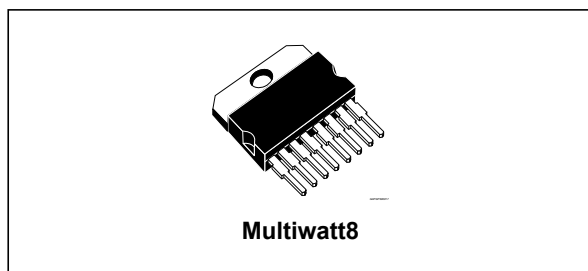


## C-terminal alternator voltage regulator (CTAVR)

Datasheet - production data



### Description

The device is a monolithic 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.

This device regulates in close loop the output of an automotive generator by controlling the field winding current by means of a pulse-width modulation (PWM) high side driver at fixed frequency.

The set-point voltage reference selected by the Engine Control Unit via C-terminal protocol is temperature flat. An internal voltage reference thermally compensated is present in the device and used when the protocol coming from ECU is absent or the wire is broken.

A self-bias circuitry is present on L pin in order to turn-on the warning lamp also when the device is not supplied (battery connection broken).

### Features

- Fully monolithic design
- High side field driver
- Field short circuit protection
- Regulated voltage driven by ECU (protocol driven)
- Regulated voltage thermally compensated (without protocol)
- Lamp driver (wake up and warning detection)
- Self start function
- Load response control (LRC)
- Field monitor (FM) output
- Thermal shutdown

**Table 1. Device summary**

Order code	Self start frequency threshold	High frequency threshold to exit precitation option	Freq. threshold to exit/enter LRC	Temp range, °C	Package	Packing
L9915-CB	fPSS,1 <sup>(1)</sup>	fPHPrex,1 <sup>(1)</sup>	fPLRC,1 <sup>(1)</sup>	T <sub>j</sub> = -40 to +150	Multiwatt8	Tube

1. Other values for VBITD, fPHPrex, fMsw and VBisp can be possible. ST reserves the right to decide on a case by case basis.

# Contents

- 1 Functional description ..... 5**
  - 1.1 Application schematic ..... 5
  - 1.2 External component required ..... 6
  
- 2 Pin description ..... 7**
  
- 3 Electrical specification ..... 8**
  - 3.1 Absolute maximum ratings ..... 8
  - 3.2 Thermal data ..... 8
  - 3.3 Electrical characteristics ..... 9
    - 3.3.1 Pin "B" ..... 9
    - 3.3.2 Pin "C" ..... 11
    - 3.3.3 Excitation fixed function ..... 13
    - 3.3.4 Pin "FM" ..... 14
    - 3.3.5 Pin "PH" ..... 15
    - 3.3.6 Pin "F" ..... 16
    - 3.3.7 Load response control function (LRC) ..... 17
    - 3.3.8 Pin "L" ..... 18
  
- 4 Package information ..... 19**
  
- 5 Revision history ..... 20**

## List of tables

Table 1.	Device summary . . . . .	1
Table 2.	Pin description . . . . .	7
Table 3.	Absolute maximum ratings . . . . .	8
Table 4.	Absolute maximum ratings and operative range by pin . . . . .	8
Table 5.	Thermal data . . . . .	8
Table 6.	Electrical characteristics - Pin "B" . . . . .	9
Table 7.	Electrical characteristics - Pin "C" . . . . .	11
Table 8.	Truth table for excitation fixed function . . . . .	13
Table 9.	Electrical characteristics - Pin "FM" . . . . .	14
Table 10.	Electrical characteristics - Pin "PH" . . . . .	15
Table 11.	Electrical characteristics - Pin "F" . . . . .	16
Table 12.	Load response control function characteristics. . . . .	17
Table 13.	Electrical characteristics - Pin "L" . . . . .	18
Table 14.	TLalarm validation time conditions . . . . .	18
Table 15.	Document revision history. . . . .	20

# List of figures

Figure 1. Application schematic . . . . . 5  
Figure 2. Pin connection (top view) . . . . . 7  
Figure 3. Internal regulation curves versus temperature @ F duty cycle = 15% . . . . . 10  
Figure 4. External regulation curve versus C duty cycle @  $T_J = 30\text{ }^\circ\text{C}$  and F duty cycle = 15%. . . . . 10  
Figure 5. Cranking security function diagram. . . . . 11  
Figure 6. Pin “C” circuit and waveform. . . . . 12  
Figure 7. Pin “C” terminal signal diagram. . . . . 12  
Figure 8. State diagram . . . . . 13  
Figure 9. Excitation fixed function is active by Com duty  $6 \pm 2\%$  after cut-in RPM. . . . . 14  
Figure 10. Pin “FM” circuit and waveform . . . . . 14  
Figure 11. Principle of phase regulation. . . . . 15  
Figure 12. Load response control function (LRC) diagram . . . . . 17  
Figure 13. Multiwatt8 mechanical data and package dimensions . . . . . 19

