DATA SHEET

TDA3665
Very low dropout voltage/quiescent current 8.5 V voltage regulator

Preliminary specification
File under Integrated Circuits, IC01

2000 Apr 25

Philips
Semiconductors

PHILIPS

Very low dropout voltage/quiescent current 8.5 V voltage regulator

TDA3665

FEATURES

- Fixed 8.5 V, 100 mA regulator
- Supply voltage range up to 33 V (45 V)
- Very low quiescent current of 15 μA (typical value)
- Very low dropout voltage
- High ripple rejection
- Very high stability:
  - Electrolytic capacitors: Equivalent Series Resistance (ESR) < 30 Ω at $I_{REG} \leq 25$ mA (see Fig.6)
  - Other capacitors: 100 nF at 200 μA ≤ $I_{REG} \leq 100$ mA.
- Pin compatible family TDA3662 to TDA3666
- Protections:
  - Reverse polarity safe (down to −25 V without high reverse current)
  - Negative transient of 50 V (R_S = 10 Ω and t < 100 ms)
  - Able to withstand voltages up to 18 V at the output (supply line may be short-circuited)
  - ESD protection on all pins
  - DC short-circuit safe to ground and V_P of the regulator output
  - Temperature protection (at T_j > 150 °C).

GENERAL DESCRIPTION

The TDA3665 is a fixed 8.5 V voltage regulator with a very low dropout voltage and quiescent current, which operates over a wide supply voltage range.

The IC is available as:

- TDA3665: $V_P \leq 45$ V, −40 °C ≤ T_{amb} ≤ +125 °C and SO4 package (automotive)
- TDA3665AT: $V_P \leq 45$ V, −40 °C ≤ T_{amb} ≤ +125 °C and SO8 package (automotive).

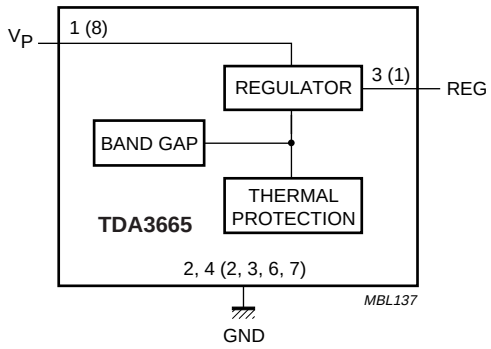
QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_P	supply voltage	regulator on				
	TDA3665		3	14.4	45	V
	TDA3665AT		3	14.4	45	V
I_q	quiescent supply current	V_P = 14.4 V; I_{REG} = 0 mA	–	15	30	μA
Voltage regulator						
V_{REG}	output voltage	11.5 V ≤ $V_P \leq$ 22 V; I_{REG} = 0.5 mA	8.08	8.5	8.92	V
		11.5 V ≤ $V_P \leq$ 45 V; I_{REG} = 0.5 mA	8.0	8.5	9.0	V
		V_P = 14.4 V; 0.5 mA ≤ $I_{REG} \leq$ 100 mA	8.0	8.5	9.0	V
$V_{REG(drop)}$	dropout voltage	V_P = 7.9 V; I_{REG} = 50 mA; $T_{amb} \leq$ 85 °C	–	0.18	0.3	V

ORDERING INFORMATION

TYPE NUMBER	PACKAGES		
	NAME	DESCRIPTION	VERSION
TDA3665	SO4	plastic small outline package; 4 leads; body width 3.5 mm	SOT223-1
TDA3665AT	SO8	plastic small outline package; 8 leads; body width 3.9 mm	SOT96-1

BLOCK DIAGRAM



Pin numbers in brackets refer to the SO8 version.

Fig.1 Block diagram.

PINNING

SYMBOL	PIN		DESCRIPTION
	SO4	SO8	
V_P	1	8	supply voltage
GND	2 and 4	2, 3, 6 and 7	ground; note 1
REG	3	1	regulator output
n.c.	–	4 and 5	not connected

Note

1. For the SO8 package all pins GND are connected to the lead frame and can also be used to reduce the total thermal resistance $R_{th(j-a)}$ by soldering these pins to a ground plane. The ground plane on the top side of the PCB acts like a heat spreader.

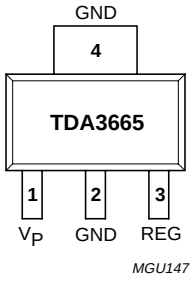


Fig.2 Pin configuration of SO4.

