以“小”见大，英飞凌变频冰箱高集成参考设计全系列

Peter Wang(IPC GC TM FAE)
Aug 2022

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2	Why choosing IMD111T for fridge applications?	8
3	Infineon IMD reference design for fridge applications	14
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增加节能家电将意味着节省更多的能源消耗

如果用英飞凌半导体产品
实现世界上所有冰箱的变频化，节省的能源相当于瑞典一年消耗的能源

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变频化将推动未来几年全球对功率半导体的需求

	2020		2024	
Room aircon	77%	~122m with VSD motors	CAGR$_{20-24}$: 13%	99%	~201m with VSD motors 3 VSD motors per device: compressor, indoor fan, outdoor fan
Washing machine	74%	~88m with VSD motors	CAGR$_{20-24}$: 10%	94%	~130m with VSD motors 2 VSD motors per device: drum, lye pump
Refrigerator	40%	~69m with VSD motors	CAGR$_{20-24}$: 21%	75%	~149m with VSD motors 1 VSD motor per device: compressor

Source: Omdia, “Major Home Appliance Market Report", November 2020

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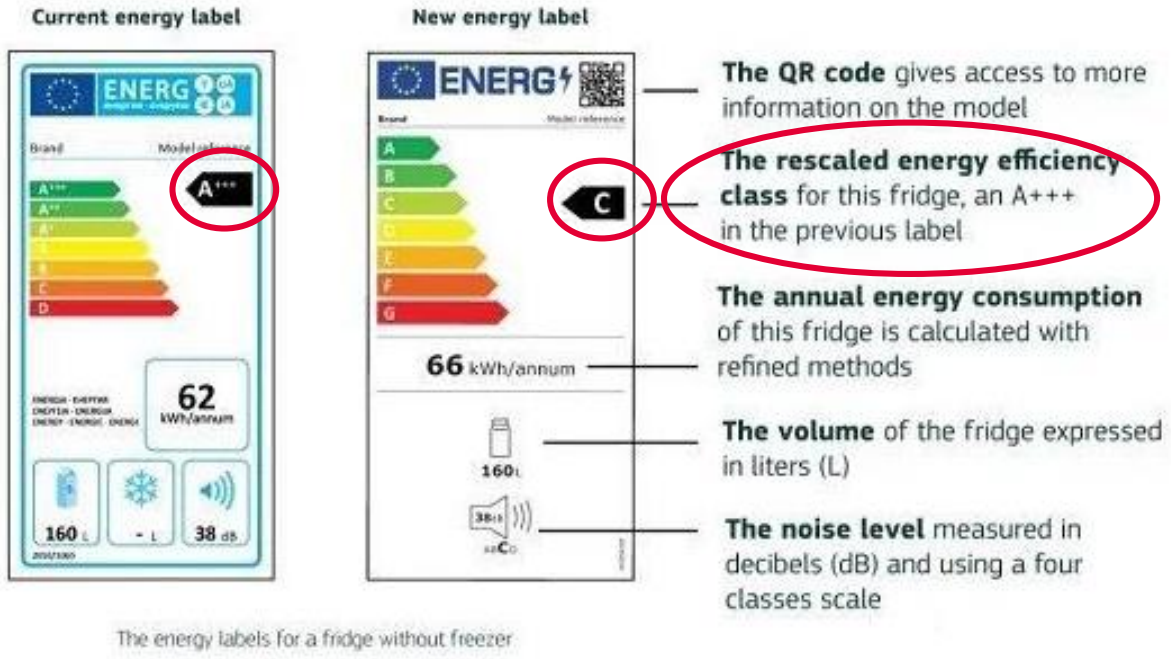
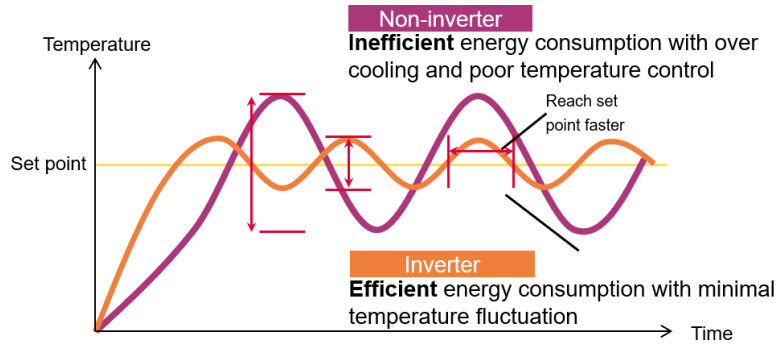
能源效率法规推动了变频化

› Energy efficiency regulations drive the use of inverters for motor control.
(EN 60335-2-24:2010/A1:2019+A2:2019, implemented from March 1st, 2021)

› Motor speed is automatically controlled on inverter models, smaller temperature variations contribute to energy efficiency



The energy labels for a fridge without freezer



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冰箱应用的设计要求

- Full power 250W (up to 300W)
- Standby power < 0.5W
- High pressure compressor startup
- Complex system control logic:
  - State machine driven by power estimation
  - Error handler
- Control interface: frequency input 30~150Hz
- Rapid development cycle. (6 months Design-in/Design-win to production)
- Lower system cost – single layer PCB, size reduction (PCB, DC bus cap)