# 1 Functional description

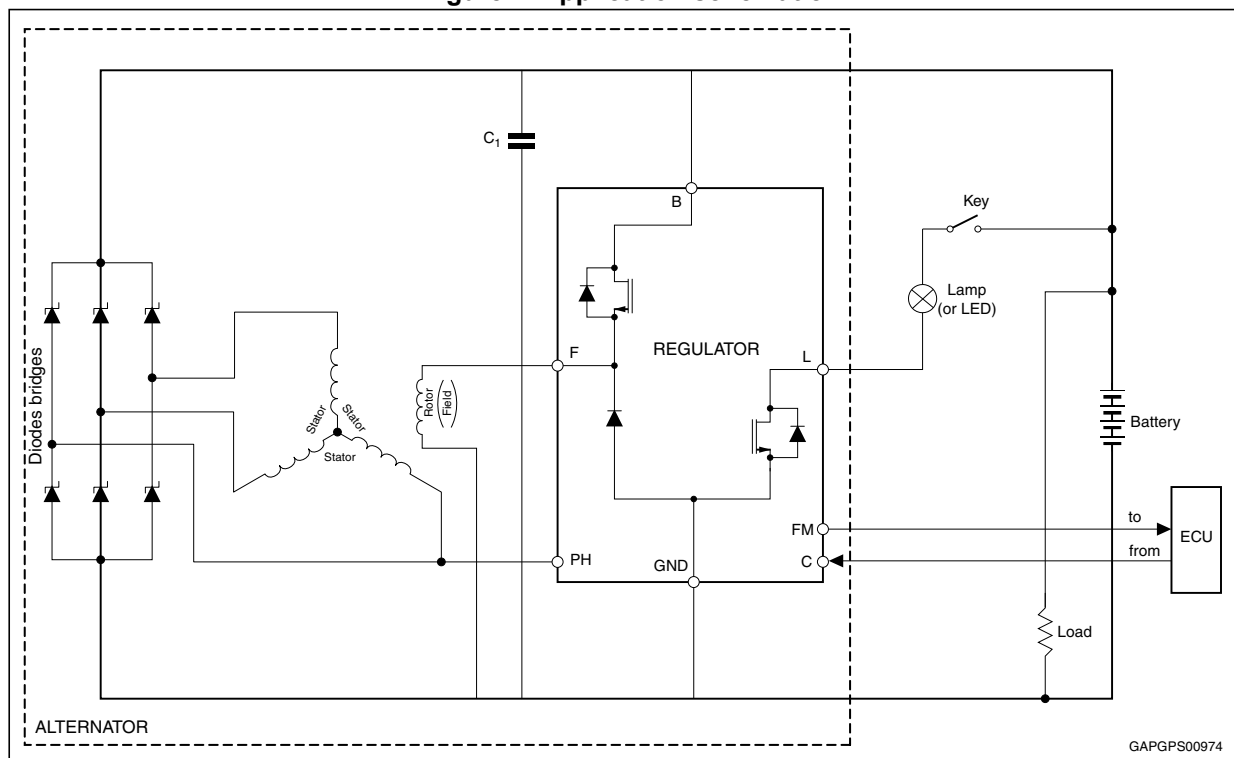
The device, supplied by the battery through B pin, remains in standby condition with low current consumption until there is no activity on the pins L, C or PH. When the switch "Key" is closed (i.e.  $V_L > V_{L_{Th}}$ ) or the ECU communicates via C-Terminal protocol through C pin (i.e. signal freq. on C pin between 100 Hz and 500 Hz) the device exits in standby condition and goes in pre-excitation characterized by an activity on F pin with fixed frequency ( $f_{FSW}$ ) and duty cycle ( $DF_{Prex}$ ). The device remains in pre-excitation until the alternator does not run. When an activity is sensed on PH pin (i.e.  $V_{PH} > V_{PH_{Th}}$  and  $f_{PH} > f_{PH_{Prex}}$ ) the device starts to regulate; if the communication is present on C pin the regulator goes in external regulation mode, otherwise it goes in internal regulation mode.

Another possibility for the device to start to regulate is the self start. In this way, although there is no activity on pins L or C (for example due to connector open), if an activity is sensed on PH pin (i.e.  $V_{PH} > V_{PH_{Th}}$  and  $f_{PH} > f_{PH_{Prex}}$ ) the device goes in self start characterized by an activity on F pin with fixed frequency ( $f_{FSW}$ ) and duty cycle ( $DF_{SS}$ ). When the frequency on PH pin rises above  $f_{P_{SS}}$  the device starts to regulate with the internal regulation mode.

The regulator stops to regulate when the frequency on PH pin falls below  $f_{P_{LPrex}}$ . If there is activity on L or C pins the device stays in pre-excitation otherwise comes back in standby.

## 1.1 Application schematic

Figure 1. Application schematic



## 1.2 External component required

The only component strictly required is the capacitor C1 (2.2 $\mu$ F suggested) to suppress radio frequency injection and has to be connected as near as possible to B and GND pins. Other capacitors can be used to increase the EMI performance.

## 2 Pin description

Figure 2. Pin connection (top view)

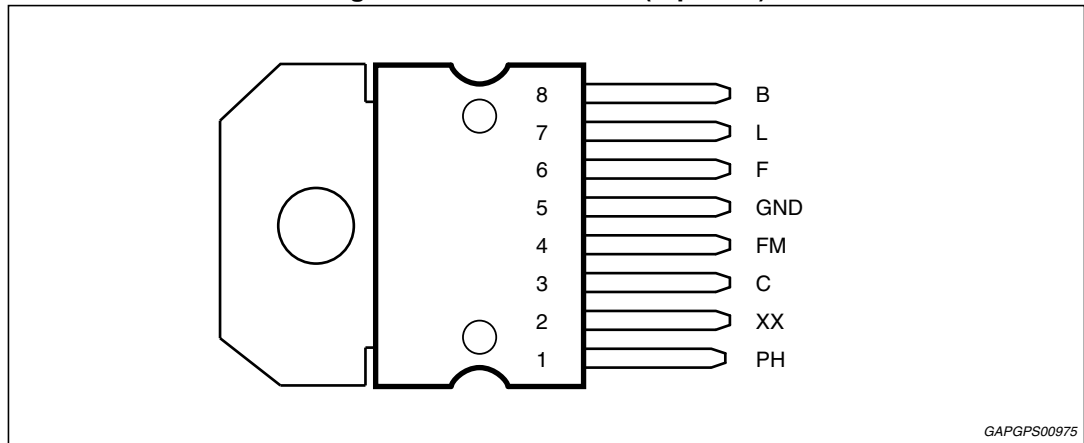


Table 2. Pin description

N°	Pin	Function
1	PH	Phase sense input
2	XX	Reserved pin (to be connected to GND)
3	C	C-Terminal (PWM signal input coming from ECU)
4	FM	Field Monitor (PWM signal going to ECU)
5	GND	Regulator ground
6	F	High side driver output to control the Field current
7	L	Key sensing and Warning Lamp terminal output
8	B	Device power supply and Battery voltage sensing

### 3 Electrical specification

#### 3.1 Absolute maximum ratings

T<sub>j</sub> = -40 to 150 °C, unless otherwise specified.

**Table 3. Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V <sub>BMAX</sub>	Transient supply voltage with 1 A and t < 1 ms	55	V
V <sub>BMAX</sub>	Transient supply voltage (low energy spikes) ISO7637-1 pulse 1,2,3 /ISO7637-3	55	V
T <sub>j</sub>	Junction temperature range	-40 to 150	°C
T <sub>stg</sub> , T <sub>case</sub>	Storage and case temperature range	-40 to 150	°C
P <sub>TOT</sub>	Total power dissipation (@ T <sub>case</sub> = 150°C, I <sub>field</sub> = 5 A)	4	W
V <sub>BR</sub>	Reverse battery voltage @ 25°C, T = 15 sec	-2.5	V
V <sub>PHmin</sub>	Normal working condition reverse voltage (PH vs. GND)	-1.5	V
I <sub>Bond</sub>	DC pin current on F, B, GND (bonding limitation)	15	A
ESD <sub>HBM</sub>	ESD HBM (All pins vs.GND)	±4	kV