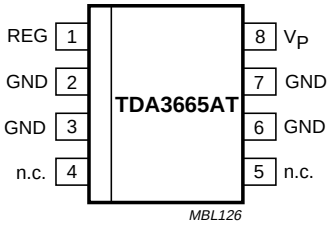


Fig.3 Pin configuration of SO8.

FUNCTIONAL DESCRIPTION

The TDA3665 is a fixed 8.5 V regulator which can deliver output currents up to 100 mA. The regulator is available in SO8 and SO4 packages. The regulator is intended for portable, mains, telephone and automotive applications. To increase the lifetime of batteries, a specially built-in clamp circuit keeps the quiescent current of this regulator very low, also in dropout and full load conditions.

The regulator remains operational down to very low supply voltages and below this voltage it switches off.

A temperature protection circuit is included which switches off the regulator output at a junction temperature above 150 °C.

A new output circuit guarantees the stability of the regulator for a capacitor output circuit with an ESR up to 22 Ω (see Figs 5 and 6). This is very attractive as the ESR of an electrolytic capacitor increases strongly at low temperatures (no expensive tantalum capacitor is required).

LIMITING VALUES

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

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_P	supply voltage				
	TDA3665		–	45	V
	TDA3665AT		–	45	V
$V_{P(rp)}$	reverse polarity supply voltage	non-operating	–	–25	V
P_{tot}	total power dissipation				
	TDA3665AT	temperature of copper area is 25 °C	–	4.1	W
	TDA3665	T_{amb} = 25 °C	–	5	W
T_{stg}	storage temperature	non-operating	–55	+150	°C
T_{amb}	ambient temperature	operating			
	TDA3665		–40	+125	°C
	TDA3665AT		–40	+125	°C
T_j	junction temperature	operating	–40	+150	°C

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th(j-a)}$	thermal resistance from junction to ambient			
	SO8	in free air; soldered in	125	K/W
	SO4	in free air; soldered in	100	K/W
$R_{th(j-c)}$	thermal resistance from junction to case			
	SO8	to centre pins; soldered in	30	K/W
	SO4	in free air	25	K/W

QUALITY SPECIFICATION

In accordance with *“SNW-FQ-611E”*.

CHARACTERISTICS

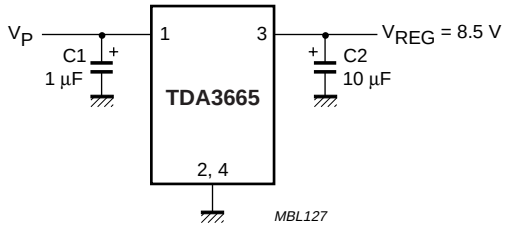
V_P = 14.4 V; T_{amb} = 25 °C; measured with test circuit (see Fig.4); unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply voltage: pin V_P						
V_P	supply voltage	regulator operating; note 1				
	TDA3665		3	14.4	45	V
	TDA3665AT		3	14.4	45	V
I_q	quiescent supply current	V_P = 4.5 V; I_{REG} = 0 mA	–	10	–	µA
		V_P = 14.4 V; I_{REG} = 0 mA	–	15	30	µA
		9.5 V ≤ V_P ≤ 22 V; I_{REG} = 10 mA	–	0.2	0.5	mA
		9.5 V ≤ V_P ≤ 22 V; I_{REG} = 50 mA	–	1.4	2.5	mA
Regulator output: pin REG; note 2						
V_{REG}	output voltage	11.5 V ≤ V_P ≤ to 22 V; I_{REG} = 0.5 mA	8.08	8.5	8.92	V
		0.5 mA ≤ I_{REG} ≤ 100 mA; T_{amb} ≤ 125 °C	8.0	8.5	9.0	V
		9.5 V ≤ V_P ≤ 45 V; I_{REG} = 0.5 mA; T_{amb} ≤ 125 °C	8.0	8.5	9.0	V
$V_{REG(drop)}$	dropout voltage	V_P = 7.9 V; T_{amb} ≤ 85 °C; I_{REG} = 50 mA	–	0.18	0.3	V
$V_{REG(stab)}$	output voltage long-term stability		–	20	–	mV/1000 h
$\Delta V_{REG(line)}$	line input regulation voltage	10.5 V ≤ V_P ≤ to 22 V; I_{REG} = 0.5 mA	–	1	30	mV
		10.5 V ≤ V_P ≤ 45 V; I_{REG} = 0.5 mA; T_{amb} ≤ 125 °C	–	1	50	mV
$\Delta V_{REG(load)}$	load output regulation voltage	0.5 mA ≤ I_{REG} ≤ 50 mA	–	10	50	mV
SVRR	supply voltage ripple rejection	f_i = 120 Hz; $V_{i(ripple)}$ = 1 V (RMS); I_{REG} = 0.5 mA	50	60	–	dB
$I_{REG(crl)}$	output current limit	V_{REG} > 7.9 V	0.17	0.25	–	A
$I_{LO(rp)}$	output leakage current at reverse polarity	V_P = –15 V; V_{REG} ≤ 0.3 V	–	1	500	µA

