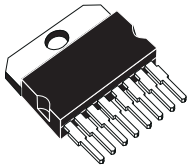
L9911

Car alternator multifunction smart voltage regulator

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)



Multiwatt8

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.

Table 1. Device summary

Order code	Package	Packing	Features
L9911F	Multiwatt8	Tube	See *Table 9*
L9911P	Multiwatt8	Tube	
L9911I	Multiwatt8	Tube	

Contents

List of tables

List of figures

1 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

1.1 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 impedance 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 (2.2µF) must be inserted between A+ and ground when using the device with very long cables.

1.2 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.

1.3 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 dalayed by a fixed time.

1.4 Load response control

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

2 Pins description

Figure 1. Pin Connection (Top view)

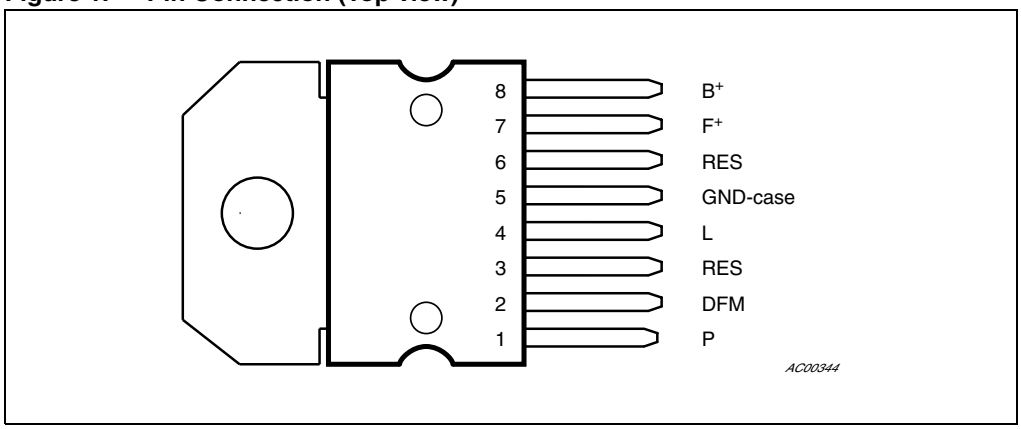


Table 2. Pin description

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.

3 Electrical specification

3.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

(T_j = -40 to 150°C, unless otherwise specified)

Symbol	Parameter	Value	Unit
V_S	DC supply voltage (2 min. @ 25°C)	24	V
	Transient supply voltage (load dump) [see] t<500ms	40	V
	Transient supply voltage (low energy spikes) (see *Figure 7*) ISO7637-1 pulse 1,2,3 /ISO7637-3	60	V
T_j	Junction temperature range	-40 to 150	°C
T_{stg}, T_{case}	Storage and case temperature range	-40 to 150	°C
P_{tot}	Total power dissipation (@ $T_{case} \leq 150°C$, $I_{field} \leq 5A$)	4	W
	Reverse battery voltage (see *Figure 7*) @ 25°C, T = 15 sec	-2.5	V
	Normal working condition reverse voltage (P vs. GND)	-1.5	V
	DC Pin Current on F+, B+, GND (bonding limitation)	15	A
	ESD Voltage MILSTD883C (All pins vs.GND)	±4	KV

3.2 Thermal data

Table 4. Thermal data

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

3.3 Electrical characteristcs

Table 5. Electrical characteristcs

(T_j = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
V_{bat}	Operating supply voltage		7		18	V
$I_{b\text{-}sinked}$	Supply battery current				25	mA
$I_{b\text{-}stby}$	Stand-by current	B+ = 12.5V, F+ = 0V			500	µA

Table 5. Electrical characteristcs (continued)