**Table 4. Absolute maximum ratings and operative range by pin**

Pin #	Pin name	Absolute max. rating		Operative range		Unit
		Min.	Max.	Min.	Max.	
1	PH	-15	50	-1.5	20	V
2	XX	-0.3	7	must be connected to GND		V
3	C	-0.3	50	-0.3	18	V
4	FM	-15	50	-0.3	18	V
5	GND	-	-	-	-	-
6	F	-1.5	B	-1.5	B	V
7	L	-0.3	50	-0.3	18	V
8	B	-2.5	50	6	18	V

#### 3.2 Thermal data

**Table 5. Thermal data**

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
R <sub>th_j-case</sub>	Thermal resistance junction-to-case	Related to MW8	-	-	1.5	°C/W
T <sub>j-sd</sub>	Thermal shutdown threshold	Temperature to disable F, FM, L drivers.	160	175	190	°C
T <sub>j-sdhy</sub>	Thermal shut-down hysteresis	L, F, FM from OFF STATE (due to thermal shutdown) to ON STATE	T <sub>j-sd</sub> -10	-	T <sub>j-sd</sub> -2	°C



### 3.3 Electrical characteristics

#### 3.3.1 Pin “B”

Table 6. Electrical characteristics - Pin “B”

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
VB <sub>OVr</sub>	Operating voltage range	-	6	-	18	V
IB <sub>stby</sub>	Standby current consumption	VB = 12.5 V; VPH = 0; VL = 0 V; C pin floating; T = -40 °C	250	-	350	μA
IB <sub>stby</sub>	Standby current consumption		200	-	300	μA
IB <sub>stby</sub>	Standby current consumption	VB = 12.5 V; VPH = 0; VL = 0 V; C pin floating; T = 130 °C	150	-	250	μA
VB <sub>ISP</sub>	Internal mode set-point voltage	VPH = 10 Vpp square wave; L pin connected to B pin with 100 Ω; C floating @ T <sub>j</sub> = 30 °C F duty cycle = 15%	14.37	14.55	14.73	V
VB <sub>ITD</sub>	Internal thermal drift	-	-1.5	-3.5	-5.5	mV/°C
VB <sub>ESP</sub>	External mode set-point voltage	VPH = 10 Vpp square wave; L pin connected to B pin with 100 Ω; C 73% PWM duty cycle @ T <sub>j</sub> = 30 °C; F duty cycle = 15%	14.37	14.55	14.73	V
VB <sub>ESP10</sub>	External mode set-point voltage (duty cycle on C = 10%)	VPH = 10 Vpp square wave; L pin connected to B pin with 100 Ω; C 10 % PWM duty cycle @ T <sub>j</sub> = 30 °C; F duty cycle = 15 %	11.5	11.7	11.9	V
VB <sub>ESP90</sub>	External mode set-point voltage (duty cycle on C = 90%)	VPH=10 Vpp square wave; L pin connected to B pin with 100 Ω; C 90 % PWM duty cycle @ T <sub>j</sub> = 30 °C; F duty cycle =15 %	15.1	15.3	15.5	V
VB <sub>ETD</sub>	External thermal drift	-	-1	0	1	mV/°C
VB <sub>DESP,1</sub>	Default external mode set-point voltage option1	VPH=10Vpp square wave; L pin connected to B pin with 100 Ω; C <2% or >98% PWM duty cycle @ T <sub>j</sub> = 30 °C; F duty cycle = 15 %	14.37	14.55	14.73	V
VB <sub>DETD</sub>	Default external thermal drift	-	-1	0	1	mV/°C
ΔVB <sub>load</sub>	Regulated voltage variation with the load (for both int./ext. regulation)	Difference between regulated voltage when F duty cycle is 5% and regulated voltage when F duty cycle is 95%	-	-	300	mV
VB <sub>wb</sub>	Regulation without battery	N. A.	10	-	16	V
VB <sub>IntOvp</sub>	Internal mode over-voltage protections threshold	Without ECU communication	15.5	16.2	16.9	V
VB <sub>ExtOvp</sub>	External mode over-voltage protections threshold	With ECU communication	16.5	17.2	17.9	V

Table 6. Electrical characteristics - Pin "B" (continued)

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$V_{B_{UV}}$	Under voltage	See note (1)	-400	$V_{B_{low}} + 700$	+400	mV
$V_{B_{low}}$	Low Voltage	See note (1)	6	6.5	7	V

1. In order to avoid unpredictable regulation regions during the engine start, the regulator implements a cranking security function.

