Application Report
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Performance of the Analog-to-Digital PWM Channel in Smart Gate Drivers

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ABSTRACT

This application report presents the performance of the isolated analog-to-digital PWM channel in the UCC21710, UCC21732, and UCC21750 single-channel smart gate drivers while measuring different signals of a motor drive. Accuracy, phase shift and noise immunity are analyzed to highlight the applications of this analog channel in a motor drive system.

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Trademarks

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1 Introduction

The smart isolated single-channel gate drivers designed for up to 1700-V IGBTs and SiC MOSFETs include advanced protection features, best-in-class dynamic performance and robustness. A differentiating feature of the gate driver is an isolated analog-to-digital PWM channel which allows reduction in system design complexity, size, and cost. The UCC21710, UCC21732, and UCC21750 devices include the analog channel that can be used for isolated sensing of signals in motor drives and there are automotive qualified, Q1, versions of each device.

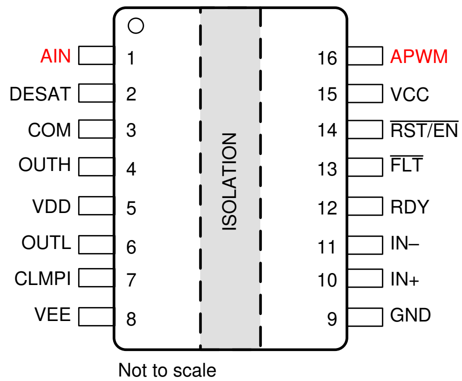

Figure 1. UCC21750 Pin Out

Applications in which the isolated gate drivers can be used include industrial motor drives; server, telecom and industrial power supplies; uninterruptible power supplies; onboard charger and DC charging stations; and traction inverters for EVs.

2 UCC217xx Features

2.1 Smart Gate Driver Features

Safety features are integrated into the UCC217xx smart gate driver family. These include fast system protection, fault feedback pin, and Miller clamping feature either internal or external, depending on the specific power level and layout restrictions. The devices within the family also offer several differentiating features. There is a 200-ns overcurrent protection feature which is designed for fast protection. This is especially important for fast-switching SiC MOSFETs. A 9-V DESAT pin is also available for IGBT protection in the case of a short circuit to measure the collector-emitter voltage as it increases. Additionally, a 0.7-V overcurrent (OC) pin is also offered for IGBT or SiC MOSFET protection to measure the current through a shunt resistor. All devices feature soft turn-off or 2-level turn-off for the safe shutdown of the IGBT or SiC switches.

2.2 Analog Channel

The UCC217xx smart gate drivers feature an isolated analog channel which allows for isolated sensing of signals without the need of additional devices. The AIN pin can accept a 0.6-V to 4.5-V signal which is converted to a PWM signal using a comparator and a sawtooth waveform. This PWM signal is then passed across the isolation barrier and the APWM pin outputs a 400-kHz signal with a 10% to 88% duty cycle which varies linearly based on the input value. The 0.6-V to 4.5-V input at the AIN pin corresponds to an 88% to 10% PWM duty cycle at the APWM pin output, respectively, giving an inverted output. The AIN-APWM bandwidth is 10 kHz.

Since the AIN input range is from 0.6 V to 4.5 V the input signals that are centered at 0 V, or referenced to 0 V, need to be level shifted and attenuated or amplified to take advantage of the full input range. With this realization, real-world signals from an AC induction motor were conditioned to fit the AIN input parameters to determine the usability of the analog channel for motor drive applications.

