

## Alternator voltage regulator with load response control

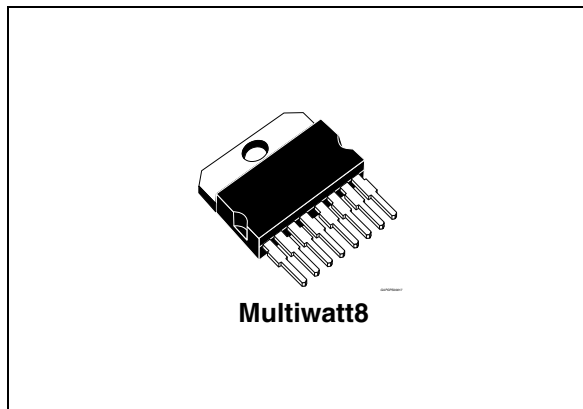
### Features

- IC regulator for 12 V type alternator
- Fixed frequency regulation loop
- 130 mΩ high side field driver
- Fail safe device with double sensing of battery voltage (VB and VS)
- Load response control (LRC) function activates after an initial time delay
- Self start function from phase frequency
- “Z” shaped regulation curve compliant with VW specification.
- Key recognition from L input
- Field driver, lamp driver and relay driver short protection
- Complex diagnostics
- Thermal shutdown at 175 °C

### Description

The L9409 is a monolithic multifunction alternator voltage regulator intended for use in automotive applications.

The device regulates the output of an automotive generator by controlling the field winding current by means of either an analog fixed frequency PWM signal or digital fixed frequency PWM signal (LRC). The Load Response Control function is activated in order to eliminate IC engine speed fluctuation and vibrations caused by the insertion



of sudden electrical loads during alternator low speed operations ( $f < 310$  Hz). Both the analog and digital duty cycle are applied to a high side driver.

The device is able to regulate the voltage either using a feedback signal from B pin or from S pin depending on application needs. S pin is intended to have a clear direct connection with the positive terminal of the car battery. If this connection gets lost the device will regulate voltage using B pin giving a fail safe functionality.

Using L pin is possible to sense key switch and a pre-excitation duty cycle is applied on the field coil in order to start phase voltage sensing. In the case L connection gets lost, device starts to generate using residual magnetism of the generator.

Field, lamp and relay drivers are protected against short circuit.

**Table 1. Device summary**

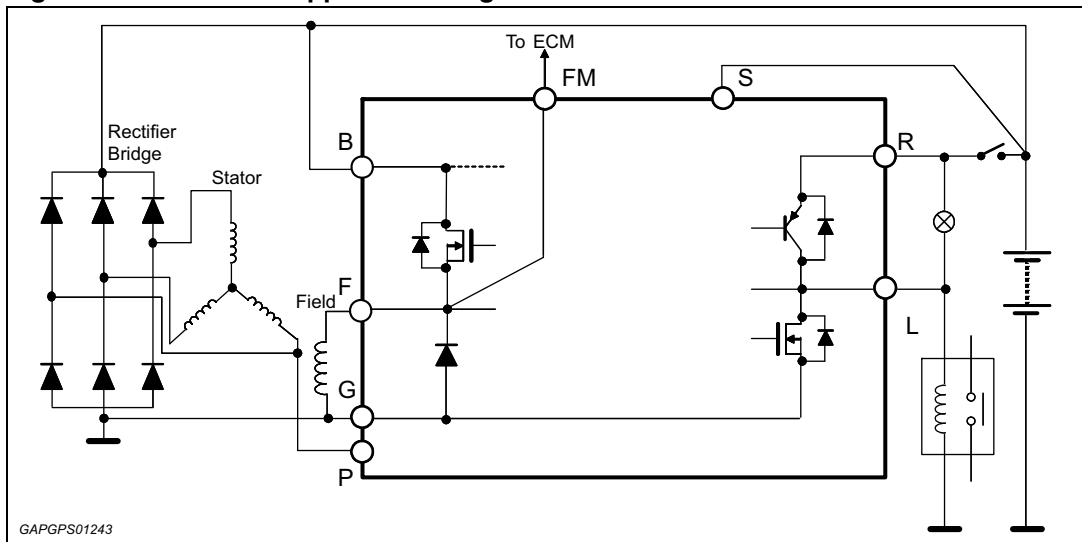
Order code	Junction temp range, °C	Package	Packing
L9409F	-40 to 150	Multiwatt8	Tube

