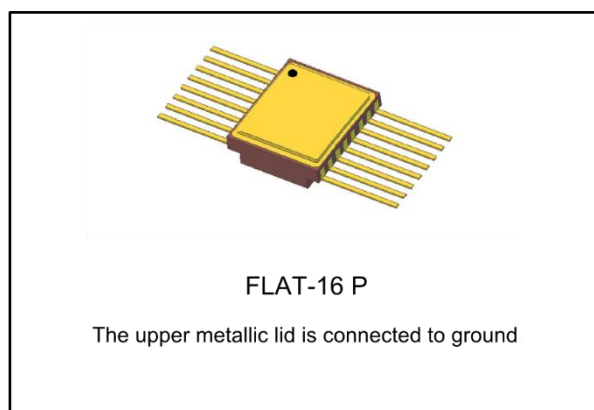


## 2 A rad-hard adjustable positive voltage regulator

Datasheet - production data



- Programmable output short-circuit current
- Remote sensing operation
- Rad-hard: guaranteed up to 300 krad MIL-STD-883J method 1019.9 high dose rate and 0.01 rad/s in ELDRS conditions
- Radiation environment: SET/SEL/SEB:
  - SEL free @ LET=120 MeV\*cm<sup>2</sup>/mg
  - SET: less than 3.3% of V<sub>OUT</sub> @ 120 MeV
- Heavy-ions SET dedicated internal circuitry implemented for absorbing output transient
- Operating junction temperature range: -55 °C to 125 °C

### Description

The RHFL6000A high-performance adjustable positive voltage regulator provides exceptional radiation performance. It is tested in accordance with mil MIL-STD-883J method 1019.9, in ELDRS conditions. The device is available in the FLAT-16P. A dedicated internal circuitry is implemented for absorbing output transients during SET events. The operating input voltage goes from 2.5 V to 12 V.

### Features

- Input voltage range from 2.5 V to 12 V
- 2 A guaranteed output current
- Low dropout voltage: 0.3 V typ. @ 0.4 A
- Embedded overtemperature and overcurrent protection
- Adjustable overcurrent limitation
- Output overload monitoring/signalling
- Adjustable output voltage
- Internal control loop accessible via an external pin, optional
- Inhibit (ON/OFF) TTL compatible control

Table 1: Device summary

Part number	SMD pin	Quality level	EPPL	Package	Lead finish	Mass (g)
RHFL6000AKP1	-	Engineering model	-	FLAT-16P	Gold	0.70
RHFL6000AKP01V <sup>(1)</sup>	5962F1521601VXC	QML-V flight	Target			
RHFL6000AKP02V <sup>(1)</sup>	5962F1521601VXA	QML-V flight	Target		Tin	

### Notes:

<sup>(1)</sup> Contact ST sales office for information about the specific conditions for products in die form and other quality levels.

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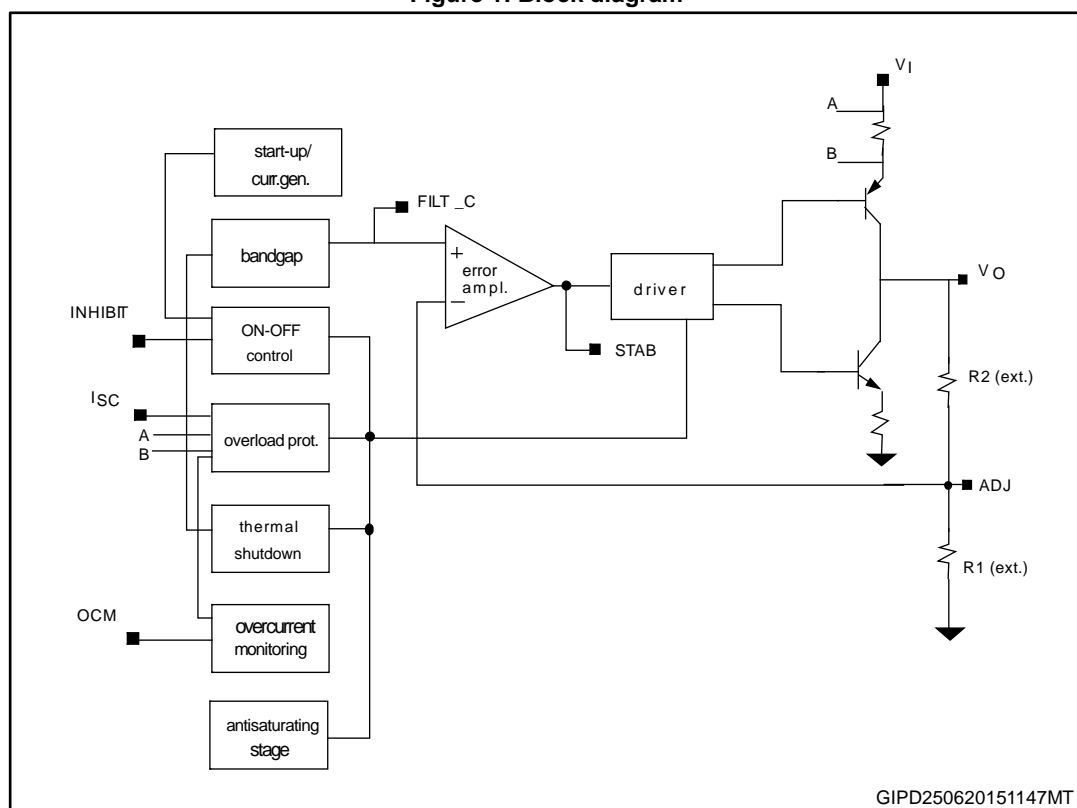
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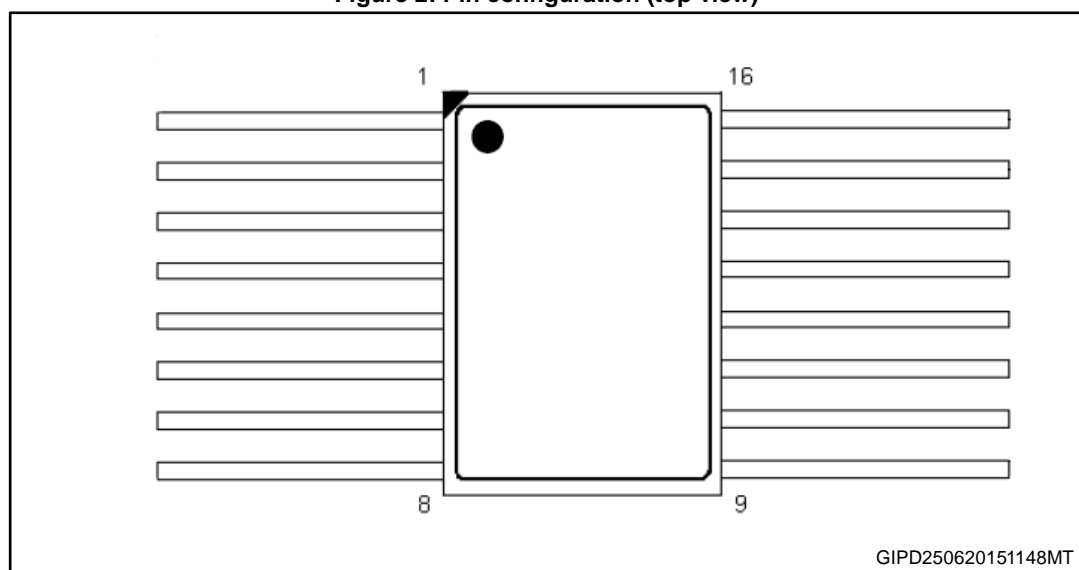
## 1 Diagram

**Figure 1: Block diagram**



## 2 Pin configuration

Figure 2: Pin configuration (top view)



The upper metallic package lid is connected to ground. The bottom metallization is electrically floating.