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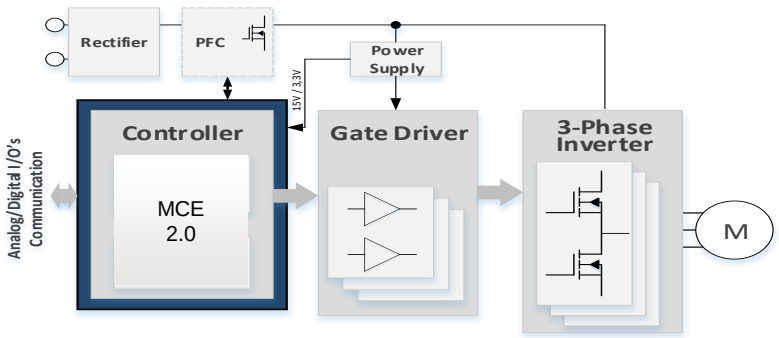
iMOTION™ 硬件集成

Flexibility → **Integration**

iMOTION™ 2.0 Controller

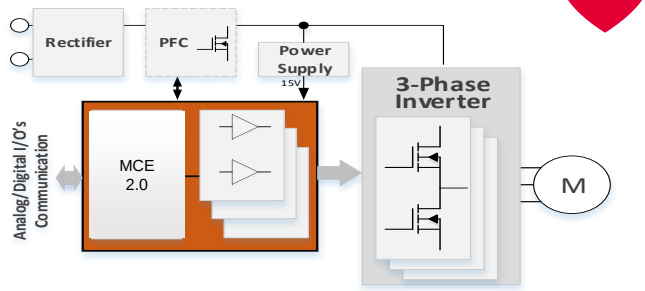


Digital Controller
MCE 2.0

Controller + Gate Driver + MOSFET's

Controller + IPM

iMOTION™ 2.0 Smart Driver



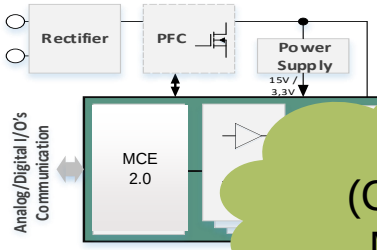
Digital Controller
MCE 2.0

+600V Gate Driver

Smart Driver + MOSFET's

User Trend

iMOTION™ 2.0 Smart IPM



IMI200 (CIPOS™ Micro)?

Digital Controller
MCE 2.0

+600V Gate Driver

+3ph 600V MOSFET power stage

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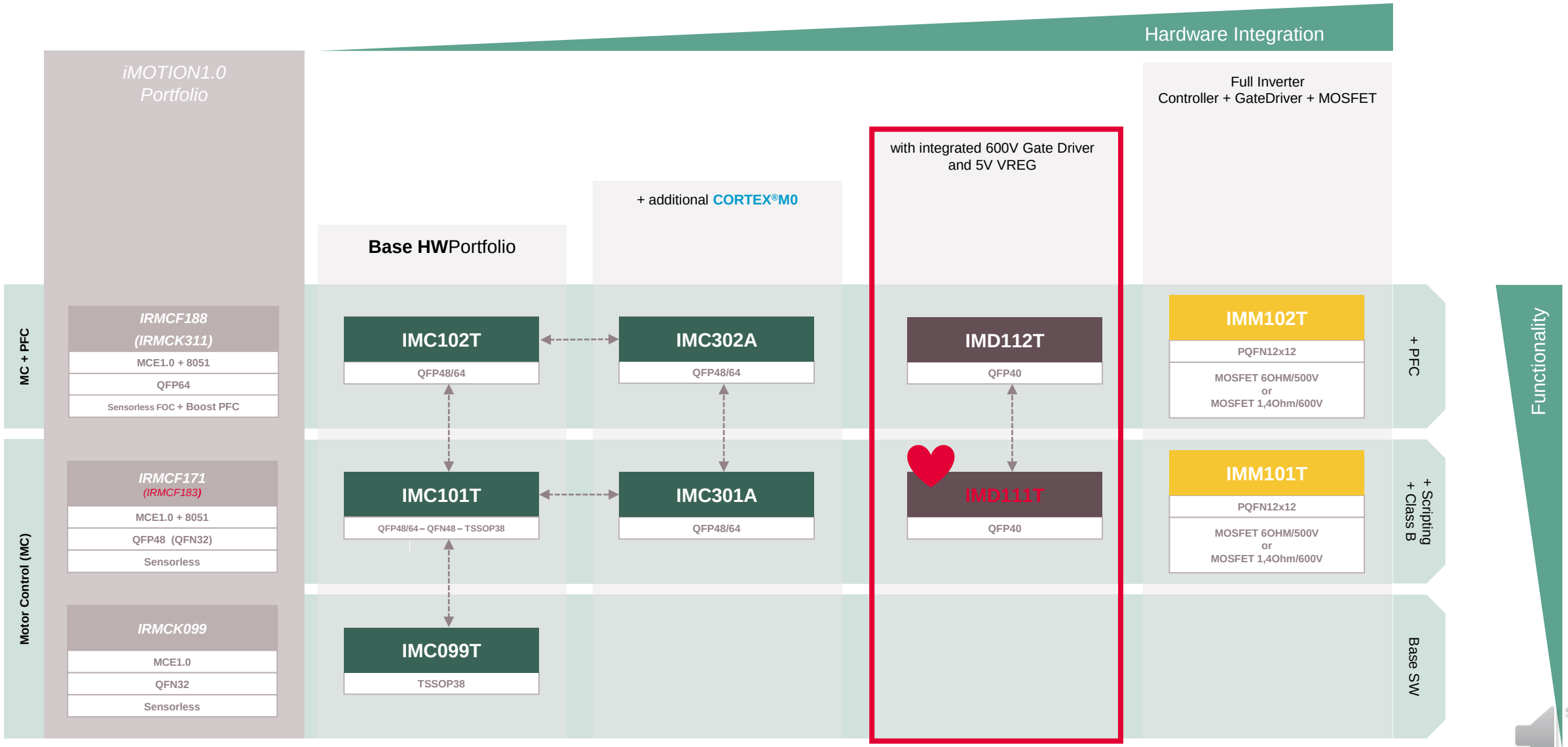
iMOTION™ 2.0 产品组合