Figure 3. Internal regulation curves versus temperature @ F duty cycle = 15%

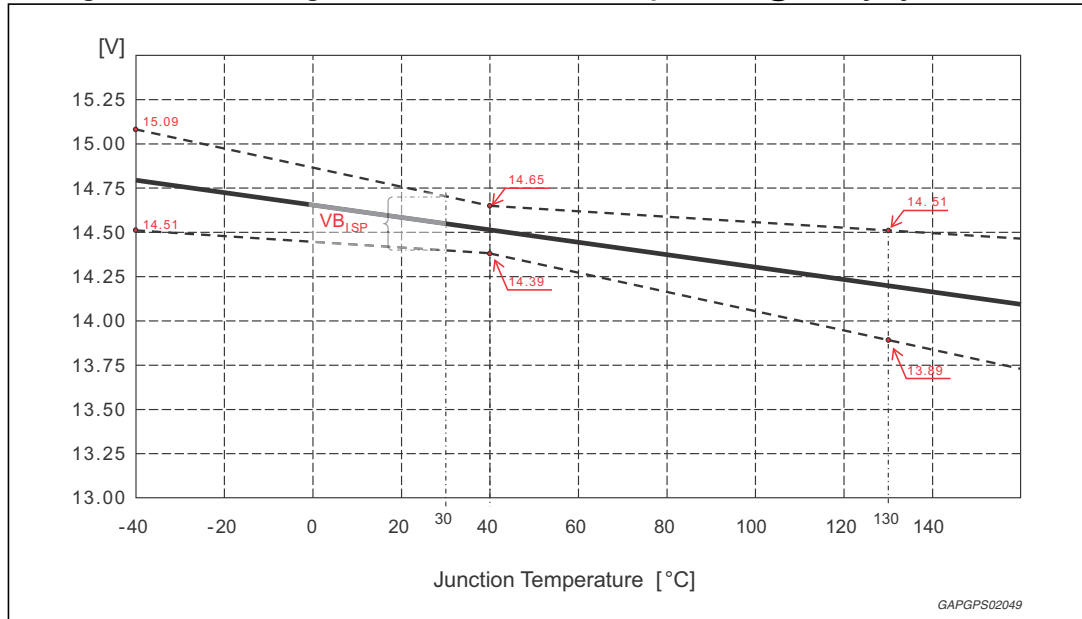
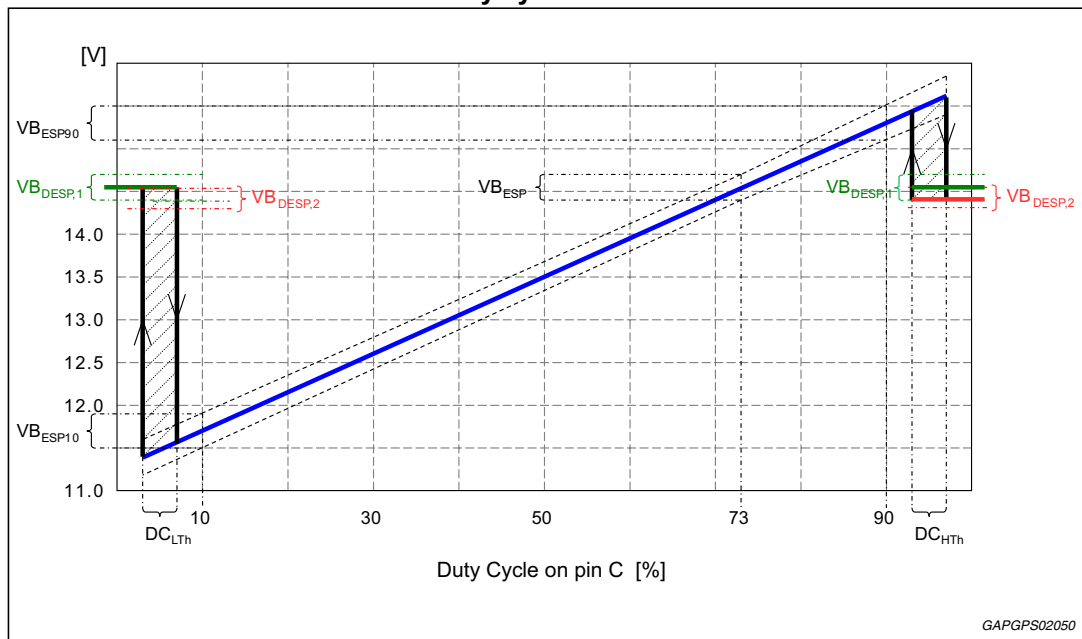
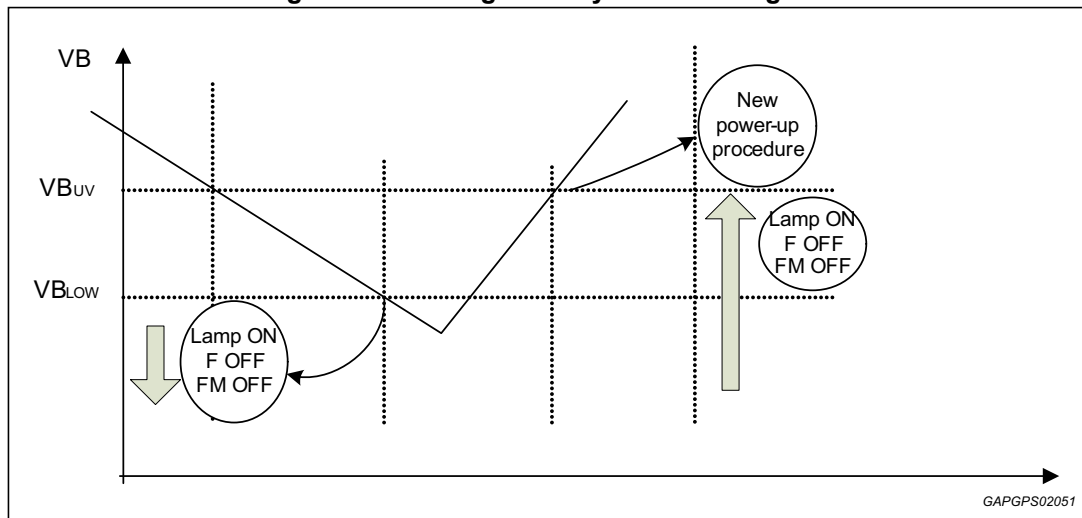


Figure 4. External regulation curve versus C duty cycle @  $T_J = 30^\circ\text{C}$  and F duty cycle = 15%



**Cranking security function**

**Figure 5. Cranking security function diagram**



At the ignition key on the device (i.e. "key" switch closed in the application schematic) starts in pre-excitation; in this phase the battery voltage is over both VBUV and VLOW and the pin F provides a fixed duty cycle. When the starter is engaged, the battery sources a big current and then the applied voltage on the device decreases, as reported in ISO 7637-1 pulse 4 specification. If the voltage on pin B decreases under VLOW threshold then the device is frozen: the device is in low current consumption with no activity on both F and FM pins, only the L pin is able to turn on the lamp.

The device remains in frozen condition until the voltage on B overcomes the VBUV threshold, after that, the device is able again to evaluate the inputs coming from both PH and C pins.

**3.3.2 Pin "C"**

**Table 7. Electrical characteristics - Pin "C"**

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
VC <sub>IRPS</sub>	Internal regulated power supply	-	6.2	6.8	7.3	V
RC <sub>pu</sub>	Pull-up resistor	-	1.75	3.5	5.7	kΩ
VC <sub>HTh</sub>	High level threshold voltage	-	3.1	3.3	3.5	V
VC <sub>LTh</sub>	Low level threshold voltage	-	1.3	1.5	1.7	V
fC <sub>VR</sub>	Valid frequency range	-	100	-	500	Hz
fC <sub>LNVR</sub>	Low not valid frequency range	-	-	-	74	Hz
fC <sub>LNVR</sub>	High not valid frequency range	-	676	-	-	Hz
TC <sub>delay</sub>	Delay time to switch from external to Internal regulation	-	30	50	100	ms
DC <sub>EDCR</sub>	External duty cycle range	-	9	-	93	%

Table 7. Electrical characteristics - Pin "C" (continued)

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
DC <sub>ef</sub>	Duty cycle on C pin to enter in excitation fixed	-	4	6	8	%
DC <sub>LTh</sub>	Low default/external regions transition threshold	-	-	-	3	%
DC <sub>HTh</sub>	High default/external regions transition threshold	-	93	95	97	%
TC <sub>MIN</sub>	Communication rejected with T <sub>ON</sub> or T <sub>OFF</sub> < TC <sub>MIN</sub>	-	15	20	40	µs