(T_j = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
$V_{reg\ 1}$	Regulated voltage & thermal drift. 3 configurations available, selectable by mask option (see *Table 8*).	I_{alt} =1A-0.9 · I_{nom}; T_{case} = 20°C; 1400<rpm<RPMMAX (see *Figure 2*)	14.0 -4.5	14.4 -3.5	14.8 -2.5	V mV/°C
$V_{reg\ 2}$		I_{alt} =10A; T_{case} = 23°C; rpm = 6000rpm;15V max. (see *Figure 3*)	14.35 -11.8	14.5 -10	14.65 -8.2	V mV/°C
$V_{reg\ 3}$		I_{alt} =10A; T_{case} = 23°C; rpm = 6000rpm (see *Figure 4*)	14.35 -6	14.5 -4	14.65 -2	V mV/°C
ΔV_{rpm}		1400<rpm<RPMMAX; I_{alt} = 10A			200	mV
ΔV_{load}		5A<I_{alt}<Inom; rpm=6000rpm			250	mV
$V_{reg\text{-}less}$	Reg. voltage without battery	I_{alt} = 3A resistive; T_{case} = 25°; 2000<rpm<RPMMAX	12		16	V
$V_{ov\text{-}p}$	Overvoltage protection threshold	Voltage on pin B+ to disable L drivers — High and low side driver off	18		22	V
$V_{ov\text{-}d}$	Overvoltage diagnosis threshold	VB+ to turn on L low side driver at VF+ > VS1	Vreg - 5%	Vreg	Vreg + 5%	V
$T_{j\text{-}sd}$	Thermal shutdown threshold	Temperature to disable F+, DFM, L (high & low side drivers)	160	175	190	ºC
$T_{j\text{-}sd\text{-}dwn}$	Thermal shut-down hysteresis	L/F+/DFM from OFF STATE (due to thermal shutdown) to ON STATE	Tj-sd-10		Tj-sd-2	ºC
$V_{uv\text{-}1}$	Under voltage diagnosis threshold	VB+ to turn on L low side driver	7.7	8.6	9.5	V
$V_{uv\text{-}up}$		VB+ to turn off L low side driver	Vuv + 0.40	Vuv + 0.50	Vuv+ 0.60	V
V_{F+_sat}	Field driver saturation voltage	T_j = 150°C; I = 4.5A			0.6	V
		T_j = 25°C; I = 7A			0.55	V
V_f	Freewheeling diode F+	I = 5A			2	V
I_{f_SCTH}	Field short circuit driver protection threshold current (see *Figure 14*)	F+ = 0V; T_j = -40°C	11		18	A
		F+ = 0V; T_j = -25°C	8.5		18	A
		F+ = 0V; T_j = -150°C	5.5		18	A
V_{s1}	Field driver ON-state detection		4.5		5.5	V
$f_{\text{-}pre}$	Pre-excitation frequency		283	333	383	Hz
Duty-pre	Pre-excitation Field driver ON-duty		15.93	18.75	21.57	%
t_r	Output voltage rise time	I_{field} = 3A resistive (see *Figure 5*)	10		50	µs
t_f	Output voltage fall time		10		50	µs
F_{sw_F+}	Field switching frequency	I_{alt} = 1A~0.9 · I_{nom}; 1400rpm<rpm<RPMMAX	250		400	Hz
If_leak	Output field driver leakage current	B+ = 24V; V_{F+} = 0			10	µA

Table 5. Electrical characteristcs (continued)

(T_j = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
DUTY-PR	Phase regulation max field ON duty	see *Figure 6*	26.56	31.25	35.94	%
V_{H_SAT}	High side driver saturation Voltage (see *Figure 8*)	With driver I_{source} = 500mA			1.5	V
V_{L_SAT}	Low side driver saturation voltage (see *Figure 8*)	With driver I_{sink} = 500mA			1.5	V
V_{LSB}	Selfbias without supply lamp driver voltage	B+ open; L connected to 12V through a 50 Ohm resistor			4	V
I_{HSC}	High side driver short circuit current protection	B+ = 12.5V; L = GND	1.2		3	A
I_{LSC}	Low Side Driver short circuit current (see *Figure 14*)	B+ = L = 12.5V	1		2	A
V_{thL}	Enable regulator supply voltage threshold		0.8		1.15	
I_{pd_L}	L terminal pull-down current when the generator is not rotating	V_L = 0.6V	0.4		3.5	mA
I_{L_sink}	L sink current when the generator is rotating	P frequency 500Hz; V_{B+} = 12V			100	µA
t_{-D}	Diagnostic alarm delay time		0.2		0.5	s
$V_{can-DFM}$	Test mode to cancel soft start/ attack (voltage)	(see *Figure 9*)	30		50	V
$t_{can-DFM}$	Test mode delay time		25			ms
V_{PHL1}	Enable control voltage input high threshold	square wave f = 1KHz			0.35	V
V_{PHL2}	Enable control voltage input low threshold	square wave f = 1KHz			0.25	V
t_{PHL1}	Enable Control Voltage Phase Filtering Time		50		115	µs
V_{PHH1}	Diagnosis phase loss input high threshold		8	9	10	V
V_{PHH2_1}	Diagnosis phase loss input low threshold		6.4	7.4	8.4	V
t_{PHd}	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_{alt} =1A~0.9 · I_{nom}; 1400rpm<rpm<RPMMAX; I_{sink} = 4mA	125		200	Hz
V_{L-DFM}	Output low voltage saturation	I-sink=14mA			1.5	V
I_{-SC_DFM}	Short circuit current protection	VB+ = VDFM = 12.5V	50		400	mA
I_{lk-DFM}	Output leakage current	V_{DFM} =16V at DFM driver OFF			5	µA

