



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

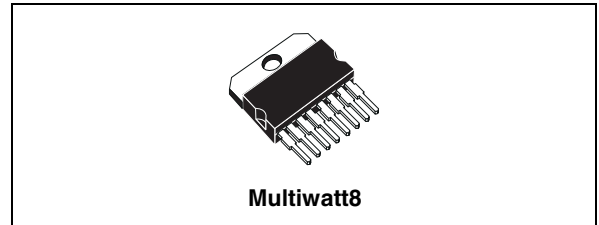


Table 1. Order Codes

| Part Number | Package | Features |
|-------------|------------|-----------------------------|
| L9911A | Multiwatt8 | See Table 9 |
| L9911B | Multiwatt8 | See Table 9 |
| L9911C | 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 μ 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)

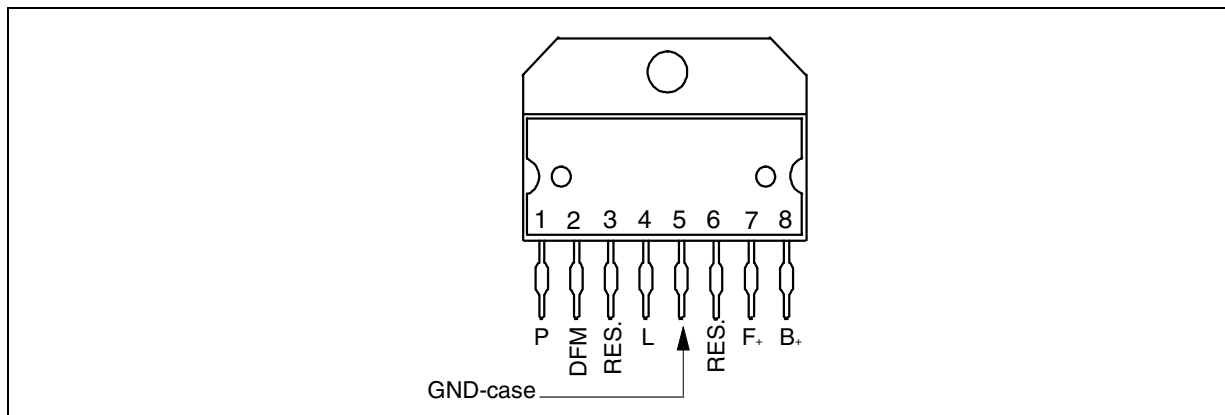


Table 2. Pin Descriptions

| 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°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 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_{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°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) | ± 4 | KV |

Table 4. Thermal Data

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

Table 5. ELECTRICAL CHARACTERISTICS(T_j = -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). | I _{alt} =1A-0.9*I _{nom} ; T _{case} =20°C; 1400<rpm<RPM _{MAX} (Fig. 3) | 14.0 -4.5 | 14.4 -3.5 | 14.8 -2.5 | V mV/°C |
| Vreg 2 | | I _{alt} =10A; T _{case} =23°C; rpm=6000rpm;15V max (Fig. 4) | 14.35 -11.8 | 14.5 -10 | 14.65 -8.2 | V mV/°C |
| Vreg 3 | | I _{alt} =10A; T _{case} =23°C; rpm=6000rpm (Fig. 5) | 14.35 -6 | 14.5 -4 | 14.65 -2 | V mV/°C |
| Delta V _{rpm} | | 1400<rpm<RPM _{MAX} ; I _{alt} =10A | | | 200 | mV |
| Delta V _{load} | | 5A<I _{alt} <I _{nom} ; rpm=6000rpm | | | 250 | mV |
| Vreg-less | Reg. Voltage without Battery | I _{alt} = 3A resistive; T _{case} =25°; 2000<rpm<RPM _{MAX} | 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 | T _j = 150°C; I = 4.5A | | | 0.6 | V |
| | | T _j = 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; 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 |
| 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 | I _{field} = 3A resistive (Fig. 7) | 10 | | 50 | μs |
| t_fall | Output Voltage Fall Time | I _{field} = 3A resistive (Fig. 7) | 10 | | 50 | μs |
| Fsw_F+ | Field switching frequency | I _{alt} =1A~0.9*I _{nom} ;1400rpm<rpm<RPM _{MAX} | 250 | | 400 | Hz |
| If_leak | Output Field Driver Leakage Current | B+ = 24V; VF+ = 0 | | | 10 | μA |

Table 5. ELECTRICAL CHARACTERISTICS (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 | Fig. 8 | 26.56 | 31.25 | 35.94 | % |
| VH_SAT | High Side Driver Saturation Voltage (Fig. 10) | With driver I _{source} =500mA | | | 1.5 | V |
| VL_SAT | Low Side Driver Saturation Voltage (Fig. 10) | With driver I _{sink} =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 _L = 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 _{alt} =1A~0.9*I _{nom} ;1400rpm<rpm<R PMMAX; I _{sink} =14mA | 125 | | 200 | Hz |
| VL-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 | 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-B | | Vreg-2 / Config-C | | Vreg-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 | L9911B | nya | nya | nya | nya | nya | nya | nya | nya | nya |
| LRC-B | nya | nya | L9911A | nya | L9911C | 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 3. Vreg-1