Figure 6. Pin "C" circuit and waveform

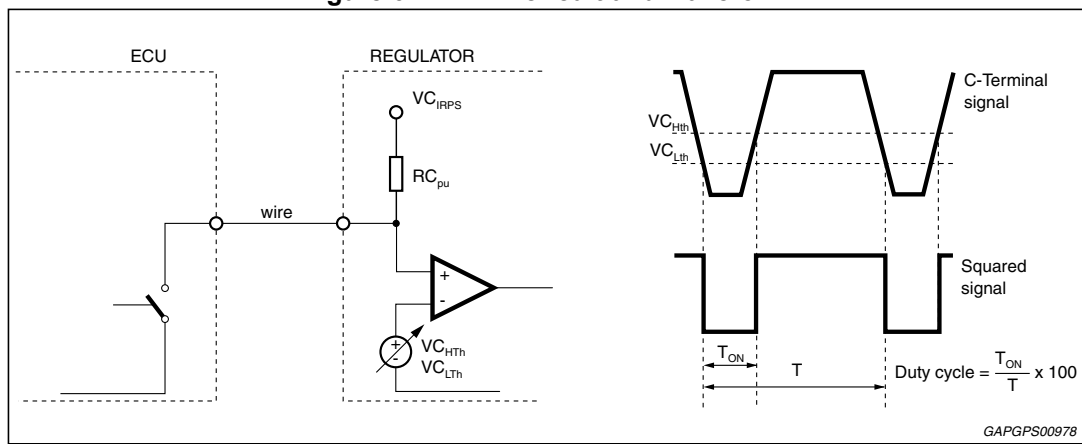
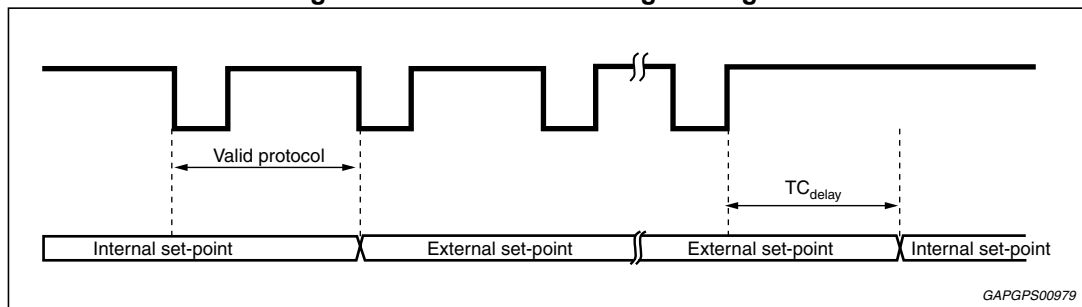


Figure 7. Pin "C" terminal signal diagram



### 3.3.3 Excitation fixed function

The excitation fixed function is active each time the COM duty cycle is between 4% and 8%.

**Table 8. Truth table for excitation fixed function**

Mode	Frequency on phase terminal	COM duty cycle	Lamp terminal condition	Field terminal condition	Start delay timer
1	< Turn On Speed	6 ±2%	Lamp On	DFPreex (Pre-Excitation Duty Cycle)	N/A
2	< Turn On Speed	No COM	Lamp On	DFPreex (Pre-Excitation Duty Cycle)	Off
3	< Turn On Speed	≤ 3% or ≥ 9%	Lamp On	DFPreex (Pre-Excitation Duty Cycle)	N/A
4	> Turn On Speed	6 ±2%	Lamp Off unless Fault Detected	DFef (Excitation Fixed Duty Cycle unless Phase regulation is required)	N/A
5	> Turn On Speed	≤ 3% or ≥ 9%	Lamp Off unless Fault Detected	Normal Regulation set by COM	Off
6	> Turn On Speed	No COM	Lamp Off unless Fault Detected	Normal Regulation-Default setpoint	On

**Figure 8. State diagram**

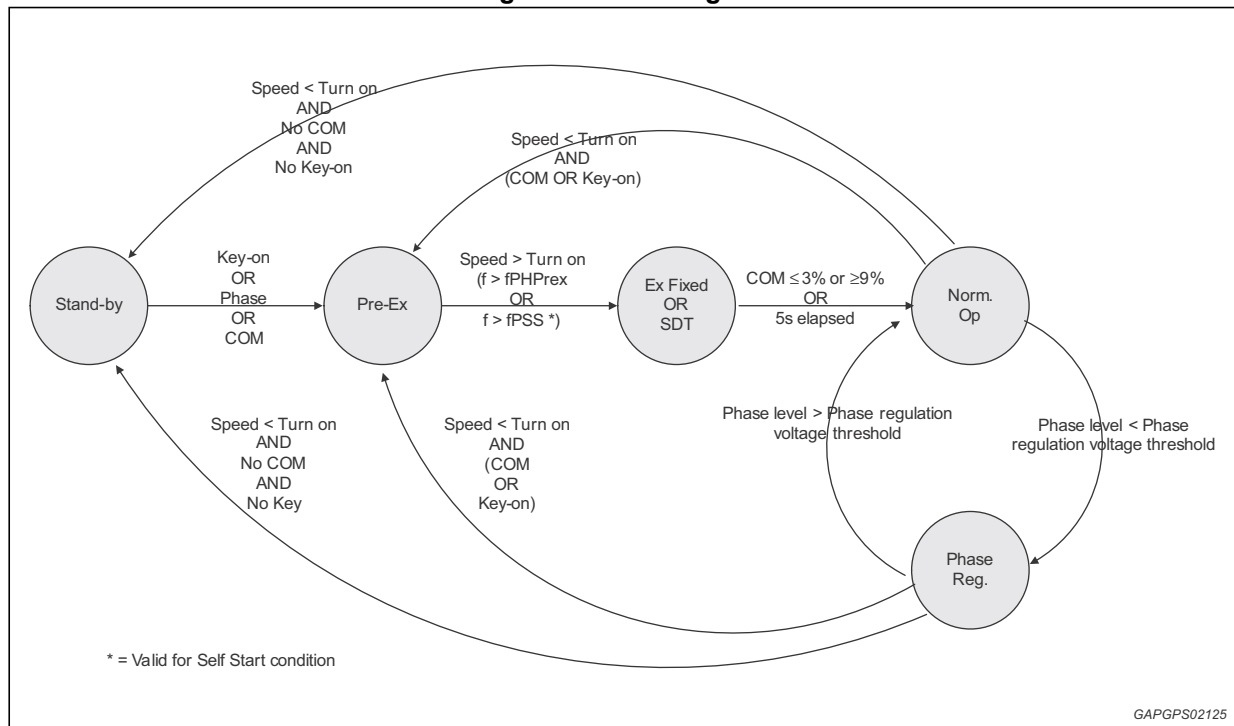
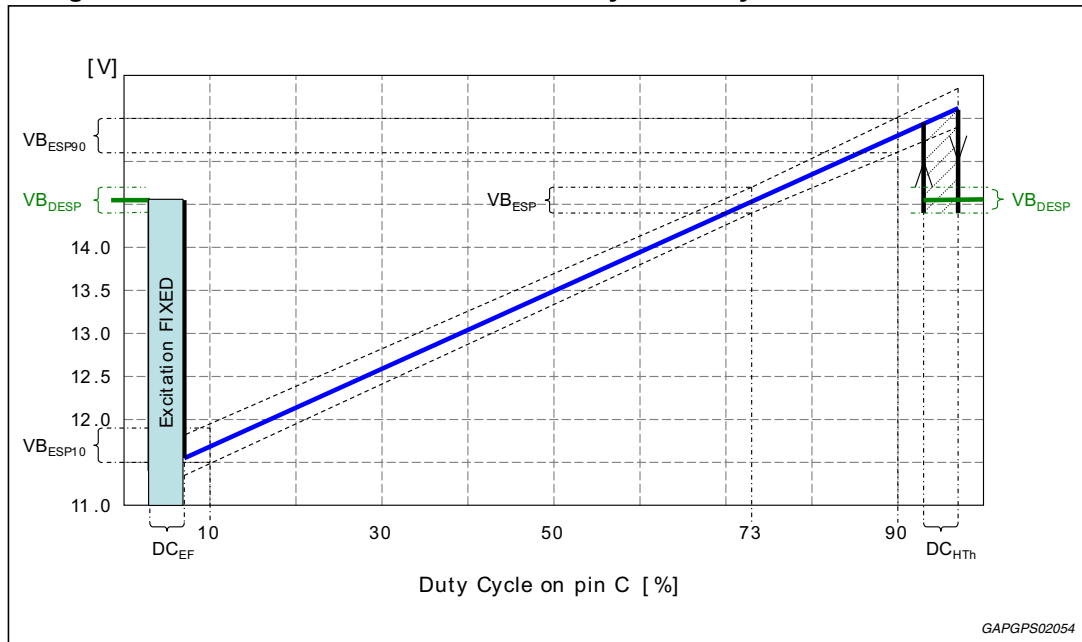


