Application Note

Selecting Gate Drivers for HVAC Systems

Rubas Khalid

ABSTRACT

Heating, ventilation, and air conditioning (HVAC) systems consist of subsystems that require a switching power device. Depending on the subsystem, different challenges arise when selecting a gate driver IC to drive the switching power device. This application note reviews the power factor correction (PFC), motor drive, and DC/DC switching converter stages in HVAC systems, summarizes the switching requirements for each stage, and provides examples of non-isolated gate drivers that can be used to drive the switching power devices found in the aforementioned stages.

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1 Introduction

HVAC systems are used to maintain a comfortable environment inside industrial, commercial, and residential buildings. HVAC systems are typically used to control the air in the environment and consist of ventilation systems, heating systems, and air-cooling systems.

For more HVAC applications, Texas Instruments covers a variety of applications found in the *HVAC system* applications page.

Modern HVAC systems use gate drivers in different subsystems, such as power factor correction (PFC) circuits, DC/DC converters, and motor drives. This application note discusses the usage of gate drivers in industrial, commercial, and residential HVAC systems, including guidelines in selecting a gate driver and key features to consider for each subsystem. Figure 1-1 shows a block diagram of an outdoor air conditioner and highlights typical subsystems where gate drivers are used.

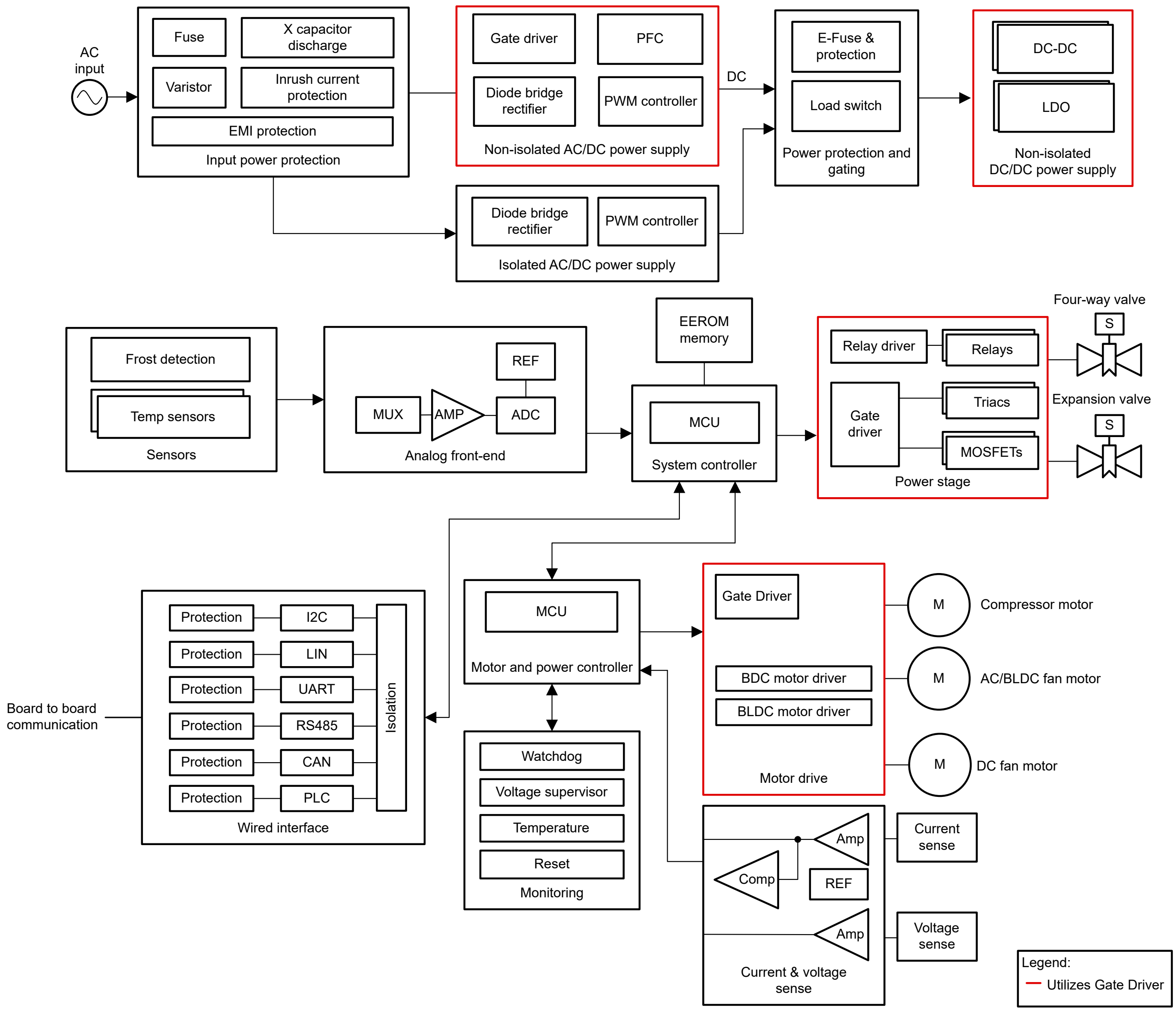

Figure 1-1. Outdoor Air Conditioner Block Diagram

2 PFC Stage

