Application Note

Mapping Application Requirements with the 120V Half-bridge Gate Driver

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ABSTRACT

When selecting a gate driver, consider the target application and topology to determine the best possible driver for that a specific end equipment. In this application note, assorted end equipment (EE) and topologies are described with regards to the 120V half-bridge gate driver selection and application. First, example EEs are considered and the topologies that are preferred in those examples. Then, the underlying design considerations for these applications and topologies are described next. This application note shows which Texas Instruments' half-bridge gate drivers are the best choice for each of these scenarios with justification for those selections. More specifically, this document shows the UCC27301A(-Q1) and the UCC27282(-Q1) gate drivers.

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1 Introduction

Design Considerations To Consider When Selecting A Half-bridge Gate Driver

When designing power electronics circuits that utilize half-bridge gate drivers, there are many factors that need to be considered. Some of those factors include power level, power density, operating frequency and converter operation such as unidirectional and bidirectional. These factors are discussed with regards to the associated half-bridge gate driver in relation to the applications where used.

Many challenges are associated with designing DC-DC converters with high power and output current levels. The following application note highlights and explains those challenges in the context of half-bridge gate drivers.

1.1 Power Level Considerations

Power demanding applications require high efficiency operation and the utilization of multiple phases to support large current outputs. These individual phases can be disabled during low power states to improve efficiency by eliminating the losses in the disabled powertrain. In these multiphase systems when light load conditions occur, some phases are disabled to reduce switching losses. When enabling a disabled phase, there are high currents within the gate driver associated with recharging the bootstrap capacitor. The FETs are also associated with high current applications that demand high gate drive currents to ensure fast switching transitions and require fast switching characteristics of the gate driver to ensure maximum efficiency. Overall, in applications with elevated power levels, a high current gate driver is best. The latest high current, half-bridge gate driver in TI's 120V portfolio is the UCC273x1A(-Q1) which features 3.7A source current and 4.5A sink current for driving these FETs. High power applications result in greater switching losses, therefore this higher current driver is needed to speed up the switching transitions and reduce the switching losses.

1.2 Power Density Considerations

In the power converter market where these half-bridge gate drivers are utilized, space and weight are often constrained despite the elevated power levels that are required. Gate drivers that feature small outline packages and incorporate thermal pads for increased heat dissipation are advantageous within these design constraints. This size constraint is excellent in multiphase systems where multiple gate driver circuits occupy circuit board space and the typical application requires high power. For high current, the UCC273x1A(-Q1) is offered in a 3mm by 3mm DRC package that is of SON type and is a 120V half-bridge driver. The UCC273x1A(-Q1) has peak drive current ratings of 3.7A source and 4.5A sink. This DRC package is the smallest package currently offered in the high current 120V half-bridge portfolio and includes the enable pin optimizing this driver to be disabled in multiphase converter operation. For lower current and less power dense applications, a 3A source and sink current 120V driver can potentially be used. When operated in single phase converter configurations, the UCC2728x(-Q1) can be used and is also offered in the small DRC package and features enable.

1.3 Converter Operating Frequency and Switching Characteristics Considerations

Increasing the switching frequencies in power converters allows for the reduction of the energy storage and passive components in the converter circuitry. This reduction has improved the power system by reducing size, weight and improving layout options for the circuit elements. The downside to increased switching frequency is the added stress to the gate driver and supporting circuitry. To account for these increased requirements, a robust driver with high current, fast switching characteristics and small form factor are important for optimization when increasing switching frequency.

