Refrigerator application and product overview

May 2022

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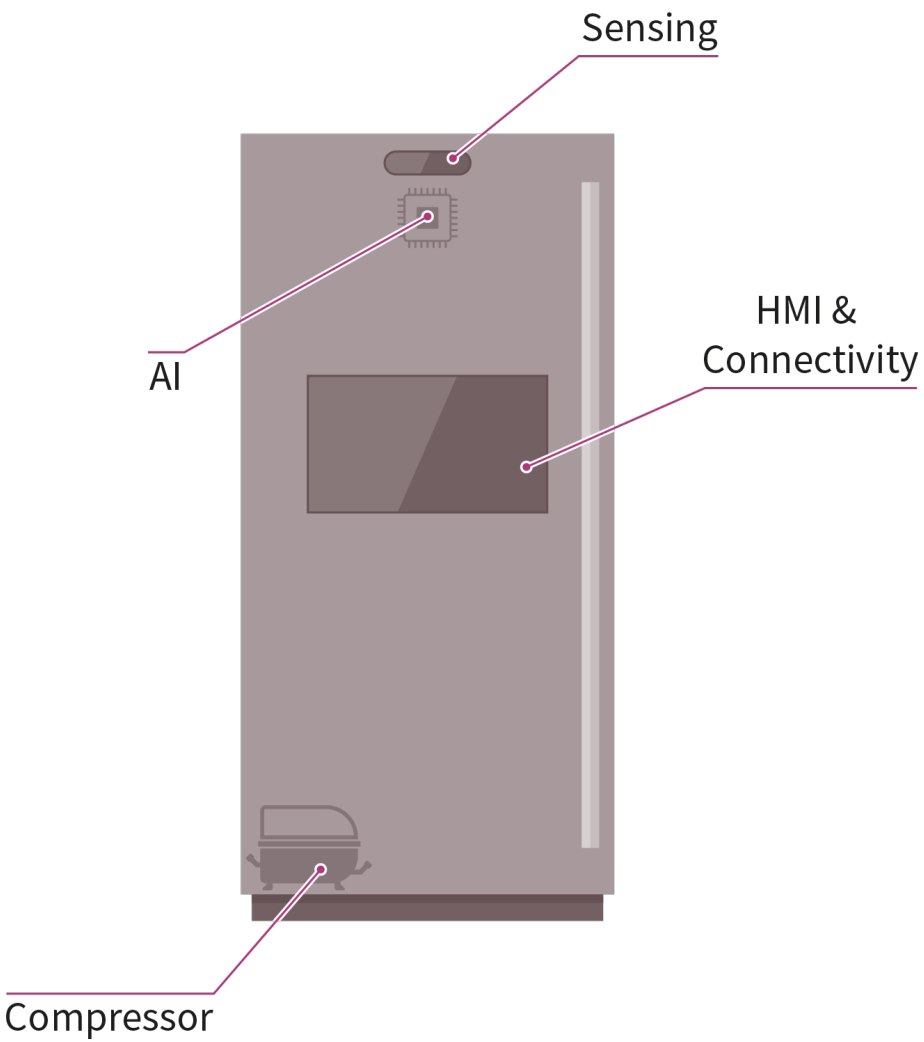
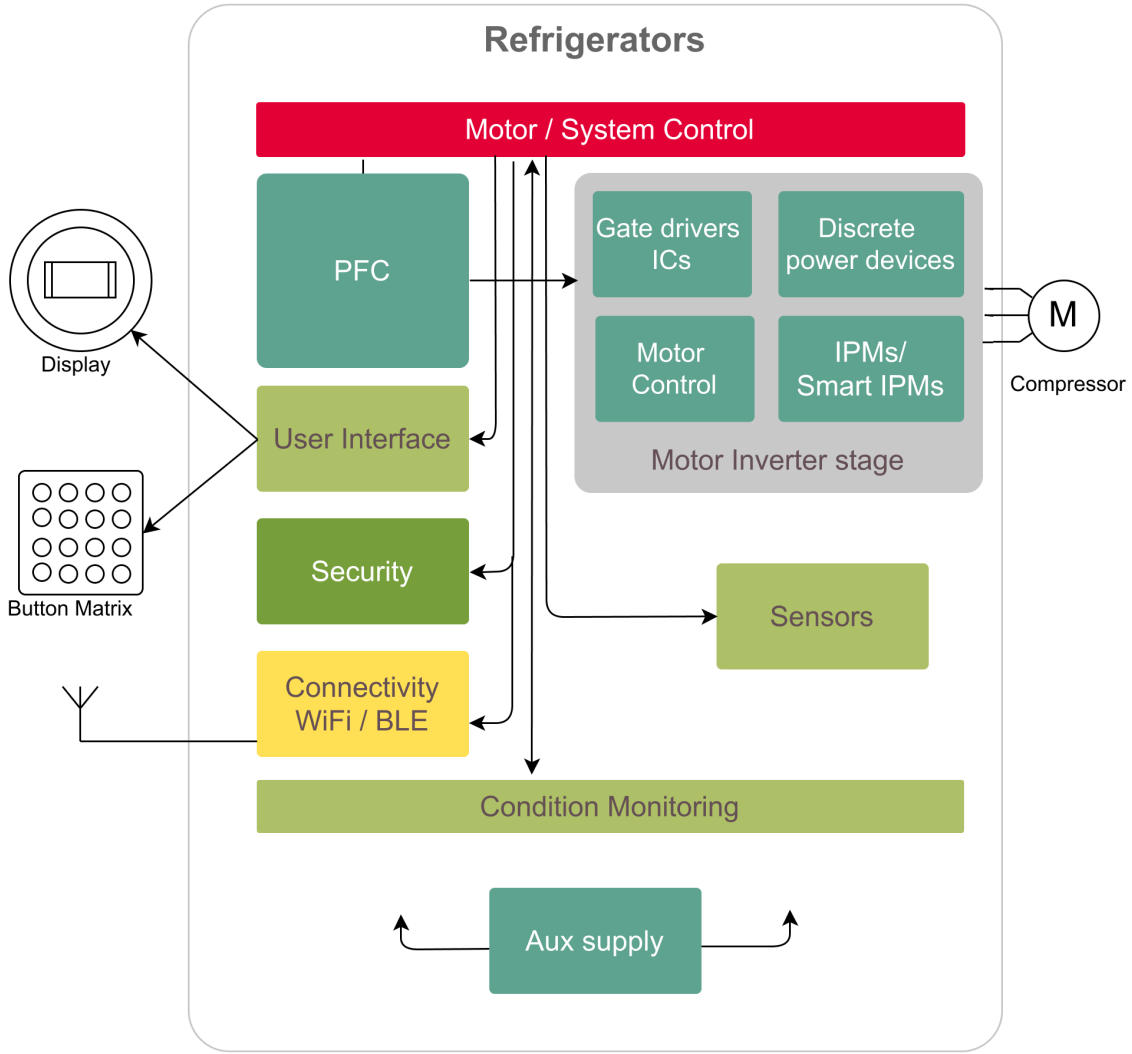
The application refrigerator

Infineon’s complete system solutions for fridges allow to implement smart, compact and energy-saving designs for an innovative end-customer experience

Block diagram – complete refrigerator system

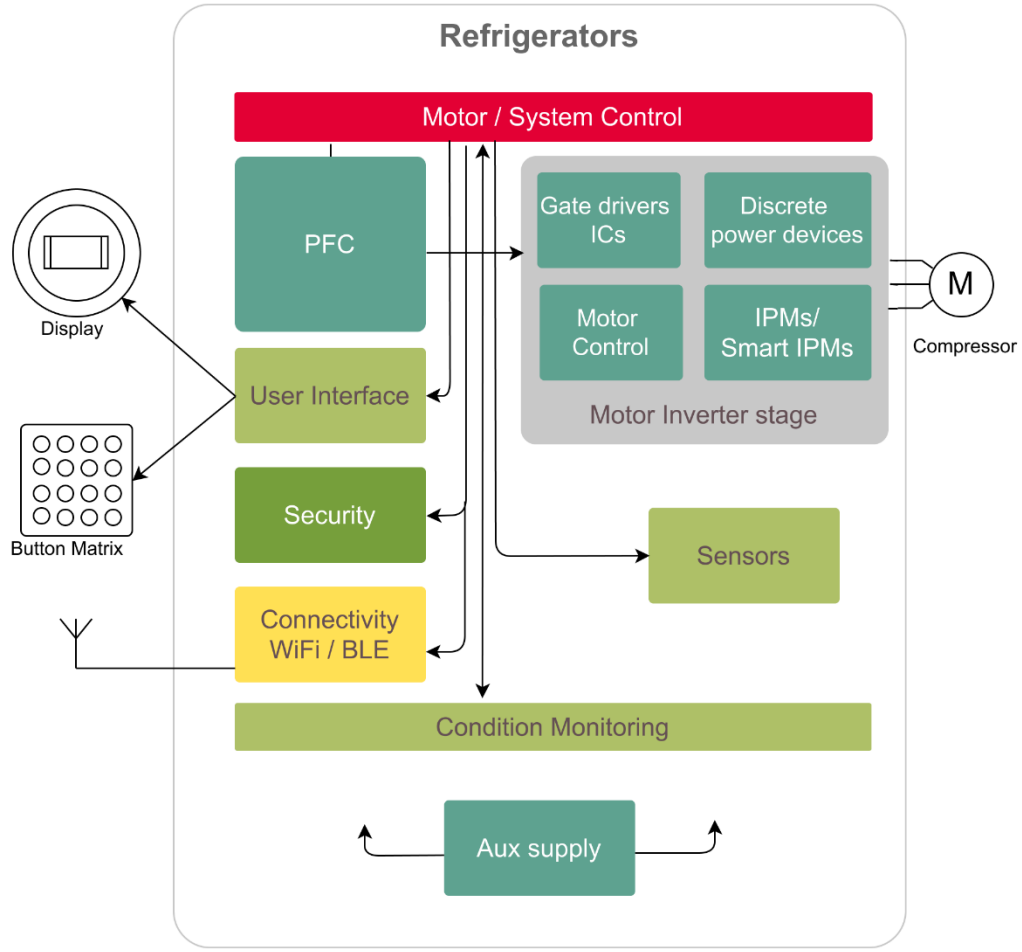




Refrigerator – Key functional blocks

Functional block	Technical description
Compressor motor drive	› Variable speed drives used in ODU compressor to control AC motor speed and torque by varying motor input frequency and voltage. › Typical power rating: Up to 300 W
Compressor PFC	› Power factor correction (PFC) of compressor motor drives improves the line-side power factor and provides a stable DC bus voltage for the drive.
User Interface	› Touch button, touch screen, mechanical buttons, voice or even gesture control.
Motor/System control	› An embedded MCU governs the fridge´s system operation including motor control, security, connectivity, user interface, AUX and sensors
Condition monitoring	› Monitor the state of health of the system using sensor- or MCU processing data
AUX supply	› Providing auxiliary control power demand, typically to power up the gate driver, cooling system, sensing, control and communication unit

Functional block diagram



Refrigerator – Product overview

Compressor

- **Motor Controller:** PSoC™, XMC™ and iMOTION™ family
- **Inverter (IPM)**: CIPOS™ Micro
- **Inverter (Discrete):** IGBTs (RC-D2 series), MOSFETs (600 V CoolMOS™ PFD7), EiceDRIVER™ gate drivers ICs
- **PFC**: TRENCHSTOP™ IGBTs, Rapid and CoolSiC™ diodes and PFC gate drivers, MOSFETs (600 V CoolMOS™ P7)
- Pressure **sensor** for precise & quick cooling
- **Auxiliary power**: CoolSET™/ 5QR series, MOSFETs (600 V CoolMOS™ P7)

