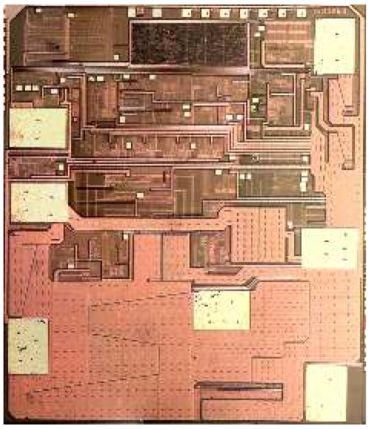
One-chip Multifunction Voltage Regulator

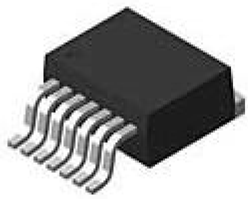
IK8006

FEATURES

IC can be as bare die or
TO 263-7 packaged

- Fully monolithic design
- Fixed frequency regulation with pulse width modulation
- High side output stage with defined ramp steepness and freewheeling diode
- Standby mode
- Wake up via L-terminal
- Emergency start and default mode
- Load response control (LRC) and soft start
- DF duty cycle transmitted via DFM-terminal
- Error indication via L-terminal
- Phase voltage regulation
- Relay function
- Thermal protection





The IK8006 is a monolithic alternator voltage regulator IC intended for use in automotive application. It includes the control section, the field power stage and the protection against short circuits. IC regulates the output voltage of an automotive generator in close loop by control the field winding current with a Pulse-Width Modulation (PWM) high side driver at fixed frequency. The alternator voltage regulator IC has the standby mode with small current consumption when no activity pin Lamp and pin PH.

After the ignition is switched ON, the Lamp-terminal is connected to the battery via the lamp. This voltage at Lamp terminal is wake-up signal for regulator. In case of missing signal at Lamp terminal, the regulator will be activated after detection of a phase signal induced by remanence of the rotor.

Table 1. Device Summary.

Order Code	Operating Temp range, T_J, ºC	Package	Option
IK8006D	-40 to 150 ºC	Bare die	-
IK8006F	-40 to 150 ºC	Bare die	-
IK8006PD2T	-40 to 150 ºC	TO 263-7	Sense pin
IK8006D2T	-40 to 150 ºC	TO 263-7	CP pin
IK8006PF2T	-40 to 150 ºC	TO 263-7	Sense pin
IK8006F2T	-40 to 150 ºC	TO 263-7	CP pin

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1. List of abbreviations

C	Suppression capacitor
C_{DFM}	Capacitor at DFM
C_L	Capacitor at Lamp
DC	Duty cycle
DF	Dynamo field
DFM	Dynamo field monitor
DF_{LRCBZ}	Blind zone. In case duty cycle changes more than value of Blind zone the LRC mode starts operation.
ECU	Engine control unit
ESD_{HBM}	Electric static discharge human body model
F_{VE}	Pre-excitation frequency
f_{DFM}	DFM frequency
f_{REG}	Regulation frequency
GND	Ground
I_{DF}	Field driver current
I_{DFM_LM}	Current limitation of DFM driver
$I_{DF\_LEAKAGE}$	Leakage current of field driver
I_{DF_LIMIT}	Current limitation of field driver
I_{L_EIN}	Inrush current of lamp driver
I_{L_LIMIT}	Current limitation of lamp driver
I_{L_NOM}	Operation current of lamp driver
I_{L_SINK}	Lamp pin sink current at standby mode
I_{R_LIMIT}	Current limitation of relay driver
I_{R_NOM}	Operation current of relay driver
$I_{STANDBY}$	Standby current
I_{V_abl}	PH pin sink current
$I_{V\_abl\_stb}$	PH pin sink current at standby mode
LRD	Load Response Drive
LRS	Load Response Start
n_0	Generator running detection speed
n_{GEN}	Generator rotation speed
n_{0_hys}	Hysteresis detection at “generator running”

n_{LR}	Load Response cut-off speed
n_{NOT}	Emergency start rotation speed
n_{start}	Start rotation speed
P	Alternator pole pairs
R_{DFM}	Series resistor at DFM
R_{SENSE_PD}	Internal pull-down resistor at pin SENSE
T1	Lamp driver
T2	Relay driver
T_{DF_FALL}	Field voltage fall time
T_{DF_RISE}	Field voltage rise time
t_{FILT}	Load Response buffer time
TF_{retry}	Retry time in case of over current at pin DF
$T_{j\text{-}sd}$	Junction temperature threshold of thermal shutdown
$T_{j\text{-}sdhy}$	Hysteresis of junction temperature threshold of thermal shutdown
TK	Temperature compensation
t_{LRD}	Ramp time Load Response Drive
t_{LRS}	Ramp time Load Response Start
T_{PH_FLT}	Phase filtering time
T_V	Derivative time
TV_{VE}	Pre-excitation duty cycle
T_{VZ}	Delay of error indication
V_{L_AUS}	Switching-off threshold at Lamp pin
V_{L_EIN}	Switching on threshold at Lamp pin
V_{LIMIT}	Voltage limitation of regulated voltage
V_{LOW}	Low voltage threshold
V_{REG}	Regulated voltage
V_V	Phase voltage
V_{V_LA}	Lamp threshold low voltage signal at PH pin
V_{V_NA}	Phase regulation threshold
V_{V_SW}	Phase threshold
$V_{V\_SW\_NOT}$	Phase threshold at emergency start
ΔV_{REG_LOAD}	Regulated voltage variation with the load
ΔV_{REG_SPEED}	Speed regulation
V(B+A)	Voltage at B+A

$V(B+A)_{DC}$	DC voltage at B+A
$V(B+A)_{LD}$	Transient voltage at B+A (Load dump)
$V(B+A)_{OVR}$	Operating voltage range
V_{DF}	Voltage at Field Driver
V_{DF_DIODE}	Direct voltage at freewheeling diode at DF pin
V_{DF_SAT}	Saturation voltage at Field driver
V_{DFM_SAT}	Voltage drop at DFM driver
VL	Voltage at pin “Lamp”
$VL_{DROP\ L}$	Voltage drop at Lamp driver
V_{OVP}	Overvoltage protection
V_{PH}	Phase voltage
V_{R_DROP}	Voltage drop at Relay driver
V_{SENSE}	Voltage at SENSE pin
V_{SENSE_BS}	Threshold voltage at pin SENSE switching sensing from “(B+A)” to “SENSE”
V_{SENSE_SB}	Threshold voltage at pin SENSE switching sensing from “SENSE” to “(B+A)”
V_{UVLOon}	Under voltage lock release
$V_{UVLOoff}$	Under voltage lock ON
$V_{UVLOhys}$	Under voltage lock out hysteresis
R_{PAR_GND}	Parasitic resistance between Pad “GND” on chip and Pin “GND” of regulator
R_{PAR_B+A}	Parasitic resistance between Pad “B+A” on chip and Pin “B+A” of regulator

2. Schematic diagram and pin description.

2.1. Schematic diagram.

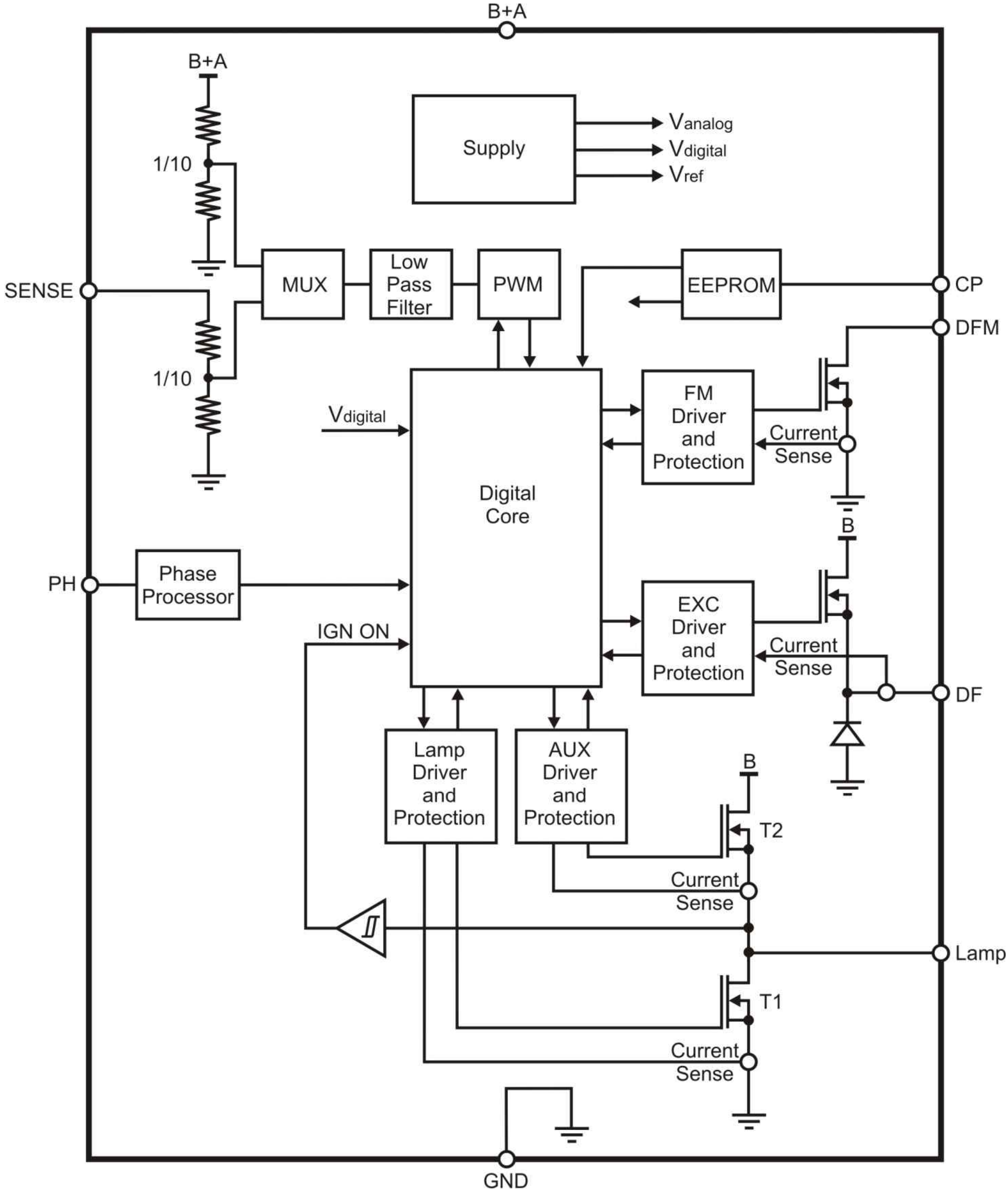


Fig. 1. Block diagram.

2.2. Pin description.

Table 2. Pin description (according block diagram fig. 1).

Pin	Function	Remark
B+A	Power supply pin and battery sense	
DF	High side driver output	
PH	Phase sense terminal	
GND	Regulator ground	
Lamp	Lamp and relay terminal	
DFM	Field monitor output	
SENSE	Battery sense input	IK8006D2T
CP	Production line programming pin (internal pad)	IK8006PD2T

3. Electrical specifications.

3.1. Device variants table programmable by EEPROM.

Table 3. Device variants table.

Parameter	Versions	Default
Set Point Voltage, V_{REG}, V	14.0/14.2/14.3/14.4/14.5/14.6/14.7/14.8	14.5
Temperature compensation, TC, mV/°C	0/-3.5/-5/-7/-10/	-7
Cut-in speed, n_{start}, rpm	720/1100/1200/1400/1500/1800/1920/2250	720
Emergency start speed, n_{NOT}, rpm	1400/2000/3100/4000	3100
Load Response cut-off speed, n_{LR}, rpm	1500/2100/2500/3000/3100/3500/4000/4500	3100
Alternator pole pairs, P	6/7/8	6
Pre-excitation duty cycle, TV_{VE1}, %	6/10/14/18/22/26/30/34	14
Load Response start/ramp, t_{LRS}, s	0/2.5/3/5/6/8/10/12	5
Load Response drive/ramp, t_{LRD}, s	0/2.5/3/5/6/8/10/12	5
Load Response Control down ratio, t_{LRDOWN} , s	0.32 to 10 with step 0.32 (Recommended value t_{LRDOWN}= t_{LRD}/4)	0.32
Blind Zone, DF_{LRCBZ}, %	3/6/12	6
Derivative time, T_V, s	0.4/2.5	0
Frequency at DFM, f_{DFM}, Hz	60/70/90/100/125/150/250/400/	60
DFM signal polarity	direct/reverse	direct
Clamp on DFM, DFM_{CLAMP}	(5 – 95)/(5 – 100)	(5 – 95)
Option “SENSE”	Yes/No	No
Load response buffer time, t_{FILT}, s	0.3/2.5	0.3

3.2. Absolute maximum ratings.

Table 4. Absolute maximum ratings.
(Tj= -40 to 150 °C, unless otherwise specified)

Symbol	Symbol Parameter Value Unit	Value	Unit
$V(B+A)_{DC}$	DC supply voltage (2 min. @ 25 °C)	24	V
$V(B+A)_{LD}$	Transient supply voltage (load dump) t < 400 ms	37	V
$V(B+A)_{R}$	Reverse supply voltage @ T_J = 25 °C, t < 15s, R_{THJA} < 4 K/W	- 2.5	V
Tj	Junction temperature range	-40 to 150	°C
ESD_{HBM}	ESD HBM (All pins vs. GND)	±8	kV

3.3. Thermal data.

Table 5. Thermal data.