Table 2: Pin description

Pin name	FLAT-16P	Pin description
$V_O^{(1)}$	1, 2, 6, 7	Output port of the regulator.
$V_I^{(2)}$	3, 4, 5	Input port of the regulator.
GND	12, 13	Ground.
I <sub>sc</sub>	8	Current limit setting pin. Connect a resistor between this pin and $V_I$ to set the current limit threshold.
OCM	10	Overcurrent monitor flag. Open collector, internally pulled up. The signal on this pin goes to low logic level when the current limit activates.
INHIBIT	14	Device Inhibit pin. Internally pulled-down. The regulator is off when this pin is set at high logic level.
ADJ	15	Feedback pin. Connect to external resistor divider for output voltage setting.
FILT C	9	Filter capacitor pin. An optional capacitor can be connected between this pin and GND.
STAB	11	An optional R-C network can be connected between this pin and GND to tune the internal control loop.
NC	16	Not internally connected.

**Notes:**

<sup>(1)</sup>All output pins must be connected together on the PCB.

<sup>(2)</sup>All input pins must be connected together on the PCB.



The upper metallic package lid is connected to ground. The bottom metallization is electrically floating.

### 3 Maximum ratings

Table 3: Absolute maximum ratings

Symbol	Parameter	Value	Unit
$V_I$	DC input voltage, $V_I$ - $V_{\text{GROUND}}$	-0.3 to 12	V
$V_O$	DC output voltage range	-0.3 to ( $V_I + 0.3$ )	V
$V_{\text{ADJ}}$	Adjustable pin voltage	-0.3 to ( $V_O + 0.3$ )	V
$I_O$	Continuous output current	2	A
$V_{\text{OCM}}$	Over current monitor pin voltage vs GND	-0.3 to 12	V
$V_{\text{ISC}}$	Current limit pin voltage vs GND	-0.3 to 12	V
INHIBIT	Inhibit pin voltage	-0.3 to 12	V
STAB	Stability capacitor pin voltage	-0.3 to 2.5	V
FILT C	Filter capacitor pin voltage	-0.3 to 1.3	V
$T_{\text{STG}}$	Storage temperature range	-65 to +150	°C
$T_{\text{OP}}$	Operating junction temperature range	-55 to +125	°C
ESD	Human body model (HBM)	2	kV
	Machine model (MM)	200	V
	Charged device model (CDM)	500	V



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

Table 4: Thermal data

Symbol	Parameter	Value	Unit
$R_{\text{thJC}}$	Thermal resistance junction-case, FLAT-16P	8.3	°C/W
$T_{\text{SOLD}}$	Maximum soldering temperature, 10 s	300	°C



## 4 Electrical characteristics

$T_J = 25\text{ }^{\circ}\text{C}$ ,  $V_I = 2.5\text{ V}$ ,  $V_O = V_{ADJ}$ ,  $C_I = C_O = 10\text{ }\mu\text{F}$  (tantalum), unless otherwise specified.

Table 5: Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
	Operating input voltage	$I_O = 1\text{ A}$ , $T_J = -55\text{ to }125\text{ }^{\circ}\text{C}$	2.5		12	V
$V_{ADJ}$	Reference voltage	$I_O = 5\text{ mA to }1\text{ A}$ , $V_O = V_{adj}$ , $T_J = -55\text{ to }125\text{ }^{\circ}\text{C}$	1.205	1.245	1.285	V
$I_{SHORT}$	Output current limit <sup>(1)</sup>	Adjustable by external resistor	1	3		A
$\Delta V_O / \Delta V_I$	Line regulation	$V_I = 2.5\text{ V to }12\text{ V}$ , $I_O = 5\text{ mA}$ , $T_J = +25\text{ }^{\circ}\text{C}$		0.1	0.4	%
		$V_I = 2.5\text{ V to }12\text{ V}$ , $I_O = 5\text{ mA}$ , $T_J = -55\text{ }^{\circ}\text{C}$		0.2	0.5	
		$V_I = 2.5\text{ V to }12\text{ V}$ , $I_O = 5\text{ mA}$ , $T_J = +125\text{ }^{\circ}\text{C}$		0.08	0.35	
$\Delta V_O / \Delta I_O$	Load regulation	$V_I = 2.5\text{ V}$ , $I_O = 5\text{ to }400\text{ mA}$ , $T_J = +25\text{ }^{\circ}\text{C}$		0.02	0.4	%
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ to }400\text{ mA}$ , $T_J = -55\text{ }^{\circ}\text{C}$		0.2	0.5	
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ to }400\text{ mA}$ , $T_J = +125\text{ }^{\circ}\text{C}$		0.03	0.3	
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ mA to }1\text{ A}$ , $T_J = +25\text{ }^{\circ}\text{C}$		0.3	0.5	
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ mA to }1\text{ A}$ , $T_J = -55\text{ }^{\circ}\text{C}$		0.3	0.6	
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ mA to }1\text{ A}$ , $T_J = +125\text{ }^{\circ}\text{C}$		0.3	0.6	
		$V_I = 2.5\text{ V}$ , $I_O = 5\text{ mA to }2\text{ A}$ , $T_J = -40\text{ to }125\text{ }^{\circ}\text{C}$		0.6		
		$V_I = 3.0\text{ V}$ , $I_O = 5\text{ mA to }2\text{ A}$ , $T_J = -55\text{ to }-40\text{ }^{\circ}\text{C}$				

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$Z_{OUT}$	Output impedance	$I_O = 100 \text{ mA DC and } 20 \text{ mA rms}$		100		mΩ
$I_q$	Quiescent current <sup>(2)</sup> ON mode	$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 5 \text{ mA}, T_J = +25 \text{ }^\circ\text{C}$			7	mA
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 30 \text{ mA}, T_J = +25 \text{ }^\circ\text{C}$			7	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 300 \text{ mA}, T_J = +25 \text{ }^\circ\text{C}$			30	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 1 \text{ A}, T_J = +25 \text{ }^\circ\text{C}$			60	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 30 \text{ mA}, T_J = -55 \text{ }^\circ\text{C}$			7	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 300 \text{ mA}, T_J = -55 \text{ }^\circ\text{C}$			35	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 1 \text{ A}, T_J = -55 \text{ }^\circ\text{C}$			80	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 30 \text{ mA}, T_J = +125 \text{ }^\circ\text{C}$			7	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 300 \text{ mA}, T_J = +125 \text{ }^\circ\text{C}$			30	
		$V_I = 2.5 \text{ V to } 12 \text{ V}, I_O = 1 \text{ A}, T_J = +125 \text{ }^\circ\text{C}$			60	
$I_{qOFF}$	Quiescent current OFF mode	$V_I = 2.5 \text{ V}, V_{INH} = 2.4 \text{ V}, \text{OFF mode}, T_J = -55 \text{ to } +125 \text{ }^\circ\text{C}$		0.2	1	mA
$V_d$	Dropout voltage	$I_O = 400 \text{ mA}, V_O = 2.5 \text{ to } 9 \text{ V}, (+25 \text{ }^\circ\text{C})$		300	450	mV
		$I_O = 400 \text{ mA}, V_O = 2.5 \text{ to } 9 \text{ V}, (-55 \text{ }^\circ\text{C})$		250	400	
		$I_O = 400 \text{ mA}, V_O = 2.5 \text{ to } 9 \text{ V}, (+125 \text{ }^\circ\text{C})$		350	550	
		$I_O = 1 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (+25 \text{ }^\circ\text{C})$		570	800	
		$I_O = 1 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (-55 \text{ }^\circ\text{C})$		470	700	
		$I_O = 1 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (+125 \text{ }^\circ\text{C})$		700	900	
		$I_O = 2 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (+25 \text{ }^\circ\text{C})$		550		
		$I_O = 2 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (-55 \text{ }^\circ\text{C})$		500		
		$I_O = 2 \text{ A}, V_O = 2.5 \text{ to } 9 \text{ V}, (+125 \text{ }^\circ\text{C})$		700		

