

Solutions for Low Power Motor Control

Liu Ting-Jun

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Motor control applications

Low power

Home & professional




Power tools, gardening tools, commercial multicopters, cordless home appliance, cordless vacuum cleaners, healthcare equipment

Consumer robotics




Consumer multicopters, vacuum robots, RC toys, service robotics, household robotics and other consumer robots

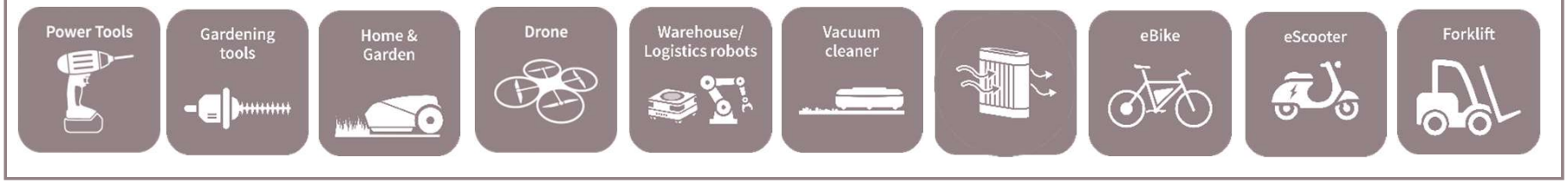
High power

Light electric vehicle



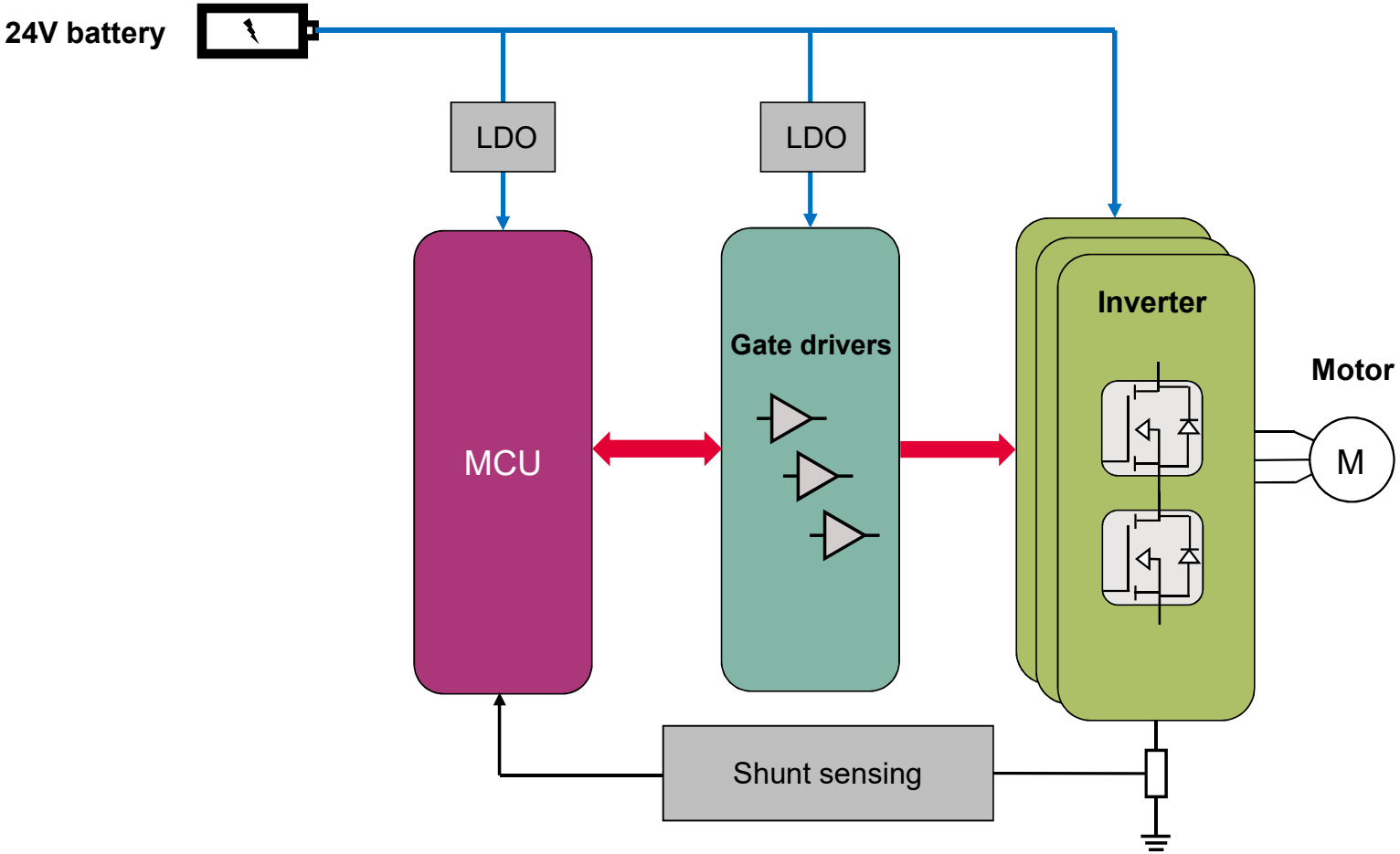

eScooter, eBike, electric wheelchair, electric forklift, low speed cars (LSEV), electric motorcycle, other battery vehicles

Home & Professional	Home Appliances	eAviation	Robotics	Light Electric Vehicles
• Cordless Power Tools • Cordless Gardening Tools	• Cordless Vacuum Cleaner	• LEA (<200V) • Multicopter (unmaned)	• Service Robots • Industrial Robots	• Electric 2 wheelers (e-bike, e-scooter, e-kickscooter, pedelec) • Electric 3/4 wheelers (LSEV, e-microcars, e-golf cart, e-rickshaw) • Light Electric Forklift (<200V)



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Motor drive system overview



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Infineon 3-phase Smart Gate Driver Overview

A gate driver that supports battery voltages from 12 to 48V.
Able to configure a wide set of parameters from PWM to braking modes

Fully configurable smart gate driver
- Brushless DC motor (BLDC)
- Permanent magnet synchronous motor (PMSM)



Designed to operate with microcontroller
- Infineon XMC1400
- IMD701A

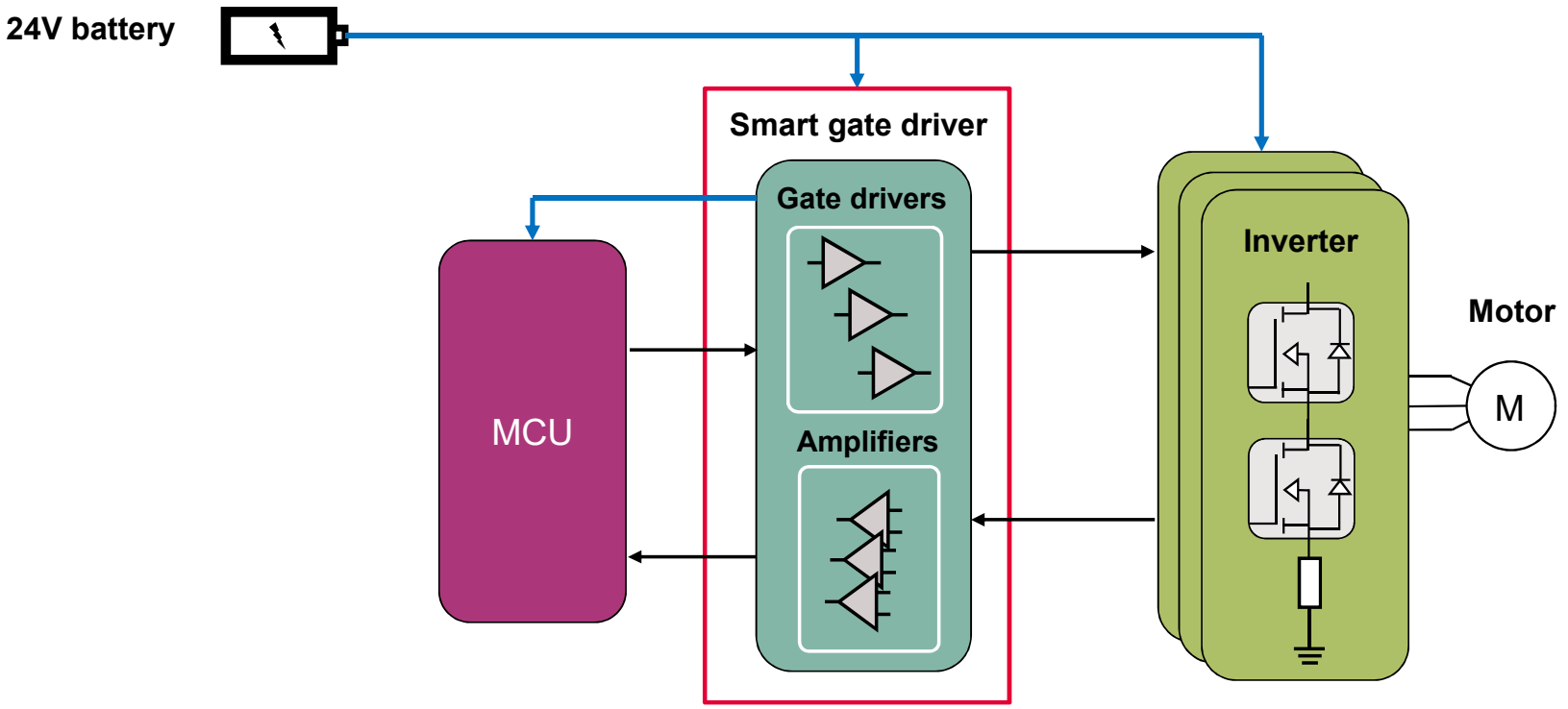
48-pin VQFN 7x7 package with all function integrated