Figure 9. Excitation fixed function is active by Com duty 6 ±2% after cut-in RPM

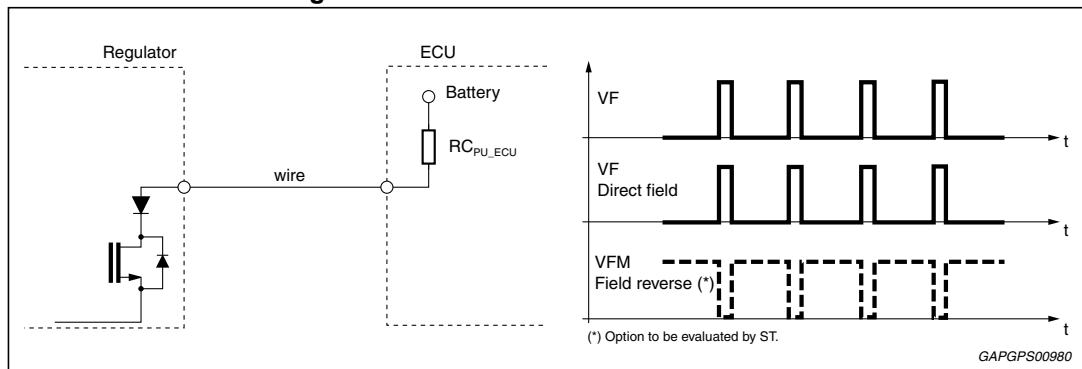


3.3.4 Pin "FM"

Table 9. Electrical characteristics - Pin "FM"

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$VM_{LVS}$	Low voltage saturation	I-sink = 7 mA	0.9	1.2	1.5	V
$fM_{SW}$	Field monitor frequency switch option	Direct field	212.5	250	287.5	Hz
$DM_{DCR}$	Field monitor duty cycle range	-	5	-	95	%
$IM_{lim}$	Field monitor current limitation	-	25	50	75	mA

Figure 10. Pin "FM" circuit and waveform



3.3.5 Pin "PH"

Table 10. Electrical characteristics - Pin "PH"

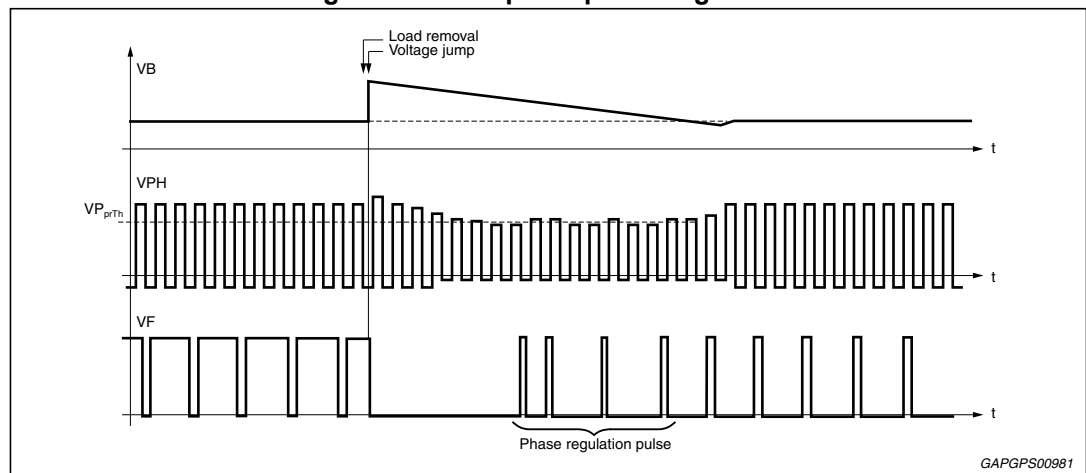
Symbol	Parameter	Test condition	Min	Typ	Max	Unit
VP <sub>HTh</sub>	High voltage threshold of hysteresis input buffer	-	300	375	450	mV
VP <sub>LTh</sub>	Low voltage threshold of hysteresis input buffer	-	225	275	325	mV
RP <sub>pd</sub>	Pull-down resistor	-	7	15	22	kΩ
TP <sub>SR</sub>	Spike rejection time	-	50	115	180	μs
IP <sub>pull-dw</sub>	Pull-down current	-	1.5	2	3.5	mA
fP <sub>HPrex,1</sub>	High frequency threshold to exit pre-excitation option1	-	102	120	138	Hz
fP <sub>HYS</sub>	Frequency hysteresis	-	10	20	30	Hz
fP <sub>LPrex</sub>	Low frequency threshold to enter pre-excitation	-	fP <sub>HPrex</sub> - fP <sub>HYS</sub>			Hz
fP <sub>SS,1</sub>	Self start frequency threshold	-	255	300	345	Hz
fP <sub>LRC,1</sub>	Frequency threshold to exit/enter in LRC option1	-	272	320	368	Hz
VP <sub>prTh</sub>	Phase regulation voltage threshold	-	6.7	7.7	8.7	V

To convert phase frequency (Hz) to rotation speed (rpm) according to alternator poles pair number (N), use the following equation: rotation speed (rpm) = phase frequency (Hz) \* 60 / N.

