



## CAR ALTERNATOR MULTIFUNCTION SMART VOLTAGE REGULATOR

PRELIMINARY DATA

### 1 Features

- FULLY MONOLITHIC DESIGN
- HIGH SIDE FIELD DRIVER
- THERMAL PROTECTION
- FIELD SHORT CIRCUIT PROTECTION
- PROTECTED DIAGNOSTIC LAMP DRIVER
- PROTECTED HIGH SIDE RELAY DRIVER
- COMPLEX DIAGNOSTICS
- LOAD RESPONSE CONTROL
- DFM OUTPUT (FIELD MONITOR)

### 2 Description

The L9911 is a monolithic multifunction alternator voltage regulator intended for use in automotive application. It includes the control section, the field power stage, fault diagnostic circuit which drives a warning lamp, and the protection against short circuits.

### 3 Circuit Operation

The alternator's voltage regulator performs the following main functions:

- 1) voltage regulation
- 2) protection
- 3) control fault diagnosis
- 4) load response control

#### 3.1 VOLTAGE REGULATION

The alternator voltage is compared with a reference voltage in an amplifier, whose output determines the switching frequency of output power MOS whose current excites the coil of the alternator; as the regulator is in fixed-frequency topology, the field switching frequency does not depend on the alternator characteristics. The regulators have an integrated filter in the voltage sensing path guaranteeing the correct behaviour of the devices also when the rectifier diodes feature very high switching spikes. The internal filtering allows the usage of the device also with very long cables connecting the alternator to the battery with an imped-

Figure 1. Package

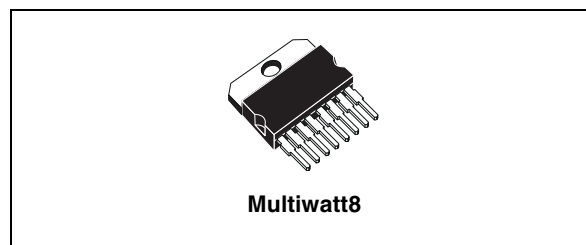


Table 1. Order Codes

Part Number	Package	Features
L9911A	Multiwatt8	See Table.9
L9911B	Multiwatt8	See Table.9

ance so high to cause a superimposed ripple on the alternator voltage higher than 5-6V. Consequently it doesn't need, in the standard application, any external component. Anyway an external capacitor (2.2 $\mu$ F) must be inserted between A+ and ground when using the device with very long cables.

#### 3.2 PROTECTION

It is present a protection against short circuits of the lamp and the relay power drivers (L) and of the field power driver (F+), a thermal drivers shutdown protection and an overvoltage protection of L power drivers.

#### 3.3 DIAGNOSIS

The circuit detects fault conditions related to the phase and F+ status and receives informations from one of the three alternator phases. In order to prevent spurious indications, fault warnings are not displayed immediately but are delayed by a fixed time.

#### 3.4 LOAD RESPONSE CONTROL

The internal circuit regulates the soft start characteristics (activated always at engine start) and the soft attack characteristics.

Figure 2. Pin Connection (Top view)

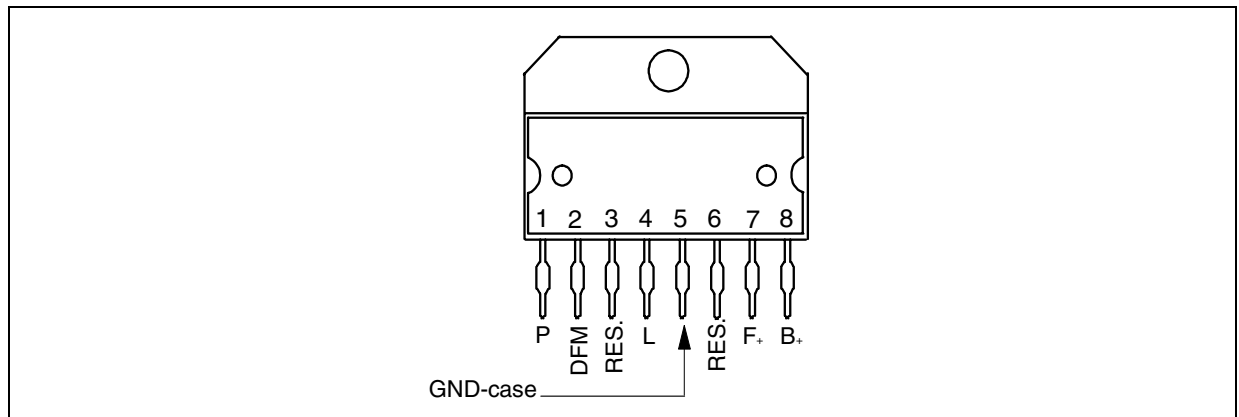


Table 2. Pin Descriptions

N°	Pin	Function
1	P	Phase sense input.
2	DFM	Field monitor output.
3	RES.	Reserved.
4	L	Lamp terminal low side driver; relay terminal high side driver.
5	GND-case	Ground.
6	RES.	Reserved.
7	F+	High side driver output.
8	B+	Sensed power supply.

Table 3. Absolute Maximum Ratings ( $T_j = -40$  to  $150^\circ\text{C}$ , unless otherwise specified)

Symbol	Parameter	Value	Unit
$V_S$	DC Supply Voltage (2 min. @ $25^\circ\text{C}$ )	24	V
	Transient Supply Voltage (load dump) [see application circuit] $t < 500\text{ms}$	40	V
	Transient Supply Voltage (low energy spikes) [see application circuit] ISO7637-1 pulse 1,2,3 /ISO7637-3	60	V
$T_j$	Junction temperature range	-40 to 150	$^\circ\text{C}$
$T_{\text{stg}}, T_{\text{case}}$	Storage and case temperature range	-40 to 150	$^\circ\text{C}$
$P_{\text{tot}}$	Total power Dissipation (@ $T_{\text{case}} \leq 150^\circ\text{C}$ , $I_{\text{field}} \leq 5\text{A}$ )	4	W
	Reverse Battery Voltage (see application diagram) @ $25^\circ\text{C}$ , $T = 15\text{ sec}$	-2.5	V
	Normal working condition reverse voltage (P vs. GROUND)	-1.5	V
	DC Pin Current on F+, B+, GND (bonding limitation)	15	A
	ESD Voltage MILSTD883C (All pins vs.GND)	$\pm 4$	KV

