DATA SHEET

TDA3616
Multiple voltage regulator with battery detection

Objective specification
File under Integrated Circuits, IC01

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Philips Semiconductors

PHILIPS

Multiple voltage regulator with battery detection

TDA3616

FEATURES

General

- One V_P-state controlled regulator
- Battery detection circuit
- Regulator, reset and battery outputs operate during load dump
- Supply voltage range of –18 to +50 V
- Low quiescent current (battery detection switched off)
- High ripple rejection
- Dual reset output
- Back-up circuit
- Adjustable reset delay timer.

Protections

- Reverse polarity safe (down to –18 V without high reverse current)
- Able to withstand voltages up to 18 V at the output (supply line may be short-circuited)
- ESD protected on all pins
- Load dump protection
- Foldback current limit protection for regulator
- The regulator output is DC short-circuited safe to ground and V_P.

GENERAL DESCRIPTION

The TDA3616 is a low power voltage regulator. It contains:

- One fixed voltage regulator with a foldback current protection, intended to supply a microprocessor, that also operates during load dump
- A provision for use of a reserve supply capacitor that will hold enough energy for regulator to allow a microcontroller to prepare for loss of supply voltage
- Reset signals which can be used to interface with the microprocessor
- A supply pin that can withstand load dump pulses and negative supply voltages
- Defined start-up behaviour; regulator will be switched on at a supply voltage higher than 7.5 V and off when the output voltage of the regulator drops below 2.4 V.

QUICK REFERENCE DATA

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_P	supply voltage					
	operating	regulator on	5.6	14.4	25	V
	jump start	$t \leq 10$ minutes	–	–	30	V
	load dump protection	$t \leq 50$ ms; $t_r \geq 2.5$ ms	–	–	50	V
I_q	quiescent supply current	standby mode	–	95	125	μA
		standby mode; $T_{amb} = 25$ °C	–	95	120	μA
Regulator						
V_O	output voltage	0.5 mA $\leq I_{REG} \leq$ 150 mA; 7 V $\leq V_P \leq$ 18 V; $T_{amb} = 25$ °C	4.8	5.0	5.2	V
		0.5 mA $\leq I_{REG} \leq$ 150 mA; 7 V $\leq V_P \leq$ 18 V	4.75	5.0	5.25	V
		I_{REG} = 30 mA; 18 V $\leq V_P \leq$ 50 V; load dump	4.75	5.0	5.25	V
V_d	drop-out voltage	I_{REG} = 150 mA; V_P = 5 V; T_{amb} = 25 °C	–	0.6	1.0	V

ORDERING INFORMATION

TYPE NUMBER	PACKAGE		
	NAME	DESCRIPTION	VERSION
TDA3616T	SO20	plastic small outline package; 20 leads; body width 7.5 mm	SOT163-1
TDA3616PH	HDIP18	plastic heat-dissipating dual in-line package; 18 leads	SOT398-1

BLOCK DIAGRAM

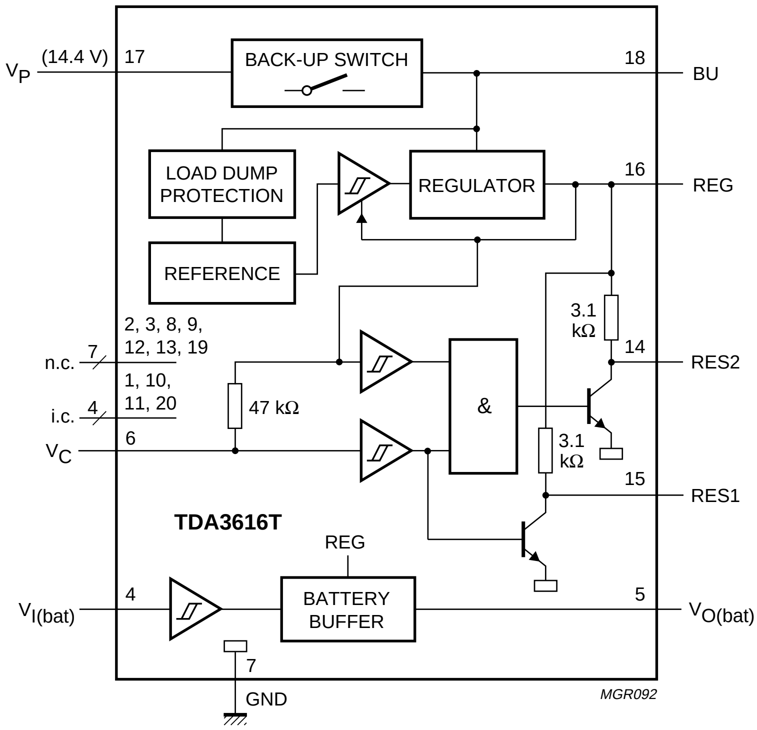


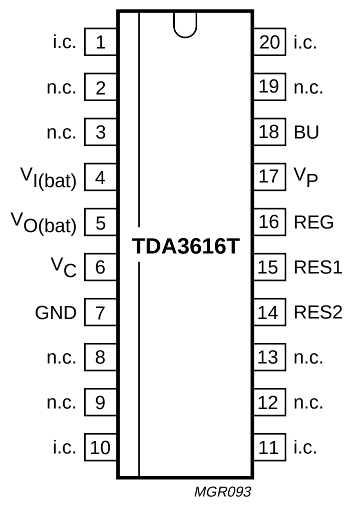
Fig.1 Block diagram (for SOT163-1).