Exposed thermal pad on bottom side allows better heat dissipation

Support **block commutation** and **FOC**

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6EDL7141 Motor drive system



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Key features of 6EDL7141

Key features

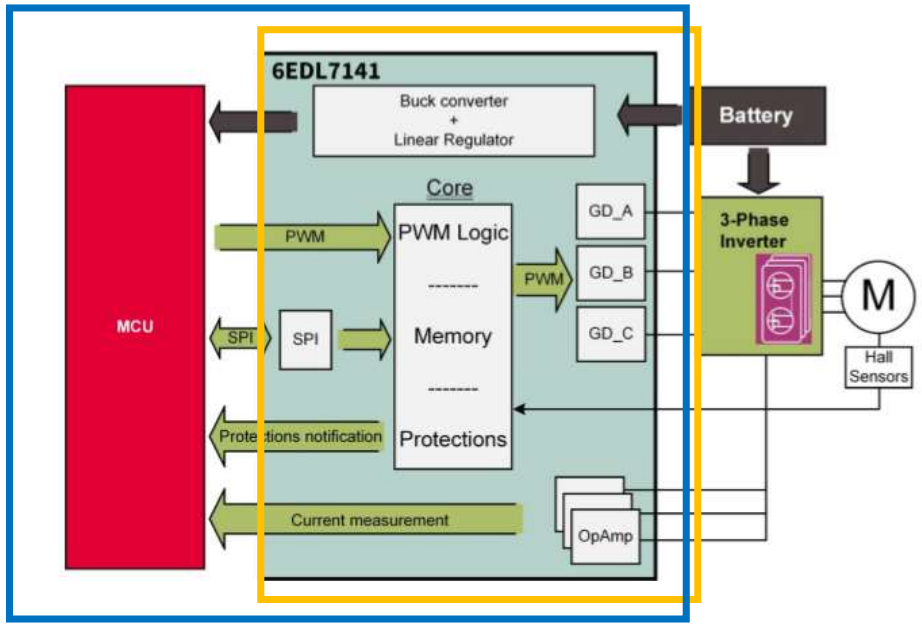
Integration:

- 5.5V~60V operating supply voltage with dual charge pumps
- High efficiency synchronous buck converter (up to 600mA)
- Linear regulator LDO (up to 300mA) capable for MCU and other auxiliary supplies
- Multiple integrated protections
- 3 current sense amplifier with adjustable gain and offset

Programmability:

- More than 50 configurable parameters
  - Buck converter and LDO outputs
  - Inverter slew rate, dead time
  - PWM and motor braking modes
- Communicate with MCU via SPI interface
- Configuration easily done through Infineon GUI tool

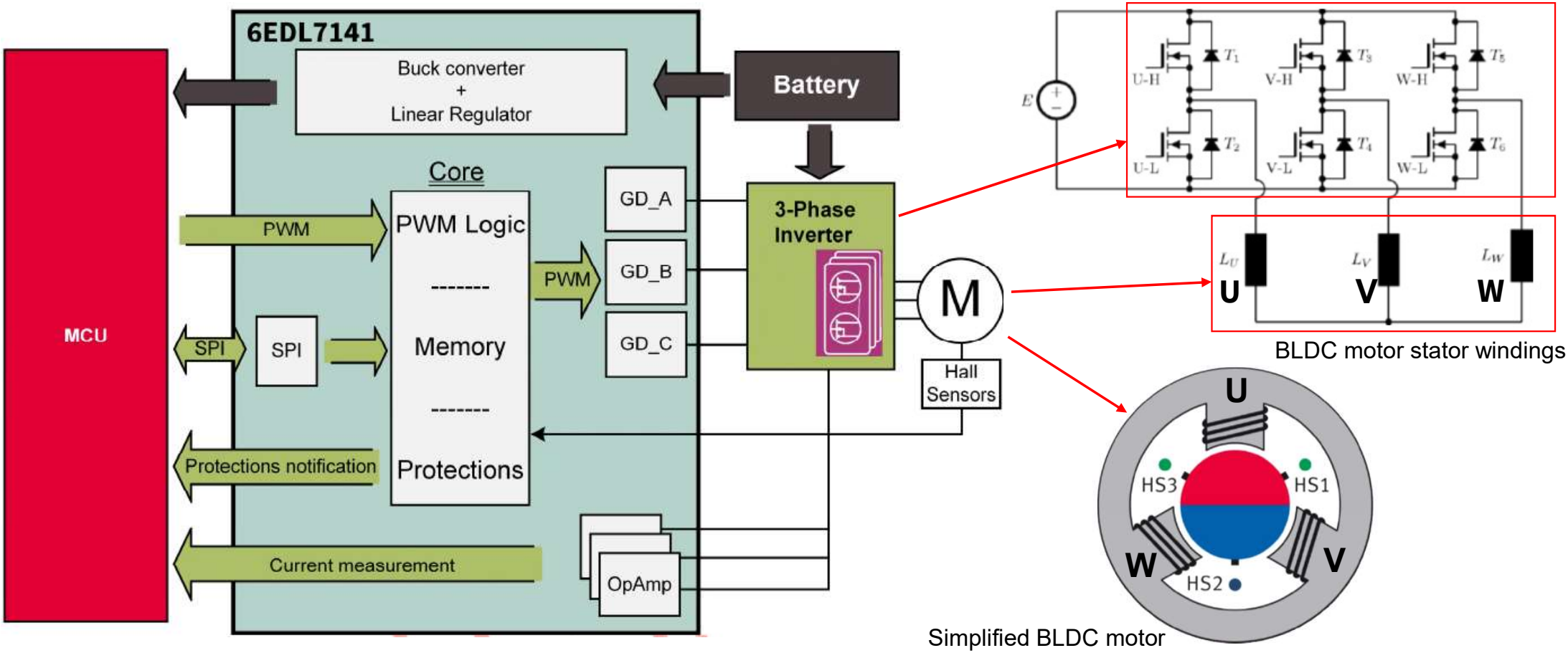
Application Schematic



IMD701A 6EDL7141

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6EDL7141 system overview



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6EDL7141 competitive advantage

