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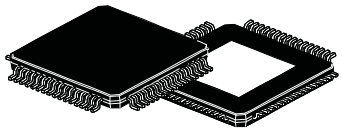
L9177A

Automotive peripheral on chip for low end engine control

Datasheet - production data



TQFP64 (10x10 mm - exposed pad down)

GADG1608171606PS

Features

- AEC-Q100 qualified
- Supply voltage from 6 V to 18 V
  - Basic functionality guaranteed down to 3.9 V
- 5 V regulator up to 300 mA with thermal shutdown protection in current limitation condition
- 5 V tracking regulator up to 40 mA and short to battery protection
- 5 V standby regulator up to 2.5 mA
- 2 channels injectors drivers
  - Parallel and serial driving
  - Output internally clamped to 60 V
  - Minimum overcurrent at 2.8 A
  - Ron 0.6 Ω worst case (at T_j = 150 °C)
- 3 relay drivers
  - 2 with parallel and serial driving, 1 with serial driving
  - Output internally clamped to 45 V
  - Minimum guaranteed output current 1 A
  - Ron 1.5 Ω worst case (at T_j = 150 °C)
- Tachometer driver
  - Parallel and serial driving
  - Minimum guaranteed output current 25 mA
  - Ron 5 Ω worst case (at T_j = 150 °C)
- Lamp driver
  - Serial driving
  - Output internally clamped to 45 V
  - Minimum guaranteed output current 1 A (2 A during in-rush)
  - Ron 1.5 Ω worst case (at T_j = 150 °C)
- Stepper motor driver
  - Parallel driving
  - Minimum guaranteed output current 500 mA - full step
  - Ron 2.6 Ω worst case on the diagonal (at T_j = 150 °C)
- O2 sensor heater
  - Parallel and serial driving
  - Output internally clamped to 45 V
  - Minimum guaranteed output current 3 A
  - Ron 0.5 Ω worst case (at T_j = 150 °C)
- Protected high side driver
  - 100 mA min. current limitation threshold
- Full diagnosis by SPI
  - Injector driver: OL, STG, OC
  - Relay and Lamp drivers: OL, STG, OC
  - O2 sensor heater: OL, STG, OC
  - Tachometer: OL, STG, OC
  - Stepper motor driver: OL, STG, STB, OC
  - general diagnostic: over-temperature
- Protection for STB, STG (for stepper motor drivers and tracking regulator)
- Self configuring variable reluctance sensor interface
- K-line transceiver
- Microcontroller reset logic
- Small Factor form package TQFP64 10 x 10 mm exposed pad down

Table 1: Device summary

Order code	Package	Packing
L9177A	TQFP64 (10x10 mm), exposed pad down (7.5x7.5 mm)	Tray
L9177ATR		Tape and reel

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1 Description

L9177A is a device realized in ST BCD proprietary technology, able to provide the full set of power supplies and signal preprocessing peripherals needed to control a 2 Cylinder internal combustion Engine for Low End Application (e.g. small motorcycle, K-car, nautical engines, etc.).

L9177A integrates a 5 V main voltage regulator, a 5 V 40 mA tracking regulator for sensor supply and a 2.5 mA 5 V standby regulator.

The two channels injector drivers, the O2 sensor heater and two relay drivers can be controlled both with parallel input and with SPI interface. One additional relay driver and the lamp driver are controlled by SPI. The stepper motor driver is designed for a double winding coil motor, used for engine idle speed control.

Low side drivers implement SR control to minimize emission.

A protected 50 mA high side driver is provided.

A Variable Reluctance Sensor interface allows the connection to a commercial magnetic pick-up, allowing the indirect measurement of internal combustion engine crank angle. A K-line (standard ISO-9141 compatible) is provided as data communication interface.

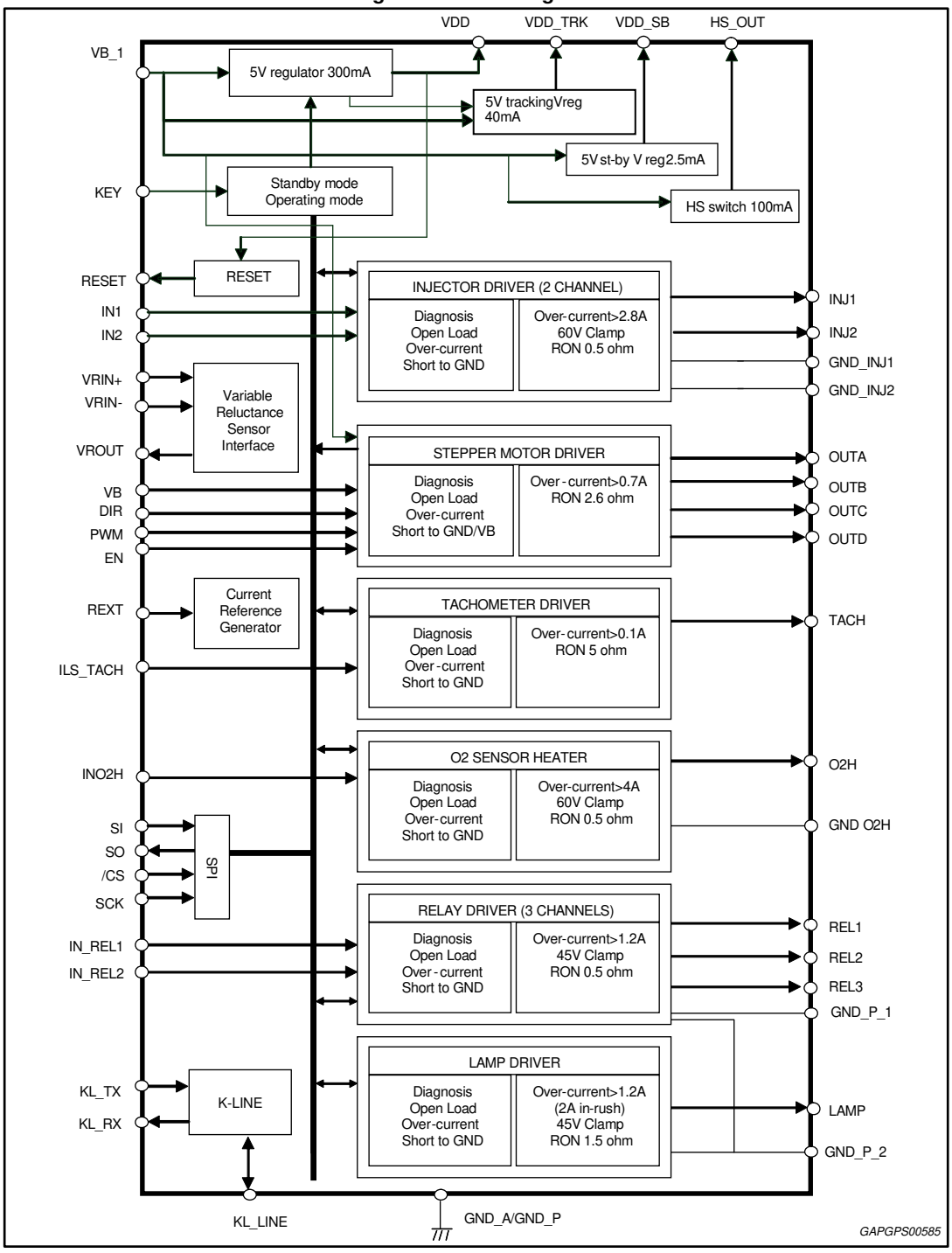
All functionalities are fully protected and provide complete diagnostics via a 24bit SPI interface. An overall protection against over temperature is provided as well.