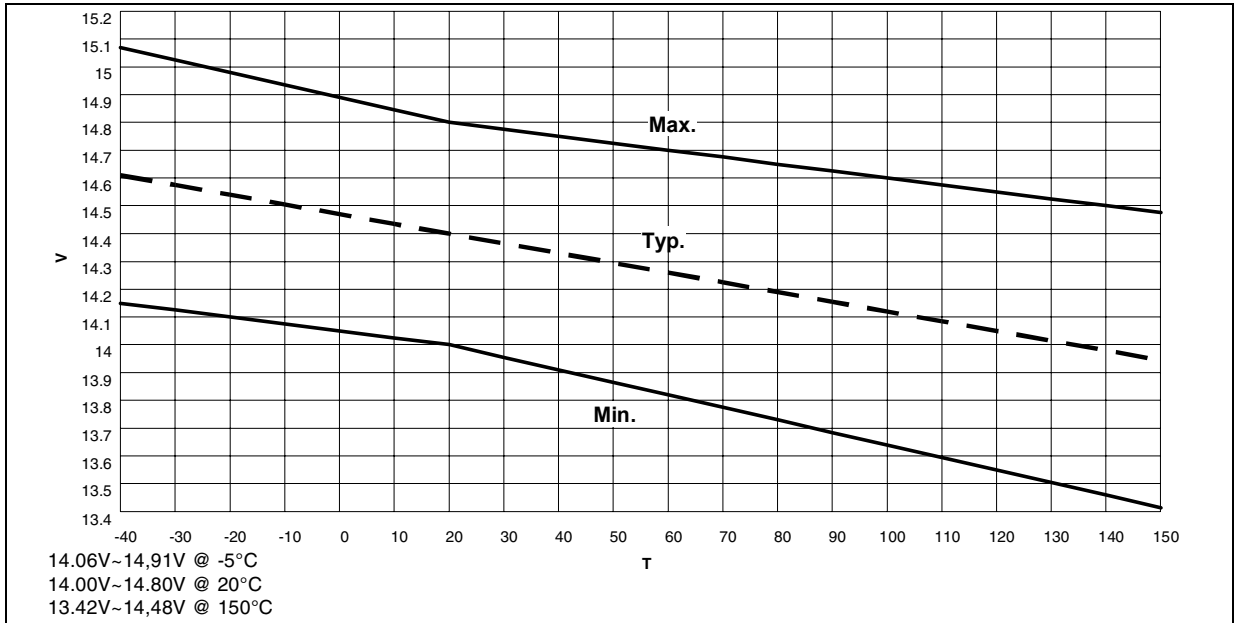


Figure 4. Vreg-2

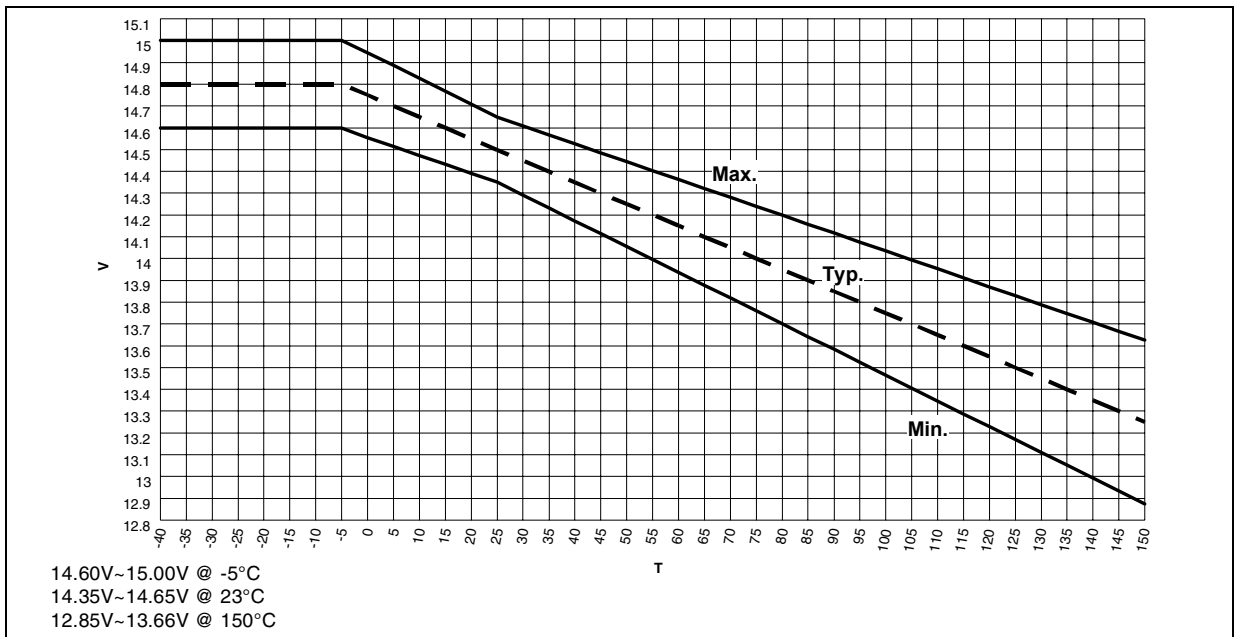