**Principle of phase regulation**

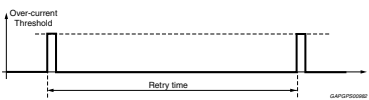
When VB is above the set-point voltage, the field driver is controlled to keep phase peak voltage from falling below VPprTh. If phase peak voltage drops below VPLTh, phase regulation does not work.

Figure 11. Principle of phase regulation



3.3.6 Pin “F”

Table 11. Electrical characteristics - Pin "F"

Symbol	Parameter	Test Condition	Min	Typ	Max	Unit
VF <sub>sat</sub>	Field driver saturation voltage	T <sub>j</sub> = 130 °C; I <sub>sun</sub> k = 4.5 A	-	-	0.6	V
		T <sub>j</sub> = 25 °C; I <sub>sun</sub> k = 7 A	-	-	0.55	V
VF <sub>diode</sub>	Freewheeling diode	I <sub>source</sub> d = 5 A	-2	-	-	V
IF <sub>leak</sub>	Field leakage current	VB = 24 V; VF = 0	-	-	5	µA
IF <sub>OVP</sub>	Field driver over-current protection	T <sub>j</sub> = -40 °C	9	-	15	A
		T <sub>j</sub> = 25 °C	8.5	-	15	A
		T <sub>j</sub> = 130 °C	8.5	-	15	A
TF <sub>retry</sub>	Retry time in case of over-current		30	40	50	ms
VF <sub>ONdet</sub>	Voltage threshold on-state detection	-	0.9	1.1	1.3	V
f <sub>SW</sub>	Field switching frequency	-	212.5	250	287.5	Hz
TF <sub>rise</sub>	Field voltage rise time	-	5	-	25	µs
TF <sub>fall</sub>	Field voltage fall time	-	5	-	25	µs
DF <sub>Preex</sub>	Field duty cycle in pre-excitation	-	11	12.5	14	%
DF <sub>SS</sub>	Field duty cycle in self start	-	4	6	8	%
DF <sub>ef</sub>	Field duty cycle during excitation FIXED	-	3	4	5	%
TF <sub>LRCUP</sub>	Load response control time (0 % to 100 % DC)	-	-	5	-	s
TF <sub>SdT</sub>	Start delay time in internal mode only	-	4.25	5	5.75	s



### 3.3.7 Load response control function (LRC)

When an electrical load is applied to the system application, a drop in the regulated voltage (VB) occurs and the alternator reacts by increasing output current. If the LRC function is active then the alternator output current is controlled by the Field current variation strategy that is directly linked to the duty cycle on Field signal.

The LRC function can operate when the alternator runs at low speed (the PH signal frequency has to be lower than fPLRC) and it is activated when a positive variation between current duty cycle on Field and its previous duty cycle values is higher than DFLRCEnab. When the LRC function is required, the duty cycle increase slowly with the defined slope DFLRCUP starting with the previous duty cycle increases by the fixed value DFLRCBZ. The actual duty cycle management during a LRC insertion is shown in the [Figure 12](#).

Figure 12. Load response control function (LRC) diagram

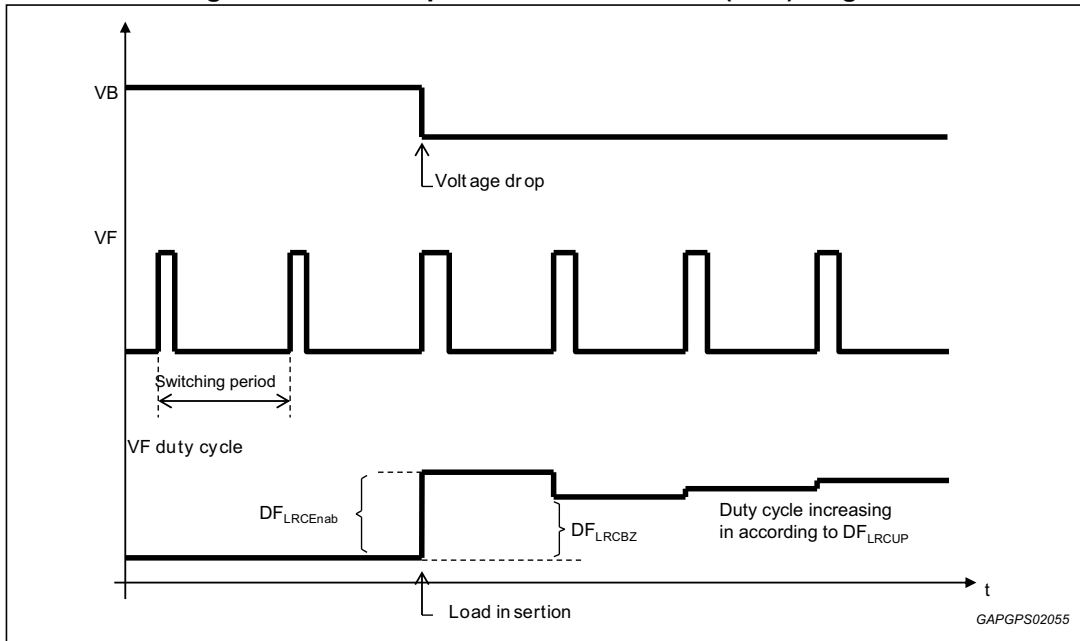


Table 12. Load response control function characteristics

Symbol	Parameter	Test condition	MIN	TYP	MAX	Unit
DF <sub>LRCUP</sub>	Positive duty cycle vs. time variation	-	100 / TF <sub>LRCUP</sub>			%/s
TF <sub>LRCDW</sub>	Load response control Time (100% to 0% DC)	-	TF <sub>LRCUP</sub> * 3 / 8			s
DF <sub>LRCDW</sub>	Negative duty cycle vs. time variation	-	- 100 / TF <sub>LRCDW</sub>			%/s
DF <sub>LRCEnab</sub>	Current vs. previous duty cycle variation to enable LRC function	-	4.1	6.7	9.2	%
DF <sub>LRCBZ</sub>	Blind zone	-	2.6	5.3	7.8	%