The device is available in TQFP64 10x10mm package with exposed pad for power dissipation optimization.

2 Block diagram and pin description

2.1 Block diagram

Figure 1: Block diagram



2.2 Pin description

Figure 2: Pin connection (top view)

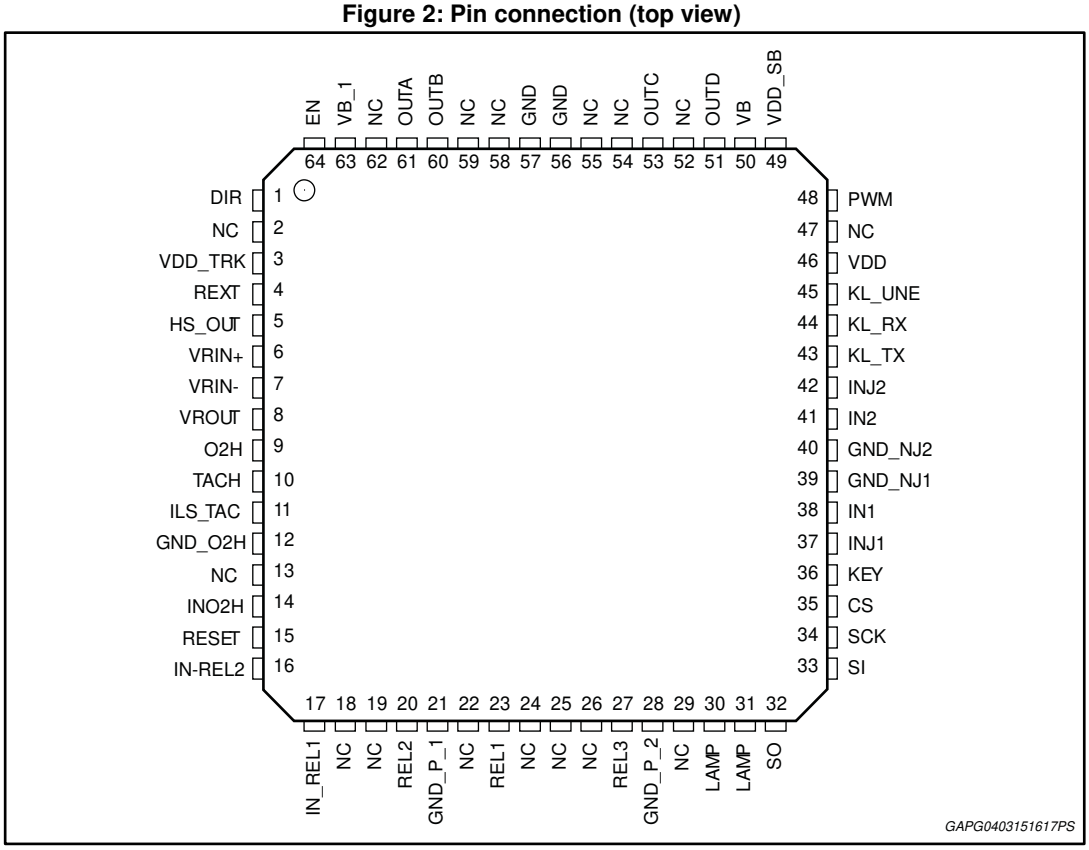


Table 2: Pin function

Pin #	Pin name	Description	I/O type	Class
1	DIR	Logic input to set stepper motor direction	I	SIGNAL
2	NC	Not connected	-	-
3	VDD_TRK	Tracking voltage regulator output	O	PWR
4	REXT	External resistor for precision current reference	I	SIGNAL
5	HS_OUT	High side switch output	O	PWR
6	VRIN+	VRS positive differential input	I	SIGNAL
7	VRIN-	VRS negative differential input	I	SIGNAL
8	VROUT	VRS output	O	SIGNAL
9	O2H	O2 sensor heater output	O	PWR
10	TACH	Tachometer driver output	O	PWR
11	ILS_TACH	Tachometer driver input	I	SIGNAL
12	GND_O2H	O2 sensor heater ground	GND	PWR
13	NC	Not connected	-	-
14	INO2H	O2 sensor heater input	I	SIGNAL
15	RESET	Reset signal to the micro	O	SIGNAL
16	IN_REL2	Relay 2 parallel control input	I	SIGNAL

Pin #	Pin name	Description	I/O type	Class
17	IN_REL1	Relay 1 parallel control input	I	SIGNAL
18	NC	Not connected	-	-
19	NC	Not connected	-	-
20	REL2	Relay 2 driver output	O	PWR
21	GND_P_1	Power ground relay 1-2	O	PWR
22	NC	Not connected	-	-
23	REL1	Relay 1 driver output	O	PWR
24	NC	Not connected	-	-
25	NC	Not connected	-	-
26	NC	Not connected	-	-
27	REL3	Relay 3 driver output	O	PWR
28	GND_P_2	Power ground for lamp	GND	PWR
29	NC	Not connected	-	-
30	LAMP	Lamp driver output	O	PWR
31	LAMP	Lamp driver output	O	PWR
32	SO	SPI data out	O	SIGNAL
33	SI	SPI data in	I	SIGNAL
34	SCK	SPI serial clock	I	SIGNAL
35	CS	SPI chip select	I	SIGNAL
36	KEY	Key signal	I	SIGNAL
37	INJ1	Injector 1driver power output	O	PWR
38	IN1	Injector 1 driver input command	I	SIGNAL
39	GND_INJ1	Injector 1 ground	GND	PWR
40	GND_INJ2	Injector 2 ground	GND	PWR
41	IN2	Injector 2 driver input command	I	SIGNAL
42	INJ2	Injector 2 driver power output	O	PWR
43	KL_TX	K-Line TX digital IN	I	SIGNAL
44	KL_RX	K-Line RX digital OUT	O	SIGNAL
45	KL_LINE	K-Line	I/O	PWR
46	VDD	5 V voltage regulator output	O	PWR
47	NC	Not connected	-	-
48	PWM	Logic Input to set Stepper Motor Speed	I	SIGNAL
49	VDD_SB	5 V standby voltage regulator output	O	PWR
50	VB	Battery line to bridge 2	I	PWR
51	OUTD	Output bridge 2	O	PWR
52	NC	Not connected	-	-
53	OUTC	Output bridge 2	O	PWR
54	NC	Not connected	-	-
55	NC	Not connected	-	-

Pin #	Pin name	Description	I/O type	Class
56	GND	Analog and power ground	GND	PWR
57	GND	Analog and power ground	GND	PWR
58	NC	Not connected	-	-
59	NC	Not connected	-	-
60	OUTB	Output bridge 1	O	PWR
61	OUTA	Output bridge 1	O	PWR
62	NC	Not connected	-	-
63	VB_1	Battery line to bridge1	I	PWR
64	EN	Logic input to enable stepper motor	I	SIGNAL
-	Pad	Exposed pad	GND	PWR

3 Electrical specifications

3.1 Operating range

The device may not operate properly if maximum operating conditions are exceeded.