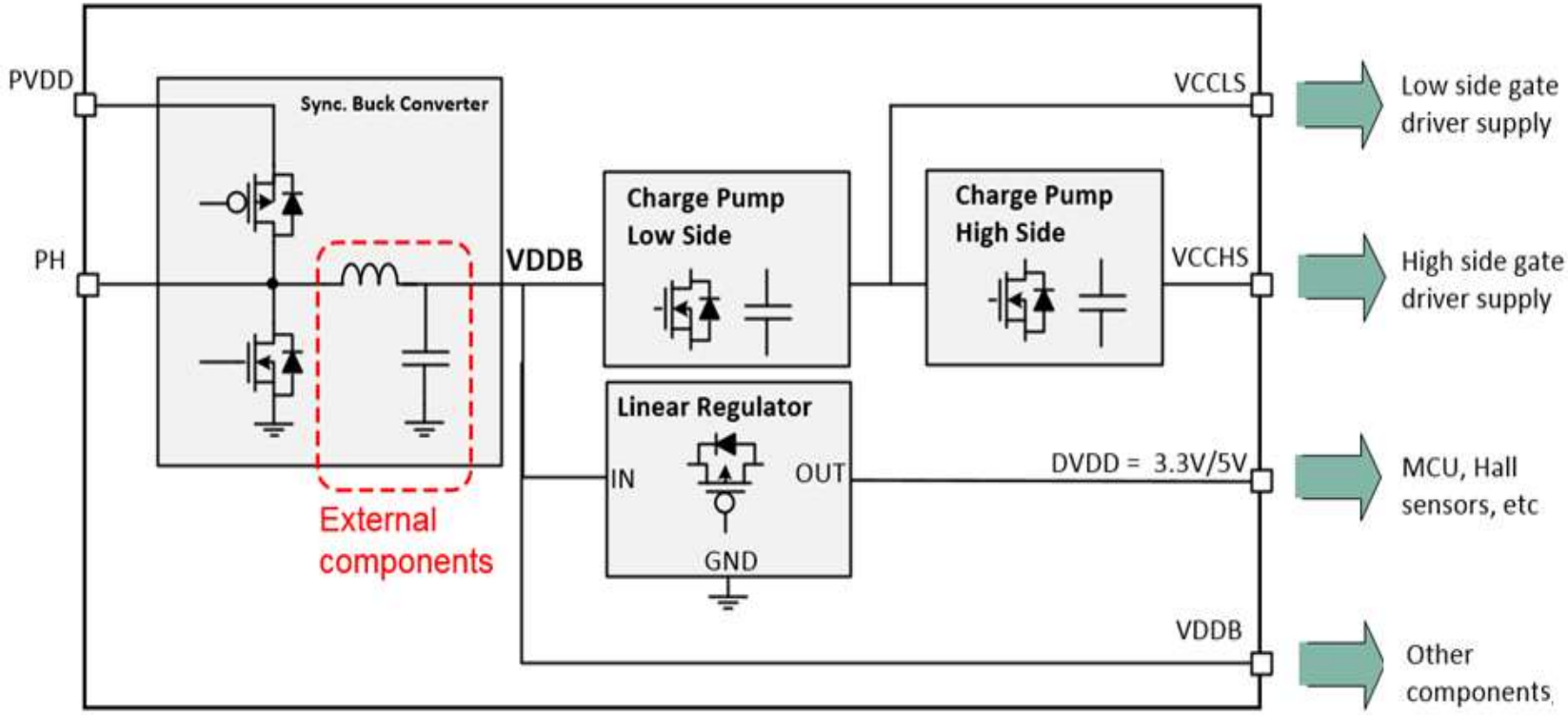
Value Drives	Competitive Advantage	System Value
Integrated Power Supply	• 600mA synchronous Buck, 300mA LDO and charge pump • Programmable frequency	• Reduce Component Count (FET, Diode, LDO IC, bootstrap diode) • EMI improvement
Programmable Gate Drive	• Three-stage gate driving • Slew rate control	• Reduce deadtime and improve efficiency • EMI improvement
Current Shunt Amplifier	• Higher precision shunt amplifiers	• More accurate current sensing for better FOC performance
Protection Features	• Hardware motor brake mode for fast fault protection	• Fast response to severe faults to protect motor and driver
Programmability	• Higher programmability and flexibility • Parameter update from MCU	• Easier for system optimization • Reduce development cycle time • Firmware update

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6EDL7141 integrated power supply

PVDD=5.5~60V

PVCC= 7/ 10/12/ 15V



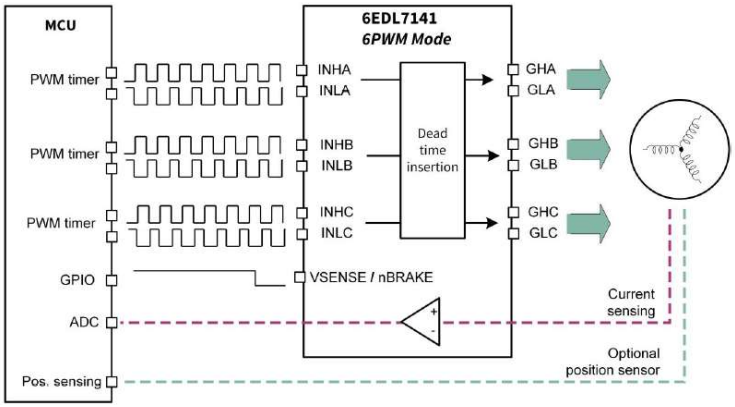
VDDB=6.5/ 7/ 8V

DVDD= 3.3/ 5V

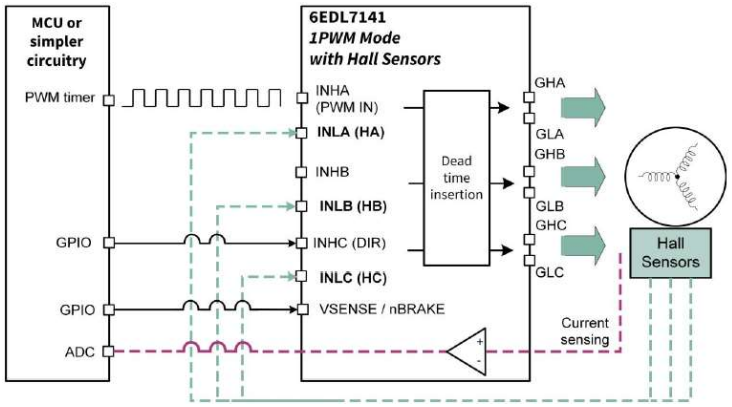
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PWM modes

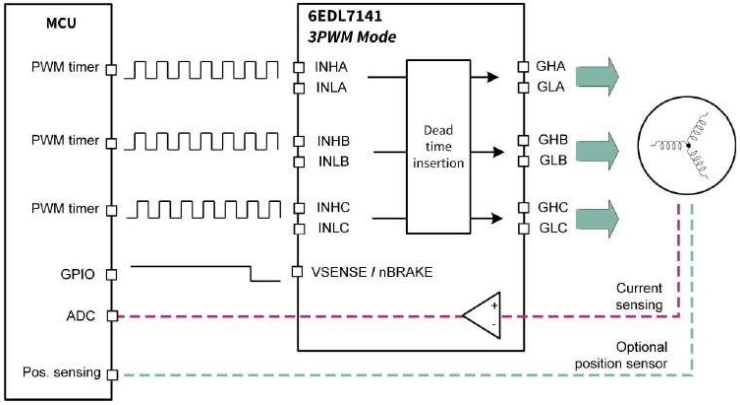
6 PWM



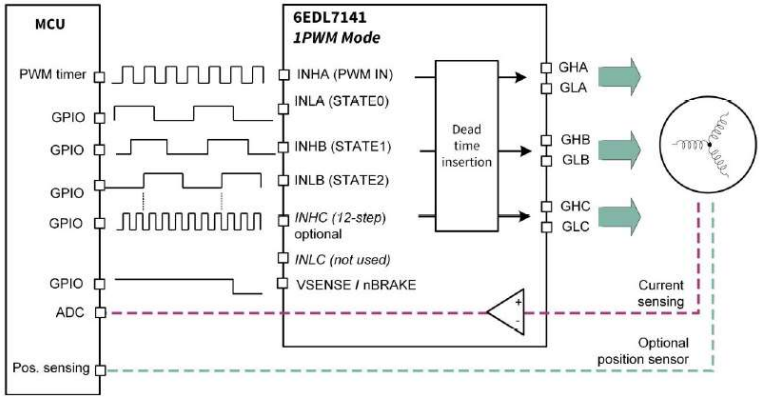
1 PWM with hall sensors



3 PWM



1 PWM without hall sensors



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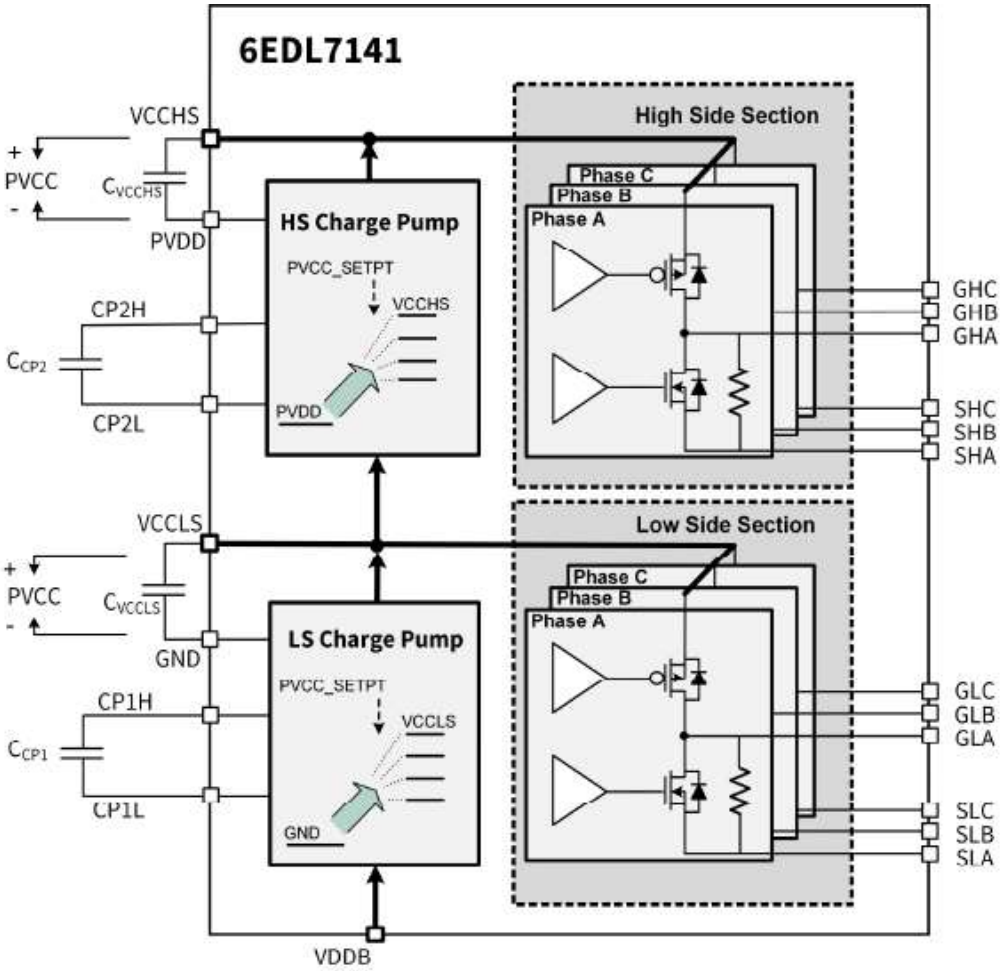
Driver charge pumps