In HVAC systems using AC power, a high-power factor is a key requirement. Power factor is the ratio of real power over apparent power, and apparent power is a combination of real and reactive power. The load only consumes real power; therefore, it is critical that the losses from reactive power are minimized as much as possible. The lower the loss, the more efficient HVAC systems can be, and PFCs are used to maximize the power factor ratio.

2.1 Boost PFC

PFCs are a key power stage in HVAC systems, and the most common PFC topology used in HVAC systems is the boost PFC. The boost PFC topology utilizes a full-bridge rectifier to first rectify the AC line voltage, and then a boost converter is used to step up the rectified voltage to a desired DC bus voltage. This topology consists of a single FET referenced to ground, requiring a low-side gate driver. Figure 2-1 shows an example of the boost PFC.

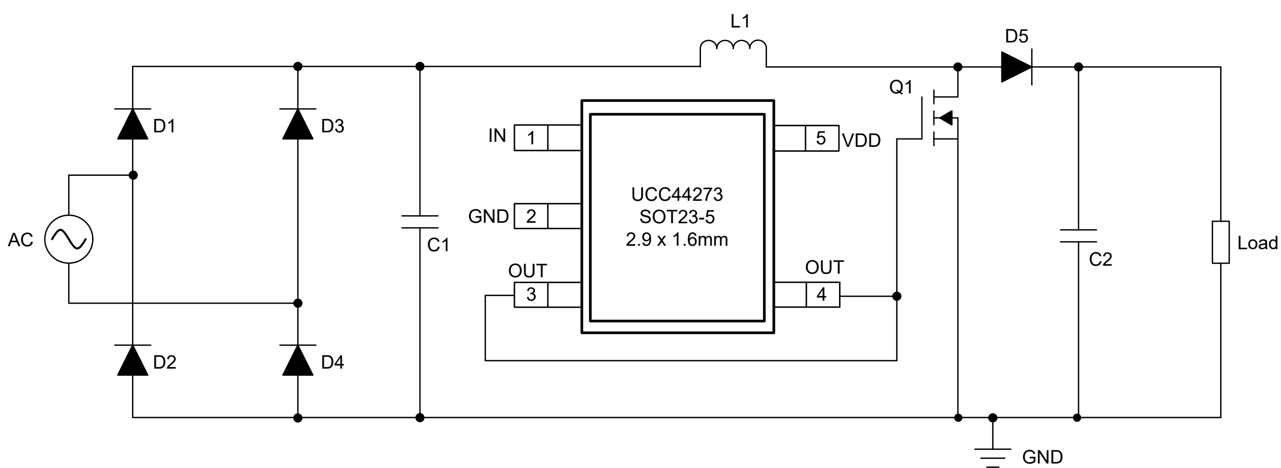

Figure 2-1. Boost PFC with UCC44273

Selecting a gate driver to drive the FET in HVAC PFC circuits requires careful consideration. Parasitic inductance and electromagnetic interference in HVAC systems can potentially cause damaging or destructive negative voltages that can affect gate drivers. To help circumvent this issue, it is important to select a gate driver with negative voltage capability to increase the robustness of the system. Another requirement to consider when designing high efficiency HVAC PFC circuit is peak drive current. A high peak drive current helps to achieve fast rise and fall time of the FET. This reduces voltage and current overlapping, which reduces switching losses to help HVAC systems achieve higher efficiency. Another consideration is the size of the gate driver IC. A smaller package allows the gate driver IC to be placed closer to the power FET, which reduces parasitic inductance due to PCB traces.

