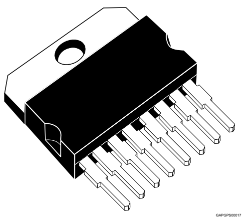
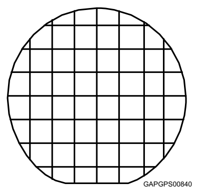
L9916B

Automotive multifunction alternator voltage regulator with PI/P control loop for 12 V / 24 V on board networks

Datasheet - production data



Multiwatt8



Bare die

Features

- AEC-Q100 qualified
- Fully monolithic design
- High side field driver
- Self start function
- Regulated voltage thermally compensated
- Configurable parameters through OTP cells
- Lamp driver (wake up and warning detection)
- Load Response Control (LRC)
- Voltage control loop configurable Proportional Integral or Proportional only

Protections

- Thermal shutdown
- Field short circuit protection
- Protected Lamp driver and high side relay driver

Description

The L9916B is a smart alternator voltage regulator intended to be used in automotive application for both 12 V and 24 V systems. The presence of OTP cells for parameters programmability makes it suitable for a wide range of charging application.

Table 1. Device summary

Order code	Package	Packing
L9916B	Multiwatt8	Tube
L9916BBDTR	Bare die	Tape and Reel

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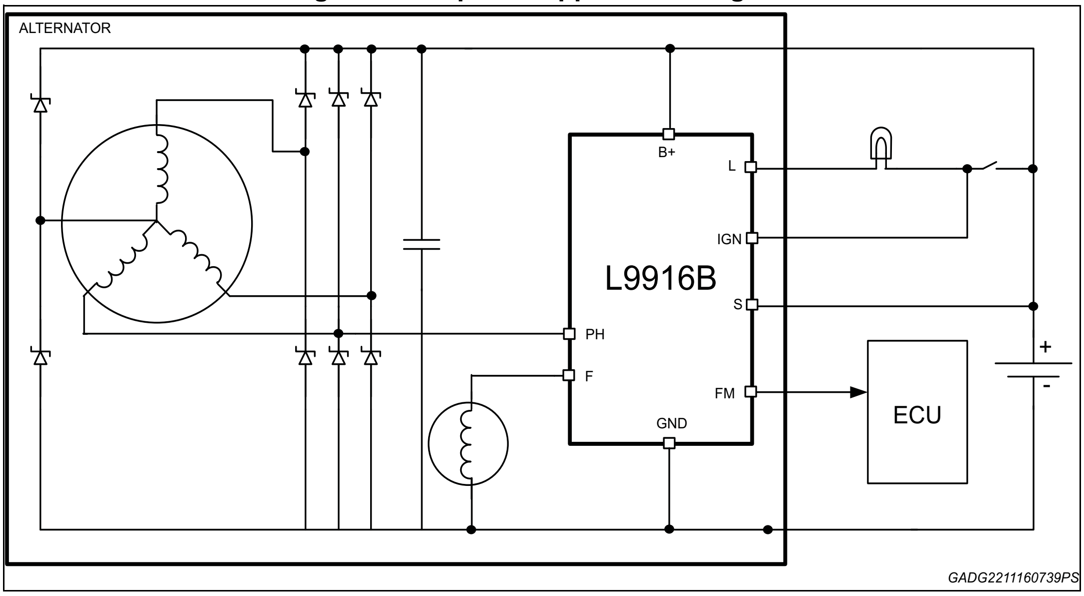
1 Functional description

The L9916B is an alternator voltage regulator with high side power output for field driving. It can be used in both 12 V and 24 V system. It supplies a current through a power high side MOSFET to the excitation coil of the alternator and provides an internal freewheeling diode.

The L9916B is suitable for multi-phase-current alternators and its target function is to keep the battery at its nominal value, whatever the vehicle demand. The set point control is achieved using an internal voltage reference thermally compensated. Continuous feedback to the ECU is provided through the field monitor output.

Slew rate control and filtering of the interface lines provide electromagnetic compatibility

Figure 1. Simplified application diagram



1.1 State diagram

The state diagram is a description of the L9916B possible working conditions.

Below it is represented a state diagram for L9916B describing its Operation Modes depending on the Speed Phase (RPM) applied to Phase pin (PH), the battery level on Battery pin (VB), the duty cycle applied by the device on Field pin (F), and the Alarm function status. Alarm function will turn-on the lamp in case of fault.

The states represented in the diagram are:

- Standby:

  it is the reference state of the FSM. It's the starting state and the final state for any regulator operation cycle (turn-on, turn-off).
- Pre-excitation:

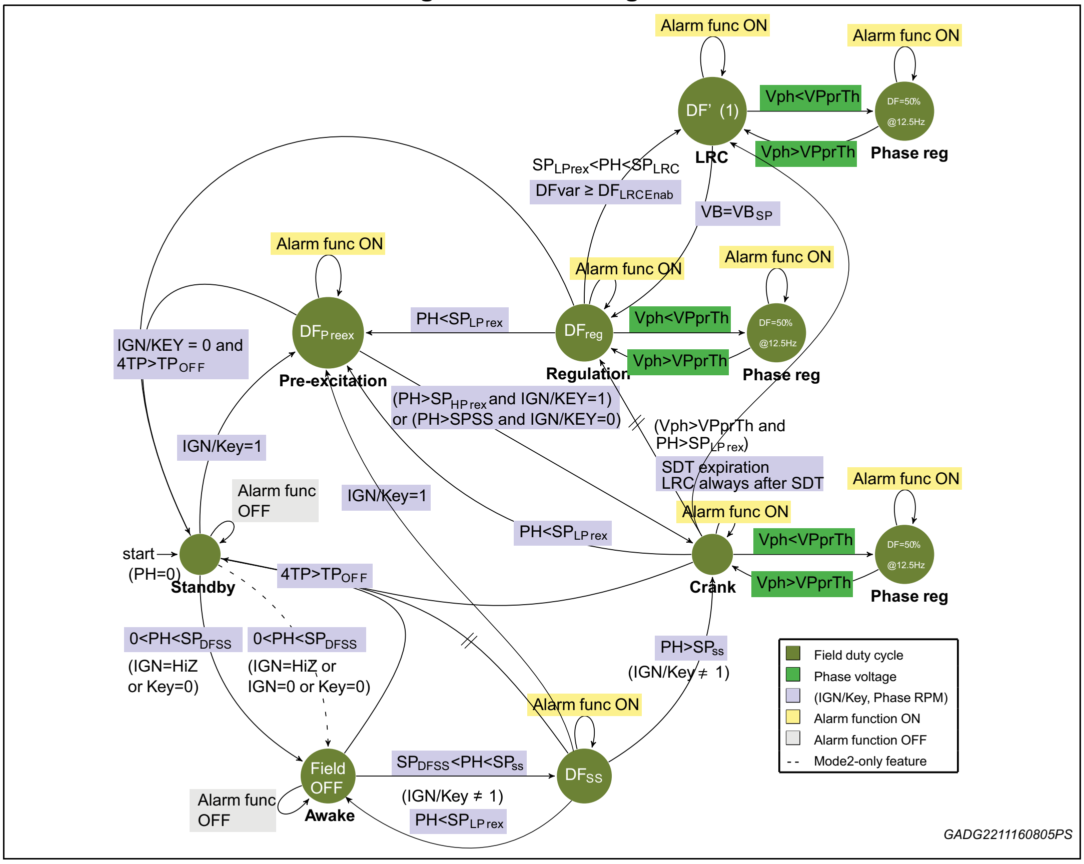
  L9916B is ready to operate (when reached from standby), or it checks external conditions to move to a different state.

- Regulation:
  L9916B is working in order to regulate the battery voltage to the required voltage set point VB_{SP}.
- Phase regulation:
  the L9916B controls the field driver to keep phase signal amplitude not falling below defined value.
- LRC:
  this state can be reached from Regulation in case there is a load variation that leads to meet some conditions on the expected field duty cycle value.
- Crank:
  this state is necessary to manage SDT (Start Delay Time) timer before entering normal regulation.

The assumptions considered in the below diagram are that the Self-start function is enabled and the wake-up source (IGN or Key) status is kept constant during the AVR working operation.

Colored tags define the condition for jumping to the next state and non-colored tags represent configurations.

Figure 2. State diagram



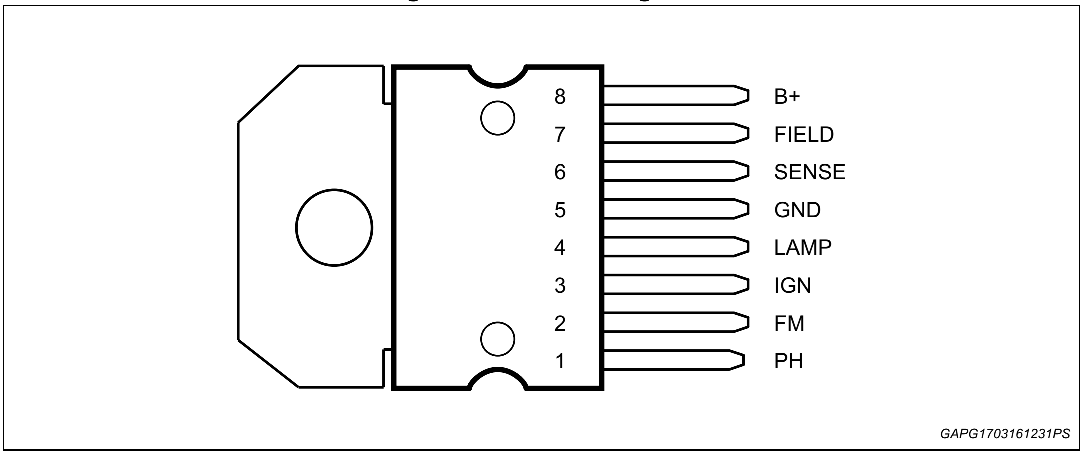
Note: *LRC procedure firstly increases DF by DF_{LRCBZ} and then it continues slowly increasing the DF using a fixed slope DF_{LRCUP}. After LRC is finished (due to VB = VB_{SP} condition reached), the new regulation duty cycle DFreg will be DF' reached by the LRC procedure.*

1.2 Pin description

Table 2. Pin out description

N°	PIN	Function
1	PH	Phase sense input
2	FM	Field Monitor (PWM signal going to ECU)
3	IGN	Ignition input
4	LAMP	Key sensing and Warning Lamp terminal output
5	GND	Regulator ground
6	SENSE	Remote battery sense input
7	FIELD	High side driver output to control the Field current
8	B+	Device power supply and Battery voltage sensing

Figure 3. Pin out diagram



1.3 External component required

The only component strictly required is the capacitor C1 (2.2 µF suggested) to suppress radio frequency injection and has to be connected as close as possible to B and GND pins.