High-side charge pump

- Supplied from the on-board buck regulator
- Provides the high side driver bias supply for all three phases

Low-side charge pump

- Supplied from the on-board buck regulator



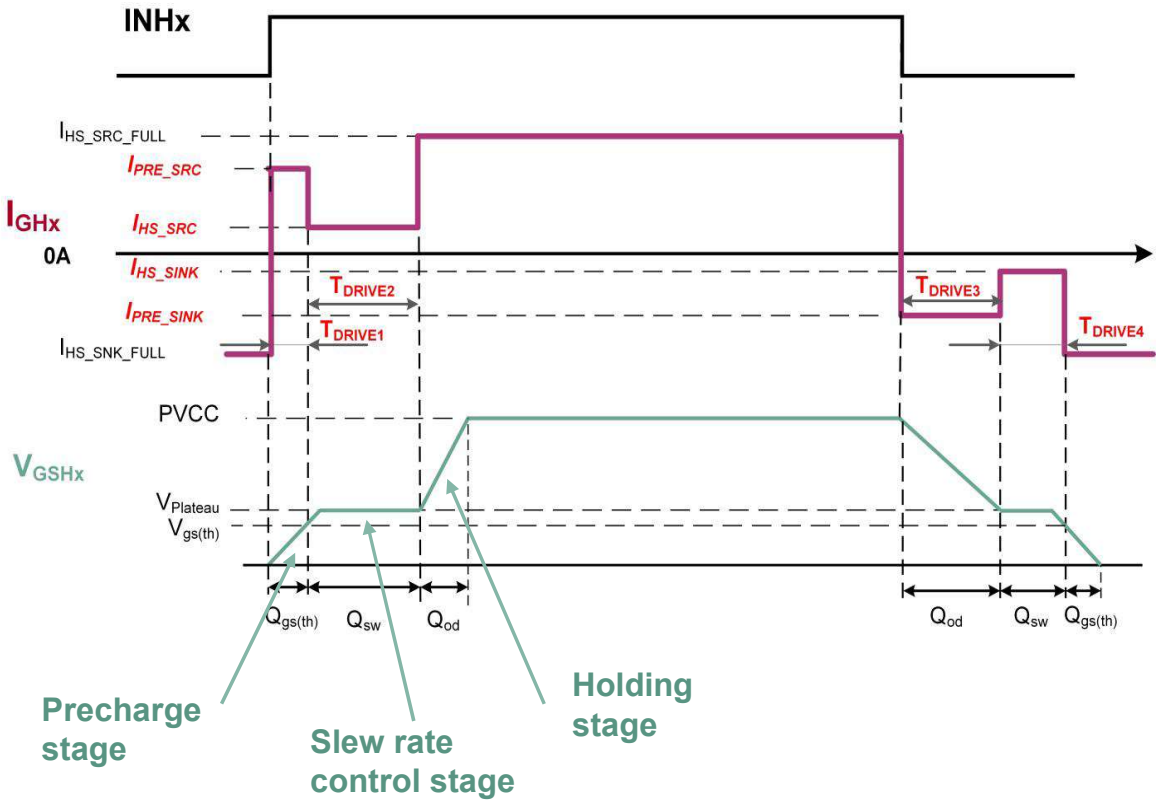
High-side & Low-side Gate drive

- Configurable drive voltage
- Configurable sink/source current up to 1.5A
- 0 to 100% duty cycle range

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Three-phase smart gate driver

- Allow EMI optimization and reduce of component count
  - Configurable gate driver supply: 7V, 10V, 12V, 15V
  - Configurable gate drive slew rate with different current levels and timings



Slew rate control

- Eliminate of diode resistor circuit
- Drive system optimization
- Better EMI performance
- Dead time optimization
- Low switching losses

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Protections



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Braking modes

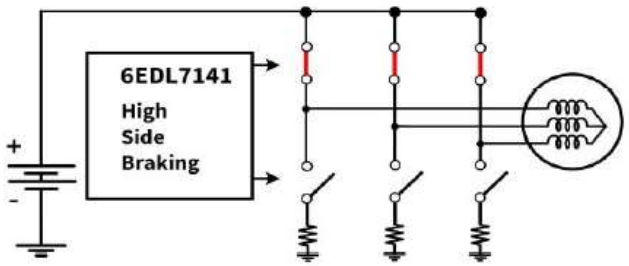
- Braking modes can be selected via the VSENSE/nBRAKE pin.

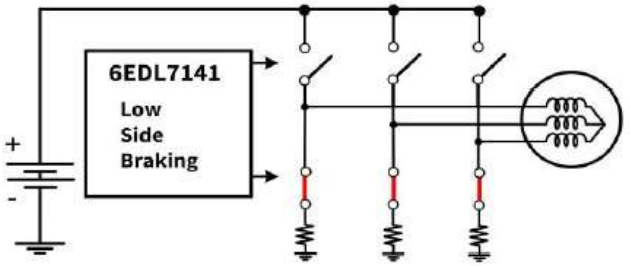
Triggered events:

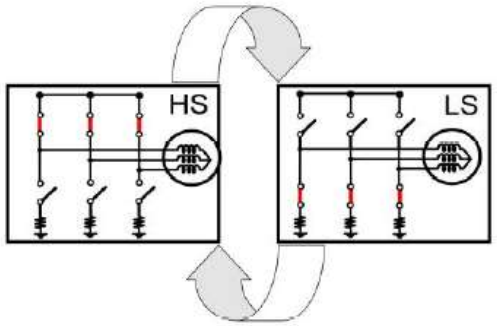
- Device brake pin
- Overcurrent protection
- Watchdog time fault

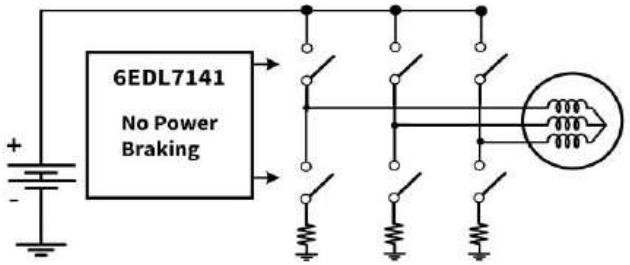
Braking modes:

- High side braking
- Low side braking
- Alternate braking
- High impedance braking