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# 1 Block and application diagram

Figure 1. Block and application diagram



## 2 Pin description

Figure 2. Multiwatt8 pin connection diagram

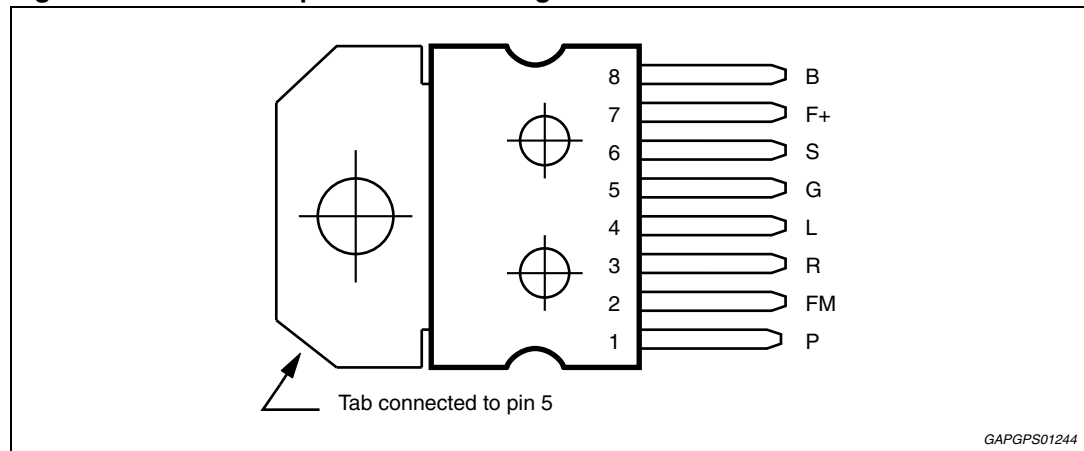


Table 2. Pin description

Pin #	Pin name	Function
1	P	Phase input
2	FM	Field monitor output
3	R	Relay terminal high side driver
4	L	Lamp terminal low side driver
5	G	Power ground
6	S	Battery sense input
7	F+	Field high side driver output
8	B	Voltage supply and generator output sense

## 3 Maximum ratings

### 3.1 Voltage maximum ratings

**Table 3. Voltage maximum ratings**

Pin	Operating range (full spec guaranteed) (V)	Maximum range (functionality guaranteed) (V)	DC Absolute maximum range (no damage guaranteed) (V)
B	8/16	8/28	-0.3/40
L	0/16	0/28	-1/40
F <sub>M</sub>	0/16	0/28	-0.3/40
S	8/16	8/28	-0.3/40
P	-1/16	-1/16	-1.5/16
F+	6/16	6/28	6/40
R	8/16	8/28	-0.3/40

**Table 4. Transient voltage maximum ratings**

Parameter	Conditions	Value	Unit
Transient supply voltage (load dump)	t < 500 ms	40	V
Transient supply voltage (low energy spikes)	ISO7637-1 pulse 1,2,3 ISO7637-3 according to application diagram ( <a href="#">Figure 1</a> )	60	V
B+ reverse battery voltage	T <sub>j</sub> = 25 °C, t = 15 s	-2.5	V
ESD voltage	MILSTD883C, All pins vs. GND	±2	kV

### 3.2 Thermal data

**Table 5. Thermal characteristics**

Symbol	Parameter	Value	Unit
T <sub>j</sub>	Junction temperature	-40 to 150	°C
T <sub>stg</sub>	Storage temperature	-50 to 175	°C
T <sub>sd</sub>	Thermal shut down	175 ±15	°C
R <sub>th j-case</sub>	Thermal resistance junction-to-case	1.5	°C/W

## 4 Device description

### 4.1 Voltage regulation

#### 4.1.1 Description

The alternator voltage is compared with a reference voltage in an amplifier. This device senses the battery voltage in two ways: the B+ pin and the S pin. The last could be left unconnected. In this condition the battery voltage is sensed from the  $V_{GO}$  pin, otherwise the S pin is used. This second condition assures a better knowledge of the real value of the battery voltage if a direct connection with the positive terminal of the battery is made as shown in [Figure 1](#). The field driver works at a fixed frequency. A variable duty cycle is applied on the field winding according with the error between the voltage set-point and the measured battery voltage. The voltage set-point depends on case temperature. A set-point voltage vs. case temperature curve is integrated in the device and is shown in [Figure 3](#).