If in the application some pins are not used, it is recommended to connect them to ground directly or with a 10 nF capacitor.

2 Electrical specifications

2.1 Absolute maximum ratings

Table 3. Absolute maximum ratings

Symbol	Parameter	Value	Unit
VB_{LD}	Transient supply voltage (load dump) t < 500 ms	58	V
VB_{MAX}	Transient supply voltage ISO7637-2 pulse 1,2,3 /ISO7637-3	58	V
T_j	Junction temperature range	-40 to 175	°C
T_{stg}, T_{case}	Storage and case temperature range	-40 to 150	°C
P_{TOT}	Total power dissipation (@ $T_{case} \leq 150°C$, $I_{field} \leq 5$ A)	4	W
VB_R	Reverse battery voltage @ 25 °C, T = 15 sec	-2.5	V
I_{Bond}	DC pin current on F, B, GND (bonding limitation)	15	A
ESD_{HBM}	ESD HBM (All pins vs.GND)	±4	kV

2.2 Internal clamping structure

Table 4. Internal clamping structure

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
V_{cl}	Internal central clamp voltage	B+ current injected I = 20 mA	58	-	64	V

2.3 Pin number with absolute maximum ratings and operative range

Table 5. Pin number with absolute maximum ratings and operative range

Pin #	Pin name	ABS max rating		Operative range		Unit
		Min	Max	Min	Max	
1	PH	-25	Vcl	-3	36	V
2	FM	-25	Vcl	-0.3	36	V
3	IGN	-25	Vcl	-0.3	36	V
4	LAMP	-0.3	B+	-0.3	36	V
5	GND	-	-	-	-	-
6	SENSE	-25	Vcl	-0.3	36	V
7	FIELD	-1.5	B+	-1.5	B+	V
8	B+	-2.5	Vcl	6	36	V

2.4 Thermal data

Table 6. Thermal data

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$R_{th\_j\text{-}case}$	Thermal resistance junction-to-case	Related to Multiwatt8	-	-	1.5	°C/W
$T_{j\text{-}sd}$	Thermal shutdown threshold	Temperature to disable F, FM, L drivers.	160	175	190	°C
$T_{j\text{-}sdhy}$	Thermal shut-down hysteresis	L, F, FM from OFF STATE (due to thermal shutdown) to ON STATE	$T_{j\text{-}sd}$-10	-	$T_{j\text{-}sd}$-2	°C
T_j	Operation temperature	-	-40	-	150	°C
		Fully functional. Parameter Deviations permissible	150	-	$T_{j\text{-}sd}$	

2.5 Electrical characteristics

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

2.5.1 Pin "B"

Table 7. Electrical characteristics - Pin "B"

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VB_{OVR}	Operating voltage range	Application info, refer to *Figure 7*	6	-	36	V
IB_{stby}	Standby current consumption 12 V	VB = 12.5 V; VPH = 0; VL = 0 V; VIGN = open; VSENSE = 0 V T = 25 °C	-	-	120	µA
IB_{stby}	Standby current consumption 12 V	VB = 12.5 V; VPH = 0; VL = 0 V; VIGN = open; VSENSE = 12.5 V T = 25°C	-	-	170	µA
IB_{stby}	Standby current consumption 24 V	VB = 24 V; VPH = 0; VL = 0 V; VIGN = open; VSENSE = 0 V T = 25 °C	-	-	160	µA
IB_{stby}	Standby current consumption 24 V	VB = 24 V; VPH = 0; VL = 0 V; VIGN = open; VSENSE = 24 V T = 25 °C	-	-	200	µA
IB_{active}	Current consumption out of standby	VB = 12.5 V; VSENSE = 12.5 V VB = 24 V; VSENSE = 24 V No current load on FIELD and LAMP	5	11	30	mA

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

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$VB_{SP12,1}$	Set-point voltage 12 V Option	VPH=10 Vpp square wave; L pin connected to B pin with 100 ohm; @ T_j = 30 °C F duty cycle = 50% (Possibility to increase by OTP bit the voltage value of +50 mV)	-0.15	13.5	+0.15	V
$VB_{SP12,2}$				13.6		
$VB_{SP12,3}$				13.7		
$VB_{SP12,4}$				13.8		
$VB_{SP12,5}$				13.9		
$VB_{SP12,6}$				14		
$VB_{SP12,7}$				14.1		
$VB_{SP12,8}$				14.2		
$VB_{SP12,9}$				14.3		
$VB_{SP12,10}$				14.4		
$VB_{SP12,11}$				14.5		
$VB_{SP12,12}$				14.6		
$VB_{SP12,13}$				14.7		
$VB_{SP12,14}$				14.8		
$VB_{SP12,15}$				14.9		
$VB_{SP12,16}$				15		
$VB_{SP24,1}$	Set-point voltage 24 V Option	VPH=20 Vpp square wave; L pin connected to B pin with 100 ohm; @ Tj=30°C F duty cycle=50% (Possibility to increase by OTP bit the voltage value of +100 mV)	-0.25	27	+0.25	V
$VB_{SP24,2}$				27.2		
$VB_{SP24,3}$				27.4		
$VB_{SP24,4}$				27.6		
$VB_{SP24,5}$				27.8		
$VB_{SP24,6}$				28		
$VB_{SP24,7}$				28.2		
$VB_{SP24,8}$				28.4		
$VB_{SP24,9}$				28.6		
$VB_{SP24,10}$				28.8		
$VB_{SP24,11}$				29		
$VB_{SP24,12}$				29.2		
$VB_{SP24,13}$				29.4		
$VB_{SP24,14}$				29.6		
$VB_{SP24,15}$				29.8		
$VB_{SP24,16}$				30		

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

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VB_{ITD1}	Internal thermal drift options 30°C<T<150°C	-	-1(12 V) -2(24 V)	0	+1(12 V) +2(24 V)	mV/°C
VB_{ITD2}		-		-2.5		
VB_{ITD3}		-		-3.5		
VB_{ITD4}		-		-7		
VB_{ITD5}		-		-10		
VB_{ITD1}	Internal thermal drift options -40°C<T<30°C	-	-2(12 V) -4(24 V)	0	+2(12 V) +4(24 V)	mV/°C
VB_{ITD2}		-		-2.5		
VB_{ITD3}		-		-3.5		
VB_{ITD4}		-		-7		
VB_{ITD5}		-		-10		
ΔVB_{load}	Regulated voltage variation with the load 12 V (24 V) system (P-Loop)	Difference between regulated voltage when F duty cycle is 10% and regulated voltage when F duty cycle is 90%	-	-	400	mV
ΔVB_{speed} (1)	Regulated voltage variation with the speed 12 V (24 V) (both P and PI loop)	Difference between regulated voltage when I_{gen} = 10 A 2000rpm<Alt speed<18000rpm	-	-	100 (150)	mV
VBwb12(1)	Regulation without battery 12 V system	I_{alt} = 5 A resistive; T_{case} = 25 °C; 2000 < rpm < 18000	12	-	16	V
VBwb24(1)	Regulation without battery 24 V system	I_{alt} = 5 A resistive; T_{case} = 25 °C; 2000 < rpm < 18000	22	-	34	V
P-Sens(2)	P-Sensitivity = dc-variation(%) per unit Err	P-Loop	-	0.2500	-	%/mV
		PI-Loop	-	0.0312 0.0416 0.0521 0.0625	-	%/mV
I-Sens(2)	I-Sensitivity = dc-rate(%/s) per unit Err	PI-Loop only	-	0.400 0.294 0.214 0.160	-	(%/s)/mV

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

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VB_{SP_CL12}	Set Point Voltage clamp at low temperature (-40°C) F duty cycle=50% 12 V system	-	14.7	15	15.3	V
VB_{SP_CL24}	Set Point Voltage clamp at low temperature (-40°C) F duty cycle = 50% 24 V system	-	28.4	29	29.6	V

1. Alternator dependent parameter not tested.
2. Error := VSetP – Vreg;
P-Sens: Delta(DC) = P-Sens * Delta(Err);
I-Sens: d(DC)/dt = I-Sens * Err.

Regulated voltage variation with the load when proportional regulation loop (P-Loop) is selected.