PINNING

SYMBOL	PIN		DESCRIPTION
	SOT163-1	SOT398-1	
i.c.	1, 10, 11, and 20	10 to 18	interconnected; heat spreader; note 1
n.c.	2, 3, 8, 9, 12, 13 and 19	–	not connected; heat spreader
$V_{I(bat)}$	4	6	battery input voltage
$V_{O(bat)}$	5	7	battery detection output voltage
V_C	6	8	reset delay capacitor
GND	7	9	ground (0 V)
RES2	14	1	reset 2 output
RES1	15	2	reset 1 output
REG	16	3	regulator output
V_P	17	4	supply voltage
BU	18	5	back-up

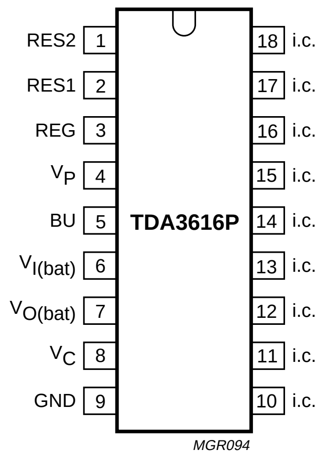
Note

1. The i.c. pins are connected to each other by the leadframe and can be kept floating or can be connected to ground.



The i.c. and n.c. pins can be connected to a heat spreader.

Fig.2 Pin configuration for SOT163-1.



The i.c. pins can be connected to a heat spreader.

Fig.3 Pin configuration for SOT398-1.

FUNCTIONAL DESCRIPTION

The TDA3616 (see Fig.1) is a voltage regulator intended to supply a microprocessor (e.g. in car radio applications). Because of low-voltage operation of the application, a low-voltage drop regulator is used in the TDA3616.

This regulator will switch on when the back-up voltage (see Section “Back-up circuit”) exceeds 7.5 V for the first time and will switch off again when the output voltage of the regulator drops below 2.4 V. When the regulator is switched on, the RES1 and RES2 outputs (RES2 can only be HIGH when RES1 is HIGH) will go HIGH after a fixed delay time (fixed by an external delay capacitor) to generate a reset to the microprocessor.

RES1 will go HIGH by an internal pull-up resistor of 3.1 kΩ, and is used to initialize the microprocessor. RES2 is used to indicate that the regulator output voltage is within its voltage range. This start-up feature is built-in to secure a smooth start-up of the microprocessor at first connection, without uncontrolled switching of the regulator during the start-up sequence.

The charge of the back-up capacitor can be used to supply the regulator and logic circuits for a short period when the supply falls down to 0 V (time depends on value of storage capacitor). The regulator is switched off at a back-up voltage of approximately 2.7 V. From this time onwards, the back-up charge will only be used for maintaining reset functions. Due to this, the reset outputs will remain LOW till the output of the regulator is dropped to 0 V.

All output pins are fully protected. The regulator is protected against load dump and short-circuit (foldback current protection). At load dump, the battery detection circuit will remain operating.

Interfacing with the microprocessor can be accomplished by means of a battery Schmitt trigger and output buffer (simple full/semi on/off logic applications). The battery output will go HIGH when the battery input voltage exceeds the high threshold level.