Table 4. Thermal Data

Symbol	Parameter	Value	Unit
$R_{\text{th j-case}}$	Thermal resistance junction to case	$\leq 1.5$	$^\circ\text{C/W}$

**Table 5. ELECTRICAL CHARACTERISTICS**(T<sub>j</sub> = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
Vbat	Operating Supply Voltage		7		18	V
Ib-sinked	Supply Battery Current				25	mA
Ib-stby	Stand-by Current	B+ = 12.5V, F+ = 0V			500	μA
Vreg 1	Regulated Voltage & Thermal Drift. 3 configurations available, selectable by mask option (see Table.8).	Ialt=1A-0.9*Inom; Tcase=20°C; 1400<rpm<RPMMAX (Fig. 3)	14.0 -4.5	14.4 -3.5	14.8 -2.5	V mV/°C
Vreg 2		Ialt=10A; Tcase=23°C; rpm=6000rpm;15V max (Fig. 4)	14.35 -11.8	14.5 -10	14.65 -8.2	V mV/°C
Vreg 3		Ialt=10A; Tcase=23°C; rpm=6000rpm (Fig. 5)	14.35 -6	14.5 -4	14.65 -2	V mV/°C
Delta Vrpm		1400<rpm<RPMMAX; Ialt=10A			200	mV
Delta Vload		5A<Ialt<Inom; rpm=6000rpm			250	mV
Vreg-less	Reg. Voltage without Battery	Ialt = 3A resistive; Tcase=-25°; 2000<rpm<RPMMAX	12		16	V
Vov-p	Overvoltage protection threshold	Voltage on pin B+ to disable L drivers	High and low side driver off	18	22	V
Vov-d	Overvoltage diagnosis threshold	VB+ to turn on L low side driver at VF+ > VS1	Vreg - 5%	Vreg	Vreg + 5%	V
Tj-sd	Thermal shutdown threshold	Temperature to disable F+, DFM, L (high & low side drivers)	160	175	190	°C
Tj-sd-dwn	Thermal Shut-down hysteresis	L/F+/DFM from OFF STATE (due to thermal shutdown) to ON STATE	Tj-sd-10		Tj-sd-2	°C
Vuv-1	Under voltage diagnosis threshold	VB+ to turn on L low side driver	7.7	8.6	9.5	V
Vuv-up		VB+ to turn off L low side driver	Vuv + 0.40	Vuv + 0.50	Vuv+ 0.60	V
VF+_sat	Field driver saturation voltage	Tj = 150°C; I = 4.5A			0.6	V
		Tj = 25°C; I = 7A			0.55	V
Vf	Freewheeling diode F+	I=5A			2	V
If_SCTH	Field short circuit driver protection threshold current (see fig. 16)	F+ = 0V; Tj = -40°C	11		18	A
		F+ = 0V; Tj = -25°C	8.5		18	A
		F+ = 0V; Tj = -150°C	5.5		18	A
Vs1	Field driver ON-state detection		4.5		5.5	V
f-pre	Pre-excitation frequency		283	333	383	Hz
Duty-pre	Pre-excitation Field driver ON-duty		15.93	18.75	21.57	%
t-rise	Output Voltage Rise Time	Ifield = 3A resistive (Fig. 7)	10		50	μs
t_fall	Output Voltage Fall Time	Ifield = 3A resistive (Fig. 7)	10		50	μs
Fsw_F+	Field switching frequency	Ialt=1A~0.9*Inom;1400rpm<rpm<RPMMAX	250		400	Hz
If_leak	Output Field Driver Leakage Current	B+ = 24V; VF+ = 0			10	μA

**Table 5. ELECTRICAL CHARACTERISTICS** (continued)(T<sub>j</sub> = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
DUTY-PR	Phase regulation max field ON duty	Fig. 8	26.56	31.25	35.94	%
VH_SAT	High Side Driver Saturation Voltage (Fig. 10)	With driver I <sub>source</sub> =500mA			1.5	V
VL_SAT	Low Side Driver Saturation Voltage (Fig. 10)	With driver I <sub>sink</sub> =500mA			1.5	V
VLSB	Selfbias without supply Lamp driver Voltage	B+ open; L connected to 12V through a 50 Ohm resistor			4	V
IHSC	High Side Driver short circuit current protection	B+ = 12.5V; L = GND	1.2		3	A
ILSC	Low Side Driver short circuit current (see fig. 16)	B+ = L = 12.5V	1		2	A
VthL	Enable Regulator Supply Voltage Threshold		0.8		1.15	
Ipd_L	L terminal Pull-down Current when the generator is not rotating	V <sub>L</sub> = 0.6V	0.4		3.5	mA
I_L_sink	L sink current when the generator is rotating	P frequency 500Hz; VB+ = 12V			100	μA
t-D	Diagnostic Alarm Delay Time		0.2		0.5	s
Vcan-DFM	Test mode to cancel soft start/ attack (voltage)	(Fig. 11)	30		50	V
tcan-DFM	Test mode delay time	(Fig. 11)	25			ms
VPHL1	Enable control voltage input high threshold	square wave f = 1KHz			0.35	V
VPHL2	Enable control voltage input low threshold	square wave f = 1KHz			0.25	V
t_PHL1	Enable Control Voltage Phase Filtering Time		50		115	μs
VPHH1	Diagnosis phase loss input high threshold		8	9	10	V
VPHH2_1	Diagnosis phase loss input low threshold		6.4	7.4	8.4	V
tPHd	Diagnostic Phase Filtering Time		50		100	μs
I_Pd-P1	Phase Pull-down Current	VP = 0.8V	1		8	mA
f-dfm	DFM Output open drain switching freq.	I <sub>alt</sub> =1A~0.9*I <sub>nom</sub> ; 1400rpm<rpm<R <sub>PMMAX</sub> ; I <sub>sink</sub> =14mA	125		200	Hz
VL-DFM	Output low voltage saturation	I <sub>sink</sub> =14mA			1.5	V
I-SC_DFM	Short circuit current protection	VB+ = VDFM = 12.5V	50		400	mA
I <sub>lk</sub> -DFM	Output leakage current	VDFM=16V at DFM driver OFF			5	μA
t-TM	Output voltage rise time	R=1K Ohm (Fig. 7)	0.5		50	μs
t-TD	Output voltage fall time	R=1K Ohm (Fig. 7)	0.5		50	μs