Table 5. Electrical characteristcs (continued)

(T_j = -40°C to 150°C; unless otherwise specified)

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
t_{-TM}	Output voltage rise time	R = 1K Ohm (see *Figure 5*)	0.5		50	µs
t_{-TD}	Output voltage fall time		0.5		50	

Table 6. Load response control parameters

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
t_ST_1	Soft start delay time (see *Figure 11*) 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 (see *Figure 11*). 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 (see *Figure 10*)		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 (see *Figure 10*)	T_j = 25°C T_j = -40 to150°C	108 102	120 120	132 138	Hz Hz
EN-2		T_j = 25°C T_j = -40 to150°C	131 124	145 145	159 166	Hz Hz
EN-3		T_j = 25°C T_j = -40 to150°C	144 136	160 160	176 184	Hz Hz
EN-4		T_j = 25°C T_j = -40 to150°C	174 165	193 193	212 221	Hz Hz
DISAB-1		T_j = 25°C T_j = -40 to150°C	270 255	300 300	330 345	Hz Hz
DISAB-2		T_j = 25°C T_j = -40 to150°C	315 298	350 350	385 402	Hz Hz
DISAB-3		T_j = 25°C T_j = -40 to150°C	367 347	408 408	449 469	Hz Hz
DISAB-4		T_j = 25°C T_j = -40 to150°C	420 397	466 466	512 535	Hz 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

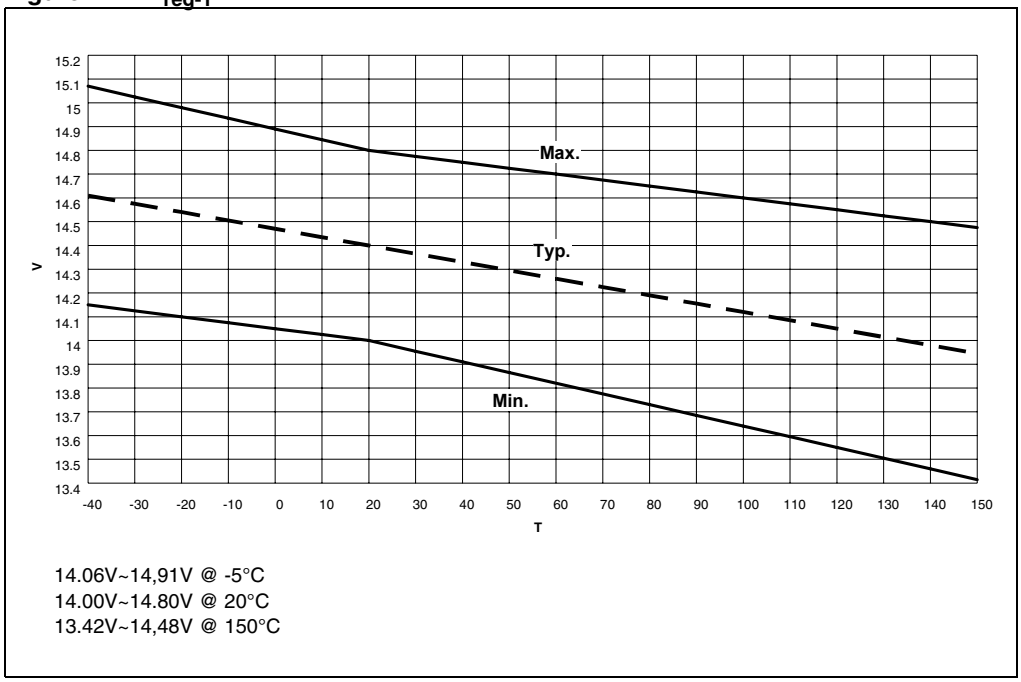
Alternator Revolution Speed (rpm)			6 Pole Pairs	8 Pole Pairs
Typical Configuration A (Config-A)	Initiate Regulation	1200	EN-1	EN-3
	LRC Cut	3000	DISAB-1	DISAB-3
Typical Configuration B (Config-B)	Initiate Regulation	1450	EN-2	EN-4
	LRC Cut	3000	DISAB-1	DISAB-3
Typical Configuration C (Config-C)	Initiate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

