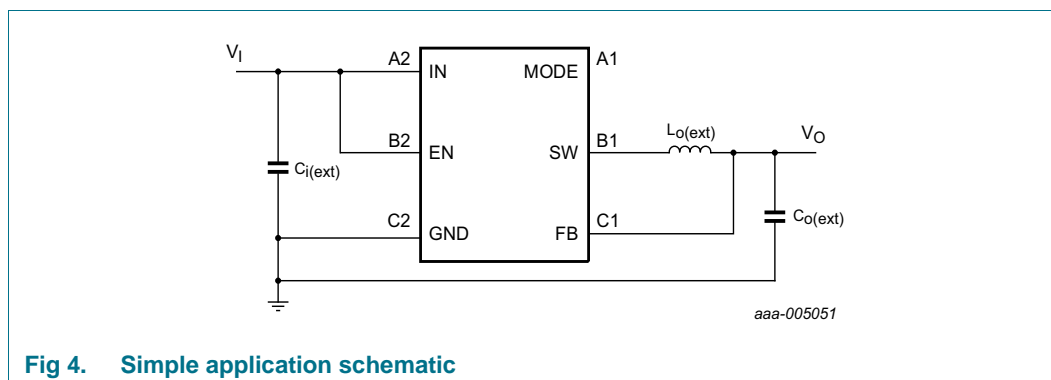


4. Block diagram



## 5. Functional description

The step-down converter ([Figure 4](#)) generates a regulated constant output voltage behind an externally connected coil at pin SW. For this operation only the inductor and two filter capacitors are required. No additional flyback diode is needed. Place the pick-off pin for FB behind the inductor to sense the output voltage.



The step-down converter starts a switching cycle with an active P-channel MOS (PMOS) which allows rising the output voltage until a defined value is reached. Then the feedback circuit turns off the PMOS switch and turns on the N-channel MOS (NMOS) as active rectification.

The step-down converter ([Figure 3](#)) consists of an integrated oscillator. It runs at high frequency to compare the return path and to control the PWM/PFM logic block and the break-before-make circuit of the integrated NMOS and PMOS transistor. This allows reaching constant output voltage with high efficiency and low output ripple.

## 5.1 Automatic PWM/PFM mode

Battery-driven applications need power-saving options. Therefore the DC-to-DC converter provides a current-sensing circuit which detects the output current. If the current is below a certain threshold, the system switches to PFM mode. In this operation, the converter uses less current and saves battery operation time. This automode can be switched off to the forced PFM mode (see [Section 5.6](#)).

## 5.2 Inrush current limiter (soft start)

The DC6M60xX6 family has an integrated soft start function to limit the maximum inrush current and to reduce an input voltage dip. Therefore the system has a turn-on procedure which starts up step-by-step over 300  $\mu$ s and limits the inrush current via a duty cycle control up to the maximum current capability.

### 5.3 Thermal protection

The DC6M60xX6 family products have an integrated thermal protection. The protection circuit senses the internal temperature of the chip and switches off the integrated PMOS power switch transistor when a defined maximum temperature is reached. After the temperature returns to a safe value, the system restarts with a soft start.

## 5.4 Short-circuit and overcurrent protection

The short-circuit and overcurrent protection senses the current through the integrated PMOS high-side driver. If the diagnostic circuit detects an overcurrent, the system switches off the PMOS to break the current flow.

## 5.5 Enable (EN)

All products have an enable pin EN which enables the device by a constant logic HIGH signal but also by applying an alternating (clock) signal to the enable pin. All devices start with a soft start ([Section 5.2](#)).

If EN is forced to a LOW level, the system is in Power-down mode. Then the input current is negligible and the output voltage sets to LOW via a resistor.

It is possible to enable all DC6M60xX6 family products by applying a clock signal which is used to enable other parts of a certain circuit such as camera modules based on the Standard Mobile Imaging Architecture (SMIA) specification. The required signal frequency has to be in the range of 5 MHz to 27 MHz with a duty cycle between 40 % and 60 %.

**Table 5. Function selection**

EN logic level	Description
HIGH or clock signal	operation
LOW	shut down

## 5.6 Function selection (MODE)

Depending on the product version, three different operation modes are available for the MODE pin.

### 5.6.1 Automatic PWM/PFM and forced PWM mode

The default operation mode is the automatic selection mode. This mode switches the device between PWM and PFM to reduce power consumption as described in [Section 5.1](#).

The automatic mode of DC6M601X6 can be switched off to use only the PWM mode. DC6M602X6 does not have this option but is available with fix mode (automatic or forced PWM).

**Table 6. Function selection DC6M601X6**

MODE logic level	Description
LOW	automatic PWM/PFM mode
HIGH	forced PWM mode

### 5.6.2 Output voltage select

DC6M602X6 offers the option to select the output voltage  $V_O$  depending on the logic level applied to the MODE pin. Depending on the logic input level either the LOW or the HIGH output voltage is selected. [Table 7](#) illustrates this behavior.

Table 7. Output voltage selection DC6M602X6

MODE logic level	Output voltage
LOW	low voltage
HIGH	high voltage

The MODE input pin has no default level. To prevent undefined states, it has to be applied with a clear LOW or HIGH level.

5.6.3 Power good output (XSHUTDOWN)

DC6M603X6 has an XSHUTDOWN or power good output. This function is often used when the converter is turned on by a clock signal (CLK) available at pin MODE.

The basic timing is depicted in Figure 5 and Table 8 where EXTCLK is the clock signal at the enable input and  $V_O$  the DC-to-DC converter output voltage. The XSHUTDOWN is the power good signal and has the same signal output level as  $V_O$ .

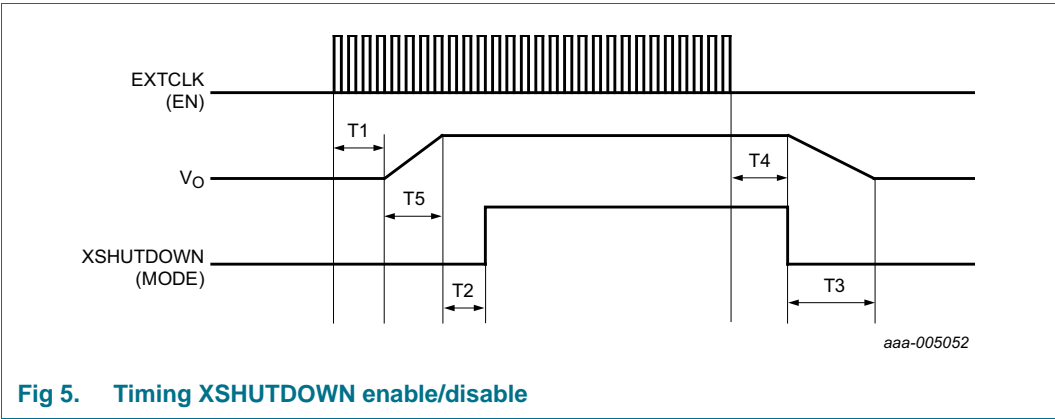


Fig 5. Timing XSHUTDOWN enable/disable

Table 8. Timing XSHUTDOWN

Symbol	Description	Min	Max	Unit
T1	EXTCLK active - $V_O$ rising	10	100	$\mu$ s
T2	$V_O$ settled - XSHUTDOWN rising	0	100	$\mu$ s
T3	$V_O$ down time; $C_{O(ext)} = 10$ pF; load current $I_L = 20$ mA	0	1000	$\mu$ s
T4	EXTCLK inactive - XSHUTDOWN down	0	100	$\mu$ s
T5	$V_O$ rising time (no-load)	30	200	$\mu$ s