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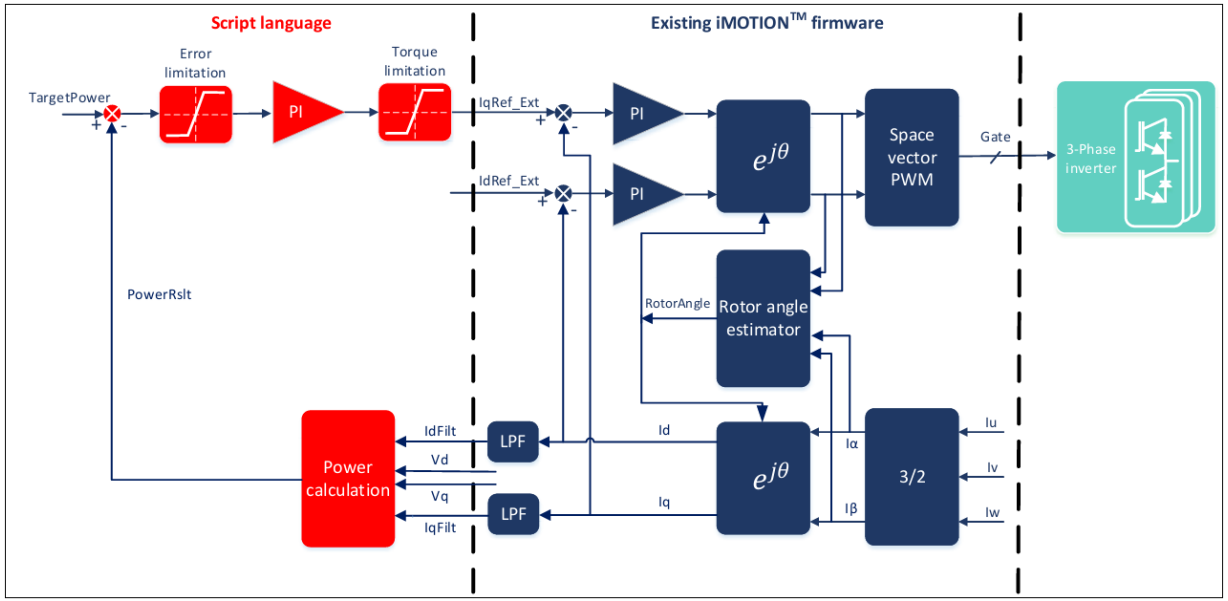
脚本引擎处理复杂的系统控制逻辑



› [Power calculation and constant-power control]

› **Script sample code in application note:**

```
001        DPwr = (IdFilt*Vd)>>12;   //Q12
002        QPwr = (IqFilt*Vq)>>12;   //Q12
003
004        TempVar = (PowerScl * (QPwr+DPwr))>>12;
005        //LPF Ts 1ms (2.5Hz -3db)
006        PwrMultiDEN= PwrMultiDEN + (TempVar - PwrRslt2);
007        PwrRslt = PwrMultiDEN >> 6;
```

› **Customer's script code for power calculation:**

```
/**********Power Derating and protection**************************/
    L_DPwr=(IdFilt*Vd)>>12; //Q12
    L_QPwr=(IqFilt*Vq)>>12; //Q12
//Power calculation code with DC bus compensation enabled
    L_TempVar1=(L_PwrScl*(L_DPwr+L_QPwr))>>12;
    L_Pwr_MultiplyDEN=L_Pwr_MultiplyDEN+(L_TempVar1-G_PwrRslt);
//Power calculation code with DC bus compensation disabled
    //L_TempVar1=((L_DPwr+L_QPwr)*VdcFilt)>>11;
    //L_TempVar2=(L_PowerScl*L_TempVar1)>>12;
    //L_Pwr_MultiplyDEN=L_Pwr_MultiplyDEN+(L_TempVar2-G_PwrRslt);
      G_PwrRslt=L_Pwr_MultiplyDEN>>6;//1count=0.01W
```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灵活的电机启动方法

- Direct Start-up
- **Park+Open-loop+Closed-loop: high pressure compressor startup**
- Catch Spin Start-up
- Angle Sensing Start-up

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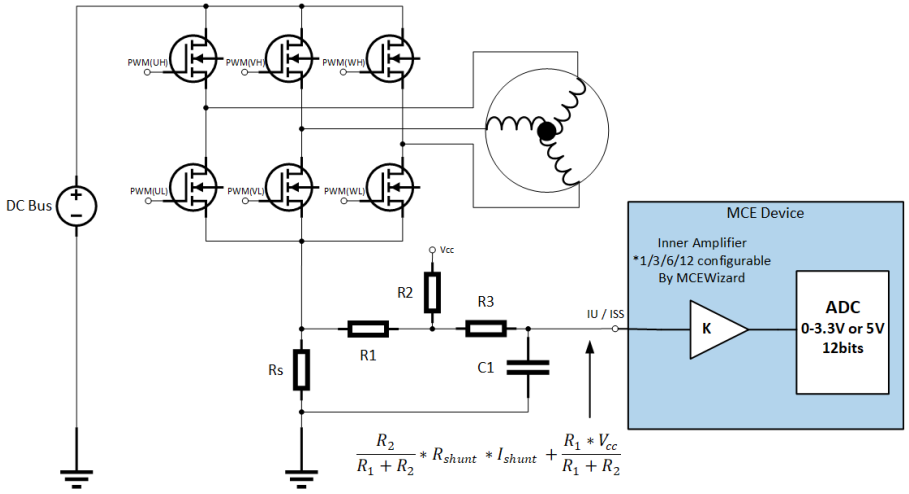
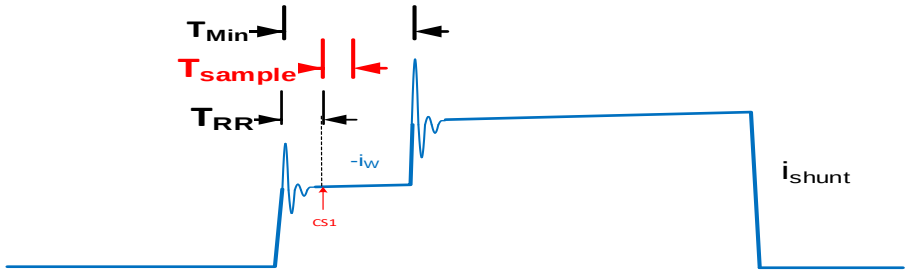
低成本的电机电流检测