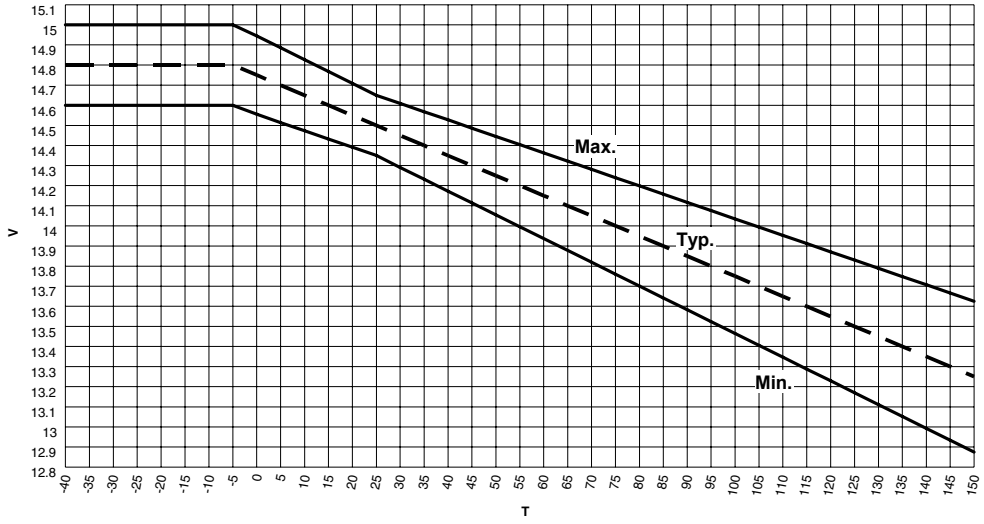
LRC Timing options	V_{reg-1} / Config-A		V_{reg-1} / Config-B		V_{reg-2} / Config-B		V_{reg-2} / Config-C		V_{reg-3} / Config-C	
	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	8 Pole Pairs	6 Pole Pairs	8 Pole Pairs
LRC-A	L9911P	nya	nya	nya	nya	nya	nya	nya	nya	nya
LRC-B	nya	nya	L9911F	nya	L9911I	nya	nya	nya	nya	nya
LRC-C	Nya	nya	nya	nya	nya	nya	nya	nya	nya	nya
LRC-D	nya	nya	nya	nya	nya	nya	nya	nya	nya	nya

Figure 2. V_{reg-1}



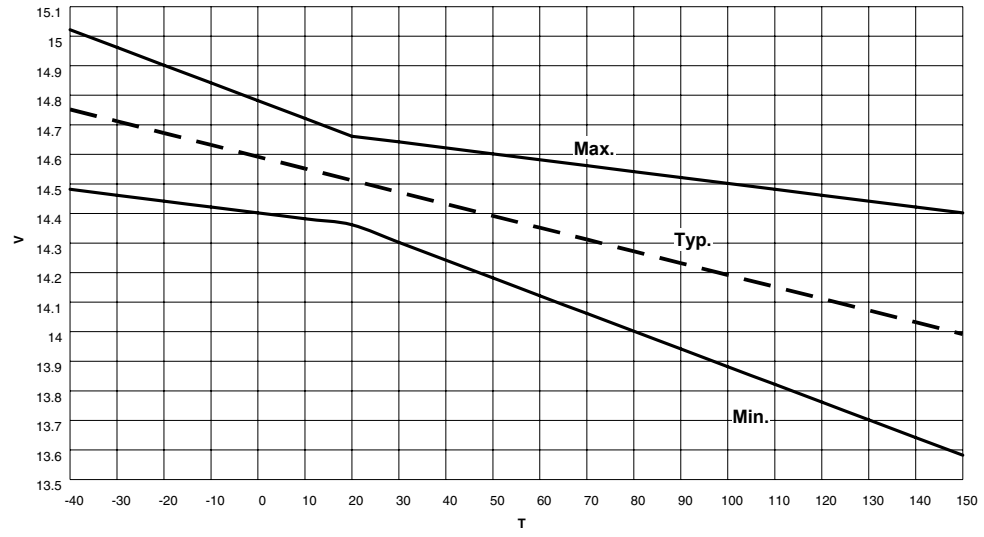
14.06V~14,91V @ -5°C
14.00V~14.80V @ 20°C
13.42V~14,48V @ 150°C