Table 3: Operating conditions

Parameter	Value	Unit
VB, VB_1 supply voltage	6 to 18 (1)	V
I/O logic	0 to VDD	V
Stepper motor outputs	-0.3 to VB, VB_1, Vb+	V
Low side outputs	-0.3 to clamp voltage	V

Notes:

(1)See *Section 3.1.1: "Supply voltage"*.

3.1.1 Supply voltage

- Below 3.9 V the device is in a safety state (internal circuitries are on but all the outputs are off).
- From 3.9 V to 5.5 V (crank functionality):
  - Reset function; VDD > 3.3 V (rds-on state) I_{VDD} = 100 mA; 3.3 V < VDD_TRK < VDD (rds-on state);
  - Low-sides, K-Line, H-Bridge OFF if Reset = 0; SPI not available, internal registers resetted if Reset = 0;
  - All Diagnosis disabled if Reset = 0; VRS function limited ($V_{diff\ max}$ = 1000 mV)
- From 5.5 V to 6 V (low battery):
  - All the functions are granted with the following degraded parameters; VDD > 4.510 V; VDD Reset function guaranteed, but no Reset asserted; Tracking error < 100 mV (I_{load} = 40 mA, rds-on state).
- From 6 V to 18 V: normal operating range
- From 18 V to V_{B_off}:
  - All the functions are granted with increased power dissipation and no reset is asserted during transient.
- From V_{B_off} to 40 V (internal circuitries are on but all the outputs are off):
  - The device is on and in a safety state.

3.2 Absolute maximum ratings

Maximum ratings are absolute ratings; exceeding any one of these values may cause permanent damage to the integrated circuit.

Table 4: Absolute maximum ratings

Parameter	Condition	Min	Max	Unit
DC supply voltage	pin VB/VB_1	-0.3	40	V
I/O low voltage pins (1)	-	-0.3	7	V
I/O low voltage digital pins (2)	-	-0.3	VDD+0.3	V
I/O power pins voltage range (3)	-	-0.3	Clamp voltage	V
TACH pin	-	-0.3	40	V
OUTA-D	-	-0.3	VB +0.3	V
KEY pin	To be protected with Rkey_ext to limit sourced/sinked current to ± 5 mA in dc conditions and ±20 mA during transients (ISO-pulses on battery line)	-0.3	10	V
VRIN- / VRIN+	Max current |20 mA| to be limited with external resistors	-0.3	VDD + 0.3	V
VDD_TRK pin	-	-2	40	V
KL_LINE pin	-	-16	40	V
Maximum voltage shift between GND pins	PIN GND, GND_O2H, GND_P_1,2, GND_INJ1,2, GNDA, GNDP	-0.3	0.3	V
I/O power pins (3)maximum energy (single pulse, max. current)	Injector drivers	-	50	mJ
	O2 sensor heater	-	60	mJ
	Relay/lamp drivers	-	25	mJ
I/O power pins (3)maximum energy (continuous pulse, max. current, 36 million pulses with T = 100 ms)	Injector drivers	-	18	mJ
	O2 sensor heater	-	22	mJ
	Relay/lamp drivers	-	8	mJ
Reverse current through O2H output without supply voltage (4)	Static (room temperature, max reverse diode voltage 1.5 V)	-	2.5	A
	Dynamic (guarantee by iso-pulse test immunity on application board)	-	-	
Reverse current through INJx outputs without supply voltage (4)	Static (room temperature, max reverse diode voltage 1.5 V)	-	2.2	A
	Dynamic (guarantee by iso-pulse test immunity on application board)	-	-	
Reverse current through LAMP output without	Static (room temperature, max reverse diode voltage 1.5v)	-	1.2	A

Parameter	Condition	Min	Max	Unit
supply voltage (4)	Dynamic (guarantee by iso-pulse test immunity on application board)	-	-	
Reverse current through RLYx outputs without supply voltage (4)	Static (room temperature, max reverse diode voltage 1.5 V)	-	1.5	A
	Dynamic (guarantee by iso-pulse test immunity on application board)	-	-	
Reverse current through TACH output without supply voltage (4)	Static (room temperature, max reverse diode voltage 1.5 V)	-	0.5	A
	Dynamic (guarantee by iso-pulse test immunity on application board)	-	-	

Notes:

(1)Pins are VDD, VDD_SB, REXT, DIR

(2)Pins are CS, SCK, SI, SO, VROUT, RESET, PWM, EN, INO2H, ILS_TACH, IN, KL_TX, KL_RX

(3)Pins are O2H, LAMP, INJ1-2, REL1-2-3

(4)Reverse battery connection, parameter not tested for info only

Table 5: ESD protection

Item	Condition	Min	Max	Unit
All pins (1)(2)	HBM	-2	2	kV
All pins	MM	-200	200	V
All pins	CDM (values for corner pins in brackets)	-500 / (-750)	500 / (750)	V
Pins to connector (3)	HBM	-4	4	kV

Notes:

(1)OUTA-D, TACH, O2H, LAMP, INJ1-2, REL1-2-3 vs. GNDP2, GNDO2: -1.5 / 1.5 kV

(2)OUTA-D, TACH, O2H, LAMP, INJ1-2, REL1-2-3 vs. GNDP1: -1 / 1 kV

(3)Pins are OUTA-D, TACH, O2H, LAMP, INJ1-2, KEY, REL1-2-3,VB,KL_LINE, VDD_TRK all GND connected together. The device is AEC-Q100 compliant.

3.3 Latch-up test

According to JEDEC 78 class 2 level A.

3.4 Temperature ranges and thermal data

Table 6: Temperature ranges and thermal data

Symbol	Parameter	Min	Max	Unit
T_{amb}	Operating temperature (ECU environment)	-40	125	°C
T_j	Operating junction temperature	-40	150	°C
T_{stg}	Storage temperature	-40	150	°C
T_{ot}	Thermal shut-down temperature	155	200	°C
O_{Thys}	Thermal shut-down temperature hysteresis	10		°C
$R_{Th\ j\text{-}amb}$	Thermal resistance junction-to-ambient (1)		20	°C/W
$R_{Th\ j\text{-}case}$	Thermal resistance junction-to-case		2	°C/W

Notes:

(1)with 2s2p PCB thermally enhanced.

3.5 Electrical characteristics

V_B = 6 V to 18 V, T_{amb} = -40 °C to 125 °C.