Notes

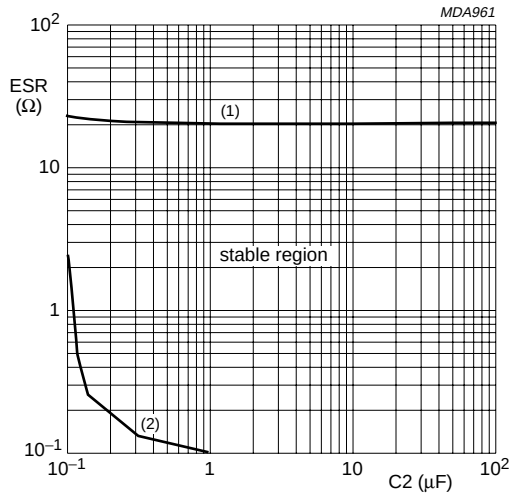
1. The regulator output will follow V_P if $V_P < V_{REG} + V_{REG(drop)}$.
2. Limiting values as applicable for both device types: V_P ≤ 45 V and –40 °C ≤ T_{amb} ≤ +125 °C.

TEST AND APPLICATION INFORMATION



C1 is optional (to minimize supply noise only).

Fig.4 Test circuit (SO4).



(1) Maximum ESR at 200 μA ≤ I_{REG} ≤ 100 mA.
(2) Minimum ESR only when I_{REG} ≤ 200 μA.

Fig.5 Graph for selecting the value of the output capacitor.

Noise

The output noise is determined by the value of the output capacitor. The noise figure is measured at a bandwidth of 10 Hz to 100 kHz (see Table 1).

Table 1 Noise figures

OUTPUT CURRENT I_{REG} (mA)	NOISE FIGURE (μV)		
	C2 = 10 μF	C2 = 47 μF	C2 = 100 μF
0.5	550	320	300
50	650	400	400

Stability

The regulator is stabilized with an external capacitor connected to the output. The value of this capacitor can be selected using the diagrams shown in Figs 5 and 6. The following four examples show the effects of the stabilization circuit using different values for the output capacitor.

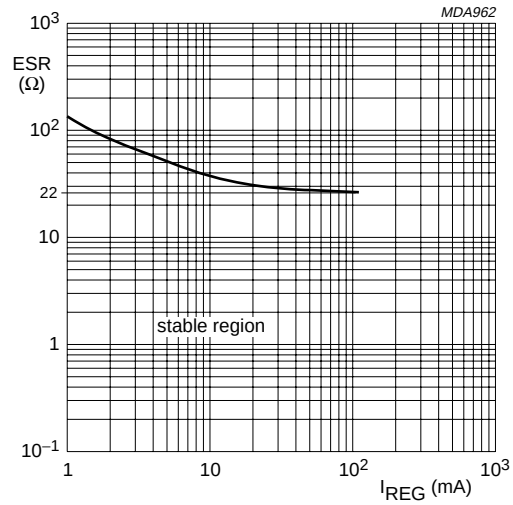


Fig.6 ESR as a function of I_{REG} for selecting the value of the output capacitor.

EXAMPLE 1

The regulator is stabilized with an electrolytic capacitor of 68 μF (ESR = 0.5 Ω). At T_{amb} = –40 °C, the capacitor value is decreased to 22 μF and the ESR is increased to 3.5 Ω. The regulator will remain stable at a temperature of T_{amb} = –40 °C.

EXAMPLE 2

The regulator is stabilized with an electrolytic capacitor of 10 μF (ESR = 3.3 Ω). At T_{amb} = –40 °C, the capacitor value is decreased to 3 μF and the ESR is increased to 20 Ω. The regulator will remain stable at a temperature of T_{amb} = –40 °C.

EXAMPLE 3

The regulator is stabilized with a 100 nF MKT capacitor connected to the output. When the output current is over 200 μA full stability is guaranteed.

Because the thermal influence on the capacitor value is almost zero, the regulator will remain stable at a temperature of T_{amb} = –40 °C.