- IMD solution can provide lowest cost motor current sensing:
  - No additional external OP-Amp are required (Internal Gain can be set via MCEWizard: 1x, 3x, 6x,12x).
  - Good current reconstruction with single shunt configuration.
    - Phase shift SVPWM can guarantee the AD sampling quality.





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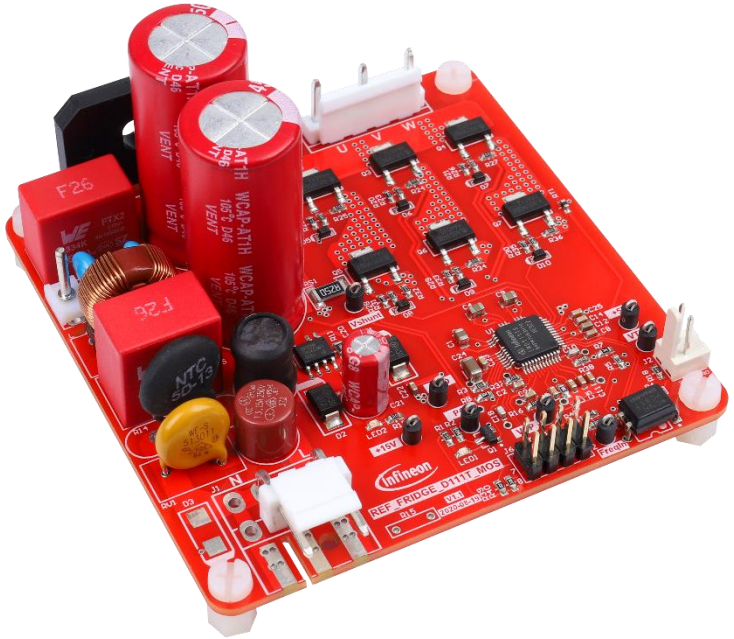
冰箱参考设计板(双层 PCBA板)

- **REF_Fridge_D111T_CoolMOS SOT223**
  - IMD111T-6F040 + CoolMOS SOT223
- REF_Fridge_C101T_IM231
  - IMC101T-T038+IM231-L6S1B
- REF_Fridge_C101T_6ED_IGBT DPAK
  - IMC101T-T038+6EDL04I06PT+IGBT RCD2 DPAK
- Dimension: 78*78 mm
- Application: Fridge, Fans, Motor Drive etc.



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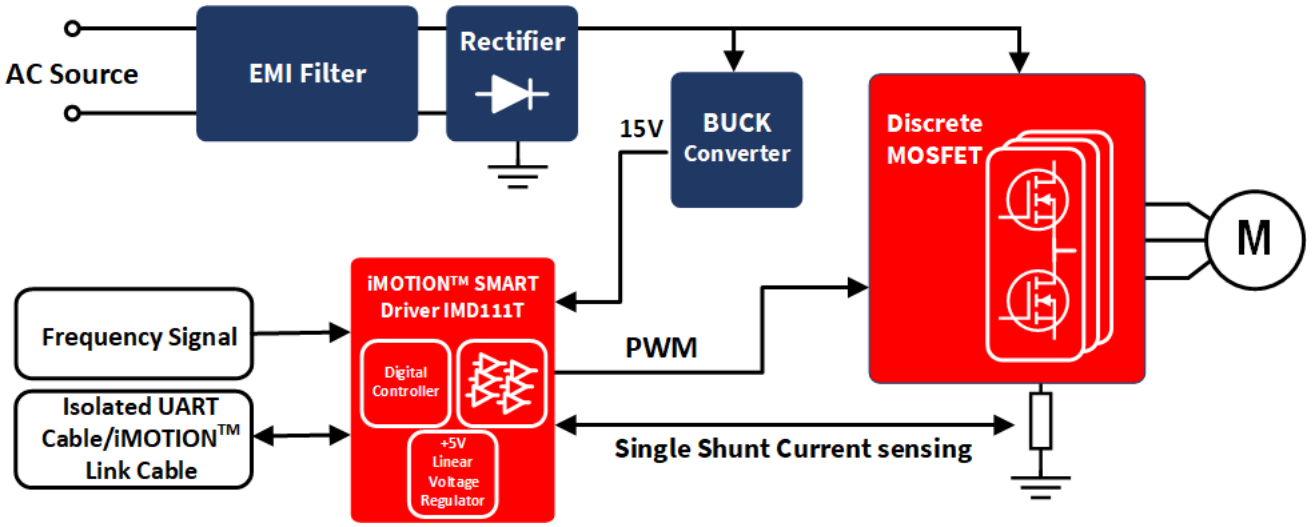
REF_Fridge_D111T_CoolMOS SOT223 特点