Figure 4. Regulated voltage variation with the load

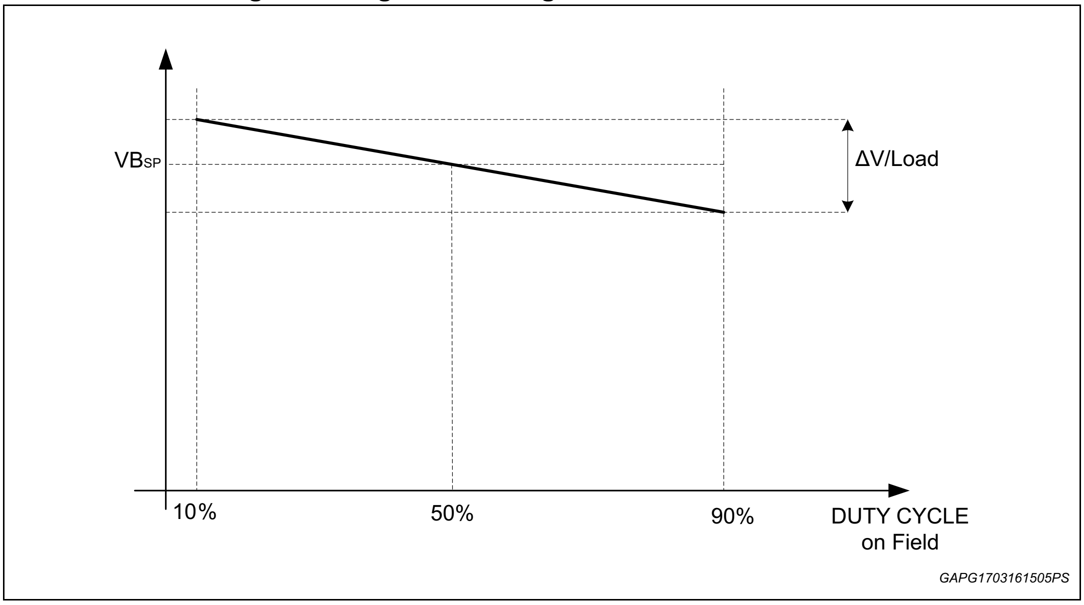
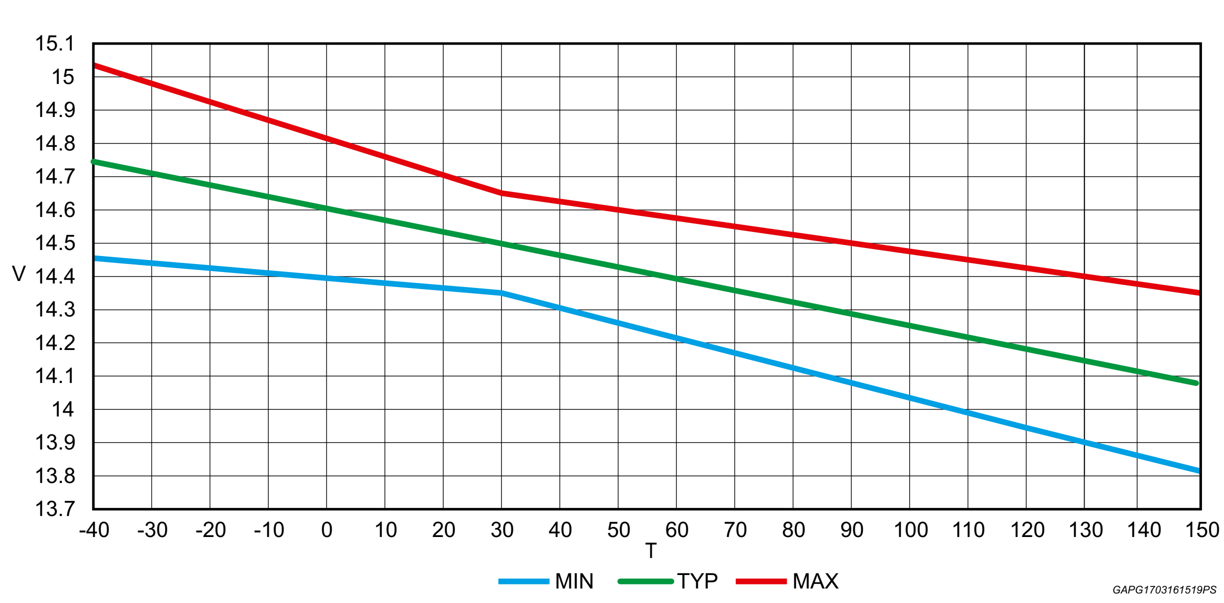


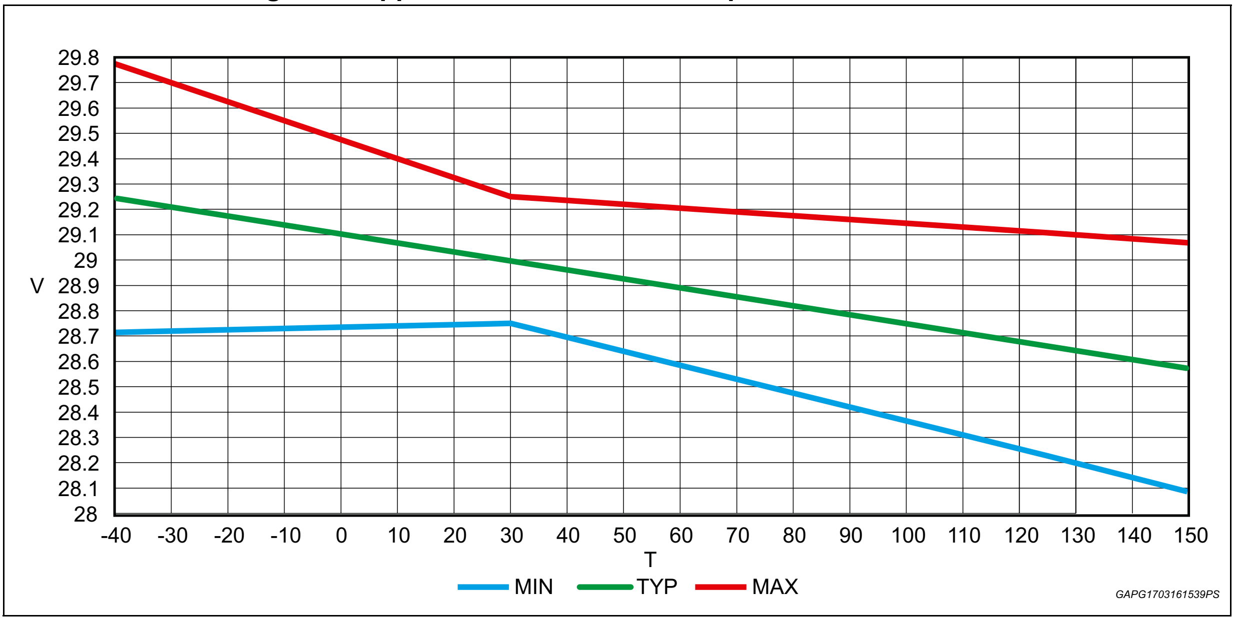
Figure 5. Application 12 V - Default setpoint with -3.5 mV/°C



Regulation curves versus temperature @ F Duty Cycle = 50%

(Example with VB_{SP} = 14.5 V, VB_{ITD} = -3.5 mV/°C)

Figure 6. Application 24 V - Default setpoint with -3.5 mV/°C



Regulation curves versus temperature @ F Duty Cycle = 50%

(Example with VB_{SP} = 29 V, VB_{ITD} = -3.5 mV/°C).

Cranking security function

In order to avoid unpredictable regulation regions during the engine start, the regulator implements a Cranking Security Function.

At the ignition key on (i.e. "key" switch closed in the application schematic) the device starts in pre-excitation; in this phase the battery voltage is over both VB_{UV} and VB_{LOW} 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 VB_{LOW} threshold then the device will be frozen: the device will be in low current consumption with no activity on both F and FM pins.

The device will remain in frozen conditions until the voltage on B overcomes the VB_{low} threshold. After that the device start again to evaluate the input coming from PH pin.

Table 8. VB over and under voltage parameters

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VB_{Ovp12V}	Over voltage protections threshold 12 V system	-	16	-	16.9	V
VB_{Ovp24V}	Over voltage protections threshold 24 V system	-	32	33	34	V
VB_{OVft}	Over voltage filter time	-	0.5	1.25	2	ms
VB_{UV12V}	Under voltage 12 V system	-	8	9	10	V
VB_{UV24V}	Under voltage 24 V system	-	16	18	20	V
VB_{low}	Low voltage	-	5	5.5	6	V
$VBLV_{filt}$	Low voltage filter time	Guaranteed down to VBlow	100	150	200	µs

Over voltage

For safety reason this function is implemented with independent circuitry with respect to the ones used by the field driver in order to guarantee that in case of overvoltage the field driver is securely switched off.

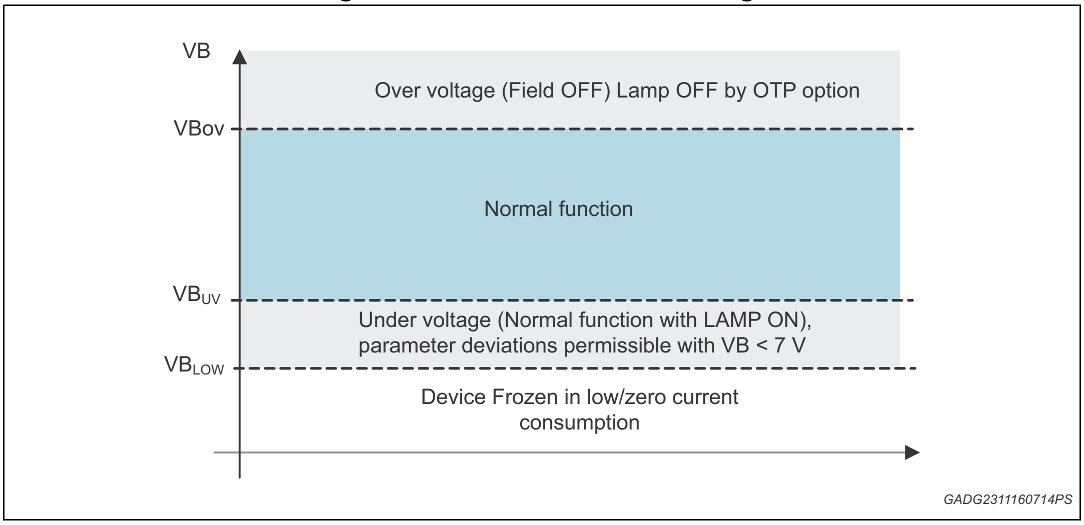
Under voltage

When detected the L9916B switches on the lamp.

Low voltage

When detected the L9916B enters in stand by condition. All drivers are OFF including the lamp driver.

Figure 7. VB over and under voltage



Behaviour to supply micro cut

The device can sustain micro-interruption in battery line without have a logic reset.

Figure 8. Behaviour to supply micro cut

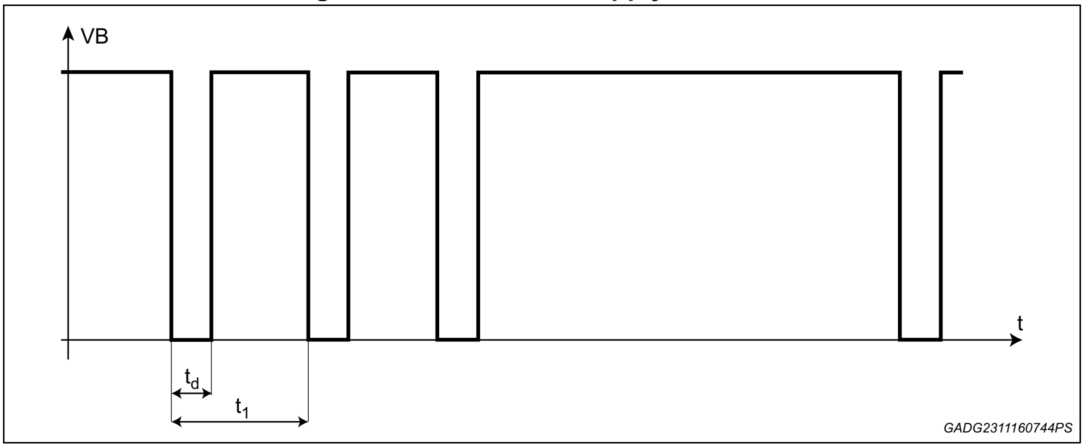


Table 9. Battery interruption time

Symbol	Parameter	Test condition / Note	Min.	Typ.	Max.	Unit
t_d	Battery interruption time	-	-	-	80	µs
t_1	Minimum time between two battery interruptions	-	1	-	-	ms

2.5.2 Pin "SENSE"

The system battery can be directly sensed using the SENSE input. If the voltage on SENSE pin goes below the $SENSE_{disc}$ threshold a sense disconnection is detected. If voltage of B+ is $SENSE_{diff}$ greater than voltage of SENSE, the device detects the SENSE voltage is not valid.