EXAMPLE 4

The regulator is stabilized with a 100 nF capacitor in parallel with an electrolytic capacitor of 10 μF connected to the output.

The regulator is now stable under all conditions and independent of:

- The ESR of the electrolytic capacitor
- The value of the electrolytic capacitor
- The output current.

Application circuits

The maximum output current of the regulator equals:

$$I_{REG(max)} = \frac{150 - T_{amb}}{R_{th(j-a)} \times (V_P - V_{REG})}$$

$$= \frac{150 - T_{amb}}{100 \times (V_P - 8.5)} (mA)$$

When T_{amb} = 21 °C and V_P = 17.5 V the maximum output current equals 140 mA.

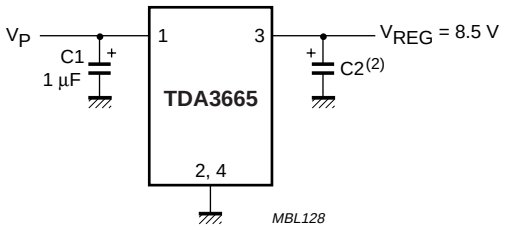
The total thermal resistance of the TDA3665 can be decreased from 125 to 50 K/W for the SO8 version. For the SO4 version it can be decreased from 100 to 40 K/W when GND pins 2 and 4 of the package are soldered to the printed-circuit board.

Application circuit with backup function

Sometimes a backup function is needed to supply, for example, a microcontroller for a short period of time when the supply voltage spikes to 0 V (or even –1 V).

This function can easily be built with the TDA3665 by using an output capacitor with a large value. When the supply voltage is 0 V (or –1 V), only a small current will flow into pin REG from this output capacitor (a few μA).

The application circuit is given in Fig.7.

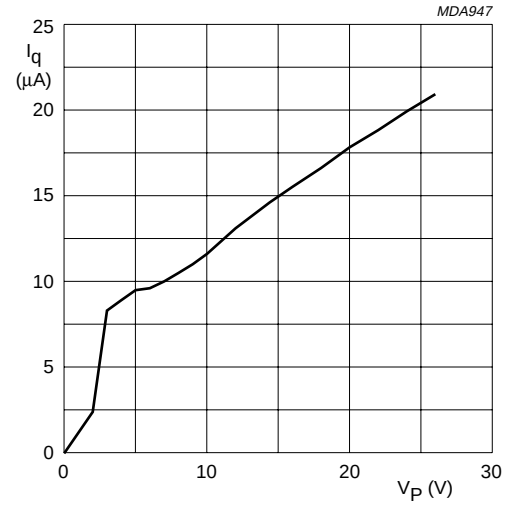


C1 is optional (to minimize supply noise only).
C2 ≤ 4700 μF.

Fig.7 Application circuit with backup function (SO4 version).

Additional application information

This section gives typical curves for various parameters measured on the TDA3665AT. Standard test conditions are: V_P = 14.4 V; T_{amb} = 25 °C.



I_{REG} = 0 mA.

Fig.8 Quiescent current as a function of the supply voltage.

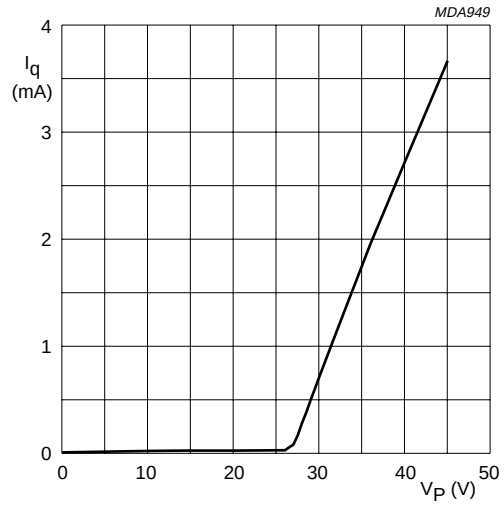
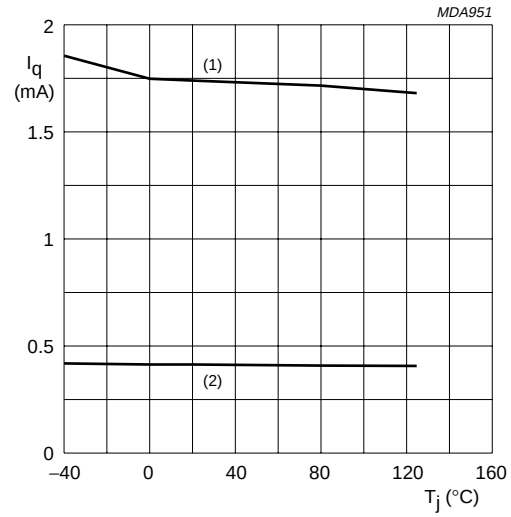
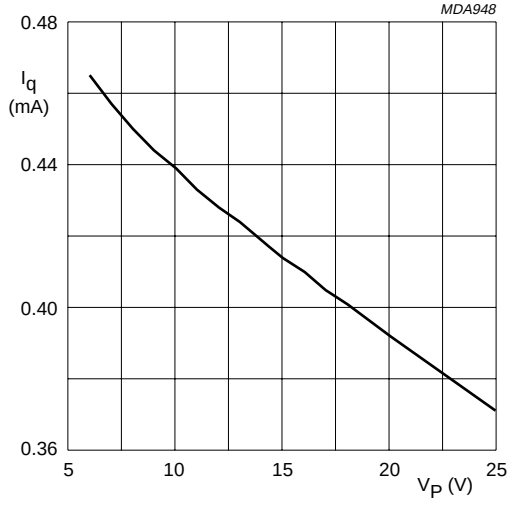