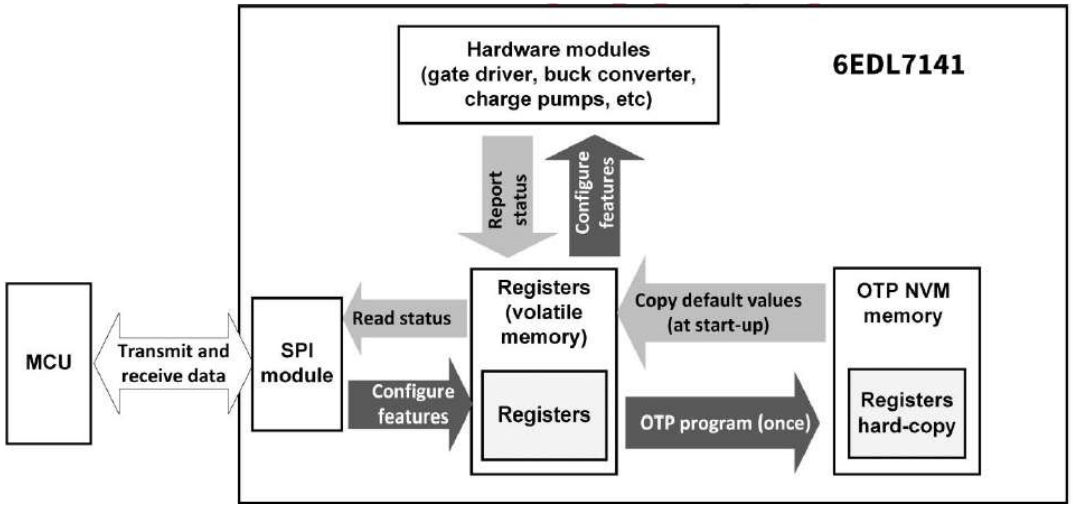






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Programmability

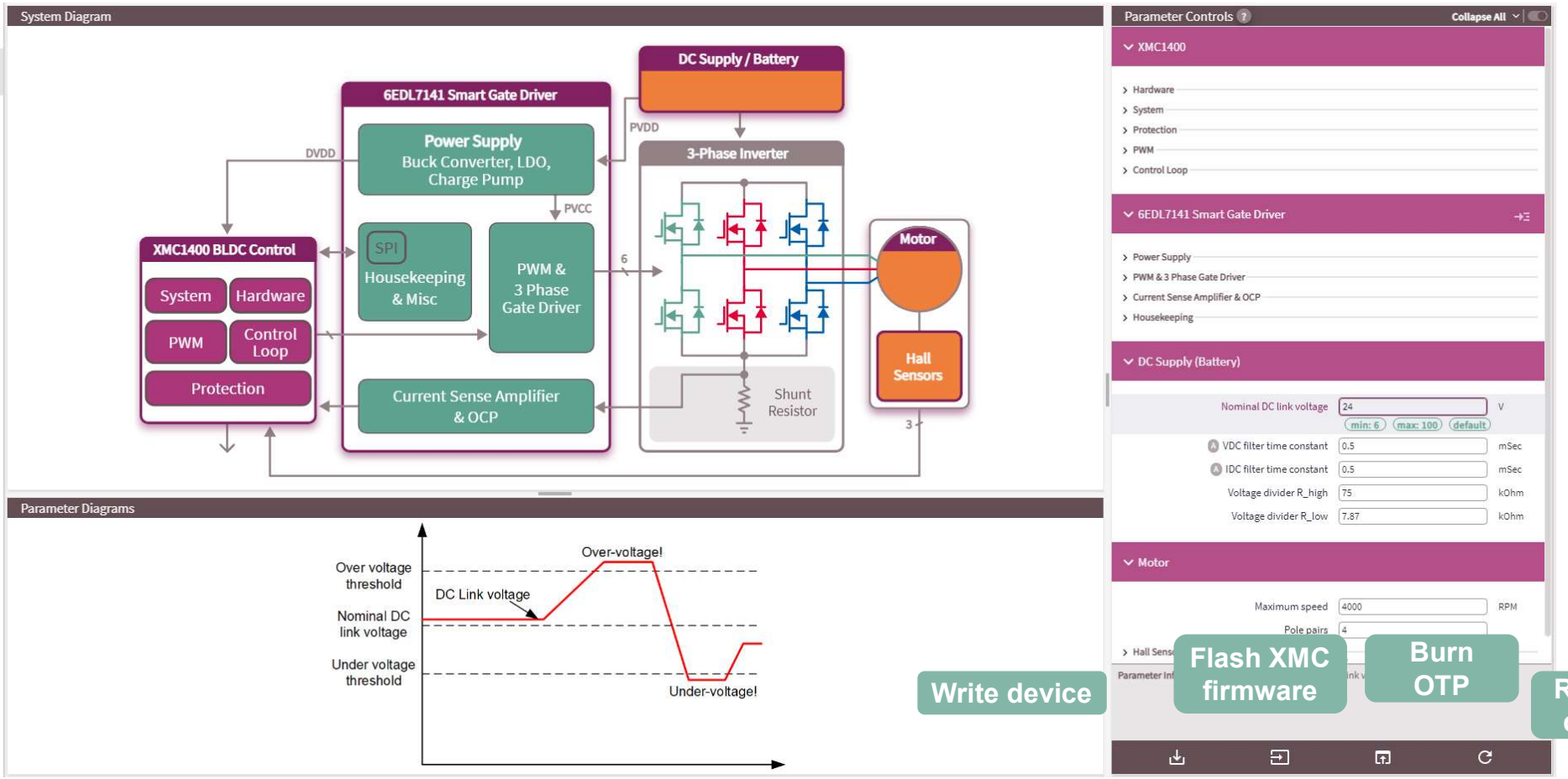


More than 50 control parameters can be configured via 3.3V/5V compatible SPI and stored in the integrated OTP memory

- **PWM modes** (6PWM, 3PWM, 1PWM)
- **Braking modes (HS, LS, alternative, Hi-Z)**
- **Buck converter frequency** (500kHz,1000kHz), **charge pump** (195kHz – 1562kHz)
- **Dead time** (120-12040ns with 80ns step)
- **Driving voltages** (7V, 10V, 12V, 15V)
- **Slew rate control** (50ns to 2550ns with 10ns steps and 16 level 10mA to 500mA current)
- **OpAmp gain** (8 options) and **offset** (4 options)
- **Optional low side Rdson sensing**
- **OCP fault reaction, triggered levels**

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GUI tool – Evaluation board 6EDL7141 + XMC



https://www.infineon.com/dgdl/Infineon-Sensorless_FOC_tuning_guide_for_BPA_motor_control_GUI-ApplicationNotes-v01_00-EN.pdf?fileId=8ac78c8c80027ecd0180a7cc755677b2

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Gate Drivers for Battery Powered Motor Drive Applications

Battery Voltage (up to)	Product	Description	Use-Case
72V	6ED2742 2ED2732/34/38	160V 3-phase SOI gate driver with PMU 160V HS+LS, integrated boot strap diode, separate power and ground	Power & Gardening tools, BLDC motor control, Servo drives
60V	1EDN7550B 1EDN7550U 1EDN8550B	1-ch TDI 4A/8A 8V UVLO, SOT-23 1-ch TDI 4A/8A 4V UVLO, TSNP 1-ch TDI 4A/8A 8V UVLO, SOT-23	Half-bridge with “low-level” MOSFETs Half-bridge with “low-level” MOSFETs, small outline Half-bridge with “normal level” MOSFETs
48V	TLE9140EQW	3-phase integrated gate driver, ISO26262 compliant	e-Scooter, e-Bike
36V	6EDL7141	Integrated, Configurable, Smart gate driver	Power & Gardening tools, Robotics, Drones, eBike



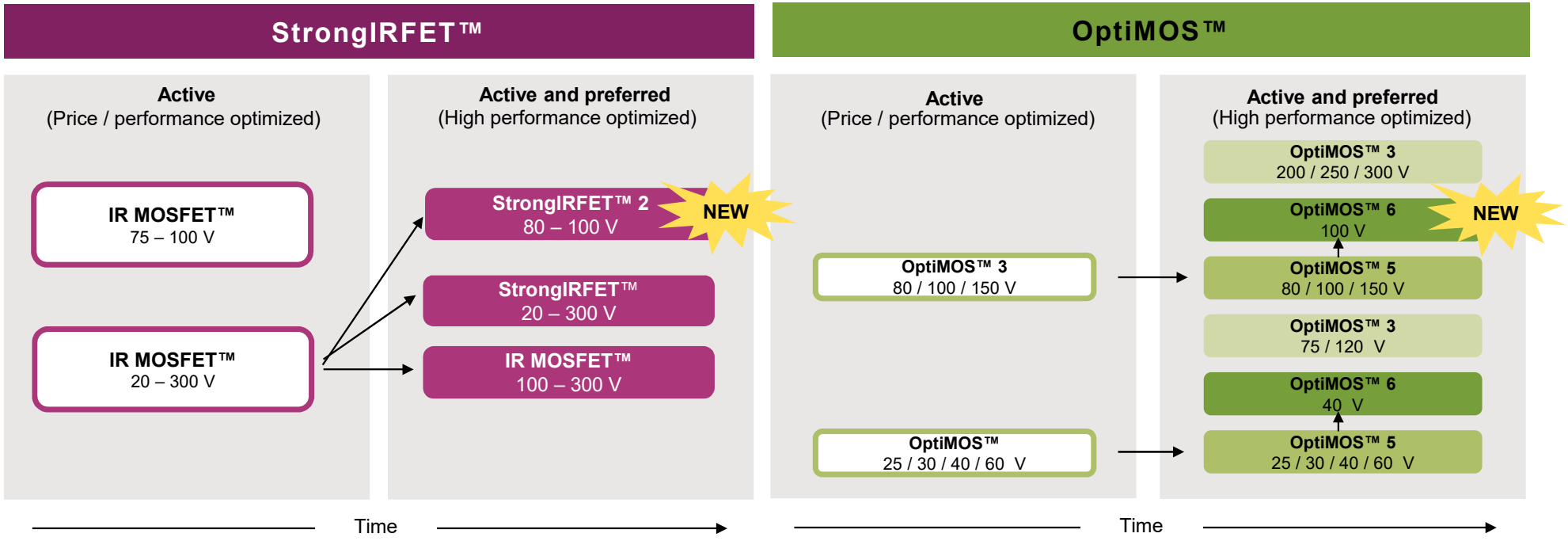




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OptiMOS™ and StrongIRFET™

20-300 V N-channel power MOSFETs



StrongIRFET™

Robust and excellent price/performance ratio

Right fit products for a broad range of application

Easy of design and flexible use

OptiMOS™

Best-in-class technology

Designed for high performance applications

Industry´s best figure of merit

High efficiency, power density and current capability

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Infineon's Dual MOSFETs for low power motor