Figure 3. V_{reg-2}



14.60V~15.00V @ -5°C
14.35V~14.65V @ 23°C
12.85V~13.66V @ 150°C

Figure 4. V_{reg-3}



14.41V~14.82V @ -5°C
14.35V~14.65V @ 23°C
13.59V~14.40V @ 150°C

Figure 5. Output voltage rise/fall time (F+, DFM)

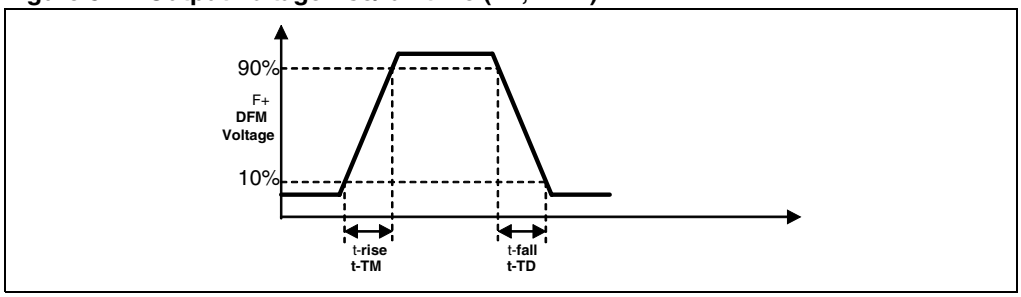
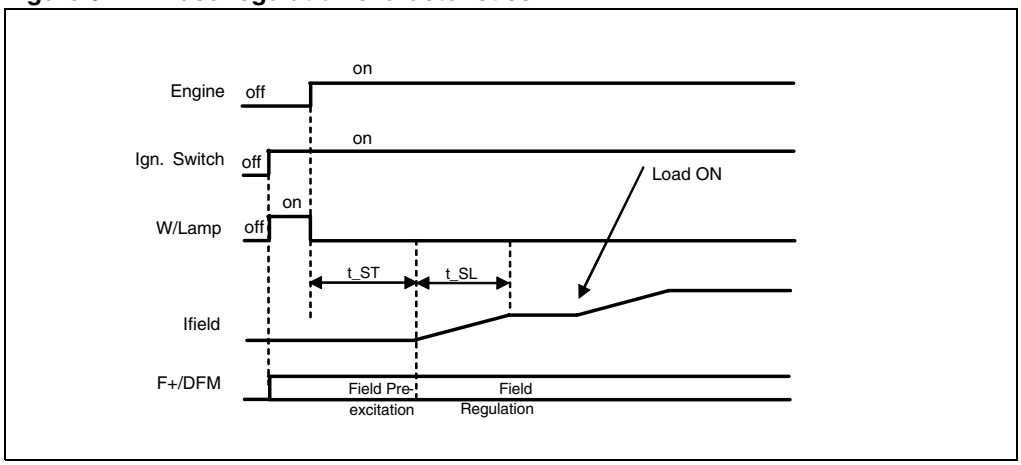