The performance metrics of the gate driver to take into consideration include the propagation delays of the driver channels, the delay matching specification with respect to both channels, and the rise and fall times of the output signals. Drivers with high drive current, such as the UCC273x1A(-Q1) with peaks of 3.7A source and 4.5A sink current enable the ability for fast rise and fall times. With a rating of 270ns rising and 160ns falling for a 100nF load with thresholds of 3V and 9V, the UCC273x1A(-Q1) is an excellent choice. Fast rise and fall times are desirable for reducing switching losses that occur during switching transitions. When looking at lower current gate drivers like the UCC2728x(-Q1), the rise and fall times are 330ns and 23ns, respectively, under the same conditions. In addition to rise and fall times, the propagation delays and delay matching specs are important for determining how fast and how accurately the gate driver reacts to inputs from the controller. For the UCC273x1A(-Q1), the propagation delay and delay matching specs are 20ns and 4ns, respectively, which provides fast switching characteristics. The lower current UCC2728x(-Q1) offers faster propagation delay and shorter delay matching specs with 16ns and 1ns respectively. But, in high efficiency demanding applications, the rise and fall times play a critical role in minimizing switching losses, so the UCC273x1A(-Q1) is a better choice in that scenario.

1.4 Bidirectional Operation Considerations

For operation in applications such as photovoltaic (PV) energy systems that include battery energy storage systems (BESS) and connections to the electric grid, bidirectional DC-DC converters are required for transfer of energy between the three different components. For instance, the DC-DC converter that connects the BESS to the bus voltage of the system can operate in buck or boost mode to satisfy the bus voltage requirements. The DC-DC converter also satisfies the transfer of energy out of the BESS or the transfer of energy into the BESS. These systems are often high power and require multiple phases, which are described as requiring special consideration for the gate driver portion of the converter. For more information on using gate drivers in bidirectional converters, refer to the *Challenges and Solutions for Half-Bridge Gate Drivers in Bidirectional DC-DC Converters* application note. Due to these challenges, a robust, high current gate driver is needed when designing for bidirectional systems. A driver such as the UCC273x1A(-Q1) can be a good candidate for bidirectional systems.

Other systems, such as the 48V to 12V DC/DC converter used in HEV and EV systems for charging the 12V battery utilize a unidirectional converter. A unidirectional converter can be utilized as energy and is only transferred from the 48V battery through a buck converter to the 12V battery. When only a single phase is utilized, the startup conditions seen for the driver are only on initial startup. This means that the control circuit is programmed for optimizing the bootstrap capacitor charging prior to switching the converter with sending LO pulses. In this case, a lower current driver can be considered such as the UCC2728x(-Q1).

When looking for a 120V half-bridge gate driver, the recently released UCC273x1A(-Q1) is poised to compete aggressively with the leading competitors. As seen in Table 1-1, the UCC273x1A(-Q1) offers many advantages. These advantages include an industry leading operating temperature rating of 150 °C, offering automotive qualification, and provides cross conduction protection with input interlock.

Table 1-1. Comparison of UCC273x1A(-Q1) and Leading Competitors

Design Considerations	UCC273x1A(-Q1)	Competitor 1	Competitor 2
Supply voltage (V_{DD}) absolute maximum	20V	18V	20V
HB bootstrap voltage absolute maximum	120V	115V	120V
Negative voltage handling on HS (<100ns) absolute minimum	-(28V - VDD) V	-25V	-12V
Source and sink current typical	3.7A, 4.5A	3A, 4.5A	4A, 6A
Propagation delay on and off typical	20ns, 19ns	20ns, 20ns	33ns, 33ns
Rise and fall times typical at 1nF	7.2ns, 5.5ns	15ns, 15ns at 2.2nF	4.6ns, 3.3ns
Enable	Yes	No	Yes
Bootstrap diode dynamic R typical	0.55 Ohm	2.5 Ohm	4.2 Ohm
Bootstrap diode forward V (typical)	0.9V	0.95V	1.4V
Operating junction temperature recommended maximum	150C	125C	125C
Package options	WSON10 3x3, SOIC8, HSOIC8	WSON10 4x4, SOIC8, HSOIC8	VSON8 4x4, WSON10 4x4, WSON10 3x3

2 Key End Equipments And Topologies for 120V Half-bridge Gate Drivers

Due to the above considerations, the application heavily determines the best gate driver for the design. For a few of the applications for 120V half-bridge gate drivers, the UCC27282(-Q1) or the UCC27301A(-Q1) can be selected.