The UCC44273 can be used to drive the FET in a boost PFC for HVAC systems. The UCC44273 has peak output current of 4A source and 4A sink and is rated up to 20V VDD. Furthermore, the driver has a rise time of 8ns, fall time of 7ns, and propagation delay of 13ns for fast and efficient switching in HVAC systems. The UCC44273 also has negative voltage capability and features under-voltage lockout (UVLO) for added robustness. Table 2-1 features a comparison between UCC44273 and the leading competitors.

Table 2-1. Comparison of UCC44273 and Leading Competitors

Design Considerations	UCC44273	Competitor 1	Competitor 2
Supply Voltage (V_{DD}) *Absolute maximum*	20V	20V	20V
Negative Voltage Handling	-6V	-0.3V	-0.3V
UVLO	4V	5V	10V
Source/Sink Current *Typical*	4A / 4A	1.5A / 1.5A	3A / 3A
Rise/Fall Time *Typical*	8ns / 7ns	10ns / 10ns	14ns / 7ns
Propagation Delay On/Off *Typical*	13ns / 13ns	50ns / 50ns	10ns / 14ns
Package	SOT-23, 5-pin	SOT-23, 5-pin	SOT-23, 5-pin

2.2 Interleaved Boost PFC

The interleaved boost PFC is an alternate PFC topology used in HVAC systems. The interleaved boost PFC features two boost converters operating 180 degrees out of phase and is typically used for higher power applications. This topology can also offer efficiency improvements at the cost of additional components. The gate driver requirements for this topology is similar to the traditional boost PFC; however, an additional low-side FET is needed for the second boost converter. To achieve this, a dual-channel low-side gate driver is commonly used. Figure 2-2 shows an example of an interleaved boost PFC.