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{INH(ON)}$	Inhibit voltage	$I_O = 5 \text{ mA}$ , $T_J = -55 \text{ to } +125 \text{ }^\circ\text{C}$			0.8	V
$V_{INH(OFF)}$	Inhibit voltage	$I_O = 5 \text{ mA}$ , $T_J = -55 \text{ to } +125 \text{ }^\circ\text{C}$	2.4			
SVR	Supply voltage rejection <sup>(3)</sup>	$V_I = V_O + 2.5 \text{ V} \pm 0.5 \text{ V}$ , $V_O = 3 \text{ V}$ $I_O = 5 \text{ mA}$	$f = 120 \text{ Hz}$ 60	70		dB
			$f = 33 \text{ Hz}$ 30	40		
$I_{SH}$	Shutdown input current	$V_{INH} = 5 \text{ V}$		15		$\mu\text{A}$
$V_{OCM}$	OCM pin voltage	Sinked $I_{OCM} = 24 \text{ mA}$ active low		0.38		V
$t_{PLH}$	Inhibit propagation delay, turn-off <sup>(3)</sup>	$V_I = V_O + 2.5 \text{ V}$ , $V_{INH} = \text{from } 0 \text{ V to } 2.4 \text{ V}$ , $I_O = 400 \text{ mA}$ , $V_O = 3 \text{ V}$ , $C_I = C_O = 10 \text{ } \mu\text{F}$			30	$\mu\text{s}$
$t_{PHL}$	Inhibit propagation delay, turn-on <sup>(3)</sup>	$V_I = V_O + 2.5 \text{ V}$ , $V_{INH} = \text{from } 2.4 \text{ V to } 0 \text{ V}$ , $I_O = 400 \text{ mA}$ , $V_O = 3 \text{ V}$ , $C_I = C_O = 10 \text{ } \mu\text{F}$			100	$\mu\text{s}$
eN	Output noise voltage <sup>(3)</sup>	$B = 10 \text{ Hz to } 100 \text{ kHz}$ , $I_O = 5 \text{ mA to } 2 \text{ A}$		40		$\mu\text{Vrms}$

**Notes:**

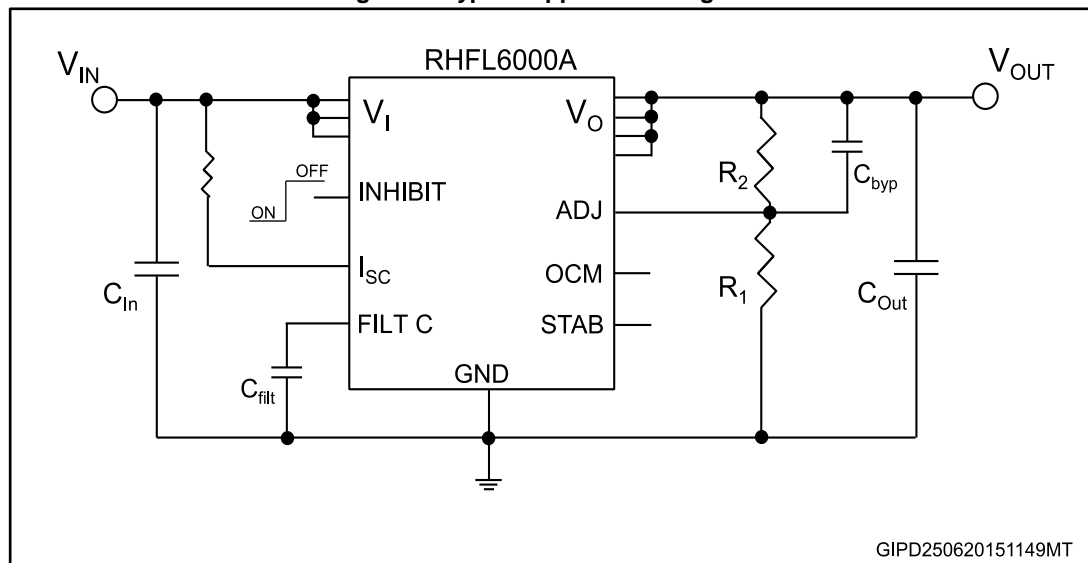
<sup>(1)</sup>These values are guaranteed by design. For each application it is strongly recommended to comply with the maximum current limit of the package used.

<sup>(2)</sup> See [Table 6: "TID tests results"](#).

<sup>(3)</sup>These values are guaranteed by design.

## 5 Typical application diagram

Figure 3: Typical application diagram



## 6 Radiations

### 6.1 Total ionizing dose (MIL-STD-883 test method 1019)

The products that are guaranteed in radiation within RHA QML-V system, fully comply with the MIL-STD-883 test method 1019 specification. The RHFL6000A is being RHA QML-V qualified, tested and characterized in full compliance with the MIL-STD-883 specification, both below 10 mrad/s (low dose rate) and between 50 and 300 rad/s (high dose rate).

- Testing is performed in accordance with MIL-prf-38535 and the test method 1019 of the MIL-STD-883 for total ionizing dose (TID).
- ELDRS characterization is performed in qualification only on both biased and unbiased parts, on a sample of ten units from two different wafer lots.
- Each wafer lot is tested at high dose rate only, in the worst bias case condition, based on the results obtained during the initial qualification.

**Table 6: TID test results**

Type	Conditions	Value	Unit
TID	50 rad(Si)/s high dose rate up to	300	krad
	10 mrad(Si)/s low dose rate up to <sup>(1)</sup>	100	
	ELDRS free up to <sup>(1)</sup>	100	
Output voltage radiation drift	From 0 krad to 300 krad at 50 rad/s, MIL-STD-883J method 1019.9	<1.1	ppm/krad
Quiescent current (ON-state)	From 0 krad to 300 krad at 50 rad/s , MIL-STD-883J method 1019.9 V <sub>I</sub> = 2.5 V to 12 V, I <sub>O</sub> = 5 to 30 mA, T <sub>J</sub> = -55 to +125 °C	<15	mA

**Notes:**

<sup>(1)</sup>300 krad low dose rate test ongoing.

## 6.2 Heavy-ions

The heavy-ion trials are performed on qualification lots only. No additional test is performed. Table below summarizes the results of heavy ions tests.

**Table 7: Heavy-ion results**

Feature	Conditions	Value	Unit
SEL/B performance	LET = 120 MeV*cm <sup>2</sup> /mg V <sub>I</sub> = 12 V	No latch-up/burn-out	-
SET performance during events	LET = 32 MeV*cm <sup>2</sup> /mg Saturated cross-section = 6.18*10 <sup>-5</sup> cm <sup>2</sup> V <sub>IN</sub> up to 9 V V <sub>I</sub> - V <sub>O</sub> ≤ 7.5 V I <sub>OUT</sub> < 300 mA	± 15% max. over less than 300 ns	% of V <sub>O</sub>
	LET = 120 MeV*cm <sup>2</sup> /mg V <sub>IN</sub> up to 12 V V <sub>I</sub> - V <sub>O</sub> < 3.0 V I <sub>OUT</sub> < 300 mA	No SET above ± 3%	
	LET = 120 MeV*cm <sup>2</sup> /mg V <sub>IN</sub> up to 4 V V <sub>I</sub> - V <sub>O</sub> < 1.5 V I <sub>OUT</sub> < 1 A	No SET above ± 3.3%	

SEL and SET performances described here below are related to the circuit configuration and bias conditions shown in [Figure 4: "Heavy Ion test configuration"](#) and [Table 8: "Bias configurations"](#) and [Table 9: "Test configurations"](#).