2.1 Automotive DC-DC converters and on-board chargers (OBC)

In automotive applications, especially the emerging electric vehicle (EV) market, the DC-DC converter circuit requires great consideration for efficiency and robustness. Within the OBCs, the main focus for the 120V half-bridge drivers is in the high voltage to low voltage portion. *Figure 1* shows an example where the HVLV DC-DC stage and the 48V to 12V converter stage utilize 120V half-bridge gate drivers

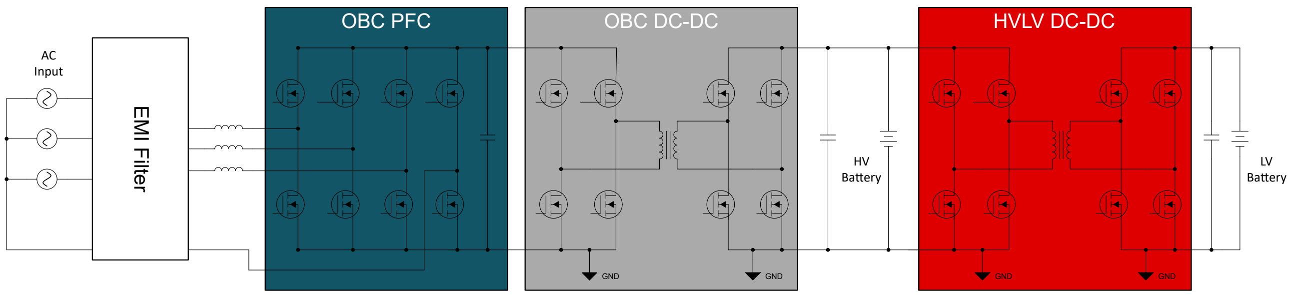

Figure 2-1. HEV, EV OBC, DC-DC Subsystem Typical Block Diagram

When looking at OBC DC-DC converters, the high voltage (400V or 48V) to low voltage (48V or 12V) portion of the system requires the usage of a full bridge or two half-bridge circuits and drivers. These 48V and 12V half-bridge circuits are often bidirectional and multiphase for managing large loads with high power output and high efficiency requirements. ITo achieve the high efficiency, reliable performance, and robustness required for this application, the UCC27301A-Q1 can be used due to the high drive current leading to fast switching capabilities and reliable performance and ability to perform in multiphase systems. Figure 2-2 shows an example of a high voltage (400V or 800V) to low voltage (48V or 12V) DC-DC converter where two UCC27301A devices can be utilized on the low voltage side.