Fig.9 Quiescent current increase as a function of high supply voltage.



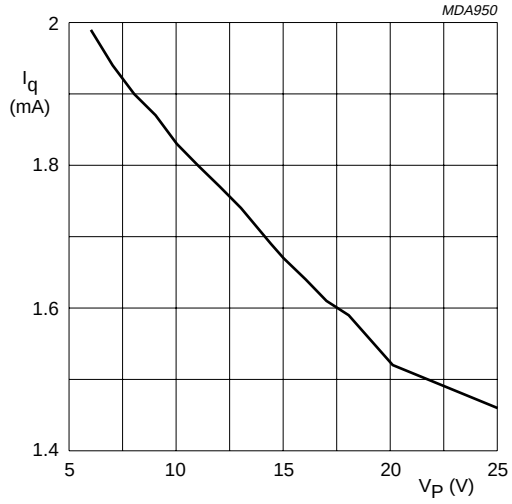
(1) I_q at 50 mA load.
(2) I_q at 10 mA load.

Fig.10 Quiescent current as a function of the junction temperature.



I_{REG} = 10 mA.

Fig.11 Quiescent current as a function of the supply voltage.



I_{REG} = 50 mA.

Fig.12 Quiescent current as a function of the supply voltage.

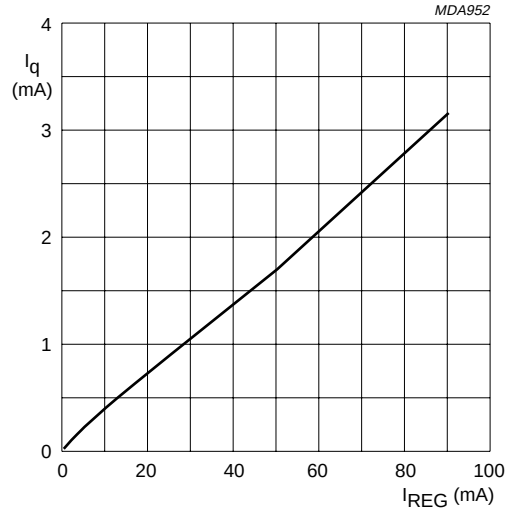
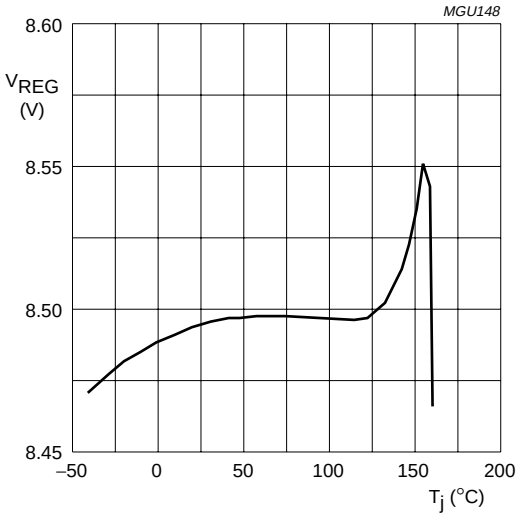
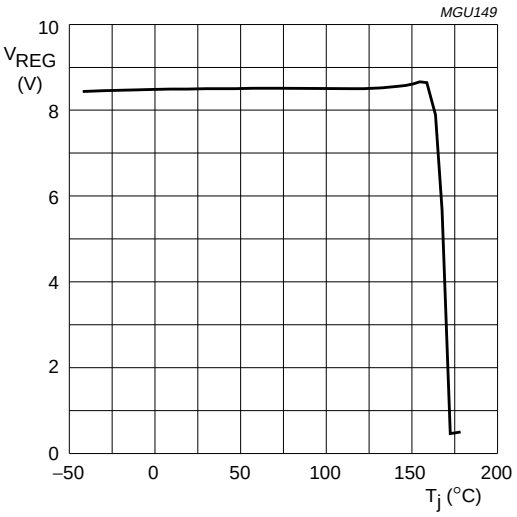