The timing diagrams are shown in Fig.4

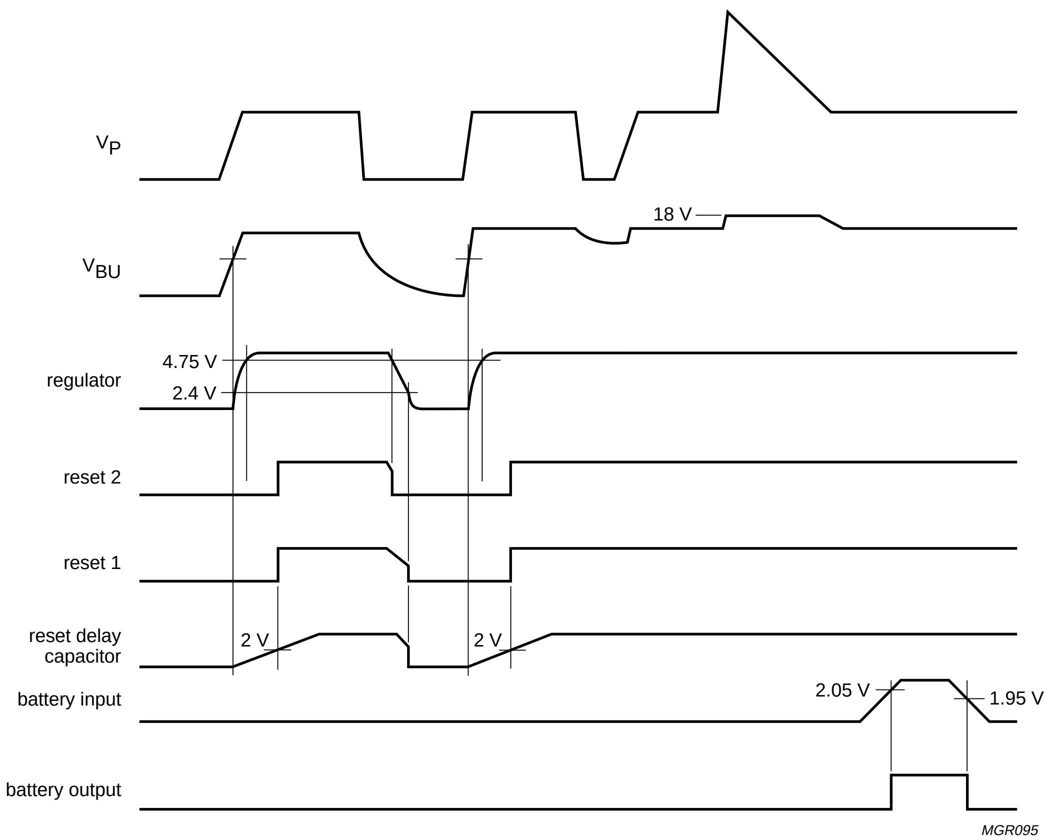


Fig.4 Timing diagrams.

LIMITING VALUES

In accordance with the Absolute Maximum Rating System (IEC 134).

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_P	supply voltage				
	operating	regulator on	–	25	V
	jump start	t ≤ 10 minutes	–	30	V
	load dump protection	t ≤ 50 ms; t_r ≥ 2.5 ms	–	50	V
V_{rp}	reverse polarity voltage	non-operating	–	–18	V
$V_{I(bat)p}$	positive pulse voltage at battery input	V_P = 14.4 V; R_I = 5 kΩ	–	50	V
$V_{I(bat)n}$	negative pulse voltage at battery input	V_P = 14.4 V; R_I = 10 kΩ; C_I = 1 nF	–	–100	V
P_{tot}	total power dissipation	V_P = 12.4 V	–	2.5	W
T_{stg}	storage temperature	non-operating	–55	+150	°C
T_{amb}	ambient temperature	operating	–40	+105	°C
T_j	junction temperature	operating	–40	+150	°C

THERMAL CHARACTERISTICS

SYMBOL	PARAMETER	CONDITIONS	VALUE	UNIT
$R_{th(j-p)}$	thermal resistance from junction to pins			
	TDA3616T		20	K/W
	TDA3616P		15	K/W
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air; on IMS board		
	TDA3616T		50	K/W
	TDA3616P		50	K/W

QUALITY SPECIFICATION

Quality specification in accordance with *“SNW-FQ-611E”*.

CHARACTERISTICS

V_P = 14.4 V; I_{REG} = 0.5 mA; –40 °C < T_{amb} < +105 °C; measurements taken in test circuit of Fig.7; unless otherwise specified.

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
Supply						
V_P	supply voltage					
	operating	regulator on; note 1	5.6	14.4	25	V
	jump start	t ≤ 10 minutes	–	–	30	V
	load dump protection	t ≤ 50 ms; t_r ≥ 2.5 ms	–	–	50	V
I_q	quiescent supply current	V_P = 12.4 V; T_{amb} = 25 °C; note 2	–	95	120	μA
		V_P = 12.4 V; note 2	–	95	125	μA
		V_P = 14.4 V; note 2	–	100	–	μA
		V_P = 50 V; load dump	–	5	20	mA
Schmitt trigger for regulator and reset 1						
V_{thr}	rising threshold voltage	$R_{L(REG)}$ = 1 KΩ	6.2	7.5	8.1	V
V_{thf}	falling threshold voltage	I_{REG} = 5 mA	2.1	2.4	2.7	V
		I_{REG} = 30 mA	–	2.25	–	V
V_{hys}	hysteresis voltage		–	5.1	–	V
Schmitt trigger for battery detection						
V_{thr}	rising threshold voltage	T_{amb} = 25 °C	2.0	2.1	2.2	V
			2.0	2.1	2.25	V
V_{thf}	falling threshold voltage	T_{amb} = 25 °C	1.9	2.0	2.1	V
			1.9	2.0	2.15	V
V_{hys}	hysteresis voltage		–	0.1	–	V
Schmitt trigger for reset 2						
V_{thr}	rising threshold voltage	note 3	4.55	4.8	5.05	V
V_{thf}	falling threshold voltage	note 3	4.5	4.75	5.0	V
V_{hys}	hysteresis voltage		–	0.05	–	V
ΔV_{track}	voltage tracking with V_{REG}	I_{sink} = 0 mA; note 4	–65	0	+65	mV
Reset 1 and reset 2 buffers						
$I_{sink(L)}$	LOW-level sink current	V_{RES} ≤ 0.5 V; note 3	2	15	–	mA
$R_{pu(int)}$	internal pull-up resistance	T_{amb} = 25 °C	2.2	3.1	4.0	kΩ
			1.9	3.1	4.6	kΩ
Reset delay						
$R_{pu(int)}$	internal pull-up resistance	T_{amb} = 25 °C; note 5	–	47	–	kΩ
V_{thr}	rising threshold voltage		1.4	2.0	2.8	V
t_d	delay time	C_d = 100 nF; note 6; see Fig.9	–	2.6	–	ms
Battery buffer						
V_{OL}	LOW-level output voltage	I_I = 0 mA	0	0.05	0.5	V
V_{OH}	HIGH-level output voltage	I_o = 5 μA; note 7	–	5.0	5.2	V