**Table 6. Load Response Control Parameters**

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
t_ST_1	Soft Start Delay Time (Fig. 13) 2 steps available, selectable by mask option (see Table.7).	Activated always at engine start		0		s
t_ST_2			1.73	2	2.35	
t_SL_1	Soft Attack Time / Soft Start Time (Fig. 13). 2 steps available, selectable by mask option (see Table 7).	From 0 to 100% field duty cycle	2.13	2.5	2.87	s
t_SL_2			7.65	9	10.35	
EN-RES (constant)	Reset frequency range to enable regulation; Frequency judged after 4 periods (Fig. 12)		40	50	60	Hz
EN-1	Soft start enable (EN) and LRC disable (DISAB) frequency ranges. 4 configurations available, selectable by mask option (possible combinations in Table 8). Always activated at engine start. Frequencies judged after 4 periods (Fig. 12)	Tj = 25°C	108	120	132	Hz
		Tj = -40 to150°C	102	120	138	Hz
EN-2		Tj = 25°C	131	145	159	Hz
		Tj = -40 to150°C	124	145	166	Hz
EN-3		Tj = 25°C	144	160	176	Hz
		Tj = -40 to150°C	136	160	184	Hz
EN-4		Tj = 25°C	174	193	212	Hz
		Tj = -40 to150°C	165	193	221	Hz
DISAB-1	Tj = 25°C	270	300	330	Hz	
	Tj = -40 to150°C	255	300	345	Hz	
DISAB-2	Tj = 25°C	315	350	385	Hz	
	Tj = -40 to150°C	298	350	402	Hz	
DISAB-3	Tj = 25°C	367	408	449	Hz	
	Tj = -40 to150°C	347	408	469	Hz	
DISAB-4	Tj = 25°C	420	466	512	Hz	
	Tj = -40 to150°C	397	466	535	Hz	

**Table 7. Load Response Control Timing Options**

	t_SL = 2.5s	t_SL = 9s
t_ST = 0s	LRC-A	LRC-D
t_ST = 2s	LRC-C	LRC-B

**Table 8. Correspondence of Frequency (typical values) to Application Features**

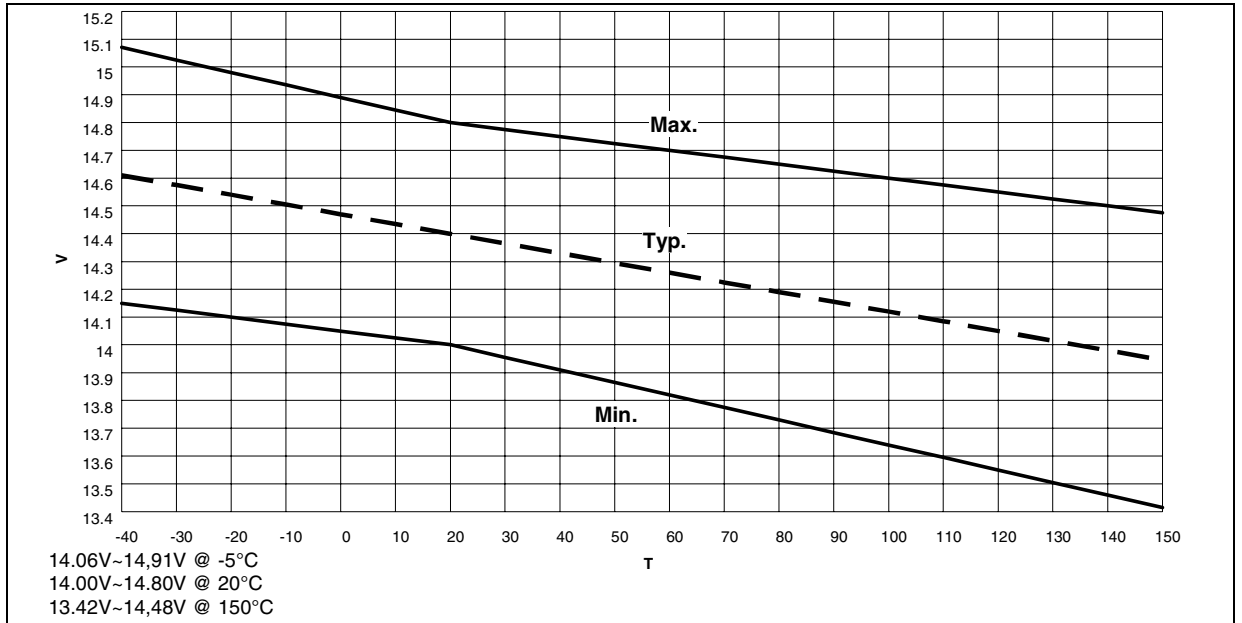
Alternator Revolution Speed (rpm)			6 Pole Pairs	8 Pole Pairs
Typical Configuration A (Config-A)	Initiate Regulation	1200	EN-1	EN-3
	LRC Cut	3000	DISAB-1	DISAB-3
Typical Configuration B (Config-B)	Initiate Regulation	1450	EN-2	EN-4
	LRC Cut	3000	DISAB-1	DISAB-3
Typical Configuration C (Config-C)	Initiate Regulation	1450	EN-2	EN-4
	LRC Cut	3500	DISAB-2	EN-4

Considering the overall WW application scenario, there is a direct correspondence between Typical Configurations A/B and regulation curve Vreg-1, and between Typical Configuration C and regulation curves Vreg-2 and Vreg-3. This is allowing the summary of all possible customizations for L9911 in the table below.

**Table 9. Customization of L9911: Combination of LRC, Regulation, and Application Options**

LRC Timing options	Vreg-1 / Config-A		Vreg-1 / Config-B		Vreg-2 / Config-C		Vreg-3 / Config-C	
	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	6 Pole Pairs	6 Pole Pairs	6 Pole Pairs
LRC-A	L9911B	nya	nya	nya	nya	nya	nya	nya
LRC-B	nya	nya	L9911A	nya	nya	nya	nya	nya
LRC-C	Nya	nya	nya	nya	nya	nya	nya	nya
LRC-D	nya	nya	nya	nya	nya	nya	nya	nya