- iMOTION™ SmartDriver IMD111T-6F040
- Ready-to-use motion controller with scripting engine and 6-channel SOI driver
- 600V CoolMOS™ PFD7 – optimized technology with lowest Qrr, ESD protection and compact SOT223 SMD package
- System solution enables best light load efficiency and compact design



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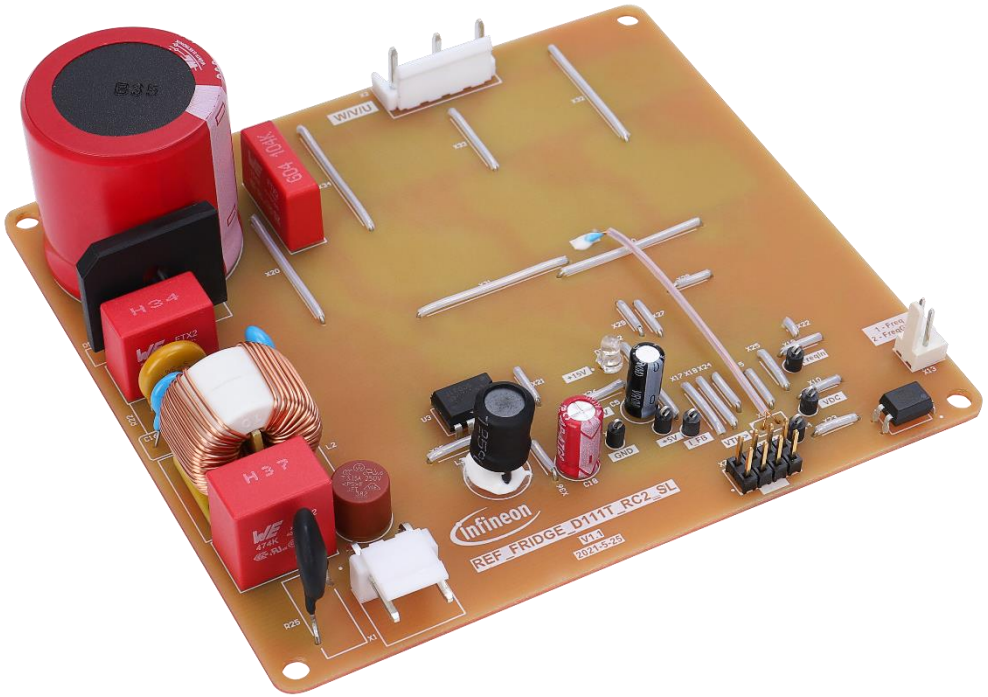
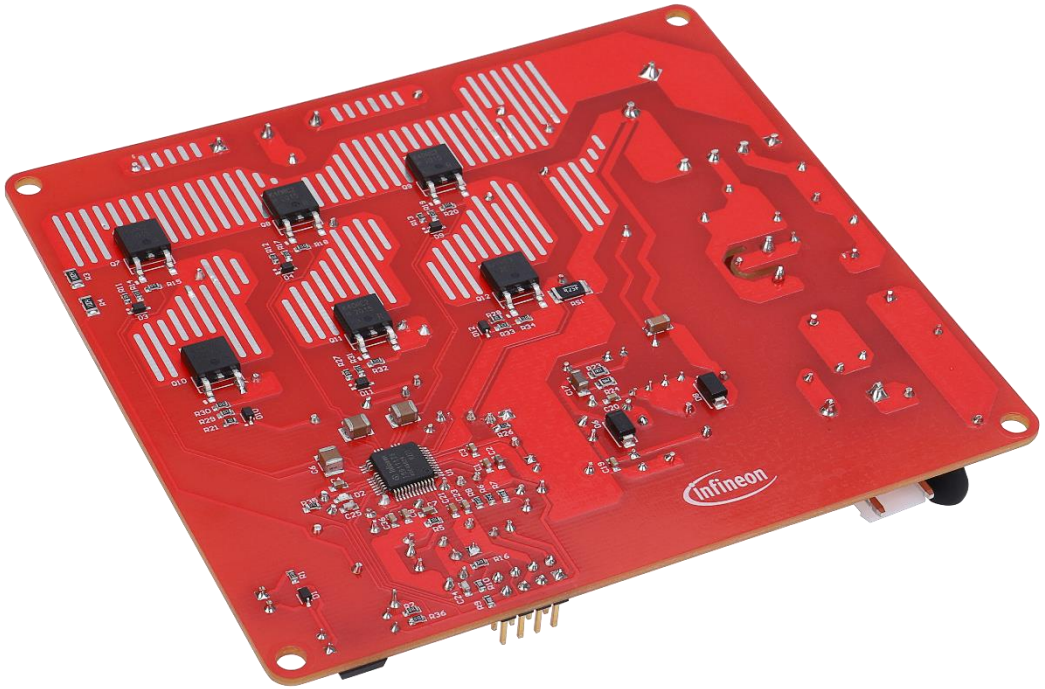
单层冰箱参考设计板





