

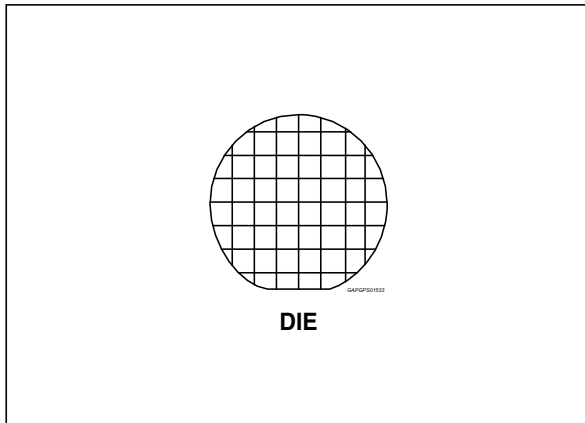


# THE DATASHEET OF L9408FDIETR



## Automotive multifunction smart alternator regulator

Datasheet - production data



- 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)

### Description

The L9408F is a monolithic multifunction alternator voltage regulator.

It includes the control section, the field power stage, fault diagnostic circuit which drives a warning lamp.

### Features

- AEC-Q100 qualified
- Fully monolithic design



Table 1. Device summary

| Order code  | Package | Packing |
|-------------|---------|---------|
| L9408FDIETR | DIE     | -       |

# Contents

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# 1 Pad description

All dimensions are in micrometers.

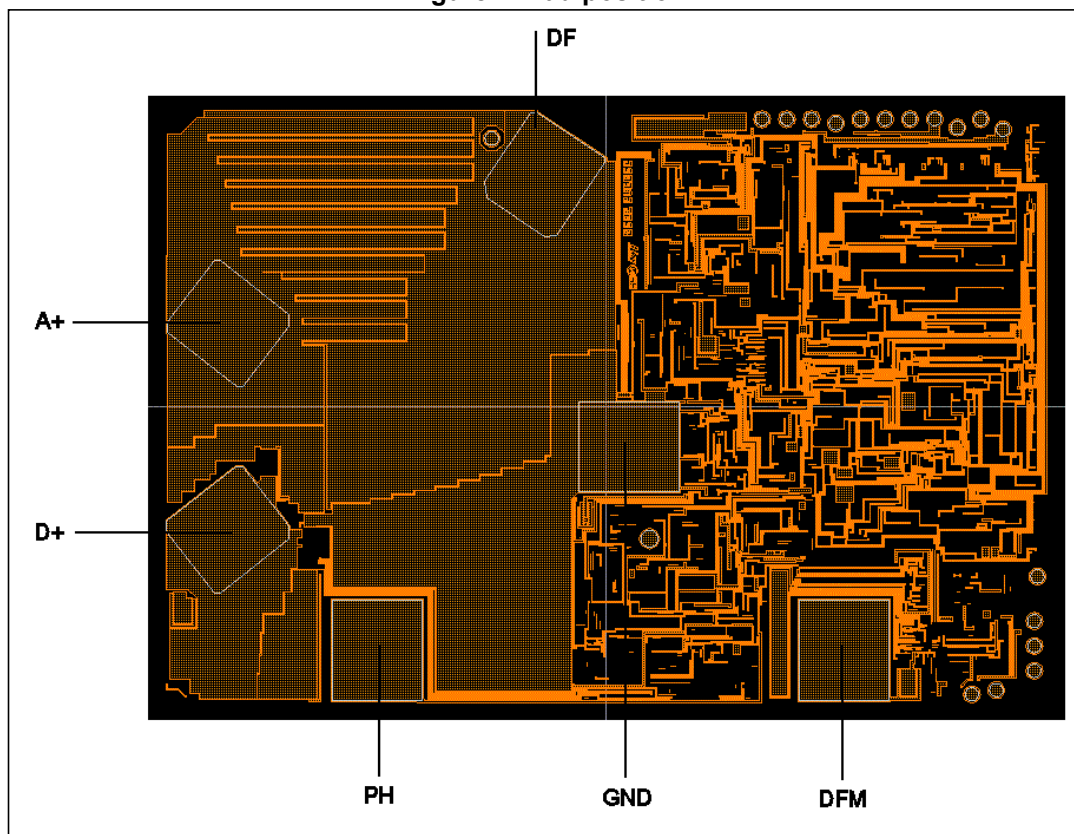
Pad placement values correspond to each pad center coordinates.