## 6. Limiting values

**Table 9. Limiting values**

*In accordance with the Absolute Maximum Rating System (IEC 60134).*

Symbol	Parameter	Conditions	Min	Max	Unit
$V_{IN}$	voltage on pin IN	4 ms transient	-0.5	+6.0	V
$V_I$	input voltage	on pins EN, MODE, FB	-0.5	+5.5	V
$V_O$	output voltage	on pin SW	-0.5	+5.5	V
$P_{tot}$	total power dissipation		-	800	mW
$T_{stg}$	storage temperature		-55	+150	°C
$T_j$	junction temperature		-30	+125	°C
$T_{amb}$	ambient temperature		-40	+85	°C
$V_{ESD}$	electrostatic discharge voltage	human body model (JESD22-001)	-2	+2	kV
		machine model (JESD22-A115)	-200	+200	V

## 7. Recommended operating conditions

**Table 10. Operating conditions**

*At recommended operating conditions;  $T_{amb} = 25\text{ °C}$ ; voltages are referenced to GND (0 V); unless otherwise specified.*

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{IN}$	voltage on pin IN		2.3	-	5.5	V
$V_I$	input voltage	on pins EN, MODE, FB	-0.5	-	$V_{IN} + 0.3$	V
$I_O$	output current		0	-	650	mA
$C_{i(ext)}$	external input capacitance		[1] -	4.7	10	μF
$C_{o(ext)}$	external output capacitance		[1] 2.2	4.7	-	μF
$L_{o(ext)}$	external output inductance		[1] -	0.47	-	μH

[1] See [Section 10 "Application information"](#).



## 8. Static characteristics

**Table 11. Characteristics**

At recommended input voltages and  $T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ ; voltages are referenced to GND (ground = 0 V); unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Input voltage and input current						
V <sub>I</sub>	input voltage	V <sub>O</sub> = 1.2 V	2.3	-	5.5	V
		V <sub>O</sub> = 1.5 V	2.3	-	5.5	V
		V <sub>O</sub> = 1.8 V	2.8	-	5.5	V
		V <sub>O</sub> = 2.85 V	3.7	-	5.5	V
I <sub>CC</sub>	supply current	operating; PWM mode; I <sub>O</sub> = 0 A	-	8	-	mA
		operating; PFM mode; I <sub>O</sub> = 0 A	-	180	-	μA
		disabled	-	0.2	-	μA
Output voltage and output current						
V <sub>O</sub>	output voltage	I <sub>O</sub> ≥ 15 mA	[1] 0.98 × V <sub>O(nom)</sub>	V <sub>O(nom)</sub>	1.02 × V <sub>O(nom)</sub>	V
		0 mA < I <sub>O</sub> < 15 mA; auto PWM/PFM mode	[1] 0.98 × V <sub>O(nom)</sub>	V <sub>O(nom)</sub>	1.04 × V <sub>O(nom)</sub>	V
I <sub>O(max)</sub>	maximum output current		650	-	-	mA
V <sub>o(ripple)(p-p)</sub>	peak-to-peak ripple output voltage	0 mA < I <sub>O</sub> < 100 mA; V <sub>I</sub> = V <sub>O(nom)</sub> + 1.2 V	[1] -	-	10	mV
		100 mA < I <sub>O</sub> < 650 mA; V <sub>I</sub> = V <sub>O(nom)</sub> + 1.2 V	[1] -	7	15	mV
Line regulation						
ΔV <sub>O</sub> /ΔV <sub>I</sub>	output voltage variation as a function of input voltage variation	2.3 V < V <sub>I</sub> < 5.5 V; I = 200 mA	-	0.03	-	%/V
Load regulation						
ΔV <sub>O</sub> /ΔI <sub>L</sub>	output voltage variation as a function of load current variation	0 A < I <sub>O</sub> < 650 mA	-	0.003	-	%/mA
Pin EN						
V <sub>IH</sub>	HIGH-level input voltage		1	-	-	V
V <sub>IL</sub>	LOW-level input voltage		-	-	0.4	V
I <sub>IH</sub>	HIGH-level input current	V <sub>IH</sub> = 1.2 V	-	-	1	μA
Pin MODE						
V <sub>IH</sub>	HIGH-level input voltage		1	-	-	V
V <sub>IL</sub>	LOW-level input voltage		-	-	0.4	V
I <sub>IH</sub>	HIGH-level input current	V <sub>IH</sub> = 1.2 V	-	-	1	μA
V <sub>OH</sub>	HIGH-level output voltage		[2] 0.9 × V <sub>O</sub>	-	1.1 × V <sub>O</sub>	V
V <sub>OL</sub>	LOW-level output voltage		[2] −0.1	-	0.3	V
Clock frequency and duty cycle						
f <sub>clk(PWM)</sub>	PWM clock frequency		5.4	6.0	6.6	MHz
f <sub>clk(PFM)</sub>	PFM clock frequency		0	-	6.6	MHz

**Table 11. Characteristics ...continued**

At recommended input voltages and  $T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$ ; voltages are referenced to GND (ground = 0 V); unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$\delta$	duty cycle	forced PWM mode				
		DC6M601X6/285S	2	-	100	%
		all other devices	2	-	92	%
		automatic forced PWM / PFM mode				
		DC6M601X6/285S	0	-	100	%
		all other devices	0	-	92	%

**Overtemperature and overcurrent protection**

$T_{sd}$	shutdown temperature		-	150	-	$^{\circ}\text{C}$
$T_{sd(hys)}$	shutdown temperature hysteresis		-	40	-	$^{\circ}\text{K}$
$I_{olim}$	output current limit		1.0	1.3	-	A
$I_{inrush(lim)}$	inrush current limit		-	0.3	-	A

**Switches**

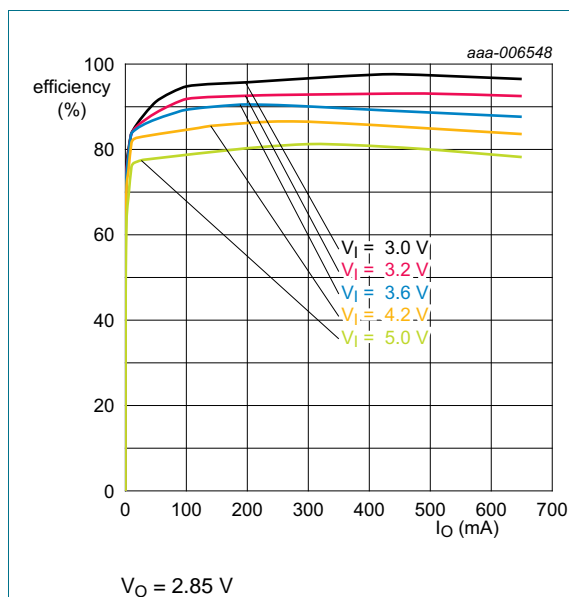
$R_{DSon}$	drain-source on-state resistance	P-channel FET; $V_{DS} = 3.6\text{ V}$	-	0.15	-	$\Omega$
		N-channel FET; $V_{DS} = 3.6\text{ V}$	-	0.3	-	$\Omega$
$I_{leak}$	leakage current	$ V_{DS}  = 5\text{ V}$	-	-	1	$\mu\text{A}$

[1]  $V_{O(nom)}$  = nominal output voltage (device specific).