The device detects a 'sense loss' when either the sense disconnection or the voltage difference comparator is active. In case of 'sense loss' the L9916B will use the B+ value to control the set point voltage, otherwise SENSE voltage will be used.

It's possible to select if the voltage setpoint is increased by 1 V in case of sense loss.

Table 10. Electrical characteristics - Pin "SENSE"

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$SENSE_{disc,12}$	Sense disconnected when Sense voltage is below	-	7.5	8.5	9.5	V
$SENSE_{disc,24}$		-	11	12	13	V
$SENSE_{diff,1}$	Voltage difference (B+) - Sense	-	1.2	1.6	2.1	V
$SENSE_{diff,2}$		-	1.8	2.3	2.9	V
VB_{SPUP}	Voltage setpoint increase in case of SENSE loss	-	0.9	1	1.1	V
TS_{StoB}	Digital filter time to switch from S to B+ regulation	-	0.8	1	1.2	ms
TS_{BtoS}	Digital filter to switch from B+ to S regulation	-	160	200	240	ms
I_{SENSE_PD}	Pull down current	-	10	45	80	µA

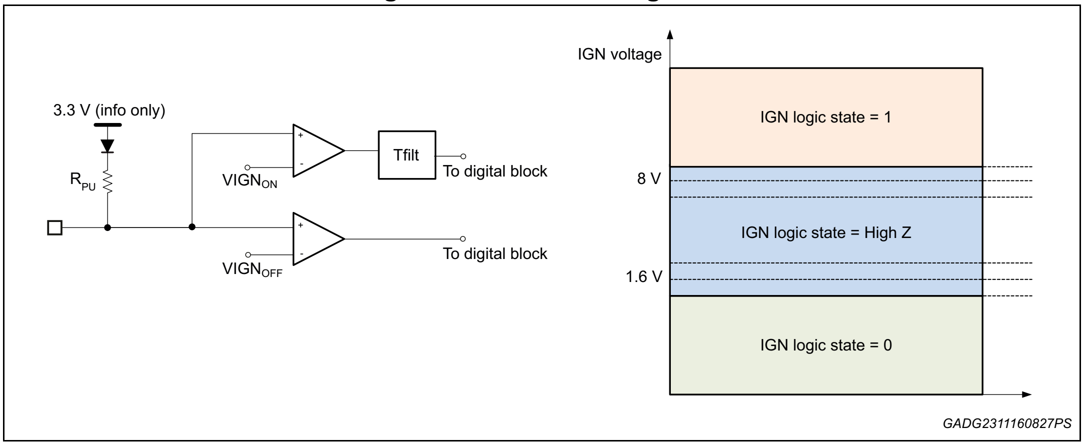
2.5.3 Pin "IGN"

The IGN pin is an input that can be used to wake-up the device in place of the Lamp and the selection is performed by OTP. The usage of one wake-up input (L or IGN) excludes the other one. The signal applied to IGN is compared to a threshold $VIGN_{ON}$ and $VIGN_{OFF}$ and the result is used to turn the device on. If not used this pin must be connected to ground directly or with a 10 nF capacitor.

Table 11. Electrical characteristics - Pin "IGN"

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$VIGN_{ON}$	Voltage threshold input comparator to switch on	-	6	8	10	V
$VIGN_{OFF}$	Voltage threshold input comparator to go in logic state = 0	-	1.3	1.6	1.9	V
$VIGN_{OFFHYS}$	Voltage threshold input comparator to go in logic state = High Z	-	$VIGN_{OFF}$ +0.25	$VIGN_{OFF}$+ 0.35	$VIGN_{OFF}$+ 0.45	V
R_{pu}	Pull-up resistance	-	26	52	80	kΩ
T_{filt}	Wake up filter time	-	-	40	-	µs

Figure 9. Pin "IGN" diagrams



2.5.4 Wake-up behaviour

In this chapter is described the device wake-up behaviour depending on the signal on IGN, L, PH pin and the dedicated OTP cells.

The device wakes-up through L pin or IGN pin.

Note: The IGN input pin is able to read 3 level voltages, the below values for IGN are intended as follows:

1 = input voltage higher then $VIGNIT_{ON}$

0 = input voltage lower then $VIGNIT_{OFF}$

High-Z = input voltage between $VIGNIT_{OFF}$ and $VIGNIT_{ON}$

IGN input not used (see *Section 2.5.3*).

Table 12. Self-start function enabled

IGN	L	PH	Regulator
X	0	Not present	OFF
X	0	Present	ON
X	1	Not present	ON
X	1	Present	ON

IGN input not used (see *Section 2.5.3*).

Table 13. Self-start function disabled

IGN	L	PH	Regulator
X	0	Not present	OFF
X	0	Present	OFF
X	1	Not present	ON
X	1	Present	ON

In case of condition L = 1, PH = present, regulator = ON the L signal becomes = 0, the regulator goes in OFF condition.

IGN input used (see *Section 2.5.3*).

Table 14. Self-start function enabled (Mode 1)

IGN	L	PH	Regulator
0	X	X	OFF
1	X	X	ON
High-Z	X	Not present	OFF
High-Z	X	Present	ON

IGN input used (see *Section 2.5.3*).

Table 15. Self-start function disabled (Mode 1)

IGN	L	PH	Regulator
0	X	X	OFF
1	X	X	ON
High-Z	X	Not present	OFF
High-Z	X	Present	OFF

IGN input used (see *Section 2.5.3*).

Table 16. Self-start function enabled (Mode 2)

IGN	L	PH	Regulator
0	X	Not present	OFF
0	X	Present	ON
1	X	X	ON
High-Z	X	Not present	OFF
High-Z	X	Present	ON

Note: X = Don't care.

2.5.5 Pin "FM"

The pin Field Monitor is used to communicate to the ECU the information about the activity on the field.

Figure 10. Pin "FM" circuit and waveform

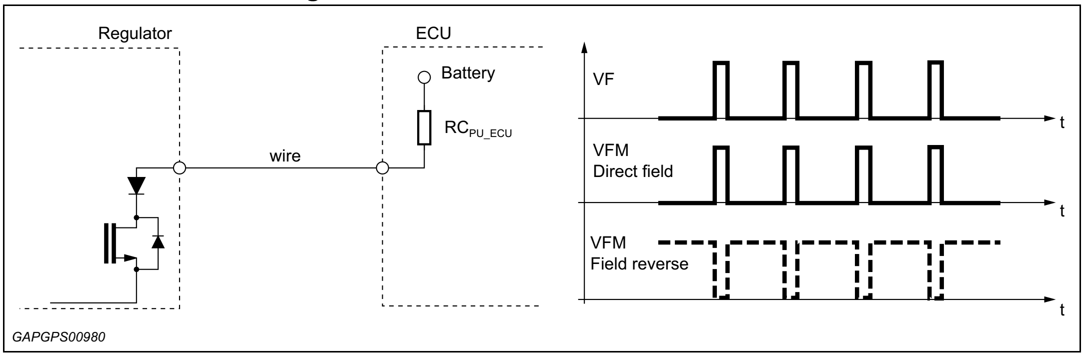
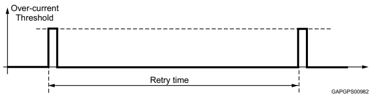


Table 17. Electrical characteristics - Pin "FM"

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VM_{LVS}	Low voltage saturation	I-sink = 14 mA	0.9	1.2	1.5	V
$fM_{SW,1}$	Field monitor frequency switch Option1	-	-	100	-	Hz
$fM_{SW,2}$	Field monitor frequency switch Option2	-	-	200	-	Hz
DM_{DCR}	Field monitor duty cycle range	In case of duty cycle clamp selected	5	-	95	%
IM_{lim}	Field monitor current limitation	-	25	50	75	mA
T_{lim}	Duration of current limitation	-	50	-	100	µs

Table 17. Electrical characteristics - Pin "FM" (continued)

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
TF_{retry}	Retry time in case of over-current		30	40	50	ms
IFM_{leak}	Leakage current	-	-	-	3	µA

Optional filter (1st order IIR with Fcut(Typ) = 130 Hz) can be used to smooth Field Monitor duty-cycle variations.The Field Monitor switching frequency can be selected using the one OTP cells.

The polarity of the Field Monitor signal can be selected "direct" or "reverse" respect to the field driver signal, using the OTP cells.

The duty cycle of the Field Monitor signal can be selected to have maximum and minimum values of 95% and 5% in case the field signal has a duty cycle higher than 95% or lower than 5%, using the OTP cells.

In case of short to VB the current output is limited to IM_{lim} for a time equal to T_{lim} then the output is switched off and turned on again after TF_{retry},

The duty cycle presented on FM is a replica with a different frequency of the duty cycle into the Field in order to provide to the ECU the information of the load connected to the alternator.

The duty cycle presented on F.M. is different from the signal on the Field in the following cases:

- In the pre-excitation state FM always it has a fixed duty cycle equal to DFPreex (12.5%) whatever the battery voltage is.
- When the device exits the pre-excitation, for all the time in which the phase regulation is active, on pin FM a signal with a duty cycle of 6% is presented. If the phase regulation persists over time the device continues to show a 6% duty cycle. Elapsed the phase regulation, the duty cycle of FM becomes equal to the duty cycle on the Field.
- In the following requests of phase regulation, the Field executes the request while the FM continues to send the information of the entity of the current load. The activation of the field needed to implement the phase regulation is excluded from the account of the duty cycle: for example, if the battery voltage rises above the set point as a consequence of a load disconnection and a phase regulation is required, the field executes while FM continues to have a duty cycle of 0% (or its clamp value) that is the real load on the alternator in that moment.