Motor control

Fan

- **Inverter (IPM):** Smart IPM, CIPOS™ Nano, CIPOS™ Micro
- **Inverter (Discretes):** IGBTs (IGBT 6 & RC-D series), gate drivers (half bridge and 3-phase drivers), MOSFETs (600 V CoolMOS™ PFD7)

HMI & connectivity

- PSoC™ 6 for **main control, touch sensing and display**
- Bluetooth / Wi-Fi **connectivity** using our AIROC™ solutions
- XENSIV™ MEMS microphone for **voice control**
- OPTIGA™ Trust M for **secured communication**

HEPA filter

- OPTIGA™ Authenticate S for **authentication**
- Pressure sensor to detect if filter is blocked

Smart Home

Sensing

- XENSIV™ magnetic hall sensors for angle / position / 3D sensing
- XENSIV™ CO_2 sensor for air quality monitoring
- XENSIV™ radar sensors for presence detection

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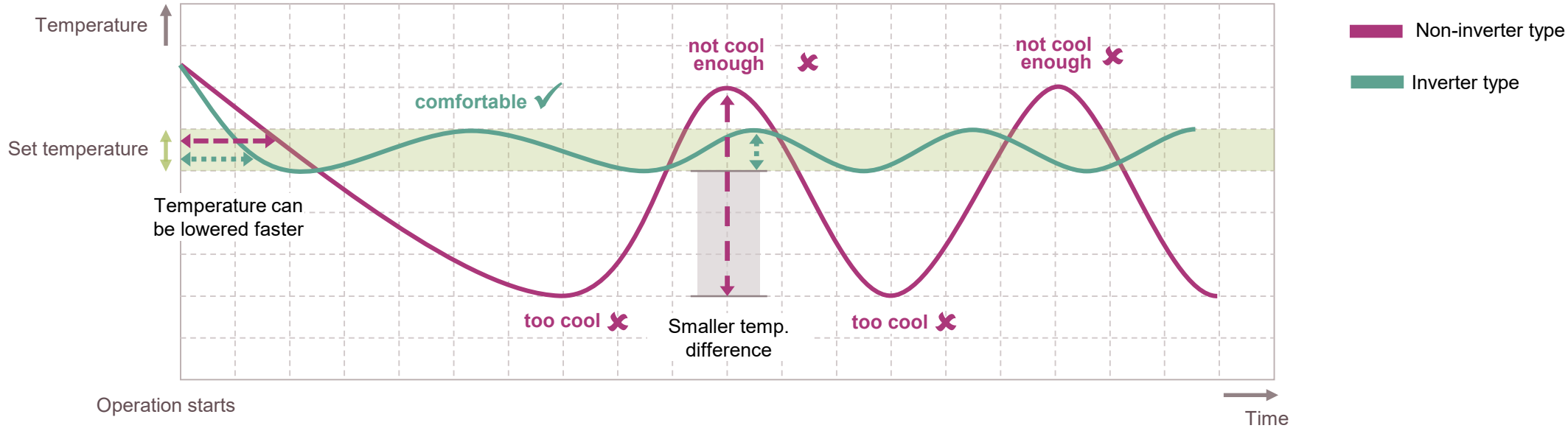
Inverterization helps refrigerators to achieve optimum performance while saving energy

Inverter technology controls the speed of the motor, finely tuned according to the required load conditions

- Smaller variations of temperatures and optimum comfort
- Reduction of electricity consumption



High-level view on the inverter

Motor controller

› Regulates speed and torque of motor by manipulating voltage and current

Gate driver

› Amplifier that accepts low power input from a controller to produce the high current gate drive for a power switch

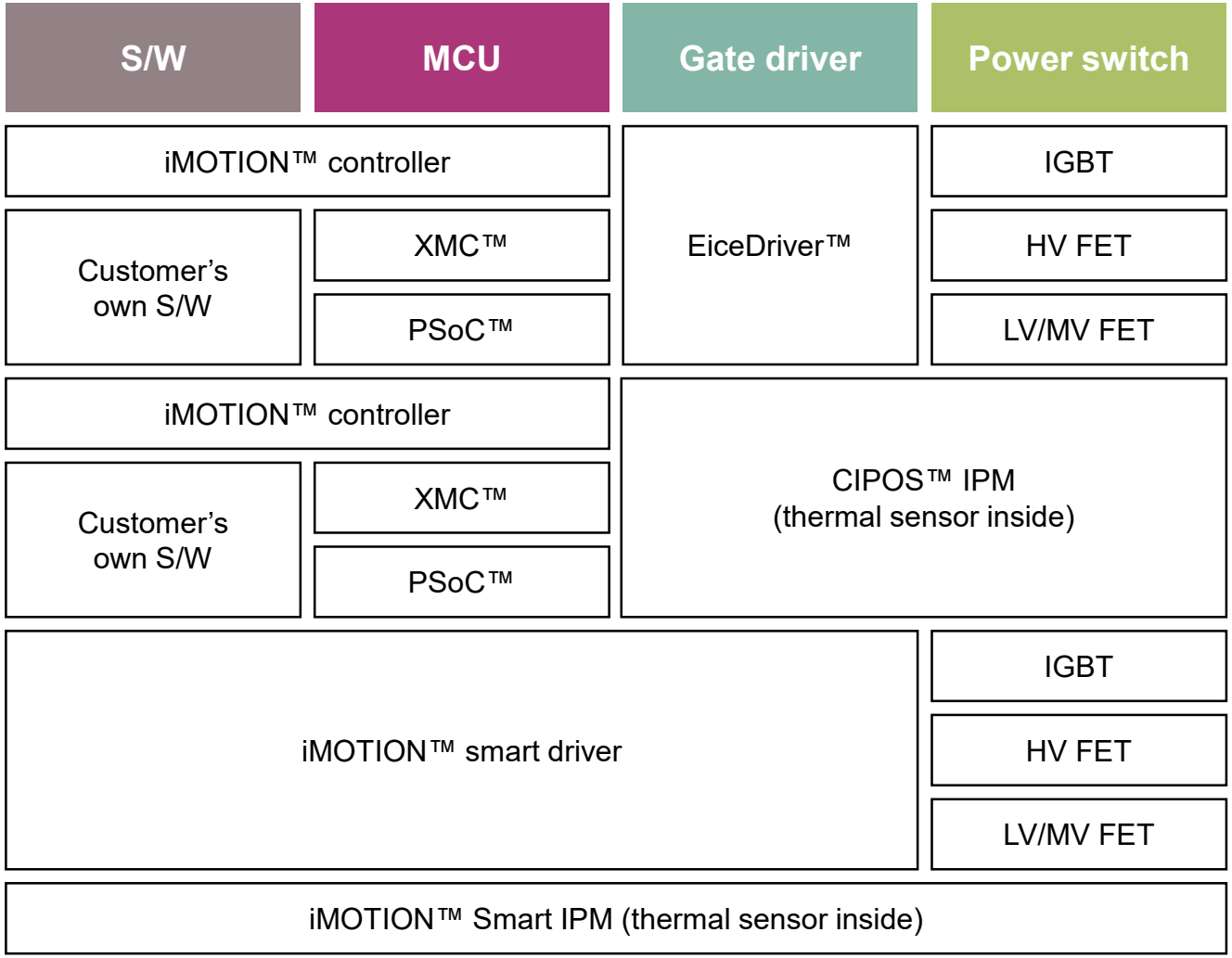
Power switch – IGBT or MOSFET

› Controls current in the motor through switching operation

Power Factor Correction – Switch-Diode-Inductor

› Improves power factor thus reducing load on the electrical distribution system & increasing energy efficiency

Infineon offers various motor control solutions to choose from



Considerations to select a solution

- **The benefit of the semiconductor solution**
  - e.g. SMD package up to 300 W without heatsink, better EMI performance of IGBT, better light load efficiency of MOSFET
- **Technical requirements of each application**
  - e.g Power MOSFETs usually lead to lower yearly inverter losses as fridge operates more than 90% of the time at less than 50% of the rated power load
- **IFX recommended offerings based on customer's preference and system specifications**
  - e.g. switching frequency, power rating, PCB space constraints, assembly process, heatsink-less, multi-source, efficiency, EMI performance, price, high or low voltage motors, internal thermal sensor, control algorithm
- **Evaluation or simulation results per each application**
  - e.g. loss simulation

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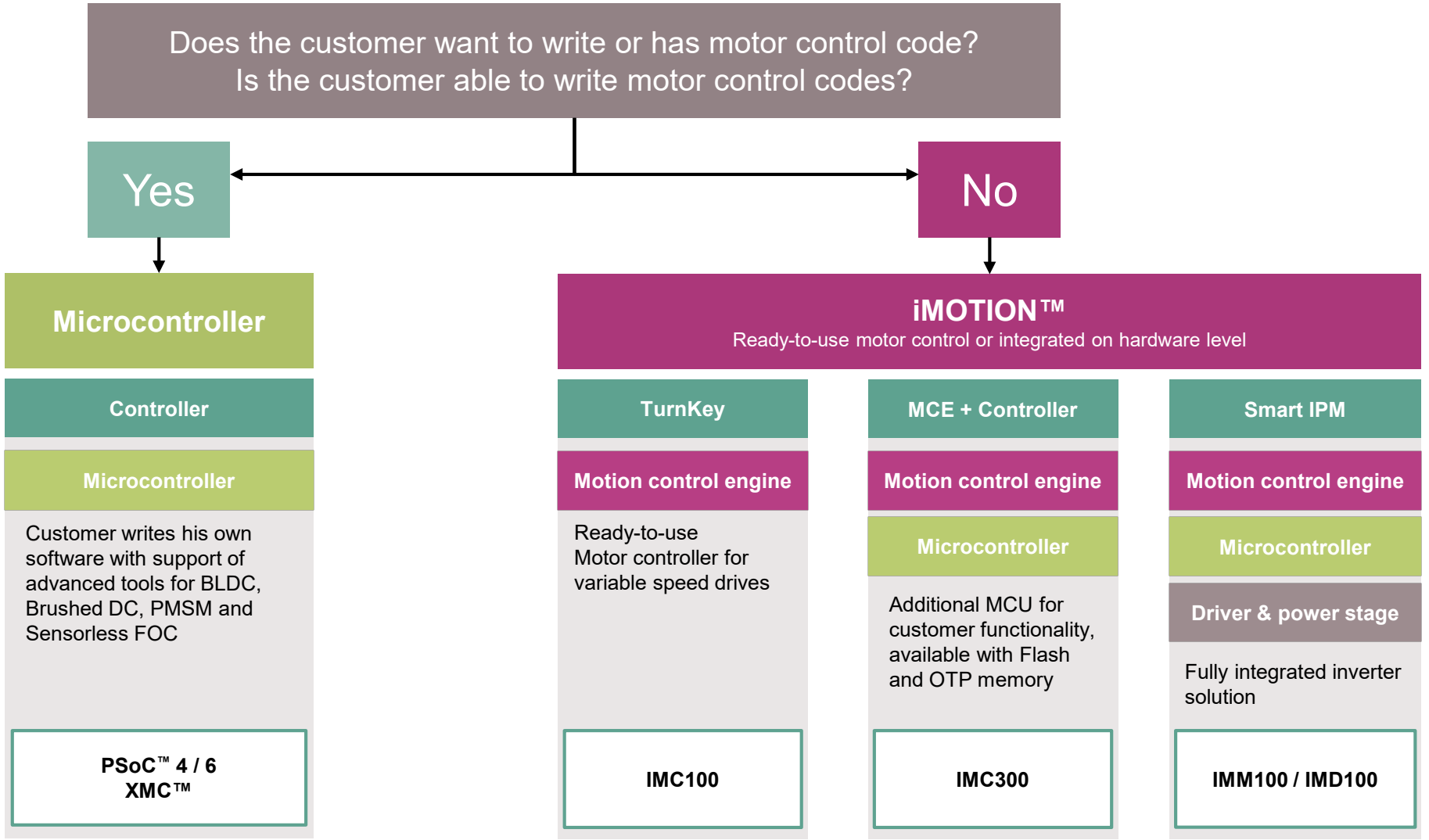
Motor Control: iMOTION™ or microcontroller?