Figure 5. Vreg-3

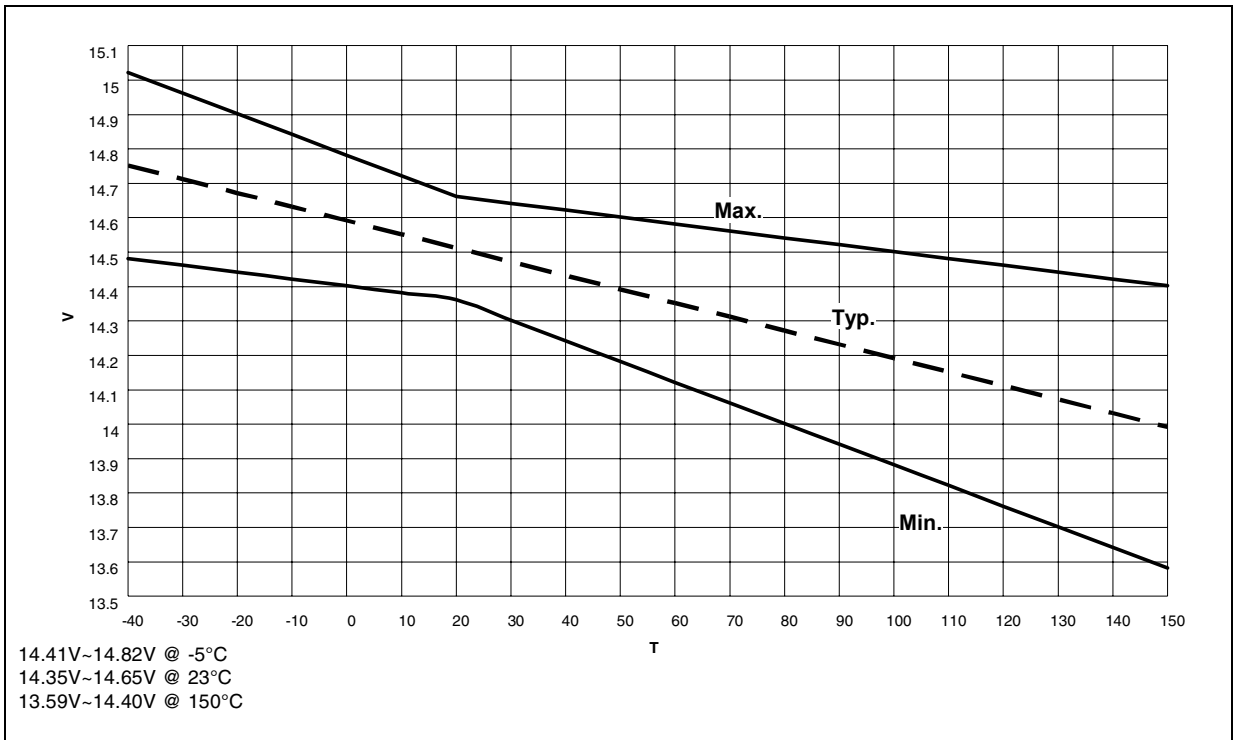


Figure 6. Output Voltage rise/fall time (F+, DFM)