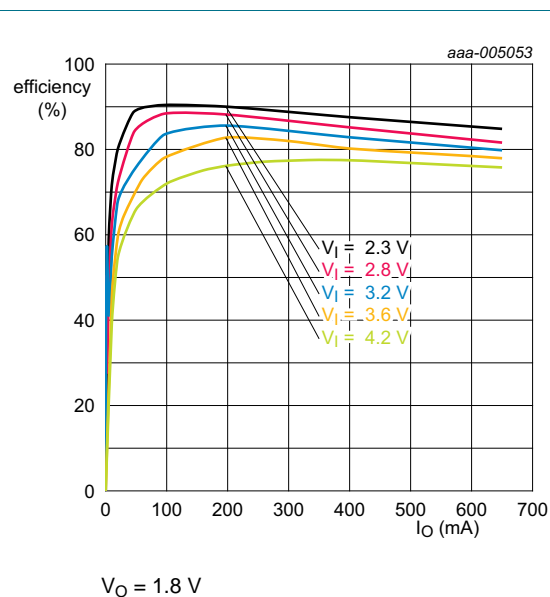
[2] Only for product versions with power good output (DC6M603X6).

## 9. Dynamic characteristics

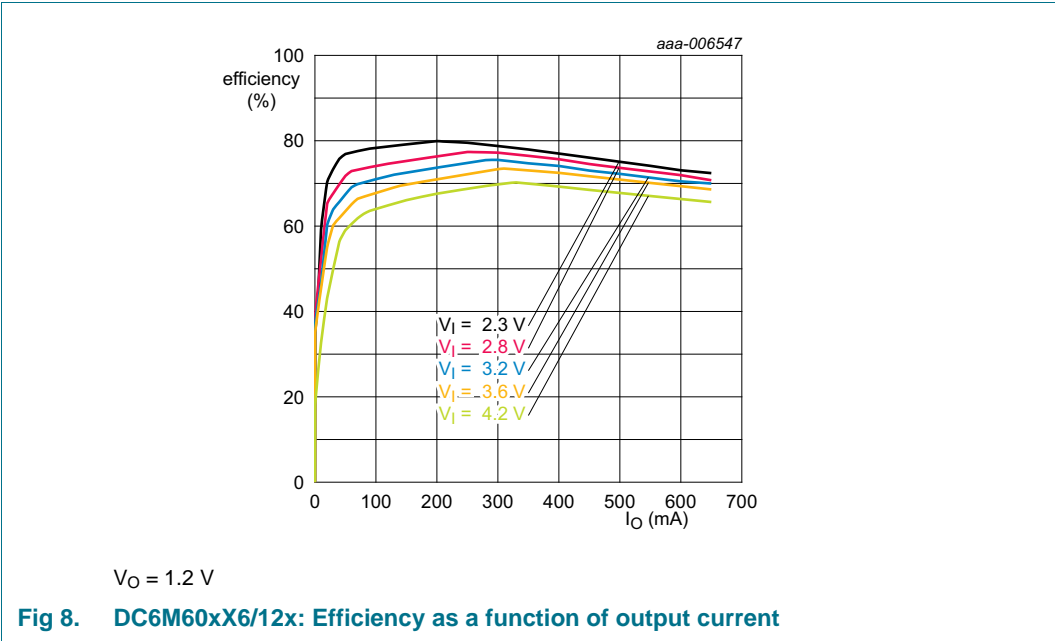
### 9.1 Efficiency



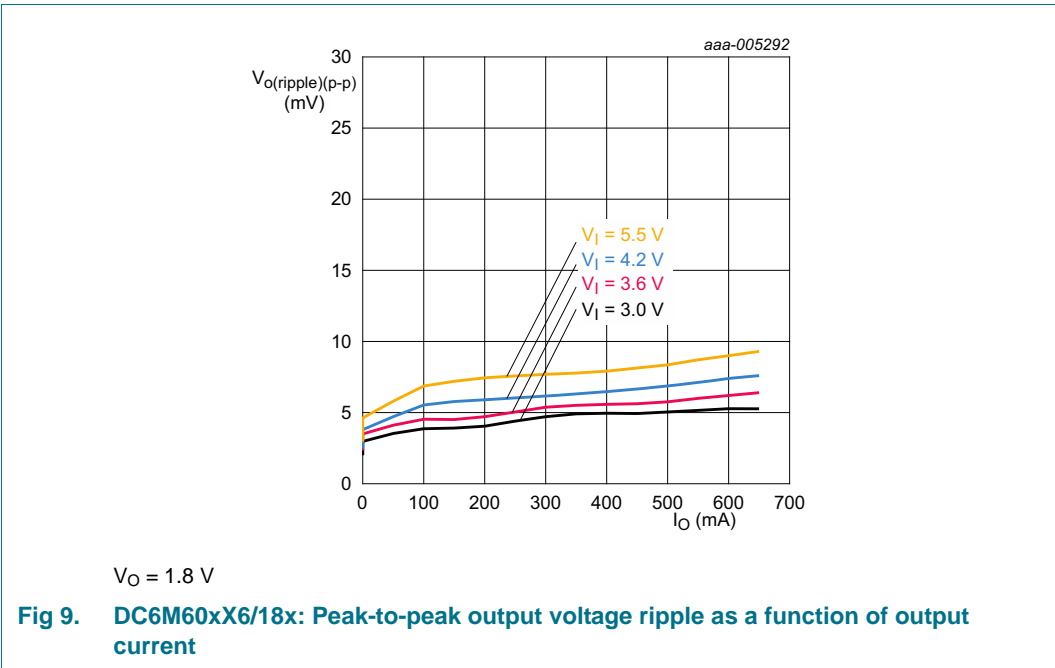
**Fig 6. DC6M60xX6/285x: Efficiency as a function of output current**



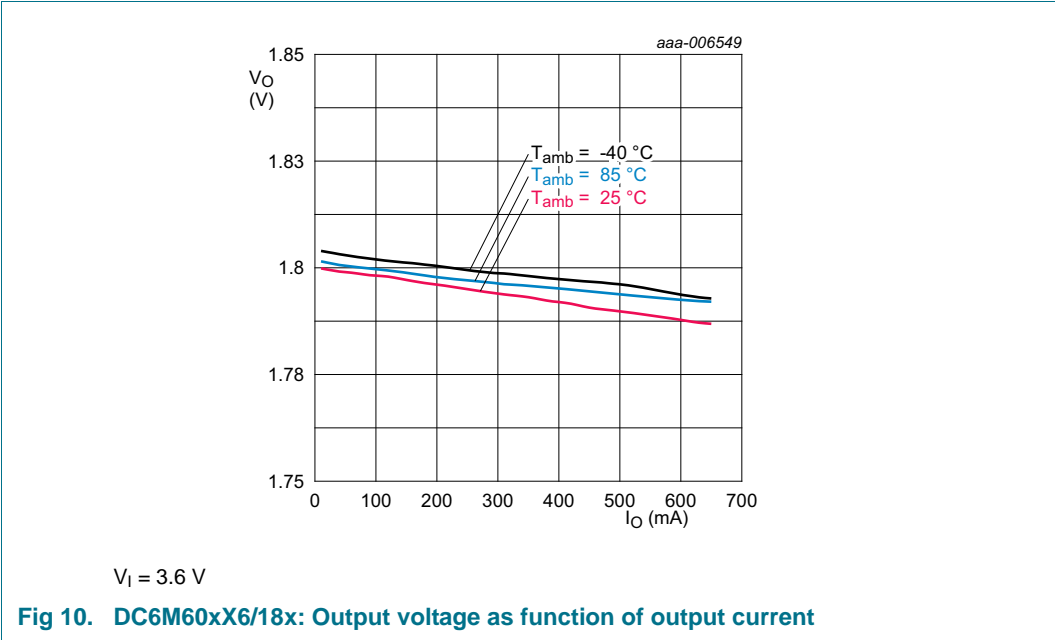
**Fig 7. DC6M60xX6/18x: Efficiency as a function of output current**