Fig.13 Quiescent current as a function of the output current.



I_{REG} = 0 mA.

Fig.14 Output voltage as a function of the junction temperature.



I_{REG} = 0 mA.

Fig.15 Output voltage thermal protection as a function of the junction temperature.

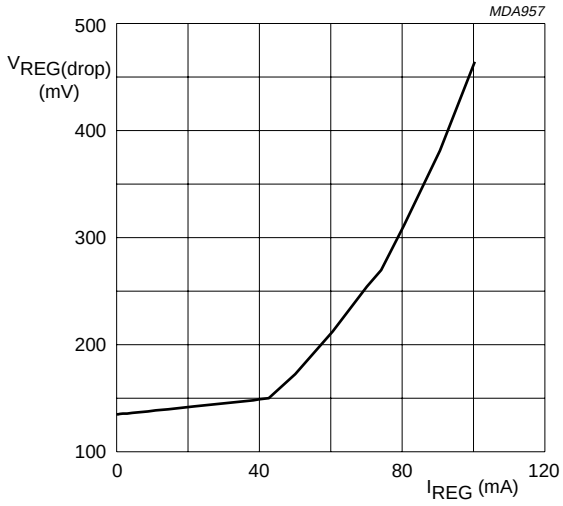
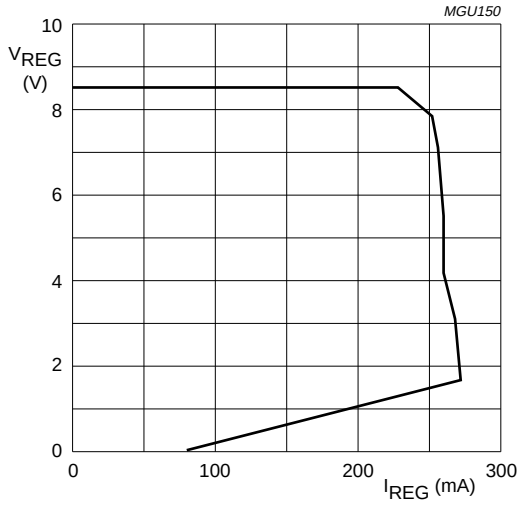
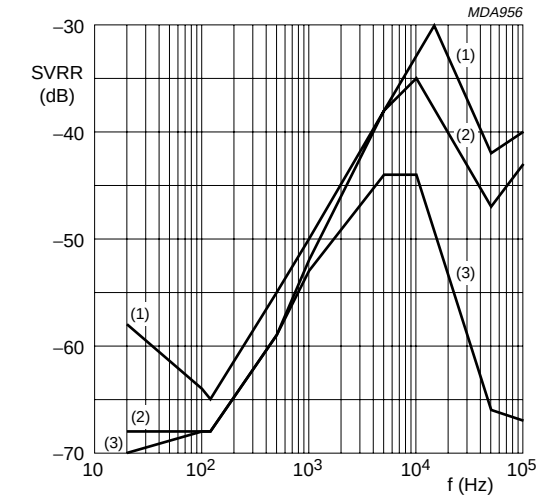


Fig.16 Dropout voltage as a function of the output current.



V_P = 10 V and pulsed load.

Fig.17 Foldback protection mode.