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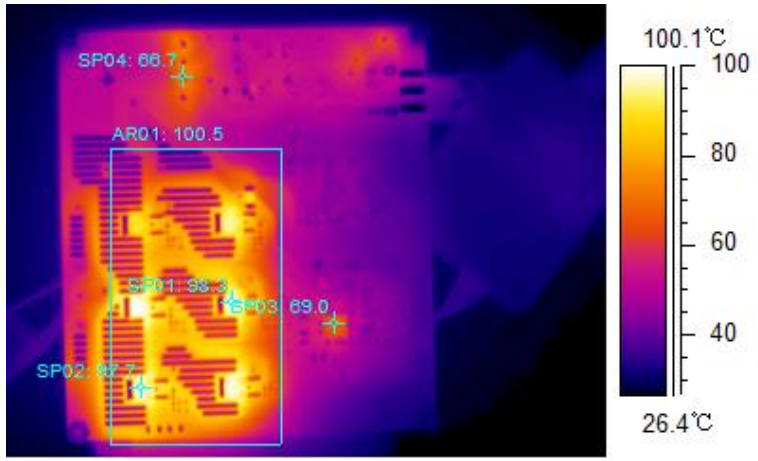
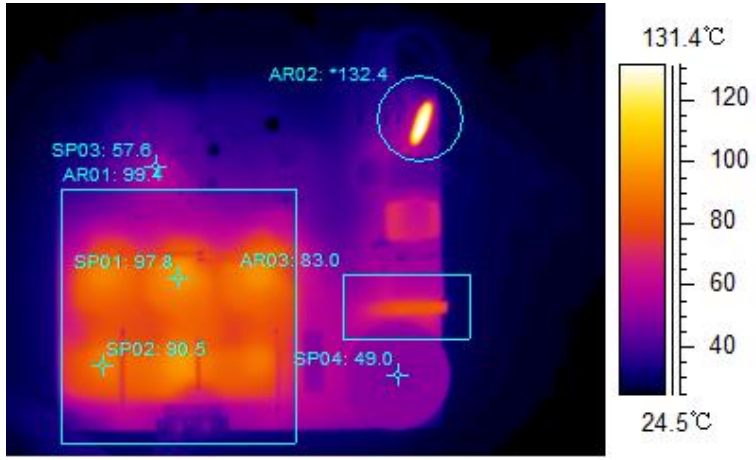
满功率温升性能

› 250W 1.2A phase current

Back side



Front side



Thermal characterization case temperature – input power 250W, ta = 25°C	
Board Type	Maximun case temperature(°C)
Two layers IMD reference design board	97
Single layer IMD referencedesign board	100.5

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基于单层板解决方案的待机功率测量

› Customer’s requirements for standby power: <0.5W

Input power of single-layer reference design board: 0.454W

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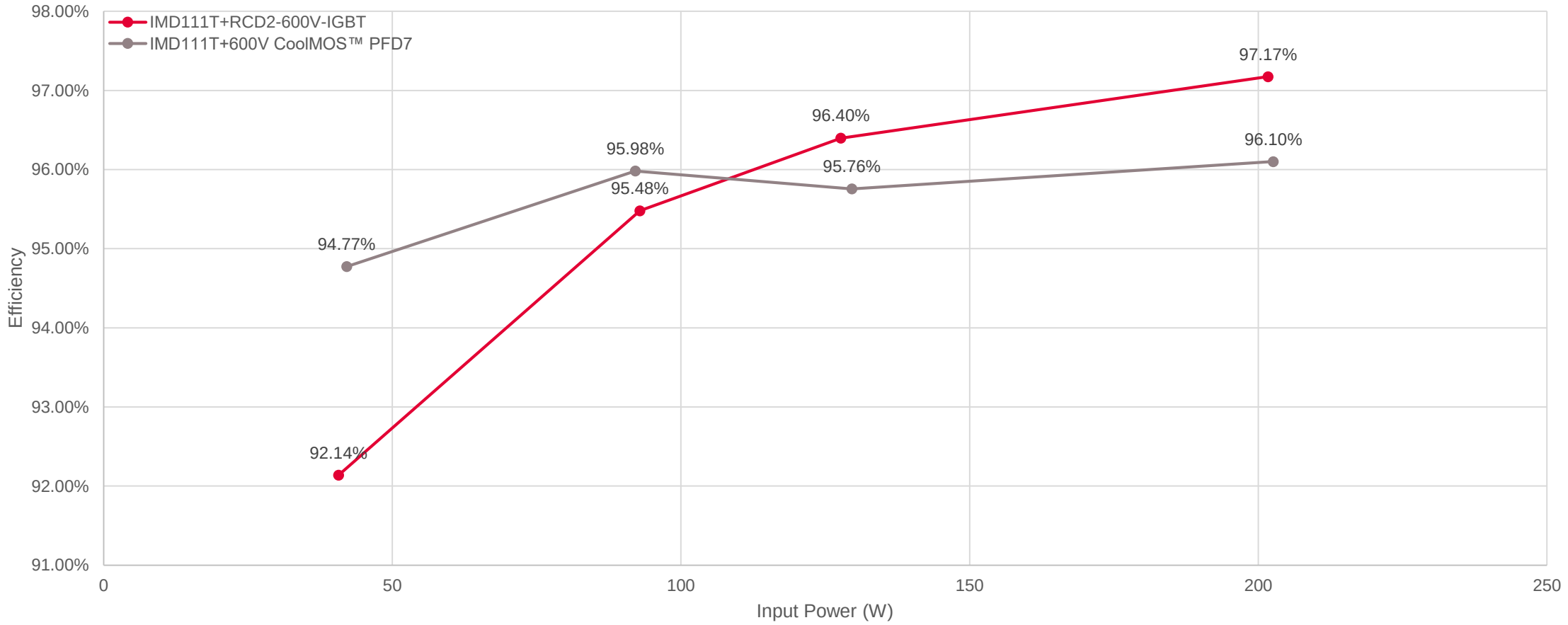
参考设计板的效率比较

› Compare the board efficiency between the IMD111T+IGBT with IMD111T+MOSFET solution based on the fridge compressor. （Based on 5kHz PWM frequency）