3.5.1 Supply

Table 7: Supply electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_B	Operating supply voltage range	-	6	-	18	V
V_{B_off}	Vbat switch off threshold voltage	-	30	32	34	V
$V_{B\ OVh}$	Overvoltage threshold hysteresis	-	0.5	-	-	V
$V_{B\ UVL}$	Undervoltage disable LOW threshold	-	3.5	3.7	3.9	V
$V_{B\ UVh}$	Undervoltage threshold hysteresis	-	0.3	-	1	V
$I_{VB(dis)}$	Standby current from VB, VB_1	VB = VB_1 = 13 V, device disabled, KEY < 0.7 V	-	-	120	µA
I_{VB}	Quiescent current	VB = VB_1 = 13 V, outputs floating	-	-	20	mA
V_{rext}	ASIC Bias reference	Application note	-	1.22	-	V
fint_clk	Internal clock reference	Application note	-	5.6	-	MHz

3.5.2 Key

Table 8: Key electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_Key_L	Input low threshold	-	1.5	-	-	V
V_Key_H	Input high threshold	-	-	-	3.3	V
V_Key_Hyst	Input voltage hysteresis	-	0.5	-	1.8	V
R_Key	Internal pull down	-	50	150	300	kΩ
T_key_deglitch	Key input filter time	Guaranteed by scan	26	-	40	µs
T_key_delay	Maximum delay time from Key to regulator enable	Time from key rising edge to 20% VDD rising edge	-	-	200	µs

Figure 3: Input threshold

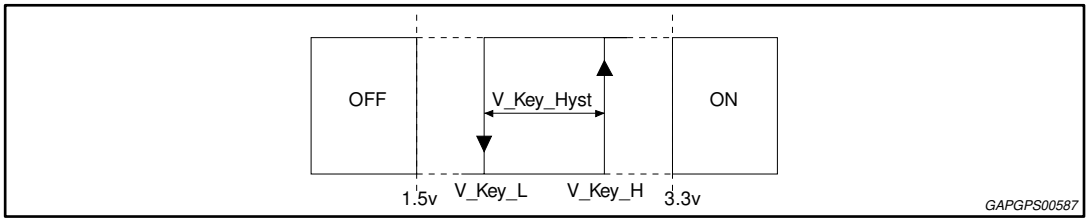
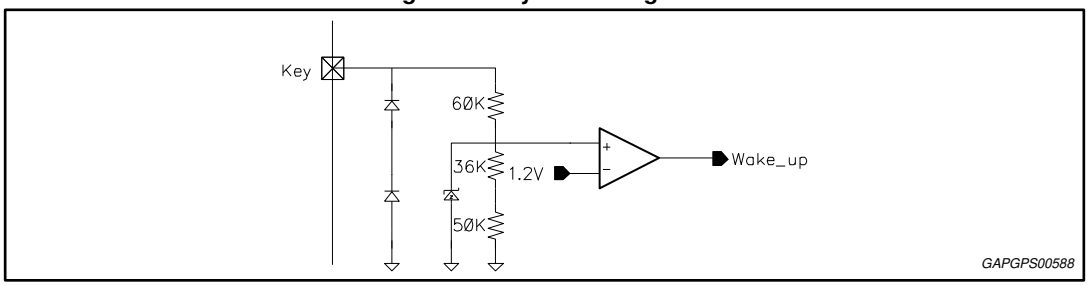


Figure 4: Key block diagram



3.5.3 Digital pins

Table 9: Digital pins characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{in_L}	Input level threshold low	-	0.3*VDD	-	-	V
V_{in_H}	Input level threshold high	-	-	-	0.7*VDD	V
V_{hin}	Input voltage hysteresis	-	0.1	-	-	V
R_pull	Internal pull-down/pull-up (1)(2)(3)	-	50	150	250	kΩ
I_pull_down	Active pull-down	-	10	-	100	µA

Notes:

(1)Pins with active pull-down: DIR.

(2)Pins with pull-down: EN, PWM, ISL-TACH, INO2H, IN_REL1-2, IN1-2;

(3)Pins with pull-up: SI, SCK, CS, KL-TX;

3.5.4 Digital output pins

Table 10: Digital output pins characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
	Output level low	I_{sink}= 2mA	-	-	0.4	V
	Output level high	I_{source}= 2mA (1)(2)	VDD-0.5	-	-	V

Notes:

(1)Pins with push-pull stage and tri-state condition: SDO

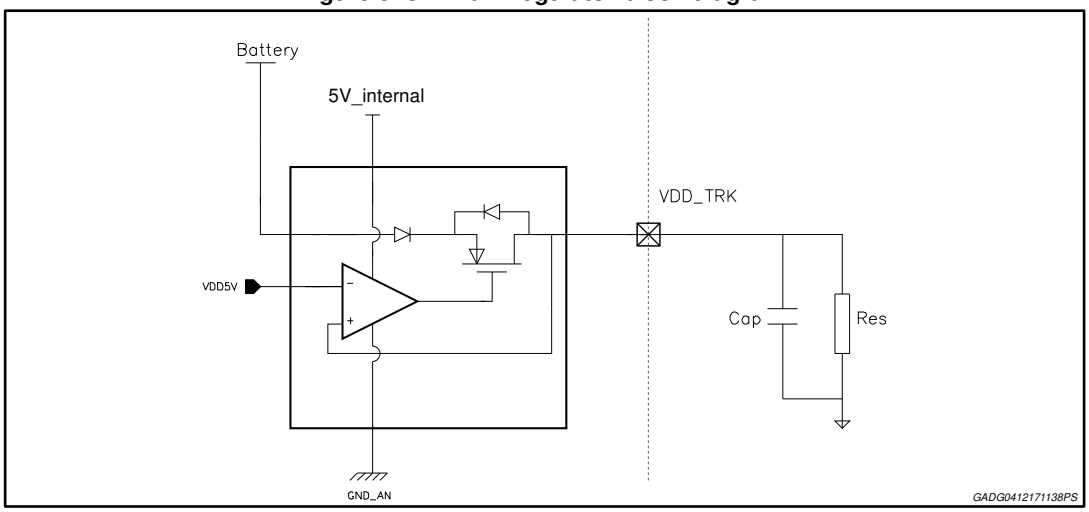
(2)Pins with open drain output: RESET, VROUT;

3.5.5 5 V voltage regulator

Table 11: VDD output electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
VDD	Output voltage	-	4.9	5	5.1	V
Ln_vdd	Line regulation	V_B = 6 V to 18 V I_{load} = 150 mA	-25	-	25	mV
Ld_vdd	Load regulation	V_B = 13 V I_{load} = 5 mA to 300 mA	-25	-	25	mV
V_{dd_OS}	Max overshoot	Recovery from ISO pulse stimuli on battery line (guaranteed by design)	-	-	5.5	V
V_{dd_SR}	Voltage slew-rate at power-on	C_{load} = 4.7 µF	2	-	25	V/ms
I_{dd}	Load current	-	5	-	300	mA
I_{dd_max}	Current limitation	Output short to 4 V	350	-	600	mA
I_{dd_STG}	Short to ground current limitation	Output shorted to GND	350	-	700	mA
PSRR	Power supply rejection ratio	Sin wave @ 1 kHz 1 Vpp; V_B = 13 V; I_{load} = 5 mA to 300 mA	40	-	-	dB
V_{dr5}	V_B - V_{dd} - V_{dd}dropout voltage	V_B = 5 V; I_{load} = 300 mA	0.30	-	0.75	V