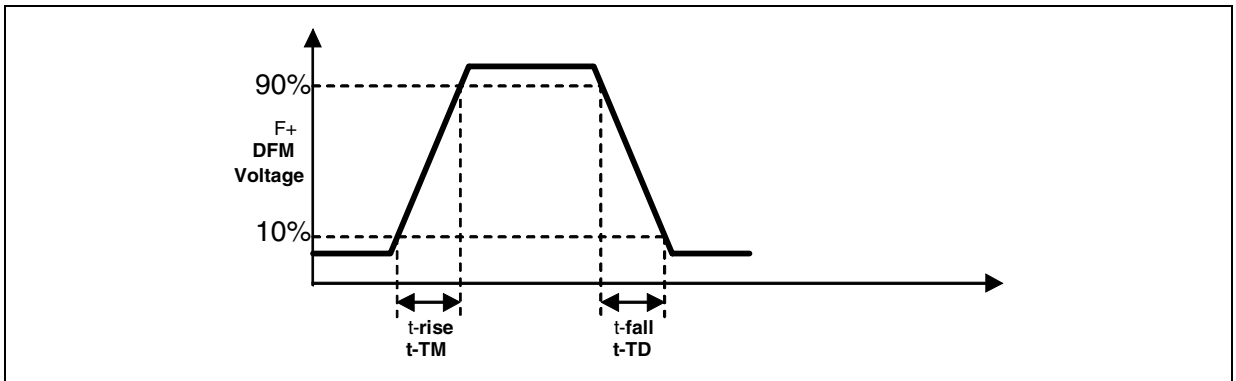
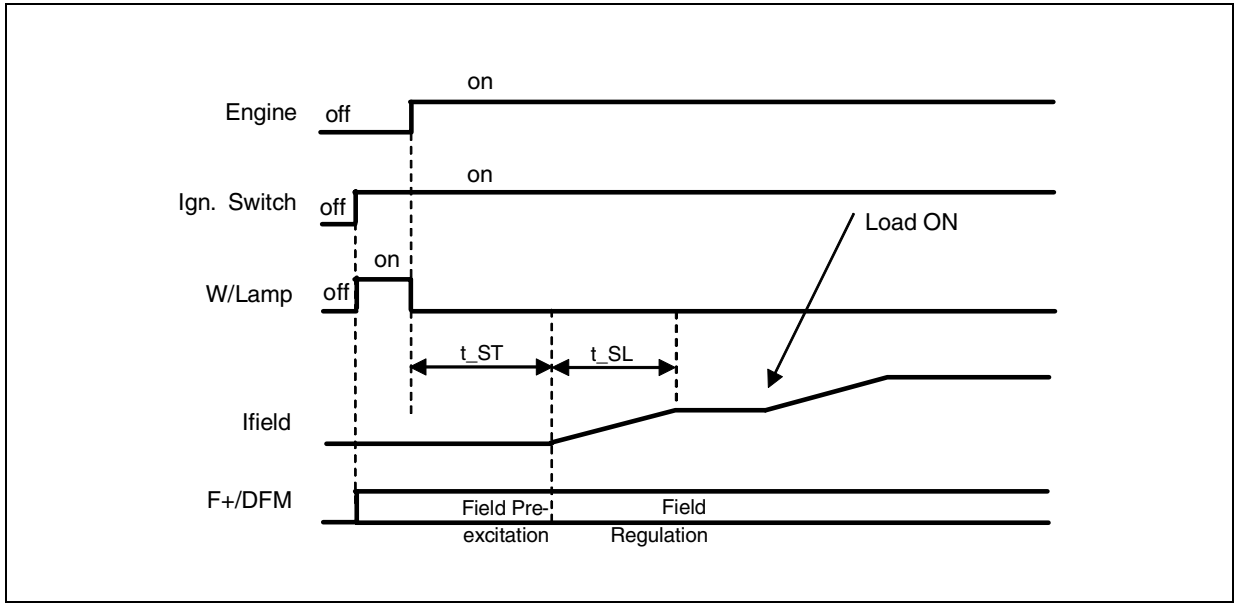


Figure 7. Phase Regulation Characteristics



PRINCIPLE OF PHASE REGULATION:

When VB+ is above the regulated voltage, the field driver is controlled to keep phase peak voltage from falling below VPHH1.

If phase peak voltage drops below VPHL1, phase regulation does not work.