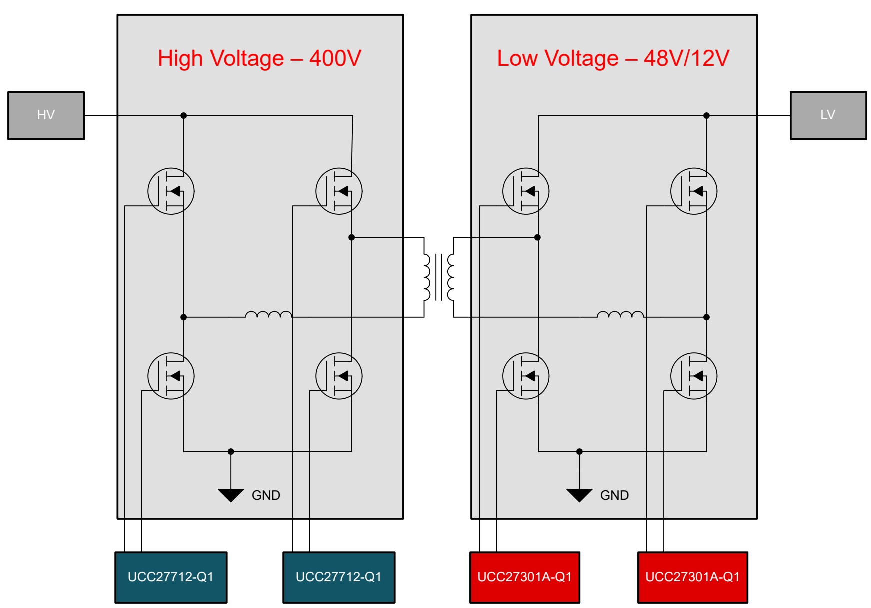

Figure 2-2. OBC High Voltage to Low Voltage DC-DC Converter

2.2 Motor Drives and Power Tools

Applications involving motors, such as 2 and 3-phase linear motor coil arrays, DC speed-variable BLDC motors, 2-phase bipolar stepper motors, and PMSM in servo drives and robotics, can implement 120V half-bridge gate drivers. The 120V driver can be used in these DC motor drive systems where the bus voltage typically ranges from 12V to 80V DC and half-bridge topologies are often used for each phase or winding. *Figure 3* shows an example of a 3-phase brushless motor (BLDC) where 3 half-bridge drive circuits are used.

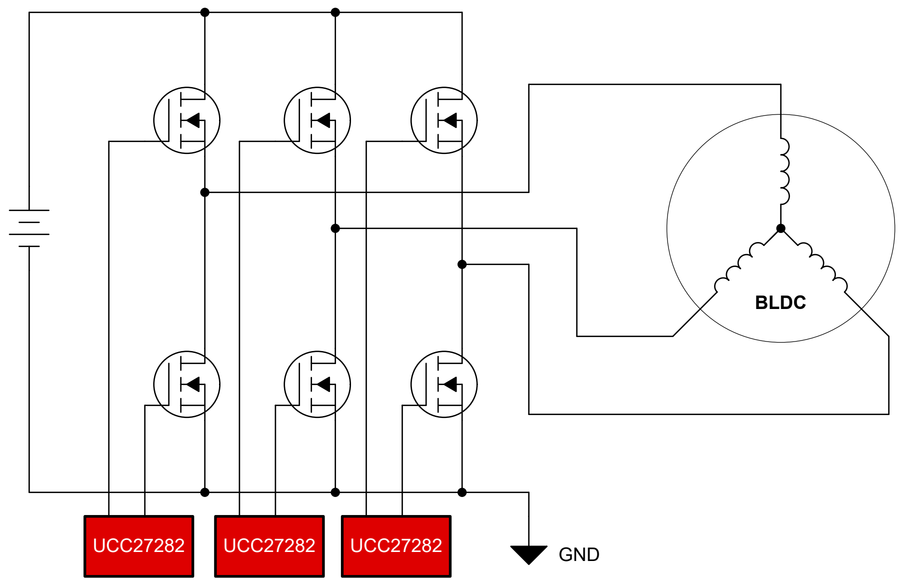

Figure 2-3. 3-Phase Brushless Motor (BLDC) Diagram

The 120V half-bridge gate drivers are offered in small packages to help customers minimize board sizes due to compact application requirements in products like cordless power tools, drones, and eBikes. These devices often operate in hot environments requiring good thermal dissipation capabilities. In addition, the devices need fast timing characteristics while maintaining low cost and having a wide VDD supply range. The UCC27282(-Q1) offers an abundance of these features such as the 10-pin, 3mm by 3mm SON, DRC package with low thermal resistance for $R_{\theta JA}$ of 47.3 °C/W. The UCC27282(-Q1) also includes 16ns typical propagation delays with 1ns of delay matching. These features along with a 20V absolute maximum rating on VDD and being very competitively priced allows for the UCC27282(-Q1) to be a great candidate for motor drive applications. Another potential candidate for motor drive applications is the LM2101, which is a 0.5A source and 0.8A sink current half bridge driver. For more information on gate drivers in motor drive applications, refer to the How to Choose a Gate Driver for DC Motor Drives application note. Figure 2-4 shows an example of a stepper motor with two half-bridge circuits and two UCC27282(-Q1) used for the A winding of the motor.