Pad placement origin is the lower left corner of the die.

**Table 2. Pad description**

| Pad name | Pad placements |         | Pad dimensions |       |
|----------|----------------|---------|----------------|-------|
|          | X              | Y       | X              | Y     |
| test     | 4299.25        | 4233.25 | 102.5          | 102.5 |
| DF       | 4021.625       | 3827.25 | 948.25         | 917.5 |
| PVREG    | 4445.25        | 2171.75 | 102.5          | 102.5 |
| P51      | 4445.25        | 1982.75 | 102.5          | 102.5 |
| P52      | 4445.25        | 1793.75 | 102.5          | 102.5 |
| P4       | 4414.25        | 1608.75 | 102.5          | 102.5 |
| P3       | 4445.25        | 1423.25 | 102.5          | 102.5 |
| P1       | 4445.25        | 1234.25 | 102.5          | 102.5 |
| P2       | 4445.25        | 1044.75 | 102.5          | 102.5 |
| P0       | 4445.25        | 856.25  | 102.5          | 102.5 |
| P54      | 4380.75        | 680.25  | 102.5          | 102.5 |
| P53      | 4445.25        | 504.25  | 102.5          | 102.5 |
| P50      | 4364.75        | 334.75  | 102.5          | 102.5 |
| OSCITEST | 961.25         | 71.75   | 102.5          | 102.5 |
| P13      | 622.75         | 95.25   | 102.5          | 102.5 |
| P12      | 432.25         | 94.75   | 102.5          | 102.5 |
| P11      | 243.25         | 94.75   | 102.5          | 102.5 |
| P10      | 94.75          | 385.75  | 102.5          | 102.5 |
| P9       | 64.75          | 571.25  | 102.5          | 102.5 |
| DFM      | 398.5          | 1546.5  | 762.0          | 685.0 |
| TW       | 1248.25        | 3029.75 | 128.5          | 128.5 |
| GND      | 1950.0         | 3187.0  | 685.0          | 762.0 |
| PH       | 398.5          | 5105.5  | 762.0          | 685.0 |
| D+       | 1319.25        | 6244.5  | 933.0          | 963.5 |
| A+       | 2888.25        | 6243.0  | 933.0          | 963.5 |

Figure 1. Pad position



## 2 Electrical specifications

### 2.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

| Symbol    | Parameter  | Value      | Unit |
|-----------|--|------------|------|
| $V_S$     | DC supply voltage (2 min. @ 25 °C)                                 | 24         | V    |
| -         | Transient supply voltage (load dump); $t < 500$ ms @ 25 °C         | 40         | V    |
| -         | Transient supply voltage (low energy spikes pulse ISO7637/1)       | 60         | V    |
| $P_{tot}$ | Total power dissipation (@ $T_{case} = 150$ °C, $I_{field} = 5$ A) | 5          | W    |
| -         | Reverse voltage all pins @ 25 °C, $T = 15$ s                       | -2.5       | V    |
| -         | DC pin current on DF, A+, GND pins (bonding limitation)            | 11         | A    |
| -         | ESD voltage (Human body model)                                     | ±4         | kV   |
| $T_j$     | Junction temperature   | -40 to 150 | °C   |
| $T_{stg}$ | Storage temperature  | -40 to 170 | °C   |