Figure 8. Application Diagram

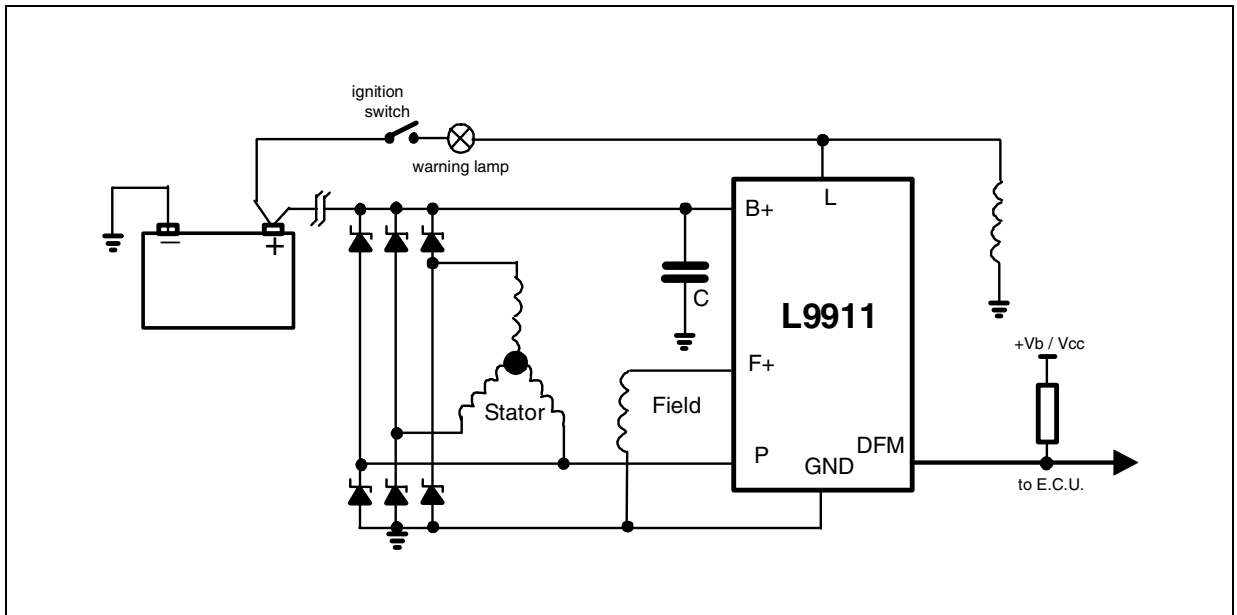


Figure 9. High Side/Low side driver saturation

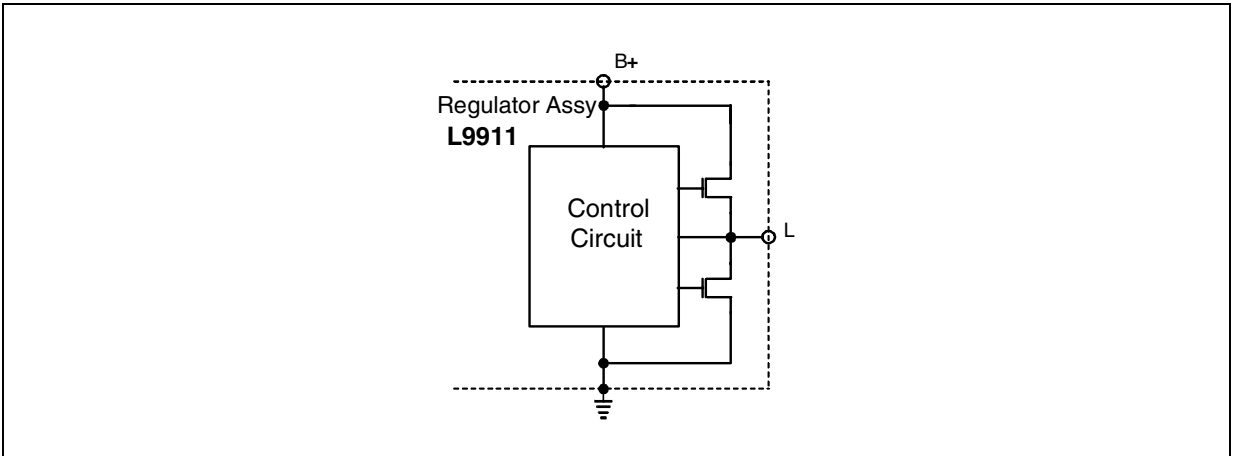


Figure 10. Test mode to cancel soft start/attack

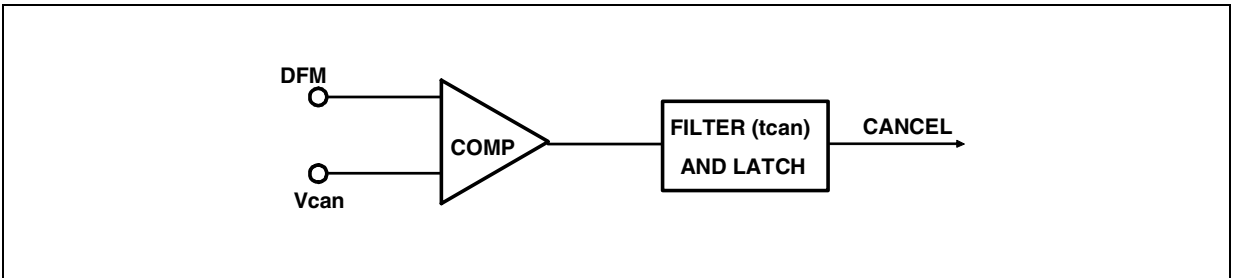


Figure 11. Soft-start enable frequency range

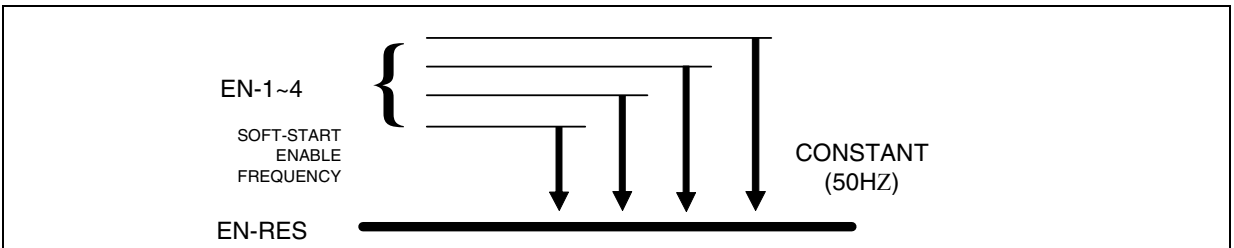


Figure 12. Soft start characteristics (always activated at engine start)