**Figure 3. Vreg-1**



**Figure 4. Vreg-2**

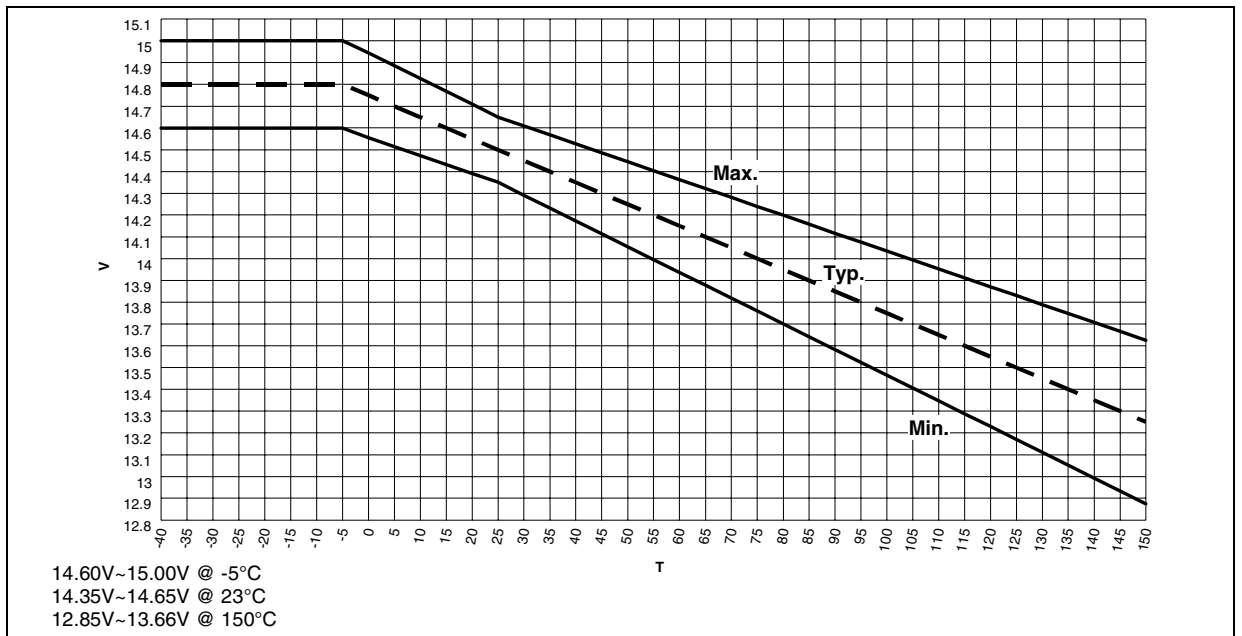


Figure 5. Vreg-3

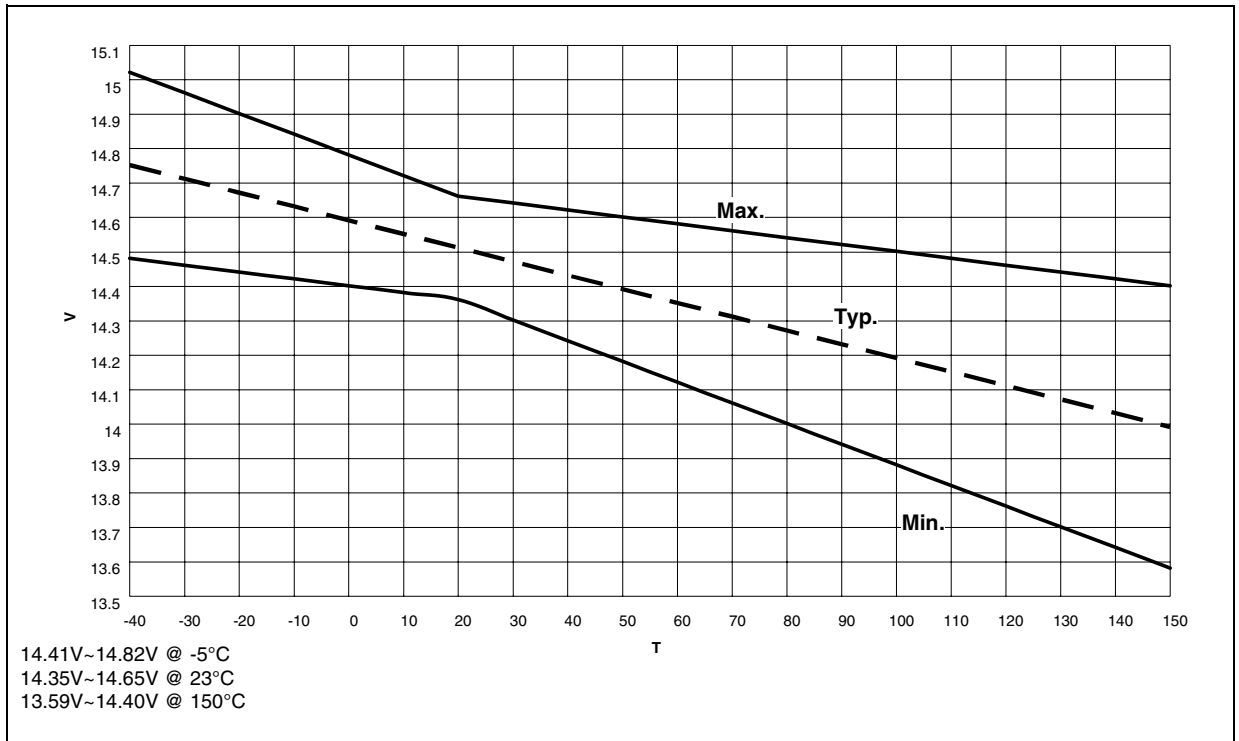


Figure 6. Output Voltage rise/fall time (F+, DFM)