**Figure 4: Heavy-ion test configuration**

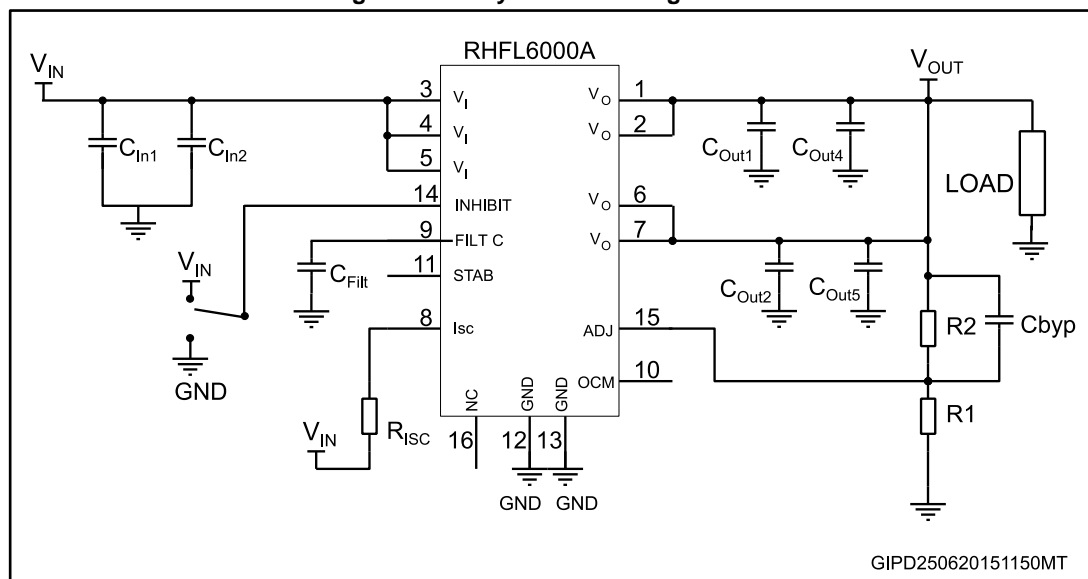


Table 8: Bias configurations

Test mode	Bias conditions
SEL	$V_{IN} = 12\text{ V}$ , $V_{OUT} = 9\text{ V}$ , $V_{INHIBIT} = 0\text{ V}$ , $I_{OUT} = 5\text{ mA}$
SET	$V_{IN} = 3\text{ V}$ , $V_{OUT} = 1.5\text{ V}$ , $V_{INHIBIT} = 0\text{ V}$ , $I_{OUT} = 1\text{ mA}$
	$V_{IN} = 9\text{ V}$ , $V_{OUT} = 0\text{ V}$ , $V_{INHIBIT} = 9\text{ V}$ , $I_{OUT} = 0\text{ mA}$
	$V_{IN} = 4\text{ V}$ , $V_{OUT} = 2.5\text{ V}$ , $V_{INHIBIT} = 0\text{ V}$ , $I_{OUT} = 1\text{ A}$
	$V_{IN} = 7\text{ V}$ , $V_{OUT} = 5\text{ V}$ , $V_{INHIBIT} = 0\text{ V}$ , $I_{OUT} = 300\text{ mA}$
	$V_{IN} = 12\text{ V}$ , $V_{OUT} = 9\text{ V}$ , $V_{INHIBIT} = 0\text{ V}$ , $I_{OUT} = 300\text{ mA}$

Table 9: Test configurations

Test mode	Test configurations	
SEL	Sel configuration	$C_{IN1} = 100\text{ }\mu\text{F}$
		$C_{OUT1} = C_{OUT2} = 47\text{ }\mu\text{F}$
		$C_{IN2} = C_{OUT4} = C_{OUT5} = 100\text{ nF}$
		$C_{byp} = 47\text{ nF}$
		$C_{filt} = 22\text{ nF}$
		$R_{ISC} = 8.2\text{ k}\Omega$
		$R_{load} = 1.8\text{ k}\Omega$
SET	SET 1	$C_{IN1} = 100\text{ }\mu\text{F}$
		$C_{OUT1} = C_{OUT2} = 47\text{ }\mu\text{F}$
		$C_{IN2} = C_{OUT4} = C_{OUT5} = 100\text{ nF}$
		$C_{byp} = 47\text{ nF}$
		$C_{filt} = 22\text{ nF}$
		$R_{ISC} = 8.2\text{ k}\Omega$
		$R_{load} = \text{depending on bias conditions}$
	SET 2	$C_{IN1} = C_{OUT1} = 220\text{ }\mu\text{F}$
		$C_{OUT5} = C_{OUT2} = \text{not connected}$
		$C_{IN2} = C_{OUT4} = 100\text{ nF}$
		$C_{byp} = 47\text{ nF}$
		$C_{filt} = 22\text{ nF}$
		$R_{ISC} = 8.2\text{ k}\Omega$
		$R_{load} = \text{depending on bias conditions}$

## 7 Additional guidelines for SET mitigation

This section provides detailed design guidelines necessary to obtain the required performance against SET. In this respect, we can identify two main areas for intervention: ground connection and external components selection.

### 7.1 Ground connections

To achieve the best performance in terms of output voltage accuracy, noise immunity and robustness against single event effects, it is recommended to implement a proper PCB layout by following the suggestions described below.

According to qualitative simulations of single events, some very short SET (i.e., a duration in the 100 ns range) are strongly dependent on the stray inductances versus GND. The best solution to reduce the parasitic inductance is the adoption of a GND plane (with separate power and sense paths where possible). By minimizing the stray GND impedance, this approach is of great assistance in controlling the amplitude of the SET events near the load.

If this solution is not applicable, we suggest using a star-bus topology, where the PCB reference GND connection is close to the GND pin of the regulator.

To achieve a good GND sense, it is necessary to comply with the following rules:

- connect the regulator GND pin and load GND node both to the sense and power GND traces on the PCB using vias to minimize the path;
- an array of multiple via structures works better than a single large one;
- for GND connectors/plugs: use separate plugs for power supply and testing probes;
- connect input/output capacitors GND terminals to GND sense on the PCB.

### 7.2 Capacitor selection

With reference to [Figure 4: "Heavy Ion test configuration"](#), a combination of capacitors must be present on the input and output ports. For the INPUT terminals, this may consist of a 100  $\mu$ F bulk capacitor ( $C_{IN1}$ ) in parallel with a polyester 100 nF one ( $C_{IN2}$ ) used for decoupling purposes.

For each of the two OUTPUT connections (pins 1, 2 and 6, 7) we suggest using a combination of a 47  $\mu$ F bulk capacitor ( $C_{OUT1}$ ,  $C_{OUT2}$ ) in parallel with a polyester 100 nF one ( $C_{OUT4}$ ,  $C_{OUT5}$ ) for decoupling purposes.

Regarding parts selection, for the 100 nF elements we suggest low-ESL and low ESR capacitors.

Concerning the selection of the three bulk capacitors, we suggest:

- using tantalum SMD;
- selecting size and ESL as small as possible;
- placing capacitors as close as possible to the input/output terminals;
- using an array of capacitors in parallel, where possible. This works better than a single capacitor against the short events.



## 8 Device description

The RHFL6000A adjustable voltage regulator contains a PNP type power element controlled by a signal resulting from an amplified comparison between the internal temperature-compensated band-gap and the fraction of the desired output voltage value obtained from an external resistor divider bridge. The device is protected by several functional blocks.

### 8.1 ADJ pin

The feedback voltage necessary for the loop regulation comes from the load through an external resistor divider (R1, R2 as in [Figure 3: "Typical application diagram"](#)) whose mid point is connected to the ADJ pin (allowing all possible output voltage settings as per user requirements).

### 8.2 Inhibit ON-OFF control

By setting the INHIBIT pin to TTL high level, the device switches off. The device is in ON state when the INHIBIT pin is set low. Since the INHIBIT pin is pulled down internally, it can be left floating whenever the inhibit function is not used.

### 8.3 Overtemperature protection

A temperature detector internally monitors the power element junction temperature. The device turns off when a temperature of approximately 175 °C is reached, returning to ON mode when the temperature decreases down to approximately 135 °C.

It should be noted that when the internal temperature detector reaches 175 °C, the active power element can be as high as 225 °C. Prolonged operation under these conditions may exceed the maximum operating ratings and device reliability cannot be guaranteed.

### 8.4 Overcurrent protection

A default internal constant current limit is set at  $I_{SHORT} = 3 \text{ A}$  (when  $V_O$  is at 0 V).

