The Problem with Traditional Vaccine Storage Freezers and How ROHM Cutting-edge Power Solutions Can Take them to the Next Level

White Paper

Introduction

Some vaccines are highly sensitive to temperature variations and must be stored at ultra-low temperatures (ULT) from the point of manufacture until just before administration to the patient. The Pfizer COVID-19 vaccine, for example, initially required super-cold storage, with temperature maintained below -60 °C (-76 °F). In the manufacturing plant and associated warehouses, maintaining these temperatures is not difficult. But as the vaccines are transported out to distribution, and then to patients, maintaining those ultra-low temperatures becomes more difficult and more costly.

The term “cold chain” refers to the supply chain that delivers products or materials that will be spoiled or destroyed if temperature varies beyond a prescribed range. Many food items, chemicals, and pharmaceuticals require tightly controlled “cold chain” logistics. The hardest part of a deep freeze temperature-controlled supply chain is the “last mile” problem. For vaccines that require extremely low temperature storage, expensive and technically complicated ultra-low temperature freezers are necessary at or near every point of vaccine administration, all over the world.

How ULT Freezers Work

Standard, short term storage freezers can typically only reach temperatures down to -20 °C, using a single stage compressor refrigeration cycle. Ultra Low Temperature (ULT) freezers, on the other hand, use a cascade refrigeration cycle with multiple compressor stages. ULT freezers commonly use two compressor stages to reach temperatures as low as -86 °C.

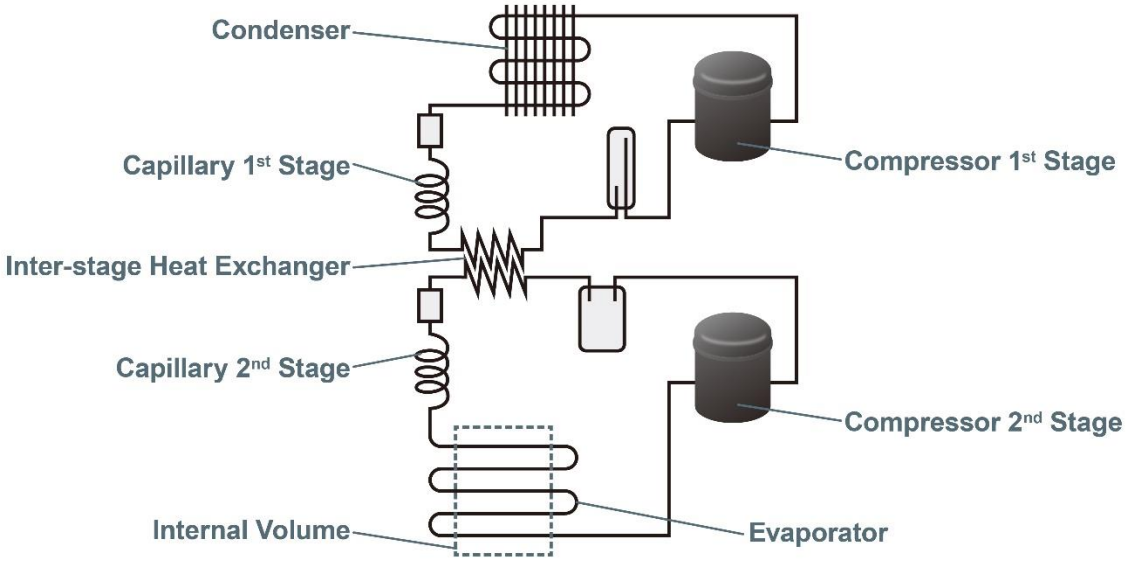


Figure 1: A two-cycle cascade refrigeration process schematic diagram

Refrigeration / freezer compressors are devices that compress a refrigerant in the condenser coils as part of the refrigeration process. This compression increases the pressure and creates heat, which is then removed from the refrigerant. In the evaporator coils, the pressure is much lower, causing evaporation (which is what lowers the temperature inside the freezer). Evaporation is an endothermic process, meaning that it absorbs heat. So the compressor is rightfully analogized as the “heart” of a refrigeration system.

Refrigeration compressors typically use a simple, inexpensive induction motor to do the compressing work. In a ULT freezer, the refrigerants are changed to provide efficiency at the proper temperatures, but the compressors are usually just two standard machines based on induction motors.