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
Tj-sd	Thermal shutdown threshold	Temperature to disable DF	160	175	190	°C
Tj-sdhy	Thermal shut-down hysteresis	DF from OFF STATE (due to thermal shutdown) to ON STATE	Tj-sd - 10	–	Tj-sd - 2	°C
R_{THJC}	Thermal resistance junction to case	TO 263-7 T_A = 25 °C, PW = 7 W	-	-	1.9	°C/W

3.4. Electrical characteristics.

Table 6. Electrical characteristics.
(Tj= -40 to 150 °C, frequency and timing parameters with tolerance ± 10% unless otherwise specified)

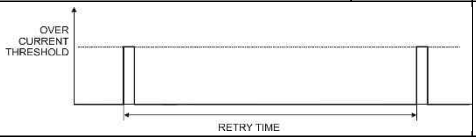
Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
Pin "B"						
$V(B+A)_{OVR}$	Operating Voltage Range	Normal condition Function DFM	6	–	18	V
V_{UVLOon}	Under Voltage Lock Release		4.5	5.0	5.5	V
$V_{UVLOoff}$	Under Voltage Lock ON		4.0	4.5	5.0	V
$V_{UVLOhyst}$	Under Voltage Lock Out Hysteresis		–	0.5	–	V
$I_{STANDBY}$	Standby current	V(B+A)=12.5V; V_{PH}=0V; Lamp" pin floating; T_j = 25±5°C	–	–	250	µA
V_{REG}	Set-Point Voltage Options selected by EEPROM (see table 3)	VPH=12Vpp square wave; (400hz), "DF" duty cycle=50%	V_{REG} -0.2	V_{REG}	V_{REG} +0.2	V
V_{LIMIT}	Voltage Limitation		–	14.9	–	V
TC	Temperature compensation. Options selected by EEPROM (see table 3)	See fig. 6	TC-2	TC	TC+2	mV/°C
ΔV_{REG_LOAD}	Regulated Voltage variation with the load @Alternator level	Difference between regulated voltage @ F duty cycle is 10% and @ F duty cycle is 90%	–	–	250	mV
ΔV_{REG_SPEED}	Speed regulation @Alternator level	15A load, 2k~10k rpm variation	–	–	100	mV
V_{LOW}	Threshold low voltage function			12		V
V_{OVP}	Overvoltage detection	Field OFF (DF duty=0%)	16.0			V

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
C	Suppression capacitor between B+A pin and GND (external)			9.1 (4.7+ 2.2 + 2.2)		µF
R_{PAR_GND}	Parasitic resistance between Pad "GND" on chip and Pin "GND" of regulator				10	mΩ
R_{PAR_B+A}	Parasitic resistance between Pad "B+A" on chip and Pin "B+A" of regulator				20	mΩ
Pin "Lamp"						
$VL_{DROP\ L}$	Voltage drop lamp driver		0.95	1.2	1.5	V
I_{L_NOM}	Operation current lamp driver		5		330	mA
I_{L_LIMIT}	Current limitation lamp driver		0.5		1.8	A
I_{L_EIN}	Minimum current for switch lamp on driver	V_L=1.3V, V(B+A)=12.5V, PH=not connected	0.7	1.8	2.5	mA
I_{L_SINK}	Sink current on pin Lamp in standby mode	V_L=0.5V, V(B+A)=12.5V, Standby mode		1.0		mA
V_{L_EIN}	Switching-on threshold, detection "Ignition ON"	See fig.10	0.5		1.1	V
V_{L_AUS}	Switching-off threshold, detection "Ignition OFF"	See fig.10	0.5		1.1	V
I_{R_NOM}	Operation current relay driver		0		500	mA
V_{R_DROP}	Voltage drop relay driver	V(B+A)=14V, I_L=-500mA	0.05	0.2	0.6	V

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
I_{R_LIMIT}	Current limitation relay driver		1.1	2.1	2.8	A
T_{VZ}	Delay time of error indication		0.4	0.5	0.6	s
C_L	Capacitor at L (external)			22		nF
Pin "PH"						
$V_{V\_SW\_NOT}$	Phase threshold Emergency start	V(B+A)=12.5V, Lamp=not connected	0.9	1.2	1.5	V
$V_{V\_SW\_NOT}$ IK8006F			0.05	0.3	0.5	V
V_{V_NOT}	Phase threshold Emergency start	V(B+A)=12.5V, Lamp=not connected, Sine at PH (f_{PH} =400Hz), T_C = -40°C to 125°C	0.6	1.45	2.5	V
V_{V_NOT} IK8006F			0.1	0.4	0.7	V
V_{V_SW}	Phase threshold	V(B+A)=12.5V, Lamp=connected	2.1	2.45	3	V
$I_{V\_abl\_stb}$	Sink current on pin PH in standby mode	V(B+A)=14B, V_{PH}=14B, Lamp=not connected	0.2	0.45	0.7	mA
I_{V_abl}	Sink current on pin PH	V(B+A)=14B, V_{PH}=14B, Lamp= connected	2.8	9	15	mA
V_{V_NA}	Phase regulation threshold		9.7	10.2	10.7	V
V_{V_LA}	Lamp threshold Low voltage signal		7.8	8.3	8.8	V
V_{V_DC}	DC-scope frequency range		0		8	V
n_0	Detection "generator running" (note 1)			580		rpm
n_{0_hys}	Hysteresis detection "generator running" (note 1)		10	20	30	rpm

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
n_{start}	Cut-in speed (normal start) Options selected by EEPROM (see table 3) (note 1)	Selected by EEPROM		n_{start}		rpm
n_{LR}	Load Response cut-off speed Options selected by EEPROM (see table 3) (note 1)	Selected by EEPROM		n_{LR}		rpm
n_{NOT}	Emergency start speed Options selected by EEPROM (see table 3) (note 1)	Selected by EEPROM		n_{NOT}		rpm
P	Alternator pole pairs. Options selected by EEPROM (see table 3)	Selected by EEPROM		P		шт.
T_{PH_FLT}	Phase filtering time		270	300	330	ms
t_{FILT}	Load response buffer time Options selected by EEPROM (see table 3)	Selected by EEPROM		t_{FILT}		ms
Pin "DF"						
V_{DF_SAT}	Field Driver saturation Voltage	Tj=130°C; Isink=4.5A	–	–	0.6	V
		Tj=25°C; Isink=7A	–	–	0.55	V
V_{DF_DIODE}	Freewheeling diode	IF =6A, Tj=25°C	–	–	2	V
$I_{DF\_LEAKAGE}$	Field leakage current	V(B+A)=16V, V_{DF}=0V, Tj=25°C (standby mode)	–	–	10	µA
I_{DF_LIMIT}	Field driver current limitation	Tj= -40°C till Tj= 150°C: - 40ºC	9.5	-	15	A
		27ºC	9	-	15	A
		150ºC	8	-	15	A

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
f_{REG}	Regulation frequency		360	400	440	Hz
F_{VE}	Pre-excitation frequency		360	400	440	Hz
T_{DF_RISE}	Field voltage rise time		–	–	25	µs
T_{DF_FALL}	Field voltage fall time		–	–	25	µs
TV_{VE1}	Pre-excitation duty cycle $V(B+A) < V_{REG}$ Options selected by EEPROM (see table 3)	Programmed by EEPROM		TV_{VE1}		%
TV_{VE2}	Pre-excitation duty cycle $V(B+A) > V_{REG}$	$V(B+A) > V_{REG}$		8.5		%
MFDC	Minimum Field Duty Cycle			5		%
t_{LRS}	Load Response start ramp/time Options selected by EEPROM (see table 3)	Programmed by EEPROM		t_{LRS}		s
t_{LRD}	Load Response drive ramp/time Options selected by EEPROM (see table 3)	Programmed by EEPROM		t_{LRD}		s
t_{LRDOWN}	Load Response Control down ratio Options selected by EEPROM (see table 3)	Recommended value $t_{LRDOWN} = t_{LRD}/4$		t_{LRDOWN}		s
DF_{LRCBZ}	Blind Zone Options selected by EEPROM (see table 3)	Programmed by EEPROM		DFLRCBZ		%
T_V	Derivative time Options selected by EEPROM (see table 3)	Programmed by EEPROM		T_V		s

Symbol	Parameter	Test Condition	Min.	Typ.	Max.	Unit
TF_{retry}	Retry time in case of over-current			25		ms
Pin “DFM” (options: direct/reverse)						
f_{DFM}	Frequency at DFM Options selected by EEPROM (see table 3)			f_{DFM}		Hz
V_{DFM_SAT}	Voltage drop low side driver	I_{DFM} = 20mA			1.5	V
I_{DFM_LM}	DFM driver current limitation		21		70	mA
R_{DFM}	Internal series resistor at DFM	Guarantee by design, for reference only.		10		Ω
DFM_{CLAMP}	Clamp on DFM Options selected by EEPROM		5	%	95	%
			5	%	100	%
C_{DFM}	Capacitor at DFM			22		nF
Pin “SENSE”						
V_{SENSE_SB}	Threshold voltage on pin SENSE switching sensing from “SENSE” to “(B+A)”.			6.0		V
V_{SENSE_BS}	Threshold voltage on pin SENSE switching sensing from “(B+A)” to “SENSE”.			7.0		V
R_{SENSE_PD}	Internal pull-down resistor on pin SENSE	Guarantee by design, for reference only.	300	400	600	KΩ

Note **1.** To convert rotation speed (rpm) to phase frequency (Hz) according to alternator poles pair (P) use the following equation:

$$\text{Phase frequency (Hz)} = \text{rotation speed (rpm)} \times P / 60$$

4. Brief functional description.

The device remains "stand-by" mode condition with a low current consumption until there is no activity on the pins "Lamp" or "PH".

When the switch IGN is ON the Lamp terminal is connected to the battery via the lamp. This voltage at Lamp terminal is wake-up signal and the device exits "stand-by" mode and goes in "pre-excitation" mode with an activity on "DF" pin at fixed frequency (f_{REG}) and duty cycle (TV_{VE}). Furthermore, regulator turns on lamp by activating the lamp driver T1.

The device remains "pre-excitation" mode until it senses an activity on "PH" pin (i.e. V_{PH}>V_{V_SW}) and n_{GEN}>n_0). The device starts the phase regulation mode, and after getting condition n_{GEN} > n_{start} the devise goes to normal regulation mode. In this case T1 will be switched OFF and T2 will be ON i.e. turns OFF the lamp and an optional relay is activated ON (see fig.1)

The relay can be used for switch ON external loads or consumers which should not be active during the start procedure.

The activation of the lamp by the regulator turns the relay OFF in case of an error.

Another possibility that the device has to start to regulate is the "Emergency start". In this way, although there is no activity on pins "Lamp" (for example due to connector open), if an activity is sensed on "PH" pin (i.e. V_{PH}>$V_{V\_SW\_NOT}$ and n_{GEN}>n_{NOT}) the device goes in normal regulation mode.

The regulator stops regulation when the alternator speed falls below n_0. If there is activity on "Lamp" pins the device stays in "pre-excitation" mode otherwise comes back in "stand-by" mode.

4.1. Normal start procedure.

After the ignition is switched ON, the Lamp terminal of IC is connected to the battery via lamp. The regulator turns ON the lamp by the lamp driver T1. The relay driver T2 stays OFF. In this case regulator goes to pre-excitation mode. Output stage of regulator is switched with a fixed frequency f_{REG} and constant duty cycle TV_{VE} at pre-excitation mode. The pre-excitation current induces a voltage in stator coil and at phase pin of the regulator respectively, as soon as the generator begin rotating.

The regulator measures the alternator rotational speed by evaluation of the phase signal. As soon as the "generator running" information (n_{GEN} >n_0) is detected the regulator switches from the pre-excitation mode to the phase regulation voltage mode 8.3V.

With a further increase in the speed of rotation and n_{GEN} becomes more the start speed threshold n_{start} during time more T_{PH_FLT} , the lamp will switch OFF, i.e. lamp driver T1 is switched OFF and relay driver T2 is switched ON. The regulator passes into phase regulation second mode. At this, the phase voltage is regulated at 10.2V for the time T_V. The alternator will proceed to the regulation mode after T_V time.