Figure 5: 5 V main regulator block diagram

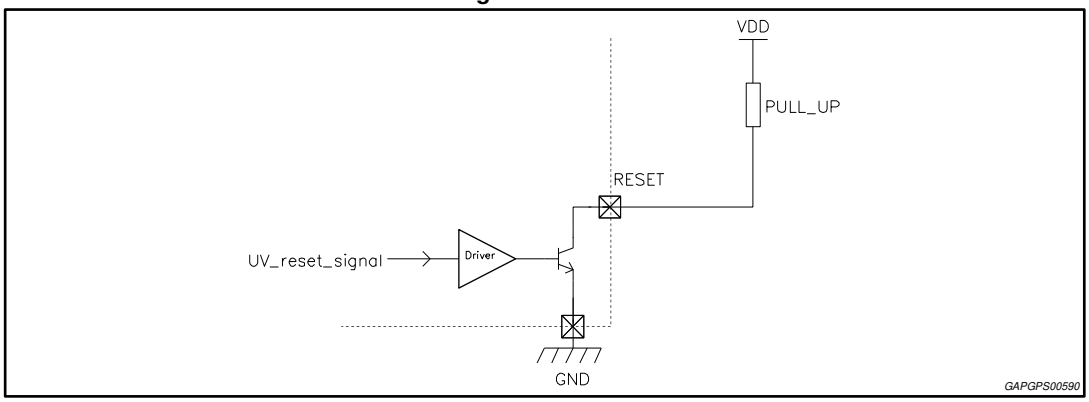


3.5.6 Reset

Table 12: Reset function electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
VUV_LO	Output low voltage	1 < VDD < Vth_UV, I_{reset} = 2 mA	-	-	0.6	V
IUV_LO	Reset current capability	1 < VDD < Vth_UV, V_{reset} = 0.6 V	2	-	-	mA
I_{lk}	Leakage current	VUV_reset = 4.5 V	-	-	1	µA
Vth_UV	VDD under voltage low threshold	V_B= 13.5 V	4.5	-	VDD - 150 mV	V
Vth_UV Tht	VDD under voltage high threshold	-	4.5	-	VDD - 50 mV	V
Vth_UV HYS	VDD under voltage hysteresis	-	50	-	-	mV
Td_UV_ rst	Power on UV reset delay	-	17	22	30	ms
T_{fUV_reset}	UV reset filter	VDD < Vth_UV	25	50	75	µs

Figure 6: Reset

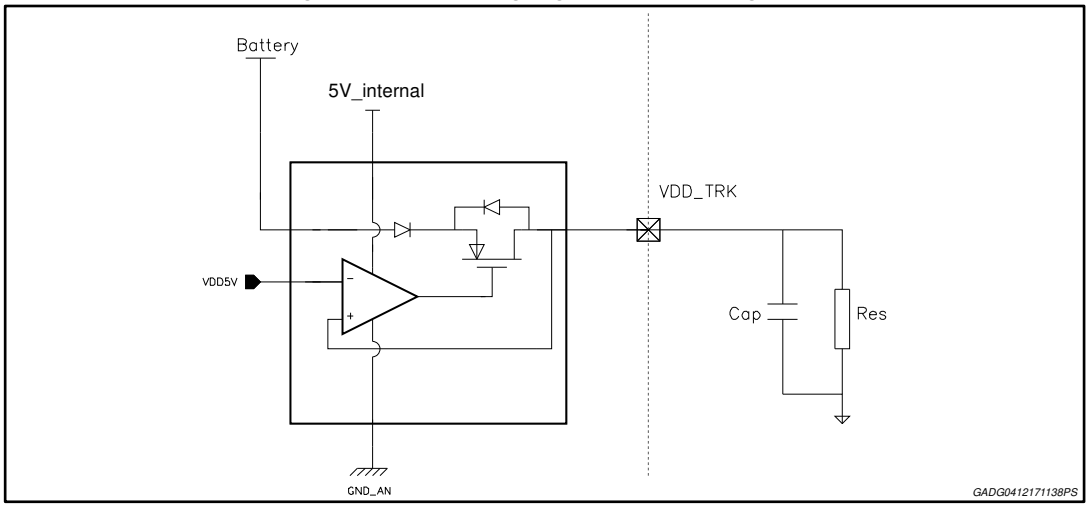


3.5.7 5 V tracking voltage regulator

Table 13: VDD_TRK output electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
DV_{ddtrk}	Output voltage tracking error	V_B = 6 V, I_{trk}= 1 to 40 mA	-15	-	15	mV
V_{short}	Tracking output short circuit voltage range	-	-2	-	V_B	V
I_{trk_max}	Output current limitation	Output short to 4 V	50	-	100	mA
I_{trk_sb}	Tracking output reverse current (limited by the regulator)	Output shorted to V_B = 16 V	-	-	10	mA
I_{dd}	Load current	-	1	-	40	mA
Ln_vdd_trk	Line regulation	V_B= 6 V to 18 V - I_{load}= 40 mA	-15	-	15	mV
Ld_vdd_trk	Load regulation	V_B= 13 V I_{load} = 1 to 40 mA	-15	-	15	mV
PSRR	Power supply rejection ratio	Sin wave @ 1 kHz 1 Vpp V_B = 13 V, I_{load} = 1 to 40 mA	40	-	-	dB

Figure 7: 5 V tracking regulator block diagram

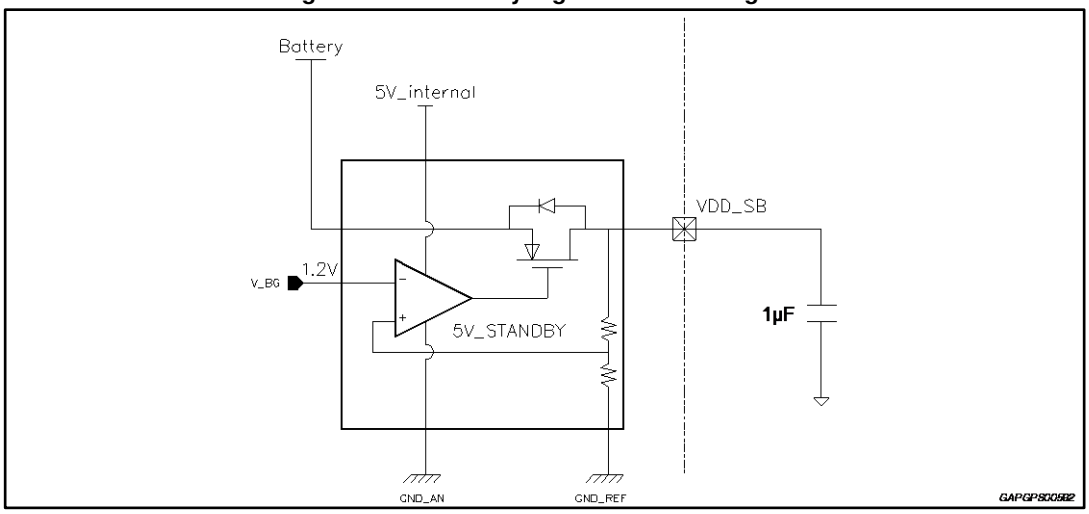


3.5.8 Standby regulator

Table 14: VDD_SB output electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
V_{ddsb}	Output voltage	-	4.75	5	5.25	V
Ln_vsb	Line regulation	V_B = 6 V to 18 V I_{load} = 1 mA	-25	-	25	mV
Ld_vsb	Load regulation	V_B = 13 V I_{load}= 0.1 mA to 2.5 mA	-25	-	25	mV
V_{dd_OS}	Max overshoot	-	-	-	5.5	V
I_{dd}	Load current	-	0.1	-	2.5	mA
I_{sb_max}	Current limitation	Output short to 4 V	5	-	50	mA
V_{sb_SR}	Voltage slew-rate at power on	C_{load} = 1 µF	2	-	30	V/ms
PSRR	Power supply rejection ratio	Sin wave @ 1 kHz 1 Vpp V_B = 13 V I_{load} = 0.1 to 1 mA	40	-	-	dB

