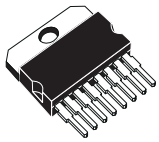
# L9407F

## CAR ALTERNATOR VOLTAGE REGULATOR

**PRODUCT PREVIEW**

- FULLY MONOLITHIC DESIGN
- LOW 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)



**Multiwatt 8**
**ORDERING NUMBER: L9407F**

### DESCRIPTION

The L9407F 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.

### 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

### 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 regulators are a self-oscillating type this frequency depends on the whole system parameter set including 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 application (2.2uF or 2.7uF) must be inserted between A+ and ground when using the device with very long cables.

### PROTECTION

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

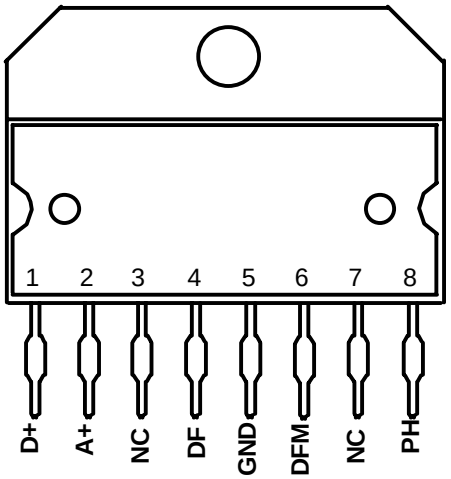
### DIAGNOSIS

The circuit detects fault conditions related to the phase and DF 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.

### LOAD RESPONSE CONTROL

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

## PIN CONNECTION




## PIN DESCRIPTION

| N° | Pin | Function |
|---|---|---|
| 1 | D+ | Lamp terminal low side driver; relay terminal high side driver |
| 2 | A+ | Alternator output voltage supply |
| 3 | NC | Not connected |
| 4 | DF | Field low side driver output |
| 5 | GND | Ground |
| 6 | DFM | Field monitor output |
| 7 | NC | Not connected |
| 8 | PH | Phase sense input |

## ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_S$ | DC Supply Voltage (2 min. @ 25°C) [all pins vs. GND] | 24 | V |
| | Transient Supply Voltage (load dump) [see application circuit] t<500ms | 40 | V |
| | Transient Supply Voltage (low energy spikes) [see application circuit] ISO7637-1 pulse 1,2,3 /ISO7637-3 | 100 (clamped at 60 by application) | V |
| $T_j$ | Junction temperature range | -40 to 170 | °C |
| $T_{stg}$, $T_{case}$ | Storage and case temperature range | -40 to 150 | °C |
| $P_{tot}$ | Total power Dissipation (@ Tcase = 150°C, Ifield = 5A) | 8 | W |
| | Reverse Voltage (see application diagram) @ 25°C, T = 15 sec all pins, except for PH (normal working condition) | -2.5 | V |
| | DC Pin Current on DF, A+, GND (bonding limitation) | 15 | A |
| | ESD Voltage MILSTD883C (All pins vs.GND) | ±4 | KV |

## THERMAL DATA

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $R_{th\ j\text{-}case}$ | Thermal Resistance Junction to Case | 0.6 | °C/W |