SYMBOL	PARAMETER	CONDITIONS	MIN.	TYP.	MAX.	UNIT
I_{OL}	LOW-level output current	$V_{OL} \leq 0.5$ V	0.2	0.5	–	mA
I_{OH}	HIGH-level output current	$V_{OH} \geq 4$ V; see Fig.6	1	12	–	mA
Regulator (I_{REG} = 5 mA; unless otherwise specified)						
V_O	output voltage	0.5 mA ≤ I_{REG} ≤ 150 mA; 7 V ≤ V_P ≤ 18 V; T_{amb} = 25 °C	4.8	5.0	5.2	V
		0.5 mA ≤ I_{REG} ≤ 150 mA; 7 V ≤ V_P ≤ 18 V	4.75	5.0	5.25	V
		I_{REG} = 30 mA; 18 V ≤ V_P ≤ 50 V; load dump	4.75	5.0	5.25	V
I_O	output current	V_P > 25 V; load dump	–	–	100	mA
ΔV_{LN}	line voltage regulation	7 V ≤ V_P ≤ 18 V	–	3	50	mV
ΔV_L	load voltage regulation	0.5 mA ≤ I_{REG} ≤ 150 mA; T_{amb} = 25 °C	–	–	70	mV
		0.5 mA ≤ I_{REG} ≤ 150 mA	–	–	85	mV
SVRR	supply voltage ripple rejection	f_i = 200 Hz; $V_{i(p-p)}$ = 2 V; I_o = 5 mA	55	60	–	dB
V_d	drop-out voltage	I_{REG} = 150 mA; V_P = 5 V; T_{amb} = 25 °C; note 8	–	0.6	1.0	V
		I_{REG} = 150 mA; V_P = 5.5 V; note 8	–	0.9	1.2	V
I_l	current limit	V_{REG} > 4.5 V; V_P > 10 V; note 9	0.25	0.6	1	A
I_{sc}	short-circuit current	$R_{L(REG)}$ ≤ 0.5 Ω; T_{amb} = 25 °C; note 10	40	80	–	mA
Back-up switch						
I_{DC}	DC continuous current	V_{BU} > 5 V; note 11	0.1	0.2	–	A
I_r	reverse current	V_P = 0 V; V_{BU} = 12.4 V	–	–	200	µA

Notes

1. Minimum operating voltage, only if V_P has exceeded 7.5 V.
2. The quiescent current is measured in standby mode. So, the battery input is connected to a low voltage source and $R_{L(REG)} = \infty$.
3. The voltage of regulator sinks as a result of a supply voltage drop.
4. Only one bandgap circuit is used as reference for both regulator and Schmitt trigger for reset. Due to this a tracking exists between the reset Schmitt trigger levels and the output voltage of the regulator.
5. The temperature coefficient of the internal resistor is 0.2%/K.
6. The delay time can be calculated with the following formula: $t_d = R_{pu(int)} \times C_d \times \ln\left(\frac{V_{REG}}{(V_{REG} - V_{thr})}\right)$
7. Battery output voltage will be equal or less than the output voltage of regulator.
8. The drop-out voltage of regulator is measured between V_P and V_{REG}.
9. At current limit, I_l is held constant (behaviour according to dashed line in Fig.5).
10. The foldback current protection limits the dissipated power at short-circuit (see Fig.5).
11. The back-up switch can deliver an additional current of 100 mA, guaranteed when the regulator is loaded with nominal loads (I_{REG} ≤ 150 mA).

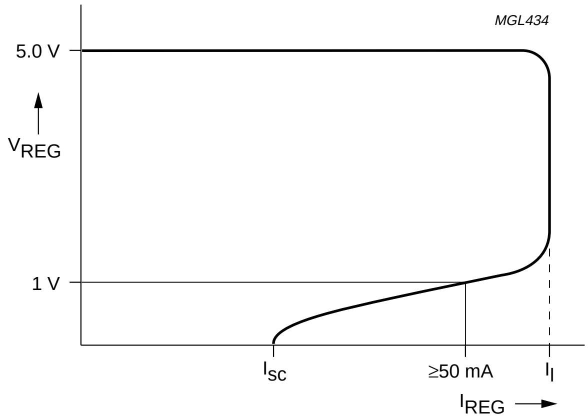


Fig.5 Foldback current protection.