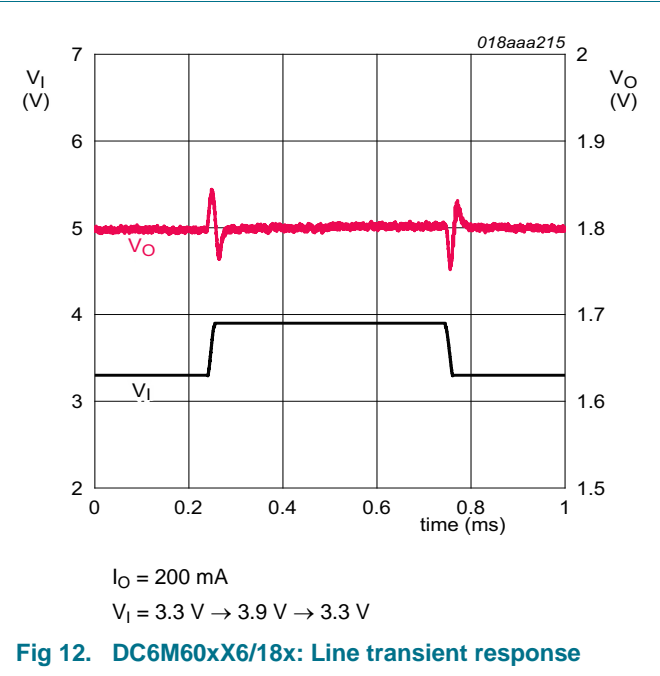
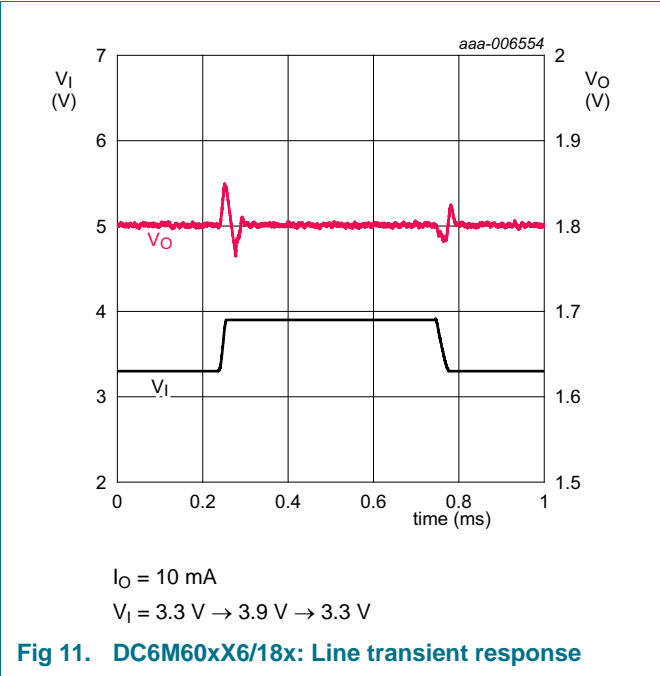
9.2 Output voltage ripple



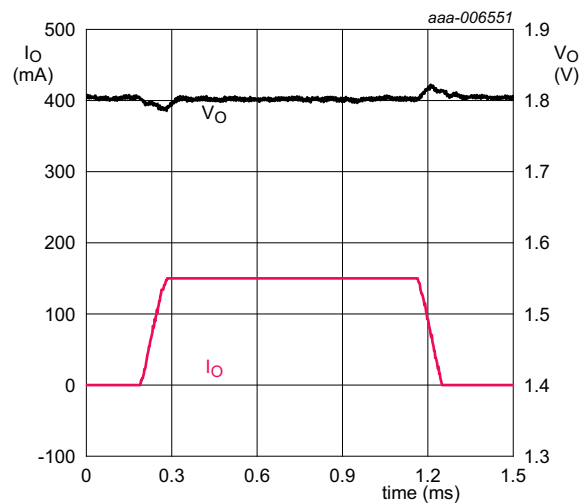
9.3 Output voltage variation



9.4 Line transient response

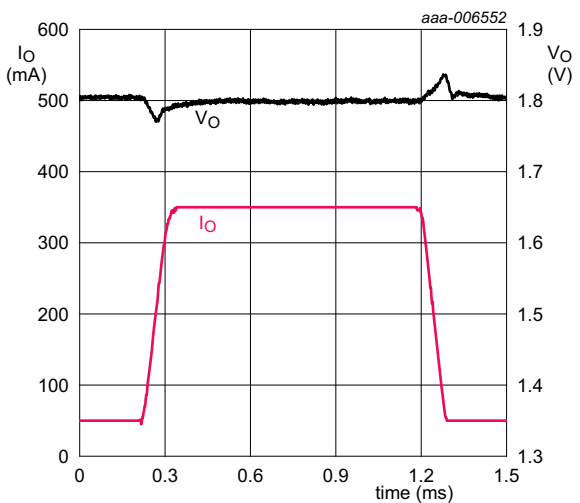


9.5 Load transient response



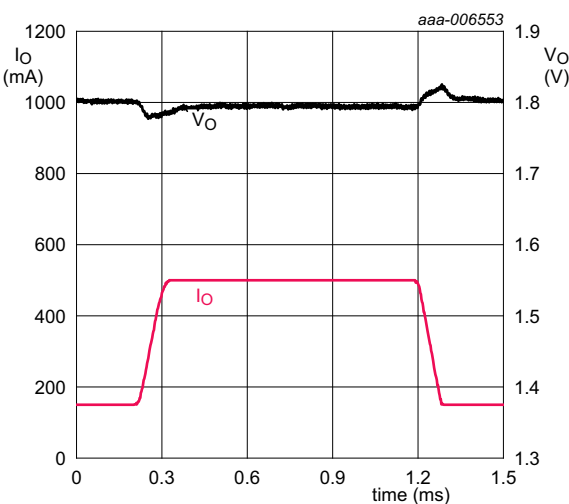
$V_I = 3.6\text{ V}$   
 $I_O = 0\text{ mA} \rightarrow 150\text{ mA} \rightarrow 0\text{ mA}$

Fig 13. DC6M60xX6/18x: Load transient response



$V_I = 3.6\text{ V}$   
 $I_O = 50\text{ mA} \rightarrow 350\text{ mA} \rightarrow 50\text{ mA}$