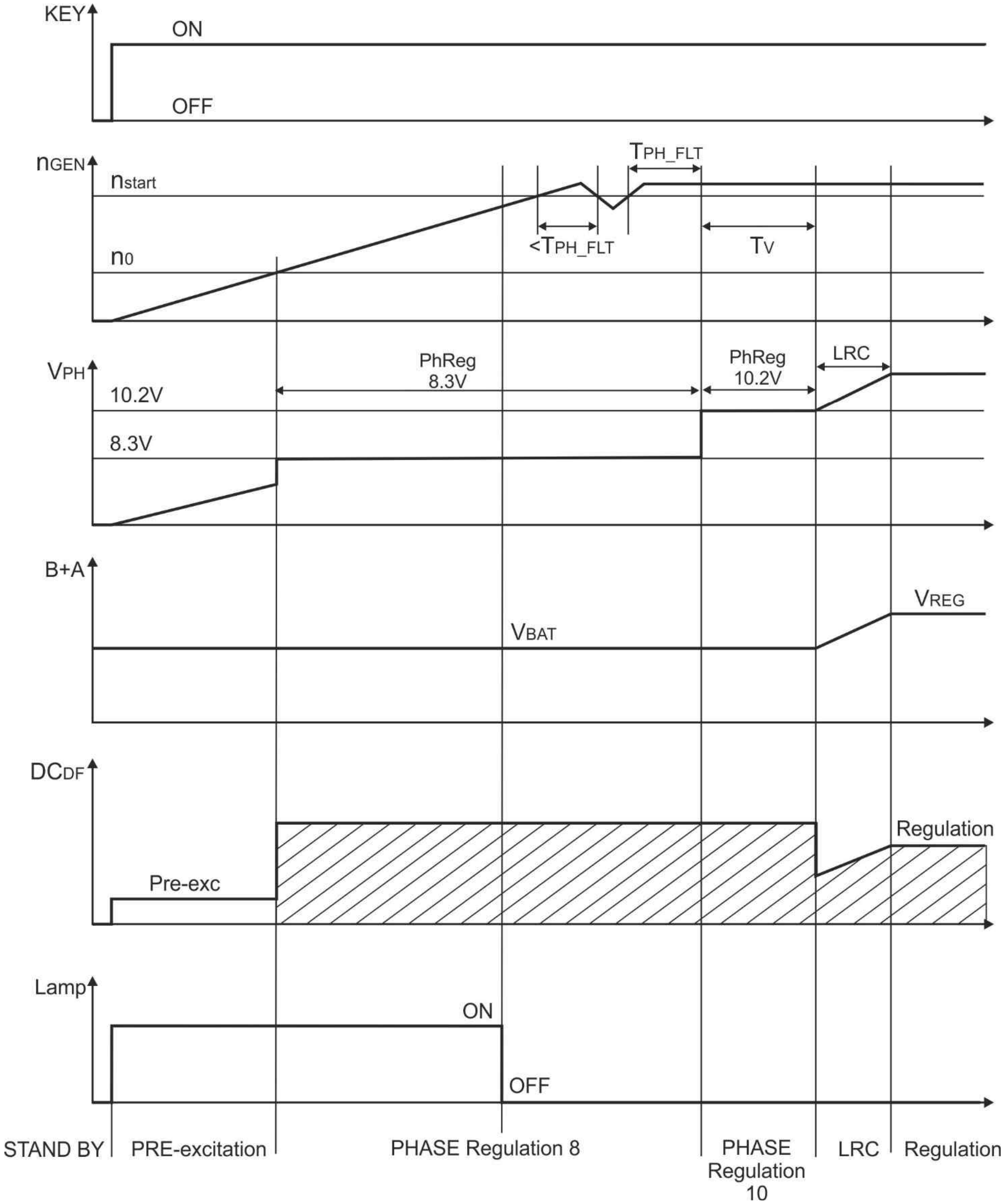


Figure 2. Normal start procedure.

Note: after detection "generator running" (n_0) and phase voltage becomes more V_{V_LA} at DC = any the Lamp is OFF.

4.2. Load Response Control function (LRC).

Load Response Control (LRC) function is very useful when there is a high vehicle load demand combined with a low engine speed. The LRC function controls the rotor current increase at the specified rate up to the LRC disable frequency. This function is only active for duty cycle increases. If there is a load current reduction, the excitation duty cycle is instantly reduced to the duty cycle corresponding to the new battery charge state. The alternator responds to loads commutation in the vehicle, slowly increasing the current in the rotor (EXC duty cycle) to avoid stalling the car.

If the LRC function is active, then the alternator output current is controlled by the DF current variation strategy that is directly linked to the duty cycle on DF output.

The LRC function can operate when the alternator runs at low speed (the alternator speed n_{GEN} as to be lower than nLR).

When the LRC function is required, the duty cycle increase slowly with the defined slope t_{LRD} with the previous duty cycle increased by the fixed value DFLRCBZ.

The actual duty cycle management during a LRC insertion is shown in the figure 3.

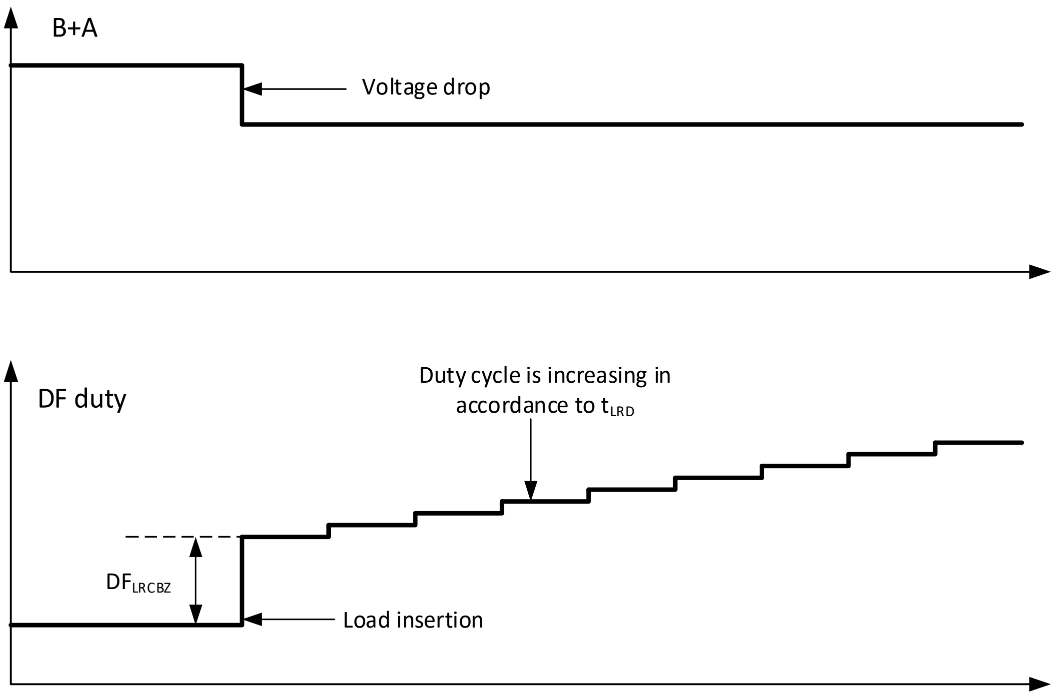


Figure 3. Duty cycle management during LRC insertion.

4.3. Load Response cut-off speed.

The Load Response control function is active for $n_{GEN} < n_{LR}$. If the alternator speed falls below the n_{LR}, the function will be activated after a buffer time of t_{FILT}. If the alternator speed exceeds n_{LR}, the function will be inactivated instantaneously (see fig.4). The Load Response cut-off speed is ignored during the start procedure, i.e. the Load Response function stays active.

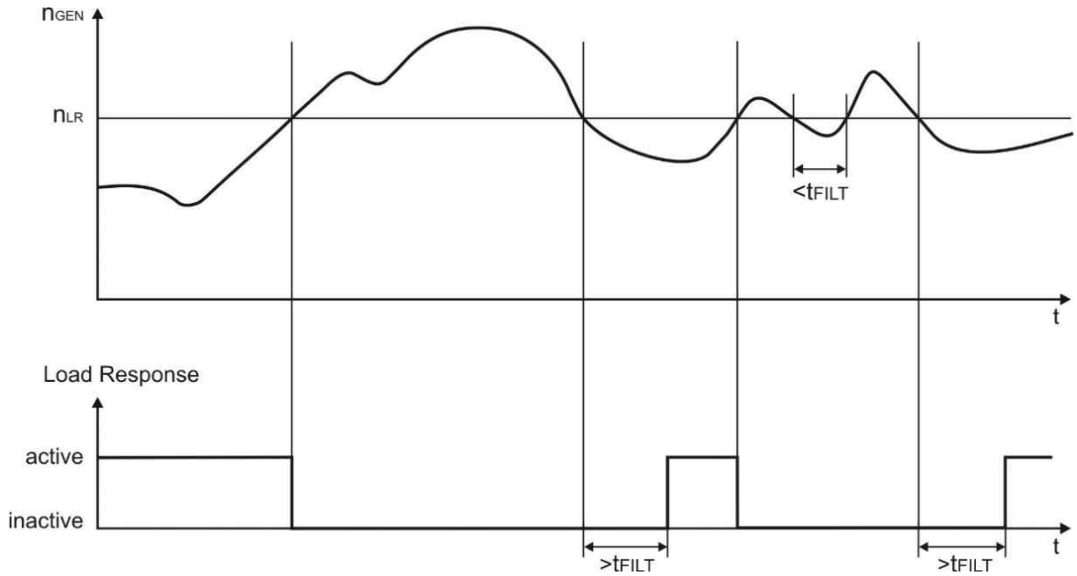


Figure 4. Activation and inactivation of Load Response control function.

4.4. Function low voltage.

In case of high electrical load switching ON, especially with bad or defect battery, the voltage of the power supply line can drop to low values. If the voltage falls under the minimum operating voltage, the generator can de-energize especially if no battery is connected.

The duration of voltage drop can be minimized by fast regulation (instantaneous switching ON of output stage DF). The threshold for under voltage is V_{LOW}, i.e. there will be a fast regulation below this limit even if load response function is active (see fig 5)

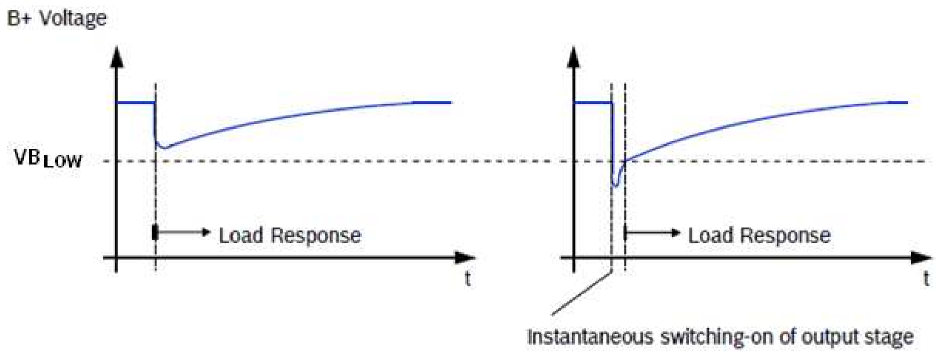


Figure 5. Low voltage function.

4.5. Phase regulation.

Over voltage, for example caused by load current drop or load dump can leads to immediate switching off the output stage. To avoid in this case a complete de-energizing of the generator the phase voltage will be regulated about 10.2V. Hereby the switching ON lamp will be prevented and the voltage can be regulated faster to the set value.

4.6. Relay function.

During the start procedure the lamp is on (T1 = ON, T2 = OFF, see fig.6).

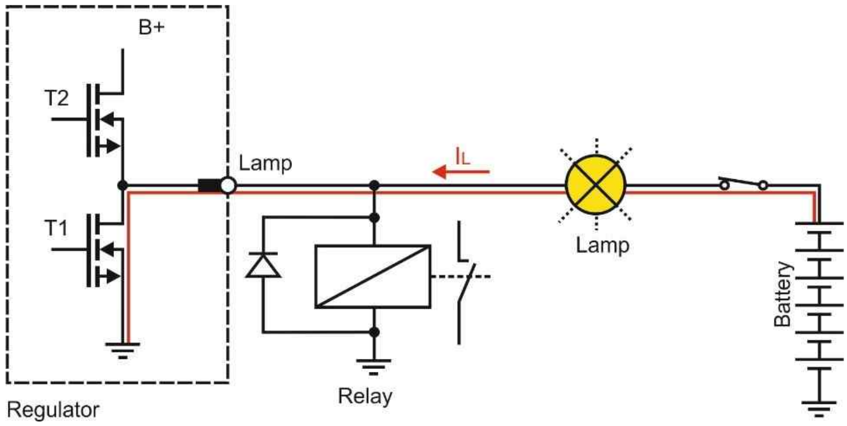


Fig. 6. Lamp ON.

As soon as the alternator speed reached n_{start}, T1 will be switched OFF and T2 will be ON.

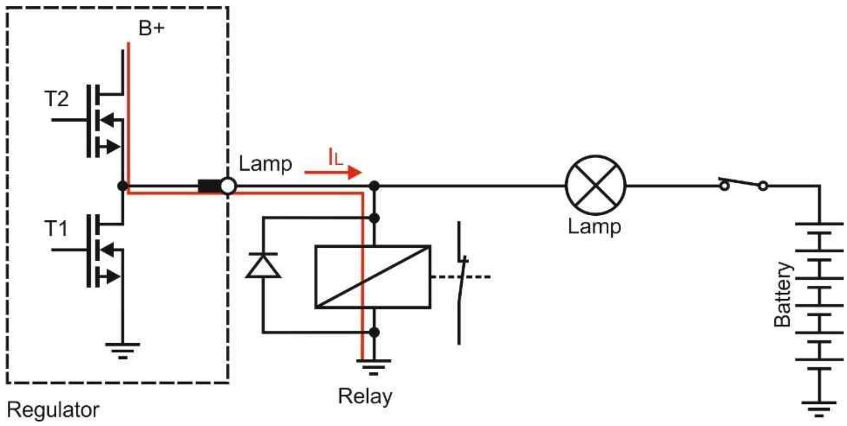


Fig. 7. Relay ON.

This turns OFF the lamp and an optional external relay is activated. The relay can be used to switch ON external loads or consumers which should not be active during the start procedure.

The activation of the lamp by the regulator in case of an error turns the relay OFF.

The relay has to be connected with a freewheeling diode.

4.7. Emergency start.

In case of missing signal at Lamp terminal, the regulator will be activated after detection of phase signal induced by remanence of the rotor. The regulator will turn in regulation mode if the alternator speed is higher than n_{NOT}.

The regulator parameters (regulation set voltage, Load Response parameter) remaining the same as in normal operation.

The start rotational speed at emergency start depends on the remanence of the rotor and the dynamic of the alternator (however n_{NOT} has to be exceeded). The emergency start function is always active, i.e. the regulator cannot be kept OFF by the Lamp terminal.