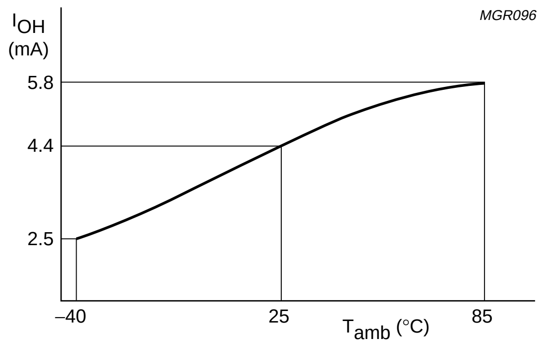
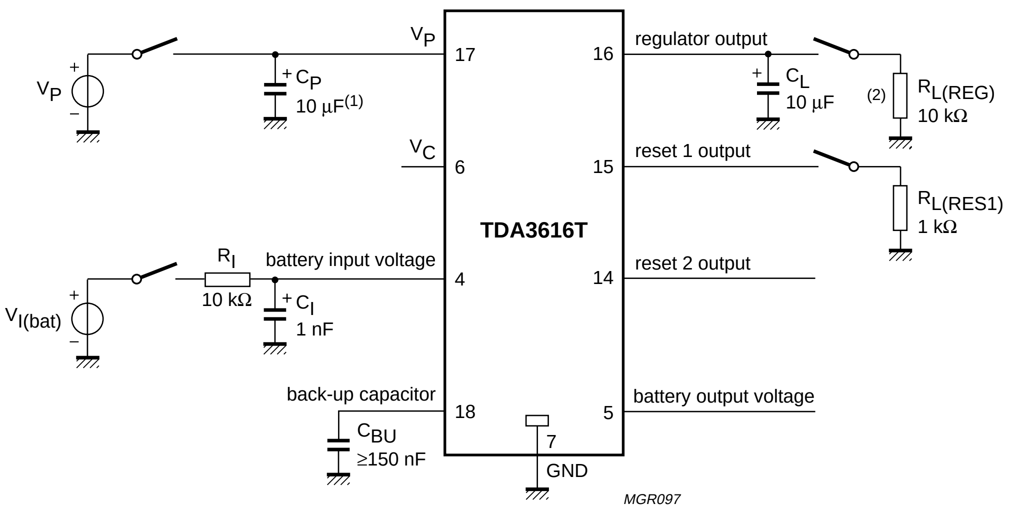


Fig.6 Battery buffer HIGH-level output current as a function of T_{amb} (typical value) at $V_{O(bat)}$ = 3 V.

TEST AND APPLICATION INFORMATION

Test information



(1) Capacitor not required for stability.

(2) $R_{L(REG)}$ = 0.5 Ω at short-circuit.

Fig.7 Test circuit for TDA3616T.

Application information

NOISE

The noise at the output of the regulator depends on the bandwidth of the regulator, which can be adjusted by the output capacitor C_L. Table 1 shows the noise figures.

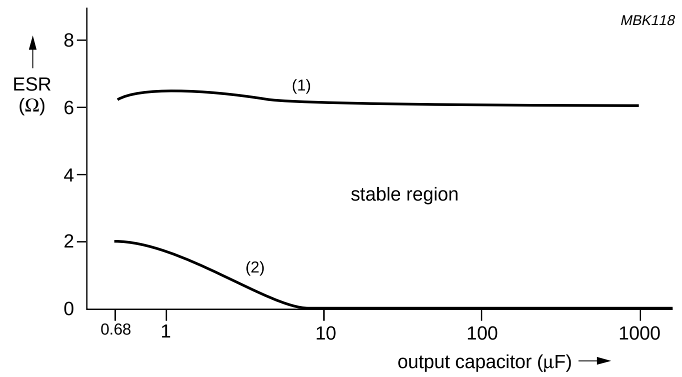
The noise on the supply line depends on the value of the supply capacitor C_P and is caused by a current noise (output noise of the regulator is translated into a current noise by the output capacitor). When a high frequency capacitor of 220 nF with an electrolytic capacitor of 100 µF in parallel is connected directly between pins V_P and GND the noise is minimized.

Table 1 Noise figures

I_O (mA)	NOISE FIGURE (µV)(1)		
	C_L = 10 µF	C_L = 47 µF	C_L = 100 µF
0.5	58	50	45
50	250	200	180

Note

1. Measured at a bandwidth of 10 Hz to 100 kHz.



(1) Maximum Equivalent Series Resistance (ESR).

(2) Minimum ESR.

Fig.8 Curve for selecting the value of the output capacitor.

STABILITY

The regulator is stabilized by the output capacitor C_L. The value of the output capacitor can be selected using the diagram shown in Fig.8. The next two examples show the effects of the stabilization circuit using different values for the output capacitor.

Remark: The behaviour of ESR as a function of the temperature must be known.