Fig 14. DC6M60xX6/18x: Load transient response

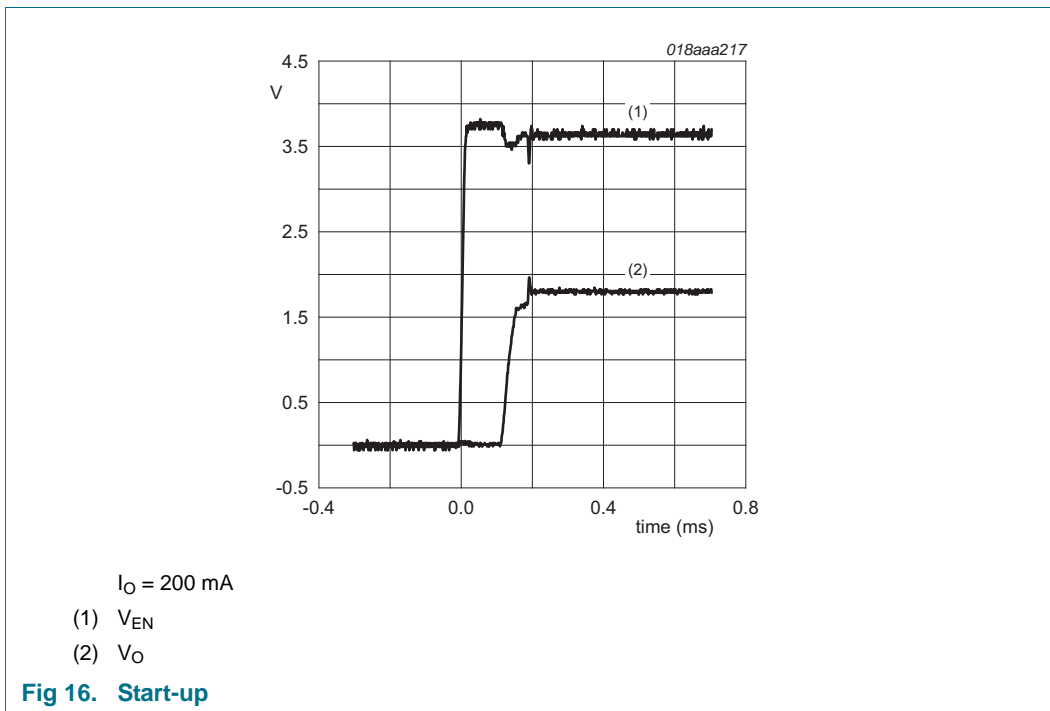


$V_I = 3.6\text{ V}$   
 $I_O = 150\text{ mA} \rightarrow 500\text{ mA} \rightarrow 150\text{ mA}$

Fig 15. DC6M60xX6/18x: Load transient response

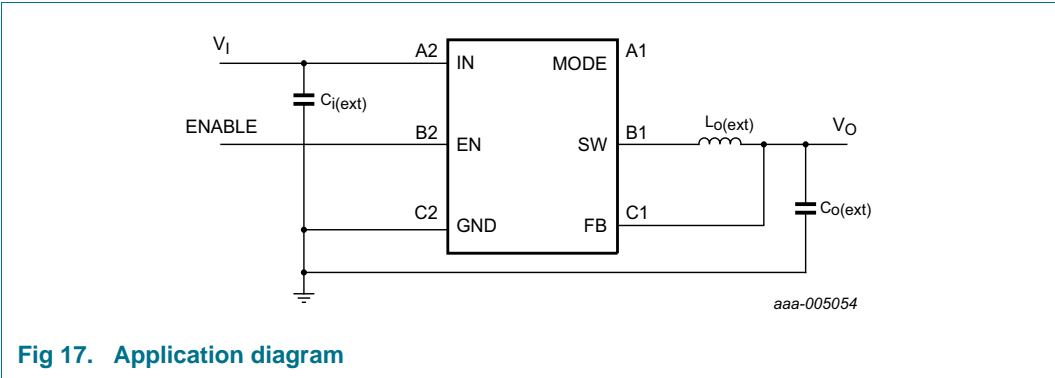
## 9.6 Start-up/enable

The start-up sequence is described by time-dependent current and voltage behavior.



10. Application information

The DC-to-DC converter requires an external coil and two decoupling capacitors.



10.1 Recommended inductors

Table 12. Recommended inductors (Figure 17)

Manufacture	Series	Dimensions (mm)
MURATA	LQM21PN1R0NGR	2.0 × 1.2 × 1.0 maximum height
	LQM21PNR54MG0	2.0 × 1.2 × 1.0 maximum height
	LQM21PNR47MC0	2.0 × 1.2 × 0.55 maximum height
	LQM21PN1R0MC0	2.0 × 1.2 × 0.55 maximum height
FDK	MIPSZ2012DOR5	2.0 × 1.2 × 1.0 maximum height
	MIPSZ2012D1R0	2.0 × 1.2 × 1.0 maximum height

10.2 Input capacitor

To eliminate unwanted voltage transients at the input, place an input decoupling capacitor of more than 4.7  $\mu$ F as close as possible to the input pin. Use therefore a capacitor with a low Equivalent Series Resistance (ESR).

10.3 Output capacitor

Use a suppressor capacitor of more than 10  $\mu$ F for the output (Figure 17). Because of the narrow spread, high temperature stability and low ESR at high frequencies use the dielectric X7R or X5R.

## 11. Marking

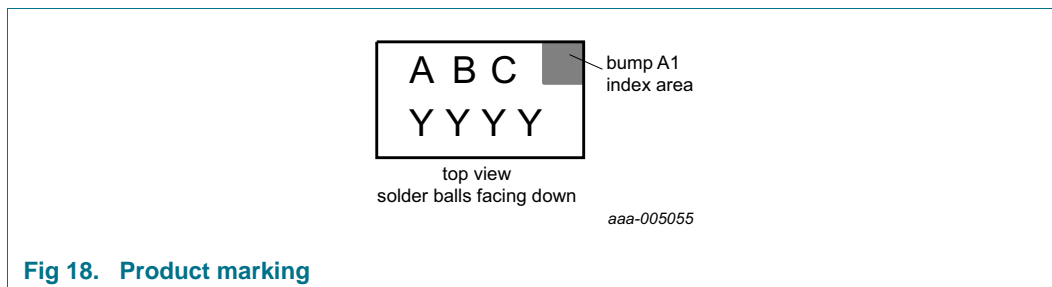


Table 13. Marking codes

Drawing reference	Marking code	Product version
A	7	DC6M601X6
	8	DC6M602X6
	9	DC6M603X6
B	A	DC6M60xX6\12x ( $V_O = 1.2$ V)
	D	DC6M60xX6\15x ( $V_O = 1.5$ V)
	G	DC6M60xX6\18x ( $V_O = 1.8$ V)
	Z	DC6M60xX6\285x ( $V_O = 2.85$ V)
	AD	DC6M602X6\1215x ( $V_O = 1.2$ V or 1.5 V)
	AG	DC6M602X6\1218x ( $V_O = 1.2$ V or 1.8 V)
	DG	DC6M602X6\1518x ( $V_O = 1.5$ V or 1.8 V)
C	A	DC6M602X6/xxxxA, DC6M603X6/xxA
	F	DC6M602X6/xxxxF
	S	DC6M601X6/xxS
YYYY	part of lot ID for traceability	-



## 12. Package outline

WLCSP6: wafer level chip-size package; 6 bumps (3 x 2)