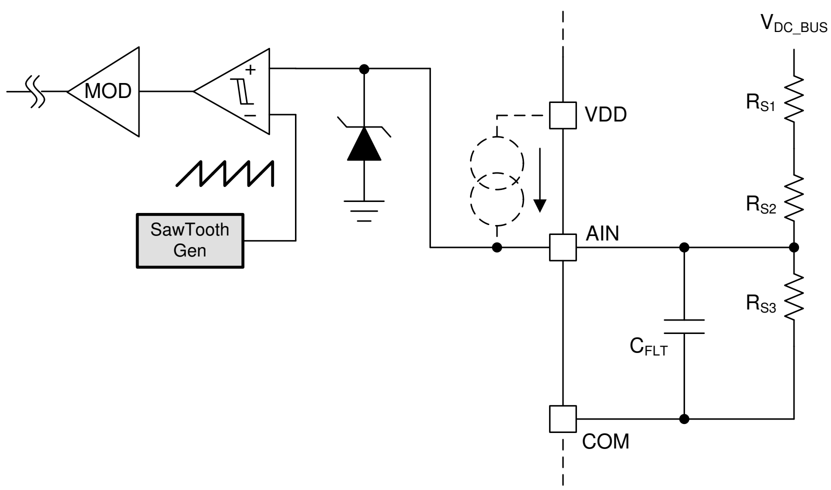

Figure 2. Isolated Analog-to-Digital PWM Channel Circuit

3 Test Data

3.1 DC Test

The response time of the isolated analog channel was determined by testing a step response input from 0.6 V to 4.5 V at the AIN pin and capturing the APWM pin output waveform showing the PWM duty cycle decrease from 88% to 10%. Figure 3 shows this response time of the analog channel.

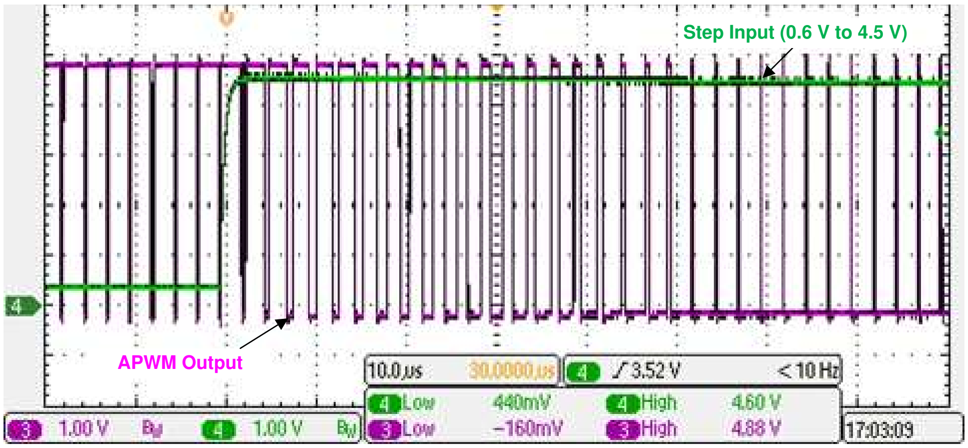

Figure 3. Step Response of APWM Pin Output

The PWM duty cycle can be measured directly by an MCU or filtered using an RC filter to remove the high frequency carrier signal and reconstruct the equivalent low-frequency analog signal. The filtered response was also captured to show the response time of the analog signal that could be input to the MCU. Since the input and output share an inverse relationship, the signal was inverted in the oscilloscope.

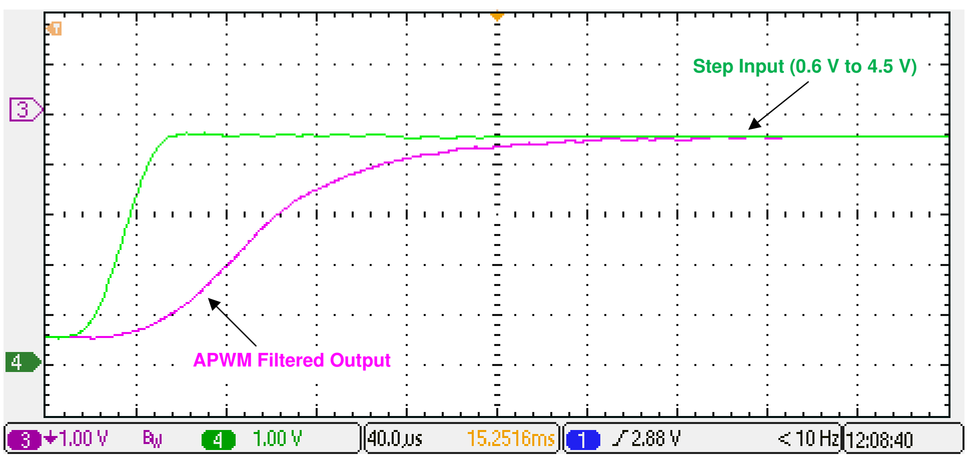

Figure 4. Step Response of Filtered APWM Pin Output

The accuracy was also tested with a benchtop power supply applying a DC input at the AIN pin and measuring the filtered output at the APWM output, displayed in Figure 5. This shows that the absolute error of the analog channel is minimal and near constant; therefore, it can be eliminated easily by calibrating the measurements to a known offset to give accurate measurements.