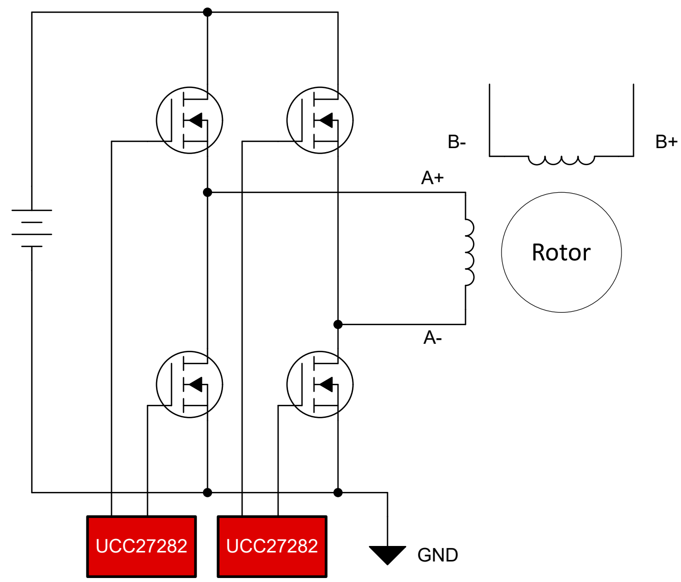

Figure 2-4. Stepper Motor Schematic Example Using UCC27282(-Q1)

2.3 Solar Power Optimizers and Microinverters

In the growing industry of solar energy, energy storage, solar power optimizers, microinverters, and string inverters operate in a power dense conditions across many different voltage levels and power levels. Some of the topologies in those systems include LLC converters, phase shifted full bridge converters, and totem pole PFCs. For these topologies, the 120V half-bridge driver can be utilized when voltage levels do not exceed the 120V rating of the driver. *Figure 5* shows an example of a solar energy system with energy storage and grid connection where DC-DC converters are utilized which typically require a half-bridge driver.