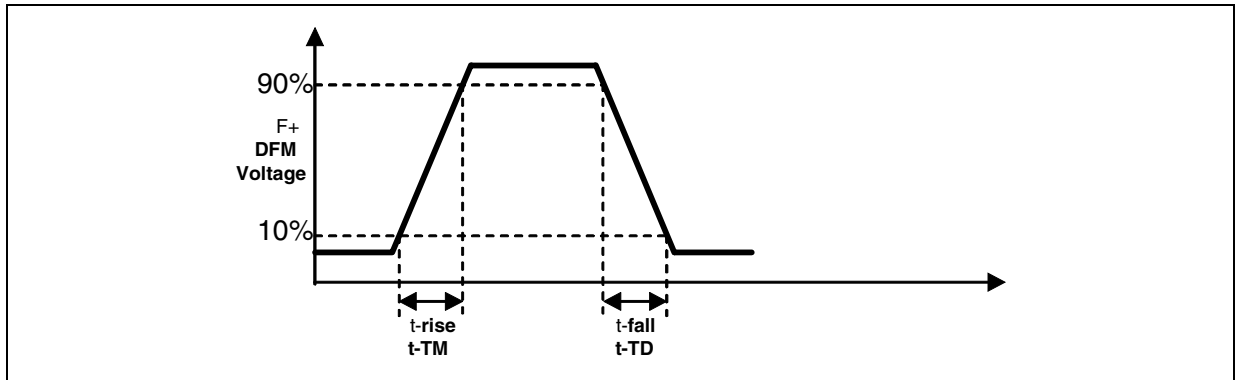
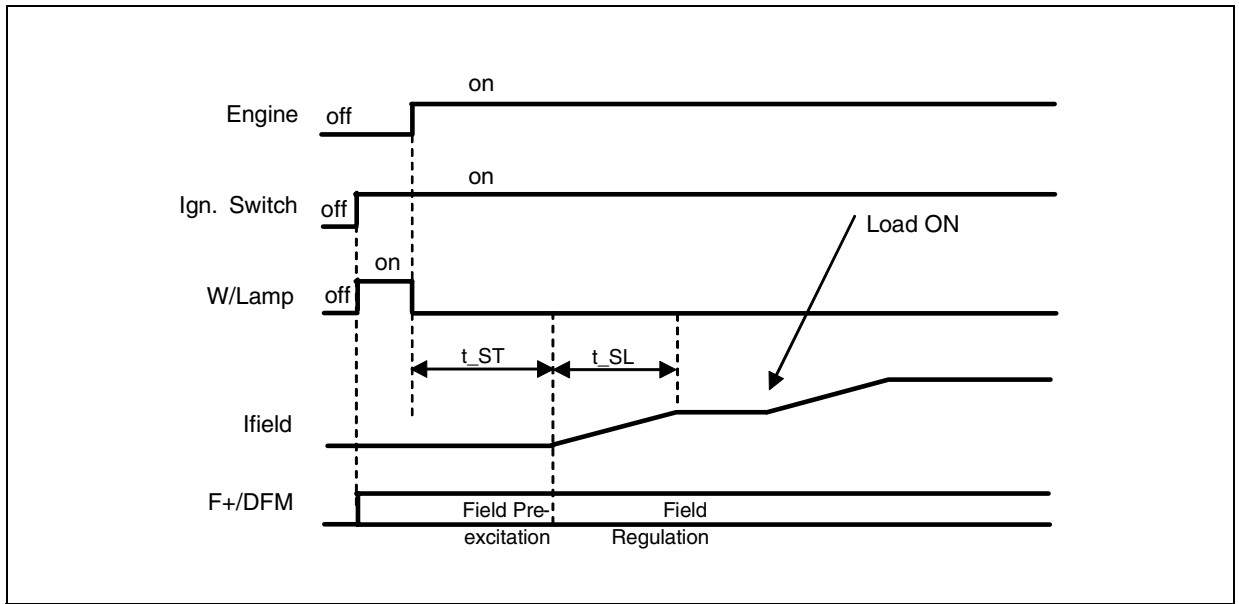


Figure 7. Phase Regulation Characteristics



**PRINCIPLE OF PHASE REGULATION:**

When  $V_{B+}$  is above the regulated voltage, the field driver is controlled to keep phase peak voltage from falling below  $V_{PHH1}$ .

If phase peak voltage drops below  $V_{PHL1}$ , phase regulation does not work.