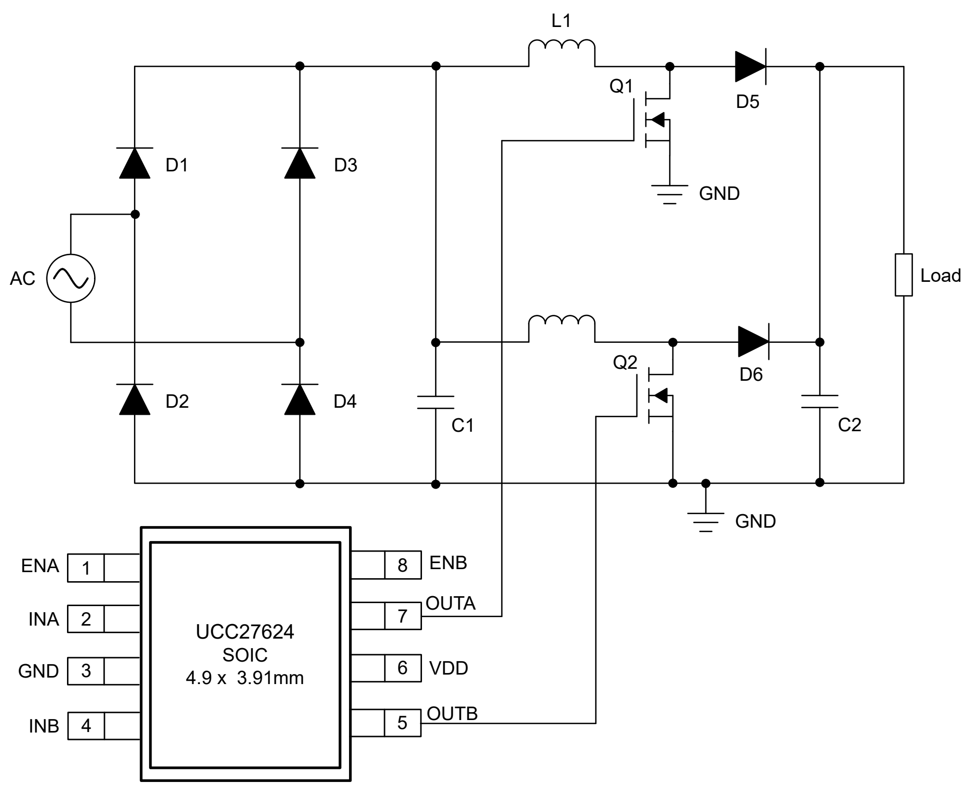

Figure 2-2. Interleaved Boost PFC with UCC27624

The UCC27624 can be used to drive the FETs in an interleaved boost PFC. Each of the two channels has a high drive strength, capable of outputting 5A source and 5A sink peak currents. This driver is also rated up to 30V VDD, allowing for greater flexibility in design. Furthermore, the driver has a rise time of 6ns, fall time of 10ns, propagation delay of 17ns, and delay matching of 1ns to for fast and efficient switching in HVAC systems. Table 2-2 features a comparison between UCC27624 and the leading competitors

Table 2-2. Comparison of UCC27624 and Leading Competitors

Design Considerations	UCC27624	Competitor 1	Competitor 2
Supply Voltage (V_{DD}) *Absolute maximum*	30V	24V	25V
Negative Voltage Handling	-10V	-6V	-6V
UVLO	4V	4V	4V
Source/Sink Current *Typical*	5A / 5A	5A / 5A	4.5A / 5.5A
Rise/Fall Time *Typical*	6ns / 10ns	8ns / 8ns	7ns / 6ns
Propagation Delay On/Off *Typical*	17ns / 17ns	20ns / 20ns	18ns / 18ns
Delay Matching *Maximum*	2ns	4ns	4ns
Package	SOIC, 8-pin	SOIC, 8-pin	SOIC, 8-pin

3 Motor Drive Stage

Motors in HVAC systems are integral to power different HVAC applications, such as fans, compressors, and pumps. These systems typically include different types of motors, such as brushed DC, brushless DC, and stepper. Motor drives are implemented with different degrees of integration, from a standalone gate driver IC to a fully integrated control, gate driver, and FET IC (full integration).

All degrees of integration lessen the components and save space in board layout; however, there are advantages in selecting the standalone gate driver IC. One advantage is better thermal performance during high-power use. Integration has multiple subcomponents in a small package, which can generate more heat when powered; however, a gate driver IC with external FETs can spread heat better, which can benefit high-power HVAC applications. Higher maximum voltage and current specifications can be achieved by using a gate driver IC with external FETs, while ICs with FETs integrated in are typically bottlenecked to the voltage and current capability of the IC. With proper layout, pairing a standalone gate driver IC as close as possible to an external FET also reduces switching loss and EMI.

Motors in HVAC systems are used to power fans, compressors, and valves. Depending on the motor application, key specifications, like voltage and peak current, and driver robustness are important to consider when selecting a gate driver. A gate driver with low peak current works best for a low-power application, while a gate driver with high peak current works best for a high-power application. Interlock can protect against cross-conduction or shoot-through in half-bridge drives, which can occur by parasitic ringing at the input. A gate driver with negative voltage capability adds robustness to the driver, as negative voltages can occur with transients arising from parasitic inductance. Figure 3-1 shows a typical three-phase inverter motor drive topology.