OptiMOS™ 25 V / 30 V Symmetrical and Asymmetrical Dual N-Channel MOSFETs in 5x6 and 3x3 PQFN							
Integrates the low side and high side MOSFET of a synchronous DC-DC converter into a single package. The small outline and the interconnection of the two MOSFETs within the package minimize the loop inductance which boosts efficiency.							
Part number	Package	Monolithically integrated Schottky like diode	BV_{DSS} [V]	$R_{DS(on),max.}$ [mΩ] @ V_{GS}=4.5 V max.		Q_g [nC] @ V_{GS}=4.5 V typ.	
				High-side	Low-side	High-side	Low-side
BSC0910NDI*	Asymmetrical Dual 5 x 6	✓	25	5.9	1.6	7.7	25
BSC0911ND*	Asymmetrical Dual 5 x 6	–	25	4.8	1.7	7.7	25
BSC0921NDI*	Asymmetrical Dual 5 x 6	✓	30	7	2.1	5.8	21
BSC0923NDI*	Asymmetrical Dual 5 x 6	✓	30	7	3.7	5.2	12.2
BSC0924NDI*	Asymmetrical Dual 5 x 6	✓	30	7	5.2	5.2	8.6
BSZ0910ND*	Symmetrical Dual 3 x 3	–	30	13	13	4	4
BSZ0909ND*	Symmetrical Dual 3 x 3	–	30	25	25	1.8	1.8
BSC0925ND*	Symmetrical Dual 5 x 6	–	30	6.4	6.4	5.2	6.7
BSC0993ND*	Symmetrical Dual 5 x 6	–	30	7	7	5.4	6.7

OptiMOS™ / StrongIRFET ™ 30 V - 100 V Dual N-Channel MOSFETs							
Integrates two independent N-channel MOSFETs into a single package for high power density and compact design. Ideal for DC motors with power rating <200W							
Part number	Package	Monolithically integrated Schottky like diode	BV_{DSS} [V]	$R_{DS(on),max.}$ [mΩ] @ V_{GS}=10 V max.		Q_g [nC] @ V_{GS}=10 V typ.	
				High-side	Low-side	High-side	Low-side
IRL6297SDTRPBF	Symmetrical Dual DirectFET™	–	20	3.8**	3.8**	54	54
IRLHS6276	Symmetrical Dual PQFN 2 x 2	–	20	45**	45**	3.1**	3.1**
IRF7907	Asymmetrical Dual SO-8	–	30	16.4	11.8	6.7**	14**
IRF7905TRPBF	Asymmetrical Dual SO-8	–	30	21.8	17.1	4.6**	6.9**
IRLHS6376TRPBF	Symmetrical Dual PQFN 2 x 2	–	30	63**	63**	2.8**	2.8**
IRF40H233	Symmetrical Dual 5 x 6	–	40	6.2	6.2	45	45
BSC072N04LD*	Symmetrical Dual 5 x 6	–	40	7.2	7.2	39	39
BSC076N04ND	Symmetrical Dual 5 x 6	–	40	7.6	7.6	28	28
BSC112N06LD*	Symmetrical Dual 5 x 6	–	60	11.2	11.2	41	41
BSC155N06ND	Symmetrical Dual 5 x 6	–	60	15.5	15.5	21	21
IRF7351	Symmetrical Dual SO-8	–	60	17.8	17.8	24	24
BSO615NG	Symmetrical Dual SO-8	–	60	150	150	14	14

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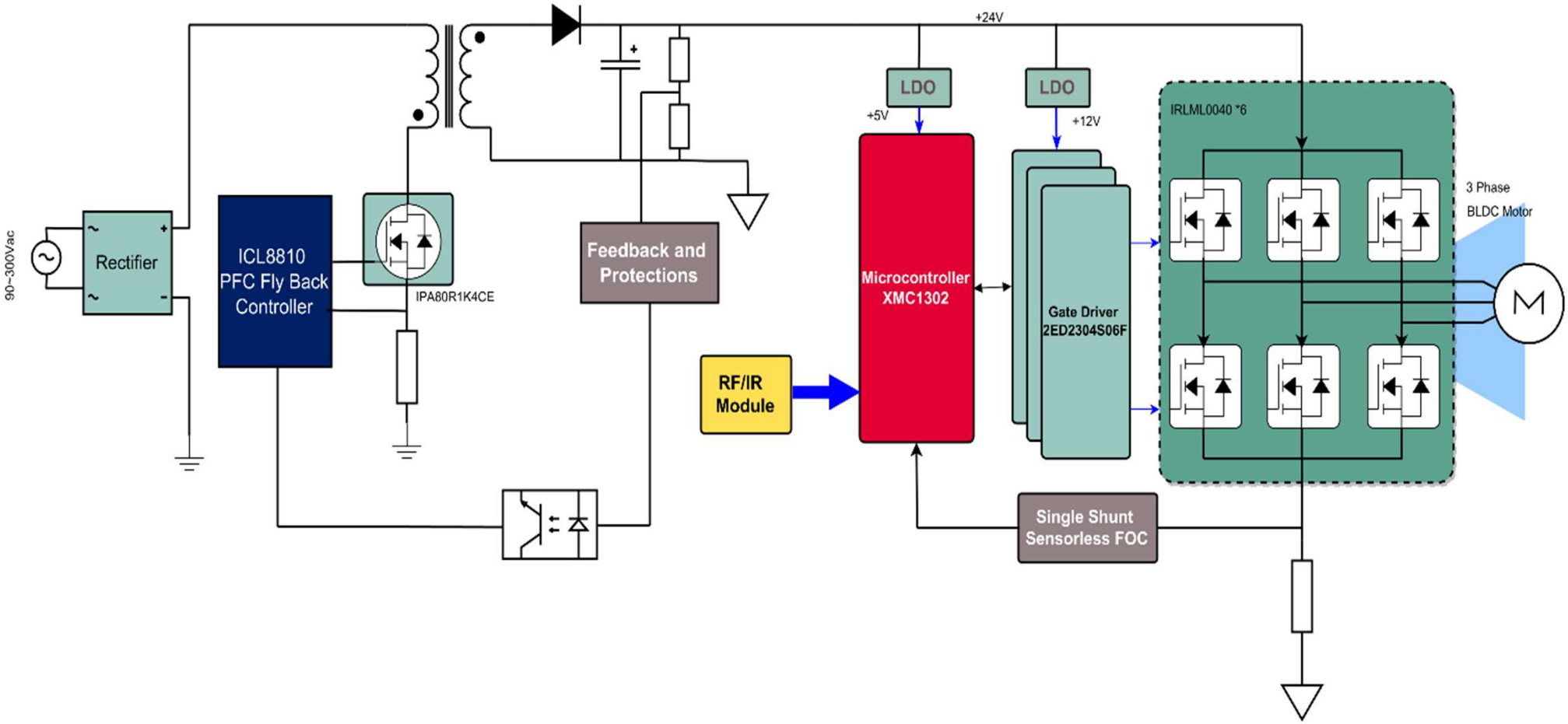
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System block diagram



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Bill of Material

Flyback PFC Section

Flyback PFC (90~300Vac)			
	Part number	**Comments**	**Quantity**
Protection and EMI	39216300000	LittleFuse 5A 350V	1
		Elcompo, Drum core,700uH, DR8x10	1
	V385LA20APW	Littlefuse, MOV VDR 385VAC 0.6W	1
	B32922C3224K000 B32921C3104M003	X2 cap 220nF/305Vac 0.1uF/305Vav	1
		CMC 39mH UU10	1
Rectifer bridge	KBP210G	Diodes, 1kV, 2A, TO	1
PFC capacitor	PCMP 489F62154	0.15uF, 630Vdc	1
PFC IC	**ICL8810**	Single stage flyback IC	1
Vin rectifier diode	1N4007	TMSC, 1kV,1A	2
HV startup	Start up resistor	Resistor	3
PFC MOS	**IPA80R1K4CE**	800V, 1.4Ω, TO220	1
PFC Diode	MBRF20200CT	200V, 20A Schottky Barrier Rectifier	1
Transformer	PQ2620 (N95)	Customised Transformer	1
RCD clamp	RDER73A222K2M1H03A	2.2nF/630V	1
	SMD Resistor 1206 package	Resistor	2
	RS1MB-13-F	Fast Recovery Rectifier, 1A	1
Output Capacitors		Wurth Electronik, 35V, 1500uF	2