Infineon microcontrollers for home appliances

	XMC / PSoC™	iMOTION™
	Solution Ready MCU	SW/HW Integrated ASSP
Applications	All applications (HMI, System Control, Motor + PFC)	Motor + PFC

Roadmap / Portfolio

Performance approach

- **PSoC™ 6**
  Cortex® M4/ M0+M4
- **XMC™ 4000**
  Cortex® M4
- **XMC™ 1000**
  Cortex® M0
- **PSoC™ 4**
  Cortex® M0/ M0+

Integration approach

- **Smart IPM**
  MCE2.0 **+ 600 V GD + Power Stage**
- **Smart Driver**
  MCE2.0 + **600 V Gate Driver**
- **Motor ASSP**
  MCE 2.0

PSoC™ selection guide for refrigerators

	Main control	Connectivity		HMI			Display drive		Motor Control	Additional features	Software
		BT	WiFi	Button	Display LCD	Display TFT	Display LCD	Display TFT	Compressor control		
PSOC™ 4000S/ 4100S	Only PSoC4100S			<7“			✓		4100S		PSoC™ creator
PSOC™ 4100 Plus/ Max	✓			<7“/9“			✓			2 CapSense® blocks	PSoC™ creator/ Modus toolbox
PSOC™ 4500S									HPFC + Compressor	Security (PSoC™ 64)	PSoC™ creator/ Modus toolbox
CY8C62x4/5	✓	Host for Wi-Fi		✓			✓	✓		Security (PSoC™ 64)	Modus toolbox
CY8C62x7/8	✓			✓			<7“			Security (PSoC™ 64)	PSoC™ creator/ Modus toolbox
CY8C63x7/8	✓	BLE		✓			<7“			Security (PSoC™ 64)	PSoC™ creator/ Modus toolbox

What is iMOTION™ 2.0?

Software integration

- **MCE 2.0**
  Motion Control Engine
- **Scripting engine**

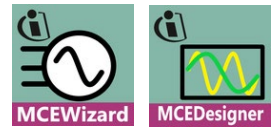
+

Hardware integration

- **Controller**
- **Smart driver**
- **Smart IPM**

+ **MADK and Reference Designs**

+ **Development tools and documentation**



With the aim of making it….

- **Easier to use than ever!**
- **Faster and cheaper to market!**

iMOTION™ selection guide for refrigerators

	Main control	Connectivity		HMI			Display drive		Motor Control		Additional features	Software
		BT	Wi-Fi®	Button	Display LCD	Display TFT	Display LCD	Display TFT	Single + PFC	Dual + PFC		
IMC100									✓	✓		Ready to use + Script engine
IMC 300									✓		Additional M0 core	Ready to use + Script engine
IMD110									✓		Integrated GD	Ready to use + Script engine
IMI110*									✓		Integrated GD + Power Stage	Ready to use + Script engine
IMM100*									✓		Integrated GD + Power stage	Ready to use + Script engine

XMC™ selection guide for fridges

	Main control	Connectivity		HMI			Display drive		Motor Control		Additional features	Software
		BT	WiFi	Button	Display LCD	Display TFT	Display LCD	Display TFT	Single + digital PFC	Dual + digital PFC		
XMC 1300									✓		MATH co-processor, 64MHz motor control timers, 5V	LLD, DAVE Apps for configuration and code generation, Class B safety Lib, XMC Lib
XMC 1400									✓		MATH co-processor, 96MHz motor control timers, 5V, 4 ACOMP	
XMC 4100/200										✓	High resolution motor control timers, 4 ADC, 125°C	

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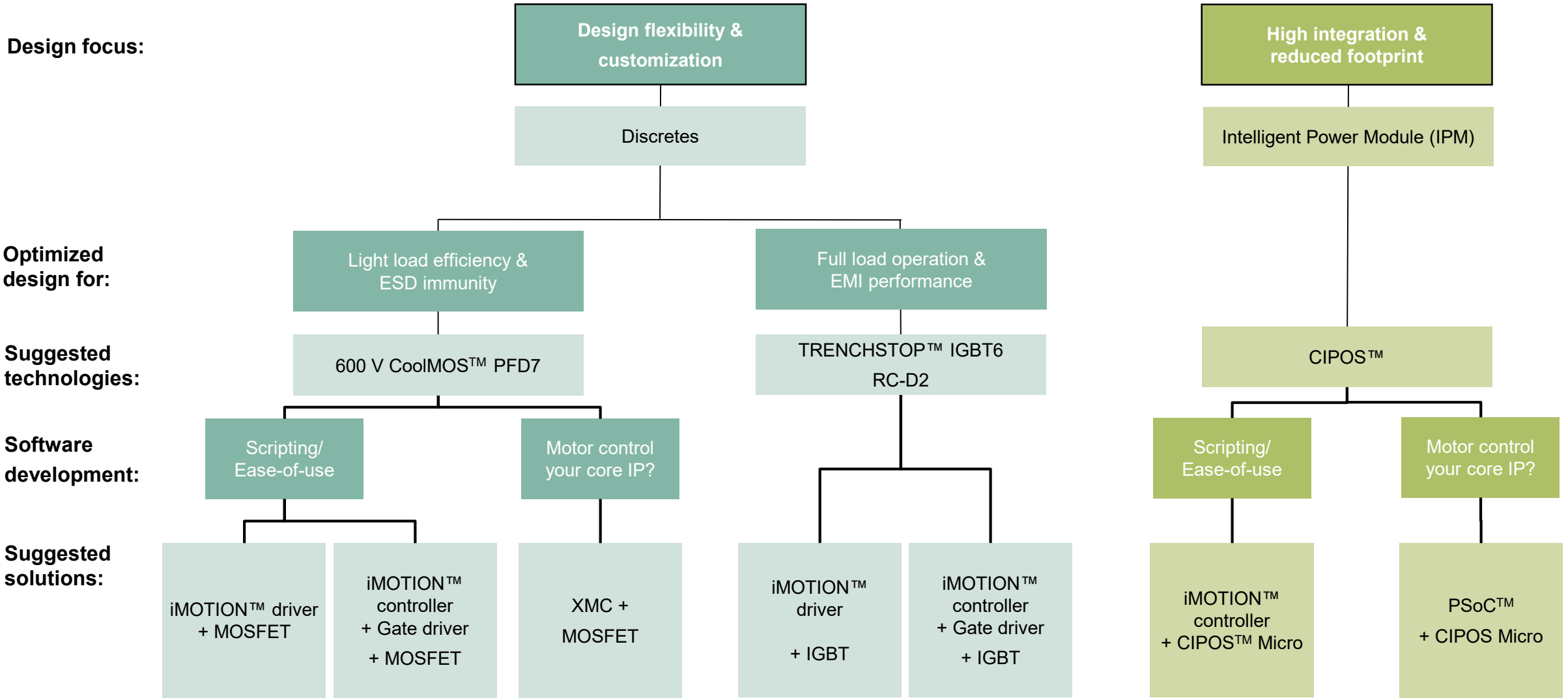
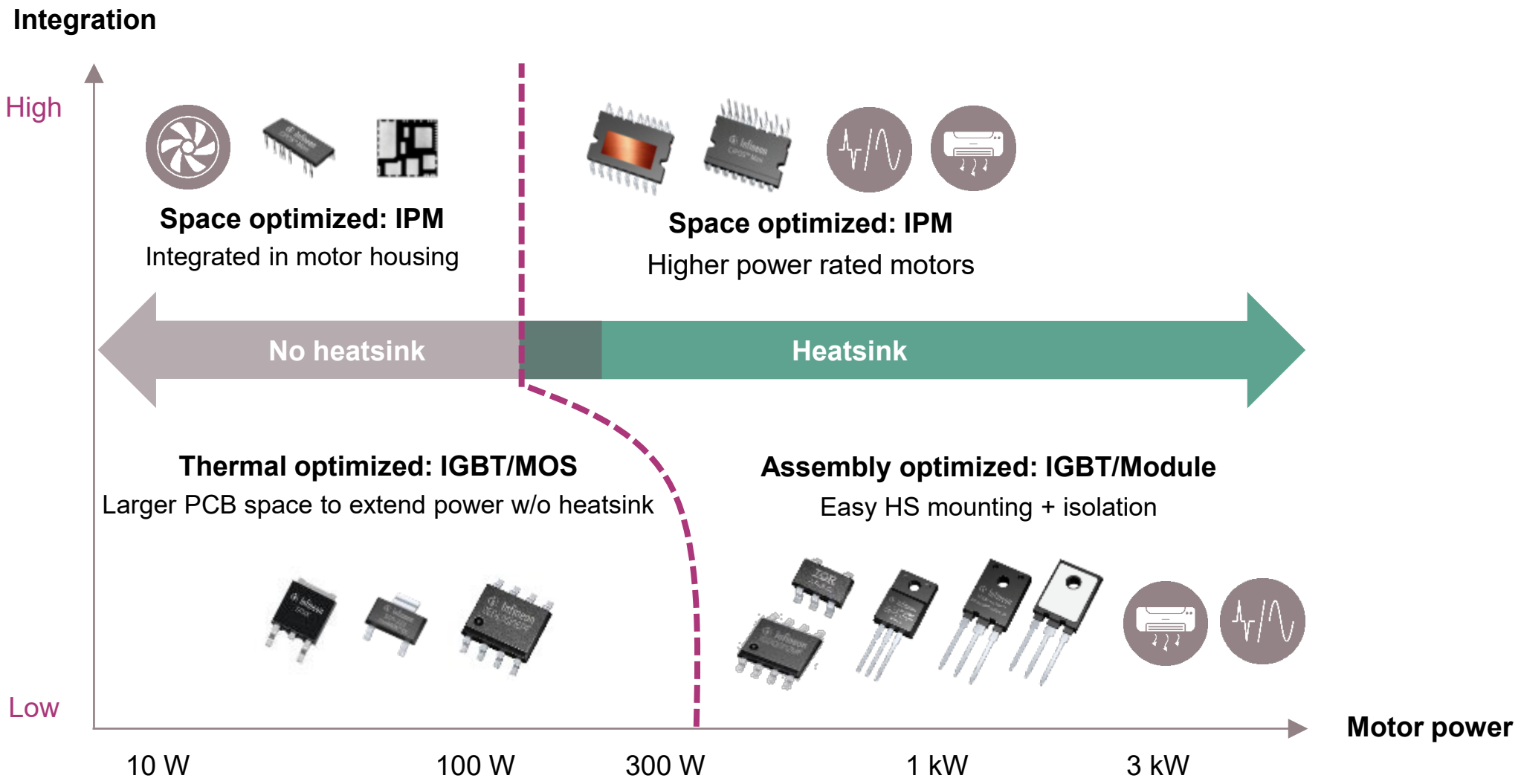
Infineon offers solutions from low to high integration choice: space, thermals and cost or assembly optimization