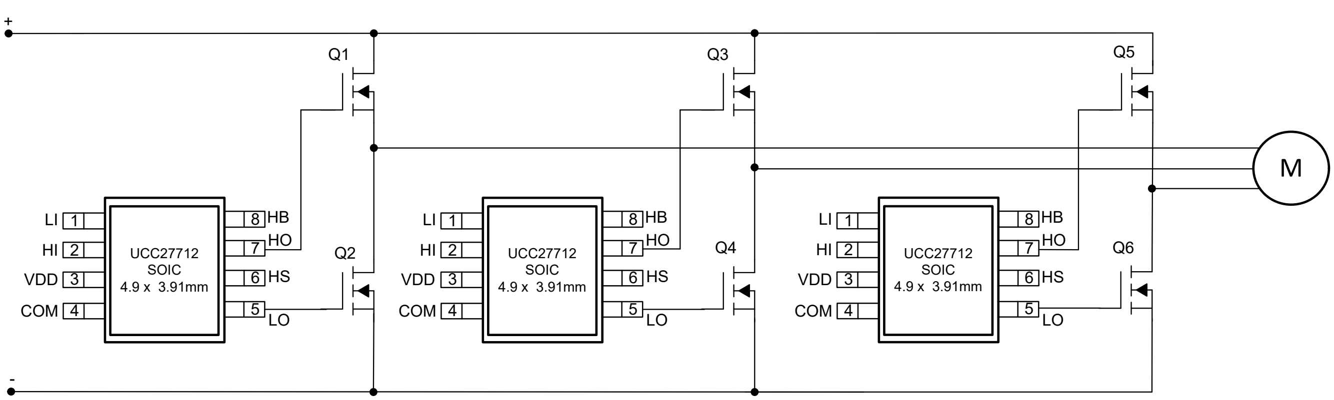

Figure 3-1. Three-Phase Inverter Motor Drive with UCC27712

For half-bridge motor drives, the UCC27710 or UCC27712 can be used to drive low-power applications. Both the UCC27710 and UCC27712 are part of the 620V, sub-3A family, feature interlock to prevent both high and low outputs from being on at the same time, and have negative voltage capability on the input pins for added robustness. The UCC27714 can be used for high-power applications. The UCC27714 is a 600V, 4A driver that also features negative voltage capability on the input pins; however, it has no interlock. In comparison to the UCC27710 and UCC27712, the UCC27714 is available in a larger package to accommodate larger creepage requirements. For low-side motor drives, like the single-switch chopper, the aforementioned UCC44273 can be used.

4 DC/DC Stage

DC/DC switching converters in HVAC systems are used to efficiently shift voltage levels for different applications. Like motor drives, there are different integration levels to consider when designing DC/DC converters, from standalone gate driver IC to full integration. The advantages in selecting a gate driver IC to drive power devices is akin to selecting a gate driver IC to drive motor drives. To summarize, gate driver ICs can provide better thermal performance, potential for higher power, and less EMI with proper PCB layout.

Switching efficiency is a critical requirement for DC/DC converters in HVAC systems. Compared to motor drivers, DC/DC converters run at a much higher switching frequency. Higher switching frequencies reduces output ripple and the size of transformers and inductors, but often with the caveat of switching losses. A gate driver with high peak currents is often sought after when selecting a gate driver to drive DC/DC converters, as high peak currents can allow for a faster rise and fall time, which reduces switching losses for an increase in system efficiency.

4.1 Synchronous Buck Converter

The synchronous buck converter is a common DC/DC converter used in HVAC systems, and are also used in HVAC end equipment, such as thermostats, controllers, and sensors. Synchronous buck converters increase efficiency by replacing the diode referenced to ground in a regular buck topology with a switching power device. This DC/DC converter topology uses a switching power device on the low-side and high-side, requiring a half-bridge driver. Figure 4-1 shows an example of a synchronous buck converter.

