Application Report
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# Input Resistor Selection Guide for Opto-compatible Isolated Gate drivers

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**ABSTRACT**

The UCC23513 is a 4-A, 5-$kV_{RMS}$ single channel isolated gate driver in a stretched SO6 package. This device is a pin-to-pin replacement for common opto-coupled gate drivers but with superior specifications such as higher common mode transient immunity, smaller propagation delay, tighter part-to-part delay matching, and longer life time. This application report helps engineers select the appropriate input resistor for three different configurations presented in the following sections. Calculating the correct input resistor ensures the value of the forward current $I_F$ does not exceed the recommended range, which guarantees the rest of the UCC23513 datasheet specifications, unless otherwise noted. The UCC23513 targets industrial motor control drives, industrial power supplies, solar inverters, and uninterruptible power supplies.

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## Trademarks



## 1 Introduction

The input stage of a gate driver is made up of either a high impedance structure, that is CMOS or TTL or a low impedance structure that is diode-based. TI's opto-compatible isolated gate driver is a current driven device which does not require certain voltage levels (TTL) or percentages of the supply voltage (CMOS) for proper operation. Instead, it requires a resistor and buffer to forward bias the device. The input stage of the UCC23513 contains a low-impedance e-diode which emulates an opto-coupler input as shown in Figure 1. Pin 1 and Pin 3 connect to the anode and cathode, respectively, of the e-diode while Pin 2 has no internal connection and can be left open or connected to ground.

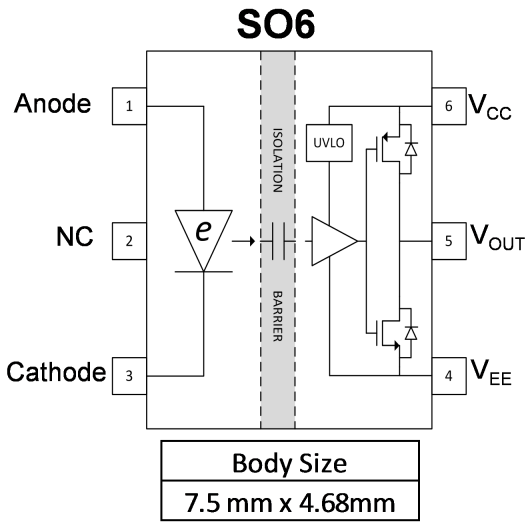


**Figure 1. UCC23513 Pinout**

In order to pass information through the reinforced isolation barrier, the e-diode must be forward biased and requires between 7 mA to 16 mA of forward current to operate. Input resistors are paired with buffers or a discrete NMOS transistor to set the forward current $I_F$. The input stage can be reverse biased with a second UCC23513 for interlock functionality by connecting anode to cathode, and cathode to anode. The output stage has a 33 V max output drive with a peak current rating of 4 A which can drive IGBTs, MOSFETs, and SiC FETs. The six pin SO6 package provides greater than 8.5 mm of creepage and clearance and it makes the UCC23513 a drop in replacement for most single channel opto-coupled gate drivers. This application report presents an overview of three configurations in order to drive the input stage of the UCC23513. Different configurations include: operating with one discrete NMOS driving the cathode, single buffer, and dual buffers to drive the input.

For the different configurations presented in Figure 2, Figure 3, and Figure 4, the following assumptions have been made:

- $V_{SUP}$ = 5 V (5% tolerance)
- $V_F$ = 1.8 ~ 2.4 V
- $R_{M1}$ = 0.25 ~ 1.0 Ω
- Tolerance of the manufacturer for $R_{EXT}$ = +/- 1%
- Target current for $I_F$ = 10 mA

## 2 Input Drive Architecture - Configuration 1 (Single Discrete NFET)

The first input drive architecture uses a resistor at the anode to set the forward current and an NFET between the cathode and ground to forward bias the e-diode as shown in Figure 2.