Figure 8. Application Diagram

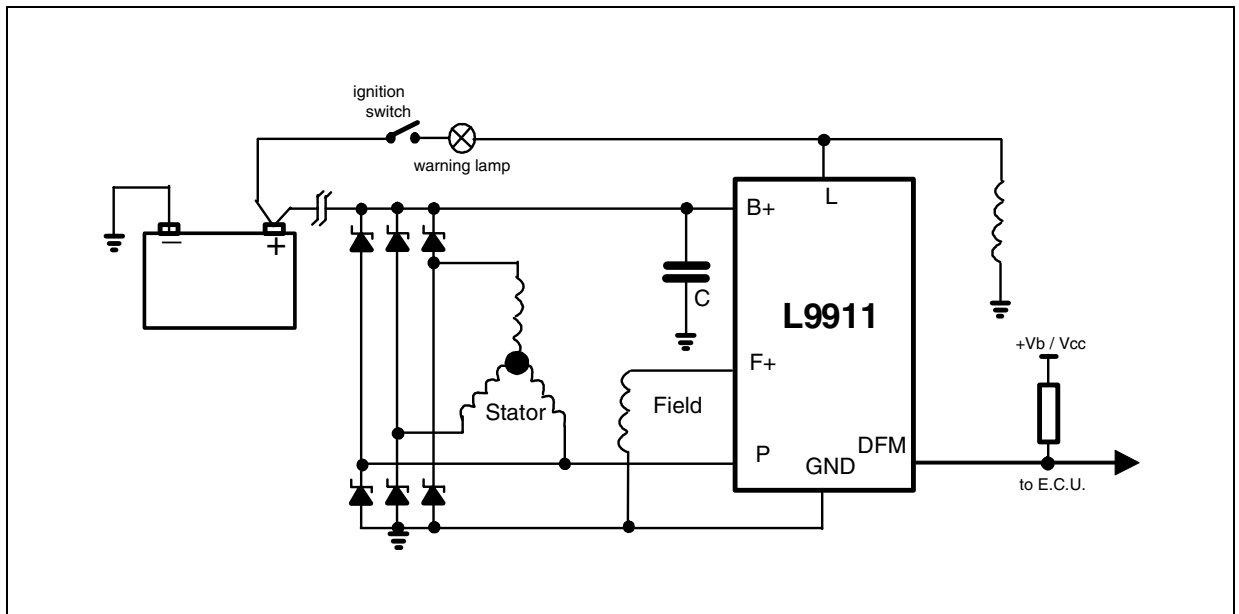




Figure 9. High Side/Low side driver saturation

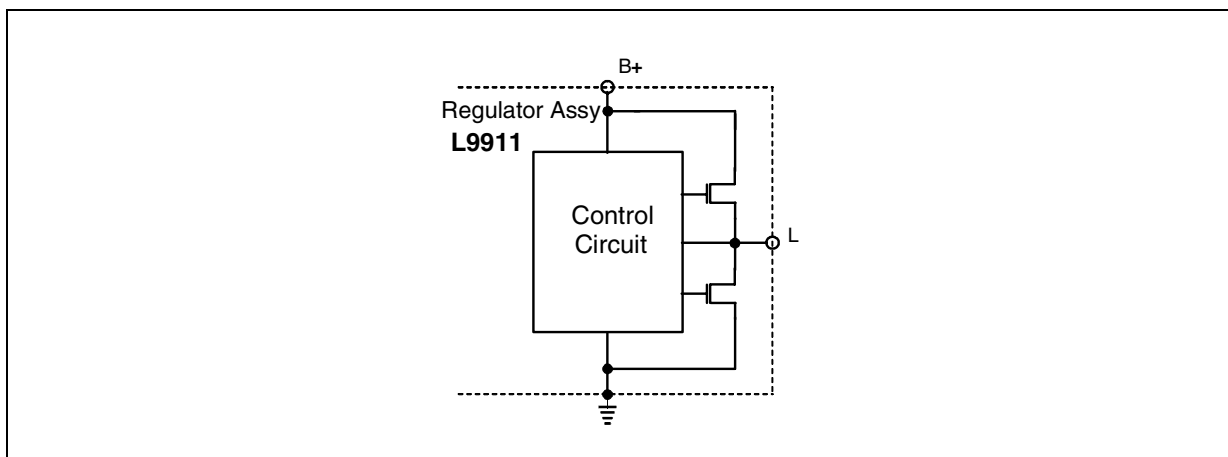


Figure 10. Test mode to cancel soft start/attack

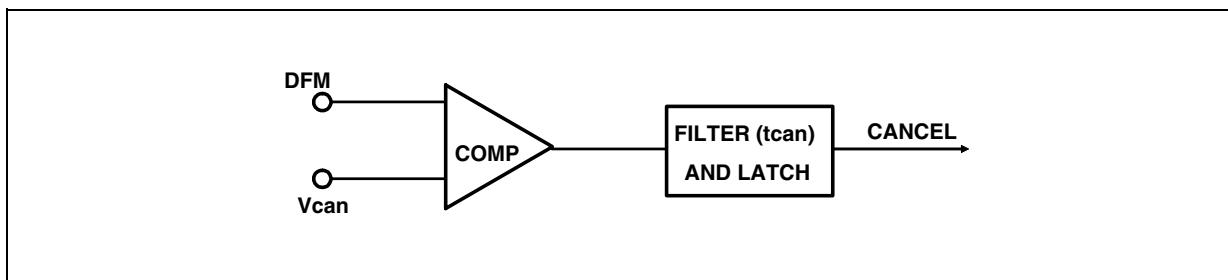


Figure 11. Soft-start enable frequency range

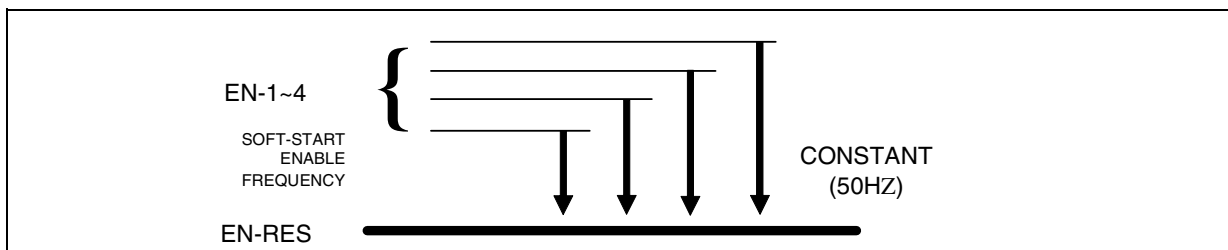


Figure 12. Soft start characteristics (always activated at engine start)