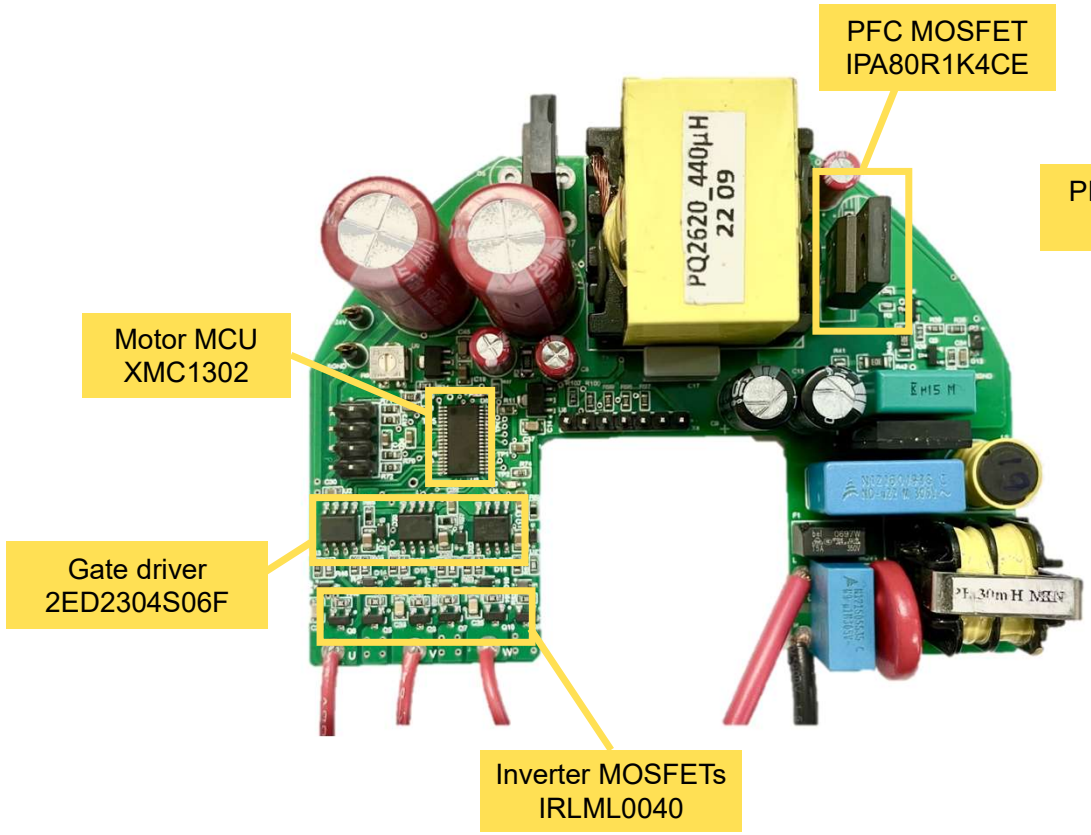
Inverter Section

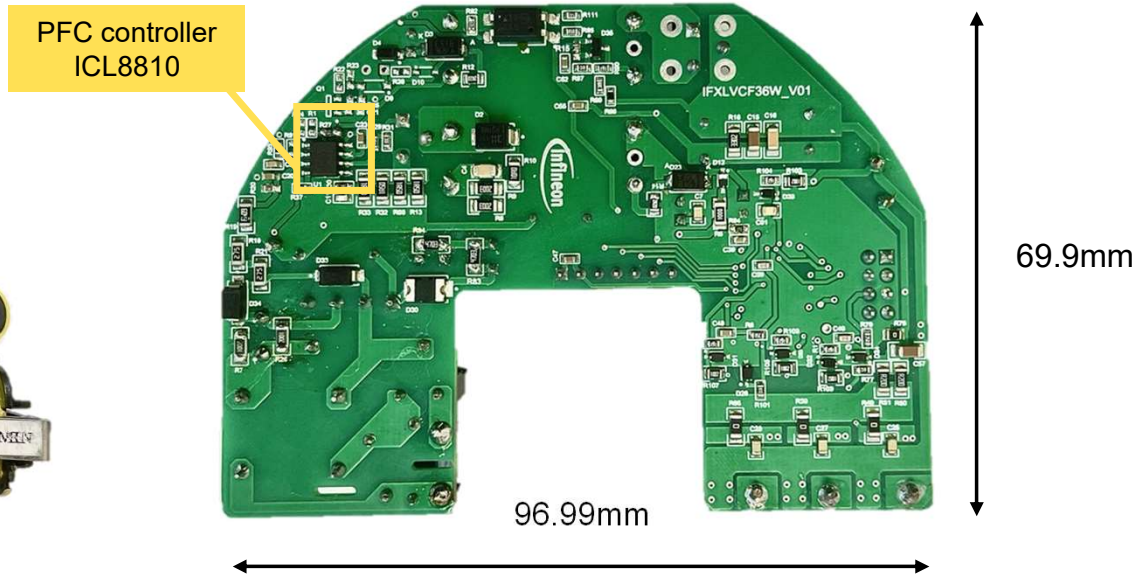
24V BLDC motor drive			
	Part number	**Comments**	**Quantity**
Motor IC	**XMC1302-T038X0200**	32bit controller, TSSOP38 pack., 200KB flash	1
Gate driver	**2ED2304S06F**	650V, Half-bridge	3
Motor Mos	**IRLML0040**	Single N, 40V, 56mΩ, SOT23	6
Auxiliary power	L78L05	Onsemi 5V, 0.1A	1
	L78L12	Onsemi 12V, 0.1A	1

5V Remote control			
	Part number	**Comments**	**Quantity**
RF remote	RX480E	Qiachip 4channels 433MHz RF receiver module	1
IR remote	IRM-3640T	Everlight IR receiver module	1

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Board structure & key components





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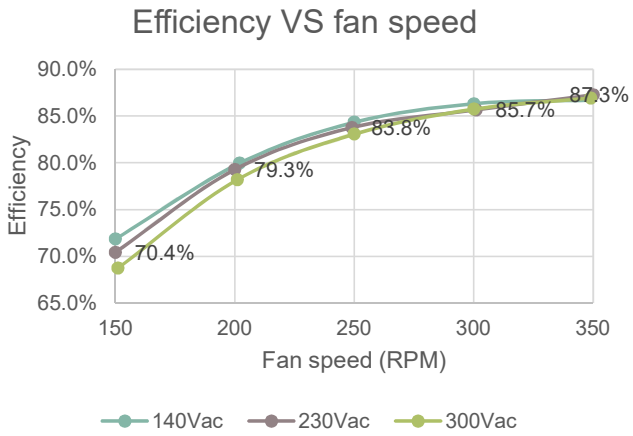
Features and functions integrated

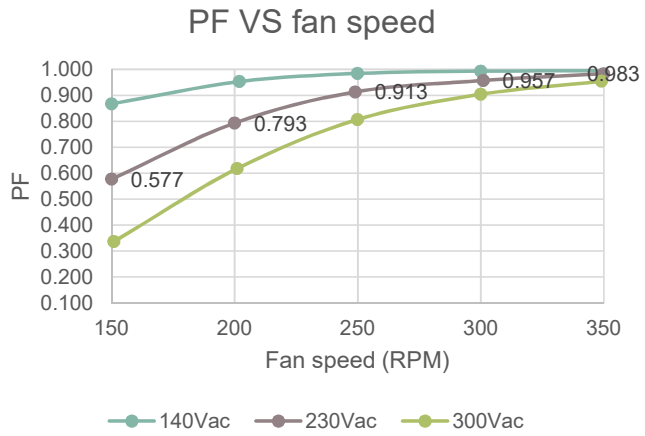
- High performance solution
  - >86% efficiency
  - >0.98 power factor
  - <5% iTHD
- Passing 4kV lightning surge test
- Robust motor dynamic response
  - 10 seconds to reach full speed
- Stall detection/ rotor locked detection for safety purpose
- Catch free run to ensure smooth motor start-up
- Auto-restart function once fault is cleared
- Last speed memory available
- Sleep-mode available for better power saving
- Provision of both RF and IR remote control
- Configurable discrete solutions as per requirements
  - Duration for stall checking
  - Auto-restarting attempts
  - Waiting time before entering sleep-mode
  - Speed levels

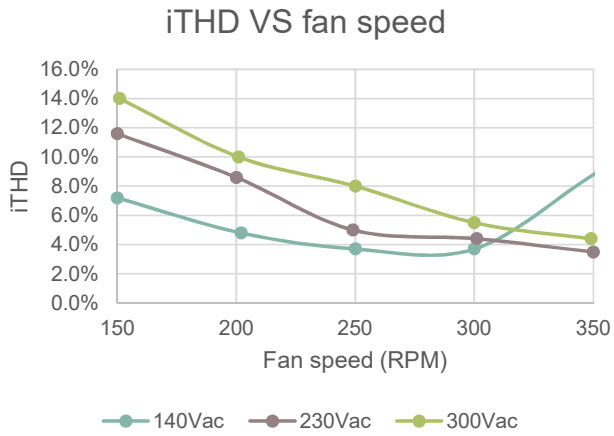
Functions	Description
Brown in	91.5 Vac
Brown out	64.5 Vac
PFC input OVP	336 Vac
PFC output OVP	35 Vdc
PFC primary OCP	3.36 A
Motor DC link UVLO	18 Vdc
Motor DC link OVP	28.4 Vdc
Motor SW OCP	4.15 A
Motor HW OCP	4.6 A
★ Stall detection	Yes, 1 s checking
Catch free run	Yes, resume from free wheeling speed
★ Fault monitoring auto-restart	Yes, once fault is cleared, system auto-restart, 3 times checking
★ Sleep mode standby	Yes, after 15 s, 0.7 W standby power at 230 Vac
Remote control available	Yes, support both radio frequency and infrared