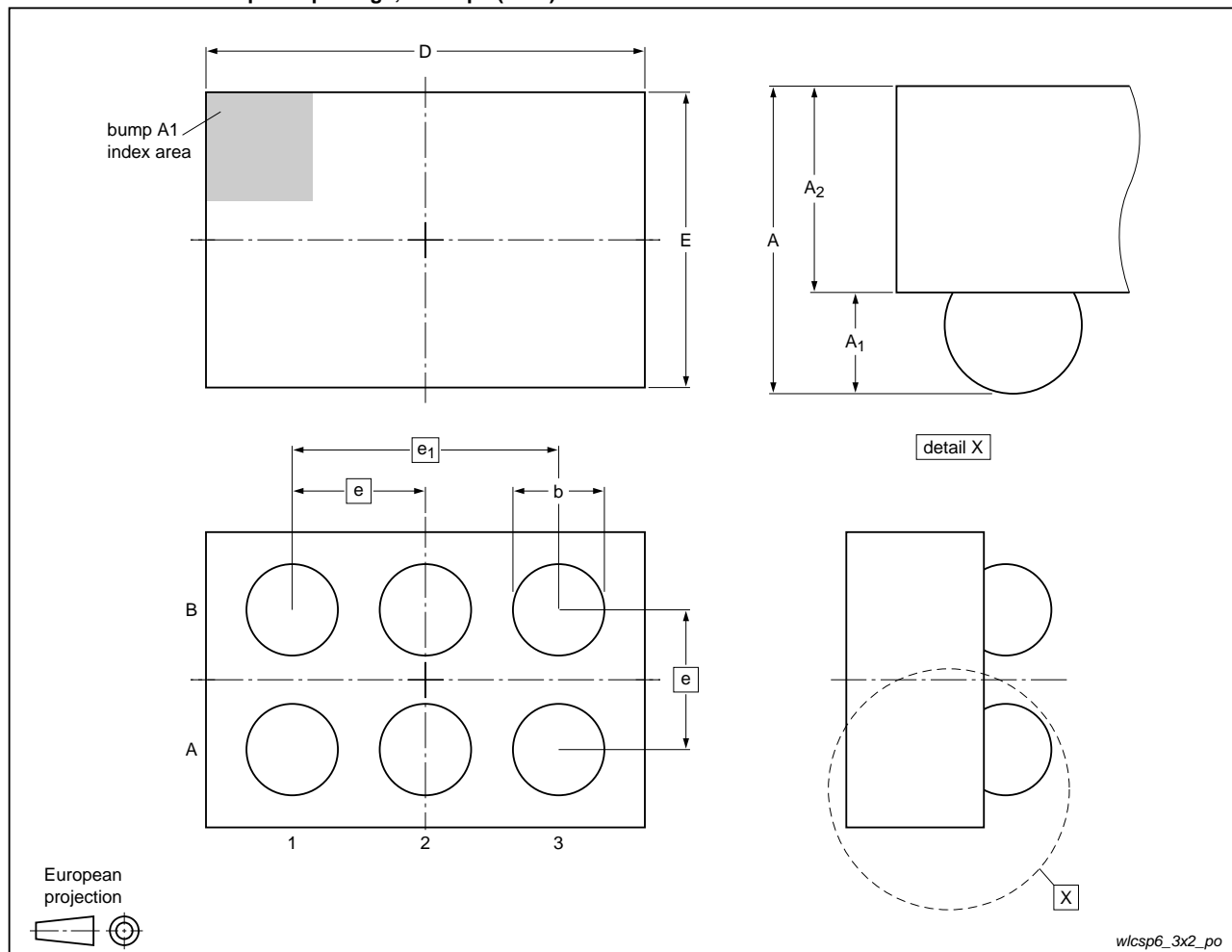


Fig 19. Package outline WLCSP6

Table 14. Dimensions of WLCSP6 (Figure 19)

Symbol	Min	Typ	Max	Unit
D	1.31	1.36	1.41	mm
E	0.91	0.96	1.01	mm
A	0.44	0.47	0.50	mm
A1	0.18	0.20	0.22	mm
A2	0.25	0.27	0.29	mm
e	0.35	0.40	0.45	mm
e1	0.70	0.80	0.90	mm
b	0.21	0.26	0.31	mm

## 13. Soldering

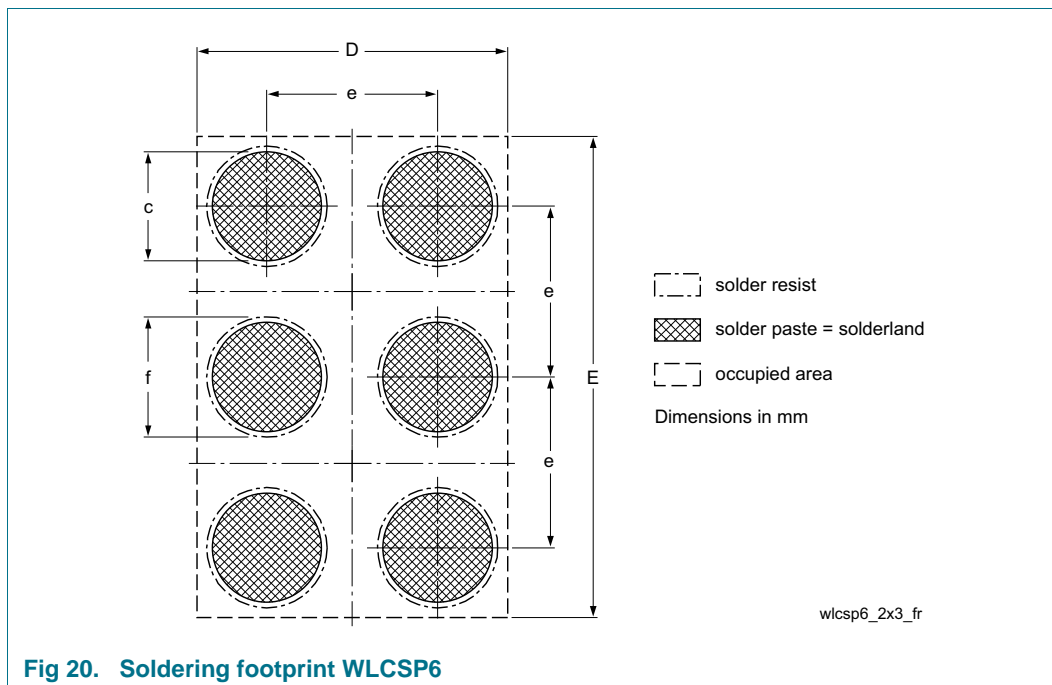


Table 15. Dimensions of soldering footprint WLCSP6 (Figure 20)

Symbol	Min	Typ	Max	Unit
D	0.91	0.96	1.01	mm
E	1.31	1.36	1.41	mm
c	-	0.25	-	mm
e	-	0.4	-	mm
f	-	0.325	-	mm

## 14. Soldering of WLCSP packages

### 14.1 Introduction to soldering WLCSP packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering WLCSP (Wafer Level Chip-Size Packages) can be found in application note AN10439 "Wafer Level Chip Scale Package" and in application note AN10365 "Surface mount reflow soldering description".

Wave soldering is not suitable for this package.

All NXP WLCSP packages are lead-free.