2.5.6 Pin "PH"

The VP_{HTh}, VP_{LTh} are the voltage thresholds for the phase input detection used when the L pin or the IGN pin is connected. In case of self-start there are 4 couples of thresholds that can be selected and that are used for the first turn-on. Once the speed exceeds the $S_{PSS,\ x}$ threshold the device will switch to the VP_{HTh}, VP_{LTh} thresholds. To calculate the rpm value with good precision an average of four phase period is done.

Table 18. Electrical characteristics - Pin "PH"

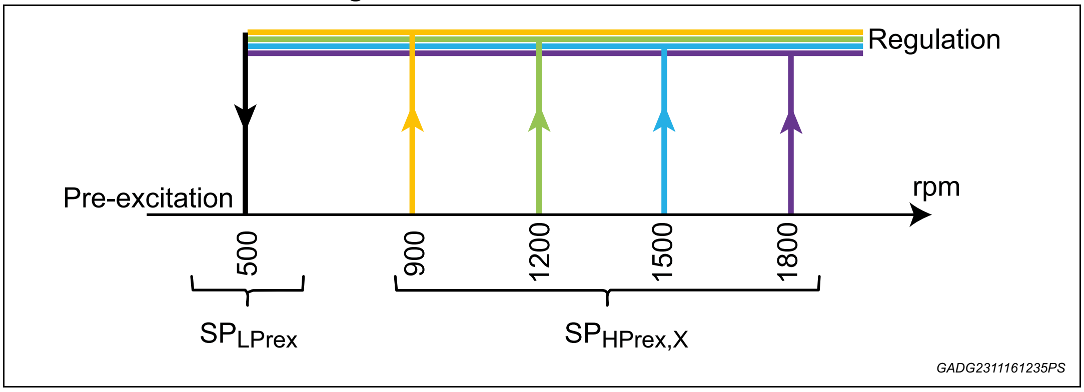
Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VP_{HTh}	High voltage threshold of hysteresis input buffer in case L or IGN connected and after self-start	-	1.3	1.45	1.6	V
VP_{LTh}	Low voltage threshold of hysteresis input buffer in case L or IGN connected and after self-start	-	0.85	1	1.15	V
VP_{HTh_SS1}	High voltage threshold of hysteresis input buffer on self-start (1)	-	0.15	0.19	0.23	V
$VP_{LTh\_\_SS1}$	Low voltage threshold of hysteresis input buffer on self-start (1)	-	0.05	0.09	0.13	V
VP_{HTh_SS2}	High voltage threshold of hysteresis input buffer on self-start (1)	-	0.25	0.37	0.45	V
$VP_{LTh\_\_SS2}$	Low voltage threshold of hysteresis input buffer on self-start (1)	-	0.15	0.24	0.35	V
VP_{HTh_SS3}	High voltage threshold of hysteresis input buffer on self-start (1)	-	0.6	0.76	0.9	V
$VP_{LTh\_\_SS3}$	Low voltage threshold of hysteresis input buffer on self-start (1)	-	0.35	0.45	0.6	V
VP_{HTh_SS4}	High voltage threshold of hysteresis input buffer on self-start (1)	-	1.1	1.22	1.35	V
$VP_{LTh\_\_SS4}$	Low voltage threshold of hysteresis input buffer on self-start (1)	-	0.85	1	1.15	V
RP_{pd}	Pull-down resistor (in addition to $IP_{pull\text{-}dw}$)	-	7	15	22	kΩ
TP_{SR}	Spike rejection time	-	70	125	180	µs
$IP_{pull\text{-}dw}$	Pull-down current (in addition to RP_{pd})	-	1.5	2	3.5	mA

Table 18. Electrical characteristics - Pin "PH" (continued)

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$SP_{HPrex,1}$	High rpm Threshold to exit pre-excitation Option1(2)	-	Typ-10%	900	Typ+10%	rpm
$SP_{HPrex,2}$	High rpm Threshold to exit pre-excitation Option2(2)	-	Typ-10%	1200	Typ+10%	
$SP_{HPrex,3}$	High rpm Threshold to exit pre-excitation Option3(2)	-	Typ-10%	1500	Typ+10%	
$SP_{HPrex,4}$	High rpm Threshold to exit pre-excitation Option4(2)	-	Typ-10%	1800	Typ+10%	
SP_{LPrex}	Low speed threshold to enter pre excitation	-	Typ-10%	500	Typ+10%	rpm
$SP_{SS,1}$	Self-start rpm Threshold options(2)	-	Typ-10%	1200	Typ+10%	rpm
$SP_{SS,2}$		-	Typ-10%	1500	Typ+10%	
$SP_{SS,3}$		-	Typ-10%	1800	Typ+10%	
$SP_{SS,4}$		-	Typ-10%	3200	Typ+10%	
$SP_{LRC,1}$	rpm Threshold to exit/enter in LRC options	-	Typ-10%	1500	Typ+10%	rpm
$SP_{LRC,2}$		-	Typ-10%	2800	Typ+10%	
$SP_{LRC,3}$		-	Typ-10%	3000	Typ+10%	
$SP_{LRC,4}$		-	Typ-10%	3200	Typ+10%	
SP_{DFSS}	rpm threshold to apply Field duty cycle in self start		Typ-10%	900	Typ+10%	rpm
$VP_{prHTh12V}$	High phase regulation voltage threshold 12 Vapp	-	6.7	7.7	8.7	V
$VP_{prLTh12V}$	Low phase regulation voltage threshold 12 Vapp	-	3	4	5	V
$VP_{prHTh24V}$	High phase regulation voltage threshold 24 Vapp	-	14	15.5	17	V
$VP_{prLTh24V}$	Low phase regulation voltage threshold 24 Vapp	-	5.2	6.2	7.2	V
TP_{OFF}	Max windows time to detect 4 phase periods	-	114	128	142	ms

1. From standby to crank @ IGN/KEY = 0.
2. Recommended: $SP_{SS} \geq SP_{HPrex}$.

Figure 11. Pre-excitation threshold



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 (rpm spread: ±10%)

Principle of phase regulation

When VB is above the set-point voltage, the field driver is controlled to keep the phase peak voltage from falling below VP_{prTh}. If the phase peak voltage drops below VP_{HTh}, the phase regulation does not work. During the Phase regulation the field is driven with a fixed duty-cycle and frequency, T_{on} = 40 ms and T_{off} = 40 ms. If during the T_{on} phase the VP_{prTh} threshold is reached the field is switched off even if the 40 ms have not elapsed.

The phase regulation is performed in both cases, either the high level phase signal does not cross the VP_{prTh} threshold or the low level phase signal does not cross the VP_{LTh} threshold.

Figure 12. Phase regulation in case VPH signal does not cross VP_{prTh}

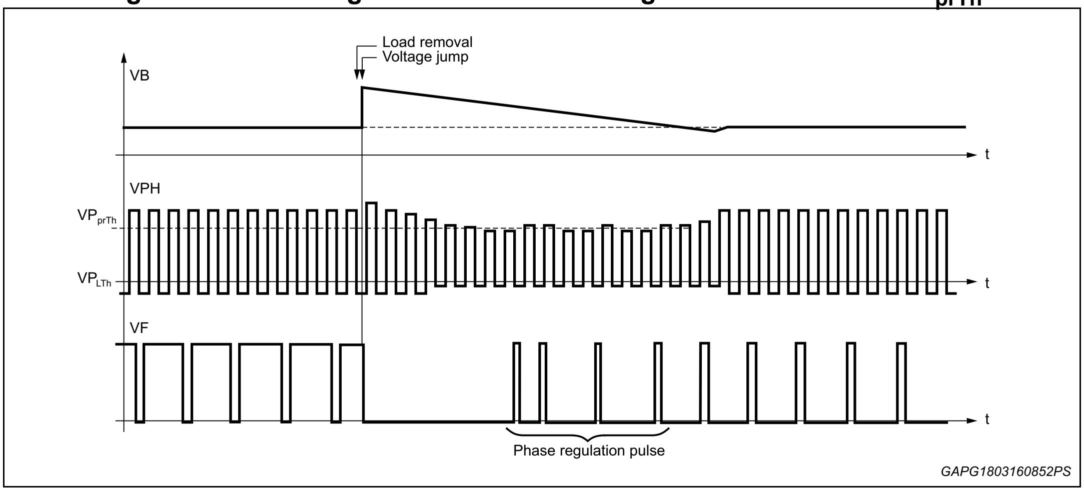
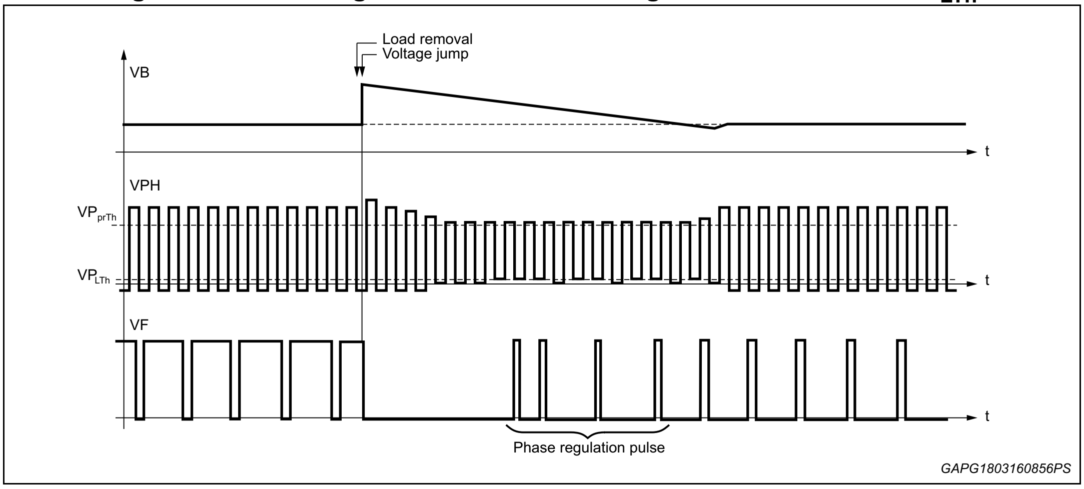


Figure 13. Phase regulation in case VPH signal does not cross VP_{LTh}



2.5.7 Pin "F"

Table 19. Electrical characteristics - Pin "F"