### 2.2 Electrical characteristics

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

Table 4. Electrical characteristics

| Symbol       | Parameter   | Test condition   | Min.          | Typ.        | Max          | Unit       |
|--------------|---|--|---------------|-------------|--------------|------------|
| $V_{bat}$    | Operating supply voltage                            | -  | 8.5           | -           | 18           | V          |
| $I_{b-sink}$ | Supply battery current                              | -  | -             | -           | 50           | mA         |
| $I_{b-stby}$ | Standby current                                     | $V_{bat} = 12$ V, $T = 25$ °C  | -             | -           | 300          | $\mu$ A    |
|              |   | $V_{bat} = 12$ V, $T = 40$ °C  | -             | -           | 500          |            |
| $V_{reg}$    | Regulated voltage & therm. drift (standard version) | $I_{alt} = 0.5 \cdot I_{nom}$ ;<br>$rpm = 0.5 \cdot RPM_{MAX}$ ; $T = 20$ °C       | 14.3<br>-4    | 14.45<br>-3 | 14.6<br>-2   | V<br>mV/°C |
|              |   | $I_{alt} = 0.2 \cdot I_{nom}$ ;<br>$rpm = 0.5 \cdot RPM_{MAX}$ ; $T = 20$ °C       | 14.1<br>-11.5 | 14.5<br>-10 | 14.9<br>-8.5 | V<br>mV/°C |
| $f_{sw}$     | Switching frequency                                 | in FSDF  | 30            | -           | 400          | Hz         |
| $V_{rpm}$    | Delta $V_{rpm}$                                     | $1800 < rpm < 12000$ ;<br>$I_{alt} = 0.3 \cdot I_{nom}$                            | -             | -           | 200          | mV         |
| $V_{load}$   | Delta $V_{load}$                                    | $0.1 \cdot I_{nom} < I_{alt} < 0.9 \cdot I_{nom}$ ;<br>$rpm = 0.5 \cdot RPM_{MAX}$ | -             | -           | 200          | mV         |
| $V_{reg}$    | Regulated voltage without battery                   | $I_{alt} = 3$ A resistive  | -             | -           | 16           | V          |

Table 4. Electrical characteristics (continued)

| Symbol                          | Parameter   | Test condition  | Min.              | Typ.               | Max                | Unit |
|---------------------------------|---|---|-------------------|--------------------|--------------------|------|
| V <sub>OV</sub>                 | D+ drivers disable threshold                      | Voltage on pin A+ to have D+ = OFF                      | 18                | -                  | 22                 | V    |
| T <sub>j-sd</sub>               | Thermal shut-down                                 | DF = Off state<br>D+ = Off state                        | 170               | -                  | 200                | °C   |
| T <sub>j-sd-hys</sub>           | Thermal shut-down hysteresis                      | DF, D+ = from off state (due to thermal shutdown) to on | 2                 | -                  | 10                 | °C   |
| R <sub>on</sub>                 | Low side driver R <sub>dson</sub>                 | T <sub>j</sub> = 150 °C; I = 3 A                        | -                 | -                  | 230                | mΩ   |
|                                 |   | T <sub>j</sub> = 25 °C; I = 1 A                         | -                 | -                  | 130                | mΩ   |
| V <sub>F</sub>                  | Freewheeling diode DF                             | I <sub>F</sub> = 5 A                                    | -                 | -                  | 2                  | V    |
| I <sub>fSC</sub> <sup>(2)</sup> | Short circuit threshold DF                        | DF = 12 V; T = -40 to 25 °C                             | 8.5               | -                  | 18                 | A    |
|                                 |   | DF = 12 V; T = 25 to 125 °C                             | 7                 | -                  | 18                 |      |
| V <sub>s1</sub>                 | Output short to ground threshold DF               | -   | 2.1               | -                  | 3.9                | V    |
| FS <sub>DF</sub>                | Pre-excitation F.S.D.F                            | f = 348 Hz ±15%   | 10.62             | 12.5               | 14.38              | %    |
| t <sub>ST</sub>                 | Soft start delay time                             | Activated at first running-on only                      | -                 | 0                  |                    | s    |
| t <sub>SL</sub>                 | Soft attack time                                  | From 0 to 100% field duty cycle                         | 2.5               | 2.88               | 3.39               | s    |
| Bl                              | Soft attack blind zone                            | % of maximum D.C. immediate variation of soft attack    | 0                 | -                  | 10                 | %    |
| t <sub>rise</sub>               | Output voltage rise time                          | I <sub>field</sub> = 3 A resistive                      | 5                 | -                  | 50                 | μs   |
| t <sub>fall</sub>               | Output voltage fall time                          |   | 5                 | -                  | 50                 |      |
| I <sub>flk</sub>                | Output field driver leakage current               | DF = 24 V   | -                 | -                  | 1                  | mA   |
| V <sub>HS</sub>                 | High side driver saturation voltage               | I <sub>source</sub> = 1 A                               | -                 | -                  | 1.2                | V    |
| V <sub>LS</sub>                 | Low side driver saturation voltage                | I <sub>sink</sub> = 0.25 A                              | -                 | -                  | 1.5                | V    |
| V <sub>LSB</sub>                | Self bias without supply lamp driver voltage      | -   | -                 | -                  | 4                  | V    |
| I <sub>HSC</sub>                | High side current limitation                      | A+ = 17.5 V; D+ = GND                                   | 1.2               | -                  | 3                  | A    |
| I <sub>LSC</sub>                | Low side current limitation                       | A+ = D+ = 17.5 V  | 0.45              | -                  | 1.5                | A    |
| V <sub>thD+</sub>               | Enable regulator voltage D+                       | -   | 0.8               | 1                  | 1.15               | V    |
| I <sub>thD+</sub>               | Enable regulator pull-down current                | -   | 0.4               | -                  | 3.5                | mA   |
| DISAB                           | Soft attack inhibition frequency                  | -   | 265               | 313                | 360                | Hz   |
| EN <sub>1</sub>                 | Soft start delay time enable frequency            | -   | 88                | 104                | 120                | Hz   |
| EN <sub>1_hy</sub>              | Soft start delay time enable frequency hysteresis | -   | EN <sub>1-8</sub> | EN <sub>1-10</sub> | EN <sub>1-12</sub> | Hz   |