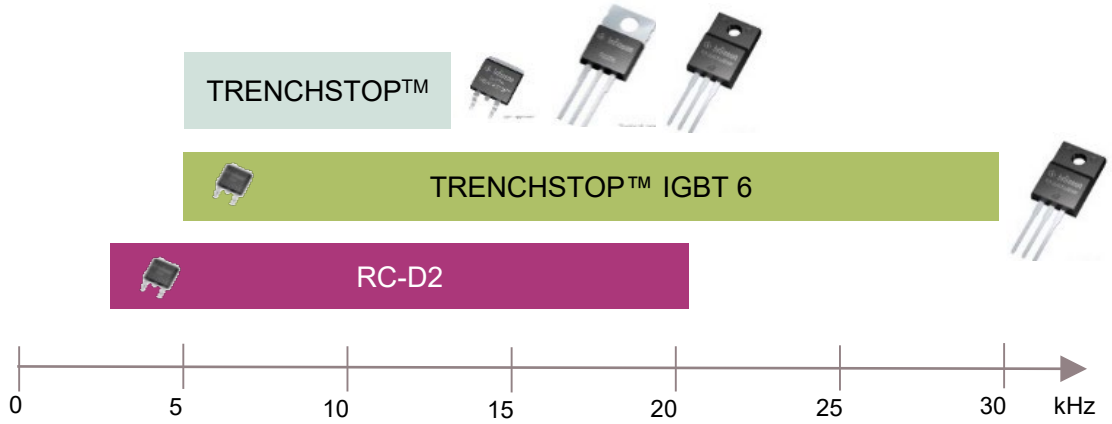
Power stage and power factor control (PFC) – Discrete or integrated



Power factor control for refrigerators – Topologies

Topology Criteria	CCM Boost PFC		Totem-pole PFC	
Suitable power range	Suitable for >1.5 kW		Suitable for > 2.5 kW	
Cost	Moderate cost		Affordable for high power	
Switching frequency	High switching frequency Low harmonics		High switching frequency Low harmonics	
Efficiency	Bridge rectifer needed		No bridge rectifier	
	Meet energy regulations		Meet energy regulations Best efficiency near 99%	
Power factor	PF ~0.99 Minimized harmonics		PF ~0.99 Minimized harmonics	
Control	Easy implementation Dedicated controller available or MCU		Slightly complex than ordinary boost PFC, and no dedicated controller available	
Form factor	Smaller form factor		Smallest form factor	

Refrigerator drives: Discrete IGBTs



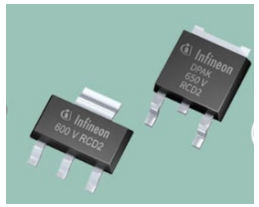
	Value
TRENCHSTOP™	**Good low frequency performance** Low $V_{ce(sat)}$ Low switching losses
TRENCHSTOP™ IGBT 6	**Performance optimized up to 30 kHz** **Co-packed with/out diodes** Lowest **switching losses and improved EMI** SC rating up to 3us
RC-D2	**Cost optimized in surface mount packages** **Monolithically integrated diode** Lowest 3 A up to 15 A 600 V in SOT 223 and DPAK SC rating up to 3us

600 V Reverse Conducting Drives 2

600 V RC-D2

- Optimized half rated diodes and 3 us SC capability
- Better controllability over the di/dt in order to further reduce EMI compared to RC-D/DF series
- Improved high voltage humidity robustness
- Easy to design products – drop in replacement RC-D2 available in DPAK and SOT 223 (Q4 2021)
- Low switching loses on competitive price -> new price/performance standard

600 V Reverse Conducting Drives 2 is the best choice for price sensitive markets



600 V RC-D2 portfolio

Ic 100°C	SOT 223 RC-D2 (Q4 2021)	DPAK RC-D2
3	IKN03N60RC2	
4	IKN04N60RC2	IKD04N60RC2
6	IKN06N60RC2	IKD06N60RC2
8		
10		IKD10N60RC2
15		IKD15N60RC2

Fan

Compressor

The unique features of CoolMOS™ 7 SJ MOSFETs bring excellent benefits for refrigerator compressors

600 - 950 V CoolMOS™ P7

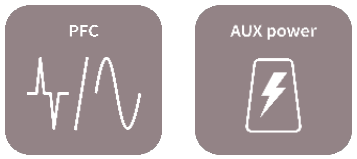
Consumer

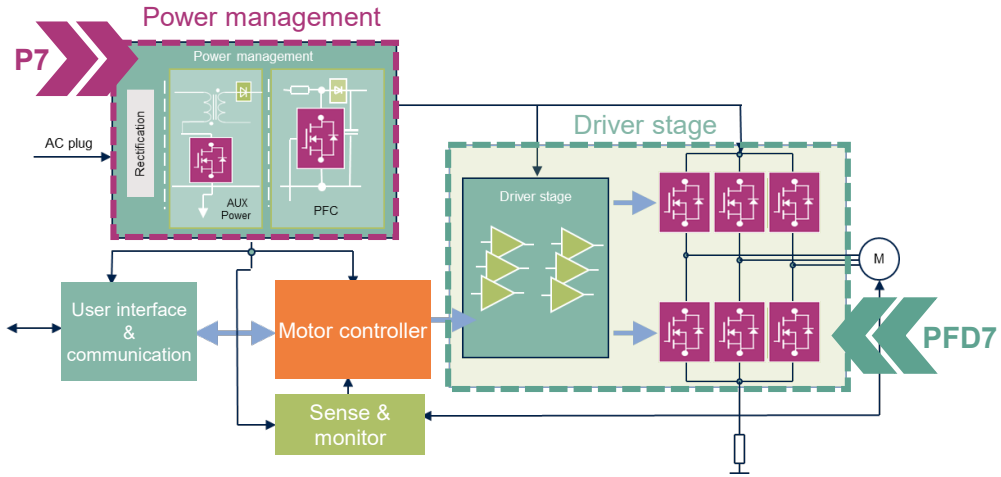
600 V CoolMOS™ PFD7

Suitable for

PFC & Flyback

topologies

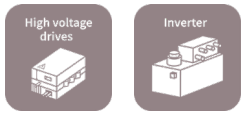




Suitable for **light load** efficient

inverters

up to 300 W



to address major and small **Home Appliances**

Technology corner stones:

- **Price competitiveness** compared to similar technologies
- Supports **increased switching frequency** to reduce magnetics
- Integrated **Zener diode** for ESD protection up to HBM Class 2
- **Perfect combination** of
  - highest efficiency
  - excellent ease-of-use and
  - outstanding portfolio granularity

Technology corner stones:

- **Improved efficiency** in hard & soft switching due to reduced E_{oss} & Q_{oss}
- Integrated **Zener diode** for ESD protection (HBM Class 2)
- **Integrated fast body diode** with ultra low Q_{rr}
  - reduced stress on device while body diode is not fully recovered
  - **extra safety margin** for repetitive hard commutation and **reduced design-in effort**
- Portfolio with wide range of $R_{DS(on)}$ values ≤ 2 Ohm
- Supporting cost effective designs with SMD solutions like SOT-223

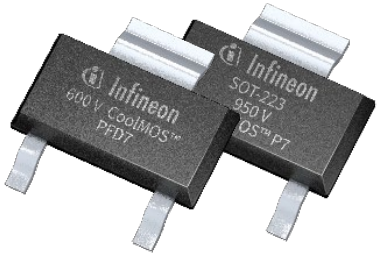
Recommended CoolMOS™ 7 SJ MOSFETs portfolio for fridges

Compressor inverters

Series: **600 V CoolMOS™ PFD7**
Packages: DPAK, SOT-223
$R_{DS(on)}$ max: 0.36 - 2.0 Ω
Examples: IPD60R1K0PFD7S, IPN60R1K5PFD7S

AUX Power

Series: **700 - 950 V CoolMOS™ P7**
Packages: DPAK, SOT-223
$R_{DS(on)}$ max: 0.6 - 4.5 Ω
Examples: IPN80R4K5P7, IPD70R2K0P7S



Recommended HB gate driver: 2ED28073J

- Supporting a **cost attractive solution**
- Enabling **ease of use**
- **Reducing** overall **BOM** count
- **Demo board** including software available

Motor Drive and PFC product overview – Intelligent Power Modules (IPM)

Fridge fan

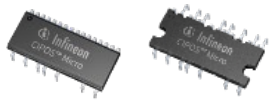
CIPOS™ Nano

Dimension [mm]	12x12
Configuration	3-phase
Voltage Rating	500 V
Rdson max.	1.7, 2.2 Ω

- Heatsink-less operation
- Smallest modules on the market
- Wide range of footprint compatible parts
- Overcurrent protection included

Fridge compressor

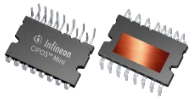
CIPOS™ Micro



Dimension [mm]	29x12x2.9	
Configuration	3-phase	
Voltage Rating	250 V, 500 V	600 V
Rdson max	0.45 - 6.0 Ω	IGBT (4/6 A)

- Wide range of footprint compatible part numbers
- Temperature feedback option
- 3 lead-form options
- Compatible with mass-market TO-2xx heat sinks and clips

CIPOS™ Mini



Dimension [mm]	36x21x3.1
Inverter	600 V 10-30 A
PFC + Inverter	600 V 10 A, 15 A
Interleaved PFC	650 V 20A, 30 A

- Rugged SOI gate driver technology
- High integration (bootstrap circuit, thermistor, single boost PFC)

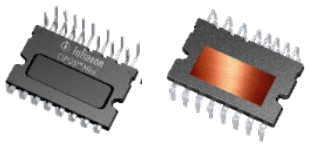
Benefits

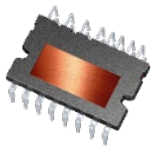
- Fast time to market
- System cost savings from smaller footprint and reduced PCB space
- Improved efficiency and power density
- UL certified package and temperature sensor

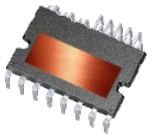
Power stage and Power Factor Control – CIPOS™ Mini IPMs

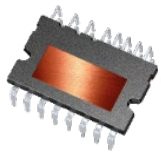
Broad range of configurations from inverter to PFC

Inverter	Asymmetric Inverter	PFC	Inverter + PFC
› 3-phase inverter › 4 ~ 30 A › Home appliances and motor drives motor power up to 3 kW	› 2-phase asymm. inverter for switch reluctance motor (SRM) › 15 A, 20 A	› 2- or 3-phase interleaved power factor correction (PFC) › 20 A or 30 A › Easy heatsink mounting in combination with Mini inverter IPM	› Inverter + PFC in one package › 10 A, 15 A, 20 A › System size reduction with PFC integration into inverter module









EiceDRIVER™ Gate Drivers for refrigerators

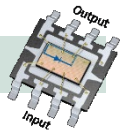
Inverter: 600-700 V Level-shift drivers

- **Level-shift:**
  - **30 years** of product leadership from IRF portfolio (first **HVIC** driver in 1989)
  - State-of-the-art **Infineon SOI** technology for superior operational ruggedness and higher frequency switching