Figure 8: 5 V standby regulator block diagram

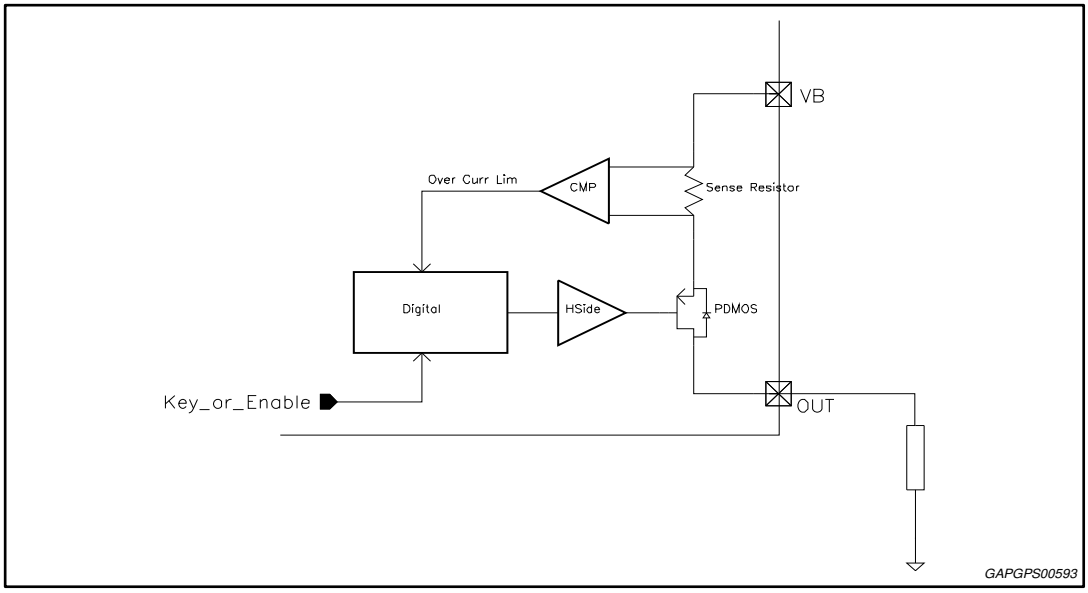


3.5.9 High side switch

Table 15: HS_OUT output electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
R_{on_hs}	Ron	I_{hs} = 50 mA	-	-	14	Ω
I_{hs_max}	Current limitation	V_B = 13.5 V	100	-	400	mA

Figure 9: High-side driver block diagram



The High side switch is intended as a protected battery and is directly controlled by key input (see *Figure 21: "A under and over voltage time diagram"*).

3.5.10 Injector driver

Table 16: Injector driver electrical characteristic

Symbol	Parameter	Condition	Min	Typ	Max	Unit
I_{max}	Output current	-	-	-	2.2	A
I_oc	Overcurrent threshold	-	2.8	-	5	A
V_{DS}	Output clamping voltage	I = 2.2 A	55	-	65	V
R_{on}	On resistance	I = 2.2 A	-	-	0.6	Ω
I_{lk_off}	Leakage current	V_{out}= 18 V, diagnosis OFF	-	-	10	µA
I_{lk_on}	Leakage current	V_{out}= 18 V, diagnosis ON	-	-	100	µA
t_{on-off}	Turn on-off delay	from CMD edge to 50% output variation	-	-	6	µs
V_{OL}	Open load output voltage	Driver in OFF condition	0.46*VDD	0.5*VDD	0.54*VDD	V
V_{diagth_H}(1)	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L}(1)	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V

Notes:

(1)$V_{diagth\_L} < V_{out} < V_{diagth\_H}$ → Open Load; $V_{out} < V_{diagth\_L}$ → Short to GND

Figure 10: Low-side driver block diagram

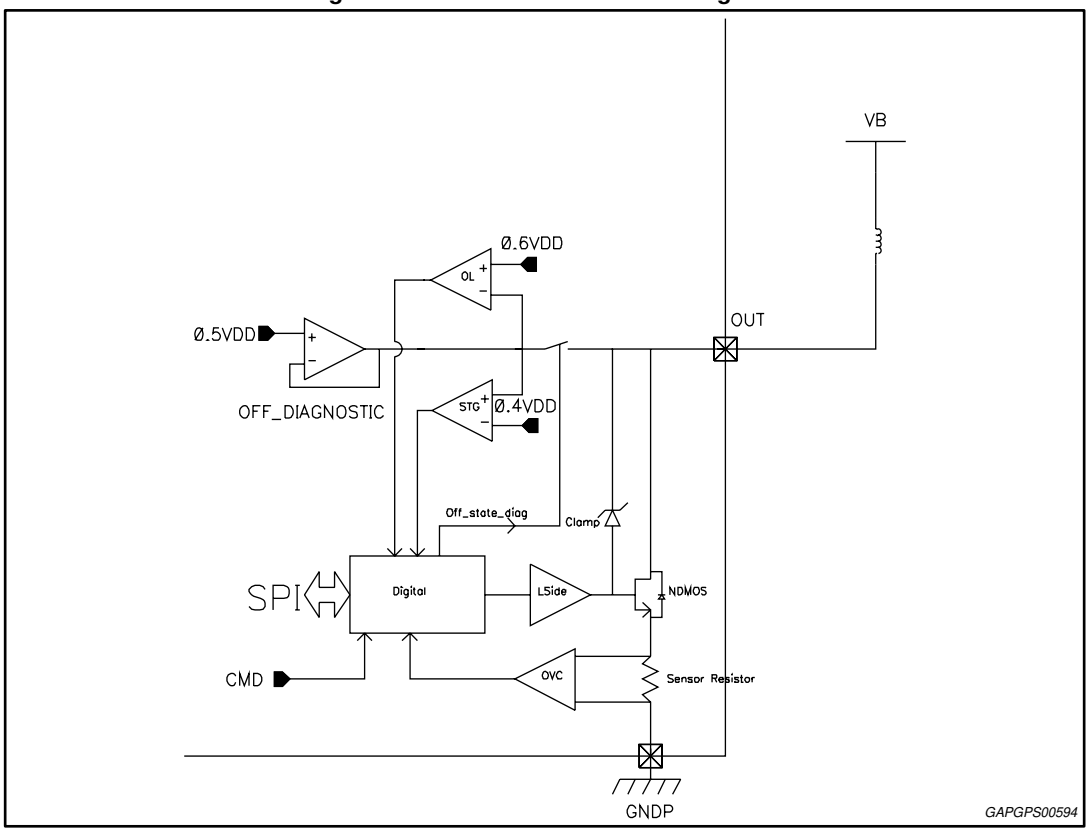
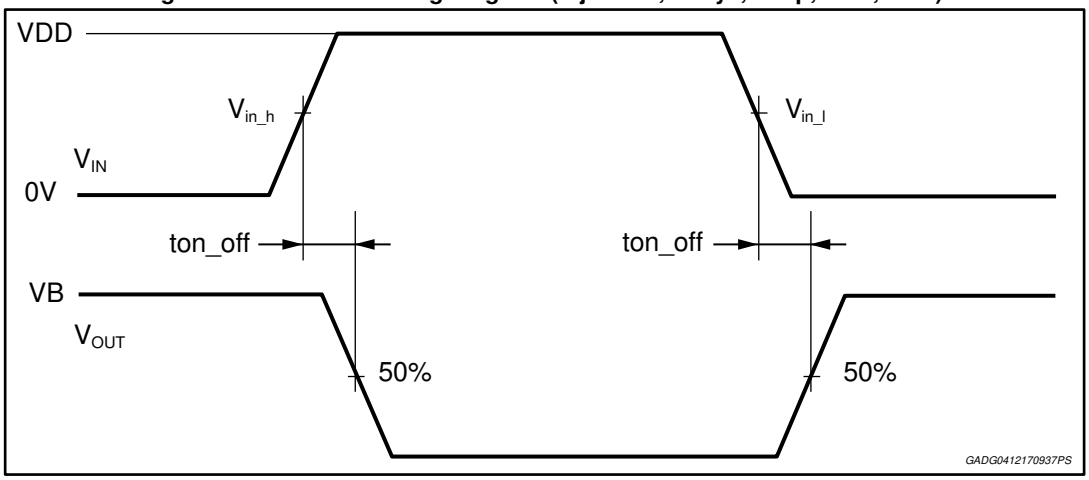