#### 4.1.2 Electrical characteristic

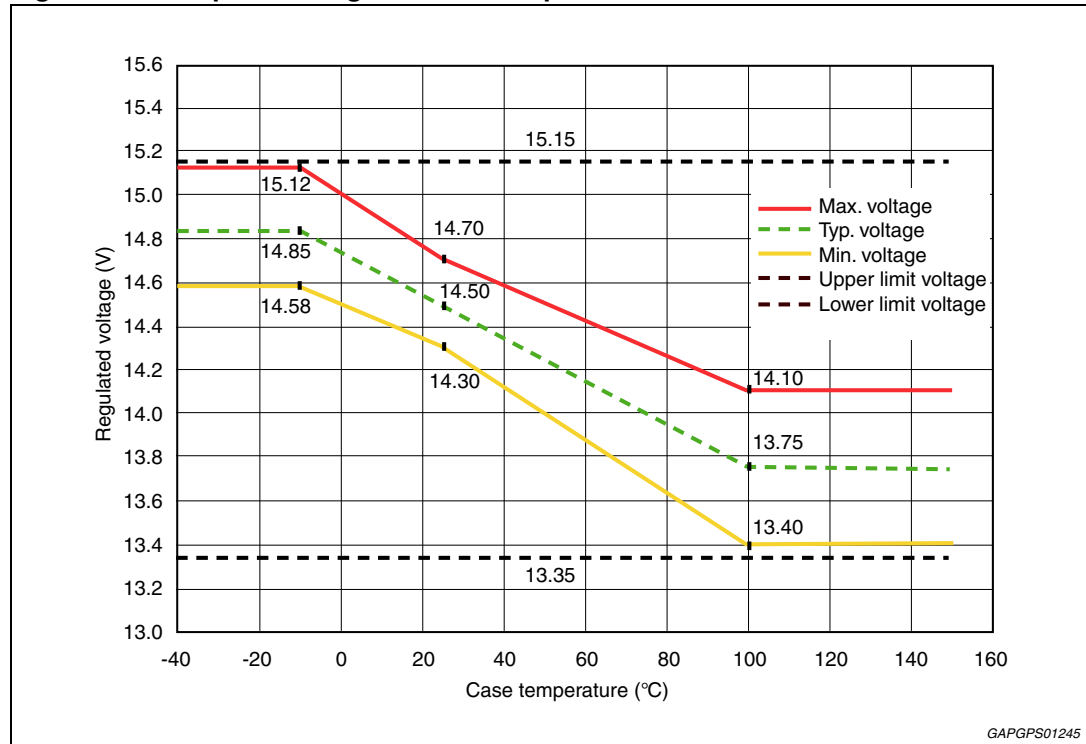
$T_j = -40$  to  $150$  °C unless otherwise specified.

**Table 6. Electrical characteristics**

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$I_{SB}$	Standby current	$V_B = 13V, -40$ °C < $T_j$ < + $150$ °C	-	-	400	μA
$V_{SF}$	Regulation set-point voltage	@ $25$ °C	-	14.5	-	V
$V_{P1}$	Initiation of regulation detection phase voltage threshold <sup>(1)</sup>	$I_P = 1mA$ (sinking current)	-	1.5	-	V
$D_{PE}$	Pre-excitation	-	19	-	25	%
$f_{IFR}$	Initiation of field regulation frequency	-	360	400	440	Hz
$T_C$	Thermal compensation	$-40$ °C ≤ $T_{case}$ ≤ $-10$ °C	-0.5	0	0.5	mV/°C
		$-10$ °C ≤ $T_{case}$ ≤ $100$ °C	-8	-10	-12	mV/°C
		$100$ °C ≤ $T_{case}$ ≤ $150$ °C	-0.5	0	0.5	mV/°C
$V_{LR}$	Load regulation	18000 rpm, 10% to 90% load	-	-	200	mV
$V_{SR}$	Speed regulation	Guarantee by design	-	-	200	mV
$R_{ON}$	Field driver on resistance	$I_F = 5$ A, $T_{case} = 125$ °C	-	-	130	mΩ
$I_{FLIM}$	Field limit current	F shorted to GND @ $-40$ °C	8	-	15	A
		F shorted to GND @ $25$ °C	8	-	15	A
		F shorted to GND @ $150$ °C	7.5	-	14.5	A
$V_F$	Field discharge rectifier	$I_F = 6$ A, $T_{case} = 25$ °C	-	-	1.85	V
$I_R$	Diode reverse current	-	-	-	20	μA
$I_{PD-P}$	Pull down current on P terminal	-	0.4	-	1.4	mA