Key products

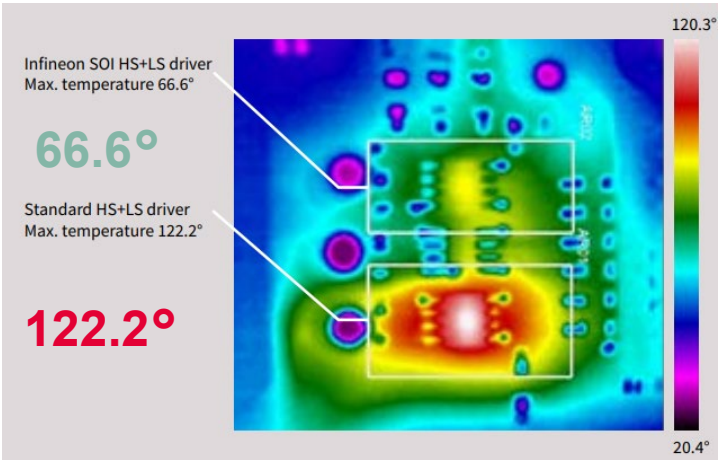
- 2ED2304S06F
- 6EDL04x06xT

Differentiation



- Largest standard portfolio
- Infineon SOI (BSD, $-V_S$, lower losses)

Infineon's SOI Technology for level-shift drivers



- Power loss comparison between Infineon SOI gate driver and standard level-shift gate driver

- Fully operational up to +650 V
- Integrated bootstrap diode (BSD)
- Tolerant to negative transient voltage ($-V_S$) up to 100 V
- Low level-shift loss in high frequency applications (below)

PFC: Low-side drivers

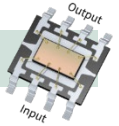
- Comprehensive families of single and dual channel low-side drivers
- New feature-rich families with **accurate (+/-5%), fast, over-current protection** for PFC in home appliances

Bold = New products

Key products

- **1ED44173/5/6N01**
- 1ED44171N01B
- IR4427, IRS4427, IRS44273

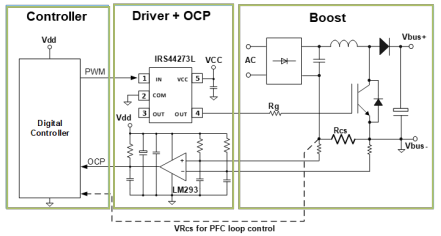
Differentiation



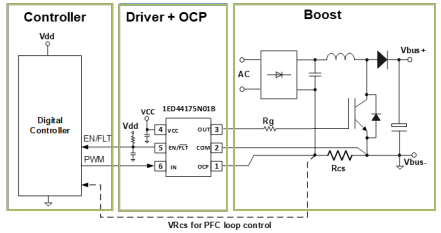
- **Integrated over-current protection (OCP) and fault reporting**
- Cost-effective
- Market-proven

1ED4417x integrated OCP

Current solution



1ED4417x solution



> 20% Cost Saving
> 50% Space Saving

1ED4417x integrates

- Low side gate driver
- Overcurrent protection
- Fault output
- Programmable fault clear time
- Enable input

Auxiliary power – 5th generation CoolSET™ for auxiliary SMPS

Robustness

- Integrated 700 V or 800 V superjunction MOSFET
- Comprehensive protection features
- Auto-restart scheme to minimize interruption

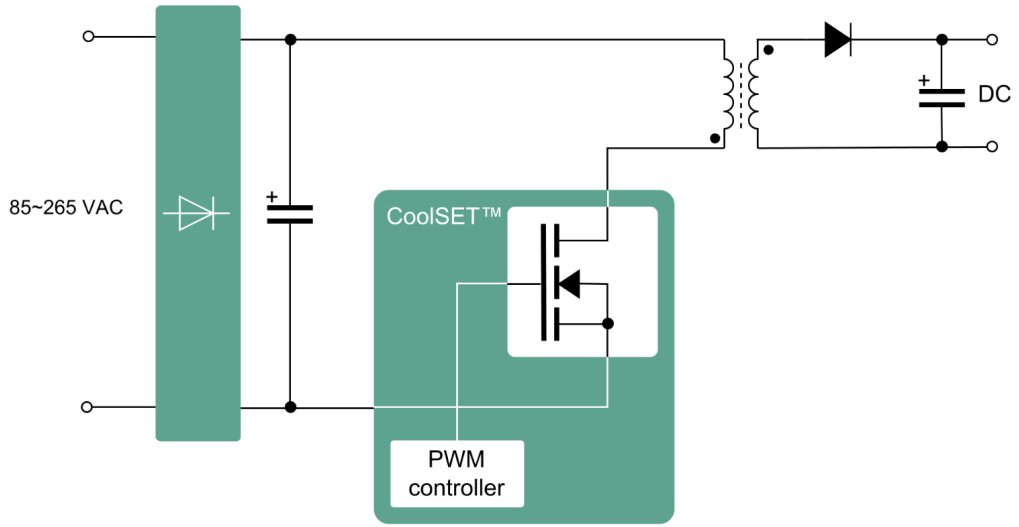
Ease of design

- Numerous design examples
- Design tools, guide and application note
- Reference designs

Broad portfolio

- Choice of fixed- frequency or quasi-resonant switching scheme
- Highest power delivery up to 43 W
- Available in DIP-7 or SMD DSO-12 package

Auxiliary SMPS in Flyback topology to perform AC/DC power conversion to power the various system blocks in home appliances.



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Refrigerators: trends, use cases and Infineon‘s offering

Connect to the Internet for wireless control

- Be informed if you forgot to close the fridge
- Look into the fridge remotely
- Be informed about the fridge´s content

Sense environment for intuitive and autonomous use

- Is someone in the room?
- How is the air quality in the fridge?
- Food and content sensing

Condition Monitoring & Predictive Maintenance

- Detect defects before they happen

User interface

- Intuitive display to control the entire smart home
- Voice control
- Gesture control

Value proposition AIROC™ connectivity solutions

Wi-Fi® 4	Wi-Fi® 5/6		Wi-Fi® 6
Lowest cost	High data throughput	Congestion/future proof	Low power consumption

Interoperability	Home Appliances must work on all continents: Broadcom is leader in routers and Cypress bought their IoT group. Thus the connectivity components have highest interoperability
Co-existence	Many applications use BT and Wi-Fi, which can interfere with each other. Our AIROC™ devices have best in class, configurable Co-Existence engines to optimise for multi protocol operation
Operating system	We support a variety of RTOS solutions including FreeRTOS, MBED OS, etc. We also support Linux and Android natively using our FMAC driver.
Tech support	We have dedicated Applications and Field Applications support locally that can help debug any issues, as well as a large community support site where you can find answers to common questions
Long distance	Our high RX sensitivity coupled with our tuning for maximum output power per region, offers greater distance and improved coverage over the deployed location, increasing the reliability and performance of the connection.
High integration	Our MCU solutions can drive the touch button/screen,whilst also serving as the main control and as a host to the Wi-Fi solution
End-customer analytics	Product analytics that improve the performance, the reliability and connectivity of the appliance by providing real-time visibility into the performance of the appliance

Make your fridge become a part of the smart home eco system with Matter

The biggest global companies came together

c|net

Google, Amazon, Apple back Matter standard so smart home devices cooperate

Smart lightbulbs, door locks, thermostats and other items should be easier to install and interconnect, and Google will upgrade many current products with Matter software updates.

https://www.cnet.com/home/smart-home/google-amazon-apple-back-matter-standard-so-smart-home-devices-cooperate/

Infineon is the leading provider for key technologies

- AIROC™ Wi-Fi® combos
- AIROC™ Bluetooth and Multi-protocol SoCs
- PSoC™ 62 and 64 MCUs
- OPTIGA™ Trust anchor

With a new open-source approach to interoperability

- Publicly available, open-source implementation built by the standard-development community
- Governing alliance (Connectivity Standards Alliance, formerly known as Zigbee) runs certification
- Record speed: smart speaker infrastructure will be over-the-air updated in ~50% of the US population and first devices will be available in mid 2022

Infineon's support for Matter

- Integration of Matter Open Source and Open Thread into Modus Toolbox
- Customers can integrate using these tools for CYW43439
- Security will be integrated into SoC to offer options of internal or external security processor for maximum flexibility
- Long term assurance across Wi-Fi® and 15.4 products

Touch control: Implement touch with the leading provider of touch solutions

1. Replace mechanical buttons with the world´s easiest touch solution — MBR3 – configurable touch controllers
2. Complex touch HMI interfaces in single MCU platform with connectivity — PSoC™ 4 touch controllers
3. Dual-core high performance touch solution with IoT edge compute capabilities — PSoC™ 6 touch controllers

Main security concerns for our customers

Identity Protection against **fake devices**

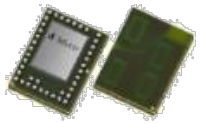
Protection against **eaves dropping**

Protection against **the manipulation of the data**

Protection against **illegal update of firmware**

Don´t let your smart fridge be the weakest point in the system.

Devices become smart by imitating human senses



Radar

Presence detection

Material detection

Magnetic

Speed

Weight, vibration, imbalance and liquid flow

Lid open/ closed

Track people

Count people

Gesture sensing

Listen to user´s voice command

Noise anomaly detection

Air quality measurement

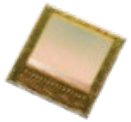
CO2

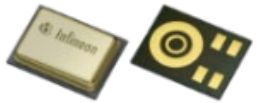
ToF

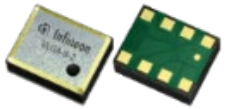
Detect clogged filter

MEMS microphone

Pressure







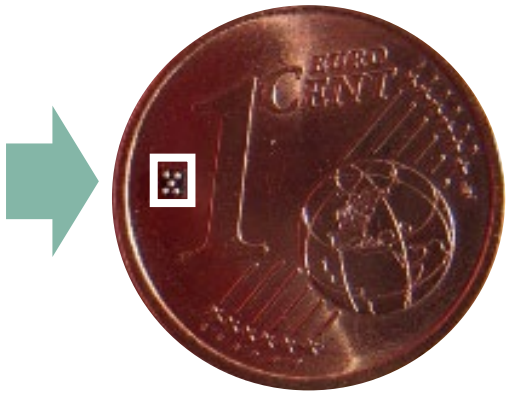
Door sensor using XENSIV™ hall sensors

Determine if door is open or closed

Detect open-close event without mechanical switches: When the door is open, the hall sensor turns on the light as the magnet in door is out of range.