4.8. Default mode.

If the signal at Lamp terminal is disconnected during normal operation ($n_{GEN} > n_{start}$), the regulator will stay in normal operation mode and will switch to standby mode only if the rotational speed is lower than n_0. The default mode function is always active, i.e. the regulator cannot be de-energized by the L-terminal.

4.9. SENSE description.

SENSE is used as reference instead of (B+A) termination for the regulated voltage. If voltage on SENSE is falling less V_{SENSE_SB}, then the regulation toggles on (B+A), and defect is immediately reported. If voltage on SENSE is rising up to V_{SENSE_BS}, then the regulation toggles back on SENSE and defect is immediately cleared.

The internal divider bridge on (B+A) and SENSE is disabled by switching to Sleep mode, to reduce standby current.

4.10. Temperature compensation.

To adapt the generator voltage to the optional battery charging voltage, the regulator voltage is reduced if the temperature increases. The temperature coefficient specifies the ramp of the voltage reduction (see fig.8). To avoid too high voltages at low temperatures, an additional limitation to V_{LIMIT} is implemented.

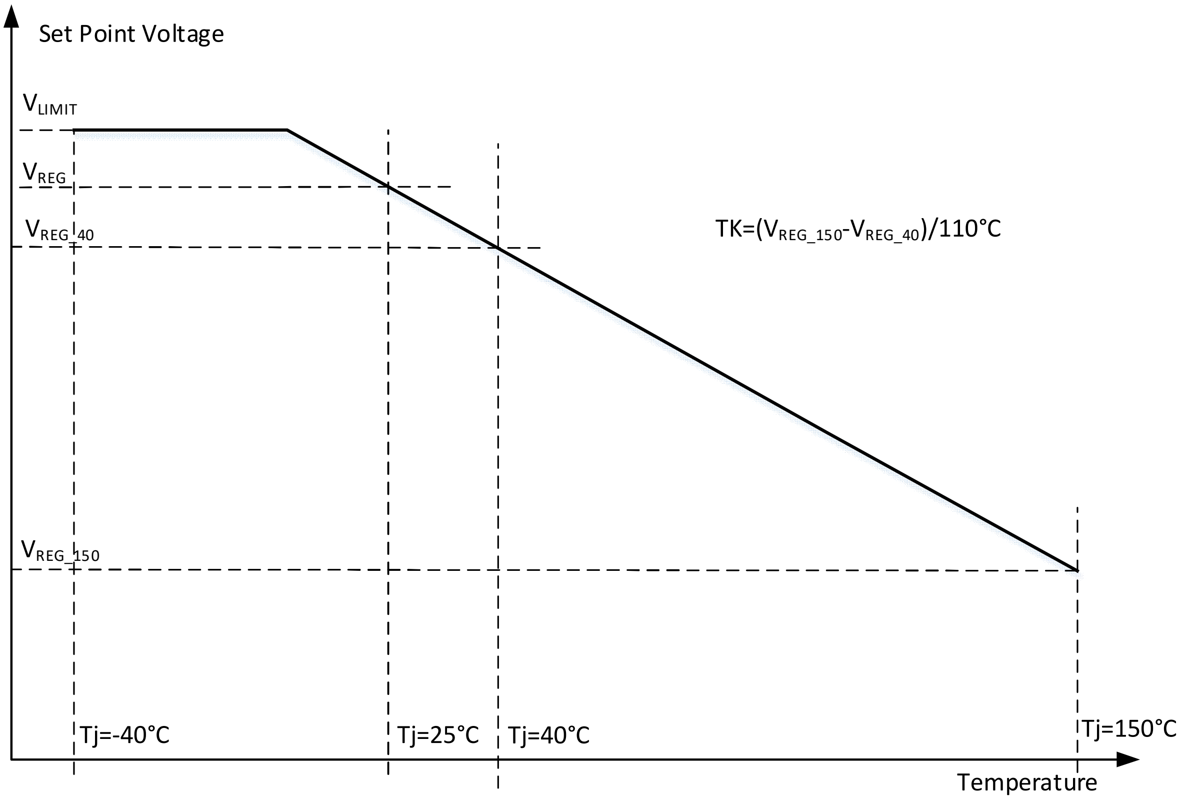


Figure 8. Temperature compensation of regulation voltage.

4.11. DFM-terminal.

The DFM terminal is a monitor for the master control unit. DFM pulse width modulated the output signal represents the duty cycle of the DF output stage (see fig. 9). It can be used by ECU for control alternator and engine. The DFM interface provides an inverted (RF) or direct (DF) image of excitation duty cycle to control unit, depending on which option is selected (see table 4).

The DFM terminal has a short circuit protection. The short circuit protection actives only if the supply voltage is applied to the regulator (B+A-terminal).

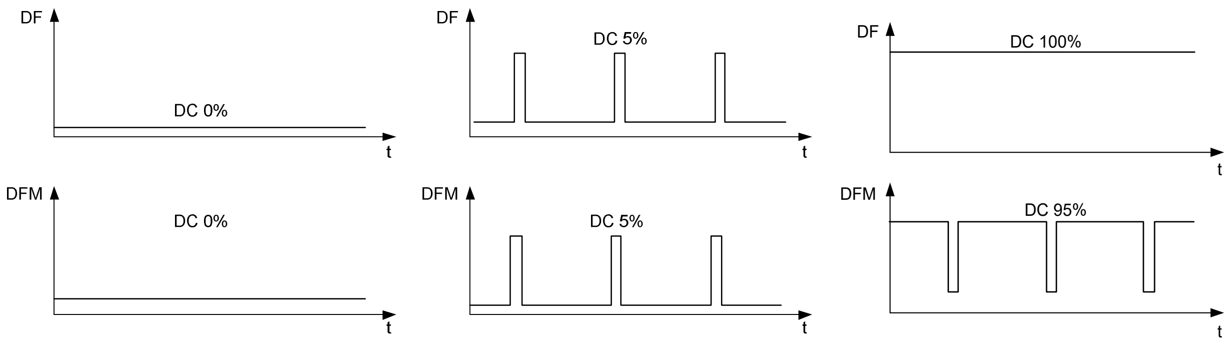


Figure 9a. DFM terminal DC 5%-95%.

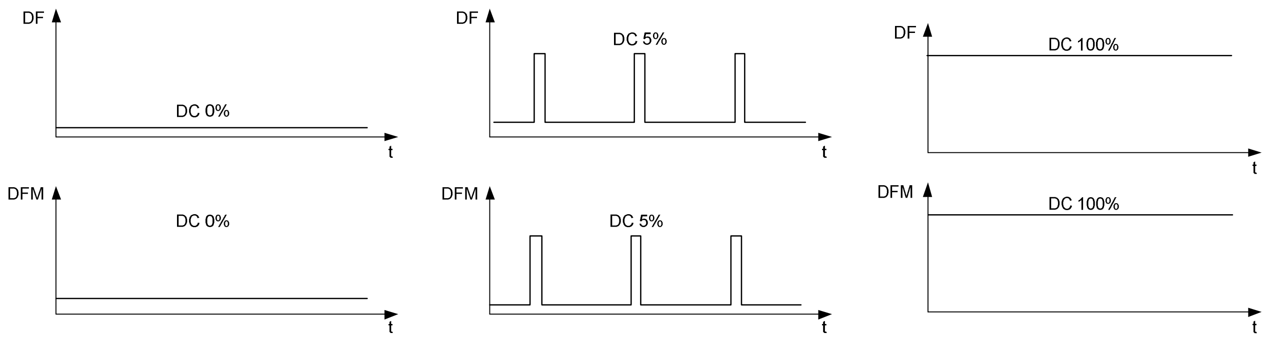


Figure 9b. DFM terminal DC 5%-100%.

4.12. Lamp Terminal.

Activation via Lamp:

For detection of "Ignition ON", the voltage level V_{LON} at Lamp has to be exceeded (see fig.10). To be more robust against voltage peaks (disturbances), an additional current sink is implemented in the regulator at the Lamp-terminal. Therefore, besides the minimum voltage at Lamp, a specified minimum switch-on current I_{L_EIN} (2.5mA) is necessary for activation of the regulator. After activation of the regulator and switching ON of the lamp driver, the current sink is deactivated; it will be activated again after transition of regulator to standby mode.

The regulator turns into regulation mode after activation and detection of the corresponding speed rotation thresholds. Below the activation threshold V_{LOFF} the regulator detect "Ignition OFF" (low level at Lamp). It turns to standby mode or stays in regulation mode if a valid alternator speed (n_{GEN} >n_0) can be measured.

The Lamp terminal has a short circuit protection. The short circuit protection is active only if the supply voltage is applied to the regulator (B+A terminal).

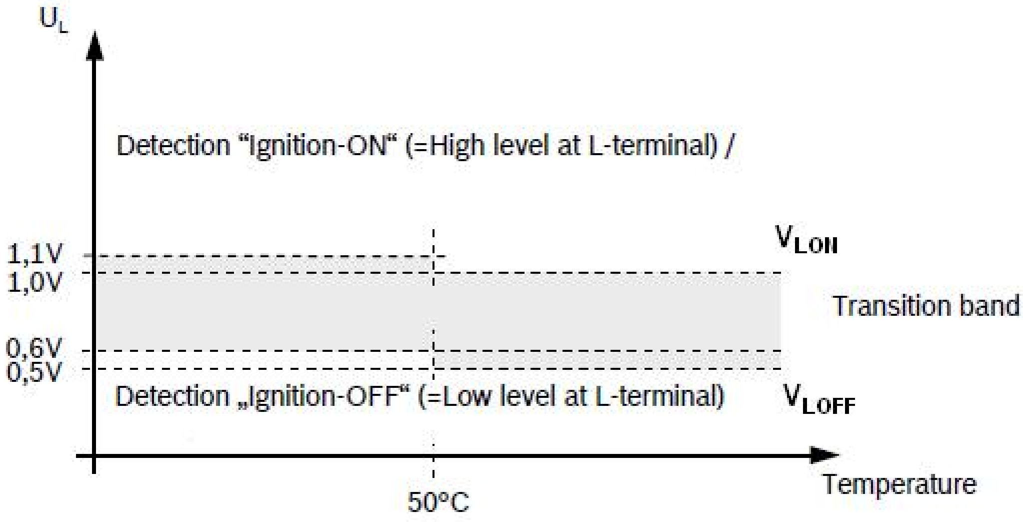


Figure 10. Activation threshold of L-terminal.

4.13. Alarm detection.

The device goes into Alarm (Fault) mode after the validation time (tVZ), if one of the conditions in the below table is verified. The device goes from Alarm mode immediately (about 50ms), if one of the conditions in the below table is disappeared.

Table 7. Alarm Detection.

Detected conditions	Related pin
V_{PH} < VV_SW or n_{GEN} < n_0	No activity on "PH" pin
I_{DF} > I_{DF_LIMIT}	"DF" shortened to "GND" (Over-current on "DF" driver). In this case alarm condition is detected after T_{VZ}. Field is turned off immediately.
V_{DF} = V(B+A) @ Field-FET off	"DF" shortened to "B+A"
V(B+A) > V_{OVP} (Overvoltage detection)	Battery sensor on "B+A" pin or "F" driver degraded
DC=100% and V_{PH} < V_{V_LA}	B+A voltage is Low
V_{SENSE} <V_{SENSE_SB}	SENSE disconnected (Option is selected by EEPROM. In this case alarm condition is detected immediately)
B+A wire disconnected (Self conducting mode)	Battery sensing terminal open detection.

4.14. Phase terminal.

For normal start (wake up via Lamp terminal).

The regulator will enter the phase regulation mode and regulating the phase voltage to 8,3V. The phase frequency (generator speed) will be evaluated between the ranges 0V to 8V. The AC-peak amplitude threshold is V_{V_SW} (2.45V typ.). Hence, all peak voltages below this threshold will not be evaluated.

For emergency start (when lamp is open).

As for more sensibility the AC-peak amplitude threshold will be switched internally to a lower value $V_{V\_SW\_not}$ (1.2V typ.). After the phase voltage reached this threshold, the regulator enters the Emergency start mode. As soon as the Emergency start threshold will be achieved (V_{V_NOT}, 1.45V typ.), the regulator enters the normal regulation mode. The evaluation of the phase signal VV is done by amplitude and frequency detection. As soon as the threshold level V_{V_SW} (level depending if lamp is connected or not) is exceed, the phase signal frequency will be evaluated.