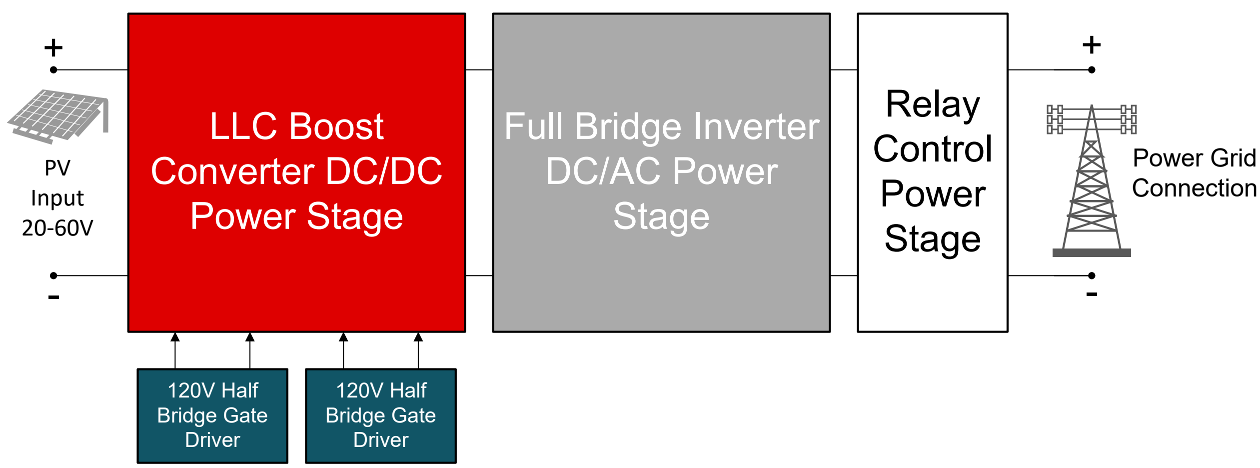

Figure 2-5. Solar Energy System Block Diagram

The high-power, efficiency demanding applications in solar energy and energy storage require a gate driver that is robust, efficient, and provides high current capabilities. In these bidirectional, power dense topologies, the gate driver requirements are important for efficiency and reliability. The UCC27301A(-Q1) offers high drive current of 3.7A and 4.5A and small package options, such as the 3mm x 3mm SON 10-pin DRC package that are critical for power dense systems. In addition, the 20V absolute maximum VDD supply rating and high noise immunity provide additional robustness and reliability. These drivers are offered with fast switching characteristics with 7.2ns of rise time with 5.5ns of fall time to make sure of efficiency. A few additional features that make the UCC27301A(-Q1) a great option for solar and energy storage applications are the robust integrated bootstrap diode, input interlock, and the enable pin functionality with low shutdown current that help when enabling and disabling phases during low and high-power scenarios. Solar and energy storage systems often utilize 48V battery systems and 20V to 60V solar panel arrays that require these 120V half-bridge drivers. Figure 2-6 shows an example of a microinverter schematic that features a full bridge LLC power stage in the DC-DC portion of the circuit that can utilize the UCC27301A(-Q1) 120V half-bridge gate driver.

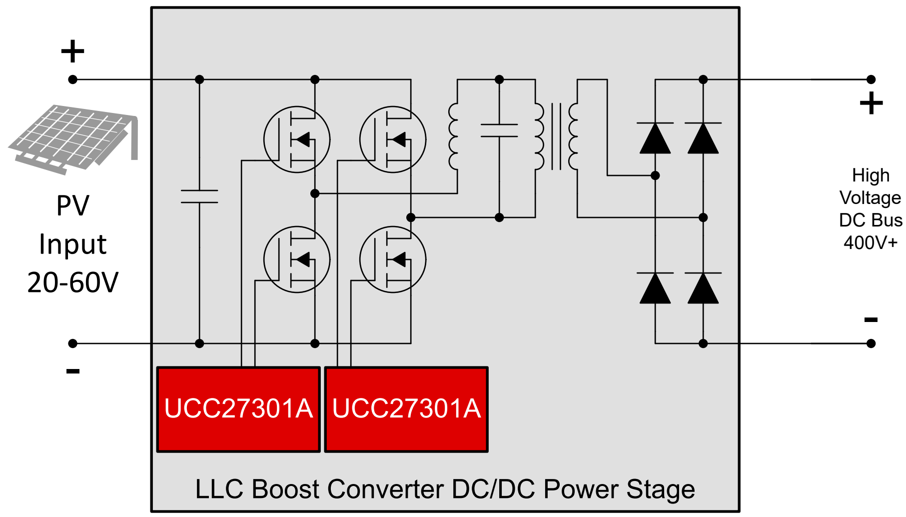

Figure 2-6. Microinverter Full Bridge LLC Power Stage Diagram

2.4 Body Electronics and Lighting

As automobiles advance technologically, manufacturers are integrating more features for driver and passenger convenience and safety. One of these components of the body electronics and lighting system includes smart glass for the sunroof, sun visors, side windows and the driver's Heads Up Display. In many of these applications, a Polymer Dispersed Liquid Crystal (PDLC) glass is used. These PDLCs typically operate with an excitation voltage of 40Vac to 80Vac, making PDLCs a potential candidate for a 120V half-bridge gate driver. Figure 2-7 shows an example of a PDLC smart glass block diagram.