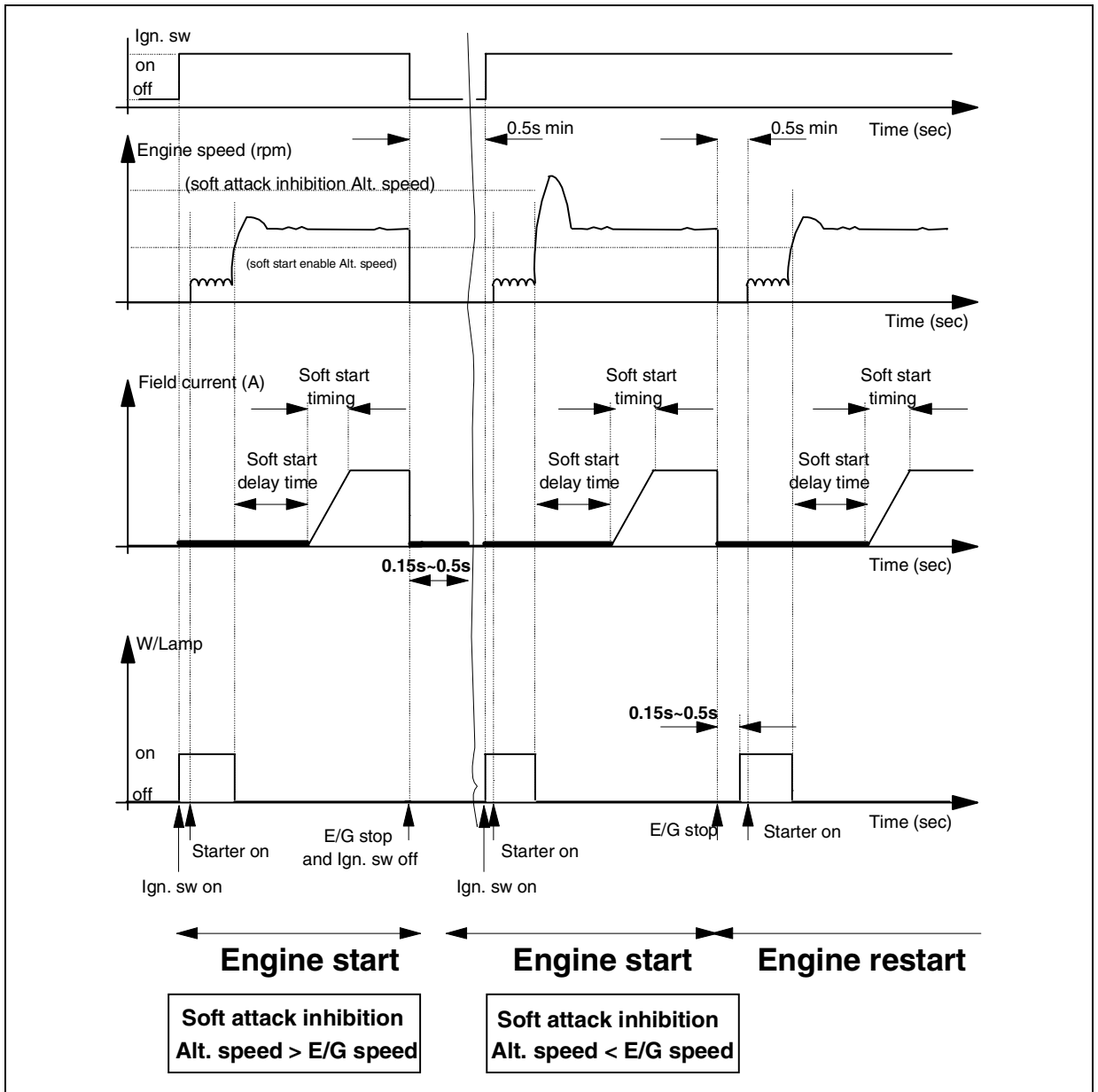


Figure 13. Soft Start/attack Characteristics

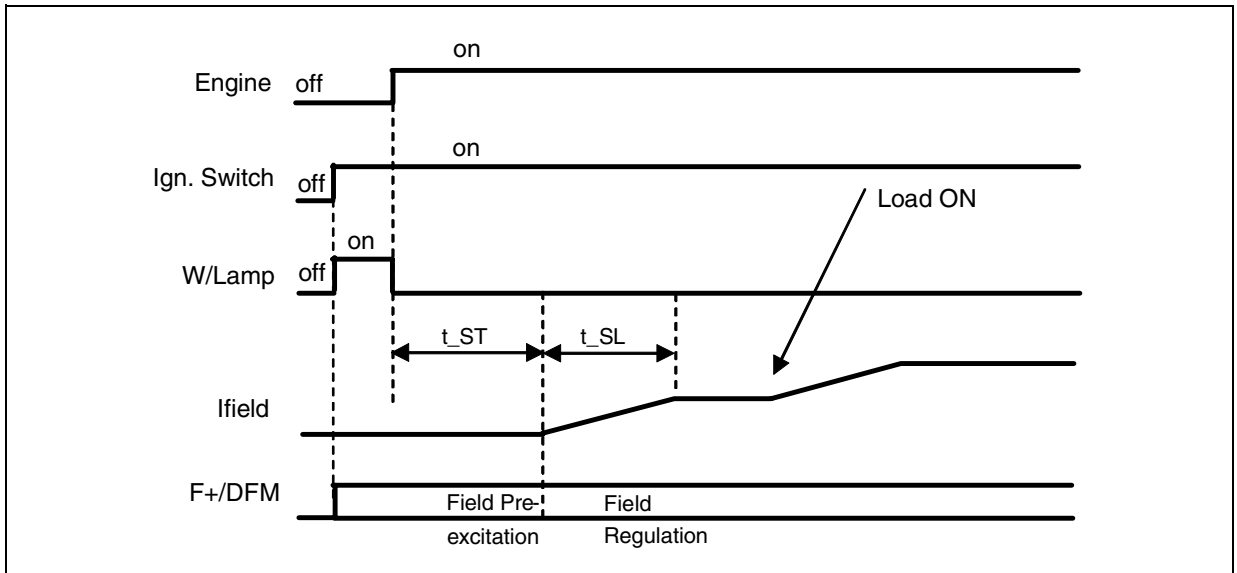


Table 10. Fault Detection

| Root Cause | Signal | Effect | Test detect |
|------------------------------------|--------|--------------------------|-----------------------------|