The Problem With Traditional ULT Freezers

There are a few significant problems with using these standard induction motor-based compressors in a ULT freezer. The most significant is simple inefficiency. Induction motors are fairly inefficient (often around 70 % -- or less), causing them to generate heat. All of the heat generated by induction motors in a refrigeration system needs to be removed from the system by the refrigeration cycle itself. This means that a significant portion of the work done by the refrigeration system is simply removing heat that the system itself is generating, rather than removing heat from the refrigeration compartment.

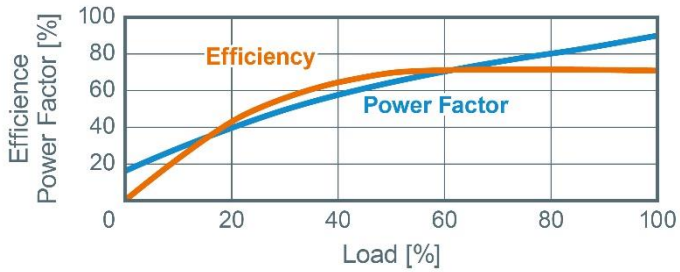


Figure 2: Induction Motor Power Factor and Efficiency

Another problem with induction motors is power factor. Induction motors, being highly reactive, have poor power factors that vary as the load varies. Under the very best circumstances and ideal load conditions, they can still only achieve a best case power factor of around 90 %. This means the apparent power they draw from the line is more than the real power they apply to their load. In some jurisdictions, including the EU and Japan (per IEC61000-3-2), power factor correction (PFC) is required by law to keep power transmission balanced.

Brushless DC Compressors Could Be a Solution

Brushless DC (BLDC) motors are different from induction motors in key ways. Most obviously, they are directly driven by DC voltages, while induction motors require AC voltages. Induction motors have electrical coils that are used to generate magnetic fields, while BLDC motors use permanent magnets. And while induction motors are simple to control - just power them up - brushless DC motors require much more complicated electronic controls. Because of these differences, BLDC motor solutions are more expensive to implement than induction motor solutions.

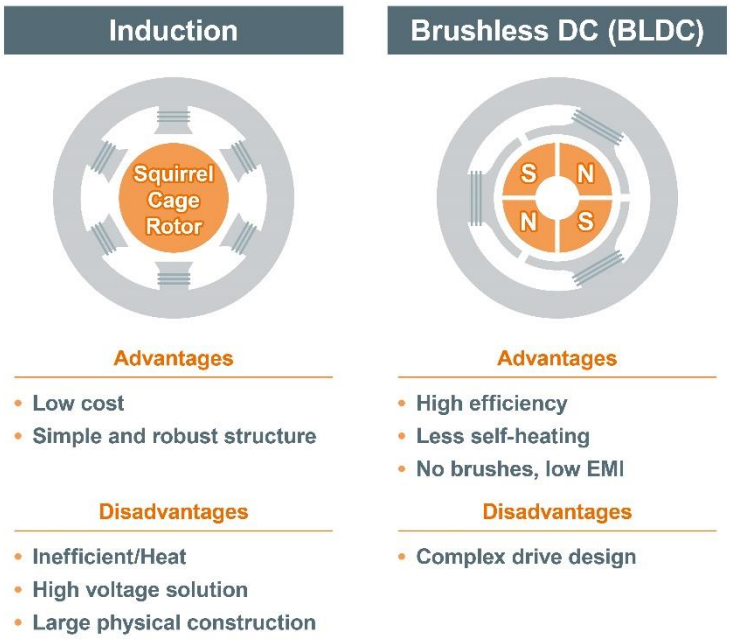


Figure 3: Induction motor vs BLDC motor

BLDC motors have not been used in the compressors of ULT freezer applications due to their cost and the technical complexity of design implementation. But some compressors for new air conditioners are already using BLDC motors, proving the concept. Advancing technologies from the ROHM Group, and changing market conditions, suggest it may be time to give BLDC compressors in ULT freezers a second look.

Using brushless DC motor-based compressors for ULT freezers would offer many advantages that could be worth the extra cost. And further, the cost and complexity of the design required to control a BLDC motor solution have both improved considerably as technology has advanced in recent years.
ROHM has an industry-leading line of BLDC motor driver solutions, including DIP modules that could be dropped into a design to handle all of the motor control. Additionally, ROHM experts in BLDC motor control stand ready and able to assist any designer tackling this challenge.

Unique Benefits for ULT Freezer Designs with BLDC-Based Compressors

The benefits of using BLDC-based compressors in a new ULT freezer design are increased power efficiency, less self-heating, and power factor correction. BLDC motors are more efficient than induction motors at turning electrical power into physical work. BLDC motors create significantly less heat, thus introducing less heat into the refrigeration system, creating even more efficient cooling. And BLDC motors can function at a power factor of 1 with proper power factor correction techniques, lowering the apparent power consumed.