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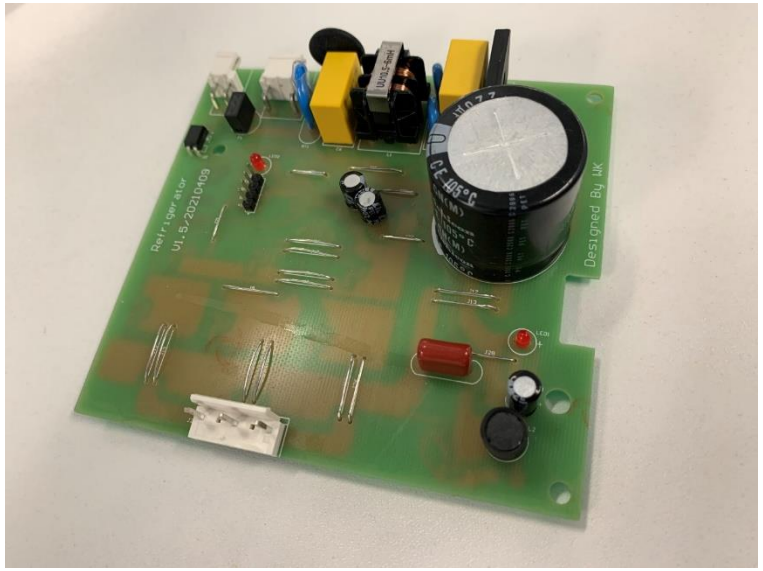
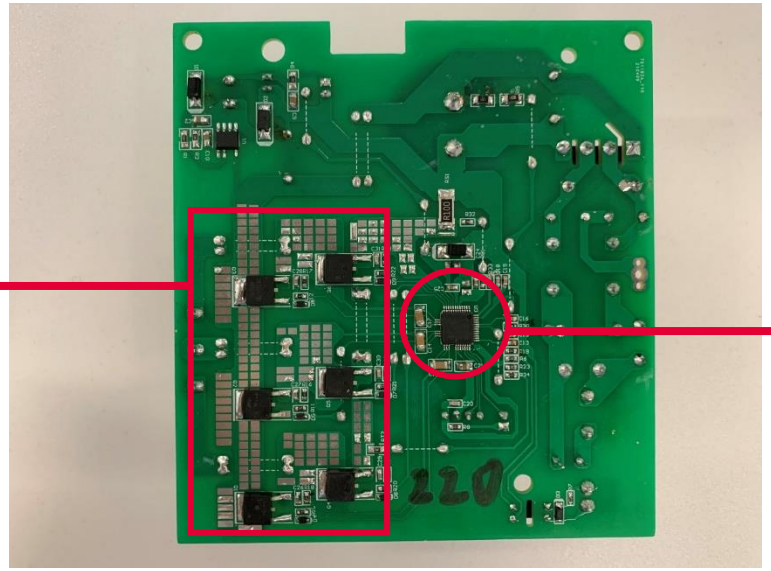
单面板PCBA案例

- PCB information: 113mm*104mm, 2oz, FR-4
- Control input: frequency control 30~150Hz (mapping to 1200~4200rpm)
  - Infineon components: IMD111T + IKN04N60RC2 *6
  - 2-layer of same size would cost 0.4USD more



IKN04N60RC2 * 6 pieces



IMD111T-6F040

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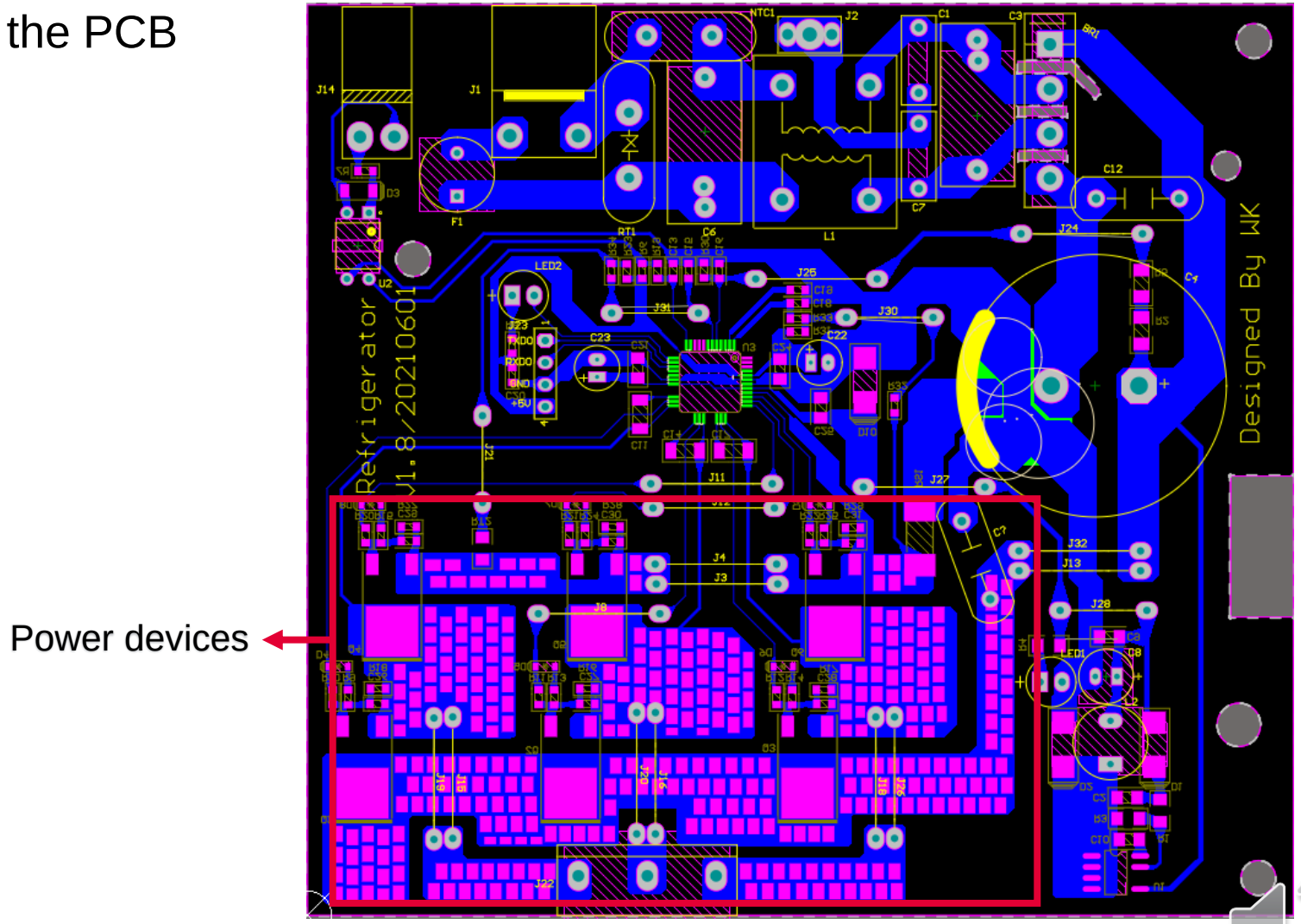
单面 PCB 布板重要点1