Example 1

The regulator is stabilized using an electrolytic output capacitor of 68 μF (ESR = 0.5 Ω). At –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 –40 °C.

Example 2

The regulator is stabilized using an electrolytic output capacitor of 10 μF (ESR = 3.3 Ω). At –40 °C the capacitor value is decreased to 3 μF and the ESR is increased to 23.1 Ω. The regulator will be instable at a temperature of –40 °C. This can be solved by using a tantalum capacitor of 10 μF.

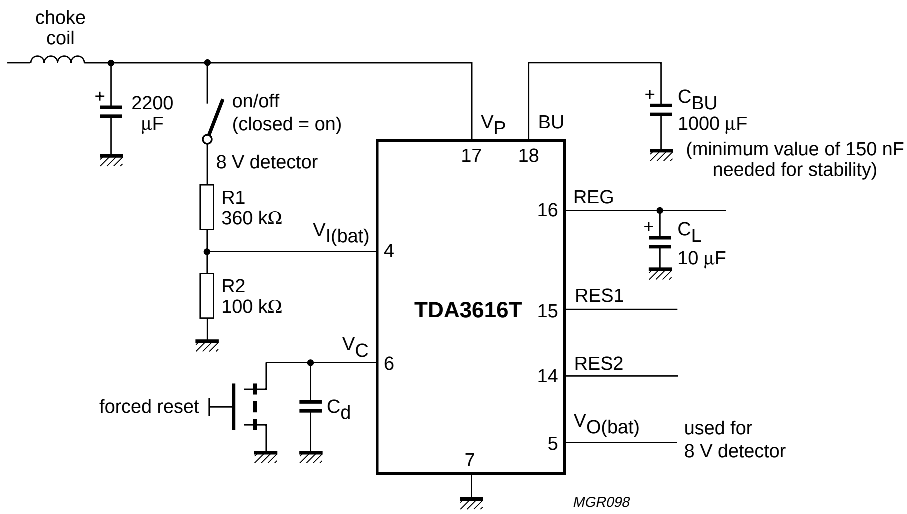


Fig.9 Typical application.

APPLICATION CIRCUIT

In Fig.9 the total quiescent current equals $I_q + I_{Rdivider}$. The specified quiescent current equals I_q. When the supply voltage is connected, the regulator will switch on when the supply voltage exceeds 7.5 V. With a timing capacitor at pin V_C the reset can be delayed (the timer starts at the same moment as the regulator is switched on).

Forced reset can be accomplished by short-circuiting the timer capacitor by using the push-button switch. When the push button is released again, the timer restarts (only when the regulator is on) causing a second reset on both RES1 and RES2.

The maximum output current of the regulator equals:

$$I_{O(max)} = \frac{150 - T_{amb}}{R_{th(j-a)} \times (V_P - V_{REG})} = \frac{150 - T_{amb}}{50 \times (V_P - 5)} \text{ [mA]}$$

When T_{amb} = 85 °C and V_P = 16 V, the maximum output current equals 118 mA. At lower ambient temperature (T_{amb} < 0) the maximum output current equals 250 mA.

Back-up circuit

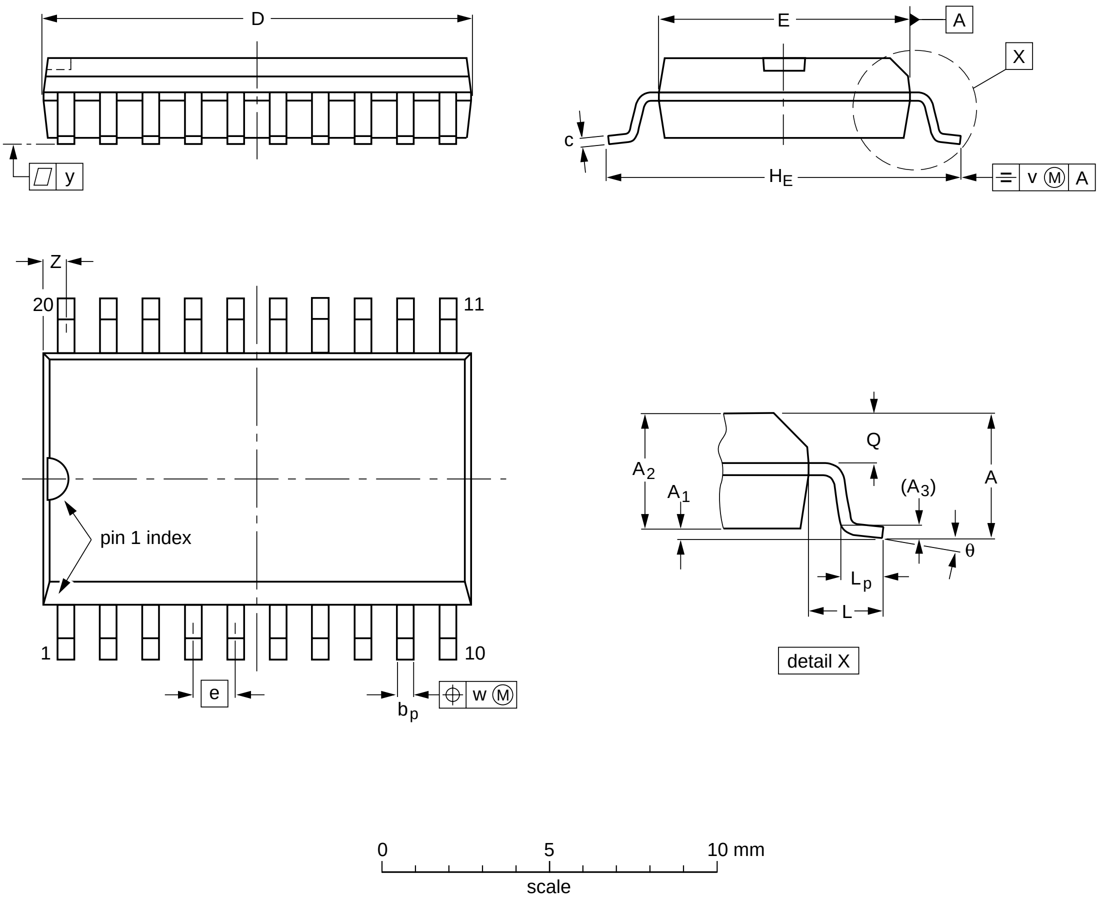
The back-up function is used for supplying the regulator and logic circuits (reset 1 and 2) when the supply voltage is disconnected. For stability **a minimum capacitor value of 150 nF** is needed.