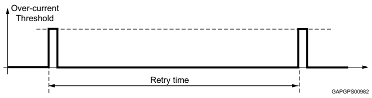
Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
Ron	Ron field driver	T_j = 130 °C; I_{sunk} = 4.5 A	-	-	130	mΩ
VF_{diode}	Freewheeling diode	$I_{sourced}$ = 5 A	-2	-		V
IF_{leak}	Field leakage current	VB = 50 V; VF = 0	-5	-	5	μA
IF_{OVP}	Field driver over-current protection	T_j = -40 °C	9	-	18	A
		T_j = 25 °C	8.5	-	18	A
		T_j= 130 °C	8	-	18	A
$TF_{OVfilter}$	Over-current filter time	-	2.5	5	7.5	μs
TF_{retry}	Retry time in case of over-current		30	40	50	ms
VF_{ONdet}	Voltage threshold ON-state detection	-	0.9	1.1	1.3	V
fF_{SW}	Field switching frequency options	-	-10%	165	+10%	Hz
T_{fall}	Voltage slew rate for field driver (Measurement is performed between 80% and 20% of the slope)	VB = 14 V R = 270 Ω	1	4	10	μs
T_{rise}	Voltage slew rate for field driver (Measurement is performed between 20% and 80% of the slope)	VB = 14 V R = 270 Ω	1	4	10	μs
DF_{Preex}	Field duty cycle in pre-excitation	-	11	12.5	14	%
DF_{SS}	Field duty cycle in self start	Applied when only “ph” signal is present and speed > SP_{DFSS} and < SP_{SS}	4	6	8	%
$TF_{LRCUP,1}$	Load Response Control Time (0% to 100% DC)	-	2.12	2.5	2.88	s
$TF_{LRCUP,2}$		-	2.55	3	3.45	
$TF_{LRCUP,3}$		-	4.25	5	5.75	
$TF_{LRCUP,4}$		-	5.1	6	6.9	
$TF_{LRCUP,5}$		-	6.37	7.5	8.63	
$TF_{LRCUP,6}$		-	7.65	9	10.35	
$TF_{LRCUP,7}$		-	8.5	10	11.5	
$TF_{LRCUP,8}$		-	10.2	12	13.8	

Table 19. Electrical characteristics - Pin "F" (continued)

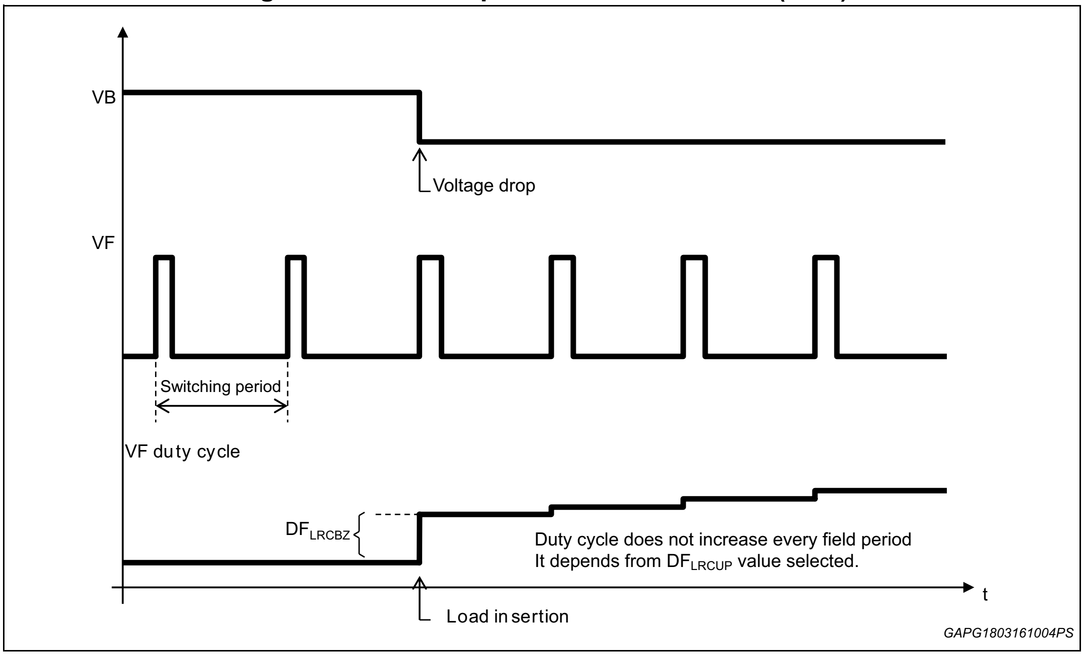
Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
DF_{LRCUP}	Positive Duty Cycle vs. time variation	-	100 / TF_{LRCUP}			%/s
TF_{LRCDW}	Load Response Control Time (100% to 0% DC)	-	TF_{LRCUP} * 3 / 8			s
DF_{LRCDW}	Negative Duty Cycle vs. time variation	-	- 100 / TF_{LRCDW}			%/s
$DF_{LRCEnab}$	Current vs. Previous Duty Cycle Variation to Enable LRC Function	P-loop selected (for PI-loop the value depend to GP value selected)	-	1.4	-	%
			-	6.8	-	
			-	12	-	
			-	24	-	
DF_{LRCBZ}	Blind Zone	-	-	0	-	%
			1.4	2.3	3.2	
			1.9	3.1	4.3	
			2.8	4.6	6.4	
			3.3	5.3	7.3	
			3.8	6.2	8.6	
			4.1	6.7	9.3	
			5	8	11	
$TF_{SDT,1}$	Start Delay Time options	-	0.4	0.5	0.6	s
$TF_{SDT,2}$		-	2.12	2.5	2.88	
$TF_{SDT,3}$		-	4.25	5	5.75	
$TF_{SDT,4}$		-	8.5	10	11.5	

Self-start function

In case no other wake up source is detected except the phase signal the device wakes up by self-start. During the self-start phase, the device will apply the DF_{SS} field duty cycle on the field if the speed is > SP_{DFSS} < SP_{SS}. Above SP_{SS} the device will work with the normal regulation.

Load response control function (LRC)

Figure 14. Load response control function (LRC)



When an electrical load is applied in the system application, a drop in the regulated voltage (VB) occurs and the alternator reacts 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 operates always after SDT expiration and when the alternator runs at low speed (the PH signal frequency has to be lower than fP_{LRC}) and it is activated when a positive variation between current duty cycle on Field and its previous duty cycle values is higher $DF_{LRCEnab}$. When the LRC function is required, the duty cycle increases slowly with the defined slope DFLRCUP starting from the previous duty cycle increased by the fixed value DF_{LRCBZ}. The actual duty cycle management during a LRC insertion is shown in the figure. Once the LRC function is started it completes the required ramp even if the alternator speed becomes higher than the SP_{LRC}.

Minimum Battery voltage rate to trigger LRC depends on Active Loop (P, PI), GP, $DF_{LRCEnab}$, DF_{LRCBZ}.

P-Loop: SR(mV/ms) = (16.67/P-Sens) * $DF_{LRCEnab}/1$;

PI-Loop: SR(mV/ms) = (16.67/P-Sens) * $DF_{LRCEnab}/4$.

For example:

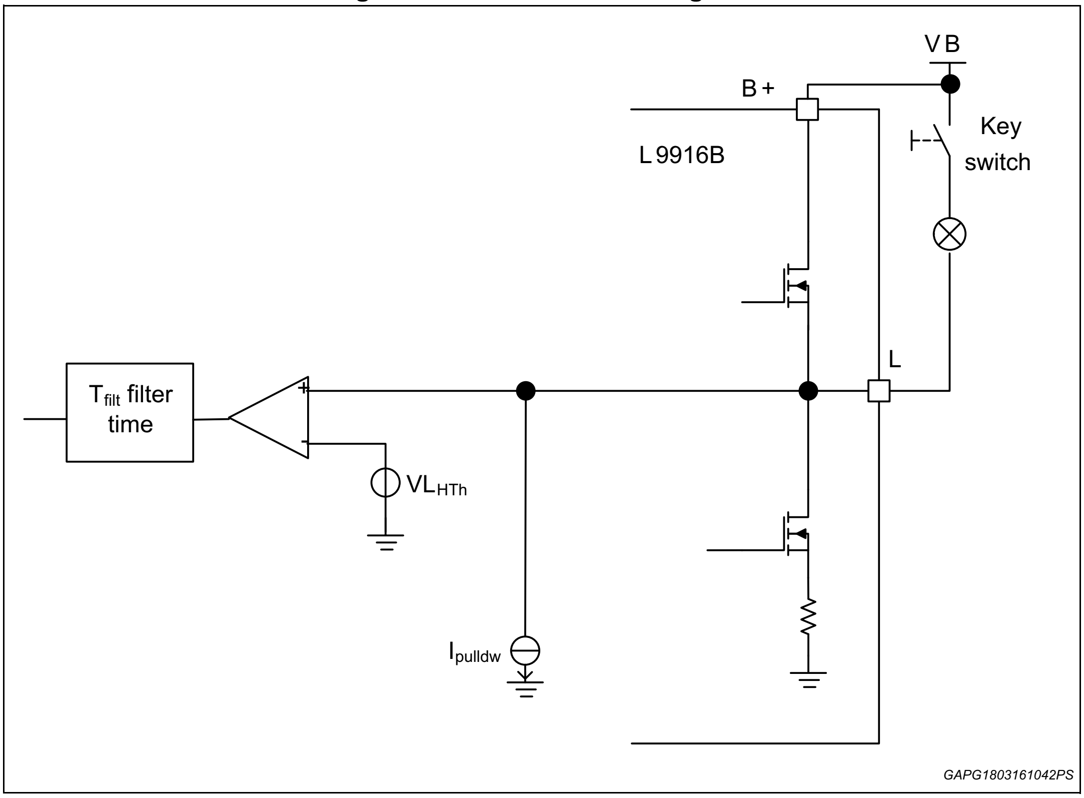
P-Sens = 0.250 %/mV (P-Loop), $DF_{LRCEnab}$=1.4%, DF_{LRCBZ}= 4.6%; $DF_{LRCEnab}/1$ = 1.4%, SR = 66.68*0.014 = 0.9335 mV/ms.

P-Sens = 0.052 %/mV (PI-Loop), $DF_{LRCEnab}$=12%, DF_{LRCBZ}= 2.3%; $DF_{LRCEnab}$/4 = 3%,

SR = 320.57*0.03 = 9.617 mV/ms.

2.5.8 Pin "L"

Figure 15. Pin "L" circuit diagram



The L pin is used to drive the fault indicator lamp and the optional auxiliary load relay.