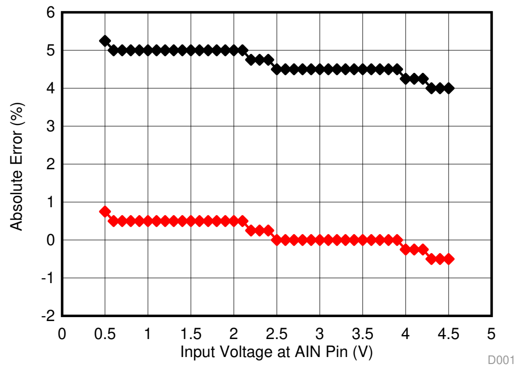

Figure 5. Absolute Error of Analog-to-Digital PWM Channel

The accuracy was also tested for DC current conditions by running an AC induction motor at 0 Hz with a switching frequency of 16 kHz. The linearity and accuracy were measured in the presence of switching noise to determine the performance of the analog channel. Figure 6 shows a motor drive diagram and Figure 7 shows the connections from the motor drive to the UCC21750 device.

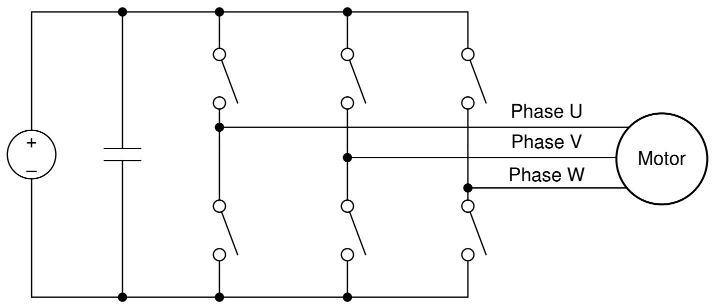

Figure 6. Motor Drive Diagram

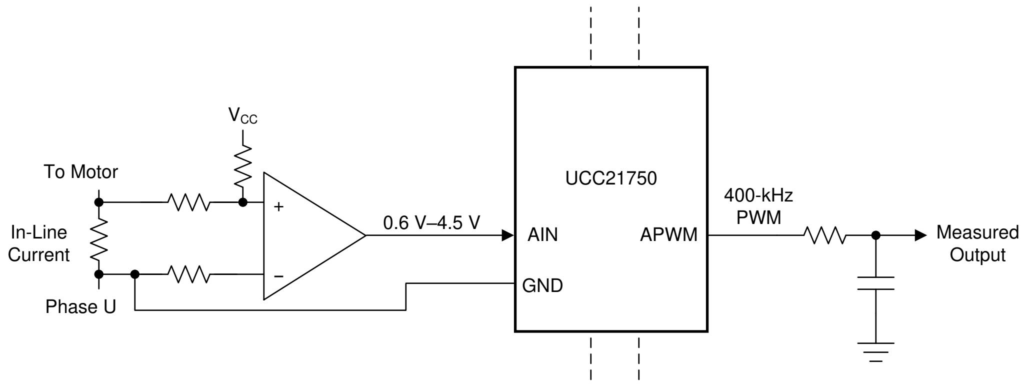

Figure 7. Block Diagram of Current Sensing Circuit

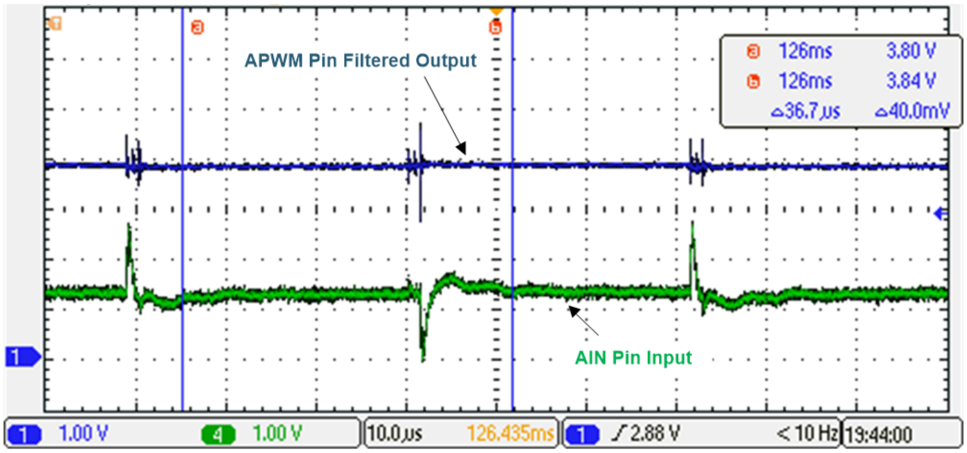

Figure 8. DC Current Measurements at AIN Pin IN

In Figure 8 the switching noise is apparent on the AIN pin where there are large spikes at approximately 16 kHz. This noise is fully eliminated by the 10-kHz bandwidth of the AIN input, but some noise is picked up by the oscilloscope probes which is seen on the filtered output. The filtered output shows a steady current measurement. The