### 14.2 Board mounting

Board mounting of a WLCSP requires several steps:

1. Solder paste printing on the PCB

2. Component placement with a pick and place machine
3. The reflow soldering itself

### 14.3 Reflow soldering

Key characteristics in reflow soldering are:

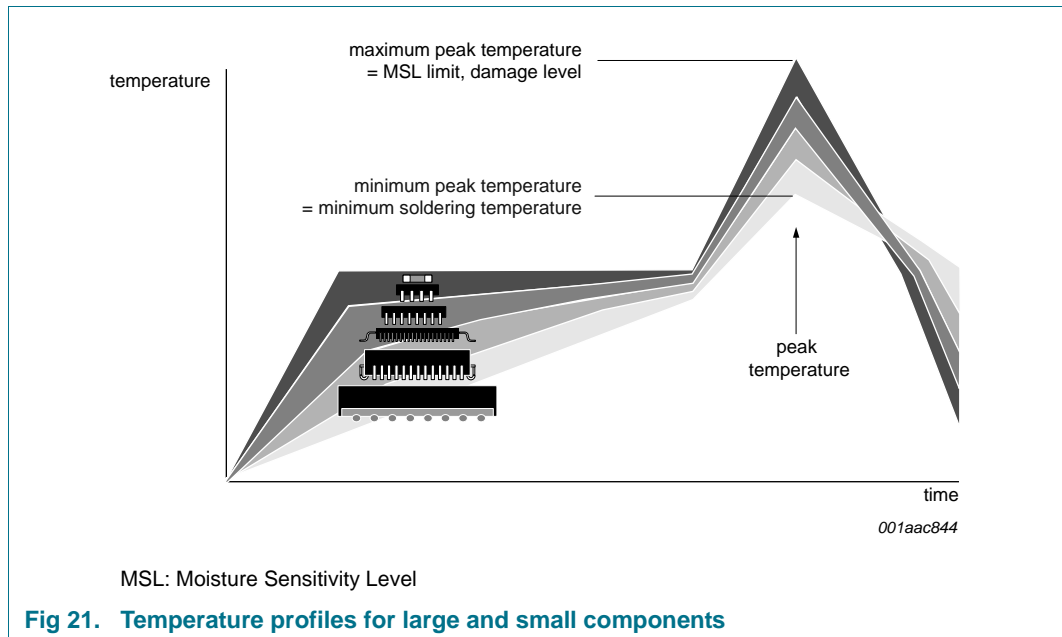
- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 21](#)) than a PbSn process, thus reducing the process window
- Solder paste printing issues, such as smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature), and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic) while being low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 16](#).

**Table 16. Lead-free process (from J-STD-020C)**

Package thickness (mm)	Package reflow temperature (°C)		
	Volume (mm <sup>3</sup> )		
	< 350	350 to 2000	> 2000
< 1.6	260	260	260
1.6 to 2.5	260	250	245
> 2.5	250	245	245

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 21](#).



For further information on temperature profiles, refer to application note *AN10365 "Surface mount reflow soldering description"*.

#### 14.3.1 Stand off

The stand off between the substrate and the chip is determined by:

- The amount of printed solder on the substrate
- The size of the solder land on the substrate
- The bump height on the chip

The higher the stand off, the better the stresses are released due to TEC (Thermal Expansion Coefficient) differences between substrate and chip.

#### 14.3.2 Quality of solder joint

A flip-chip joint is considered to be a good joint when the entire solder land has been wetted by the solder from the bump. The surface of the joint should be smooth and the shape symmetrical. The soldered joints on a chip should be uniform. Voids in the bumps after reflow can occur during the reflow process in bumps with high ratio of bump diameter to bump height, i.e. low bumps with large diameter. No failures have been found to be related to these voids. Solder joint inspection after reflow can be done with X-ray to monitor defects such as bridging, open circuits and voids.

#### 14.3.3 Rework

In general, rework is not recommended. By rework we mean the process of removing the chip from the substrate and replacing it with a new chip. If a chip is removed from the substrate, most solder balls of the chip will be damaged. In that case it is recommended not to re-use the chip again.

Device removal can be done when the substrate is heated until it is certain that all solder joints are molten. The chip can then be carefully removed from the substrate without damaging the tracks and solder lands on the substrate. Removing the device must be done using plastic tweezers, because metal tweezers can damage the silicon. The surface of the substrate should be carefully cleaned and all solder and flux residues and/or underfill removed. When a new chip is placed on the substrate, use the flux process instead of solder on the solder lands. Apply flux on the bumps at the chip side as well as on the solder pads on the substrate. Place and align the new chip while viewing with a microscope. To reflow the solder, use the solder profile shown in application note AN10365 "Surface mount reflow soldering description".

#### 14.3.4 Cleaning

Cleaning can be done after reflow soldering.

## 15. Mounting

### 15.1 PCB design guidelines

It is recommended, for optimum performance, to use a Non-Solder Mask Defined (NSMD), also known as a copper-defined design, incorporating laser-drilled micro-vias connecting the ground pads to a buried ground-plane layer. This results in the lowest possible ground inductance and provides the best high frequency and ElectroStatic Discharge (ESD) performance. Refer to [Table 17](#) for the recommended PCB design parameters.

**Table 17. Recommended PCB design parameters**

Parameter	Value or specification
PCB pad diameter	250 µm
Micro-via diameter	100 µm (0.004 inch)
Solder mask aperture diameter	325 µm
Copper thickness	20 µm to 40 µm
Copper finish	AuNi or OSP
PCB material	FR4

### 15.2 PCB assembly guidelines for Pb-free soldering

**Table 18. Assembly recommendations**

Parameter	Value or specification
Solder screen aperture diameter	250 µm
Solder screen thickness	100 µm (0.004 inch)
Solder paste: Pb-free	SnAg (3 % to 4 %); Cu (0.5 % to 0.9 %)
Solder to flux ratio	50 : 50
Solder reflow profile	see <a href="#">Figure 22</a>

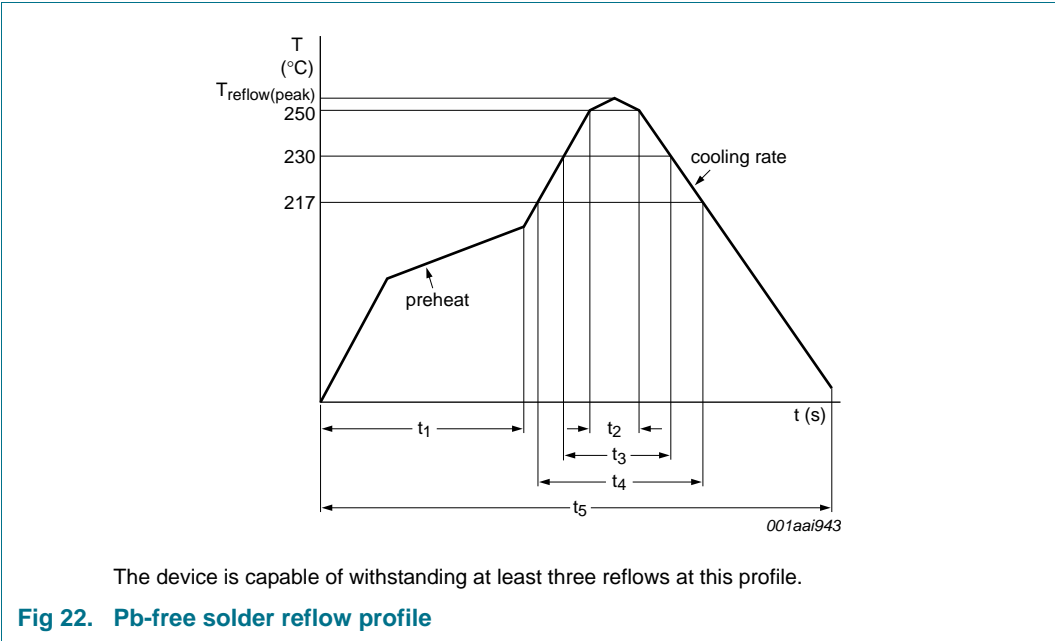


Table 19. Characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$T_{\text{reflow(peak)}}$	peak reflow temperature		230	-	260	°C
$t_1$	time 1	soak time	60	-	180	s
$t_2$	time 2	time during $T \geq 250\text{ °C}$	-	-	30	s
$t_3$	time 3	time during $T \geq 230\text{ °C}$	10	-	50	s
$t_4$	time 4	time during $T > 217\text{ °C}$	30	-	150	s
$t_5$	time 5		-	-	540	s
$dT/dt$	rate of change of temperature	cooling rate	-	-	-6	°C/s
		preheat	2.5	-	4.0	°C/s