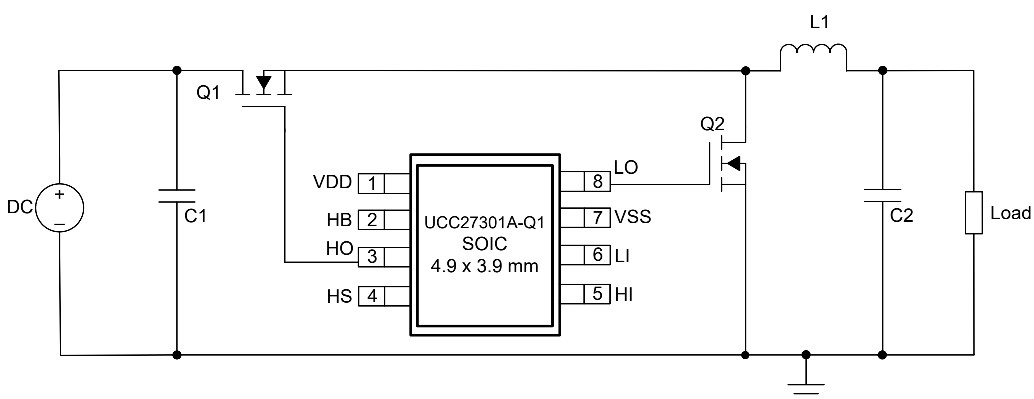

Figure 4-1. Synchronous Buck Converter with UCC27301A-Q1

The UCC27311A-Q1 can be used to drive the switching power devices in a synchronous buck converter. The driver has a high drive strength of 4.5A peak source current and 3.7A peak sink current. This high drive strength allows for a fast rise and fall time, which reduces switching losses and ultimately increase the efficiency of the switching converter. The UCC27311A-Q1 also has negative voltage handling on the input pins for added robustness. The UCC27301A-Q1 is a similar driver to the UCC27311A-Q1, but has interlock for added protection against cross-conduction. Both the UCC27311A-Q1 and UCC27301A-Q1 have an integrated bootstrap diode.

4.2 Flyback Converters

The flyback converter is another DC/DC topology used in HVAC systems. Diode bridge rectification is first used to rectify 120V or 230VAC input, which is then chopped by a switching power device, and then finally goes through the transformer to be converted into lower voltage rails. In a flyback converter, the switching power device used to chop the primary side DC voltage is referenced to ground, requiring a low-side driver. Figure 4-2 shows an example of a flyback converter.

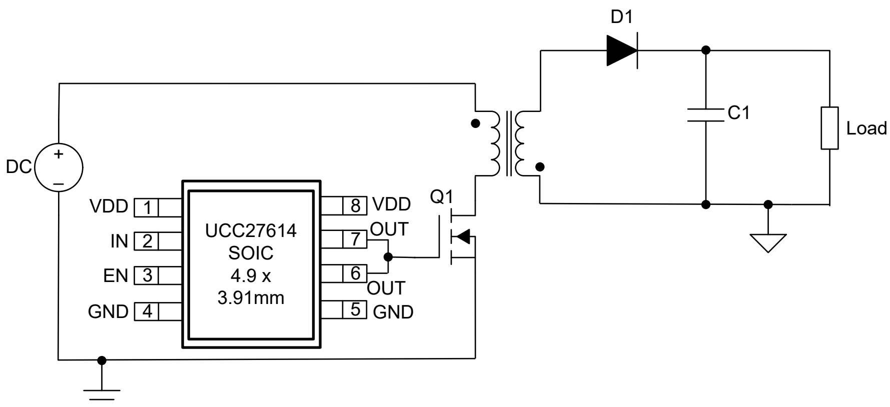

Figure 4-2. Flyback Converter with UCC27614

The UCC27614 can be used to drive the switching power device in a flyback converter. The UCC27614 features a high VDD rating of 30V to allow for flexibility in system design, and the UCC27614 also has a high drive strength of 10A peak source and sink current to increase switching efficiency. The driver also has a negative voltage capability for added robustness. The UCC44273 can also be used as a low quiescent option for designs that require a lower power consumption or smaller footprint.

5 Summary

Modern day HVAC systems consist of different power stages and motor drives that can require a gate driver. Texas Instruments offers a number of gate drivers to fit HVAC needs. The large portfolio of low-side gate drivers can be used in critical areas of HVAC systems, such as the PFC stage. Alongside low-side drivers, Texas Instruments also offers numerous half-bridge drivers used in motor drivers for applications such as fans, compressors, and pumps. Texas Instruments gate driver portfolio can also be used in DC/DC converters in HVAC systems and end equipment, such as thermostats, controllers, and sensors. With a high-performance and competitive portfolio of gate drivers, HVAC systems can be smaller, robust, and efficient.

6 References

- Texas Instruments, *HVAC System*, product page.
- *Review of Different Power Factor Correction (PFC) Topologies' Gate Driver Needs*, application note.
- Texas Instruments, *How to Choose a Gate Driver for DC Motor Drives*, application note.
- Texas Instruments, *Selecting the right level of integration to meet motor design requirements*, technical article.
- Texas Instruments, *How the Switching Frequency Affects the Performance of a Buck Converter*, application note.