Figure 6. Phase regulation characteristics



3.4 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 7. Application diagram

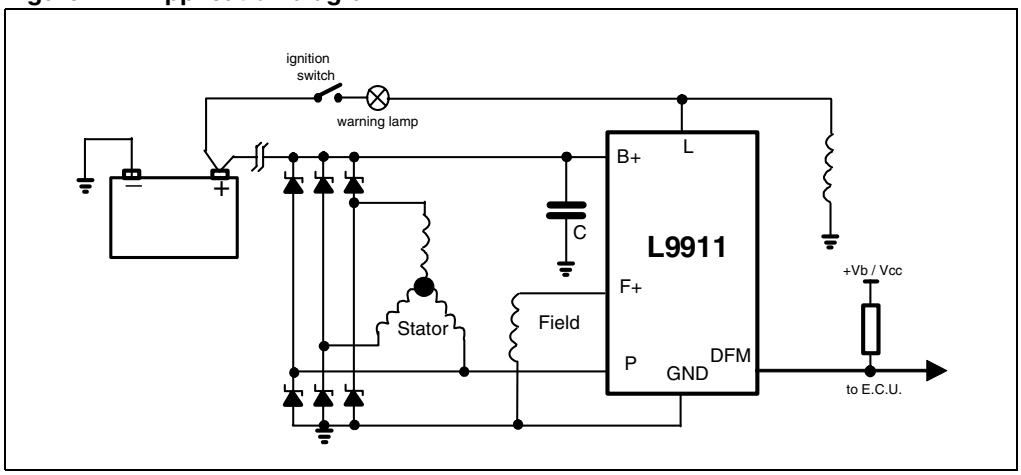


Figure 8. High side/low side driver saturation

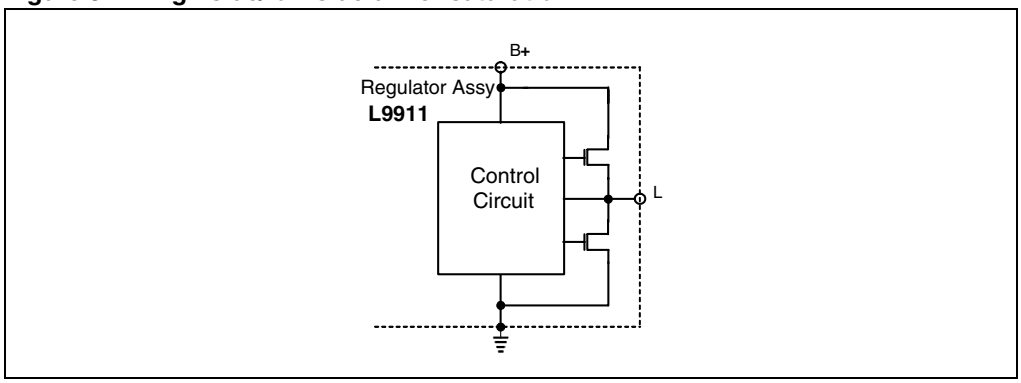


Figure 9. Test mode to cancel soft start/attack

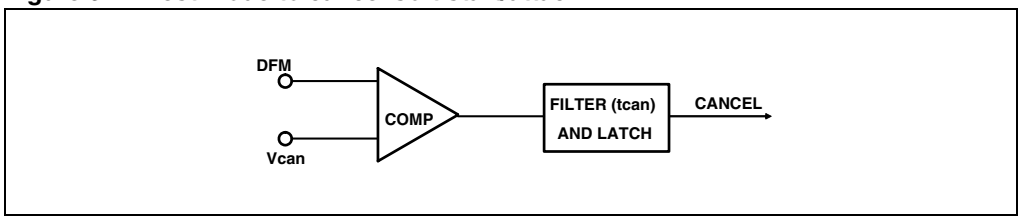


Figure 10. Soft-start enable frequency range

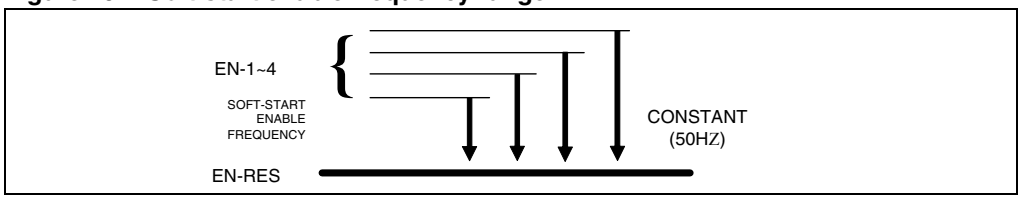


Figure 11. Soft start characteristics (always activated at engine start)