Removing Inefficiencies in a Critical Application

Using induction motors in compressors for refrigerators is inefficient, and using two of them in ultra-low temperature freezer applications is doubly so. They are inefficient from a power perspective and from a heat / refrigeration cycle perspective. Brushless DC motors offer a compelling alternative, in exchange for some additional cost and technical complexity. But the cost of BLDC based compressors is offset by energy efficiency and regulatory compliance. ROHM offers a comprehensive portfolio for BLDC motor systems, and BLDC motor control expertise, to help with the technical complexity.

Switching from induction motors to BLDC motors is advantageous in terms of efficiency. However, the cost increases and the design becomes complicated. ROHM has a solution for BLDC motors, making it easy to handle complex designs.

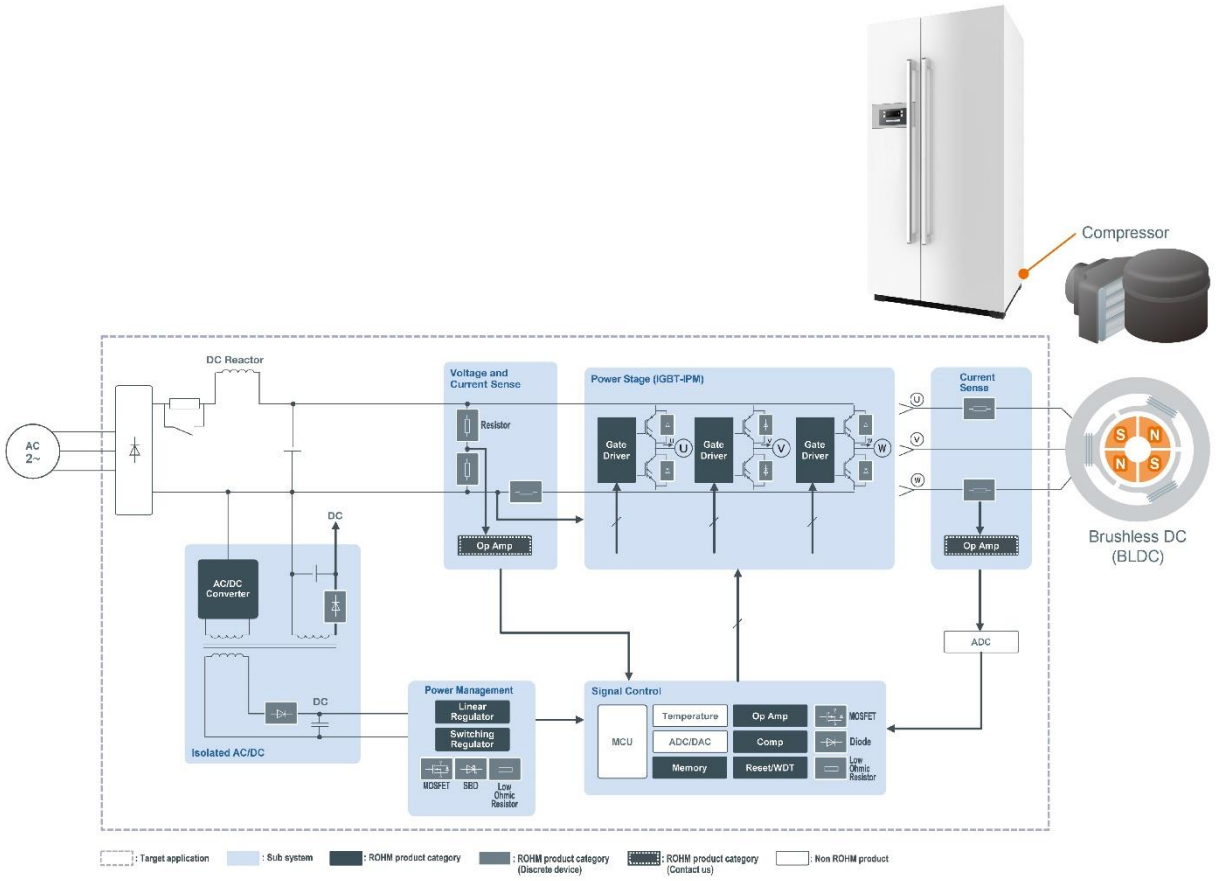
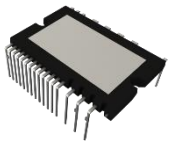


Figure 4: ROHM BLDC motor solution reference design
(reference [Motor Driver - Single Phase Non-Isolated AC240V | Motor | Industrial Equipment | Solution | ROHM Semiconductor - ROHM Co., Ltd.](#))

As shown Figure 4, ROHM reference design help you create ultra-low temperature freezer application with superior energy efficiency.