Table 4. Electrical characteristics (continued)

| Symbol     | Parameter                                | Test condition  | Min.              | Typ.              | Max               | Unit    |
|------------|--|---|-------------------|-------------------|-------------------|---------|
| $V_{PHL1}$ | Enable control voltage PH high threshold | Square wave 1 kHz   | 0.67              | 0.795             | 0.92              | V       |
| $V_{PHL2}$ | Enable control voltage PH low threshold  | -   | $V_{PHL1} - 0.48$ | $V_{PHL1} - 0.57$ | $V_{PHL1} - 0.66$ | V       |
| $t_{PH}$   | PH filtering time                        | -   | 15                | -                 | 120               | $\mu$ s |
| $V_{PHH1}$ | Diag. phase loss high voltage            | -   | 9                 | 10.25             | 11.5              | V       |
| $V_{PHH2}$ | Diag. phase loss low voltage             | -   | 4                 | 5                 | 6                 | V       |
| $t_{PHD}$  | Diagnostic PH filtering time             | -   | 50                | -                 | 200               | $\mu$ s |
| $I_{PH}$   | Phase pull-down current                  | -   | 1                 | -                 | 8                 | mA      |
| $t_D$      | Diagnostic alarm delay                   | -   | 0.48              | 0.575             | 0.65              | s       |
| $f_{DFM}$  | DFM open drain switching frequency       | in FSDF   | 30                | -                 | 400               | Hz      |
| $V_{ol}$   | Output low voltage DFM                   | $I_{sink} = 25$ mA  | -                 | -                 | 1.5               | V       |
| $I_{dfml}$ | Short circuit protection DFM             | $V_{DF\_MON} = 12$ V                                      | 25                | -                 | 200               | mA      |
| $I_{lk}$   | Output leakage current DFM               | $V_{DF\_MON} = 24$ V                                      | -                 | -                 | 0.1               | mA      |
| $t_{TM}$   | DFM output voltage rise time             | $R = 2.7$ k $\Omega$ ; $C = 1$ nF;<br>$V_{alim} = 13.5$ V | 0.05              | -                 | 50                | $\mu$ s |
| $T_{TD}$   | DFM output voltage fall time             | $R = 2.7$ k $\Omega$ ; $C = 1$ nF;<br>$V_{alim} = 13.5$ V | 0.05              | -                 | 50                | $\mu$ s |