This value can be decreased via an external resistor ( $R_{SHORT}$ ) connected between the  $I_{SC}$  and  $V_I$  pins, with a typical value range of 10 k $\Omega$  to 200 k $\Omega$ .

To maintain optimal regulation, it is necessary to set  $I_{SHORT}$  1.6 times greater than the desired maximum operating current ( $I_O$ ). When  $I_O$  reaches  $I_{SHORT}-300 \text{ mA}$ , the current limiter intervenes,  $V_O$  starts to drop and the OCM flag is raised. When no current limitation adjustment is required, the  $I_{SC}$  pin must be left unbiased.

The combination of overcurrent and overtemperature circuits provides the RHFL6000A with a high level of protection against destructive junction temperature excursions in all load conditions.

### 8.5 OCM pin

The OCM pin is an open collector flag normally pulled up at  $V_I$  by a 5 k $\Omega$  resistor.

It goes to low state when the current limit becomes active. It is buffered and can sink 10 mA.

## 8.6 STAB pin

The STAB pin gives user direct access to regulator internal control loop stability adjustment. Its usage is optional and it should be left unconnected when not used.

## 8.7 FILT C pin

The FILT C pin helps reduce SET rate when bypassed to GND through a 22 nF ceramic capacitor. Its usage is optional and it should be left unconnected when not used.

## 9 Application information

To adjust the output voltage, the R2 resistor must be connected between the V<sub>O</sub> and ADJ pins. The R1 resistor must be connected between ADJ and ground. Resistor values can be derived from the following formula:

$$V_O = V_{ADJ} (R1 + R2) / R1$$

where

$$V_{ADJ} = 1.248 \text{ V typ.}$$

The minimum output voltage is therefore V<sub>ADJ</sub> and minimum input voltage is 2.5 V.

The RHFL6000A operates correctly when the V<sub>I</sub> - V<sub>O</sub> voltage difference is slightly above the power element saturation voltage (V<sub>d</sub>, dropout voltage).

A minimum load current of 0.5 mA must be set to ensure proper regulation under no-load condition. It is advisable to make this current flow into the resistor divider.

For this reason, we suggest selecting an R1 value not higher than 10 kΩ.

The RHFL6000 FLAT-16 package offers multiple input and output pins.

All of the available V<sub>I</sub> pins should always be externally interconnected. The same must be applied to all the available V<sub>O</sub> pins, otherwise the stability and reliability of the device cannot be guaranteed.

The inhibit function switches off the output current very quickly. According to Lenz's Law, external circuitry reacts with Ldi/dt terms which can be of high amplitude in case of serial inductive elements or large stray PCB inductance. Large transient voltage would develop on both device terminals. It is advisable to protect the device output with Schottky diodes to prevent negative voltage excursions. A 14 V Zener diode could protect the device input.

The input and output capacitors must be connected as close as possible to the device terminals.

Since the RHFL6000A voltage regulator is manufactured with very high speed bipolar technology (6 GHz f<sub>T</sub> transistors), the PCB layout must be designed with exceptional care, with very low inductance and low mutually coupling lines. Otherwise, high frequency parasitic signals may be picked up by the device resulting in system self-oscillation.

On the other hand, the benefit of this technology is SVR performance extended to high frequencies.

## 9.1 Notes on the 16-pin hermetic FLAT package

The RHFL6000A adjustable voltage regulator is available in a high thermal dissipation 16-pin hermetic FLAT package, whose bottom flange is metallized to allow direct soldering or gluing to a heat sink (efficient thermal conductivity). The upper metallic package lid is connected to ground. The bottom metallization is electrically floating.

## 9.2 FPGA supply

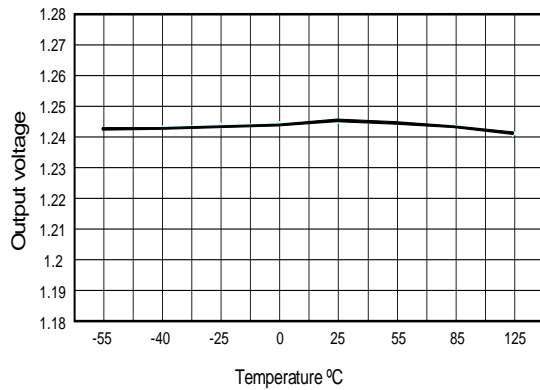
FPGA devices are very sensitive to VDD transients beyond a few % of their nominal supply voltage (usually 1.5 V).

The RHFL6000A includes specific integrated circuitry designed to absorb the output transients under heavy ion beams, rendering it suitable for safe FPGA supply operation.

## 10 Typical performance characteristics

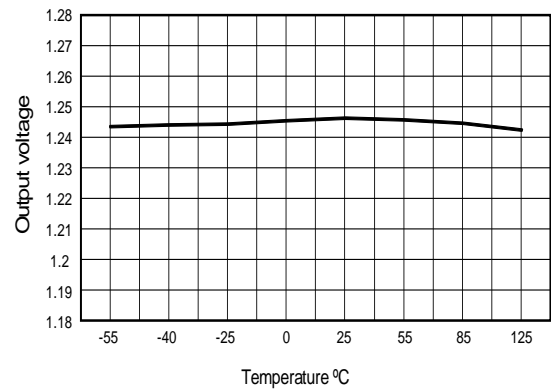
( $C_{IN} = C_{OUT} = 10 \mu F$  tantalum, unless otherwise specified)

**Figure 5: Output voltage vs temperature**  
( $V_{IN} = 2.5 V$ ,  $I_{OUT} = 5 mA$ )



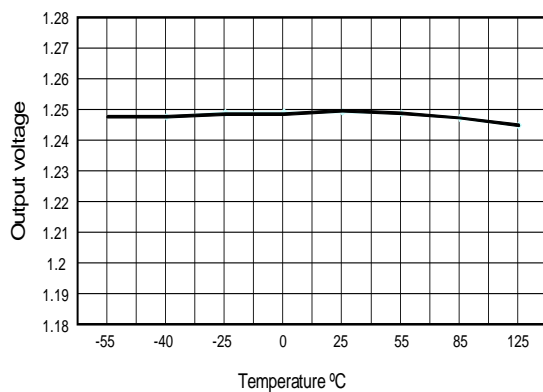
GIPD240620151357MT

**Figure 6: Output voltage vs temperature**  
( $V_{IN} = 2.5 V$ ,  $I_{OUT} = 400 mA$ )



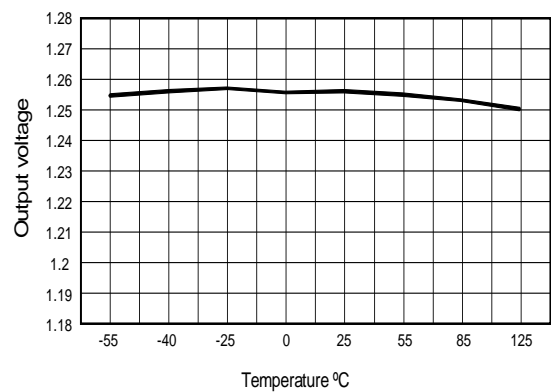
GIPD240620151216MT

**Figure 7: Output voltage vs temperature**  
( $V_{IN} = 2.5 V$ ,  $I_{OUT} = 1 A$ )

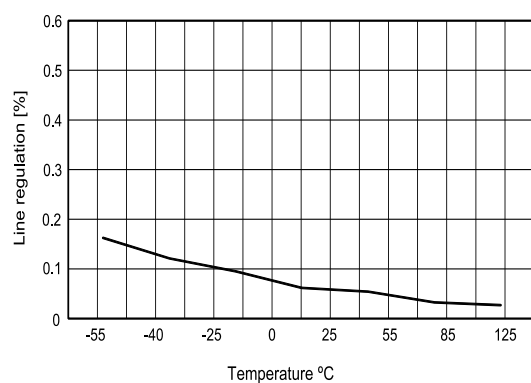


GIPD240620151155MT

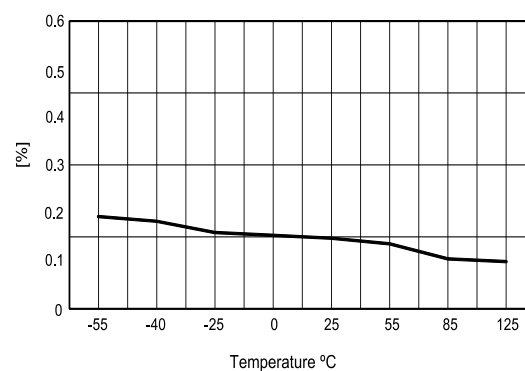
**Figure 8: Output voltage vs temperature**  
( $V_{IN} = 2.5 V$ ,  $I_{OUT} = 2 A$ )