The device exits the stand-by mode when the switch "Key" is closed (i.e. $VL>VL_{HTh}$).

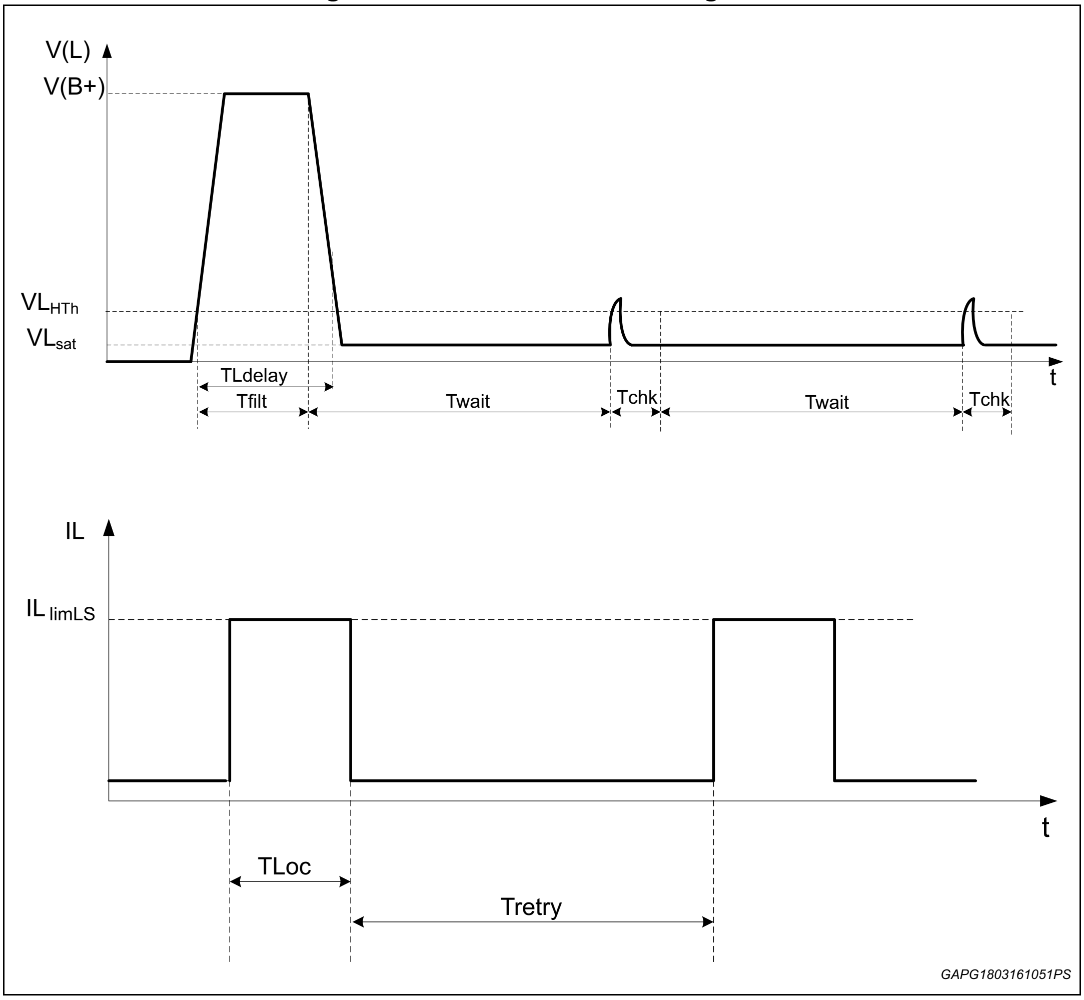
The Lamp is driven by an internal low side N-channel MOSFET whereas the relay is driven by an internal high-side N-channel MOSFET.

The current in Low side driver is limited to IL_{limLS} for a time TL_{OC}, then the driver is switched off. After T_{retry} the low side driver is turned on again.

To reduce the power dissipation in the lamp driver while it is ON, the following strategy is implemented: after key-on, as soon as the L pin voltage overcomes VL_{th}, after T_{filter} time it is brought to VL_{sat} voltage (between its drain and source), then the key status is verified every T_{wait} time intervals within a T_{chk} time window.

During this window, if the key is switched on the L voltage reaches the VL_{HTh} value and immediately returns to the VL_{sat} value before the window expiration whereas, if the key is no longer active, the L voltage cannot increase and remains below key detection threshold (VL_{HT}).

Figure 16. Pin "L" waveform diagrams

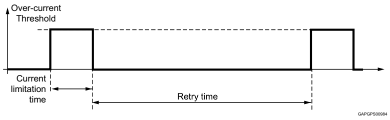


The high side driver is switched off if the current overcomes the IL_{OVCHS} for $T_{LH\ filter}$ time.

Table 20. Electrical characteristics - Pin "L"

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
VL_{SAT}	Lamp Driver saturation Voltage	I_{sunk} =300 mA	-	-	0.3	V
R_{onL}	Ron Lamp driver	T_j = 175 °C; I_{sunk} = 300 mA	-	-	1	Ω
$I_{pulldw,1}$	Pull down current	-	0.6	1	1.4	mA
$I_{pulldw,2}$		-	25	50	75	µA
T_{filt}	Key-on filter time	-	-	40	-	µs
T_{chk}	Key presence check time window	Digital window time	-	-	1	ms
T_{wait}	Key presence interval	-	34	40	46	ms
VL_{HTh}	High Voltage Threshold key-ON detector	-	0.8	0.9	1	V

Table 20. Electrical characteristics - Pin "L" (continued)

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
$IL_{limLS,12V}$	LS current limitation threshold	-	1.2	-	2.4	A
$IL_{limLS,24V}$	LS current limitation threshold	-	0.6	-	1.2	A
TL_{delay}	Turn ON delay time	-	-	-	100	us
TL_{OC}(1)	Maximum time duration of linear current limitation		-	30	35	ms
TL_{retry}	Retry time (time where the transistor is OFF) in case of over-current duration > TL_{OC}		510	600	690	ms
VH_{sat}	Relay Driver saturation Voltage	$V(B+) = 12.6\ V$; $I_{sourced} = 0.3\ A$	-		1	V
Ron_{HS}	Ron HS relay driver	$T_j = 175\ °C$; $I_{source} = 300\ mA$	-	-	3	Ω
IL_{OVCHS}	HS Over-current threshold	-	1	-	2	A
$TL_{HSretry}$	Retry time in case of over-current	-	30	40	50	ms
$TL_{Hfilter}$	HS Over current filter time	-	-	5	-	µs
$TL_{alarm,1}$	Alarm validation time	-	0.42	0.5	0.58	s
$TL_{alarm,2}$		-	0.85	1	1.15	
$TL_{alarm,3}$		-	1.27	1.5	1.73	
$TL_{alarm,4}$		-	1.7	2	2.3	
T_{Ldis}	High side Disable time	-	400	475	550	ms

1. In case Lamp Driver exceeds safety temperature, it will be turned OFF.

2.6 Alarm detection

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

Table 21. Alarm detection

Detection condition	Related pin/ Description	Configurable
VPH< VP_{prTh} and VB<VB_{SP}	F driver or its connection degraded	No
IF>IF_{OVP}	F shortened to GND (Over-current on F driver)	No
VB>VB_{SP} and VF>VF_{ONdet}	F shortened to B	No
VB>VB_{Ovp12V} | VB>VB_{Ovp24V} (1)	Battery sensor on B pin or F driver degraded	Yes
VB<VB_{UV}	Low B Voltage (Battery under-voltage)	No
VSENSE< $SENSE_{disc}$	SENSE connection loss	Yes
$VIGNIT_{OFF}$<VIGN< $VIGNIT_{ON}$	VIGN open	Yes

1. in case of OTP bit enabled the High Side and Low Side drivers will be disabled when an Over-Voltage occurs. To avoid High side turn off during a normal load dump event, the High side driver is turned OFF only after TL_{dis}.

In case of VPH<VPHTh or PH frequency < f_{PLPrex} the device enters in pre-excitation state and turns ON the lamp.

Also during self start when SPDFss < PH < SPss, the device will enters in wakeup mode and turn on the lamp.

2.7 End of line test mode

Through the FM pin the device can enter a special "test mode" where some time consuming functions are not present.

The functions that are not present are:

LRC, SDT and TL_{alarm}

To enter the "test mode" it is necessary to bring the FM pin voltage to V_{FM_TM} and the device must not be in overvoltage condition (VB> VBO_{vp}).

Table 22. End of line test mode

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
V_{FM_TM}	Voltage threshold to enter in EOL test mode	-	37	41	45	V

2.8 OTP programming

The programming of the device parameters is achieved by using the I^2C interface which is implemented on two pins (PH and DFM) having also such alternative functions.

Here below some general information on the I^2C

The L9916B is I^2C slave device, so SCL (clock line from I^2C Master device) is input, while SDA (data line) is bidirectional to allow transmit/receive operations to/from I^2C master device. Both SCL and SDA lines are connected to a positive power supply voltage via pull-up resistor. The I^2C protocol defines the proper operations of the link. When the bus is free, both lines are High (pulled-up). The output stages of the devices connected to the bus must have an open-drain or open-collector to perform the wired-AND function. The maximum link rate is 400 kbit/s.

The required voltage for the OTP programming is 15.7 V±0.5 V.

For the programming procedure refer to the dedicated document.