1. Available through a metal option of the actual device.
2. Not tested on the die version.

Figure 2. Application diagram

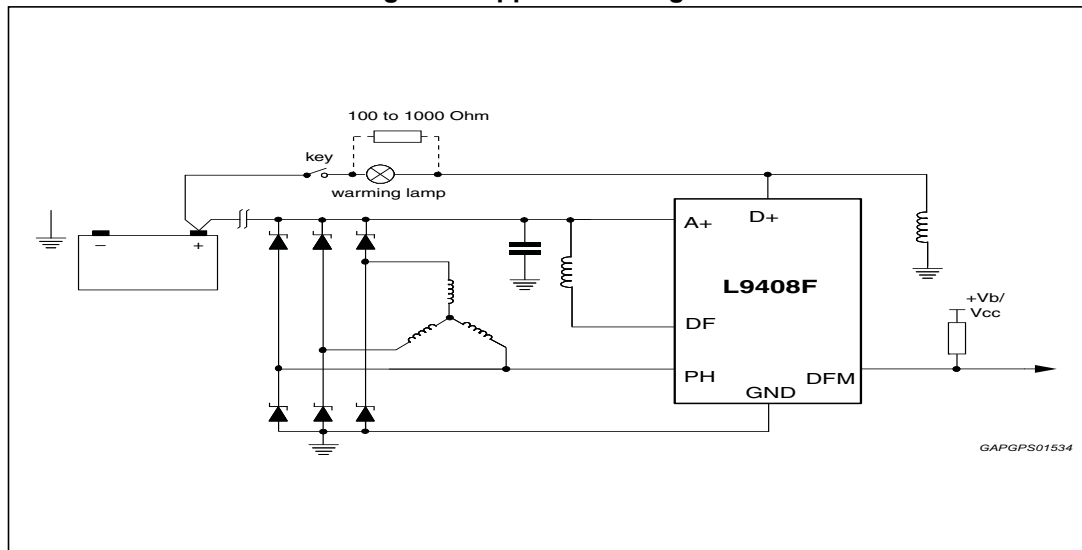


Table 5. Thermal compensation ( $V_{reg}$ , standard version)

| Temperature [°C] | Vreg     |          |          |
|------------------|----------|----------|----------|
|                  | Min. [V] | Typ. [V] | Max. [V] |
| -40              | 14.43    | 14.645   | 14.86    |
| 25               | 14.30    | 14.45    | 14.60    |
| 125              | 13.90    | 14.15    | 14.40    |

Figure 3. Thermal compensation diagram (Vreg, standard version)