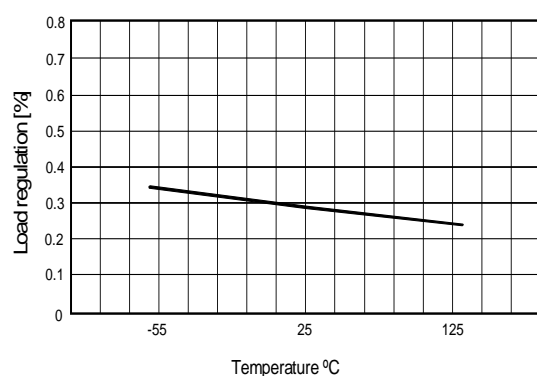
GIPD240620151148MT

**Figure 9: Line regulation vs temperature** $V_{IN} = 2.5 \text{ V to } 12 \text{ V} - I_{OUT} = 5 \text{ mA}$ 

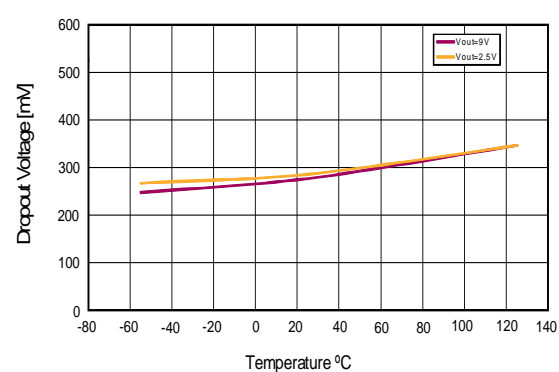
GIPD240620151142MT

**Figure 10: Load regulation vs temperature**  
( $I_{OUT} = 5 \text{ mA to } 400 \text{ mA}$ ) $V_{IN} = 2.5 \text{ V}$ 

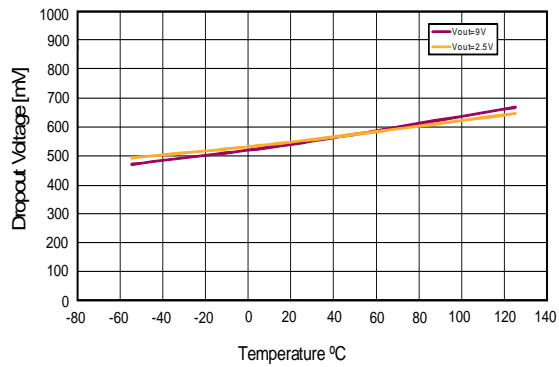
GIPD240620151136MT

**Figure 11: Load regulation vs temperature**  
( $I_{OUT} = 5 \text{ mA to } 1 \text{ A}, V_{IN} = 2.5 \text{ V}$ )

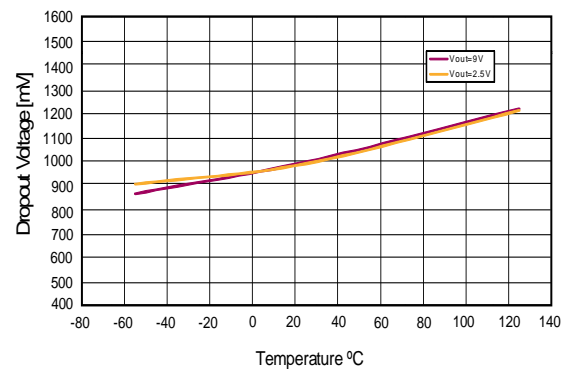
GIPD240620151125MT

**Figure 12: Dropout voltage vs temperature**  
( $I_{OUT} = 0.4 \text{ A}$ )

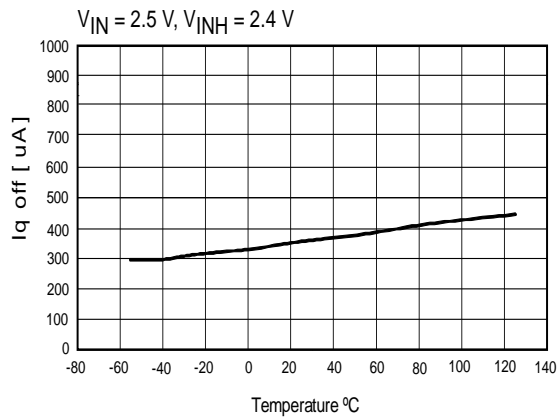
GIPD290620151104MT

**Figure 13: Dropout voltage vs temperature**  
( $I_{OUT} = 1\text{ A}$ )

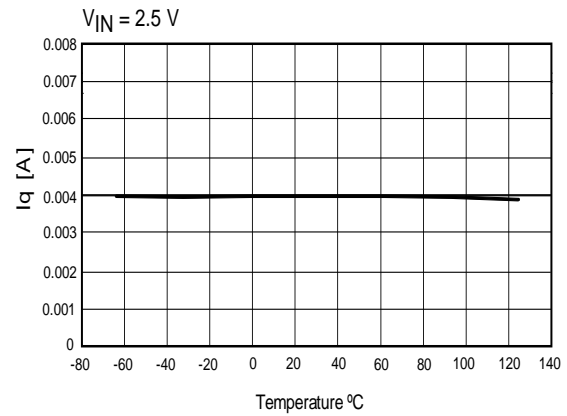
GIPD240620151103MT

**Figure 14: Dropout voltage vs temperature**  
( $I_{OUT} = 2\text{ A}$ )

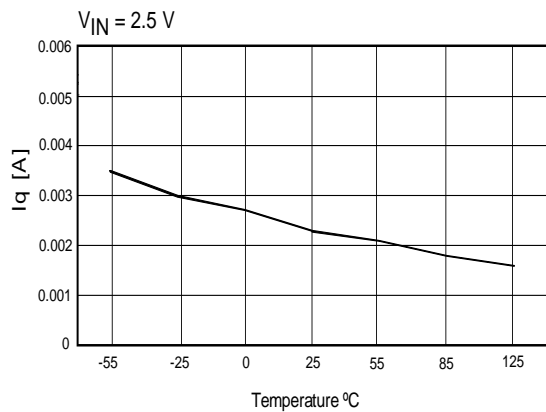
GIPD230620151454MT

**Figure 15: Quiescent current (OFF mode)**

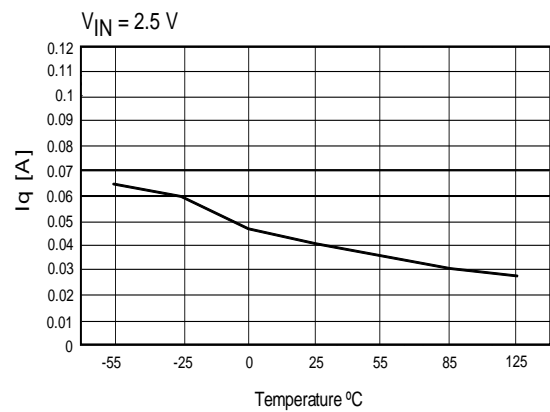
GIPD230620151442MT

**Figure 16: Quiescent current**  
(ON mode,  $I_{OUT} = 5\text{ mA}$ )

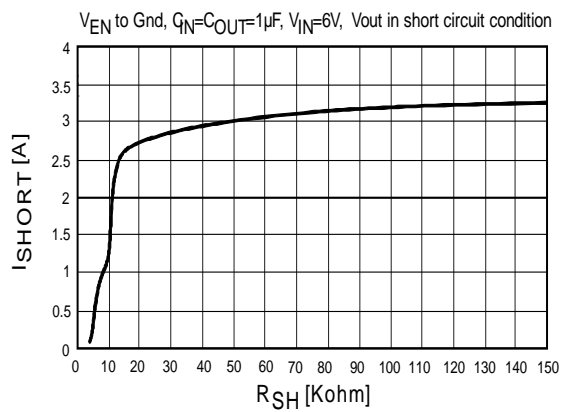
GIPD230620151432MT

Figure 17: Quiescent current (ON mode,  $I_{OUT} = 1\text{ A}$ )