Whether you choose the highest level of integration with ROHM IGBT IPMs or aim for the best cost/performance ratio with discrete components, IGBTs, MOSFETs and Gate Drivers are designed to work together seamlessly. This allows you to create running system with low power consumption and a smaller factor.

ROHM IGBT IPM series is the optimal solution for high integrated ultra-low temperature freezer applications with unparalleled power management.
BM6437x series, 600 V IGBT IPMs, deliver industry-leading low-noise characteristics by leveraging built-in IGBT characteristics and soft recovery of the internal FRD under higher power efficiencies.
ROHM Field Stop Trench IGBTs, RGT/RGS series or **SiC MOSFETs**, **SCT series** are the best choice whenever the layout flexibility and thermal performances optimization are the major factors. These discrete products can be combined with suitable **Gate Driver products**.
For power supply, **ROHM isolated AC/DC series** offer higher performance and robustness.



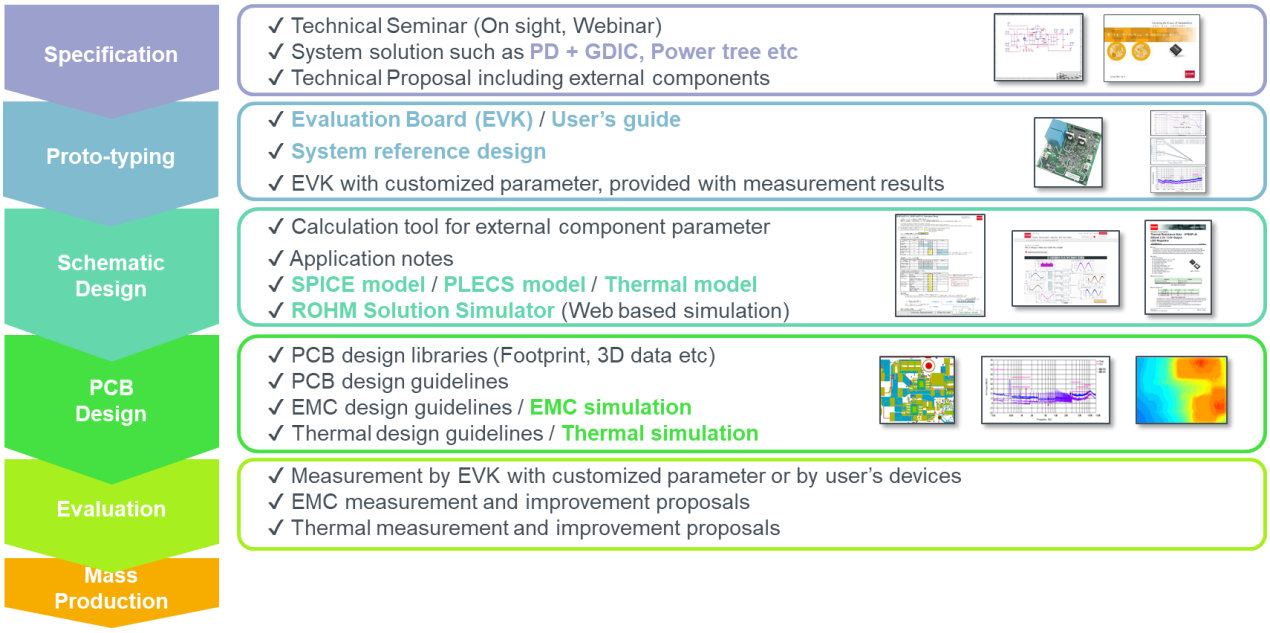
IGBT IPM
BM6437x series

IGBTs
RGT/RGS series
SiC MOSFETs
SCT series

Gate Drive
BM61M41RFV-C,
BM60212FV-C and more

AC/DC
BM1PxxFJ,
BM2Pxx and more

To achieve the best performance with minimizing your design efforts, ROHM provides full coverage application support in your development flow based on extensive experience.



Conclusion

It is time to seriously consider BLDC compressor designs for ULT freezer applications. The COVID-19 pandemic, for many in the industry, serves as a reminder of the need to be prepared to more efficiently store and distribute vaccines. BLDC-based ULT freezers could be one important part of increased preparedness in the future, and ROHM is prepared to partner with design engineers who are ready to take on the challenge.

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