## ELECTRICAL CHARACTERISTCS

($T_{case}$ = -40ºC ÷ 150ºC; unless otherwise specified)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| Vbat | Operating Supply Voltage | | 6 | | 18 | V |
| Ib-sinked | Supply Battery Current | | | | 50 | mA |
| Ib-stby | Stand-by Current | Vbat = A+, DF = 12.5V | | | 500 | uA |
| Vreg | Regulated Volt. & Therm. Drift | Ialt=1A-0.9*Inom; Tcase=20ºC; 1200<rpm<RPMMAX; Vreg clamped at 14.8V Max. (Fig.3) | 13.9<br>-4.5 | 14.35<br>-3.5 | 14.8<br>-2.5 | V<br>mV/°C |
| fsw | Switching Frequency | preexcitation | 30 | | 400 | Hz |
| | Delta Vrpm | 1500<rpm<RPMMAX; Ialt=5A; Tcase=23ºC | | | 200 | mV |
| | Delta Vload | 5A<Ialt<Inom; rpm=6000rpm; Tcase=23ºC | | | 250 | mV |
| Vreg | Reg. Voltage without Battery | Ialt = 3A resistive; Tcase=25º; 2000<rpm<RPMMAX | 12 | | 16 | V |
| Vov | D+ Drivers Disable Threshold | Voltage on pin A+ to have D+ OFF | 18 | | 22 | V |
| Tj-sd | Thermal Shut-down | D+/DF = OFF STATE | 180 | 200 | 220 | ºC |
| Tj-sd-hys | Thermal Shut-down hysteresis | D+/DF from OFF STATE (due to thermal shutdown) to ON STATE | Tj-sd-2 | | Tj-sd-10 | ºC |
| Vuv | Low voltage detection threshold | D+ low side driver ON after diagnosis delay time | 7.7 | 8.6 | 9.5 | V |
| Vuv-hys | Low voltage detection threshold hysteresis | D+ low side driver OFF without delay | Vuv + 0.40 | Vuv + 0.50 | Vuv + 0.60 | V |
| Ron LSD | Low Side Driver Rdson | T = 150ºC; I = 4.5A | | | 189 | mΩ |
| Ron LSD | Low Side Driver Rdson | T = 25ºC; I = 7A | | | 107 | mOhm |
| Vf | Freewheeling diode DF | I=5A | | | 2 | V |
| If_SCTH | Short Circuit Threshold DF | DF = 12V; Tcase = -40ºC | 11 | | 18 | A |
| | | DF = 12V; Tcase = -25ºC | 8.5 | | 18 | A |
| | | DF = 12V; Tcase = -150ºC | 5.5 | | 18 | A |
| Vs1 | Output Short to GROUND DF Threshold | | 2.1 | | 3.9 | V |
| FS_duty | Pre-excitation F.S.D.F. | f = 333Hz +/- 15% | 15.93 | 18.75 | 21.57 | % |

**ELECTRICAL CHARACTERISTCS** (continued)
($T_{case}$ = -40ºC ÷ 150ºC; unless otherwise specified)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| t_ST | Soft Start Delay Time (see fig. 5) | activated always at engine start | | 0 | | s |
| t_SL | Soft Attack Time / Soft Start Time (see fig. 5) | from 0 to 100% field duty cycle | 2.45 | 3 | 3.45 | s |
| Bl | Soft Attack Blind Zone | percentage of maximum duty cycle immediate variation at soft attack | 0 | | 10 | % |
| t-rise | Output Voltage Rise Time | Ifield = 3A resistive (Fig. 6) | 4 | | 50 | µs |
| t_fall | Output Voltage Fall Time | Ifield = 3A resistive (Fig. 6) | 5 | | 50 | µs |
| If_leak | Output Field Driver Leakage Current | DF = 24V | | | 1 | mA |
| VH_SAT | High Side Driver Saturation Voltage (Fig. 9) | I source = 1A | | | 1.2 | V |
| VL_SAT1 | Low Side Driver Saturation Voltage | I sink = 0.5A | | | 2 | V |
| VL_SAT2 | Low Side Driver Saturation Voltage | I sink = 0.3A | | | 1.5 | V |
| VLSB | Selfbias without supply Lamp driver Voltage | | | | 4 | V |
| IHSC | High Side Driver short circuit current (Fig. 9) | A+ = 17.5V; D+ = GND | 1.2 | | 3 | A |
| ILSC | Low Side Driver short circuit current | A+ = D+ = 17.5V | 0.7 | | 2.5 | A |
| VthD+ | Enable Regulator Voltage D+ | | 0.5 | 0.7 | 0.9 | V |
| IthD+ | Enable Regulator pull-down Current D+ | | 0.4 | | 3.5 | mA |
| L-t-D | Lamp on delay at Ign. switch turn on | (Fig. 7) | | | 2 | ms |
| Vcan | Test mode to cancel soft start/ attack (voltage) | (Fig. 8) | 36 | | 44 | V |
| VPHL1 | Enable control voltage input high threshold | square wave f = 1KHz | 0.67 | 0.795 | 0.92 | V |
| t_PH | PH Filtering Time | | 50 | | 200 | µs |
| VPHH1 | Diagnosis phase loss input high threshold | | 9 | 10.25 | 11.5 | V |
| VPHH2 | Diagnosis phase loss input low threshold | guaranteed by design | 4 | 5 | 6 | V |
| tPHd | Diagnostic PH Filtering Time | guaranteed by design | 50 | | 200 | µs |
| I_Th-PH | Phase Pull-down Current | | 1 | | 8 | mA |