With a supply voltage of 14.4 V the back-up capacitor will be fully charged till approximately 14.2 V. At the moment the supply voltage is lower than the voltage on pin BU the back-up switch will be opened (this back-up switch acts like an ideal diode) and the charge of the back-up capacitor is used for supplying the regulator and the logic circuits. The back-up capacitor is mainly discharged by the load of the regulator. After a certain period the regulator output will be disabled and the back-up capacitor is only discharged by the quiescent current of the IC itself.

In combination with the battery detection Schmitt trigger, an early warning can be given to the microprocessor to indicate that the battery voltage has dropped down to a not acceptable low value, causing the microcontroller to run on back-up charge. The early warning level can be programmed with resistors R1 and R2 in Fig.9.

PACKAGE OUTLINES

SO20: plastic small outline package; 20 leads; body width 7.5 mm **SOT163-1**



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

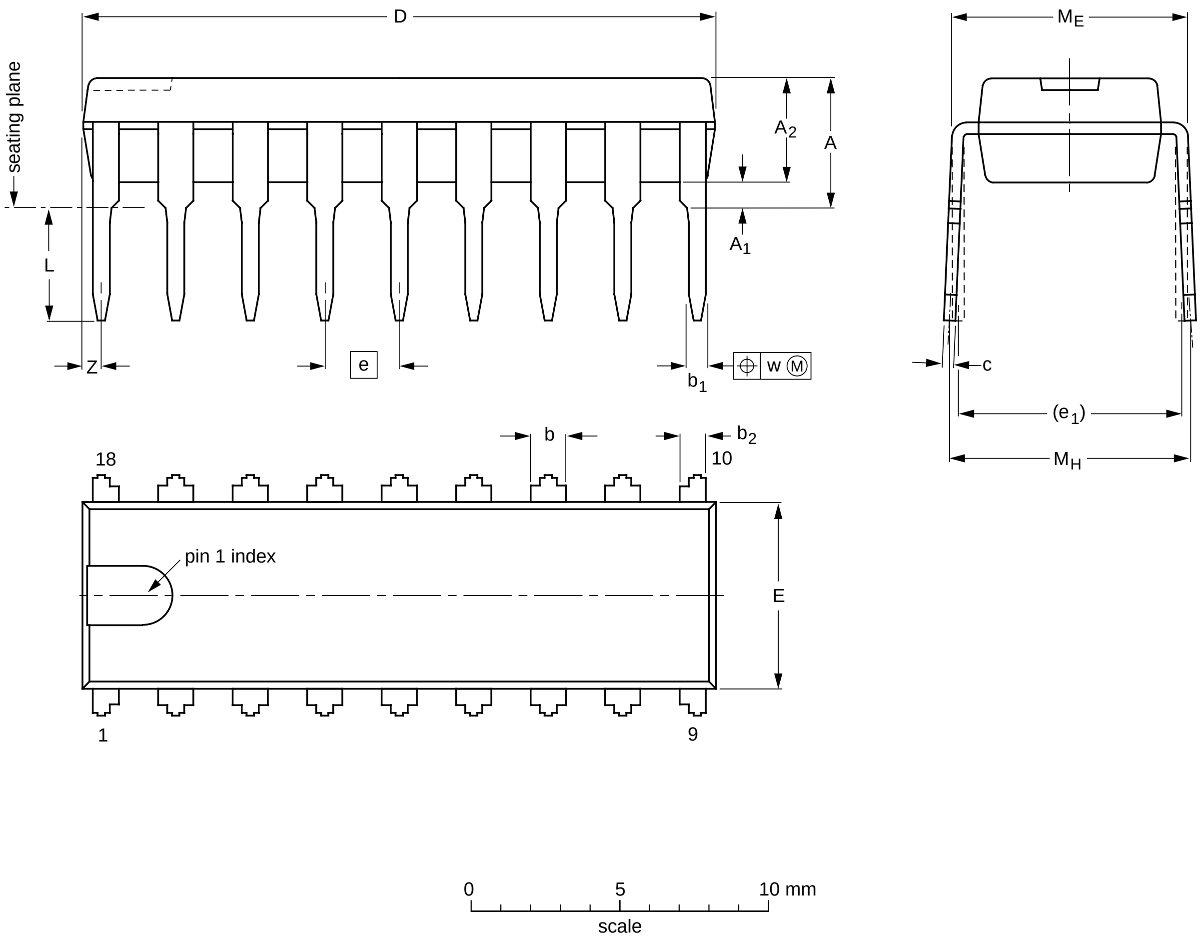
UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (1)	e	H_E	L	L_p	Q	v	w	y	Z (1)	θ
mm	2.65	0.30 0.10	2.45 2.25	0.25	0.49 0.36	0.32 0.23	13.0 12.6	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8° 0°
inches	0.10	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.51 0.49	0.30 0.29	0.050	0.419 0.394	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