Figure 11: Low-side timing diagram (injectors, relays, lamp, tach, O2H)



3.5.11 Relay drivers

Table 17: Relay driver characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
I_{max}	Output current	-	-	-	1	A
I_oc	Overcurrent threshold	-	1.2	-	2.5	A
V_{DS}	Output clamping voltage	I = 1 A	40	-	50	V
R_{on}	On resistance	I = 1 A	-	-	1.5	Ω
I_{lk_off}	Leakage current	V_{out} = 18 V, diagnosis OFF	-	-	10	µA
I_{lk_on}	Leakage current	V_{out} = 18 V, diagnosis ON	-	-	100	µA
t_{on_off}	Turn on-off delay	From CMD (serial or parallel) rising edge	-	-	6	µs
V_{OL}	Open load output voltage	Driver in OFF condition	0.46*VDD	0.5*VDD	0.54*VDD	V
V_{diagth_H} (1)	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L} (1)	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V

Notes:

(1) $V_{diagth\_L} < V_{out} < V_{diagth\_H}$ → Open Load; $V_{out} < V_{diagth\_L}$ → Short to GND

3.5.12 Lamp driver

Table 18: Lamp driver characteristics

Symbol	Parameter	Condition	Min	Typ	Max	unit
I_{LI}	Linear current limitation	-	2	-	4	A
I_{oc}	Overcurrent threshold	Masked for lamp driver during in-rush	1.2	-	2.4	A
t_{dgmsk}	Diagnosis masking time	Guaranteed by scan	2	-	5	ms
V_{DS}	Output clamping voltage	I = 200 mA	40	-	50	V
R_{on}	On resistance	I = 200 mA	-	-	1.5	Ω
I_{lk_off}	Leakage current	V_{out} = 18 V, diagnosis OFF	-	-	10	µA
I_{lk_on}	Leakage current	V_{out} = 18 V, diagnosis ON	-	-	100	µA
t_{on_off}	Turn on-off delay	From SPI CS rising edge	-	-	6	µs
V_{OL}	Open load output voltage	Driver in OFF condition	0.46*VDD	0.5*VDD	0.54*VDD	V
V_{diagth_H} (1)	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L} (1)	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V

Notes:

(1) $V_{diagth\_L} < V_{out} < V_{diagth\_H}$ → Open Load; $V_{out} < V_{diagth\_L}$ → Short to GND

3.5.13 Tachometer driver

Table 19: Tachometer driver electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
I_{oc}	Overcurrent threshold	-	100	-	500	mA
R_{on}	On resistance	I = 25 mA	-	-	5	Ω
I_{lk_off}	Leakage current	V_{out} = 18 V, diagnosis OFF	-	-	10	µA
I_{lk_on}	Leakage current	V_{out} = 18 V, diagnosis ON	-	-	100	µA
t_{on_off}	Turn on-off delay	From CMD (serial or parallel) rising edge	-	-	6	µs
V_{OL}	Open load output voltage	driver in OFF condition	0.46*VDD	0.5*VDD	0.54*VDD	V
V_{diagth_H} (1)	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L} (1)	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V

Notes:

(1) $V_{diagth\_L} < V_{out} < V_{diagth\_H}$ → Open Load; $V_{out} < V_{diagth\_L}$ → Short to GND

3.5.14 Stepper motor driver

Table 20: Stepper motor driver electrical characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
I_{oc}	Overcurrent threshold	ON condition	0.85	-	2	A
R_{dsON}	On resistance HS+LS	I_{out}= 0.5 A, T_j= 150 °C, V_B= 14 V	-	-	2.6	Ω
$f_{stepper}$	Working frequency	Application note	-	-	20	kHz
V_{out_off} (1)(2)(3)	OUTA_B_C_D output voltage	OUTA short to OUTB; OUTC short to OUTD; Stepper driver disable	0.44*VDD	0.5*VDD	0.54*VDD	V
V_{diagth_H}	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L}	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V
I_{DSS_OUT}	Output leakage current	Driver in OFF condition	-	-	10	µA
t_{scvb}	Over current switch_off time	Guaranteed by scan	-	-	25	µs
t_{rb}	Rise output time	V_B = 12 V, R_l = 39 Ω	-	-	15	µs
t_{fb}	Fall output time	V_B = 12 V, R_l = 39 Ω	-	-	15	µs
$t_{rb\text{-}a}$	Rise output time	T_{amb} = 25 °C, V_B = 12 V, R_l = 39 Ω	-	-	10	µs
$t_{fb\text{-}a}$	Fall output time		-	-	10	µs
t_{pHLb}	Turn-off in/out delay time	V_B = 12 V, R_l = 39 Ω	-	-	15	µs
t_{pLHb}	Turn-off in/out delay time		-	-	15	µs
$V_{reverse\_HS}$	Reverse HS diode drop	Driver in OFF condition $I_{injected}$= 0.5 A	-	-	1.5	V

Symbol	Parameter	Condition	Min	Typ	Max	Unit
$V_{reverse\_LS}$	Reverse LS diode drop	Driver in OFF condition $I_{Sourced}$ = 0.5 A	-	-	-1.5	V

Notes:

(1)VoutA < Vdiagth_H and VoutB > Vdiagth_Lor VoutC < Vdiagth_H and VoutD > Vdiagth_L → No Fault

(2)VoutA_B_C_D <Vdiagth_L → Short to GND

(3)VoutA >Vdiagth_H and VoutB < Vdiagth_L or VoutC > Vdiagth_H and VoutD < Vdiagth_L → Open load VoutA_B_C_D > Vdiagth_H → Short to Battery