Sensors not visible

No physical contact required, therefore no mechanical wear



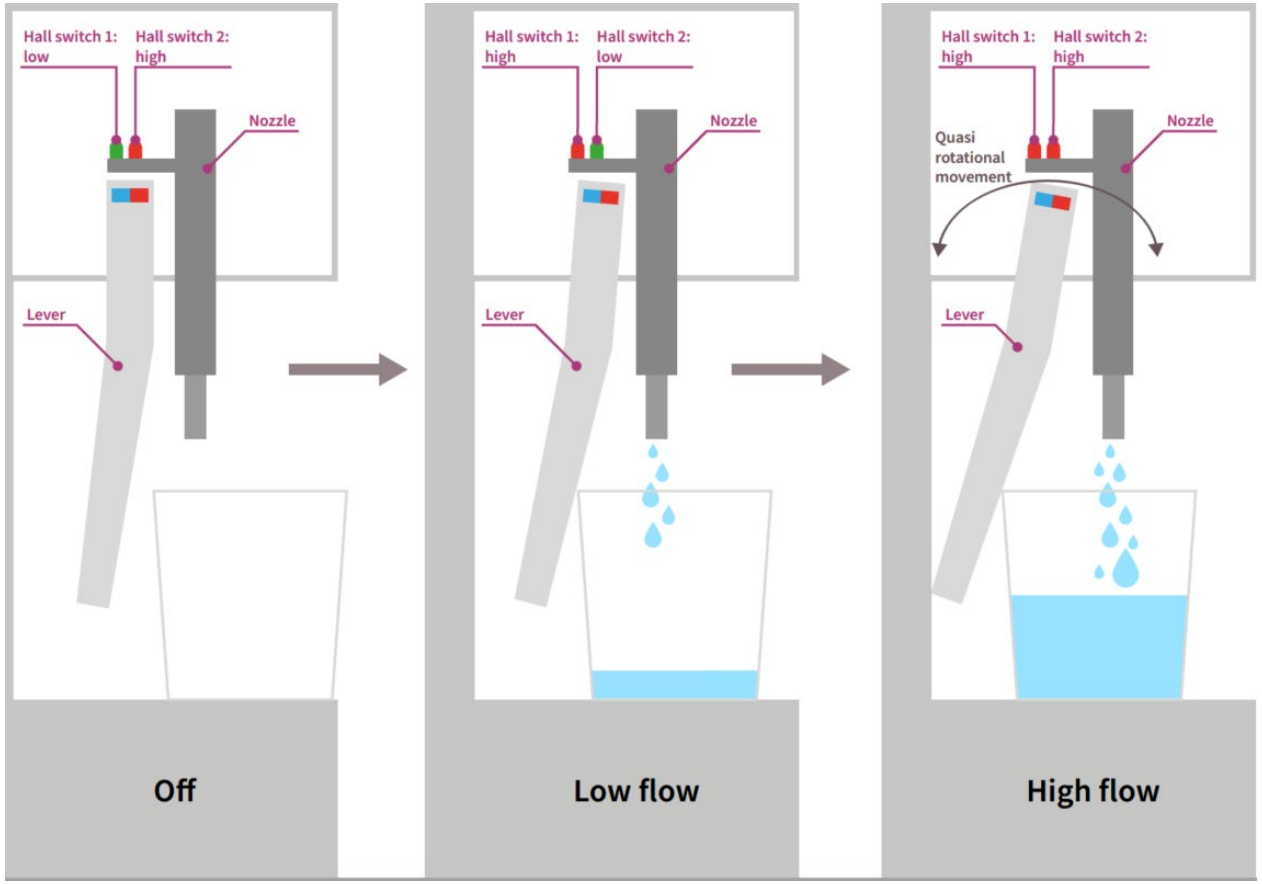
Infineon offer

- Smallest 3D Hall sensor
- Ultra low power modes and bus capability
- Several demo boards with different application use cases available
- Software modules supporting XMC and PSoC™

Water and ice dispenser positioning with XENSIV™ hall sensors

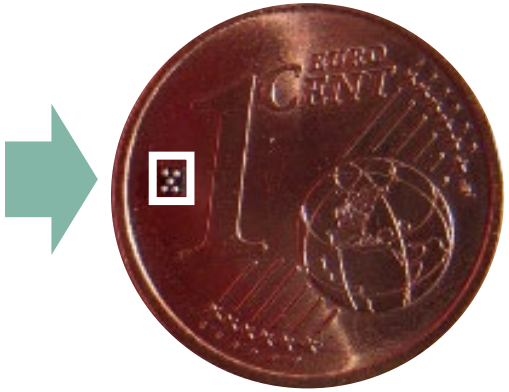
Determine position of lever to dispense ice or water

Detect the position of the lever to dispense ice or water at variable speed: The hall sensor detects the distance of the magnet mounted to the lever.



Sensors not visible

No physical contact required, therefore no mechanical wear



Infineon offer

- Smallest 3D Hall sensor
- Ultra low power modes and bus capability
- Several demo boards with different application use cases available
- Software modules supporting XMC and PSoC™

Tank and water level measurements using XENSIV™ sensors and CapSense® technology

Determine fill rate of water tank or drain pan

Keep water from overflowing, stop water inflow or inform the user accordingly.
Water tanks for the water dispenser at the right level
Avoid water leakage from the drain pan

Infineon offers several options to detect water depending on your needs

Infineon offer

- CapSense® Liquid Level Sensing Shield (Link)
- XENSIV™ radar sensor
- MEMS microphone for ultrasonic measurements

Temperature control dials: position sensor and touch sensing

Implement Human-Machine-Interface to control temperature

User adjusts temperature with a rotary control dial, mechanical buttons, touch buttons or touch screens. Infineon offers solutions for each of these options.

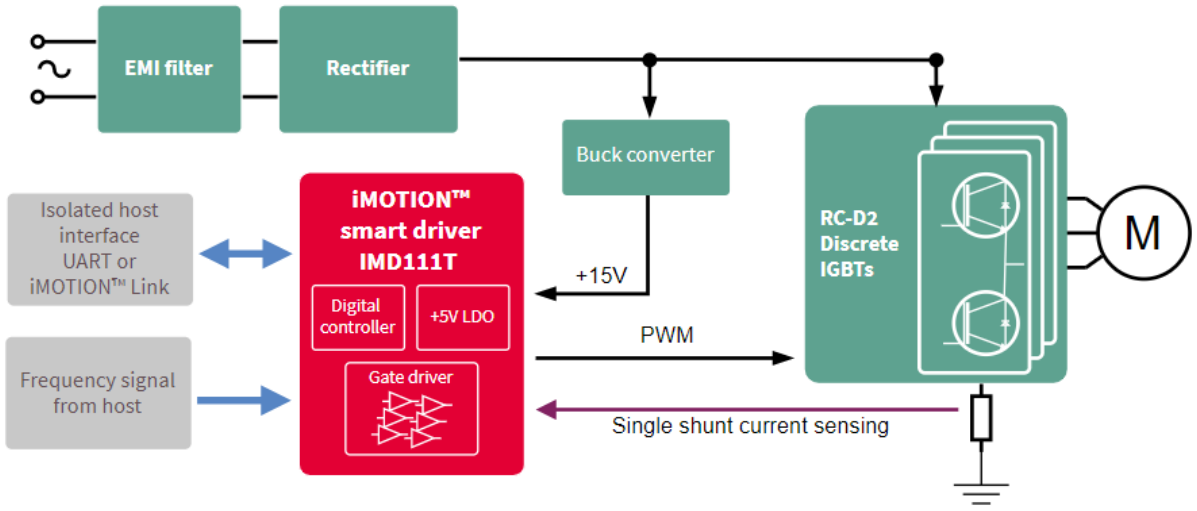
Infineon offer

- 3D magnetic sensors for rotary control dials and buttons can be easily implemented with Infineon‘s 3D magnetic sensor 2Go kits
- Touch buttons and touch screens:
  Infineon‘s PSoC™ controllers offer the most robust, sensitive and integrated solutions in the market

Table of contents

Fridge compressor up to 300 W using a discrete IGBT solution

Device	Details	Part #	Pcs
iMOTION™ driver	Controller with scripting functionality and integrated driver	IMD111	1
IGBT RC-D2	600 V Reverse Conducting IGBT Drives 2 in TO-252 package	IKD04N60RC2	6



Key features and benefits

- iMOTION™ Smart Driver + discrete IGBT
- Cost optimized
- Good efficiency at all load levels
- Low EMI
- System solution enable compact and scalable designs optimized for low losses in pull-down mode and EMI performance
- Designed for sensor-less FOC motor control using single shunt
- Easy to design-in – fast time to market

Application assumptions

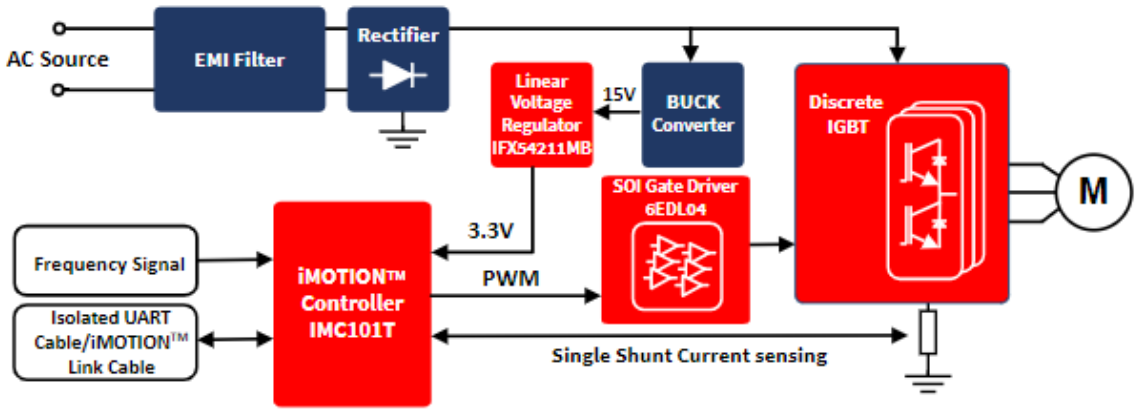
- Full load operation important, due to high thermal constraints
- Stringent cost vs. EMI trade-off
- Integration is a valuable feature, but with the possibility to tune the EMI performances of the switch

Fridge compressor up to 300 W using a discrete IGBT solution REF_FRIDGE_C101T_6ED

Device	Details	Part #	Pcs
iMOTION™	Controller with scripting functionality Fully programmable ARM MCU	IMC101T-T038	1 1
IGBT	600 V Reverse Conducting IGBT Drives 2 in SOT-223 package	IKD04N60RC2	6
Gate driver	3-phase gate driver with over current protection	6EDL04I06PT	1
Voltage regulator	Regulates input voltage up to 18V. Good for low standby currents	IFX54211MD	1

Key features and benefits

- iMOTION™ controller + gate driver + IGBT
- Highest customization possible as all components can be flexibly chosen
- Eases second sourcing
- Good efficiency at all load levels
- Cost optimized
- System solution enable scalable designs optimized for low losses in pull-down mode and EMI performance
- Designed for sensor-less FOC motor control using single shunt



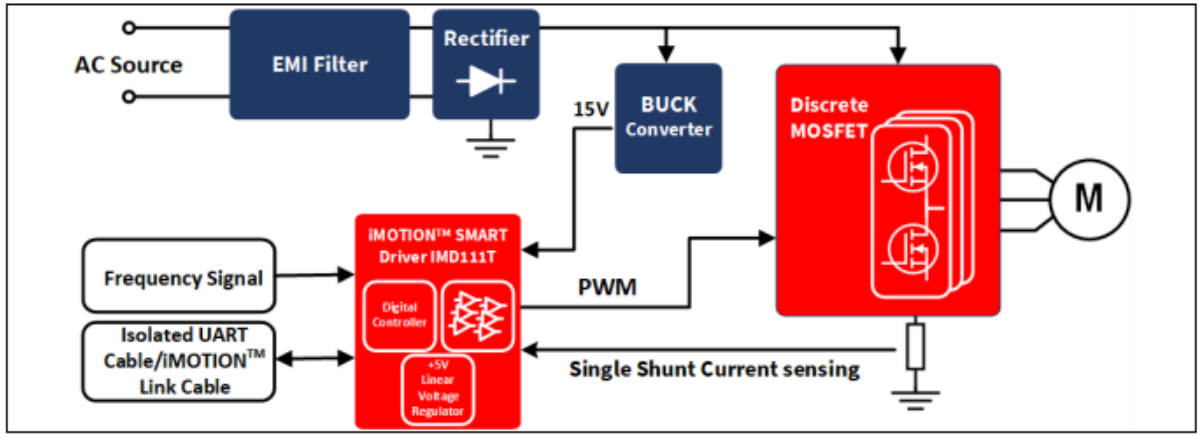
Application assumptions

- Flexibility is a must at the cost of lower integration
- Customers have the experience and preference to design and optimize the gate driver stage for highest EMI performance
- Second sourcing is a must-have requirement (except maybe for the MCU)
- Customers want to use own code (possible only with XMC™ and PSoC™)