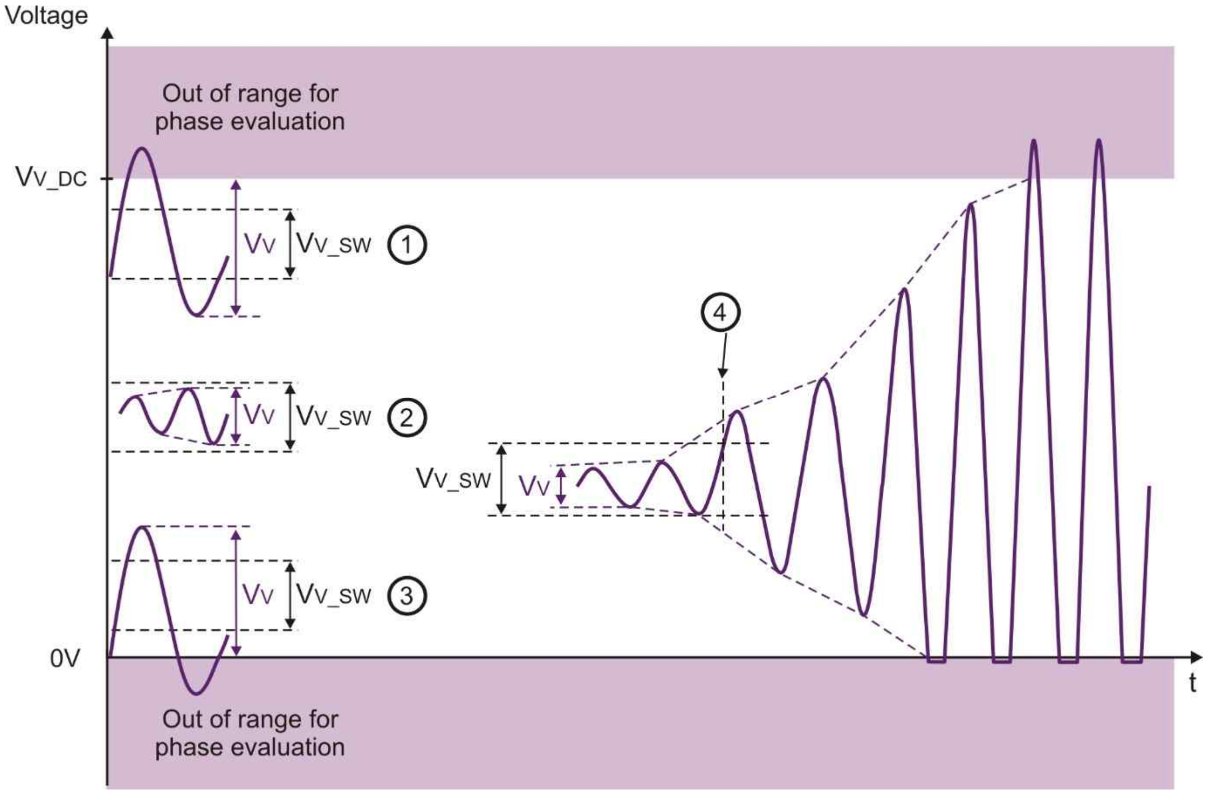


Figure 11. Phase voltage - example of amplitude evaluation.

1. Phase voltage V_V > phase threshold V_{V_SW} ①
   Phase signal will be evaluated. The voltage signal which exceeds the upper phase DC level V_{V_DC} will not be recognized.
2. Phase voltage V_V < phase threshold V_{V_SW} ②
   Phase signal will not be evaluated.
3. Phase voltage V_V > phase threshold V_{V_SW} ③
   Phase signal will be evaluated. The voltage signal which underruns the lower phase DC level of 0V will not be recognized.
4. Point of time when the phase voltage V_V exceeds the phase threshold V_{V_SW} ④
   At this time phase signal starts evaluation.

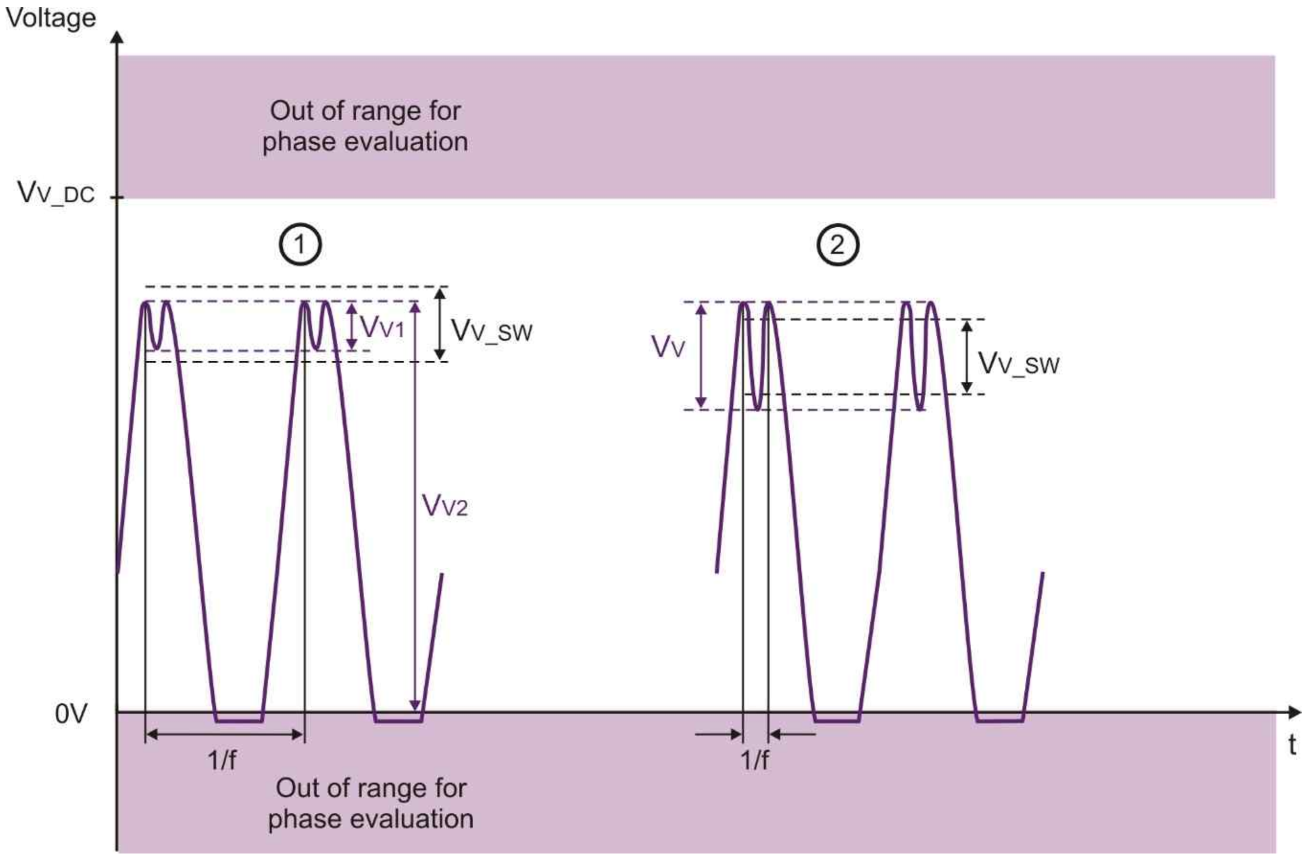


Figure 12. Phase voltage - example of frequency evaluation.

1. Phase voltage ripple V_{V1} < phase threshold V_{V_SW} ①
   Ripple will not be evaluated. Phase voltage V_{V2} > phase threshold V_{V_SW}.
   Phase frequency evaluation is correct

2. Phase voltage ripple V_V > phase threshold V_{V_SW} ②
   The ripple will be evaluated as phase signal frequency. Wrong phase frequency evaluation.

4.15. Typical application.

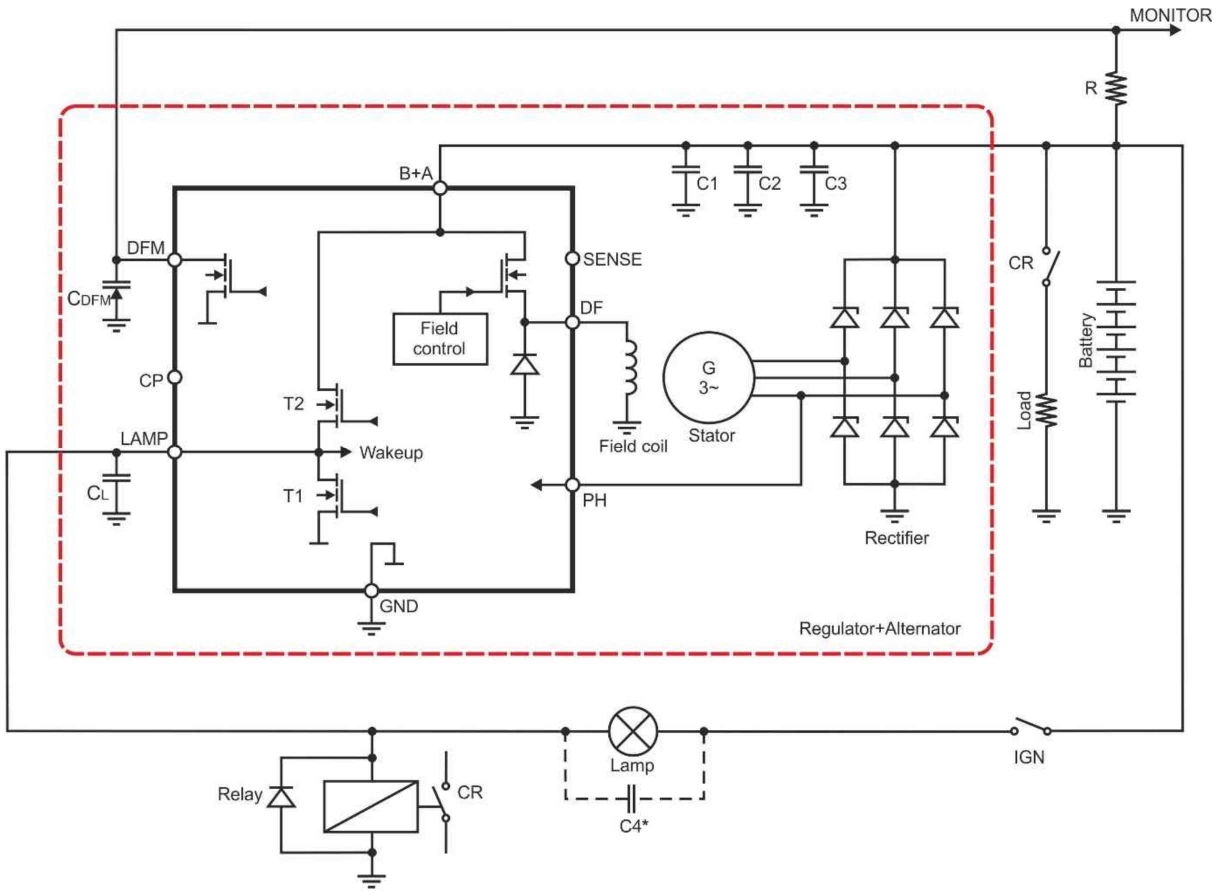


Figure 13. Typical application diagram.

Notes:

Rectification diodes should have the break down voltage more 22 V and less 27 V. In opposite case the IK8006 should be protected by TVS. Operation voltage for TVS should be more 20 V but break down TVS voltage should be between 25 V and 35 V.

Parasitic resistance on pin B+A should be less 20 mOhm and on pin GND should be less 10 mOhm.

Recommended:
C1 = 2.2 uF;
C2 = 2.2 uF;
C3 = 4,7 uF;
C4 = 100 nF;
C_L = 22 nF;
C_{DFM} = 22 nF;
R = 1 kOhm.

Capacitor C4 is installed for lamp blinking protection under high level electromagnetic interference.

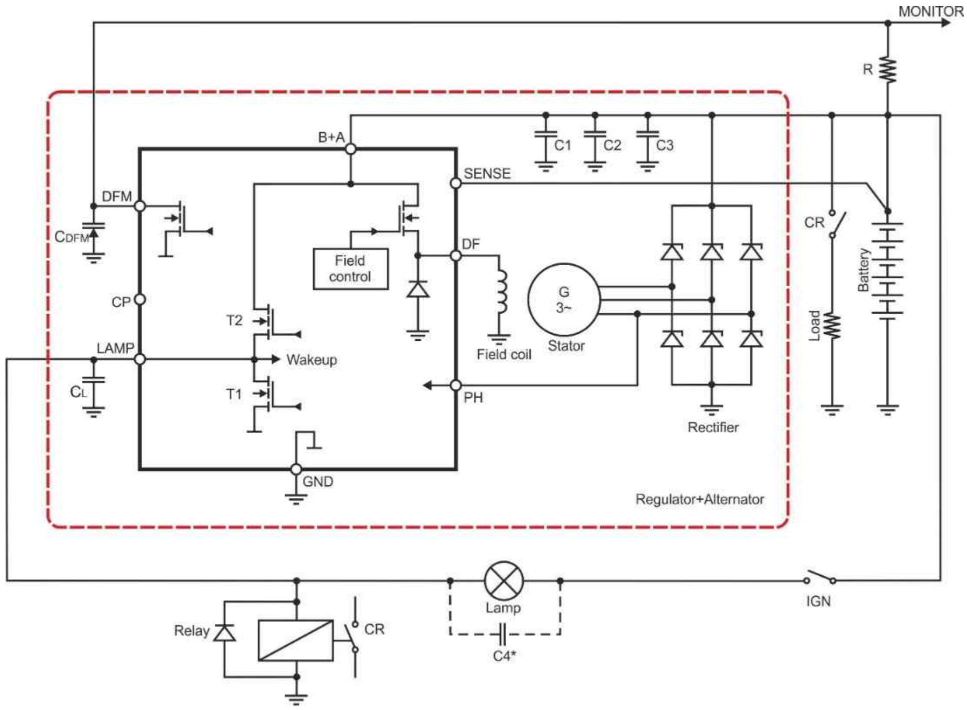


Figure 14. Application diagram with SENSE option of bare die and IK8006PD2T.