GIPD230620151152MT

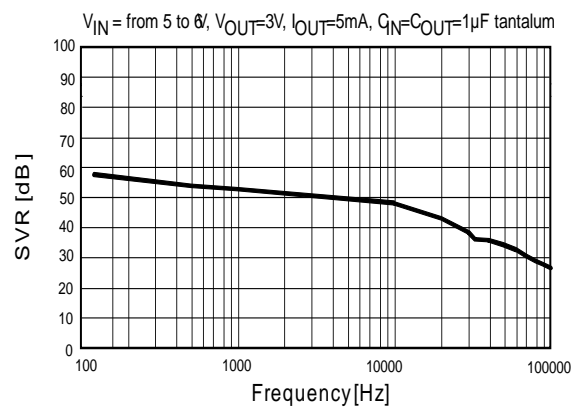
Figure 18: Quiescent current (ON mode,  $I_{OUT} = 2\text{ A}$ )

GIPD260620151051MT

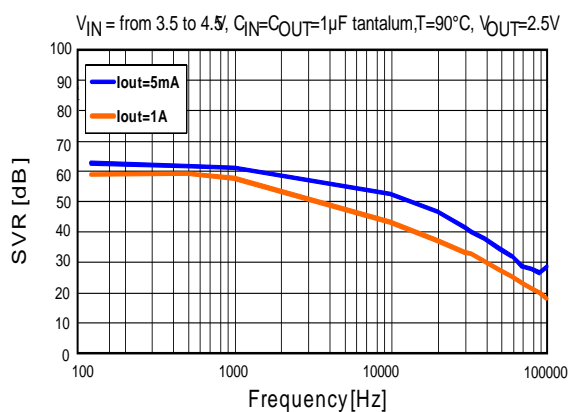
Figure 19: Short-circuit current vs  $R_{SHORT}$ 

GIPD230620151141MT

Figure 20: SVR vs frequency

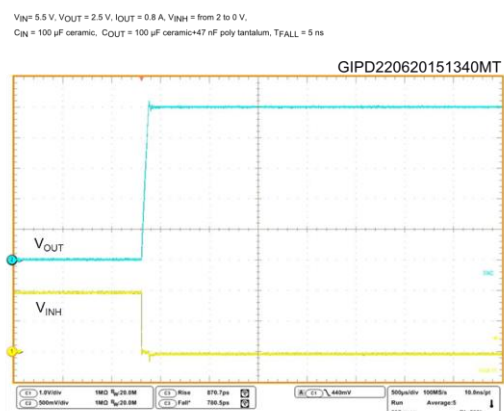


GIPD230620151129MT

Figure 21: SVR vs frequency ( $T = 90^\circ\text{C}$ )

GIPD230620151047MT

Figure 22: Turn-on transient

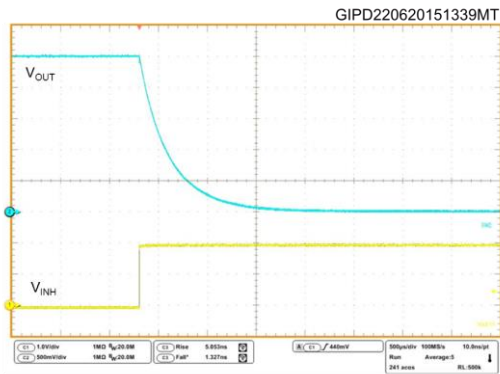


GIPD220620151340MT



Figure 23: Turn-off transient

$V_{IN} = 5.5\text{ V}$ ,  $V_{OUT} = 2.5\text{ V}$ ,  $I = 0.8\text{ A}$ ,  $V_{IN}$  from 0 to 2 V,  
 $C_{IN} = 100\text{ }\mu\text{F}$  ceramic,  $C_{OUT} = 100\text{ }\mu\text{F}$  ceramic+47 nF poly tantalum,  $T_{RISE} = 5\text{ ns}$

Figure 24: Line transient ( $I_{OUT} = 0.8\text{ A}$ ,  $V_{OUT} = 3\text{ V}$ )

$V_{IN}$  to Gnd,  $V_{IN}$  from 5 V to 12 V and vice versa No  $C_{IN}$ ,  $C_{OUT} = 10\text{ }\mu\text{F}$  tantalum

Figure 25: Line transient ( $I_{OUT} = 2\text{ A}$ ,  $V_{OUT} = 2.5\text{ V}$ )

$V_{IN}$  to Gnd,  $V_{IN}$  from 5 V to 2 V and vice versa  $I_{OUT} = 2\text{ A}$ , No  $C_{IN}$ ,  $C_{OUT} = 10\text{ }\mu\text{F}$  tantalum  $V_{OUT} = 2.5\text{ V}$

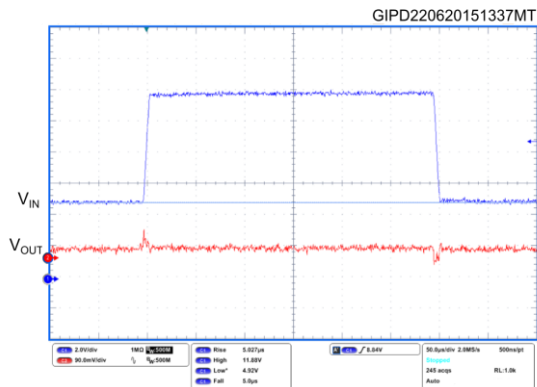


Figure 26: Load transient

$V_{IN} = 5\text{ V}$ ,  $I_{OUT}$  from 5 mA to 2 A and vice versa,  $C_{IN} = C_{OUT} = 10\text{ }\mu\text{F}$  tantalum  $V_{OUT} = 1.24\text{ V}$

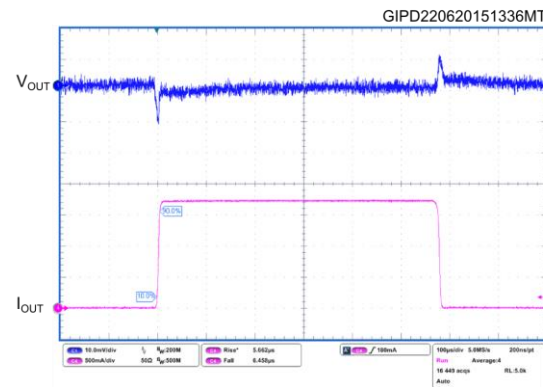


Figure 27: Stability area for ceramic capacitor

$C_{IN} = 22\text{ }\mu\text{F}$ ,  $V_{IN}$  from 2.5 V to 12 V,  $I_{OUT}$  from 10 mA to 2 A,  $V_{OUT} = 1.24\text{ V}$ , no  $C_{byp}$ , no  $C_{filter}$