Link to reference design

Fridge compressor up to 300 W using a discrete MOSFET solution

Device	Details	Part #	Pcs
iMOTION™ controller	Controller with scripting functionality and integrated driver	IMD111T-6F040	1
MOSFET: 600 V CoolMOS™ PFD7	SJ MOSFET with integrated fast body diode, tailored for light load efficiency in low power inverters ≤300 W, available in DPAK and SOT-223	IPN60R600PFD7S	6



Key features and benefits

- iMOTION™ Smart Driver + discrete MOSFET
- Efficiency optimized @light load
- Particularly robust towards ESD (>2kV)
- System solution enable compact and scalable designs optimized for light load efficiency Designed for sensor-less FOC motor control using single shunt
- Motor control easy to design-in – fast time to market

Application assumptions

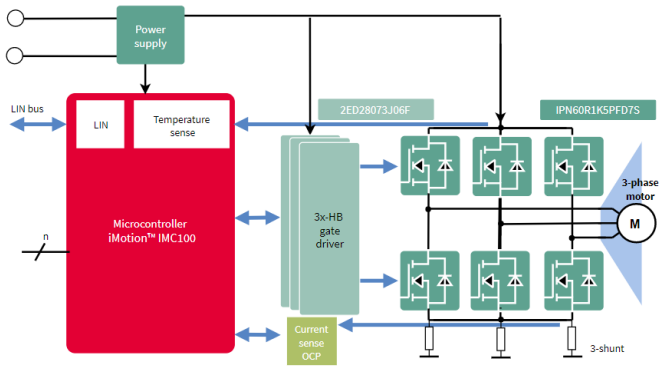
- Light load operation important, to improve energy labeling by ~1%*
- High ESD capability device level is of particular importance
- High integration solution featuring iMOTION™ Smart Driver

*compared to IGBT based solution. Reduction of yearly energy losses estimated for a typical refrigerator profile with an overall energy consumption of 214 kWh per year

Link to reference design

Fridge compressor up to 150 W using a discrete MOSFET solution

Device	Details	Part #	Pcs
iMOTION™ controller	Controller with scripting functionality	IMC101T-T038	1
MOSFET: 600 V CoolMOS™ PFD7	SJ MOSFET with integrated fast body diode, tailored for light load efficiency in low power inverters ≤300 W, available in DPAK and SOT-223	IPN60R1K5PFD7S	6
Gate driver	600 V half-bridge gate driver with integrated bootstrap diode	2ED28073J06F	3
Diode	Silicon Schottky Diode	BAT54-03W	1
Voltage regulator	Monolithic integrated fixed NPN type voltage regulator	IFX1117ME V33	1



Key features and benefits

- iMOTION™ controller + gate driver + MOSFET
- Efficiency optimized @light load
- Highest customization possible as all components can be flexibly chosen
- Eases second sourcing

Application assumptions

- Light load operation important, to improve energy labeling by ~1%*
- Flexibility is a must at the cost of lower integration
- Second sourcing is a must-have requirement
- Customers have the experience and preference to design and optimize the gate driver stage, to improve EMI vs. losses trade-off

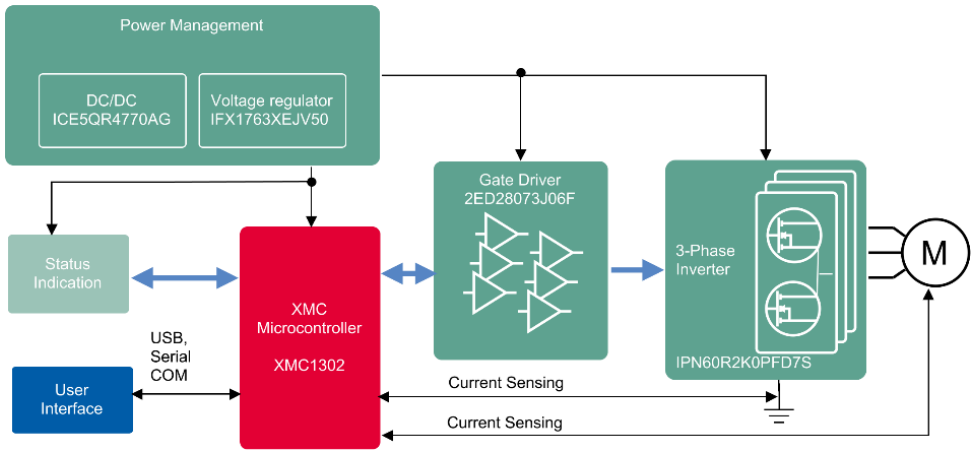
*compared to IGBT based solution.

Reduction of yearly energy losses estimated for a typical refrigerator profile with an overall energy consumption of 214 kWh per year

Link to eval board

Fridge compressor up to 100 W using a discrete MOSFET solution

Device	Details	Part #	Pcs
XMC™	32-bit Microcontrollers with ARM® Cortex®-M0 with focus on low-cost embedded control applications	XMC1302	1
MOSFET: 600 V CoolMOS™ PFD7	SJ MOSFET with integrated fast body diode, tailored for light load efficiency in low power inverters ≤300 W, available in DPAK and SOT-223	IPN60R2K0PFD7S	6
Gate driver	600 V half-bridge gate driver with integrated bootstrap diode	2ED28073J06F	3
CoolSet™ Gen5	Integrated flyback controller and power switch	ICE5AR4770	1



Key features and benefits

- Compact 3-phase motor drive system
- Designed for sensor-less FOC and Block Commutation motor control
- Speed controlled using µC/Probe™ GUI's

Furthermore, the hardware in the board and the motor control software provide:

- A synchronous rectification algorithm to reduce reverse-current hard-commutation stress
- A complete optimizable code based on customers application requirements
- 3-phase or 2-phase Space Vector Modulation (SVM)
- Hardware & software overcurrent protection

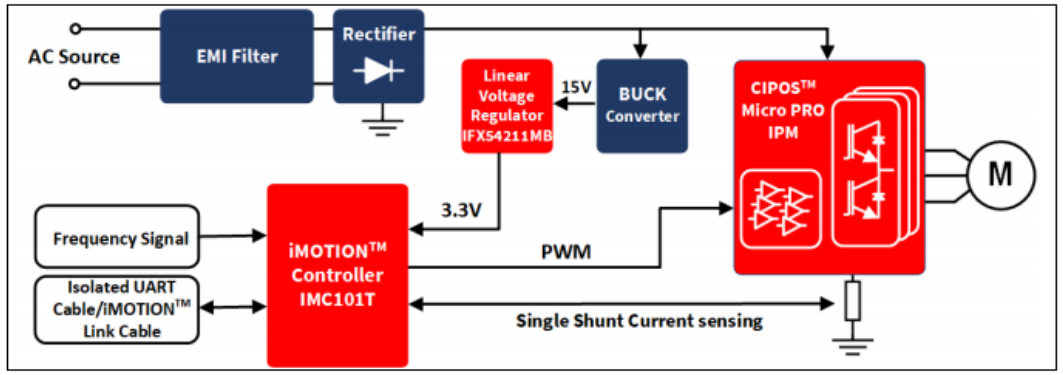
Application assumptions

- Flexible platform with open source code
- Customers want to develop/use own code
- Flexibility is a must at the cost of lower integration
- Second sourcing is a must-have requirement

Link to reference design

Fridge compressor up to 400 W using an integrated solution

Device	Details	Part #	Pcs
iMOTION™ Controller	Controller with scripting functionality	IMC101T-T038	1
CIPOS Micro IPM	Integrated Gate driver and IGBTs	IM241-S/M6T2J	1
Voltage regulator	Regulates input voltage up to 18 V. Good for low standby currents	IFX54211	1



Key features and benefits

- iMOTION™ Controller + IPM
- Power density optimized
- Good efficiency at all load levels
- Takes lowest space
- Short time-to-market
- Slow switching speed of IPM improves EMI emissions

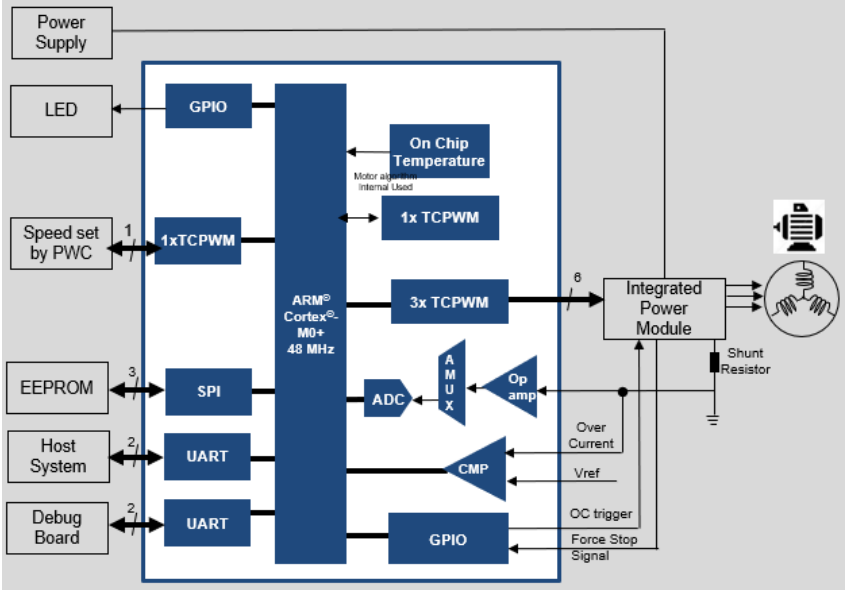
Application assumptions

- Full load operation important, due to high thermal constraints
- Stringent cost vs. EMI trade-off
- Small system size to maximize cooled volume
- Scalable platform for different refrigerator sizes, using IPMs with identical pinout

Link to reference design

Fridge compressor up to 400 W using an integrated solution

Device	Details	Part #	Pcs
PSoC™ controller	32-bit Microcontrollers with ARM® Cortex®-M0	CY8C4146AZI-S423 (PSoC 4100S)	1
CIPOS™ Micro IPM	IPM for Compressor with IGBT	IM231-L6S1B	1
CoolSet™ Gen5	Integrated flyback controller and power switch	ICE5AR4770	1



Key features and benefits

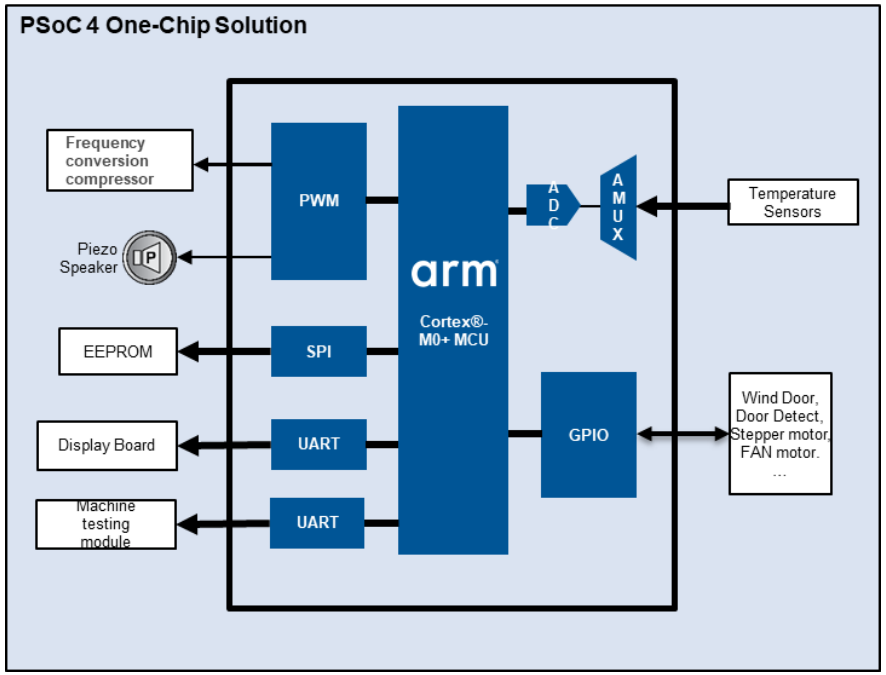
- PSoC™ for motor control which can also be used for additional system control and HMI.
- Short time-to-market, Flexible SW benefitting the individual startup performance and integrated with FOC compressor control
- Optimized SVPWM with 4us, 1-shunt sampling
- Competitive BOM cost with integrated CMP/OPA in MCU
- Directly close loop startup without open loop drag, no stop clamping, closed-loop smooth running at full speed.
- Full scale protection: over/under voltage, over current (phase current and AC input), motor running power real-time calculation and protection, IPM over temperature, sample hardware fault, phase loss, rotor lock.