1. This threshold on the phase signal is used to detect the phase frequency,  $f_{IFR}$ , for the Initiation of field regulation.

Figure 3. Set-point voltage vs. case temperature

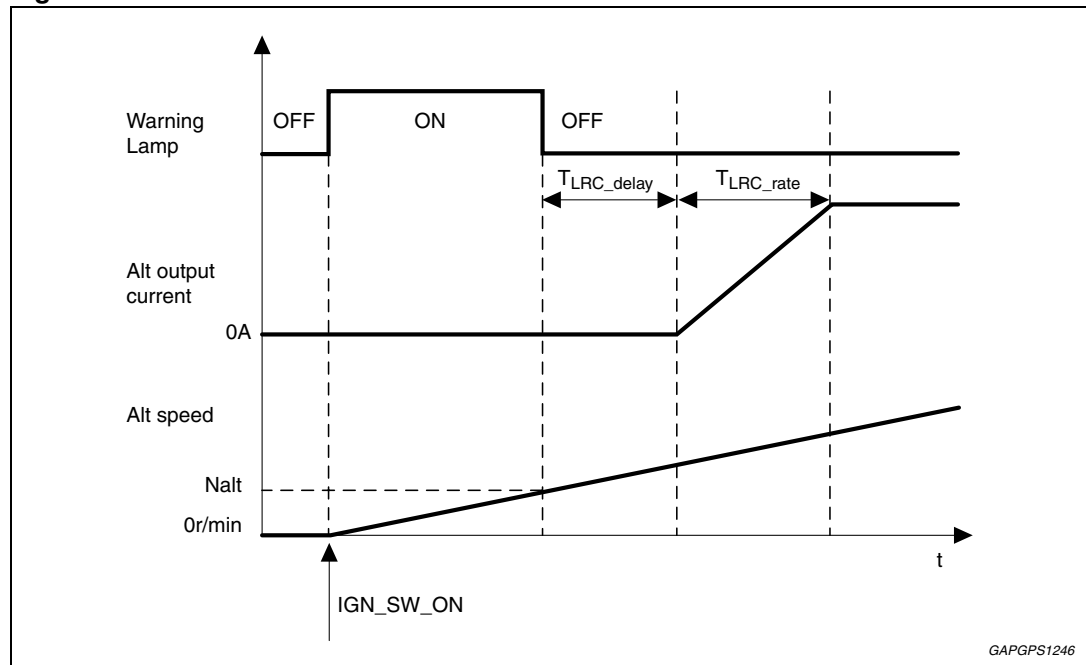


## 4.2 Load response control (LRC)

### 4.2.1 Description

This function controls the sudden torque increase on engine when the last is started or electric load is changed within the idling speed. In particular, the alternator output current is increased gradually at a constant rate ( $LRC_{rate}$ ) when generating is started. The time needed to ramp up from 0% to 100% of duty cycle is defined as  $T_{LRC\_rate}$ . This function is enabled when the alternator achieves a certain speed ( $f_{LRC\_EN}$ ) and after a delay time ( $T_{LRC\_delay}$ ).  $T_{LRC\_delay}$  is defined as the period from  $N_{alt}$  attainment to the start of generating as described in [Figure 4](#). The LRC is disabled while the alternator rotor speed is greater than a set value ( $f_{LRC\_DIS}$ ).

**Figure 4. LRC function**



### 4.2.2 Electrical characteristics

$T_j = -40$  to  $150$  °C, unless otherwise specified.