**ELECTRICAL CHARACTERISTCS** (continued)
($T_{case}$ = -40ºC ÷ 150ºC; unless otherwise specified)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| EN | Soft start enable frequency range | Tcase = 25ºC<br>Tcase = -40 to150ºC | 144<br>136 | 160<br>160 | 176<br>184 | Hz<br>Hz |
| f_RESS_SS | Reset frequency range to enable soft start | | 40 | 50 | 60 | Hz |
| DISAB | Soft start enable frequency range | Tcase = 25ºC<br>Tcase = -40 to150ºC | 367<br>347 | 408<br>408 | 449<br>469 | Hz<br>Hz |
| f-dfm | Output open drain switching freq. | preexc. mode; Isink=14mA | 30 | | 400 | Hz |
| VL-DF-MON | Output low voltage saturation | I-sink=14mA | | | 1.5 | V |
| I-DF-MON | Short circuit current protection | V-DF-MON=24V field fully on | 15 | | 120 | mA |
| Ilk-DF-MON | Output leakage current | V-DF-MON=24V field off | | | 0.1 | mA |
| t-TM | Output voltage rise time | R=2.7K Ohm; C=1nF;<br>Valim=13.5V (Fig. 6) | 0.05 | | 50 | us |
| t-TD | Output voltage fall time | R=2.7K Ohm; C=1nF;<br>Valim=13.5V (Fig. 6) | 0.05 | | 50 | us |
| t-D | Diagnostic Alarm Delay Time | | 0.15 | | 0.5 | s |