16. References

[1] IEC60134 — Rating systems for electronic tubes and valves and analogous semiconductor devices

[2] IEC61340-3-1 — Method for simulation of electrostatic effects - Human body model (HBM) electrostatic discharge test waveforms

[3] JESD22-A115C — Electrostatic discharge (ESD) Sensitivity Testing Machine Model (MM)

[4] NX2-00001 — NXP Semiconductors Quality and Reliability Specification

[5] AN10365 — NXP Semiconductors application note "Surface mount reflow soldering description"

## 17. Revision history

Table 20. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
DC6M60XX6_FAM v.2	20130129	Product data sheet	-	DC6M60XX6_FAM v.1
Modifications:	<ul style="list-style-type: none"><li>• <a href="#">Section 1 "Product profile"</a>: updated</li><li>• <a href="#">Table 11</a>: output voltage <math>V_O</math> and drain-source on-state resistance <math>R_{DSon}</math> updated</li><li>• <a href="#">Section 9 "Dynamic characteristics"</a>: updated</li></ul>			
DC6M60XX6_FAM v.1	20120921	Preliminary data sheet	-	-

## 18. Legal information

### 18.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

### 18.2 Definitions

**Draft** — The document is a draft version only. The content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included herein and shall have no liability for the consequences of use of such information.

**Short data sheet** — A short data sheet is an extract from a full data sheet with the same product type number(s) and title. A short data sheet is intended for quick reference only and should not be relied upon to contain detailed and full information. For detailed and full information see the relevant full data sheet, which is available on request via the local NXP Semiconductors sales office. In case of any inconsistency or conflict with the short data sheet, the full data sheet shall prevail.

**Product specification** — The information and data provided in a Product data sheet shall define the specification of the product as agreed between NXP Semiconductors and its customer, unless NXP Semiconductors and customer have explicitly agreed otherwise in writing. In no event however, shall an agreement be valid in which the NXP Semiconductors product is deemed to offer functions and qualities beyond those described in the Product data sheet.

### 18.3 Disclaimers

**Limited warranty and liability** — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors.

In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory.

Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the *Terms and conditions of commercial sale* of NXP Semiconductors.

**Right to make changes** — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

**Suitability for use** — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

**Applications** — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products.

NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

**Limiting values** — Stress above one or more limiting values (as defined in the Absolute Maximum Ratings System of IEC 60134) will cause permanent damage to the device. Limiting values are stress ratings only and (proper) operation of the device at these or any other conditions above those given in the Recommended operating conditions section (if present) or the Characteristics sections of this document is not warranted. Constant or repeated exposure to limiting values will permanently and irreversibly affect the quality and reliability of the device.

**Terms and conditions of commercial sale** — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at <http://www.nxp.com/profile/terms>, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

**No offer to sell or license** — Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights.



**Export control** — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

**Quick reference data** — The Quick reference data is an extract of the product data given in the Limiting values and Characteristics sections of this document, and as such is not complete, exhaustive or legally binding.

**Non-automotive qualified products** — Unless this data sheet expressly states that this specific NXP Semiconductors product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. NXP Semiconductors accepts no liability for inclusion and/or use of non-automotive qualified products in automotive equipment or applications.

In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NXP Semiconductors' warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NXP Semiconductors' specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NXP Semiconductors for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NXP Semiconductors' standard warranty and NXP Semiconductors' product specifications.

## 18.4 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

## 19. Contact information

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)

## 20. Contents

<b>1</b>	<b>Product profile</b> . . . . .	<b>1</b>	<b>15</b>	<b>Mounting</b> . . . . .	<b>21</b>
1.1	General description . . . . .	1	15.1	PCB design guidelines . . . . .	21
1.2	Features and benefits . . . . .	1	15.2	PCB assembly guidelines for Pb-free soldering . . . . .	21
1.3	Applications . . . . .	1			
1.4	Quick reference data . . . . .	1	<b>16</b>	<b>References</b> . . . . .	<b>22</b>
<b>2</b>	<b>Pinning information</b> . . . . .	<b>2</b>	<b>17</b>	<b>Revision history</b> . . . . .	<b>23</b>
<b>3</b>	<b>Ordering information</b> . . . . .	<b>3</b>	<b>18</b>	<b>Legal information</b> . . . . .	<b>24</b>
3.1	Ordering options . . . . .	3	18.1	Data sheet status . . . . .	24
3.1.1	Naming convention . . . . .	4	18.2	Definitions . . . . .	24
<b>4</b>	<b>Block diagram</b> . . . . .	<b>4</b>	18.3	Disclaimers . . . . .	24
<b>5</b>	<b>Functional description</b> . . . . .	<b>5</b>	18.4	Trademarks . . . . .	25
5.1	Automatic PWM/PFM mode . . . . .	5	<b>19</b>	<b>Contact information</b> . . . . .	<b>25</b>
5.2	Inrush current limiter (soft start) . . . . .	5	<b>20</b>	<b>Contents</b> . . . . .	<b>26</b>
5.3	Thermal protection . . . . .	5			
5.4	Short-circuit and overcurrent protection . . . . .	6			
5.5	Enable (EN) . . . . .	6			
5.6	Function selection (MODE) . . . . .	6			
5.6.1	Automatic PWM/PFM and forced PWM mode . . . . .	6			
5.6.2	Output voltage select . . . . .	6			
5.6.3	Power good output (XSHUTDOWN) . . . . .	7			
<b>6</b>	<b>Limiting values</b> . . . . .	<b>8</b>			
<b>7</b>	<b>Recommended operating conditions</b> . . . . .	<b>8</b>			
<b>8</b>	<b>Static characteristics</b> . . . . .	<b>9</b>			
<b>9</b>	<b>Dynamic characteristics</b> . . . . .	<b>10</b>			
9.1	Efficiency . . . . .	10			
9.2	Output voltage ripple . . . . .	11			
9.3	Output voltage variation . . . . .	12			
9.4	Line transient response . . . . .	12			
9.5	Load transient response . . . . .	13			
9.6	Start-up/enable . . . . .	14			
<b>10</b>	<b>Application information</b> . . . . .	<b>15</b>			
10.1	Recommended inductors . . . . .	15			
10.2	Input capacitor . . . . .	15			
10.3	Output capacitor . . . . .	15			
<b>11</b>	<b>Marking</b> . . . . .	<b>16</b>			
<b>12</b>	<b>Package outline</b> . . . . .	<b>17</b>			
<b>13</b>	<b>Soldering</b> . . . . .	<b>18</b>			
<b>14</b>	<b>Soldering of WLCSP packages</b> . . . . .	<b>18</b>			
14.1	Introduction to soldering WLCSP packages . . . . .	18			
14.2	Board mounting . . . . .	18			
14.3	Reflow soldering . . . . .	19			
14.3.1	Stand off . . . . .	20			
14.3.2	Quality of solder joint . . . . .	20			
14.3.3	Rework . . . . .	20			
14.3.4	Cleaning . . . . .	21			

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

© NXP B.V. 2013.

All rights reserved.

For more information, please visit: <http://www.nxp.com>

For sales office addresses, please send an email to: [salesaddresses@nxp.com](mailto:salesaddresses@nxp.com)

Date of release: 29 January 2013

Document identifier: DC6M60XX6\_FAM