**Table 7. Electrical characteristics**

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$f_{LRC\_EN}$	LRC enable frequency	LRC enabled above this frequency	130	145	160	Hz
$f_{LRC\_DIS}$	LRC transition frequency	LRC disabled above this value	270	300	330	Hz
$T_{LRC\_delay}$	Load response control delay	delay of activation of LRC	2.1	-	3.5	s
$T_{LRC\_rate}$	Load response control rate <sup>(1)</sup>	-	2.1	-	2.9	s

1. This is the time duration that L9460 takes to ramp up from 0% to 100% duty cycle in response to an increased load on the generator.



## 4.3 Lamp and relay driver

### 4.3.1 Description

The lamp driver has two functions:

- Switch on the warning lamp in the dash board when any of fault operation occurs.
- Judge if IG-SW is turned on or not.

### 4.3.2 Electrical characteristic

$T_j = -40$  to  $150$  °C unless otherwise specified.

**Table 8. Electrical characteristics**

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{LSAT}$	Lamp driver saturation voltage	$I_L = 1$ A @ $-40$ °C	1.2	-	1.4	
		$I_L = 1$ A @ $25$ °C	1.2	-	1.45	V
		$I_L = 1$ A @ $150$ °C	1.2	-	1.50	V
$V_{LON}$	Lamp on voltage	$I_L = 0.2$ A, $V_B =$ open, $T_j = -40$ °C	4.7	-	6.2	V
		$I_L = 0.2$ A, $V_B =$ open, $T_j = 25$ °C	4.5	-	5.5	V
		$I_L = 0.2$ A, $V_B =$ open, $T_j = 150$ °C	3.5	-	5	V
$I_{LIML}$	Limitation lamp current	-	-	2.5	A	
$V_{WU-L}$	Wake-up voltage at L terminal	-	0.8	1	1.1	V
$I_{PD-L}$	Pull down current	$V_L = 0.8$ V	0.8	-	3	mA

### 4.3.3 Relay driver description

This terminal is used to provide a current to electric loads such as a Relay coil connected between L terminal and GND. While L terminal is turned off, a current of max. 2.5 A is provided to the relay coil, using a high side driver, between R terminal and L terminal, after a time delay of 300  $\mu$ s. The R terminal can be connected to the ignition switch, B terminal or it can be left open.

### 4.3.4 Electrical characteristic

$T_j = -40$  to  $150$  °C unless otherwise specified.

**Table 9. Electrical characteristics**

Symbol	Parameter	Test condition	Min.	Typ.	Max.	Unit
$V_{RSAT}$	Relay driver saturation voltage	$I_R = 1$ A @ $25$ °C	0.2	-	0.6	V
$I_{RTHR}$	Relay threshold current	-	1.3	-	2.5	A
$T_{RD}$	Relay driver activation delay	-	-	300	-	$\mu$ s

## 4.4 Protection and diagnosis

**Table 10. Fault lamp driver to function**

#	Conditions	Delay
1	Phase voltage < $V_{PL}$ . The alternator is not generating, the belt is broken or alternator is not rotating	Yes
2	$V_B - V_s > 2\text{ V}$ OR $V_s > V_{OH}$ . Over voltage warning	Yes
3	$V_s < V_{SO}$ AND Phase frequency > $f_{LRC\_EN}$ . S terminal is open during generation	Yes
4	$V_B < V_{BO}$ AND Phase frequency > $f_{LRC\_EN}$ . B terminal is open during generation	Yes
5	Phase frequency < $f_{LRC\_EN}$	Yes

The table above lists the conditions that cause the fault lamp driver to function. To prevent lamp flicker, specific faults are required to be present for  $T_{DELAY}$  seconds before the lamp driver is activated. This delay is indicated in [Figure 11](#).