**Figure 1. DF Monitor Electrical configuration**

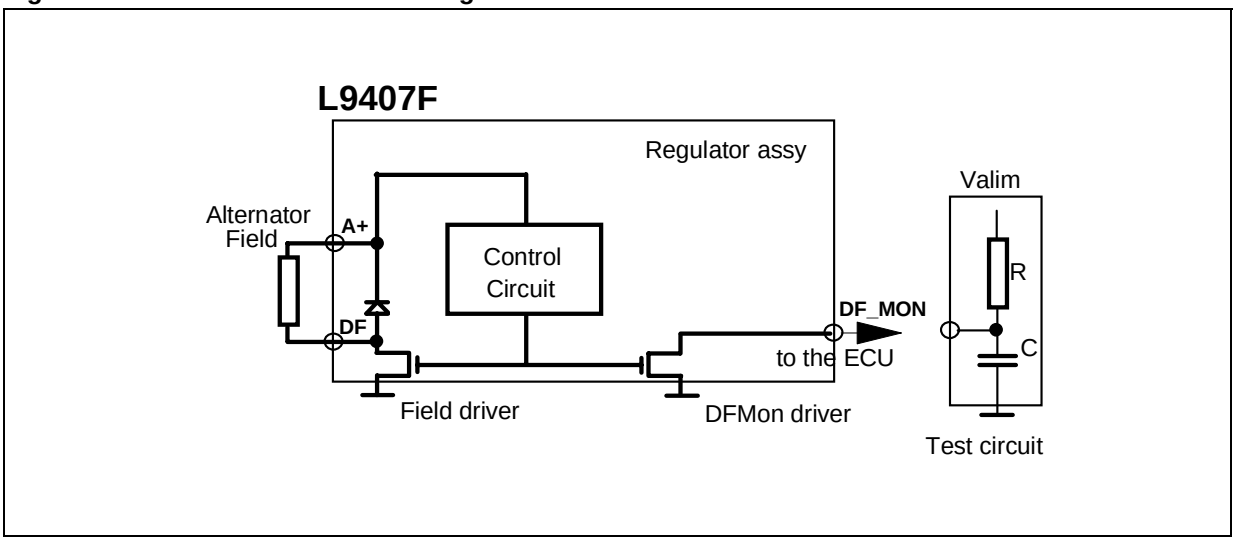


**Figure 2. Application Diagram**

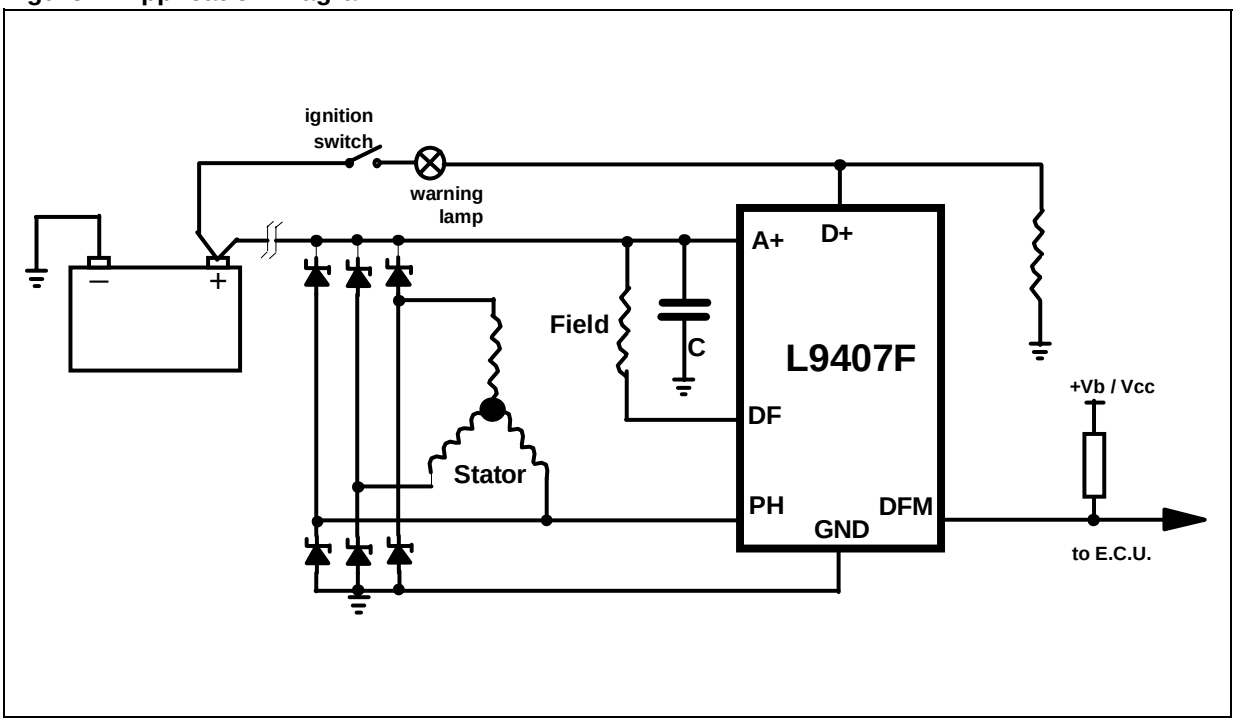



**Figure 3. L9407F THERMAL COMPENSATION (Vreg. )**

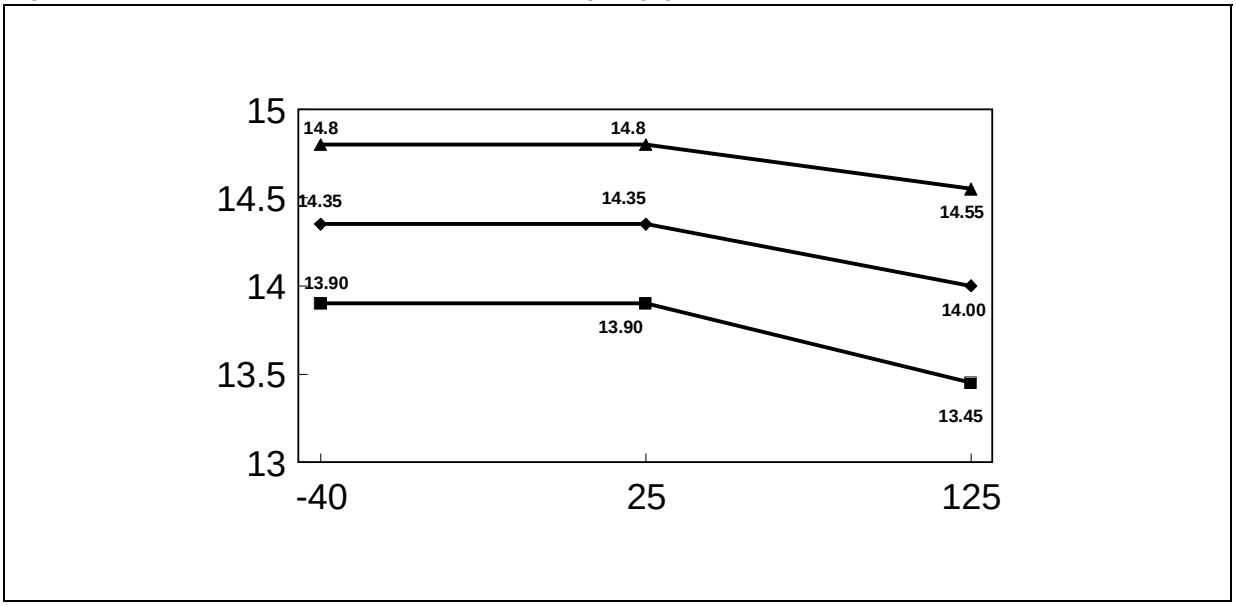


**Figure 4. Characteristics (Active always at engine start)**

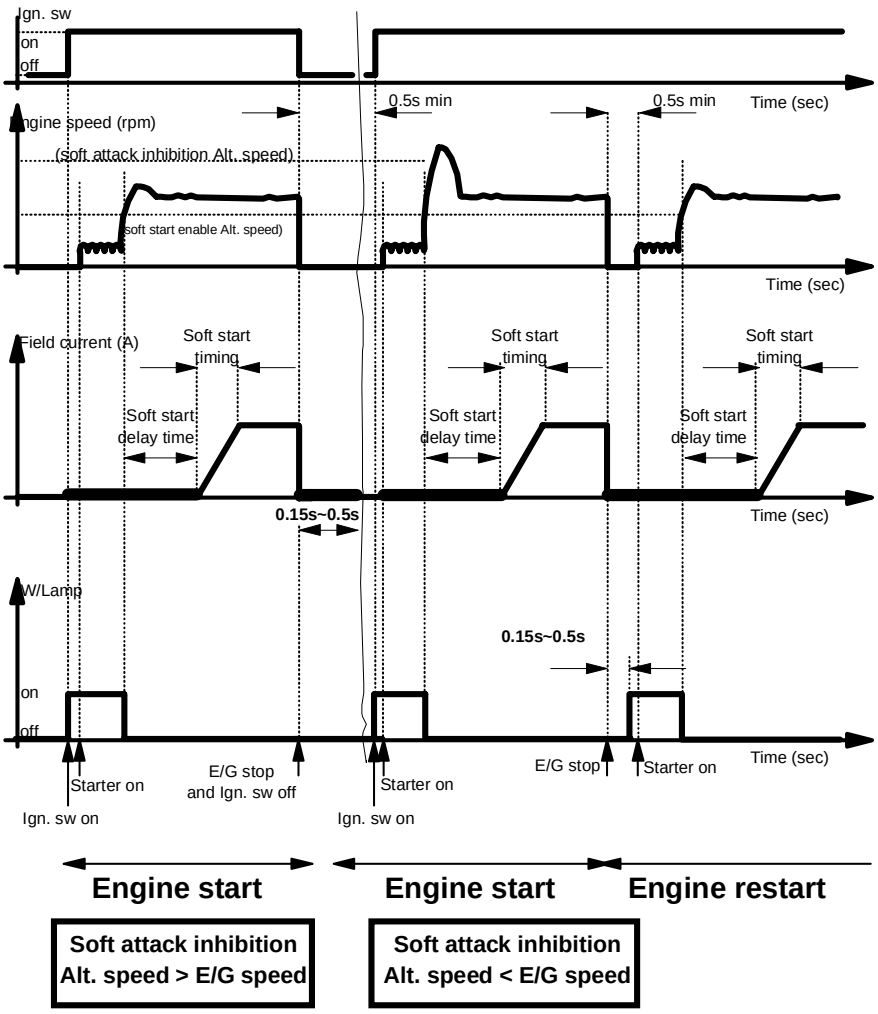



**Figure 5. Soft Start/attack Characteristics**

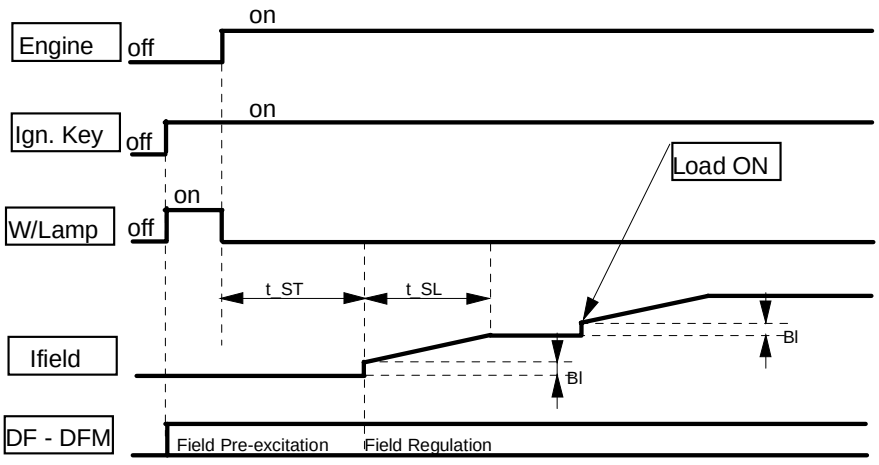


**Table 1. FAULT DETECTION TABLE**

| Root Cause | Signal | Effect | Test detect |
|---|---|---|---|
| Alternator belt breaking | PH | Alternator disexcitation | VPH<VPHH & VA+<Vreg |
| Brushes open | PH | Alternator disexcitation | VPH<VPHH & VA+<Vreg |
| Driver Open | PH | Alternator disexcitation | VPH<VPHH & VA+<Vreg |
| Field interruption | PH | Alternator disexcitation | VPH<VPHH & VA+<Vreg |
| Field short circuit to the battery | PH | Alternator disexcitation | VPH<VPHH & VA+<Vreg |
| Field short circuit to the ground | DF | Overvoltage | DF<VS1 & VA+>Vreg |
| Battery discharge (Field Driver open) | A+ | Undervoltage | VA+<Vreg |
| No fully excited | A+ | Undervoltage | VA+<Vuv |
| Battery discharge | A+ | Undervoltage | VA+<Vuv |

The diagnostic result is disabled during the Soft-start delay time t_ST and the soft-start / soft attack timing t_SL