| Alternator belt breaking | P | Alternator disexcitation | $VP < VPHH1$ & $VB+ < Vreg$ |
| 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 | $VB+ < Vuv$ |

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

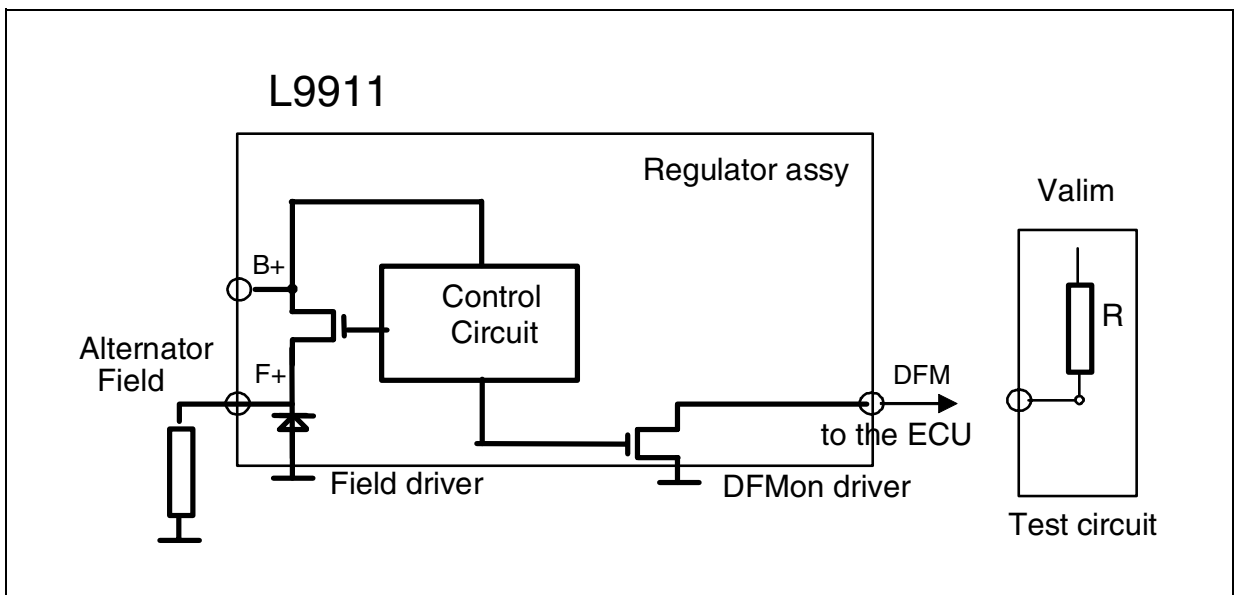
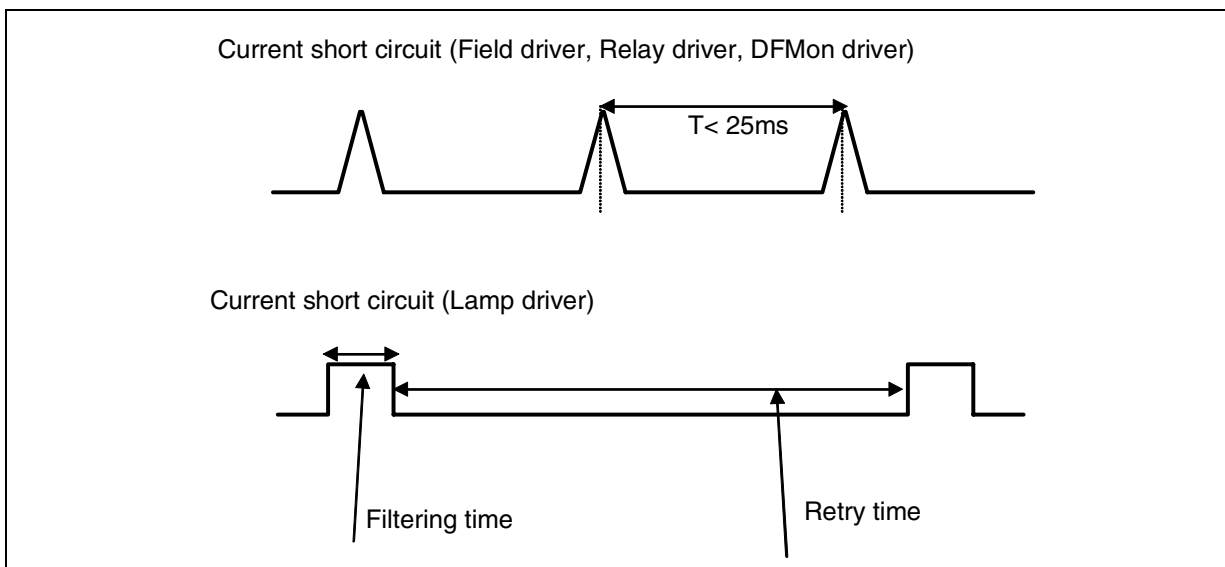