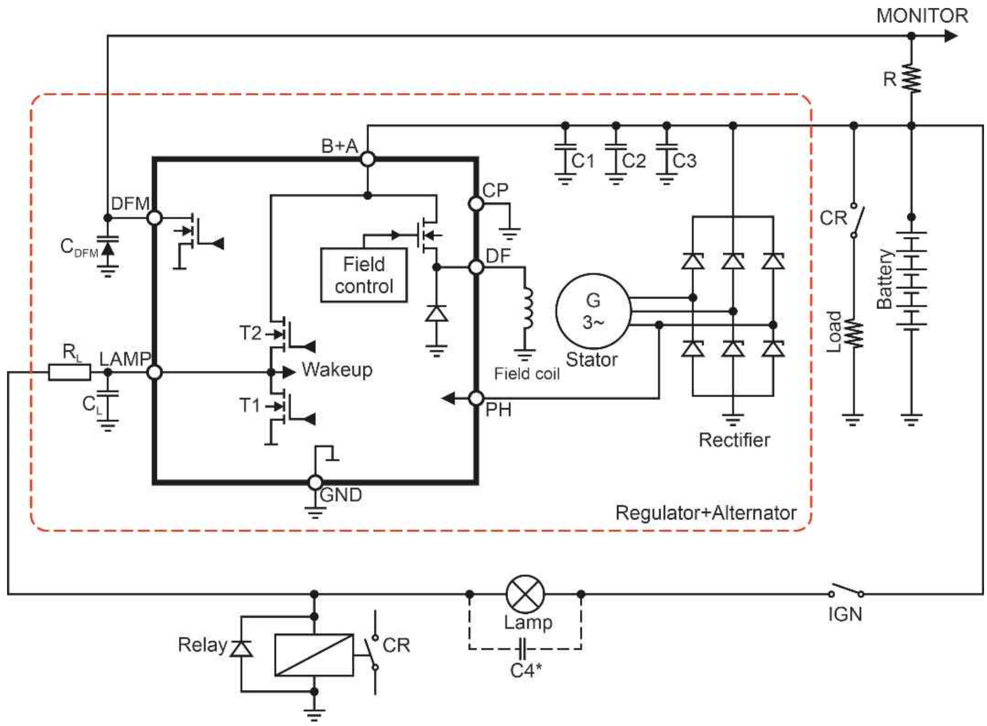


Figure 15. Application diagram with CP packaged option of IK8006D2T.

4.16. Typical operation sequence.

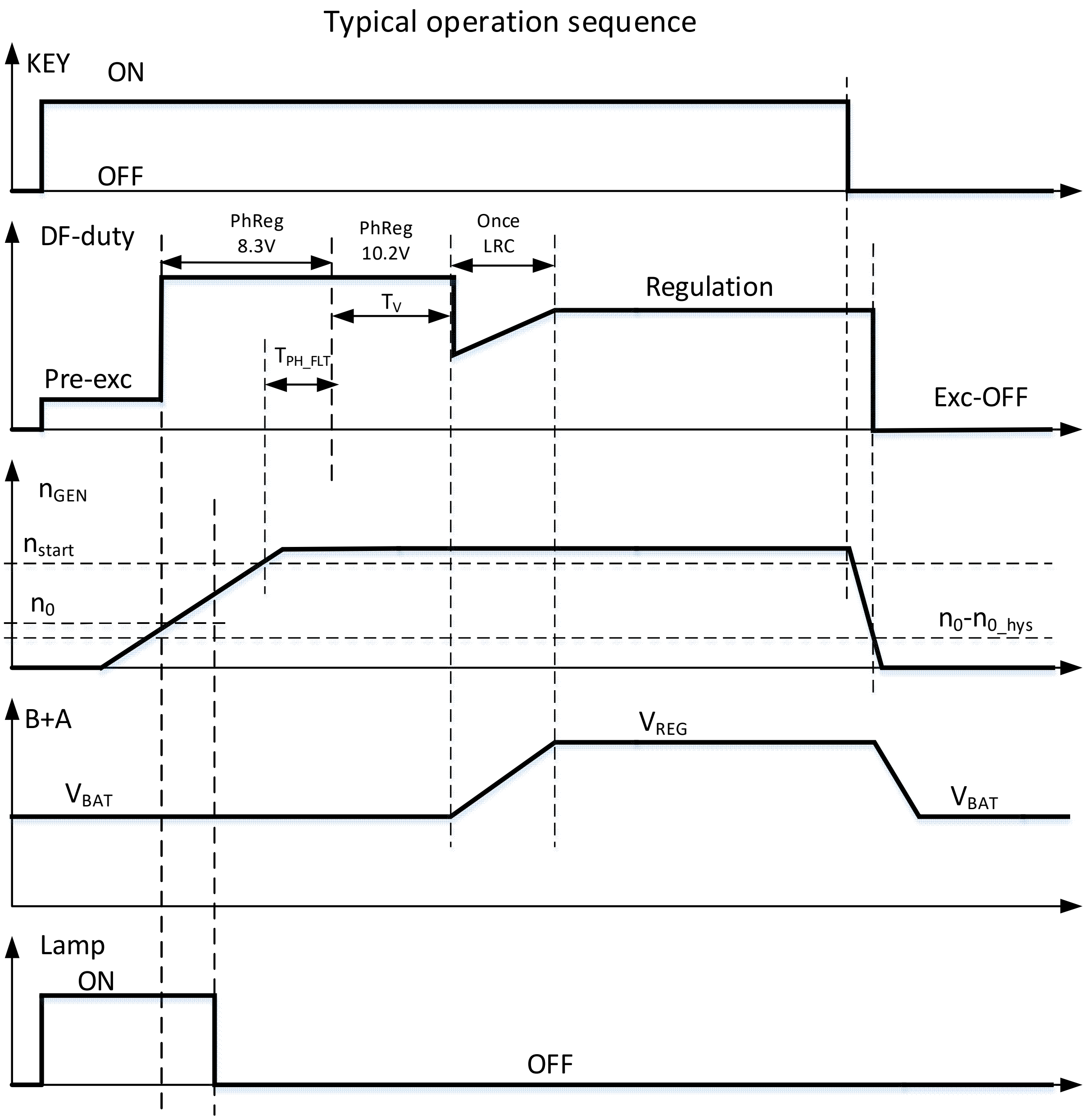


Figure 16. Typical operation sequence.

Note: after detection “generator running” (n_0) and phase voltage becomes more V_{V_LA} at DC = any the Lamp is OFF.

4.17. Lamp is continuously open circuit operation.

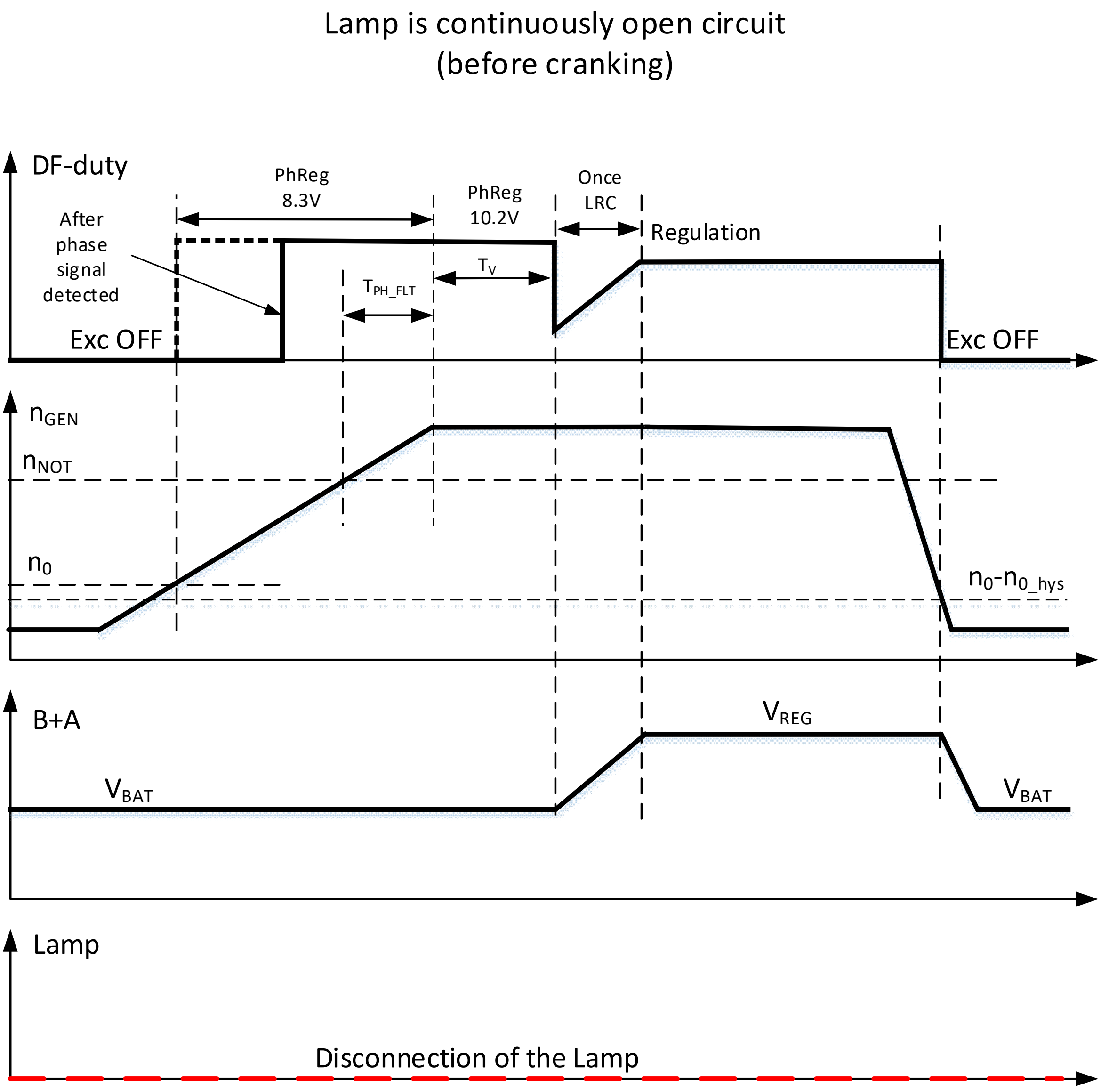


Figure 17. Lamp open operation.

4.18. Lamp is become open during running operation.

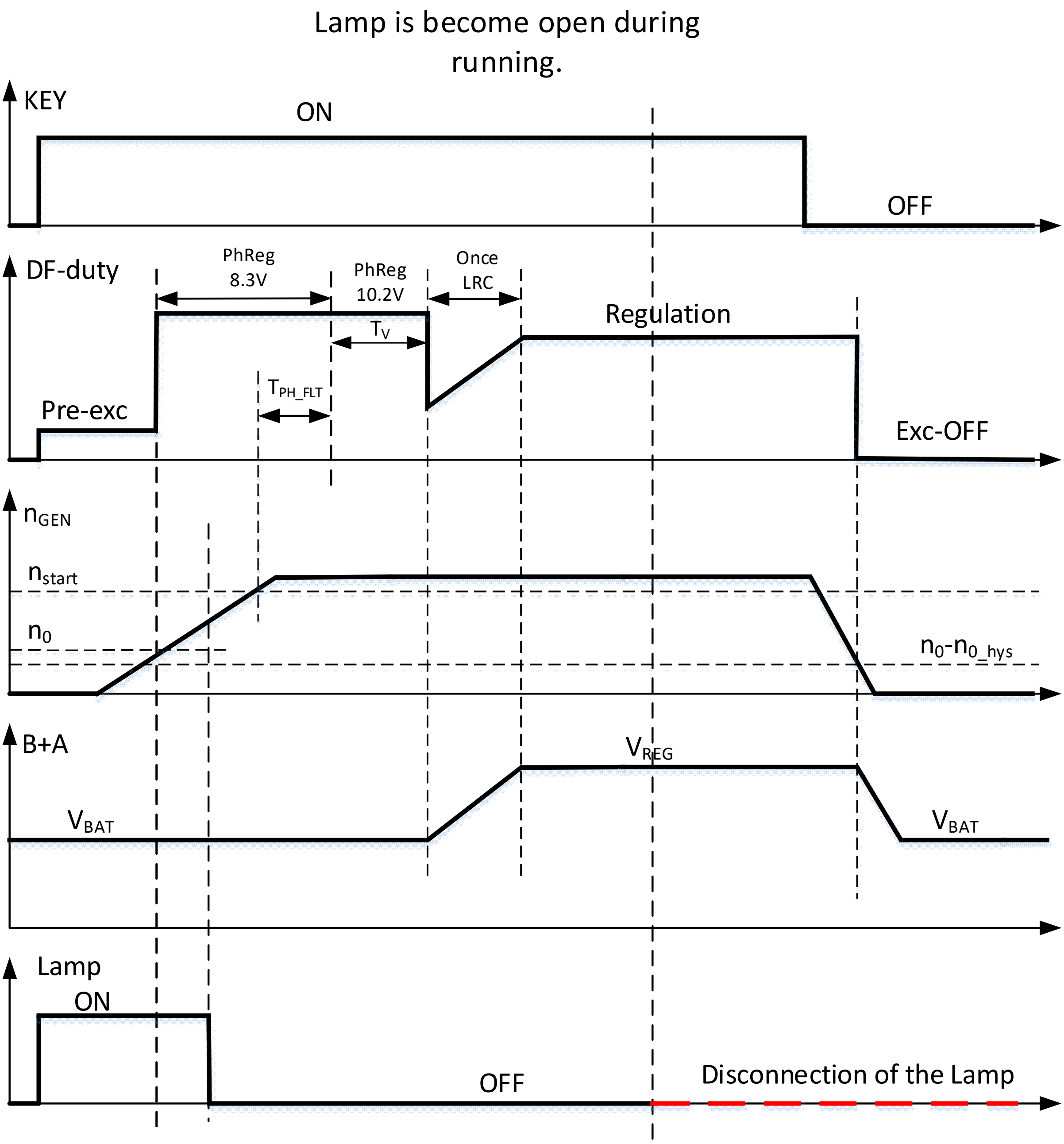


Figure 18. Lamp is become open during running.

Note: after detection "generator running" (n_0) and phase voltage becomes more V_{V_LA} at DC = any the Lamp is OFF.