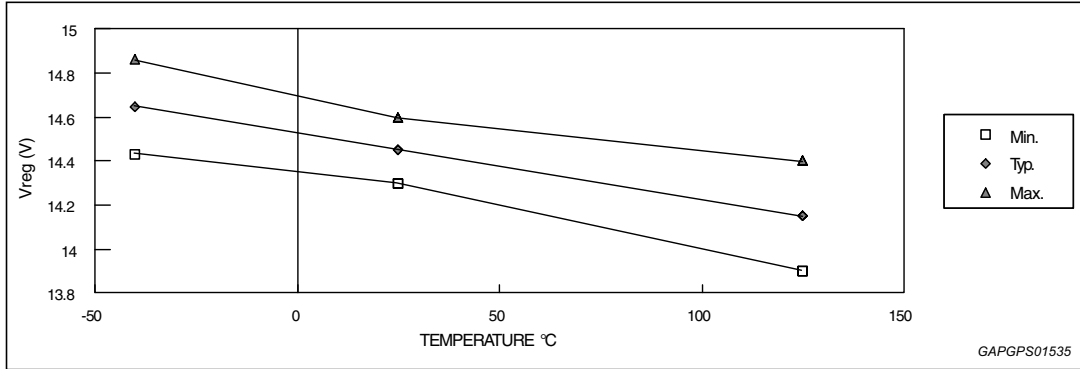


Figure 4. Load transient example

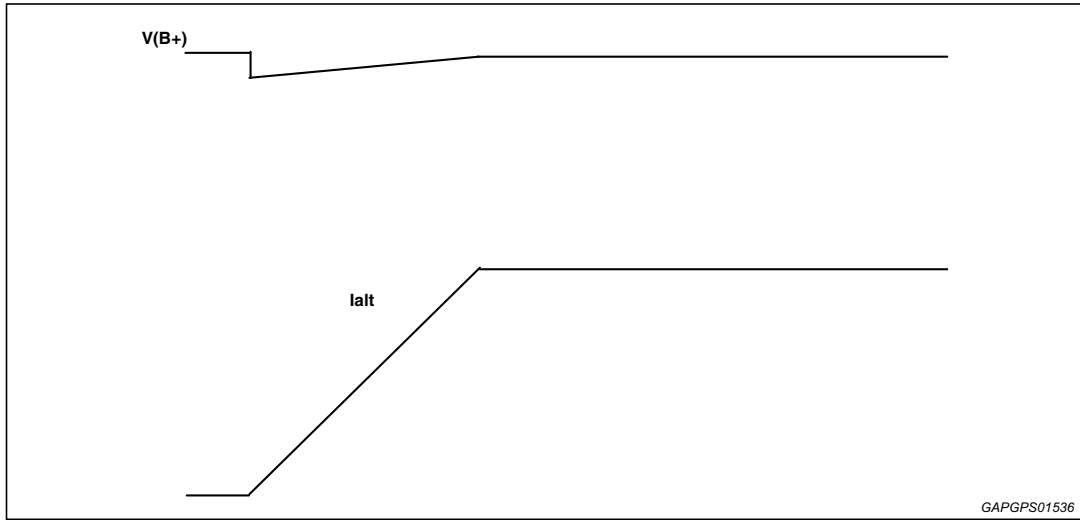


Figure 5. Start-up timing

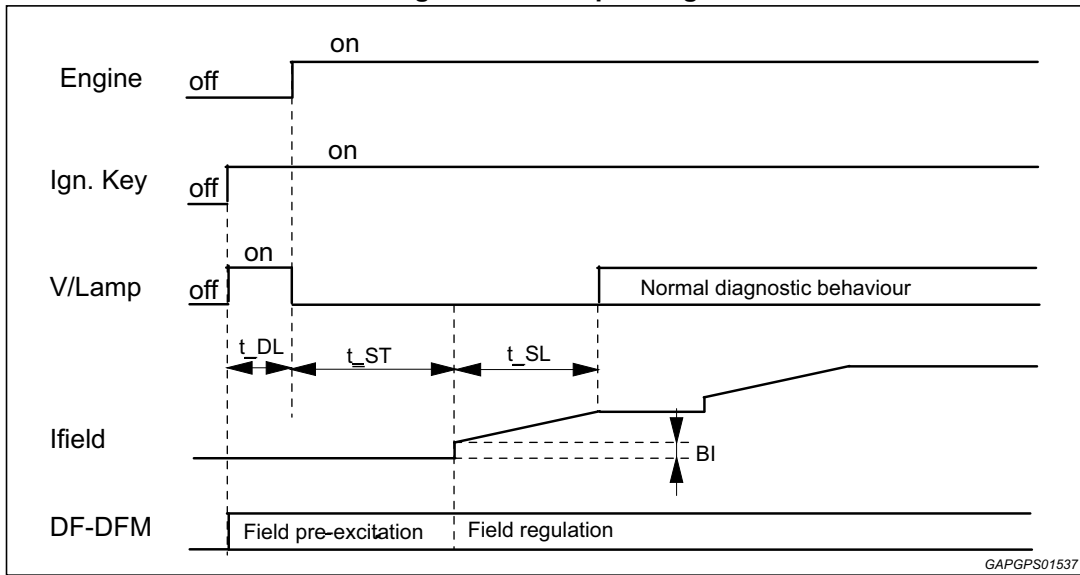
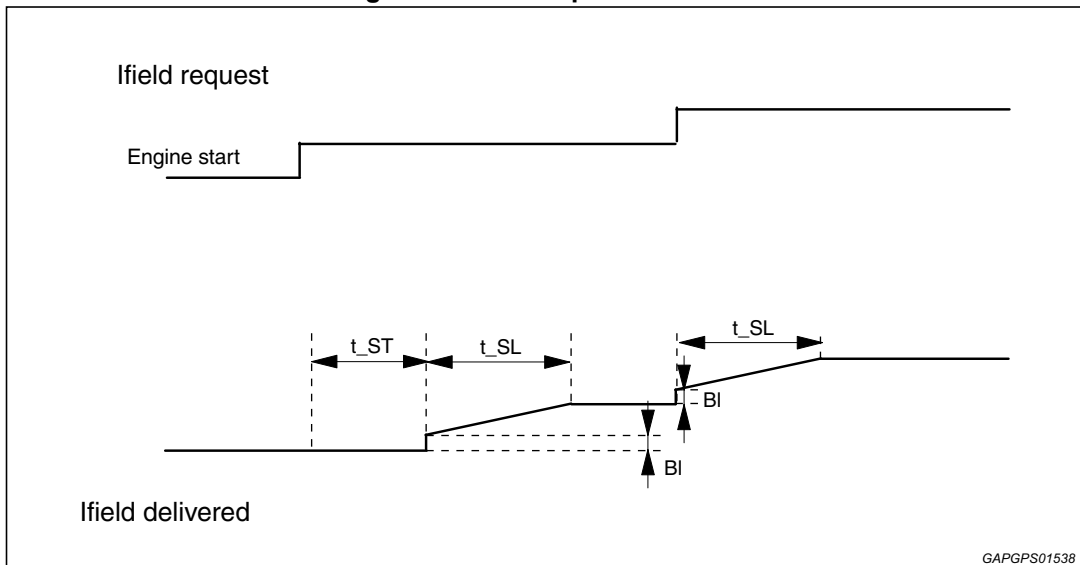