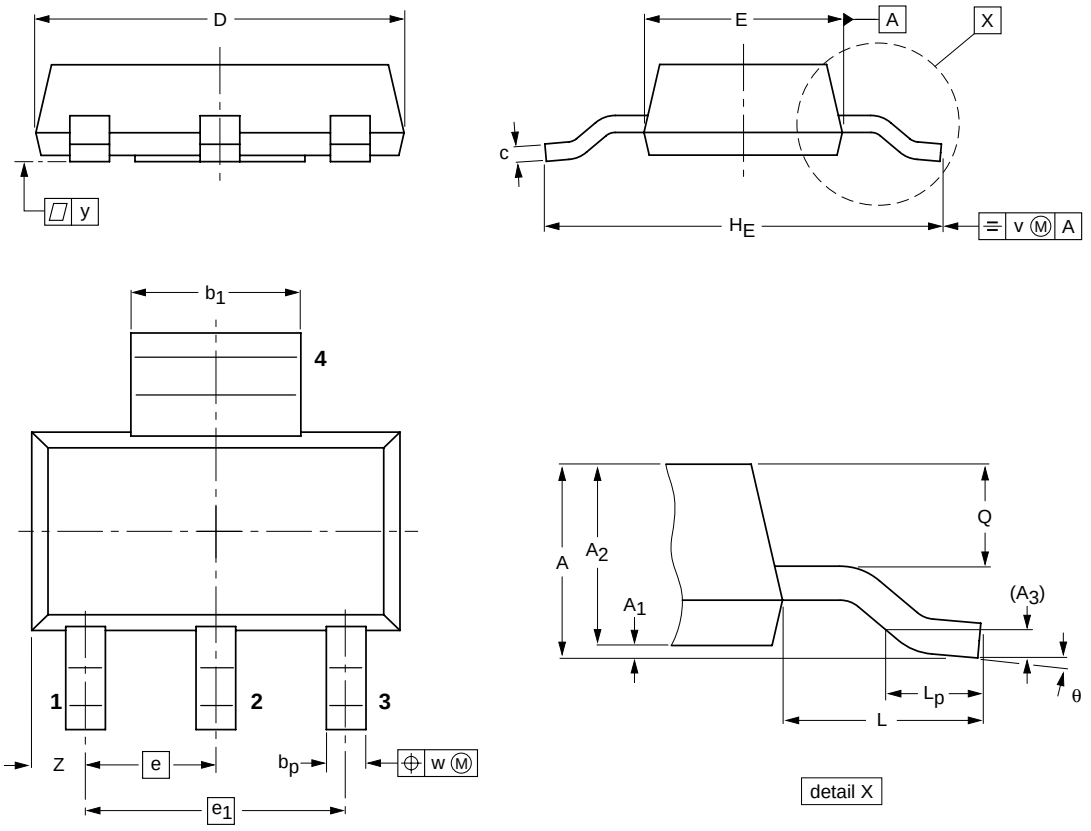


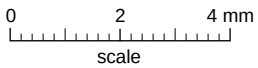
C2 = 10 µF.
(1) SVRR at R_L = 10 kΩ.
(2) SVRR at R_L = 500 Ω.
(3) SVRR at R_L = 100 Ω.

Fig.18 SVRR as a function of the ripple frequency.

PACKAGE OUTLINES

SO4: plastic small outline package; 4 leads; body width 3.5 mm **SOT223-1**





DIMENSIONS (mm are the original dimensions)

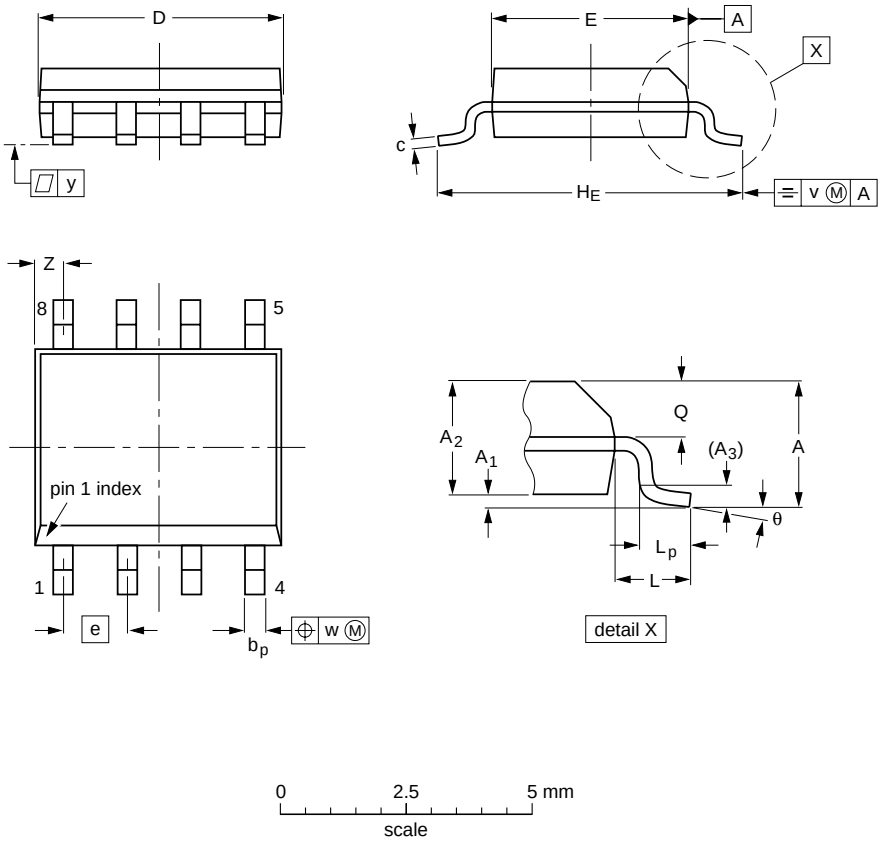
UNIT	A max.	A_1	A_2	A_3	b_p	b_1	c	$D^{(1)}$	$E^{(1)}$	e	e_1	H_E	L	L_p	Q	v	w	y	Z	θ
mm	1.8	0.10 0.02	1.7 1.5	0.25	0.85 0.65	3.15 2.95	0.35 0.25	6.7 6.3	3.7 3.3	2.3	4.6	7.3 6.7	1.75	1.02 0.62	1.0 0.8	0.2	0.1	0.1	1.2 0.7	10° 0°