3.3.8 Pin "L"

Table 13. Electrical characteristics - Pin "L"

Symbol	Parameter	Test condition	Min	Typ	Max	Unit
$V_{Lsat}$	Lamp driver saturation voltage	$V_B = 12.5\text{ V}; I_{sunk} = 0.5\text{ A}$	1	1.2	1.4	V
$V_{LsatSB}$	Lamp driver saturation voltage in self bias condition	B pin floating; $I_{sunk} = 300\text{ mA}$	1	-	4	V
$R_{Lpulldw}$	Pull down resistor	-	2	4	8.2	k $\Omega$
$V_{LHTh}$	High voltage threshold key-ON detector	-	0.8	0.9	1	V
$V_{LTh}$	Low voltage threshold key-on detector	-	0.7	0.8	0.9	V
$I_{Lim}$	Over-current limitation	-	1	1.5	2	A
$T_{LOC}$	Maximum time duration of linear current limitation		25	30	35	ms
$T_{retry}$	Retry time in case of over-current duration > $T_{LOC}$		510	600	690	ms
$T_{delay}$	Turn on delay time	-	-	-	100	$\mu\text{s}$
$T_{alarm}$	Alarm validation time	-	340	400	460	ms

Alarm detection

The device turns ON the lamp after the validation time ( $T_{Lalarm}$ ) if one of the conditions in the below table is verified.

Table 14.  $T_{Lalarm}$  validation time conditions

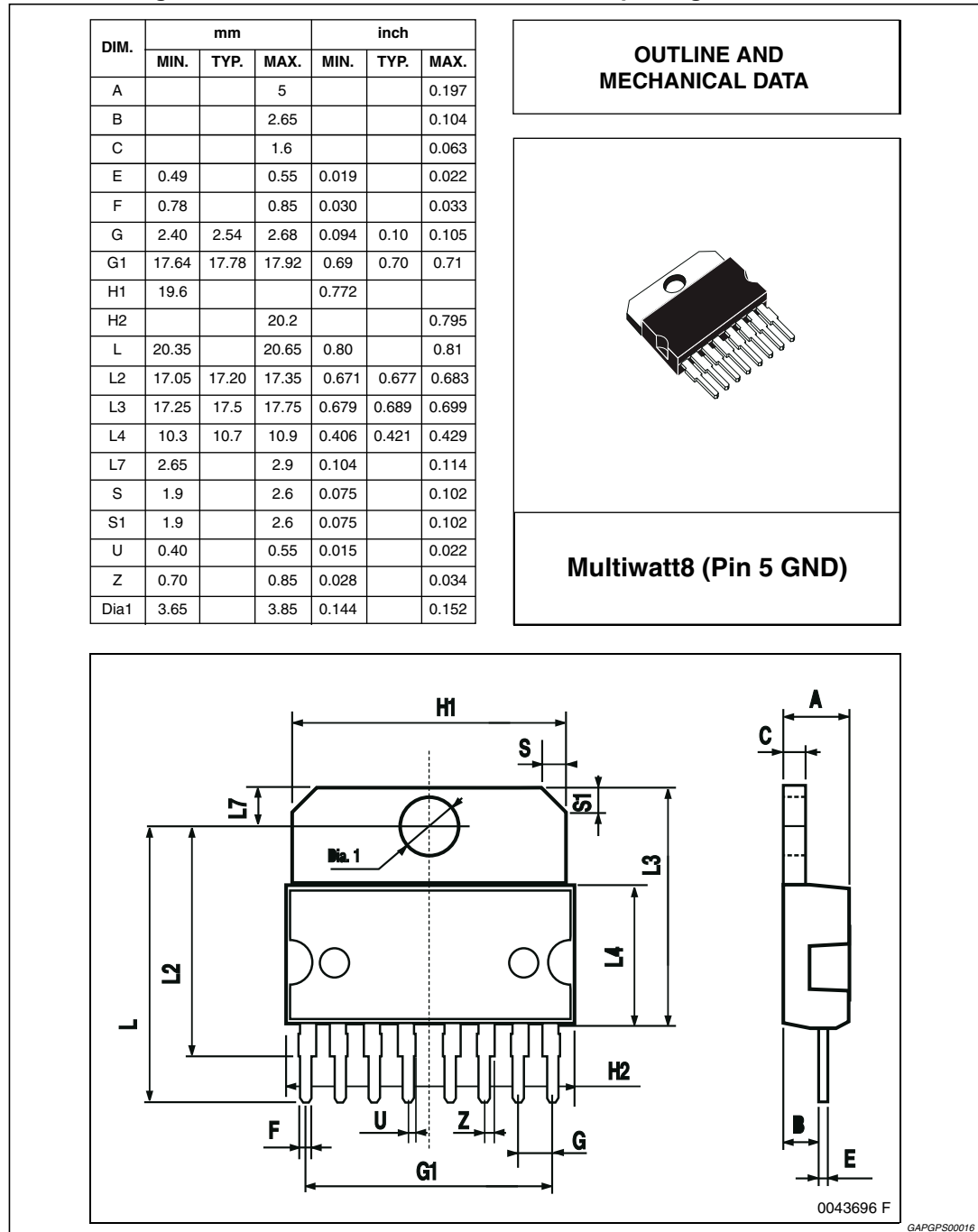
Detection condition	Related pin
$V_{PH} < V_{PHTh}$ or PH frequency < $f_{P_{LPrex}}$	No activity on PH pin
$V_{PH} < V_{P_{prTh}}$	F driver or its connection degraded
$I_F > I_{F_{OVP}}$	F shortened to GND (Over-current on F driver)
$V_B > (V_{B_{ISP}}, V_{B_{ESP}})$ and $V_F > V_{F_{ONdet}}$	F shortened to B
$V_B > V_{B_{IntOvp}} \mid V_B > V_{B_{ExtOvp}}$	Battery sensor on B pin or F driver degraded
$V_B < V_{B_{UV}}$	Low B Voltage (Battery under-voltage)

# 4 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK<sup>®</sup> packages, depending on their level of environmental compliance. ECOPACK<sup>®</sup> specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com).

ECOPACK<sup>®</sup> is an ST trademark.

**Figure 13. Multiwatt8 mechanical data and package dimensions**



## 5 Revision history

Table 15. Document revision history

Date	Revision	Changes
09-Jun-2014	1	Initial release.

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