Table 6. Fault detection

| Root cause                         | Signal | Effect                    | Test detect                                |
|------------------------------------|--------|---------------------------|--|
| Alternator belt breaking           | PH     | Alternator dis-excitation | $V_{PH} < V_{PHH} \ \& \ V_{A+} < V_{reg}$ |
| Brushes open                       | PH     | Alternator dis-excitation | $V_{PH} < V_{PHH} \ \& \ V_{A+} < V_{reg}$ |
| Field interruption                 | PH     | Alternator dis-excitation | $V_{PH} < V_{PHH} \ \& \ V_{A+} < V_{reg}$ |
| Field short circuit to the battery | PH     | Alternator dis-excitation | $V_{PH} < V_{PHH} \ \& \ V_{A+} < V_{reg}$ |
| Field short circuit to the ground  | DF     | Overvoltage               | $DF < VS1 \ \& \ V_{A+} > V_{reg}$         |

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

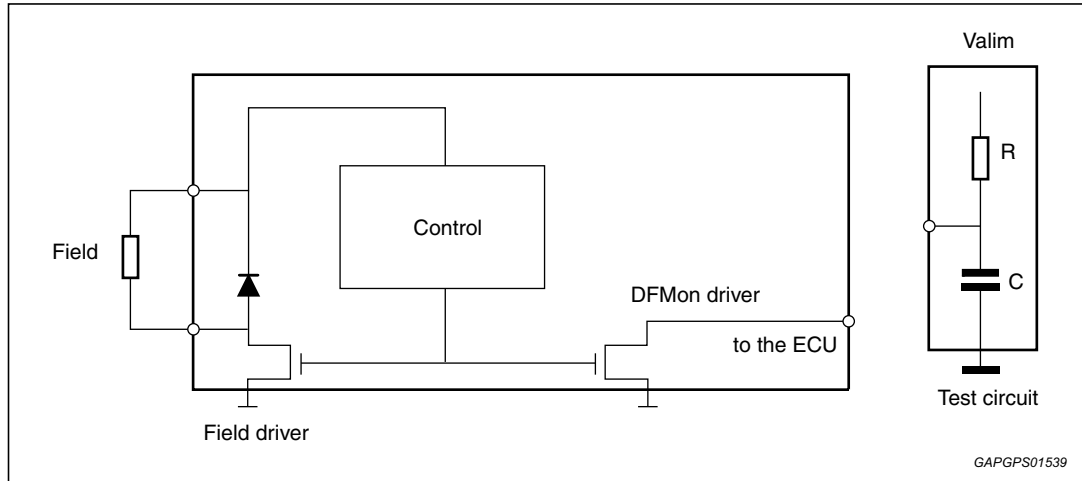
Figure 6. Load response control



**Table 7. Application summary features (standard option)**

| Regulation  | Thermal drift | Pre-exc.  | Soft start       | Soft attack | DF monitor |
|-------------|---------------|-----------|------------------|-------------|------------|
| Voltage (V) | (mV/°C)       | FS_DF (%) | Delay Timing (s) | Timing (s)  | function   |
| 14.45       | -3            | 12.5      | 0                | 2.88        | YES        |

**Figure 7. DFMonitor electrical configuration**



### 3 Revision history

**Table 8. Document revision history**

| Date        | Revision | Changes          |
|-------------|----------|------------------|
| 16-Jun-2016 | 1        | Initial release. |

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