measurements were taken from –9 A to 9 A to determine the linearity of the output to input relationship for DC measurements. The analog channel provides a linear output across the full-scale range; this is plotted in Figure 9.

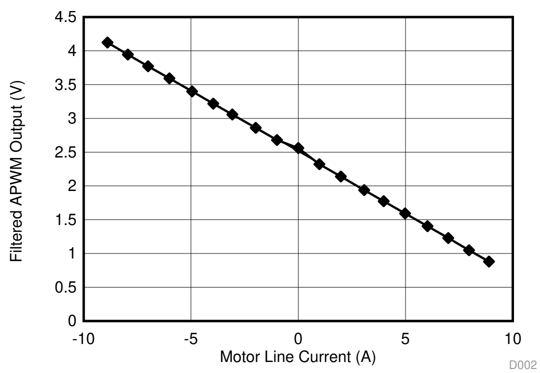

Figure 9. Current Measurements at AIN Pin Input and APWM Filtered Output While Running the Motor at 0 Hz

Looking at the use-case of the analog channel for a digital input signal, an input was stepped from 5 V to 0 V and the response time at 2 V, the threshold for a 5-V logic signal was measured. Figure 10 shows the response time for the use-case of the analog channel as an isolated digital signal. Thus, the analog channel can also be used as an isolated digital channel for transfer of status or alarm signals.

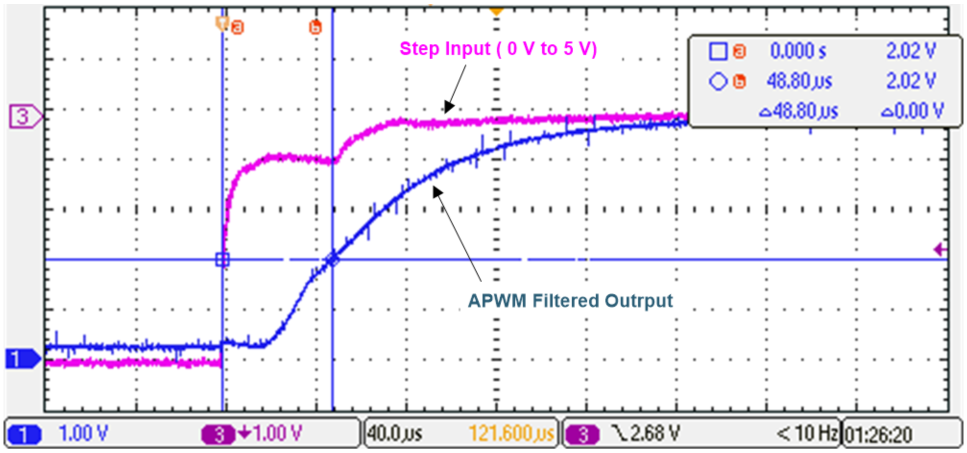

Figure 10. Digital Input Response Time 5 V to 0 V

3.2 AC Test

The line-to-line voltage was measured using a resistor divider between two phases of the motor and this signal was conditioned to meet the AIN pin input specifications of 0.6 V to 4.5 V.