1. Additional dummy pads to increase the PCB heat sink capability.



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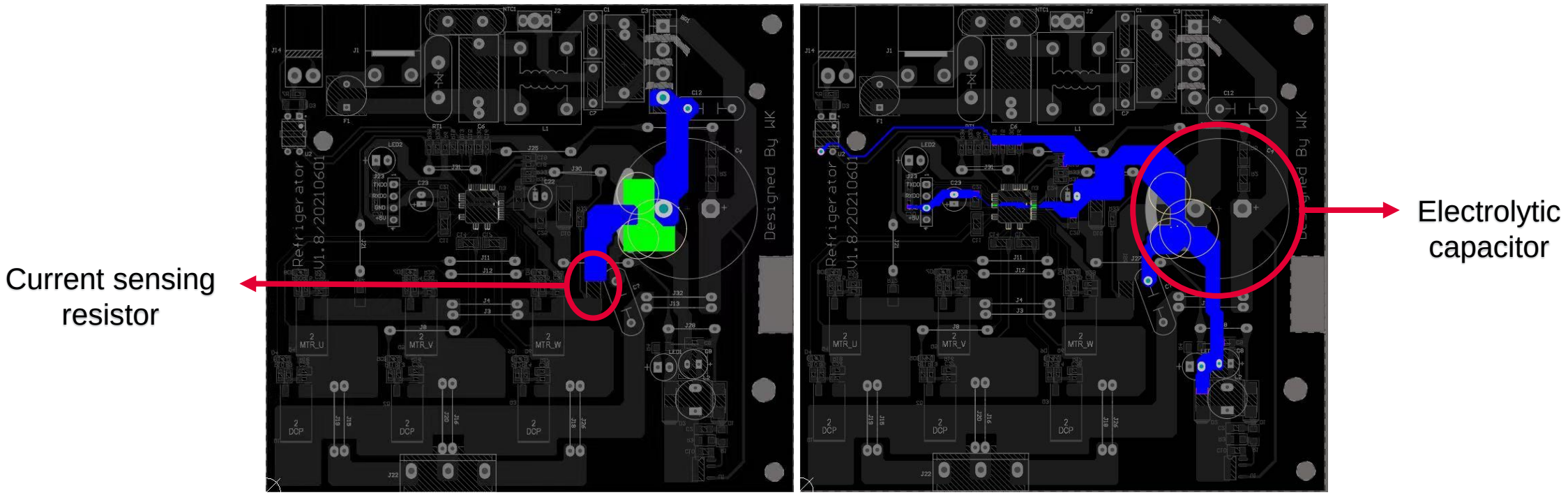
单面 PCB 布板重要点2

2. Power ground and digital ground are connected to the electrolytic capacitor at a single point. Avoid the jump wire for ground layout.



› Power ground

› Digital ground

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英飞凌iMOTION™资料提供

Application pages

- Home Appliances
- Video - New power products for home appliances (S1)

Collaterals and brochures

- Articles, Whitepapers, …
- Application Notes
- Videos
- Product Information IMC100, IMC300, IMD110 and IMM100 (partly on myInfineon)

Software

- MCE Firmware
- MCE Wizard/Designer

Evaluation boards / Reference designs

- MADK – Control and Power boards
- Reference Boards – available on the product family / application pages

Support

- Infineon Developer Community: iMOTION and MADK
- disti.techsupport@infineon.com

For further information visit

www.infineon.com/iMOTION
www.infineon.com/MADK
www.infineon.com/IPM

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如何在冰箱应用里面设计IMD（内置驱动）– 主要结论

Motor controller with 600V three phase gate driver and 5V voltage regulator

Rapid development cycle and lower system cost

Rich IMD reference design for fridge applications

Single-layer PCBA success story for fridge application

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英飞凌旗舰店

There are four fridge reference boards on sale!! Look forward to more boards launches!!

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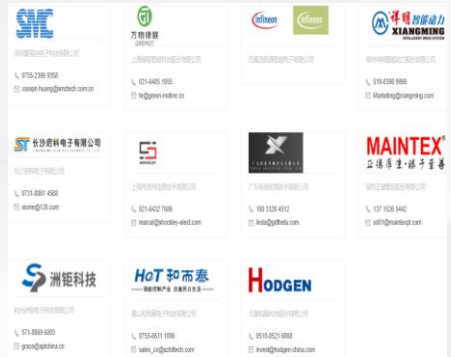

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