Figure 17. I^2C interface circuit

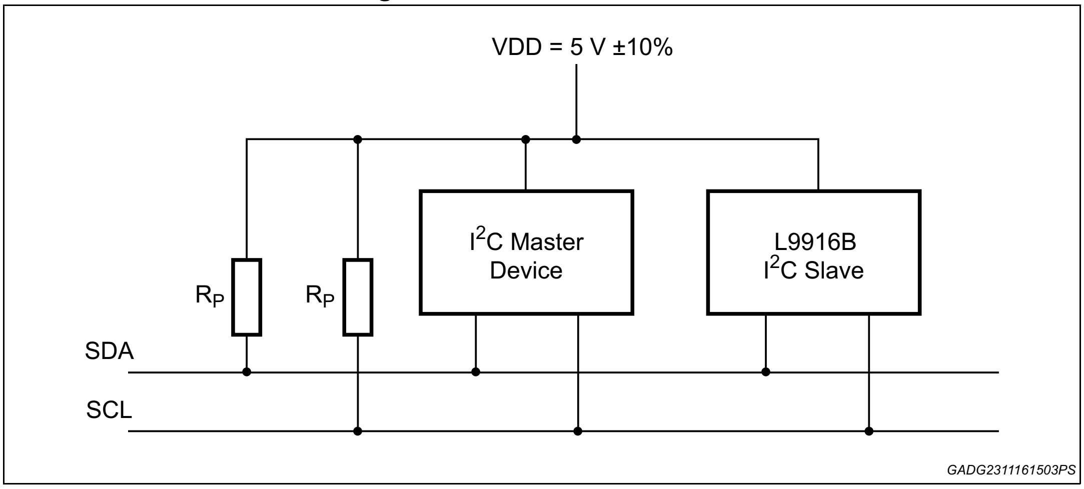


Table 23. OTP programming electrical characteristics

Symbol	Parameter	Test condition / Note	Min	Typ	Max	Unit
f_{SCL}	Clock frequency	-	10	-	400	kHz
VIL	Input low voltage	-	-	-	1.5	V
VIH	Input high voltage	-	2.3	-	-	V

2.8.1 External pull up resistor sizing

Given:

C_p = wiring (line) capacitance

f = Target frequency

R_p = Pull up resistor

T = 1/f

τ = Time constant

and assuming that for proper operation τ<T/4, if the target frequency (SCL) is 100 kHz and the line capacitance is C_p = 100 pF we got:

T = 1/f = 10 µs

τ = R_p*C_p < T/4 = 2.5 ms ≥ R_p < 2.5 ms/100 pF = 25 kΩ.

3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 Multiwatt 8 (pin 5 GND) package information

Figure 18. Multiwatt 8 (pin 5GND) package outline

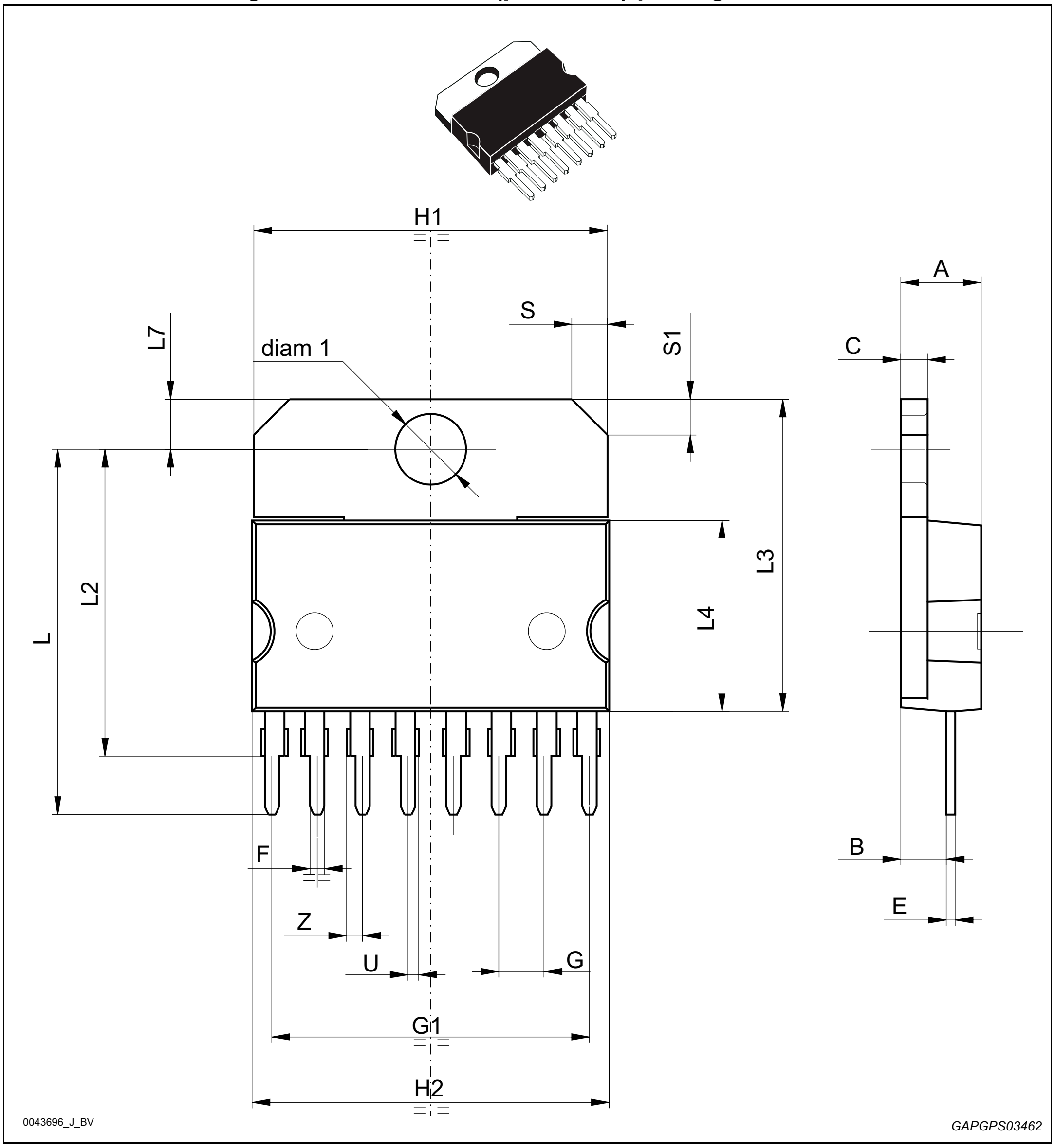


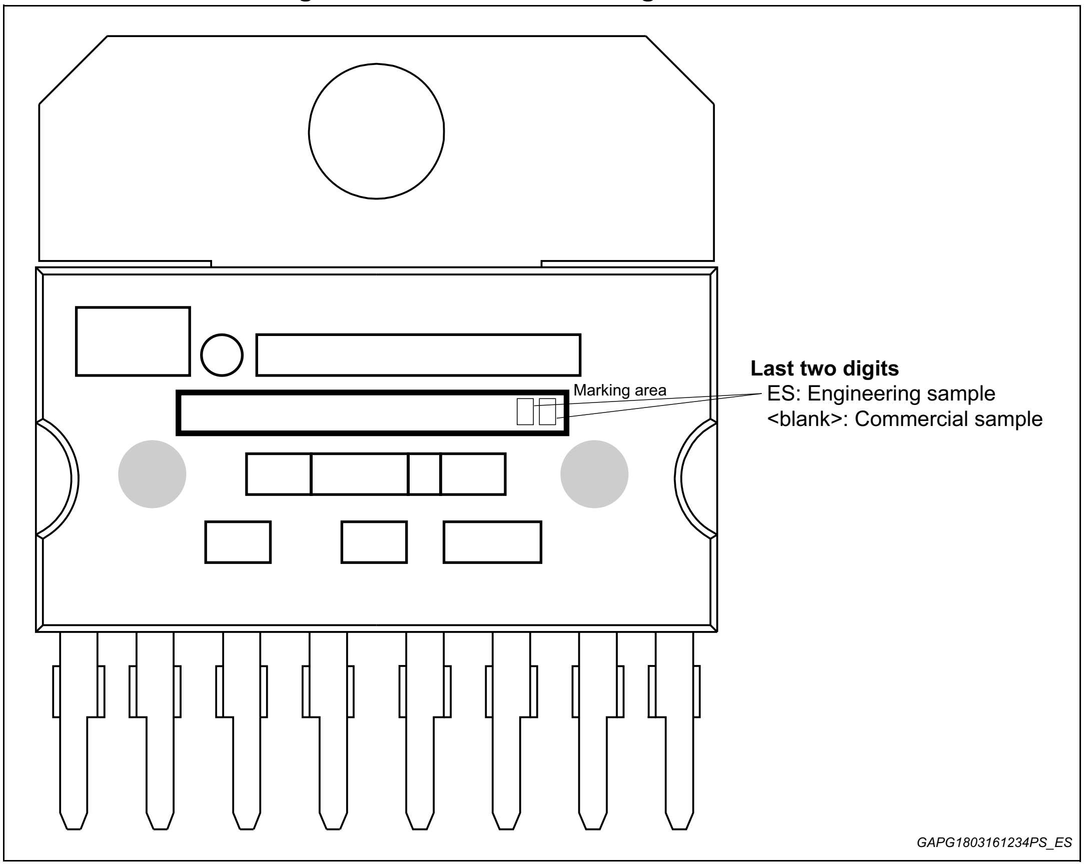
Table 24. Multiwatt 8 (pin 5GND) package mechanical drawing

Ref	Dimensions					
	Millimeters			Inches[(1)]		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A	-	-	5	-	-	0.1969
B	-	-	2.65	-	-	0.1043
C	-	-	1.6	-	-	0.0630
E	0.49	-	0.55	0.0193	-	0.0217
F	0.78	-	0.85	0.0307	-	0.0335
G	2.40	2.54	2.68	0.0945	0.1000	0.1055
G1	17.64	17.78	17.92	0.6945	0.7000	0.7055
H1	19.6	-	-	0.7717	-	-
H2	-	-	20.2	-	-	0.7953
L	20.35		20.65	0.8012		0.8130
L2	17.05	17.20	17.35	0.6713	0.6772	0.6831
L3	17.25	17.5	17.75	0.6791	0.6890	0.6988
L4	10.3	10.7	10.9	0.4055	0.4213	0.4291
L7	2.65	-	2.9	0.1043	-	0.1142
S	1.9	-	2.6	0.0748	-	0.1024
S1	1.9	-	2.6	0.0748	-	0.1024
U	0.40	-	0.55	0.0157	-	0.0217
Z	0.70	-	0.85	0.0276	-	0.0335
diam1	3.65	-	3.85	0.1437	-	0.1516

1. Values in inches are converted from mm and rounded to 4 decimal digits.

3.2 Multiwatt 8 marking information

Figure 19. Multiwatt 8 marking information



Parts marked as ‘ES’ are not yet qualified and therefore not approved for use in production. ST is not responsible for any consequences resulting from such use. In no event will ST be liable for the customer using any of these engineering samples in production. ST’s Quality department must be contacted prior to any decision to use these engineering samples to run a qualification activity.

4 Revision history

Table 25. Document revision history

Date	Revision	Changes
22-Aug-2017	1	Initial release.
23-Oct-2019	2	Updated Title and Features in cover page Minor text changes.