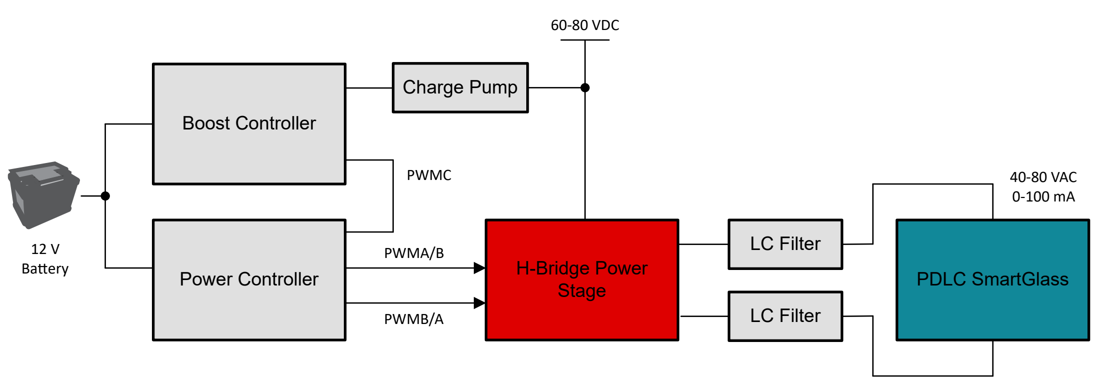

Figure 2-7. PDLC Smart Glass Block Diagram

In these PDLC smart glass systems, the power stage uses an H bridge with an LC filter to create the waveform needed to power the PDLC at 50Hz to 60Hz. This is done by switching at 100kHz to 500kHz with a PWM signal controlled by the MCU. To achieve high switching frequencies, a half-bridge driver with fast switching characteristics is needed. The UCC27282-Q1 features fast switching capabilities with 16ns typical propagation delays and 1ns of typical delay matching abilities. The UCC27282-Q1 also is capable of 12ns rise times and 10ns fall times with a 1nF load. Figure 2-8 shows an example of the H-bridge configuration in the PDLC system utilizing two of the UCC27282-Q1.

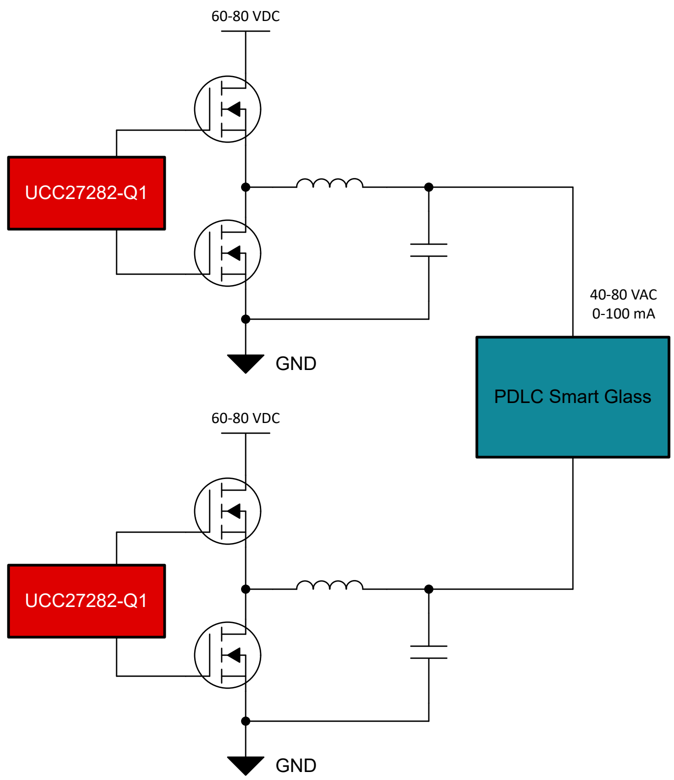

Figure 2-8. PDLC Smart Glass Schematic Diagram of the H-bridge Utilizing UCC27282-Q1

3 120V Non-isolated Half-bridge Gate Driver Portfolio Overview

Within the Texas Instruments gate driver portfolio, there are a variety of options for 120V half-bridge gate drivers allowing for proper gate driver selection and design optimization. Some of the most prominent options include the UCC272x1 and UCC2720x family of devices, the UCC2728x family, and the newly released UCC273x1A family, which is an extension of the UCC272x1 and UCC2720x family. Table 3-1 and Table 3-2 highlights the specification and feature differences between all of these families and individual products across industrial and automotive variants in the high current 120V half-bridge gate drivers.