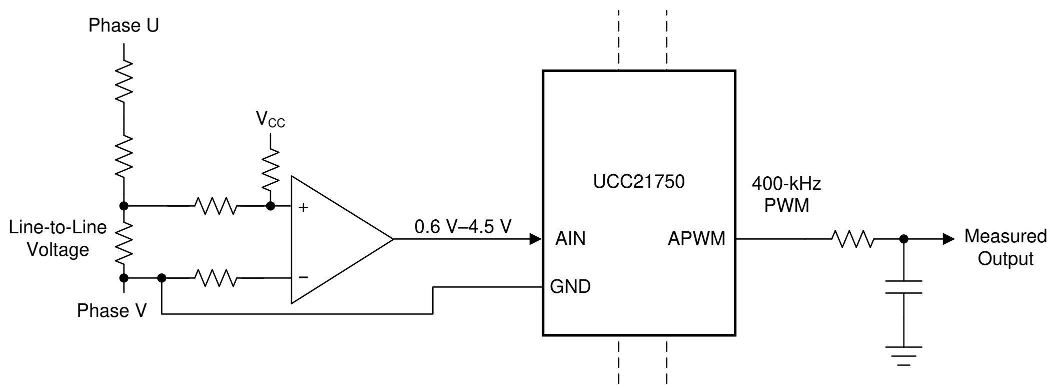

Figure 11. Block Diagram of Voltage Sensing Circuit

The AIN pin input and the filtered output from the APWM pin were connected to an oscilloscope using isolated probes to look at the performance of the analog channel when measuring the line-to-line voltage of a motor.

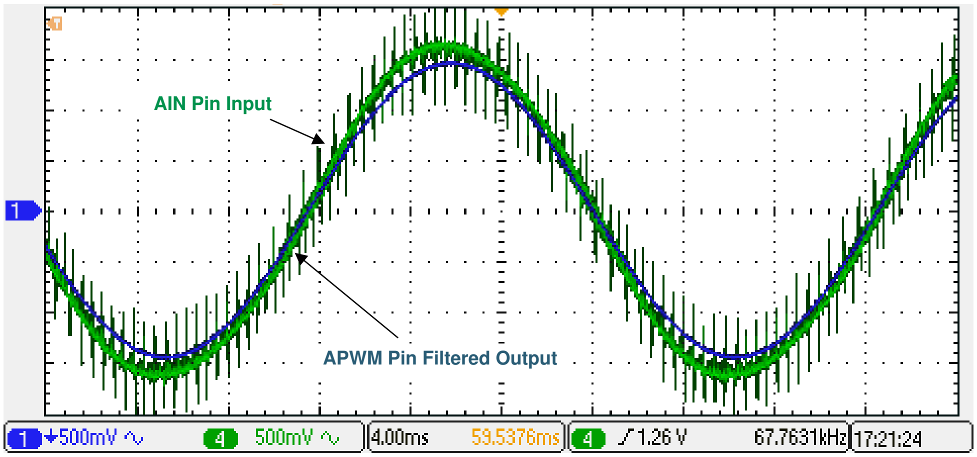

Figure 12. Line-to-Line Voltage Measured at AIN Pin and Filtered Output of APWM Pin

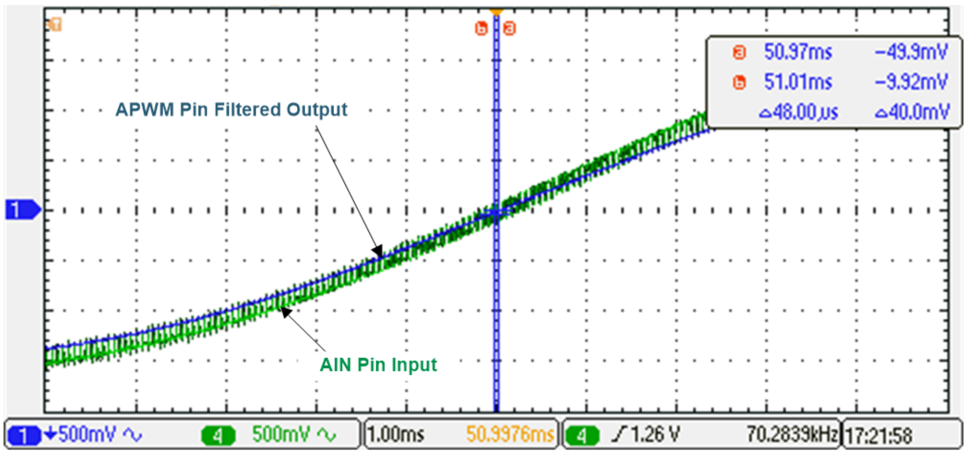

Figure 13. Line-to-Line Voltage Measured at AIN Pin and Filtered Output of APWM Pin