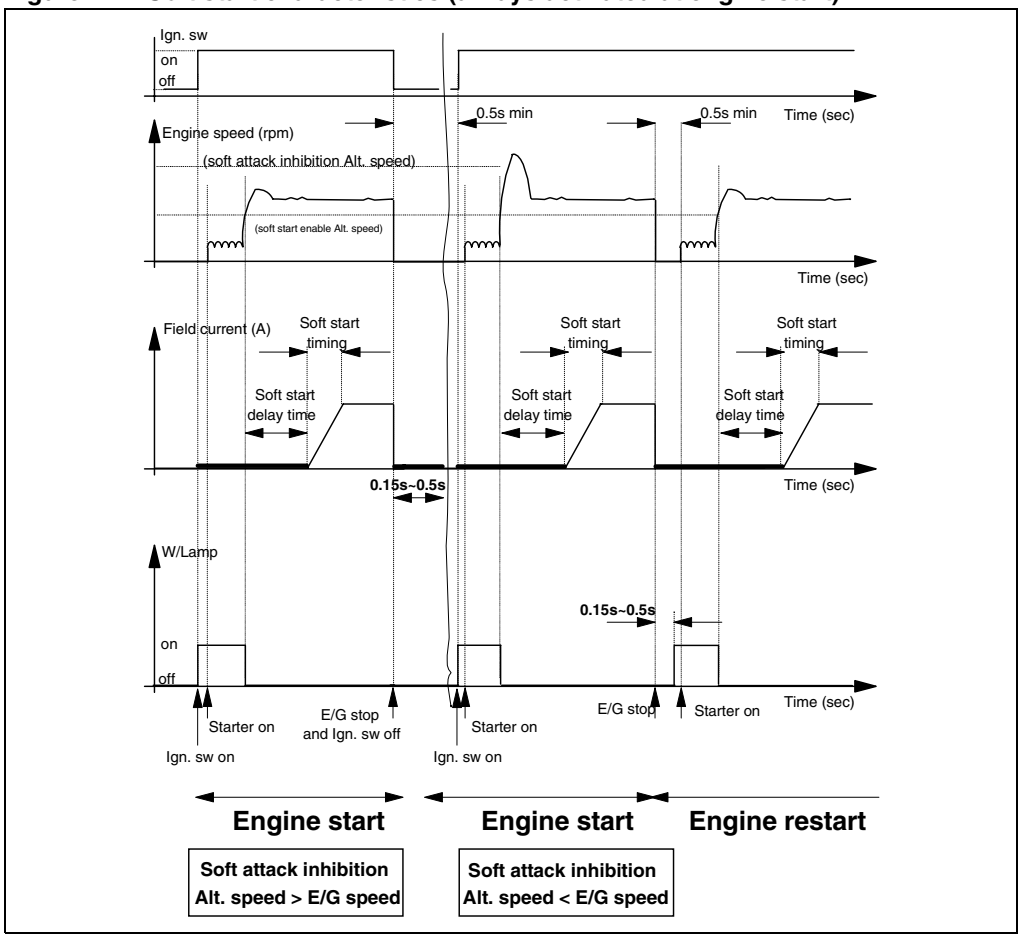


Figure 12. Soft start/attack characteristics

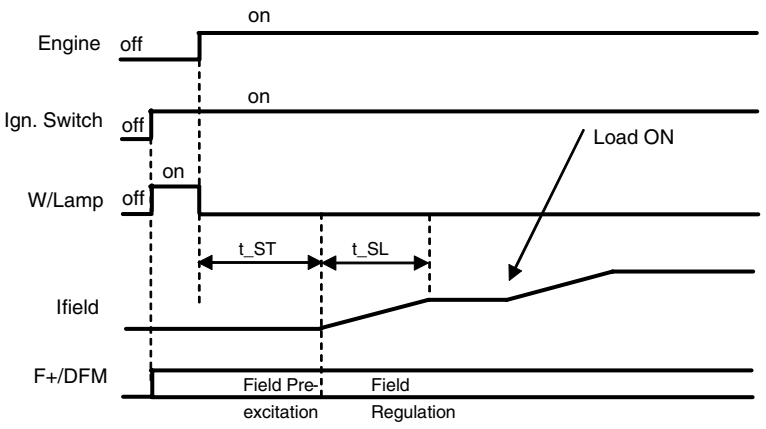


Table 10. Fault detection

Root Cause	Signal	Effect	Test detect
Alternator belt breaking	P	Alternator disexcitation	VP<VPHH1 & VB+<Vreg
Brushes open	P	Alternator disexcitation	VP<VPHH1 & VB+<Vreg
Field Driver Open	P	Alternator disexcitation	VP<VPHH1 & VB+<Vreg
Field interruption	P	Alternator disexcitation	VP<VPHH1 & VB+<Vreg
Field short circuit to the battery	F+	Overvoltage	VF+>VS1 & VB+ > Vov-d
Field short circuit to the ground	P	Alternator disexcitation	VP<VPHH1 & VB+<Vreg
Battery discharge	B+	Undervoltage	VB+<Vuv

Note: 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 13. DFMonitor electrical configuration