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System performance







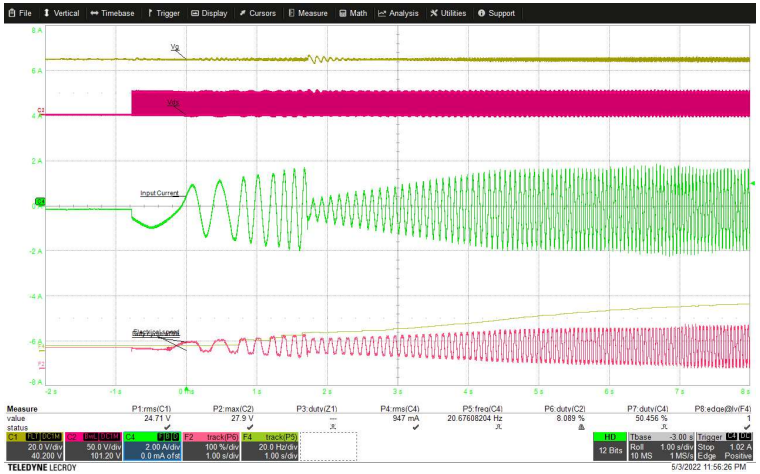
At 230 Vac input	
Efficiency	87.3%
Power factor	0.98
iTHD	3.5%
Standby power	0.7W
Max speed input power	37.2W

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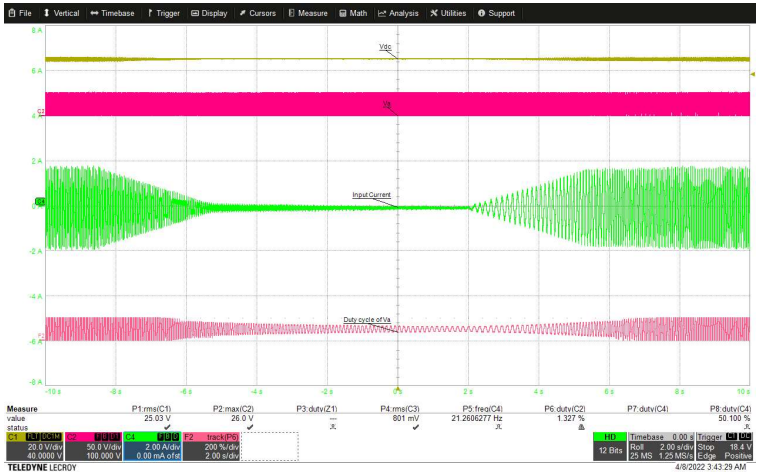
Motor dynamic response

Vdc Phase voltage Va Phase current Duty cycle of Va

Max speed startup



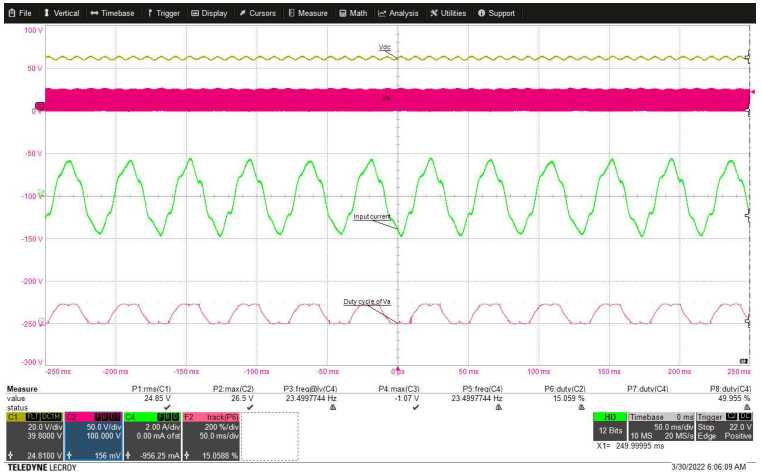
Restart at low speed



Max speed stop



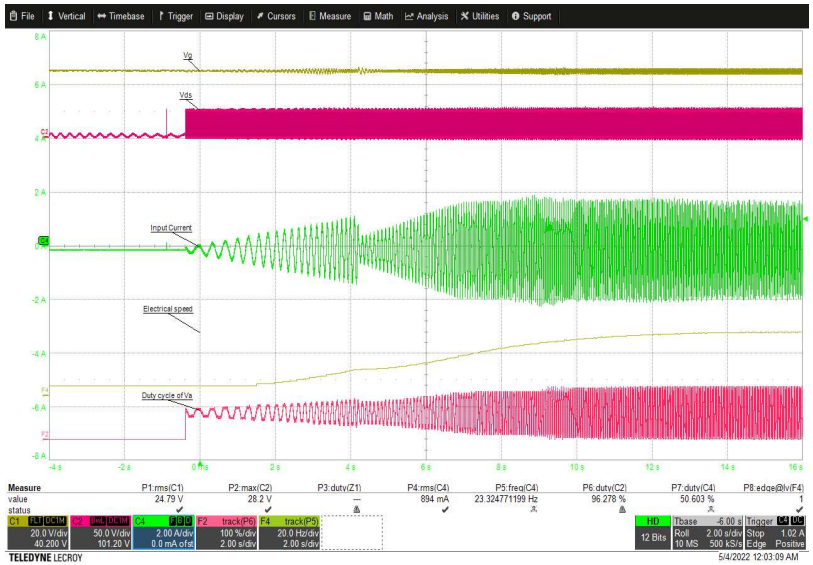
Max speed current (trapezoidal motor)



Test condition: 4 pole-pair trapezoidal bemf motor, max speed 350 RPM, 5 speed levels

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Additional functions





Catch free run

- Motor is able to resume spinning from certain speed due to external forces
- Guarantee smooth transient and startup

Stall detection with auto restart

- Motor lock detection is integrated for safety purpose
- System auto-restarts for a few times as designed, if fault continues to present, system stops retrying.

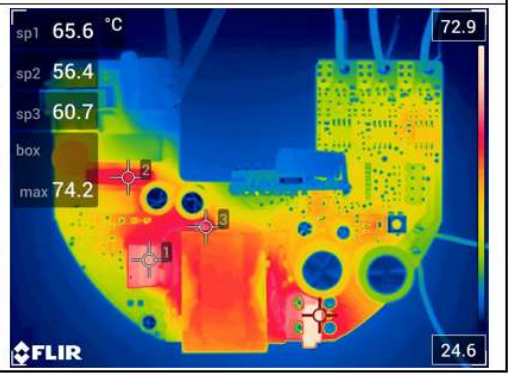
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Thermal performance

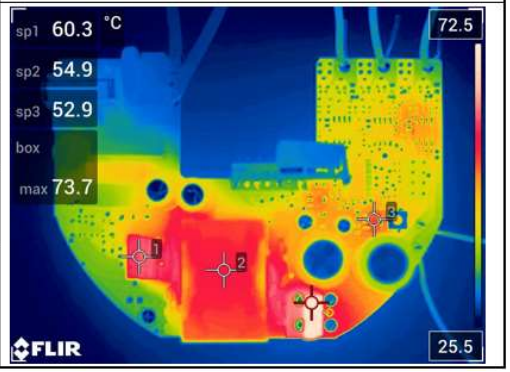
90 Vac

Location	Component	Thermal temperature (°C)	Thermal image
Sp1	Output diode	71.5	
Sp2	Rectifier bridge	66.8	
Sp3	Differential mode choke	61.4	
max	PFC MOSFET	74.2	

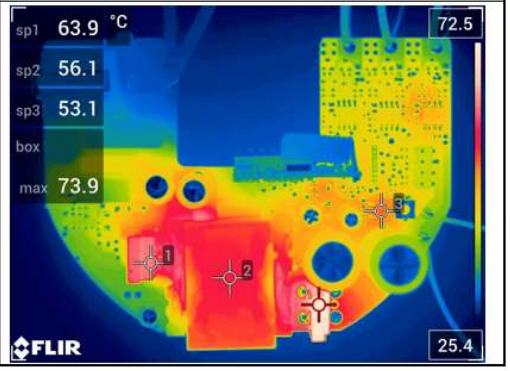
140 Vac

Location	Component	Thermal temperature (°C)	Thermal image
Sp1	PFC MOSFET	65.6	
Sp2	Rectifier bridge	56.4	
Sp3	Underneath transformer	60.7	
max	Output diode	74.2	

230 Vac

Location	Component	Thermal temperature (°C)	Thermal image
Sp1	PFC MOSFET	60.3	
Sp2	Transformer	54.9	
Sp3	5V LDO	52.9	
max	Output diode	73.7	

300 Vac

Location	Component	Thermal temperature (°C)	Thermal image
Sp1	PFC MOSFET	63.9	
Sp2	Transformer	56.1	
Sp3	5V LDO	53.1	
max	Output diode	73.9	

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