Figure 15. Short circuit drivers' protection

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[®] 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. ECOPACK is an ST trademark.

ECOPACK specifications are available at: www.st.com.

Figure 16. Multiwatt8 Mechanical Data & Package Dimensions

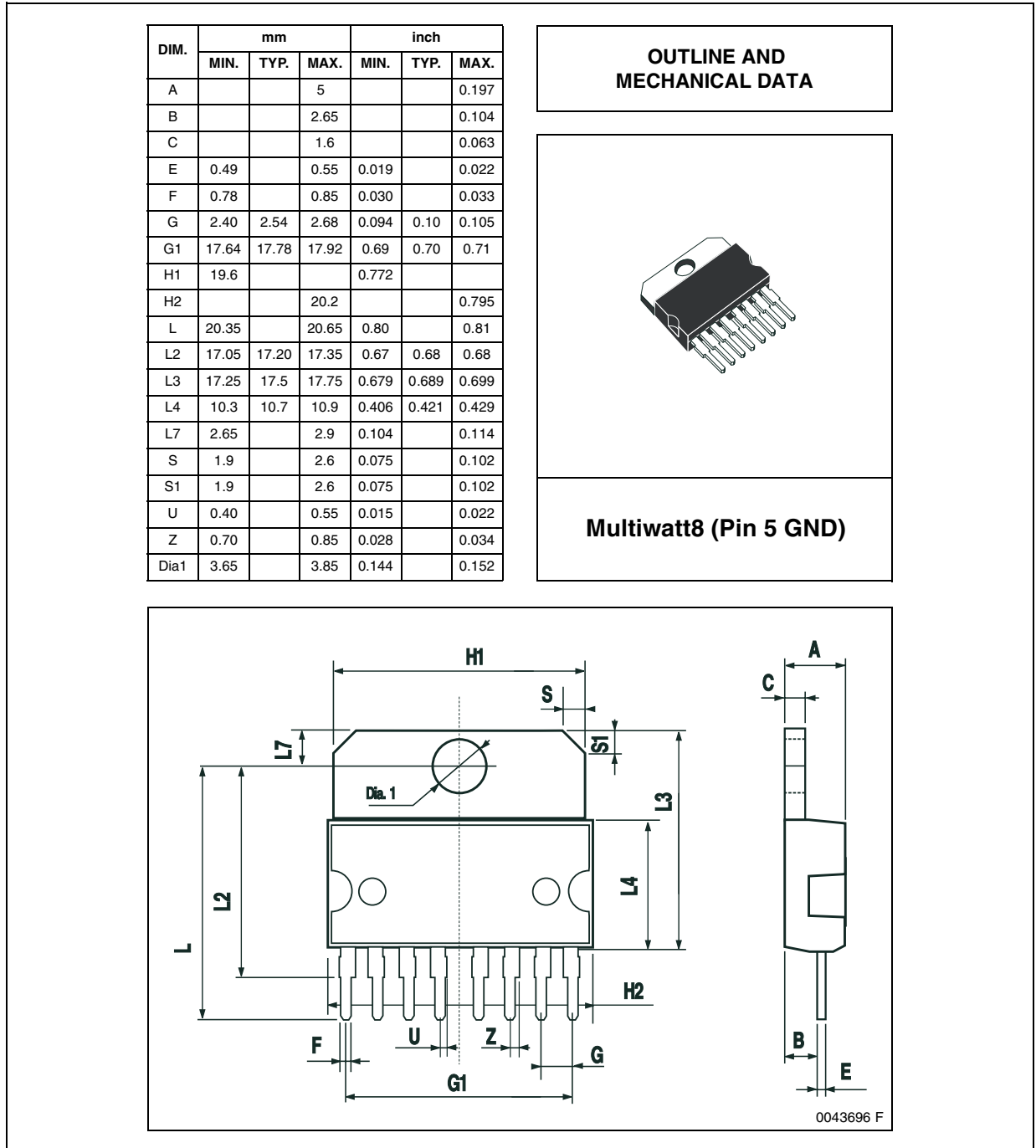


Table 11. Revision History

| Date | Revision | Description of Changes |
|-------------|-----------------|--|
| 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. |
| 28-Nov-2005 | 4 | Added the L9911C part number. Updated the Table 9. |

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