4.19. Lamp is become open during start-up operation.

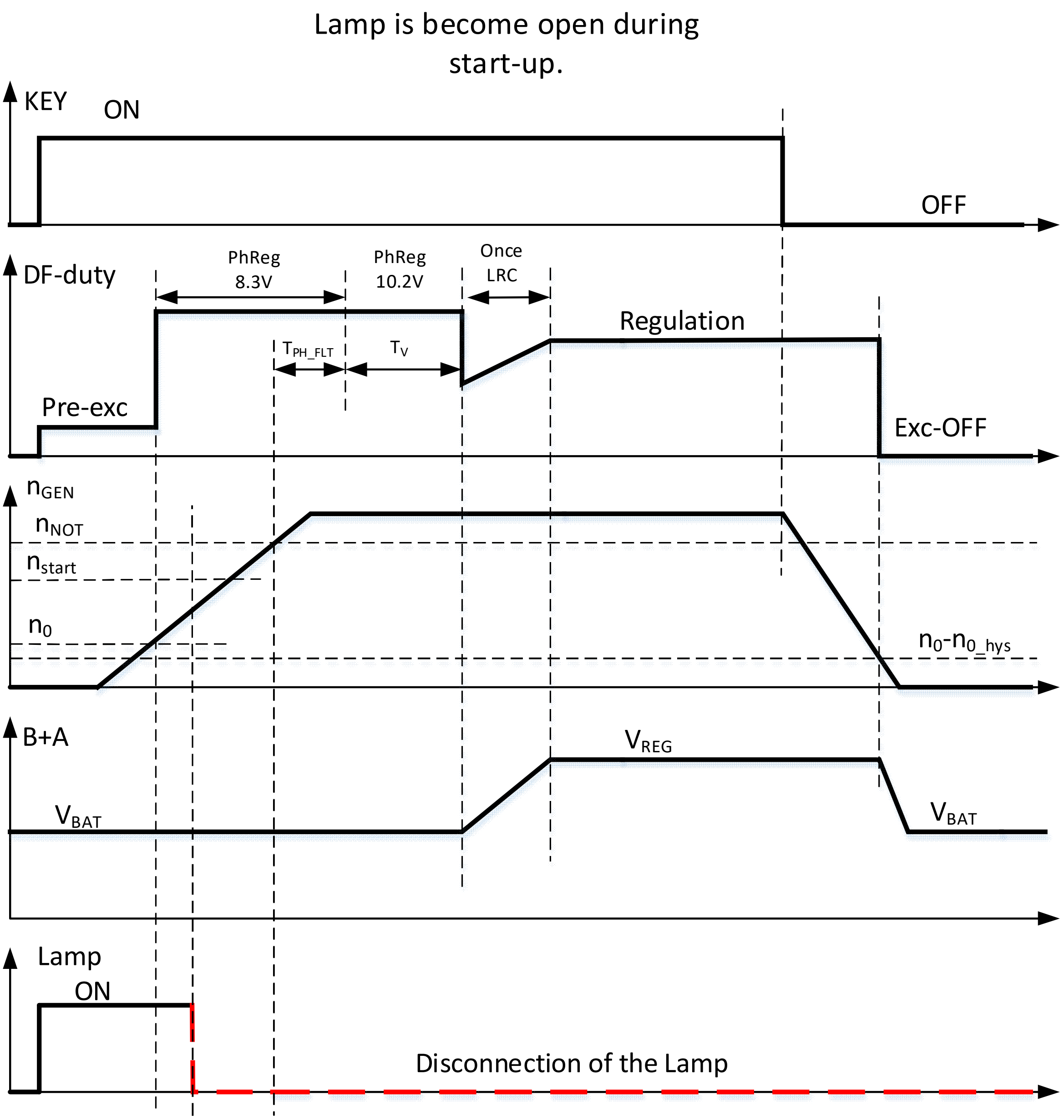


Figure 19. Lamp is become open during start-up.

4.20. Belt breaks operation.

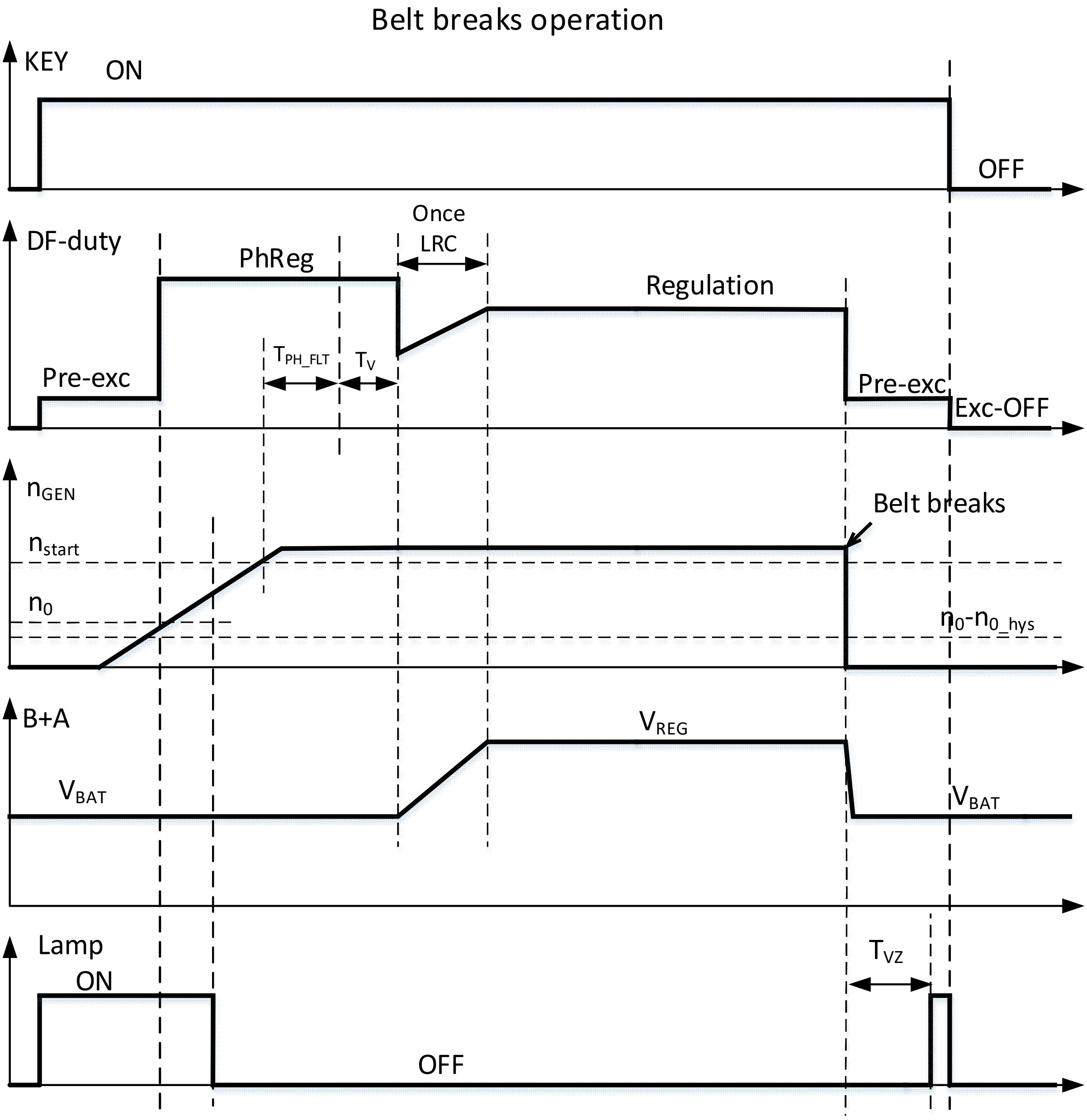
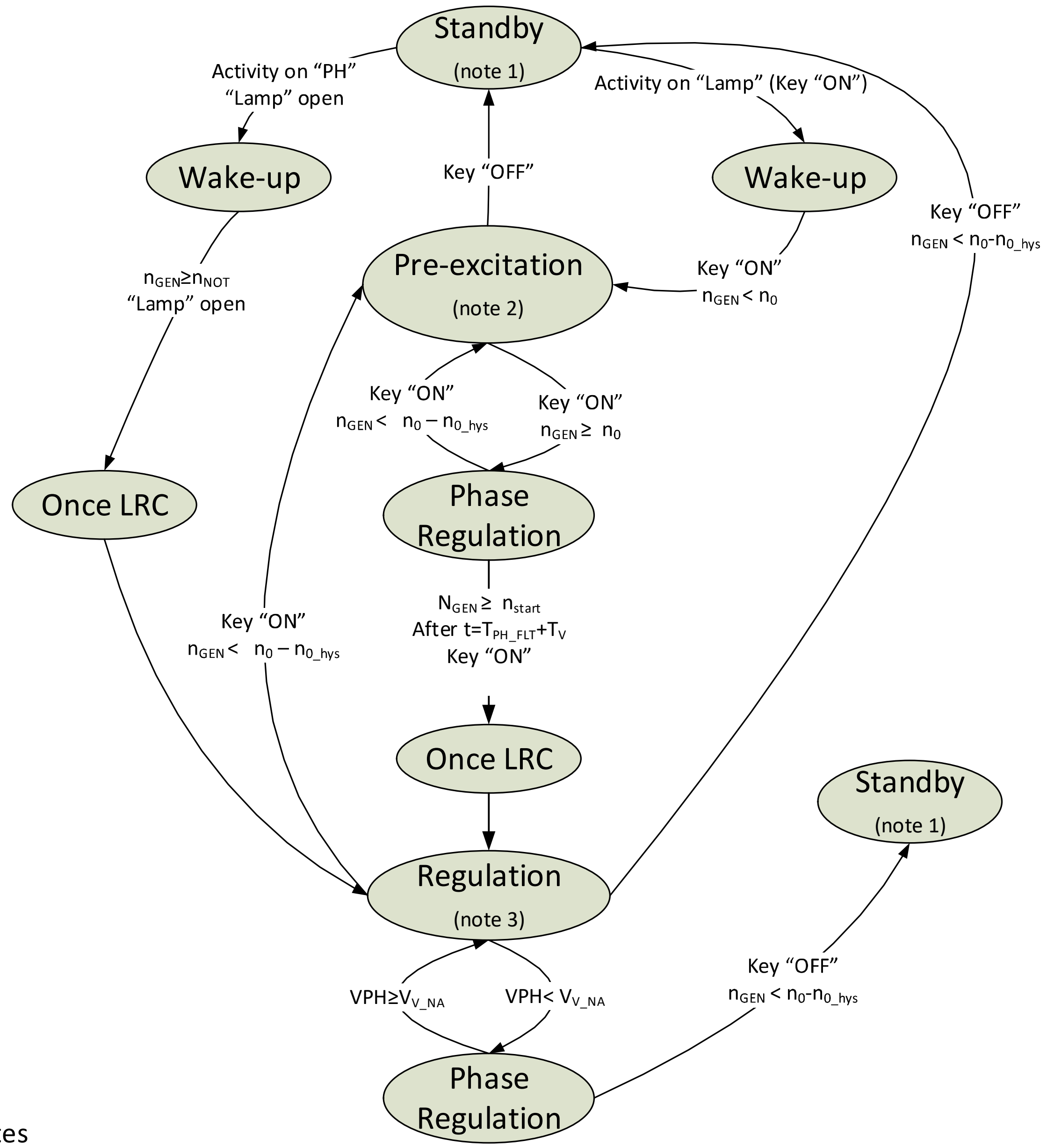


Figure 20. Belt breaks operation.

Note: after detection "generator running" (n_0) and phase voltage becomes more V_{V_LA} at DC = any the Lamp is OFF.