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			
SOT163-1	075E04	MS-013AC				~~95-01-24~~ 97-05-22

HDIP18: plastic heat-dissipating dual in-line package; 18 leads **SOT398-1**



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

UNIT	A max.	A_1 min.	A_2 max.	b	b_1	b_2	c	D (1)	E (1)	e	e_1	L	M_E	M_H	w	Z (1) max.
mm	4.7	0.51	3.7	1.40 1.14	0.67 0.50	1.05 0.75	0.47 0.38	21.85 21.35	6.5 6.2	2.54	7.62	3.9 3.1	8.32 8.02	8.7 7.7	0.25	1.0
inches	0.19	0.02	0.15	0.06 0.04	0.03 0.02	0.04 0.03	0.02 0.01	0.87 0.84	0.26 0.24	0.10	0.30	0.15 0.12	0.33 0.32	0.34 0.30	0.01	0.04

Note

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

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	EIAJ			
SOT398-1						~~94-04-13~~ 95-01-25

SOLDERING

Introduction

There is no soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and surface mounted components are mixed on one printed-circuit board. However, wave soldering is not always suitable for surface mounted ICs, or for printed-circuits with high population densities. In these situations reflow soldering is often used.

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"* (order code 9398 652 90011).

HDIP

SOLDERING BY DIPPING OR BY WAVE

The maximum permissible temperature of the solder is 260 °C; solder at this temperature must not be in contact with the joint for more than 5 seconds. The total contact time of successive solder waves must not exceed 5 seconds.

The device may be mounted up to the seating plane, but the temperature of the plastic body must not exceed the specified maximum storage temperature ($T_{stg\ max}$). If the printed-circuit board has been pre-heated, forced cooling may be necessary immediately after soldering to keep the temperature within the permissible limit.

REPAIRING SOLDERED JOINTS

Apply a low voltage soldering iron (less than 24 V) to the lead(s) of the package, below the seating plane or not more than 2 mm above it. If the temperature of the soldering iron bit is less than 300 °C it may remain in contact for up to 10 seconds. If the bit temperature is between 300 and 400 °C, contact may be up to 5 seconds.

SO

REFLOW SOLDERING

Reflow soldering techniques are suitable for all SO packages.

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 techniques exist for reflowing; for example, thermal conduction by heated belt. Dwell times vary between 50 and 300 seconds depending on heating method. Typical reflow temperatures range from 215 to 250 °C.

Preheating is necessary to dry the paste and evaporate the binding agent. Preheating duration: 45 minutes at 45 °C.

WAVE SOLDERING

Wave soldering techniques can be used for all SO packages if the following conditions are observed:

- A double-wave (a turbulent wave with high upward pressure followed by a smooth laminar wave) soldering technique should be used.
- The longitudinal axis of the package footprint must be parallel to the solder flow.
- The package footprint must incorporate solder thieves at the downstream end.

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.

Maximum permissible solder temperature is 260 °C, and maximum duration of package immersion in solder is 10 seconds, if cooled to less than 150 °C within 6 seconds. 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.

REPAIRING SOLDERED JOINTS

Fix the component by first soldering two diagonally-opposite end leads. Use only a low voltage soldering iron (less than 24 V) 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.

DEFINITIONS

Data sheet status	
Objective specification	This data sheet contains target or goal specifications for product development.
Preliminary specification	This data sheet contains preliminary data; supplementary data may be published later.
Product specification	This data sheet contains final product specifications.
Limiting values	
Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.	
Application information	
Where application information is given, it is advisory and does not form part of the specification.	

LIFE SUPPORT APPLICATIONS

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