Note

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT223-1		TO-261				~~99-08-04~~ 99-12-15

SO8: plastic small outline package; 8 leads; body width 3.9 mm **SOT96-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	$D^{(1)}$	$E^{(2)}$	e	H_E	L	L_p	Q	v	w	y	$Z^{(1)}$	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	5.0 4.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8^o 0^o
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.20 0.19	0.16 0.15	0.050	0.244 0.228	0.041	0.039 0.016	0.028 0.024	0.01	0.01	0.004	0.028 0.012	

Notes

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT96-1	076E03	MS-012				~~97-05-22~~ 99-12-27

SOLDERING

Introduction to soldering surface mount packages

This text gives a very brief insight to a complex technology. A more in-depth account of soldering ICs can be found in our *"Data Handbook IC26; Integrated Circuit Packages"* (document order number 9398 652 90011).

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering is not always suitable for surface mount ICs, or for printed-circuit boards with high population densities. In these situations reflow soldering is often used.

Reflow soldering

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement.

Several methods exist for reflowing; for example, infrared/convection heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 and 200 seconds depending on heating method.

Typical reflow peak temperatures range from 215 to 250 °C. The top-surface temperature of the packages should preferable be kept below 230 °C.

Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

  The footprint must incorporate solder thieves at the downstream end.
- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Typical dwell time is 4 seconds at 250 °C.
A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C.

When using a dedicated tool, all other leads can be soldered in one operation within 2 to 5 seconds between 270 and 320 °C.

Suitability of surface mount IC packages for wave and reflow soldering methods

PACKAGE	SOLDERING METHOD	
	WAVE	REFLOW(1)
BGA, SQFP	not suitable	suitable
HLQFP, HSQFP, HSOP, HTSSOP, SMS	not suitable(2)	suitable
PLCC(3), SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended(3)(4)	suitable
SSOP, TSSOP, VSO	not recommended(5)	suitable

Notes

1. All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *"Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods"*.
2. These packages are not suitable for wave soldering as a solder joint between the printed-circuit board and heatsink (at bottom version) can not be achieved, and as solder may stick to the heatsink (on top version).
3. If wave soldering is considered, then the package must be placed at a 45° angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
4. Wave soldering is only suitable for LQFP, TQFP and QFP packages with a pitch (e) equal to or larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
5. Wave soldering is only suitable for SSOP and TSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.

DATA SHEET STATUS

DATA SHEET STATUS	PRODUCT STATUS	DEFINITIONS (1)
Objective specification	Development	This data sheet contains the design target or goal specifications for product development. Specification may change in any manner without notice.
Preliminary specification	Qualification	This data sheet contains preliminary data, and supplementary data will be published at a later date. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.
Product specification	Production	This data sheet contains final specifications. Philips Semiconductors reserves the right to make changes at any time without notice in order to improve design and supply the best possible product.

Note

1. Please consult the most recently issued data sheet before initiating or completing a design.

DEFINITIONS

Short-form specification — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

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Printed in The Netherlands 753503/25/01/pp20 Date of release: 2000 Apr 25 Document order number: 9397 750 06702

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