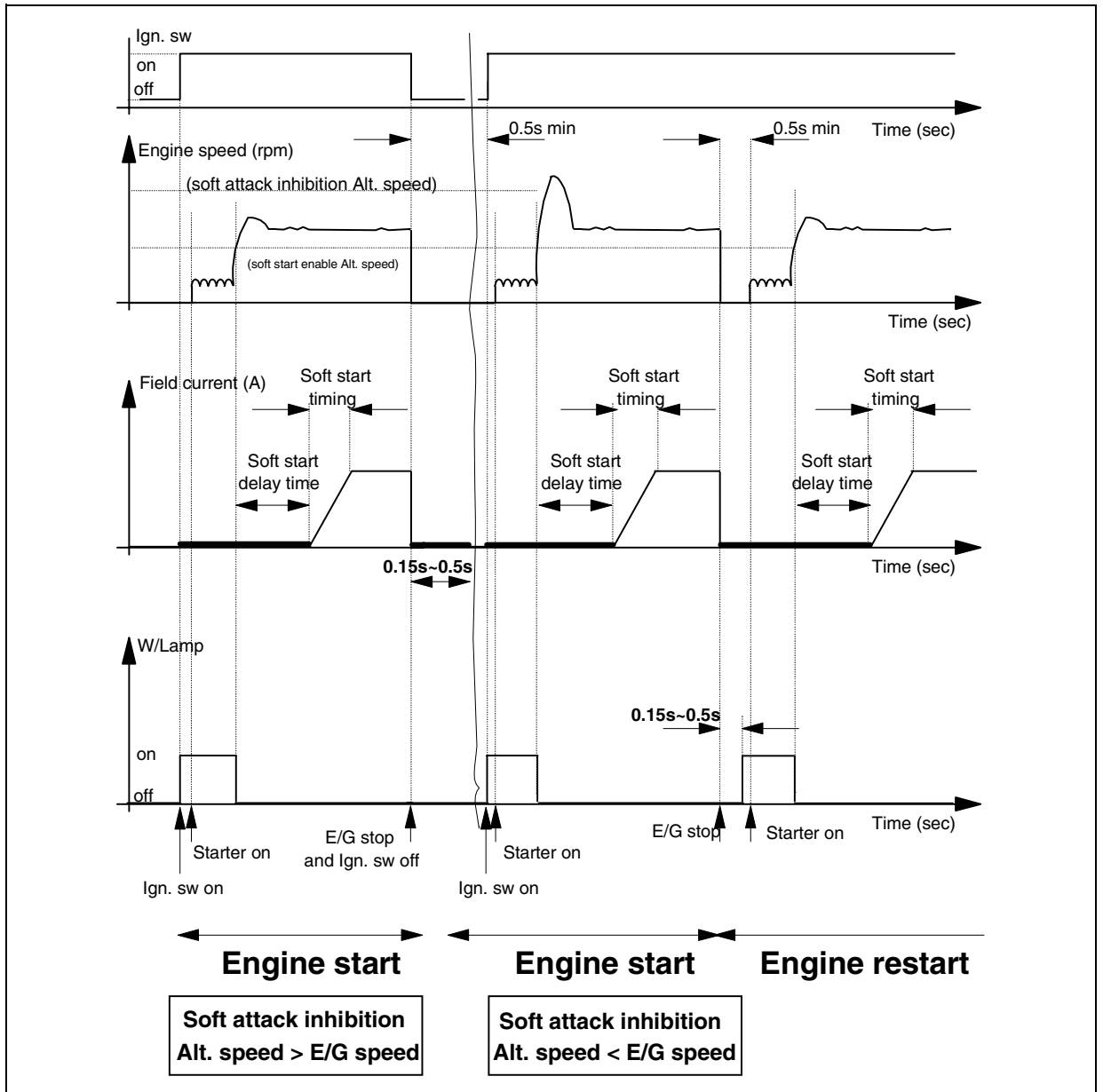


Figure 13. Soft Start/attack Characteristics

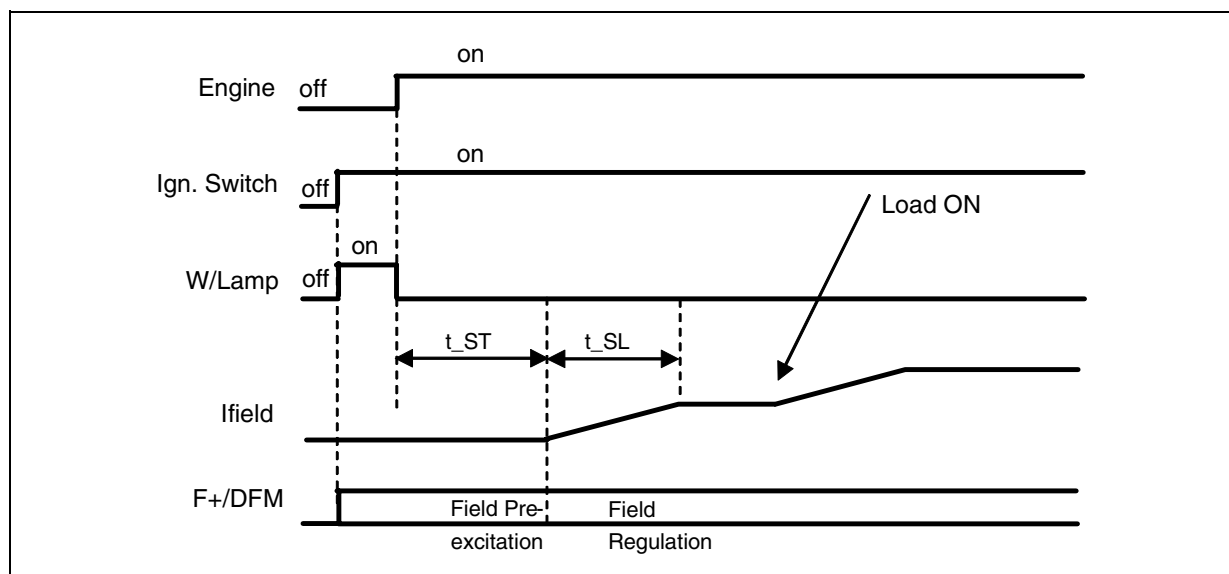
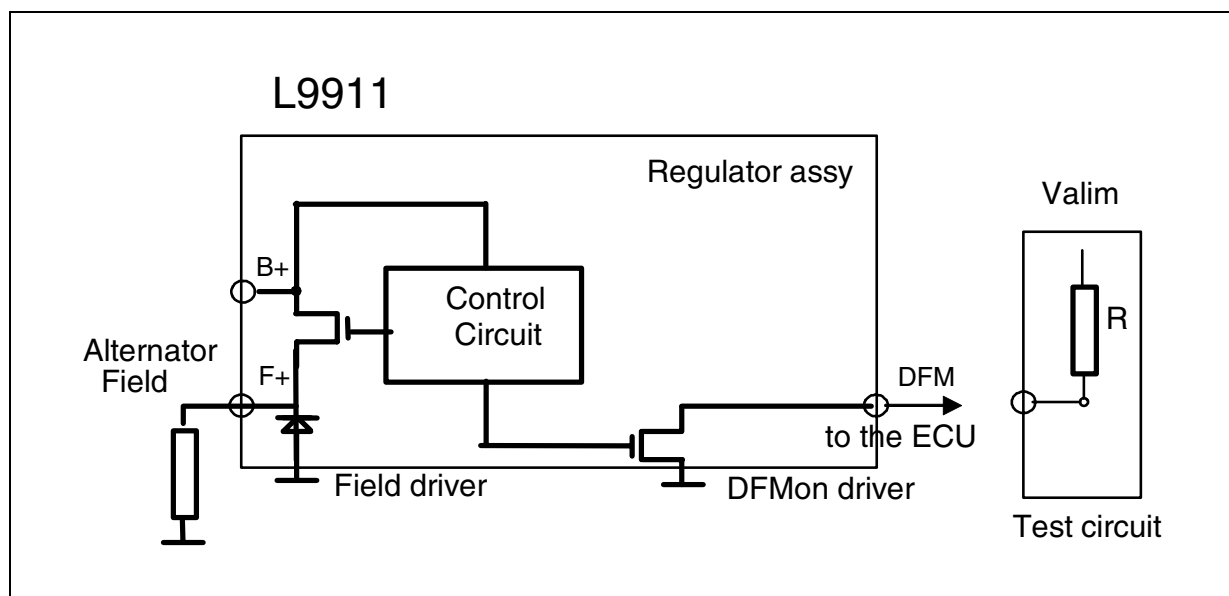