### 4.4.1 Diagnostic electric parameters

**Table 11. Diagnostic electric parameters**

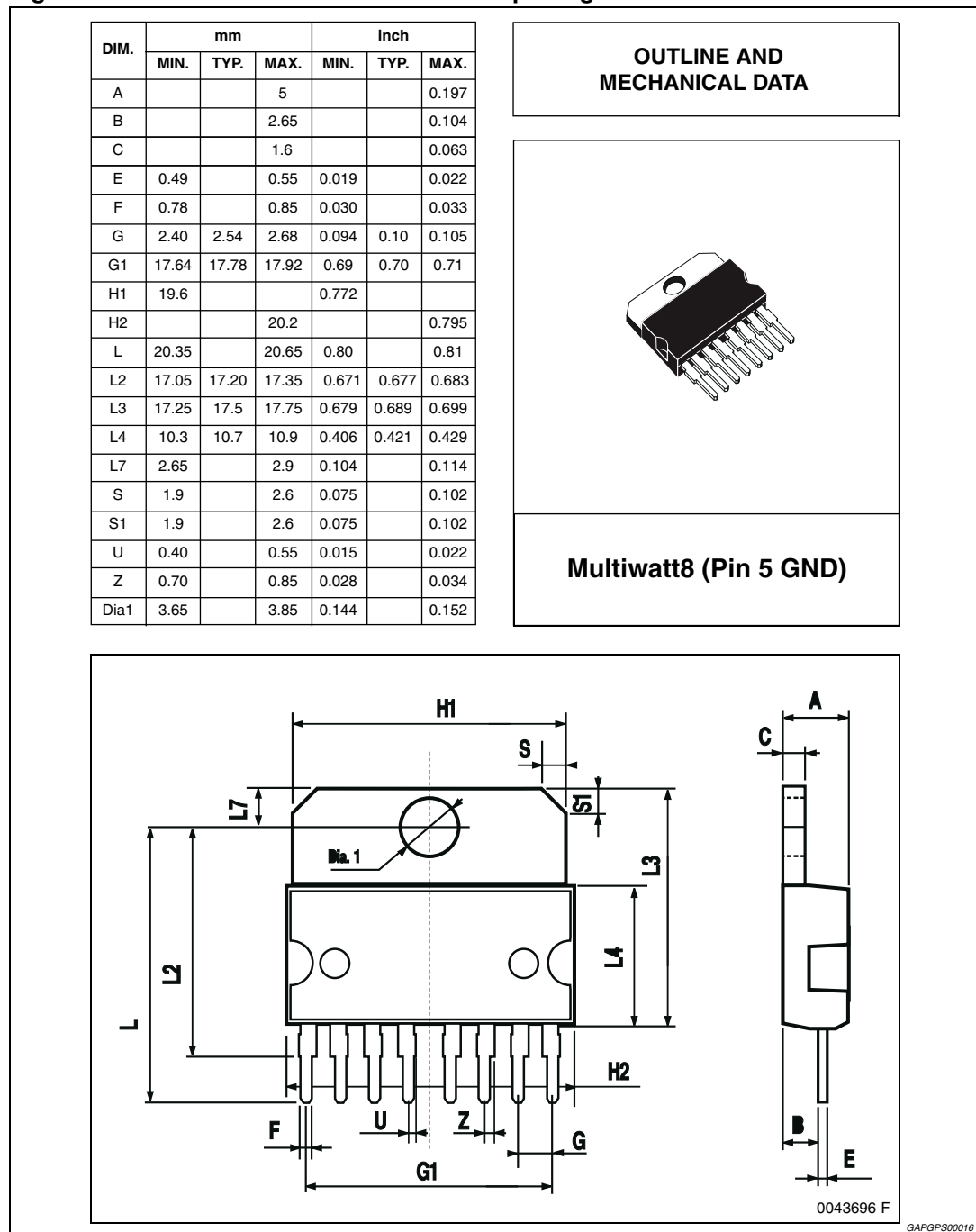
Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$V_{PL}$	Low voltage warning threshold	-	5	6	7	V
$V_{OH}$	Over voltage protection threshold	-	15.1	16.5	17.5	V
$V_{SO}$	S-terminal open threshold	-	7	-	12	V
$V_{BS}$	Open threshold	-	1.6	2.0	2.2	V
$f_{LRC\_EN}$	Low speed threshold	-	130	145	160	V
$T_{DELAY}$	Fault indication delay time	-	0.8	-	1.2	s

# 5 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).

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**Figure 5. Multiwatt8 mechanical data and package dimensions**



## 6 Revision history

**Table 12. Document revision history**

Date	Revision	Changes
12-Jan-2011	1	Initial release.
19-Sep-2013	2	Updated Disclaimer.

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