Measurements were taken while varying the motor AC voltage from 0 V to 400 V and frequency from 0 Hz to 50 Hz to determine the linearity of the analog channel and how accurately the signals can be transferred across the isolation barrier. The filtered output of the analog channel was significantly less noisy than the AIN input due to the 10-kHz bandwidth of the AIN input and the low pass filter at the APWM output.

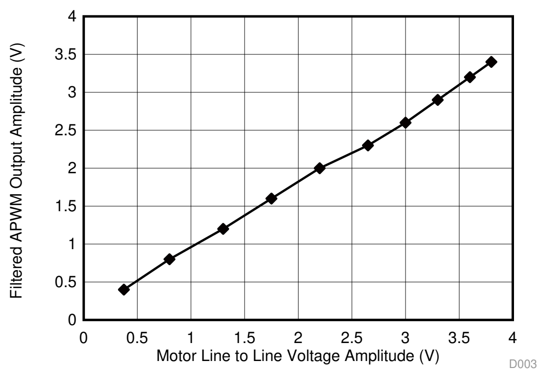

Figure 14. Filtered APWM Output vs Line to Line Voltage Amplitude

The linear input output relationship of the analog channel and low offset error means that with calibration high accuracy can be achieved in signal measurements due to the precision of the channel.

Similar to the line-to-line voltage, in-line current was measured while running the motor by conditioning the shunt measurement for the AIN pin input range and measuring the filtered APWM pin output, shown in Figure 7.

The current waveform in Figure 15 shows similarities to the line-to-line voltage measurements with an accurate reconstruction of the waveform with a delay. The noise carried across the isolation barrier is also mitigated as seen in the voltage measurements.

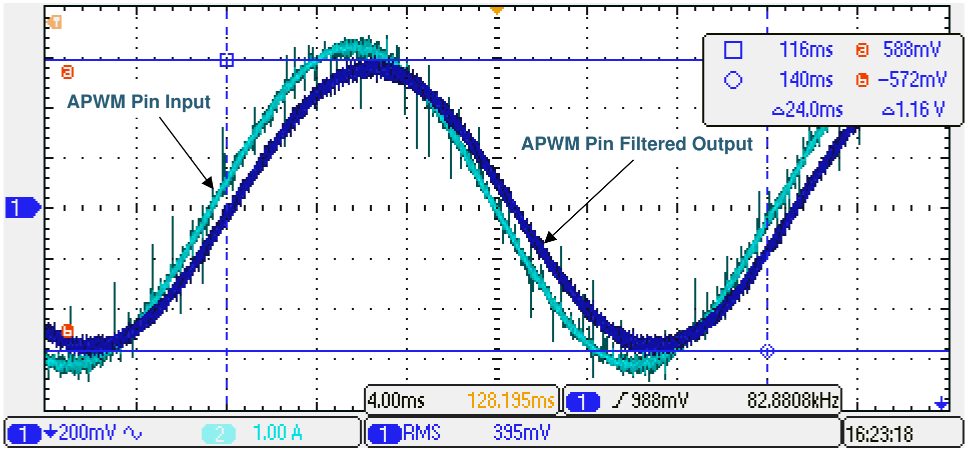

Figure 15. In-Line Current Measured at AIN Pin and Filtered Output of APWM Pin

4 Summary

As the performance requirements and safety features of motor drives increase while size decreases, more sensing capabilities need to be added in a compact and integrated design. With the UCC217xx smart gate driver family, the integrated safety features and analog channel provide the necessary functions to overcome this design challenge.

This application report provides insight into what the UCC217xx smart gate driver family offers using its analog-to-digital PWM channel. The integrated analog channel offers high accuracy with a linear output while isolating the signal, which allows for reduced BOM count and board size while simplifying design.

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