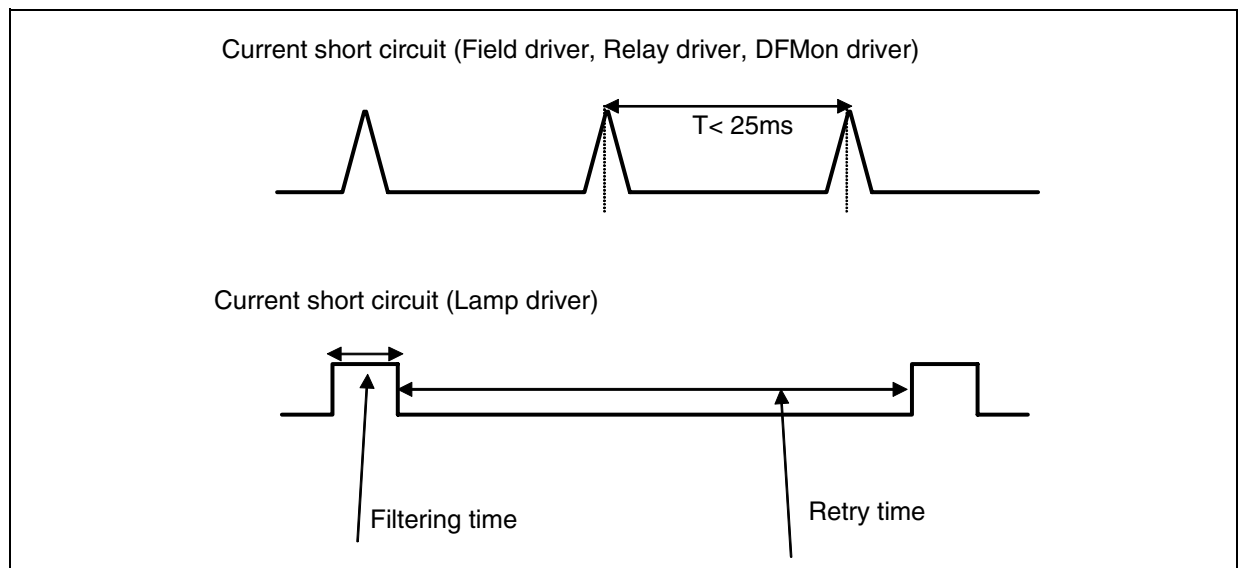
Table 10. Fault Detection

Root Cause	Signal	Effect	Test detect
Alternator belt breaking	P	Alternator disexcitation	$VP < V_{PHH1}$ & $VB+ < V_{reg}$
Brushes open	P	Alternator disexcitation	$VP < V_{PHH1}$ & $VB+ < V_{reg}$
Field Driver Open	P	Alternator disexcitation	$VP < V_{PHH1}$ & $VB+ < V_{reg}$
Field interruption	P	Alternator disexcitation	$VP < V_{PHH1}$ & $VB+ < V_{reg}$
Field short circuit to the battery	F+	Overvoltage	$VF+ > VS1$ & $VB+ > V_{ov-d}$
Field short circuit to the ground	P	Alternator disexcitation	$VP < V_{PHH1}$ & $VB+ < V_{reg}$
Battery discharge	B+	Undervoltage	$VB+ < V_{uv}$

The diagnostic result is disabled during the Soft-start delay time  $t_{ST}$  0...3 and the soft-start / soft attack timing  $t_{SL}$  0...3

Figure 14. DFMonitor Electrical configuration



**Figure 15. Short circuit drivers' protection**

Field driver, DFmon driver and Relay driver are protected in switching mode (not linear), with a retry time less than 25ms.

Lamp driver is protected in linear mode, with a retry time of 1s.

## 4 Package Information

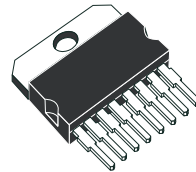
In order to meet environmental requirements, ST offers these devices in ECOPACK<sup>®</sup> packages. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

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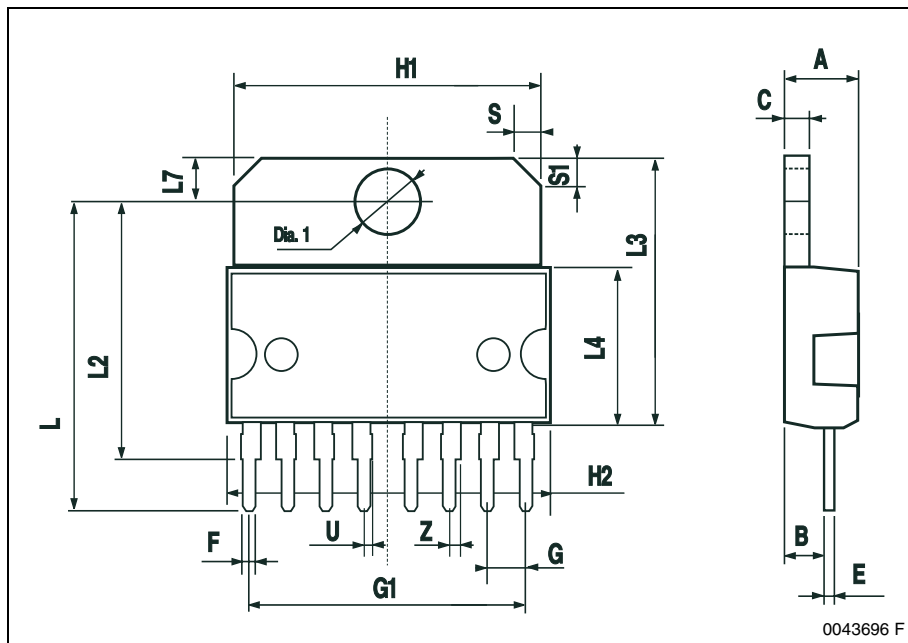
**Figure 16. Multiwatt8 Mechanical Data & Package Dimensions**

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			5			0.197
B			2.65			0.104
C			1.6			0.063
E	0.49		0.55	0.019		0.022
F	0.78		0.85	0.030		0.033
G	2.40	2.54	2.68	0.094	0.10	0.105
G1	17.64	17.78	17.92	0.69	0.70	0.71
H1	19.6			0.772		
H2			20.2			0.795
L	20.35		20.65	0.80		0.81
L2	17.05	17.20	17.35	0.67	0.68	0.68
L3	17.25	17.5	17.75	0.679	0.689	0.699
L4	10.3	10.7	10.9	0.406	0.421	0.429
L7	2.65		2.9	0.104		0.114
S	1.9		2.6	0.075		0.102
S1	1.9		2.6	0.075		0.102
U	0.40		0.55	0.015		0.022
Z	0.70		0.85	0.028		0.034
Dia1	3.65		3.85	0.144		0.152

### OUTLINE AND MECHANICAL DATA



### Multiwatt8 (Pin 5 GND)



0043696 F

**Table 11. Revision History**

<b>Date</b>	<b>Revision</b>	<b>Description of Changes</b>
June 2004	1	First Issue.
May 2005	2	Modified Figure 2, Table 2 and Table 5; Updated Figure 10, 11 and 14; Add Table 7. Add ordering numbers.
07-Nov-2005	3	Updated Table 5. Added new tables 6-9.

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