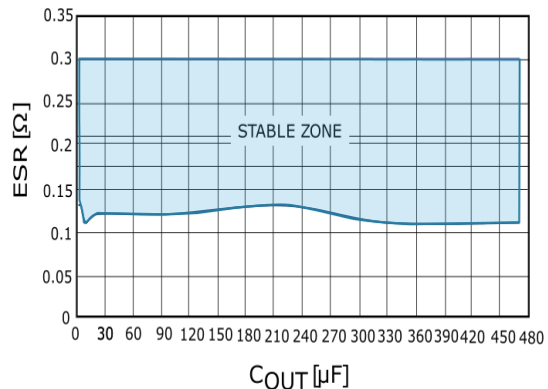
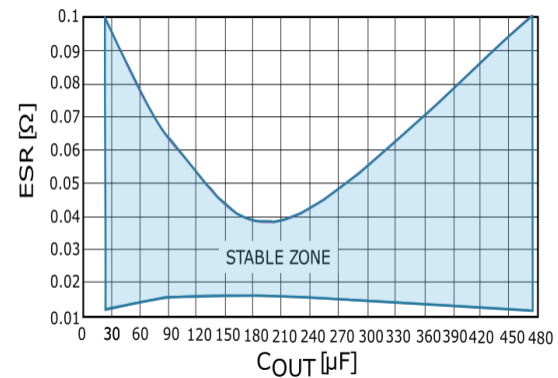


Figure 28: Stability area for tantalum capacitor

$C_{IN} = 1\text{ }\mu\text{F}$ ,  $V_{IN}$  from 2.5 V to 12 V,  $I_{OUT}$  from 10 mA to 2 A,  $V_{OUT} = 1.24\text{ V}$ , no  $C_{byp}$ , no  $C_{filter}$



## 11 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](http://www.st.com). ECOPACK® is an ST trademark.

### 11.1 FLAT-16P package information

Figure 29: FLAT-16P package outline

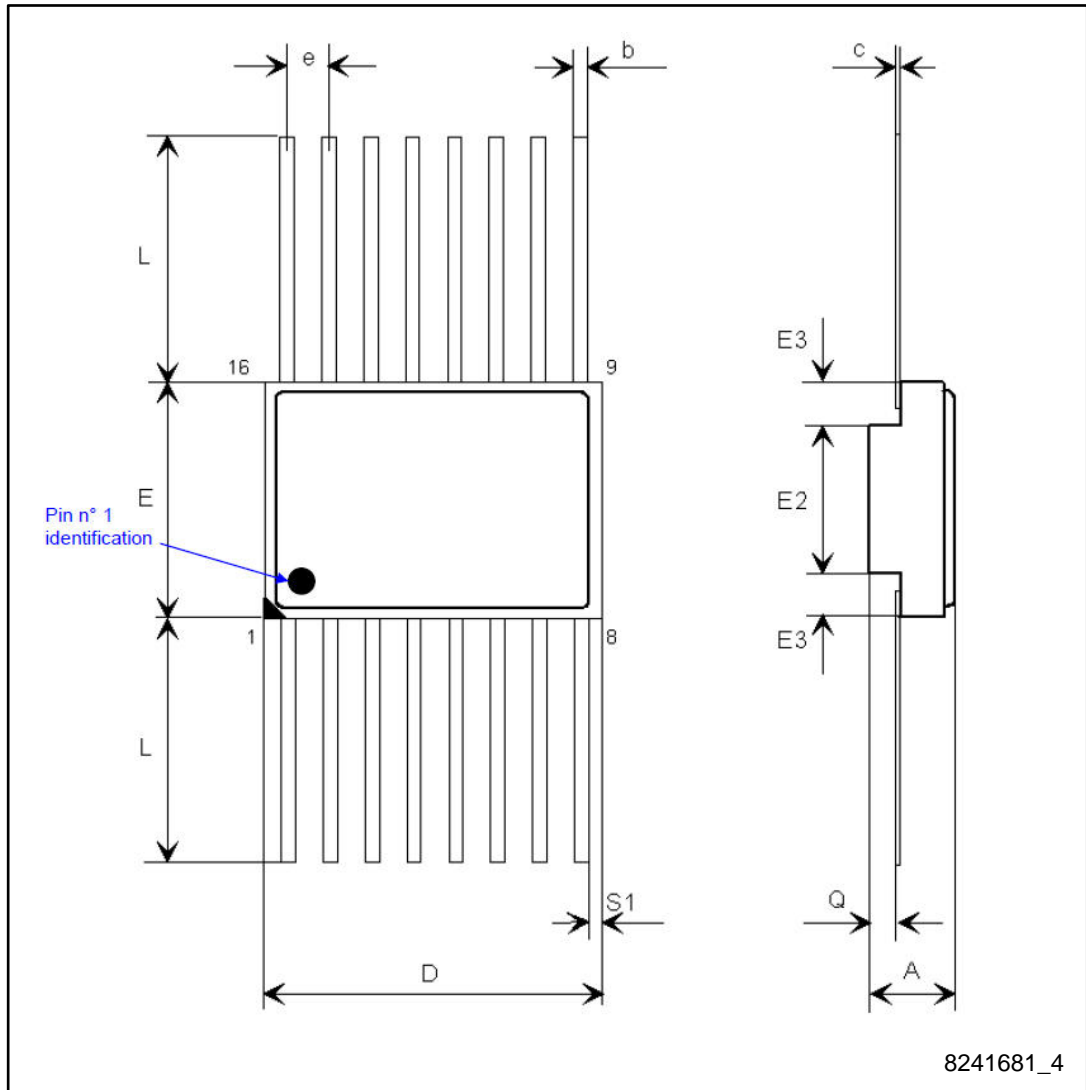


Table 10: FLAT-16P package mechanical data

Dim.	mm			Inch		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	2.42		2.88	0.095		0.113
b	0.38		0.48	0.015		0.019
c	0.10		0.18	0.004		0.007
D	9.71		10.11	0.382		0.398
E	6.71		7.11	0.264		0.280
E2	3.30	3.45	3.60	0.130	0.136	0.142
E3	0.76			0.030		
e		1.27			0.050	
L	6.35		7.36	0.250		0.290
Q	0.66		1.14	0.026		0.045
S1	0.13			0.005		

## 12 Ordering information

Table 11: Order code

Part number	SMD pin	Quality level	EPPL	Package	Lead finish	Marking <sup>(1)</sup>	Packing
RHFL6000AKP1	-	Engineering model	-	FLAT-16P	Gold	RHFL6000KPA1	Strip pack
RHFL6000AKP01V	5962F1521601VXC	QML-V flight	Target	FLAT-16P	Gold	5962F1521601VXC	Strip pack
RHFL6000AKP02V	5962F1521601VXA	QML-V flight	Target	FLAT-16P	Tin	5962F1521601VXA	Strip pack

**Notes:**

<sup>(1)</sup>Specific marking only. The full marking includes in addition:

- for the engineering models : ST logo, date code, country of origin (FR)
- for QML flight parts : ST logo, date code, country of origin (FR), manufacturer code (CSTM), serial number of the part within the assembly lot.

Contact ST sales office for information about the specific conditions for:

- 1) Products in die form
- 2) Other quality levels
- 3) Tape and reel packing

### 12.1 Traceability information

Date code in formation is structured as described below:

Table 12: Date code

Model	Date code
EM	3yywwN
QML flight	yywwN

where:

- yy = year
- ww = week number
- N = lot index in the week

## 12.2 Documentation

The table below gives a summary of the documentation provided with each type of products:

**Table 13: Table of documentation by product**

Quality level	Documentation
Engineering model	-
QML-V flight	Certificate of conformance (including group C and D reference) Precap report (100% high and low magnification) SEM report Screening summary Group A summary (quality conformance inspection of electrical tests) Group B summary (quality conformance inspection of mechanical tests) Group E (quality conformance inspection of wafer lot radiation verification test)

## 13 Revision history

**Table 14: Document revision history**

Date	Revision	Changes
21-Sep-2015	1	First release.
12-Oct-2015	2	Updated Table 7: "Heavy ions results". Minor text changes.
15-Feb-2016	3	Document status promoted from preliminary data to production data. Updated Table 1: "Device summary" and Table 11: "Order code". Minor text changes.
14-Apr-2016	4	Updated <i>Table 5: "Electrical characteristics"</i> . Minor text changes.
05-Dec-2017	5	Updated the description in cover page. Minor text changes.

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