4.21. State diagram.

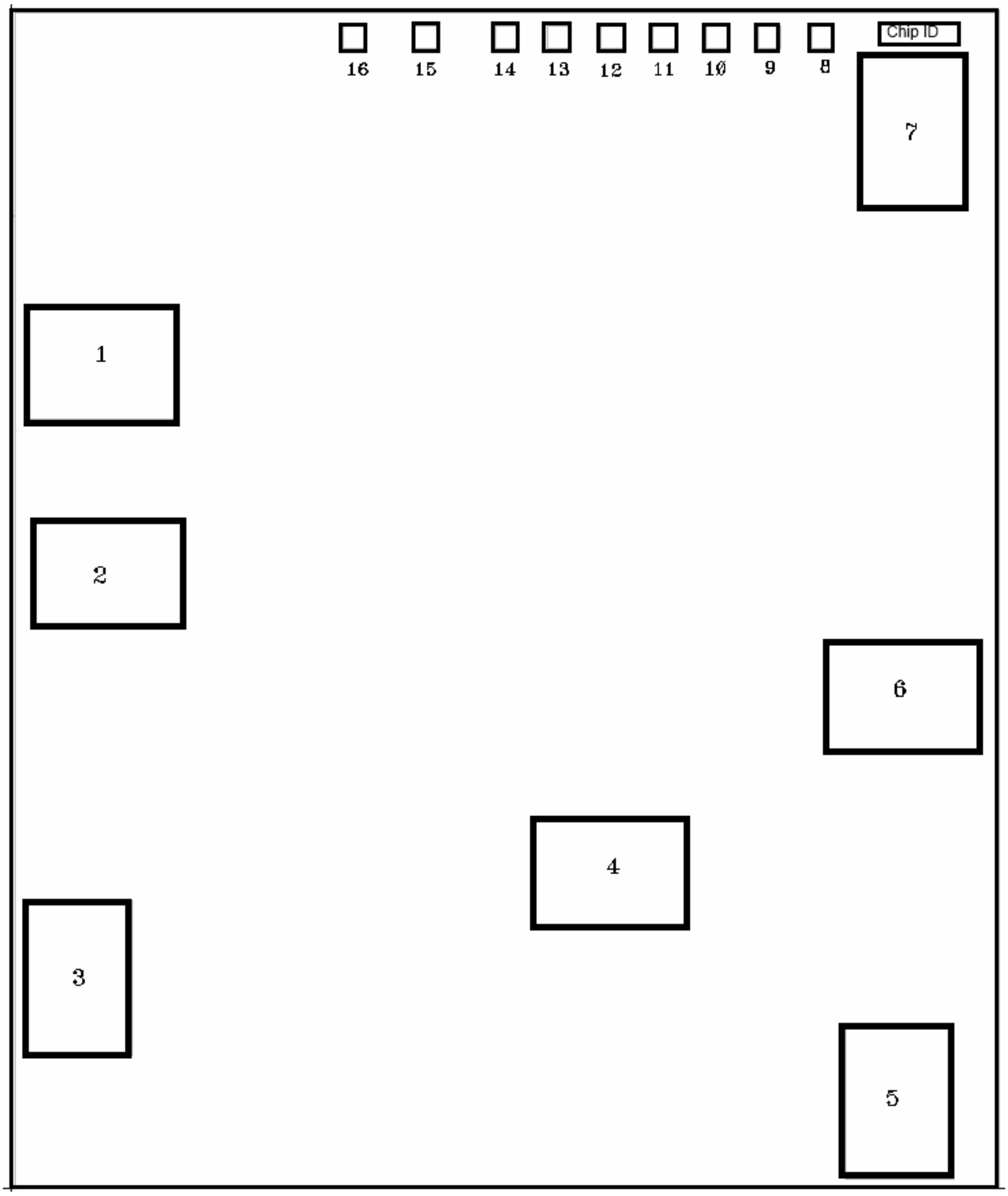


Notes

1. Standby mode means:
   - Low consumption current
   - Excitation OFF
2. Pre-excitation mode means:
   - $FD = TV_{VE1}$ if VSENSE voltage or (B+A voltage) < V_{REG}
   - $FD = TV_{VE2}$ if VSENSE voltage or (B+A voltage) > V_{REG}
3. Regulation mode means:
   - Regulation with LRC if $n_{GEN} < n_{LR}$
   - Regulation without LRC if $n_{GEN} > n_{LR}$
4. If Key "OFF" and $n_{GEN} < n_0 - n_{0\_hys}$ Regulator goes in to "standby"mode from all states.

5. Recommendation assembly of chip.

Pad location.



Chip size X=4500um, Y=5300um (without scribe track)

Chip ID in the layer “MET2” is “8006D” or “8006F”,
coordinates (X / Y) is (3951 / 5154) µm.

Coordinates of the Pads (“POR” layer)

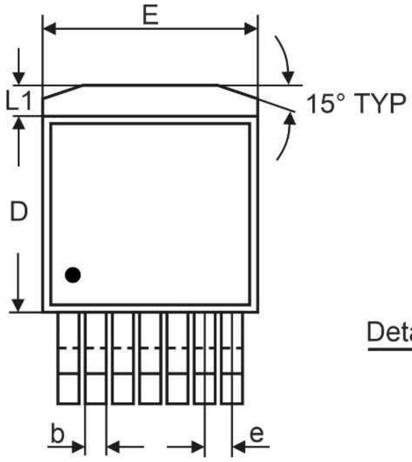
Pad Number	Left-bottom corner of the Pad		Center of the Pad		Pad Name
	X, µm	Y, µm	X, µm	Y, µm	
1	61.3	3460.3	408.3	3707.3	DFM
2	92.0	2519.5	439.0	2766.5	Lamp
3	59.0	598.1	306.0	945.1	B+A
4	2379.3	1172.5	2726.3	1419.5	DF
5	3800.0	44.3	4047.0	391.3	PH
6	3721.0	1968.3	4068.1	2215.3	GND
7	3864.3	4400.0	4111.3	4747.0	SENSE
16	1513.7	5124.1	1564.1	5174.5	CP

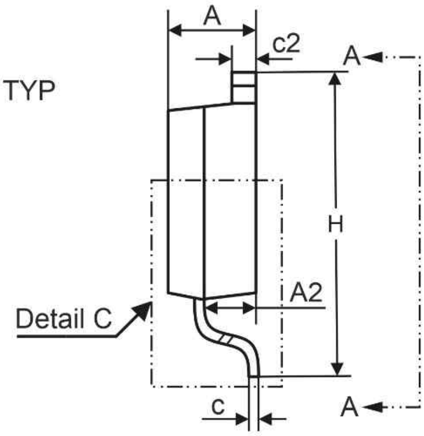
Wire bonding pad size for pads 1,2,3,4,5,6,7 are:
1. 706.0 x 506.0 um on metal layer;
2. 694.0 x 494.0 um on POR layer.

Wire bonding pad size for pad 16 are:
1. 139.2 x 139.2 um on metal layer;
2. 130.0 x 130.0 um on POR layer.

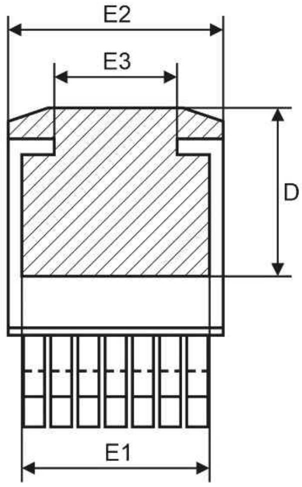
Note:
1) Wafer thickness is 406 um typical.
2) Back side of wafer is under GND voltage. Back side metal should be connected to GND pad.
3) Die bonding should be made by soldering alloy with melting point more 220°C or silver epoxy compound with thermal conductivity more 50 W/K*m.
Recommended to use the tin-silver-copper alloy with 3.0-4.0% of silver.
4) Back side metal is – Ni 0.2 um – Ag – 0.15 um.
5) Top level metal thickness is 2.7 um typical.
6) Wire thickness should be 0.2 mm.

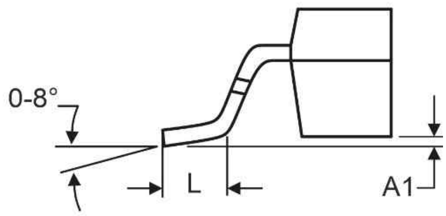
6. Package information and pinout.





A-A





Detail C

	Dimensions, mm		
	Min	Nom	max
A	4.250	4.400	4.550
A1	0	0130.	0.250
A2	2.250	2.400	2.550
b	0.500	0.600	0.700
c	0.400	0.500	0.600
c2	1.200	1.300	1.400
D	9.050	9.250	9.450
D1	6.900	7.000	7.100
E	9.800	10.000	10.200
E1	7.250	7.350	7.450
E2	9.700	9.900	10.100
E3	7.800	8.000	8.200
e	-	1.270	-
H	14.650	15.000	15.350
L	2.400	2.700	3.000
L1	0.800	1.000	1.200

Recommended solder pad layout

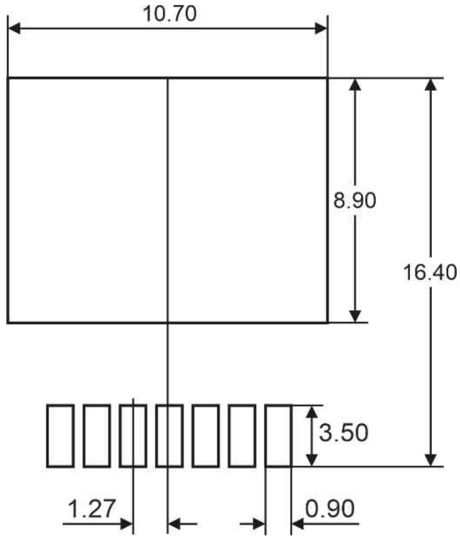


Table 8. Description of pinout IK8006PD2T or IK8006PF2T.

Pin	Symbol	Description.
1	SENSE	Battery sense input
2	DFM	Field monitor output
3	Lamp	Lamp and relay terminal
4	GND	Regulator ground
5	DF	High side driver output
6	B+A	Power supply pin and battery sense
7	PH	Phase sense terminal

Table 9. Description of pinout IK8006D2T or IK8006F2T.

Pin	Symbol	Description.
1	CP	Production line programming pin
2	DFM	Field monitor output
3	Lamp	Lamp and relay terminal
4	GND	Regulator ground
5	DF	High side driver output
6	B+A	Power supply pin and battery sense
7	PH	Phase sense terminal

7. Revision history

Date	Rev	Changes	Remark
14.12.2015	0.00	Initial release	
29.12.2015	0.01	Changes according customer request (indicated by blue color)	
30.12.2015	0.02	1. Page 12. Fig. 7. Changed by customer request. 2. Page 23. Table 7. DFM_{CLAMP} changed by customer request.	
04.01.2016	0.03	1. Page 12, 13. Fig. 7. DFMCLAMP changed by customer request.	
07.01.2016	0.04	1. Page 12. Added relay function description. 2. Page 15. Table 3. Excluded row 8. 3. Page 18. Updated according meeting with customer. 4. Page 18. Table 5. Load dump condition time 400ms installed. 5. Page 21. Table 7. T_{FLT} updated. 6. Page 23. Table 7. Pin “Sense” limitation updated.	
11.01.2016	0.05	1. Page 19. Table 7. Added “TBD” 2. Page 22, 23. Table 7. Added – Guarantee by design, for reference only.	
11.01.2016	0.06	1. Page 19. Table 7. V_{OVP} is changed to 16.0	
04.11.2016	1.00	1. Page 18. Table 4. Device variant table. Changed default state. Option “SENSE” No in default state. 2. Page 20. Defined value of suppressor capacitor between B+A pin and GNG (external). C = 6.9 (2.2 + 4.7) Uf typ. 3. Added parameter R_{PAR_GND}. Parasitic resistance between Pad “GND” on chip and Pin “GND” of regulator 4. Added parameter R_{PAR_B+A}. Parasitic resistance between Pad “B+A” on chip and Pin “B+A” of regulator 5. Defined value of Sink current on pin Lamp in standby mode. I_{L_SINK} =1.0Ma typ. 6. Defined value of Capacitor at L. C_L = 22Nf typ. 7. Page 23. Defined value of Capacitor at DFM. C_{DFM} = 22Nf typ. 8. Page 24. Changed typical application schematic. Added parasitic resistances R_{PAR_GND}, R_{PAR_B+A} and defined values of capacitances and resistances.	
27.03.2017	1.01	1. Page 18. Table 5. Absolute maximum ratings. Changed parameter $V(B+A)_{LD}$ from 45V to 37V (same as Bosch product CR719). 2. Changed Typical application. -Resistor at pin DFM is placed outside alternator. -Typical value resistor at pin DFM changed from 7K to 1K. -Alarm Lamp is shunted by capacitor 100Nf. 3. The description of function is updated.	
05.04.2017	1.02	1. Page 19. Table 4. Added parameter “Clamp on DFM” DFM_{CLAMP} .	

Date	Rev	Changes	Remark
17.04.2017	1.03	1. Changed pad location. New chip design. 2. Renamed parameter “Inrush current lamp driver” to “Minimum current for switch lamp on driver”. 3. Updated values boundaries of parameters: -“Minimum current for switch lamp on driver” -“Switching-on threshold detection ignition ON” -“Switching-off threshold detection ignition OFF”	
24.05.2017	1.04	1. Page 20. Table 7. Changed parameter $I_{STANDBY}$ from 300 Ua max. to 250 Ua max.	
13.06.2017	1.05	1. Page 8, page 14. Added recommended value $t_{LRDOWN}=t_{LRD}/4$. 2. Page 27. Updated typical application diagram. 3. Page 36, 37. Added package drawing. 4. All pages upgraded.	
20.06.2017	1.06	1. Page 11. Table 6. Suppression capacitor between B+A pin and GND changed to 9.1Uf. 2. Page 27. Suppression capacitor between B+A pin and GND changed to 9.1Uf.	
19.09.2017	1.07	1. Page 1. Added package option IK8006P. 2. Page 38. Added description of pinout IK8006P.	
31.10.2017	1.08	1. Correction ‘Oder Code’ according to IK regulation at page#1, page#38.	
23.05.2018	1.09	1. Page 1. Added the die photo. 2. Page 17. Updated Normal start procedure. 3. Page 29. Update Typical operation sequence. 4. Page 31. Updated Lamp is become open during running. 5. Page 33. Updated Belt break operation. 6. Page 36. Updated Coordinates of the Pads.	
23.03.2021	1.10	1. Page 8. Table 3 changed the T_V time. 2. Page 28. Inserted new one Fig. 15 for IK8006PD2T. 3. Page 36. Pad 16 sizes changed. 4. Page 37. Package information changed.	
03.03.2022	1.11	Page 9. Table 4, Table 5 updated for $V(B+A)_R$ and R_{THJC}	
07.04.2022	1.12	Page 1. Table 1. Updated “Option” Page 7. Table 2. Updated. Page 28. Fig. 14. Updated. Page 37. Indicated pins numbering.	
10.03.2023	1.13	Page 1. Table 1. Updated “Option” Page 28. Fig. 14 and 15 updated. Page 36. Table updated. CP pin coordinate. Page 38. Table 8 and 9 updated.	
3.04.2023	1.14	Page 1. Table 1. Added the IK8006F items. Page 12. Table 6. Added the IK8006F parameters (marked yellow) Page 35. IK8006F inserted. Page 38. IK8006F inserted.	
12.01.2024	1.15	Page 12. Table 6. Updated Page 36. Note updated.	
21.03.2024	1.16	Page 9 . ESD Level Updated	