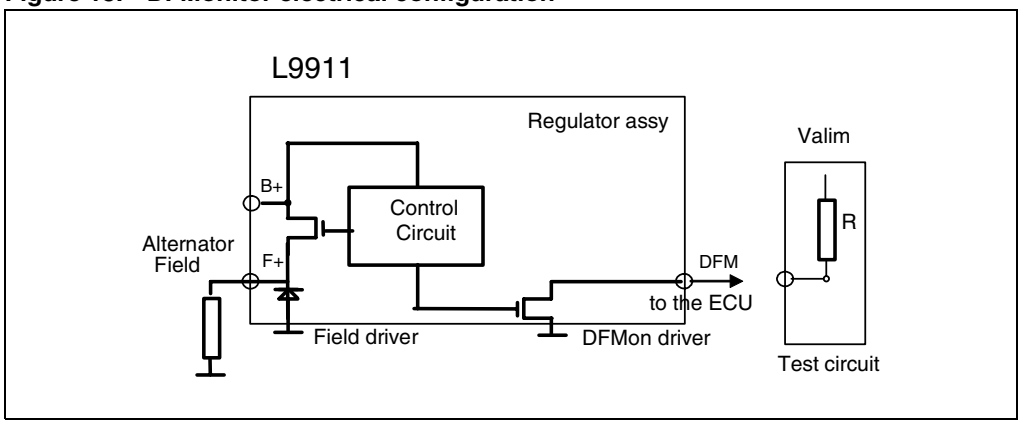
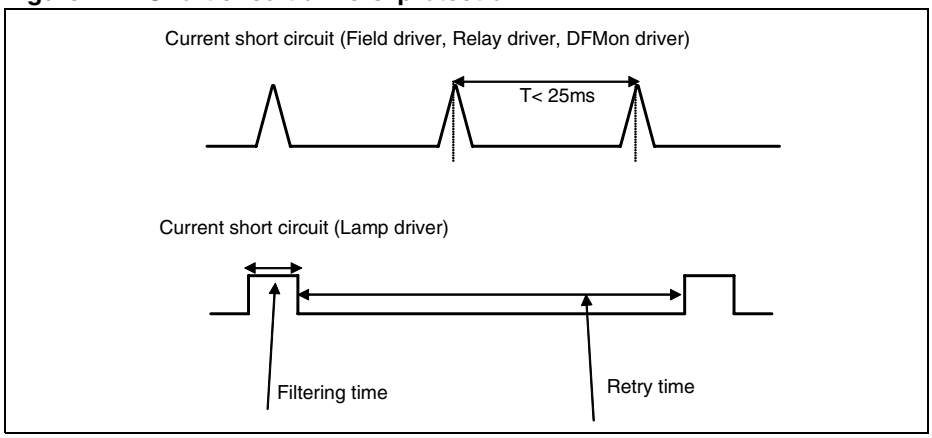


Figure 14. Short circuit drivers' protection



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

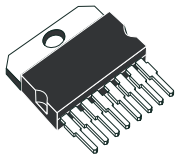
In order to meet environmental requirements, ST offers this device in ECOPACK® packages. This package has a Lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label.

ECOPACK is an ST trademark. ECOPACK specifications are available at: www.st.com.

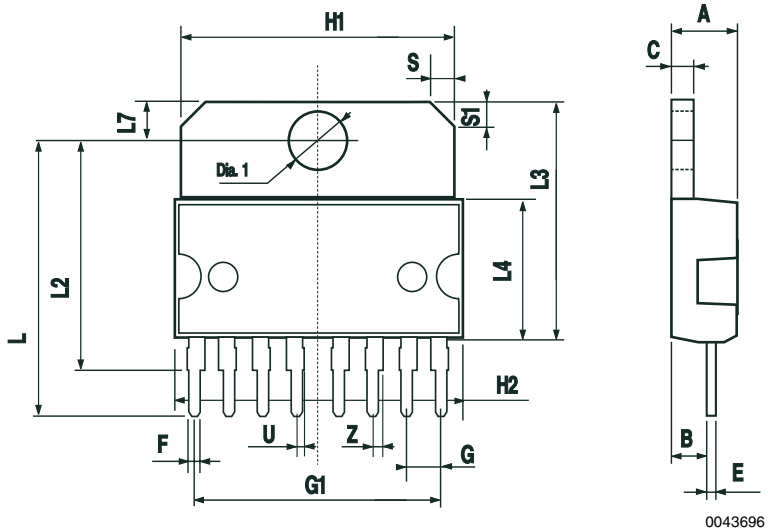
Figure 15. Multiwatt8 mechanical data and package dimensions

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)



5 Revision history

Table 11. Document revision history

Date	Revision	Changes
22-Jun-2004	1	Initial release.
18-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.
28-Nov-2005	4	Added the L9911C part number. Updated the Table 9.
11-Jul-2007	5	Document reformatted following new graphic layout. Updated order codes, see *Table 1*.

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries (“ST”) reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST’s terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST’S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER’S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com