Figure 12: Stepper motor driver block diagram

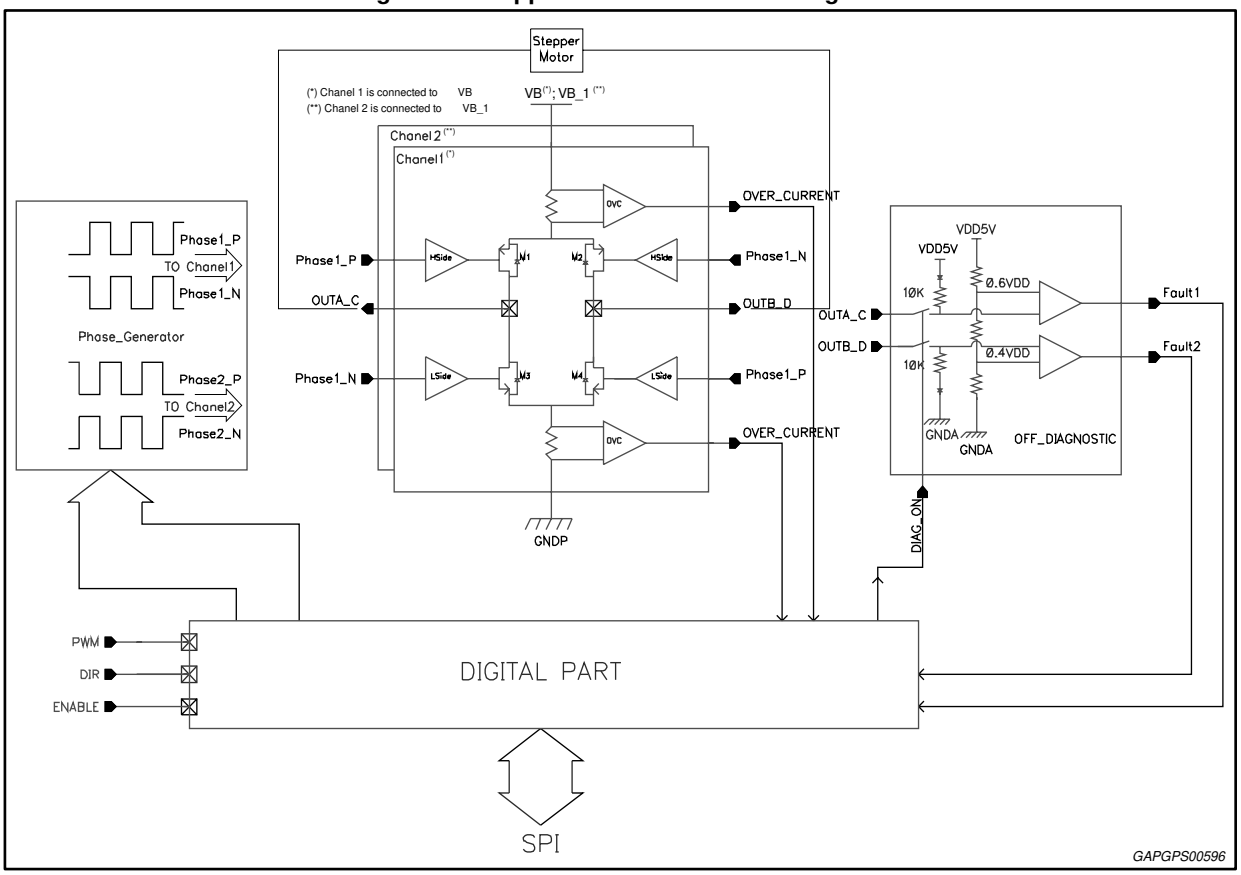
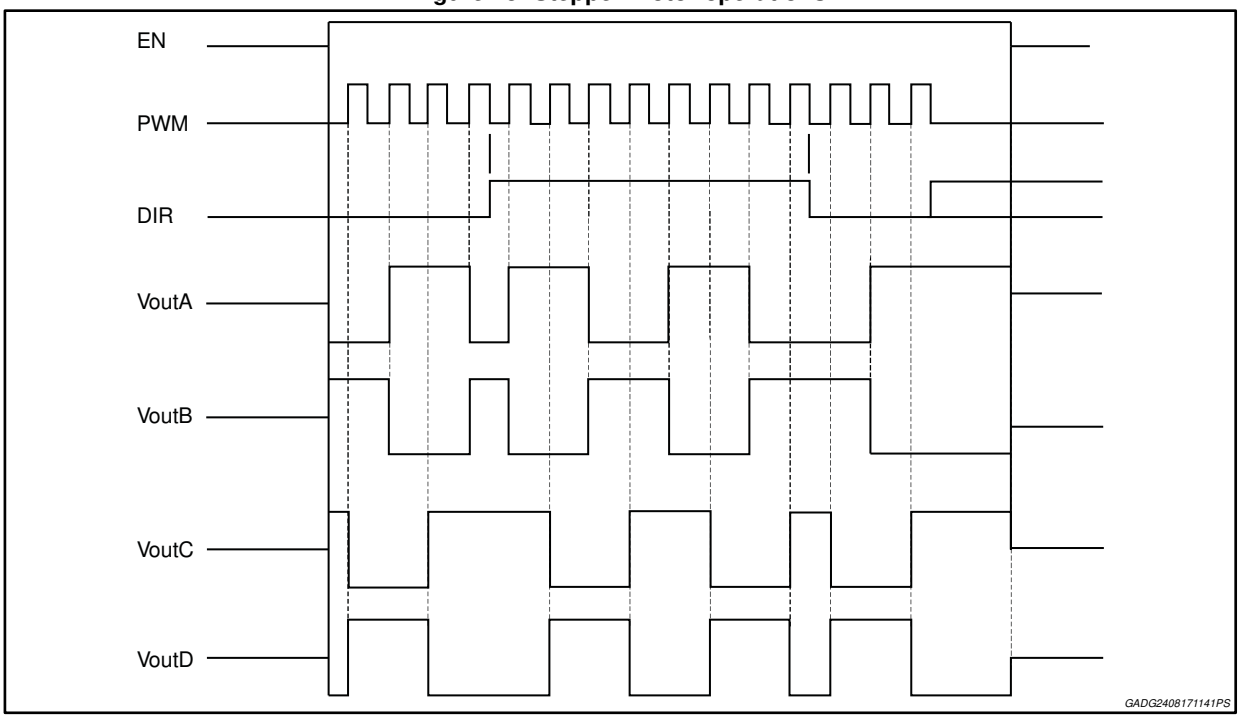


Figure 13: Stepper motor operations



3.5.15 O2 sensor heater driver

Table 21: O2 sensor heater driver characteristics

Symbol	Parameter	Condition	Min	Typ	Max	Unit
R_{dsON}	On resistance	I_{out}= 3 A	-	-	0.5	Ω
V_C	Output clamping voltage	I_{out}= 3 A	40	-	50	V
I_{lk_off}	Leakage current	V_{out}= 18 V, diagnosis OFF	-	-	10	µA
I_{lk_on}	Leakage current	V_{out}= 18 V, diagnosis ON	-	-	100	µA
t_{on_off}	Turn on-off delay	From CMD (serial or parallel) rising edge	-	-	6	µs
V_{OL}	Open load output voltage	Driver in OFF condition	0.46*VDD	0.5*VDD	0.54*VDD	V
I_{OC}	Overcurrent threshold		3.8	-	5	A
V_{diagth_H} (1)	Diagnostic high threshold	Driver in OFF condition	0.54*VDD	0.6*VDD	0.66*VDD	V
V_{diagth_L} (1)	Diagnostic low threshold	Driver in OFF condition	0.36*VDD	0.4*VDD	0.44*VDD	V

Notes:

(1) $V_{diagth\_L} < V_{out} < V_{diagth\_H}$ → Open Load; $V_{out} < V_{diagth\_L}$ → Short to GND