Table 3-1. Industrial High Current 120V Half-bridge Non-isolated Gate Driver Comparison

	UCC27282	UCC27284	UCC27288	UCC27289	UCC27200(A)	UCC27201(A)	UCC27211(A)	UCC27212	UCC27301A	UCC27311A
HB Abs max	120V	120V	120V	120V	120V	120V	120V	120V	120V	120V
Drive current	3A, 3A	3A, 3A	3A, 3A	3A, 3A	3A, 3A	3A, 3A	3.7A, 4.5A	3.7A, 4.5A	3.7A, 4.5A	3.7A, 4.5A
Interlock	Y	N	N	N	N	N	N	N	Y	N
Prop. delay	16ns	16ns	16ns	16ns	20ns	20ns	20ns	20ns	20ns	20ns
Rise and fall times	12ns, 10ns	12ns, 10ns	12ns, 10ns	12ns, 10ns	8ns, 7ns	8ns, 7ns	7.2ns, 5.5ns	7.2ns, 5.5ns	7.2ns, 5.5ns	7.2ns, 5.5ns
Delay matching	1ns	1ns	1ns	1ns	1ns	1ns	4ns	4ns	4ns	4ns
Enable	Y	Y	N	Y	N	N	N	N	Y	Y
Bootstrap diode	Y	Y	N	Y	Y	Y	Y	Y	Y	Y
UVLO	5V	5V	8V	8V	8V	8V	8V	5V	8V	8V
Smallest package	3x3mm DRC (SON-10)	3x3mm DRC (SON-10)	5x4mm D (SOIC-8)	3x3mm DRC (SON-10)	3x3mm DRC (SON-9)	3x3mm DRC (SON-9)	4x4mm DPR (SON-10)	4x4mm DPR (SON-10)	3x3mm DRC (SON-10)	3x3mm DRC (SON-10)

Table 3-2. Automotive High Current 120V Half-bridge Non-isolated Gate Driver Comparison

	UCC27282-Q1	UCC27284-Q1	UCC27200-Q1	UCC27201A-Q1	UCC27211A-Q1	UCC27212A-Q1	UCC27301A-Q1	UCC27311A-Q1
HB Abs max	120V	120V	120V	120V	120V	120V	120V	120V
Drive current	3A, 3A	3A, 3A	3A, 3A	3A, 3A	3.7A, 4.5A	3.7A, 4.5A	3.7A, 4.5A	3.7A, 4.5A
Interlock	Y	N	N	N	N	N	Y	N
Prop. delay	16ns	16ns	20ns	20ns	20ns	20ns	20ns	20ns
Rise and fall times	12ns, 10ns	12ns, 10ns	8ns, 7ns	8ns, 7ns	7.2ns, 5.5ns	7.2ns, 5.5ns	7.2ns, 5.5ns	7.2ns, 5.5ns
Delay matching	1ns	1ns	1ns	1ns	4ns	4ns	4ns	4ns
Enable	Y	Y	N	N	N	N	Y	Y
Bootstrap diode	Y	Y	Y	Y	Y	Y	Y	Y
UVLO	5V	5V	8V	8V	8V	5V	8V	8V
Smallest package	3x3mm DRC (SON-10)	3x3mm DRC (SON-10)	5x4mm DDA (HSOIC-8)	5x4mm DDA (HSOIC-8)	5x4mm DDA (HSOIC-8)	5x4mm DDA (HSOIC-8)	3x3mm DRC (SON-10)	3x3mm DRC (SON-10)

4 Summary

The UCC2728x family of devices provide an established product with many options in features and industry standard pinouts that create the ability of the designer to select the best fit for the end products needs. These end products such as appliances and motor drives are dependent on high volume operation with cost competitive products that this family can provide.

The UCC273x1A, UCC272x1(A), and UCC2720x(A) family of products offer variations in drive current, package, switching times, and UVLO with proven reliability along with the new added part numbers and features providing fresh, new opportunities for designers to utilize this family in applications. These products are excellent candidates in the microinverter and automotive DC-DC applications where robustness, drive current, and features are a necessity

5 References

- Texas Instruments, Challenges and Solutions for Half-Bridge Gate Drivers in Bidirectional DC-DC Converters, application note
- Texas Instruments, How to Choose a Gate Driver for DC Motor Drives, application note
- Texas Instruments, UCC27301A product page
- Texas Instruments, UCC27301A-Q1 product page
- Texas Instruments, UCC27311A product page
- Texas Instruments, UCC27311A-Q1 product page
- Texas Instruments, UCC27282 product page
- Texas Instruments, UCC27282-Q1 product page
- Texas Instruments, LM2101 product page

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