**Figure 6. Output Voltage rise/fall time (DF, DF_MON)**

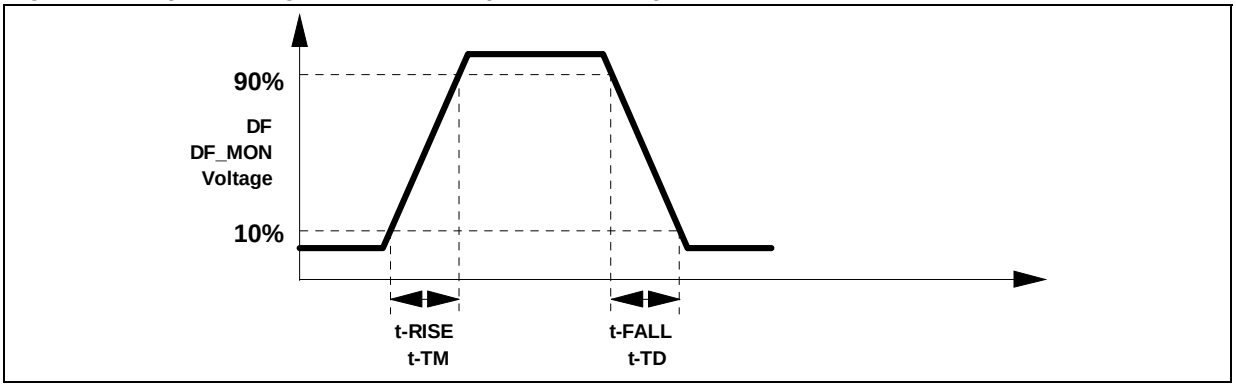



**Figure 7. Lamp on delay at Ign. switch turn on**

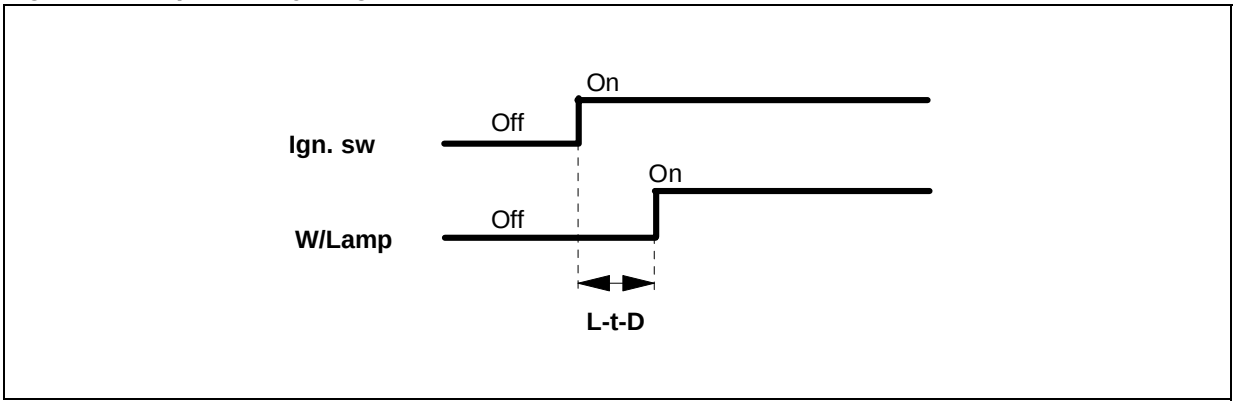


**Figure 8. Test mode to cancel soft start/attack**

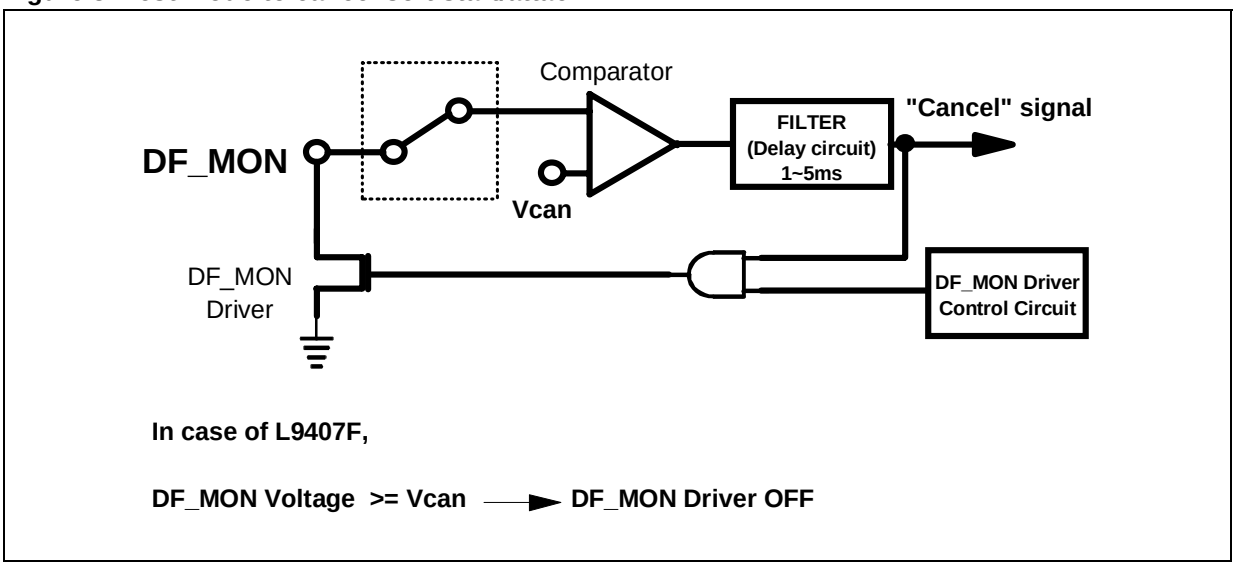
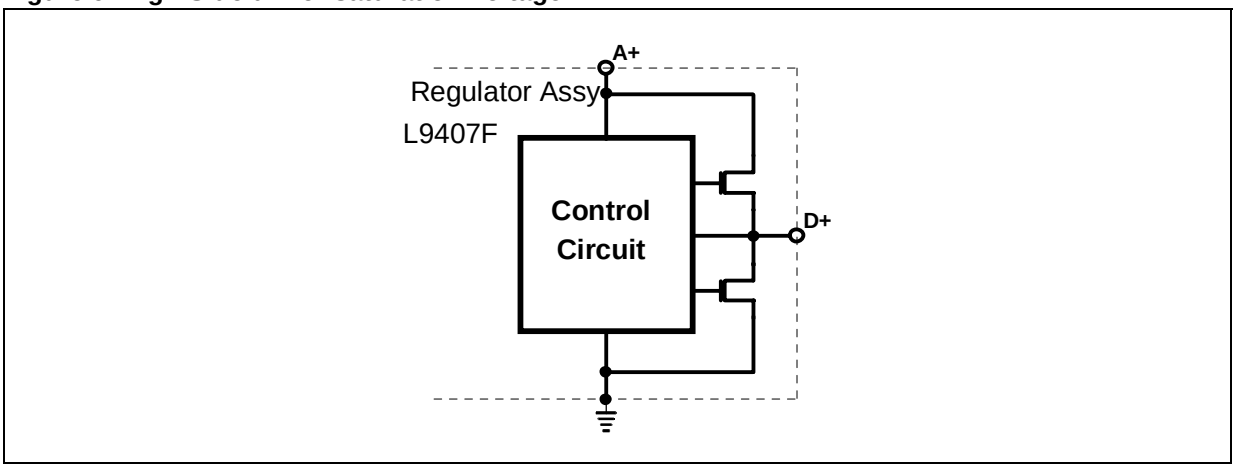


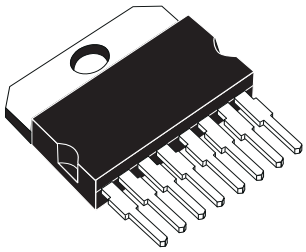

**Figure 9. High Side driver saturation voltage**



| 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 |
| F1 | 0.68 | | 0.75 | 0.027 | | 0.029 |
| 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 |
| L5<br>L5* | 15.45<br>15.05 | | 15.75<br>15.35 | 0.61<br>0.59 | | 0.62<br>0.60 |
| 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 |

L5 = with wedged frame std.
L5* = with wedged frame anchor holes.

## OUTLINE AND MECHANICAL DATA



**Multiwatt8 (Floating)**