Application assumptions

- Full load operation important, due to high thermal constraints
- Stringent cost vs. EMI trade-off
- Small system size to maximize cooled volume
- Scalable platform for different refrigerator sizes, using IPMs with identical pinout
- PSoC: Integrated with OpAmp to reduce BOM cost
- Reliable motor control algorithms

Fridge system control

Device	Details	Part #	Pcs
PSoC™ controller	32-bit Microcontrollers with ARM® Cortex®-M0	CY8C4146AZI-S423	1



Key features and benefits

- One chip solution for system control
- Integrates all main control functions and communication interfaces in a powerful Arm® Cortex® - M0
- Includes up to 256 KB Flash to store configuration profiles
- Provides class B library for safe operation
- Integrated CapSense and segLCD features to support system control and HMI 2in1 solution.

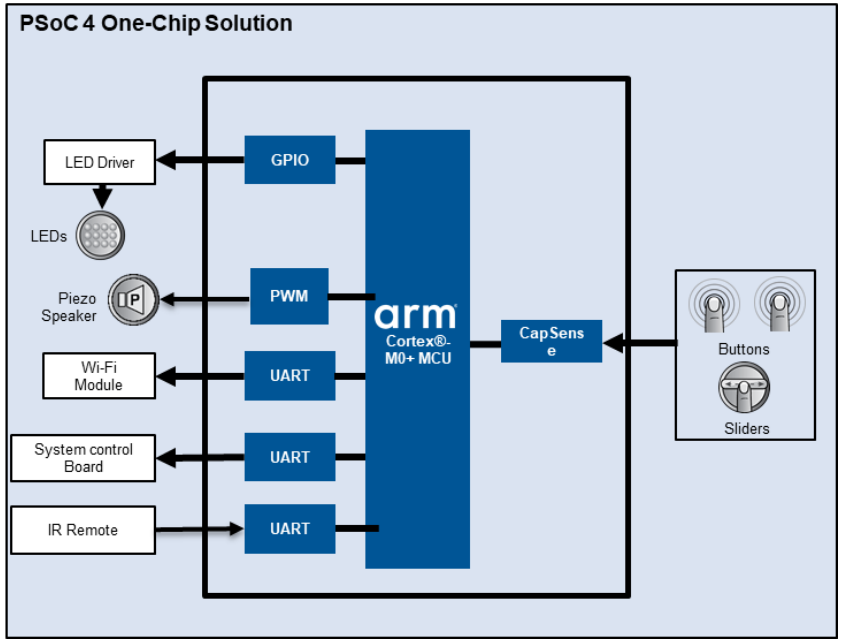
Application assumptions

- Implement all main control functions and communication interfaces in single chip.
- Requires Class B certification
- Integrated system control and HMI in single chip.

Link to demo board

Fridge touch display using CapSense® and display 2-in-1 HMI

Device	Details	Part #	Pcs
PSoC™ controller	32-bit Microcontrollers with ARM® Cortex®-M0	CY8C4025AZI-S413	1



Key features and benefits

- PSoC™ 4 integrate the SegLCD and CapSense® user interfaces to implement 2in1 HMI one-chip solution.
- Includes up to 256 KB Flash to store configuration profiles and Support OTA feature.
- Provides class B library for safe operation.

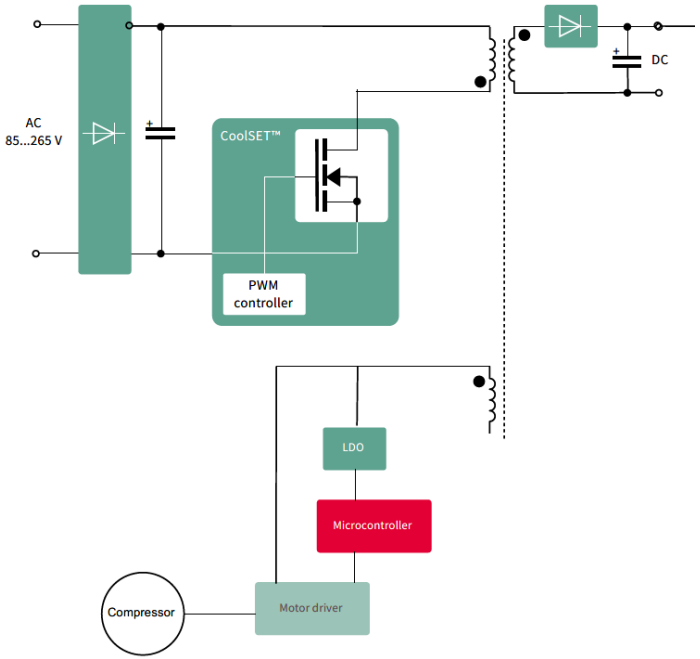
Application assumptions

- Implement all HMI functions and communication interfaces in single chip.
- Requires Class B certification
- High density Flash to support OTA
- Seems it's a trend to integrated system control and HMI in single chip.

Link to demo board

33 W refrigerator auxiliary power supply

Device	Details	Part #	Pcs
CoolSET™	Quasi-resonant flyback controller with integrated 700 V MOSFET	ICE5QR1070AZ	1



Key features and benefits

- Auxiliary power, PWM controller and MOSFET in one package
- High power delivery in SMD package up to 42 W
- Very low dpm rate
- Efficiency: 84%
- Input frequency: 47-64 Hz
- Output power of ref design: 33 W

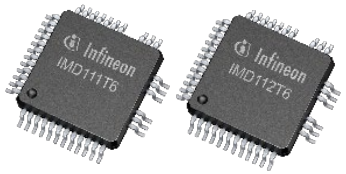
Application assumptions

- Robust line input protection
- High efficiency
- Cost efficient with multi-output SMPS design

Link to reference design

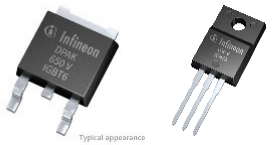
Table of contents

iMOTION™ SmartDriver turning any motor



Key features SmartDriver IMD110		Key value
Flexibility	The SmartDriver can drive **almost an MOSFET or IGBT** in a variable speed drive inverter	**Design re-use** for multiple power ratings
Ready to use	Field proven Motion Control Engine (MCE 2.0) provides **motor and PFC control algorithm**	**Shortest time-2-market**
Robustness and Reliability	**Rugged and reliable** SOI gate driver and package with improved **creepage and clearance**	**Robust and reliable** drive inverter
Cost optimization	High integration and small package for **reduced BOM cost**	**Reduced system costs**
Functional safety	Full set of **protections** in hard- and software and support for safety acc. to **IEC 60335 ('class B')**	**Protection in design and application stage**

Focus product / 650 V TRENCHSTOP™ IGBT6
Performance optimized for low power drive up to 300 W

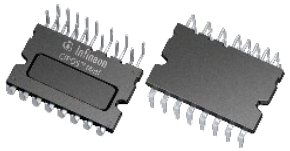


Key features 650 V TRENCHSTOP™ IGBT6		Key value
Lowest V_{CEsat} & low switching losses	Optimized for low conduction losses, best-in-class efficiency in low power motor drives up to 1 kW	**Low losses** to meet energy efficiency requirements
Best-in-class controllability	Great trade-off between controllability and switching losses	**Lower system cost** on EMI filtering
650 V breakdown voltage	Increased reliability	**Additional headroom** for unstable grid voltages

Focus product / 600 V RC-D2
Optimized for low power drive < 300 W

Key features 600 V RC-D2		Key value
New price/ performance standard	Optimized for consumer drives	**Great** trade-off between price and performance
Broad portfolio	DPAK: offered in 4 variants with a collector current IC ranging from 4 to 15 A; SOT 223 package variants available in Q4 2021	Drop in **replacement**
Improved EMI	Enhanced controllability to reduce EMI noise compared to previous RC-D technologies	**Easy to design in**
HV-H3TRB ruggedness	HV humidity ruggedness improvement to protect the system	**High system reliability**

CIPOS™ Mini IM51x-series IPM with CoolMOS™ MOSFETs



Key features CIPOS™ Mini IM51x-series		Key value
High efficiency	High efficient intelligent power modules that integrate CoolMOS™ MOSFETs to improve power efficiency of applications, such as compressors, pumps, and fans, or other motor drives up to up to 600 W	Improved energy efficiency
Excellent light load efficiency	The integrated CoolMOS™ MOSFETs offer significant lower switching and conduction losses comparing to IGBTs. It enables IM512x-series to reduce power consumption, especially under light load conditions.	Reduced power consumption
2- or 3-phase inverter configuration	IM51x-series offer low on-resistance of 310 mΩ and 10 A at 25°C with 600 V break down voltage. Full-bridge (IM512) and 3-phase (IM513) inverter configuration are available for easy implementation.	Ease of use
Enhanced reliability	The system reliability is further enhanced by the built-in NTC for temperature monitoring, integrated under-voltage lock-out function, and an over-current protection (OCP) features..	Stable system reliability

Focus product / 600 V CoolMOS™ PFD7
Optimized for light-load performant low power drives < 300 W

Key features 600 V CoolMOS™ PFD7		Key value
Light-load efficiency up to 300 W	Attractive solution for refrigerator compressors, offering **improved efficiency,** especially at steady state & **light load conditions below 300 W**	Increased **efficiency** and improved **thermal behaviour**
Best-in-class fast body diode	Integrated robust **fast body diode** with ultra low Q_{rr} & industry's **fastest recovery time** (T_{rr})	**Robustness** and **reliability** Reduced **switching losses**
Integrated ESD protection	**Integrated Zener diode** for ESD protection ≤ 2 kV (HBM Class 2)	Eliminated **ESD related yield losses**
Right-fit portfolio	Wide range of $R_{DS(on)}$ values ≤ 2 Ohm and industry-leading SMD package offering (e.g. SOT-223)	**BOM cost** reduction & **PCB savings** **Easy manufacturing**

Focus product / Gen 5 CoolSET™
High efficiency & low standby for HA aux power solutions

Key features Gen 5 CoolSET™		Key value
Broad portfolio	Highest power delivery up to 43 W in DIP & DSO package	BOM savings
Higher performance	High light-mid load efficiency and low standby	High performance design
Ease of design	Numerous aux power reference designs with design tools/guide & application notes	Faster time to market
Highest quality & system robustness	Integrated with 700 V or 800 V superjunction mosfet and comprehensive protection features	Reliable supplier

Part of your life. Part of tomorrow.