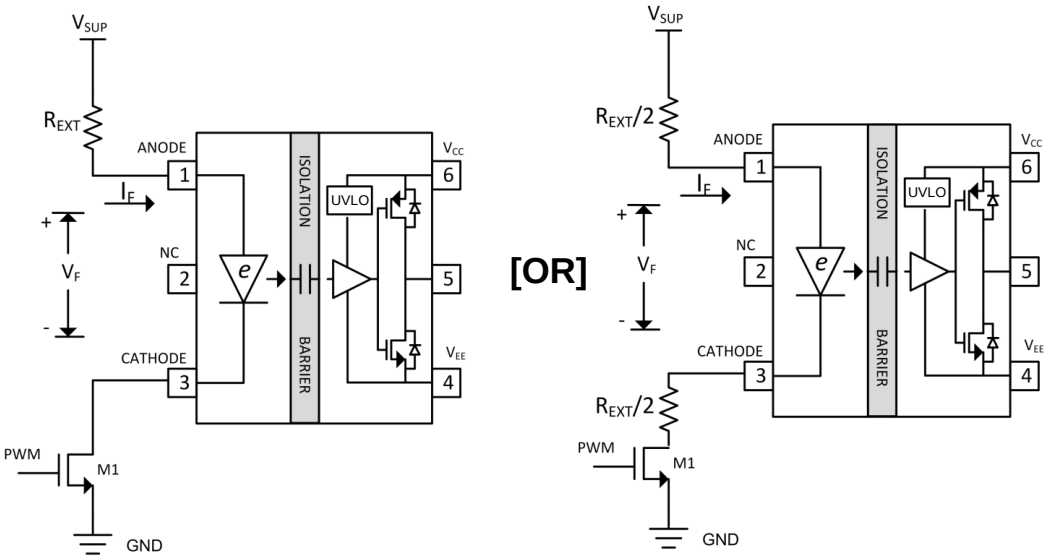


**Figure 2. Input Drive with NMOS at Cathode**

The current is set by the series resistance $R_{EXT}$ and the turn-on resistance of the NFET, $R_{M1}$. A PWM signal from a controller drives the gate of the NFET which lowers the potential of the cathode to slightly above the ground reference. Use Equation 1 to determine the required resistor value to forward bias the UCC23515. Another option is to place resistors on the anode and cathode to match the typical application circuit of opto-couplers as shown in the right-hand side of Figure 2.

$$R_{EXT} = \frac{[V_{SUP} - V_F]}{I_F} - R_{M1} \quad (1)$$

The benefits of driving the UCC23513 with an NFET instead of using a buffer or two is lower cost and reduced board space. Select an NFET with low on-resistance, $R_{DSON}$ in order to minimize power dissipation across the switch.

For the assumptions given in the introduction, Equation 1 recommends a value for $R_{EXT}$ of 290 Ω with a range of 218 Ω ~ 331 Ω.

## 3 Input Drive Architecture - Configuration 2 (One Buffer)

The second input drive architecture uses a buffer on the anode with a series external resistor $R_{EXT}$ to set the forward current. The PWM is now fed through the buffer which enables its output to source current from $V_{SUP}$ through the series resistive combination of $R_{EXT}$ and $R_{OH}$ as shown in Equation 2.

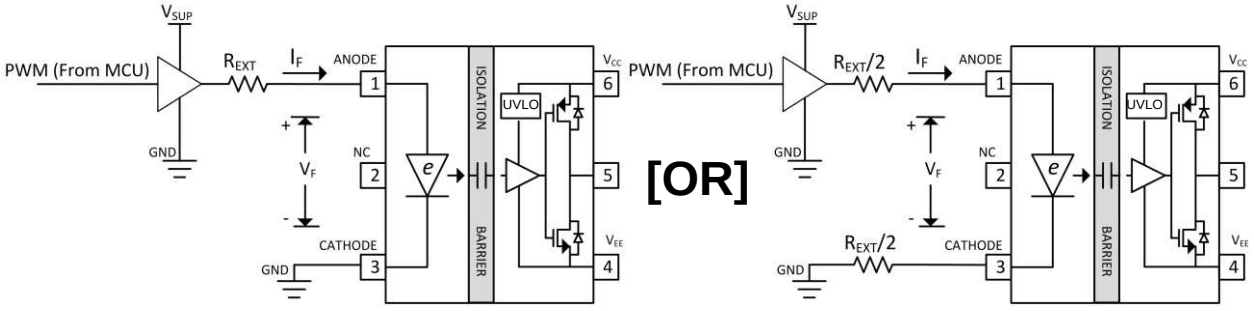


**Figure 3. Input Drive with One Buffer**

$$R_{EXT} = \frac{[V_{SUP} - V_F]}{I_F} - R_{OH\_buf} \quad (2)$$

The benefits of driving the input of the UCC23513 with a buffer instead of a discrete NFET is faster sourcing and sinking ability to forward bias or reverse bias the e-diode. Apart from setting the current to forward bias the e-diode, the external resistor limits the current from the buffer to protect the input stage of the UCC23513.

If the design calls for two external resistors, divide the result of Equation 2 in half and place the resistors on either side of the e-diode as shown in Figure 3.

For the assumptions given in the introduction, Equation 2 recommends a value for $R_{EXT}$ of 272 Ω with a range of 204 Ω to 311 Ω.

## 4 Input Drive Architecture - Configuration 3 (Two Buffers)

The interlock configuration in Figure 4 takes advantage of the minimum reverse breakdown voltage of 8 V of the e-diode. The inputs of two UCC23513 devices are connected in such a way that prevents both e-diodes from being forward biased at the same time. For normal operation, a reverse bias of 5 V is permissible. This configuration prevents shoot-through in the FET or IGBT due to potential erroneous PWM signals that are fixed high (or low).

Two buffers and two external resistors set the forward current for two UCC23513 devices in an interlock configuration.

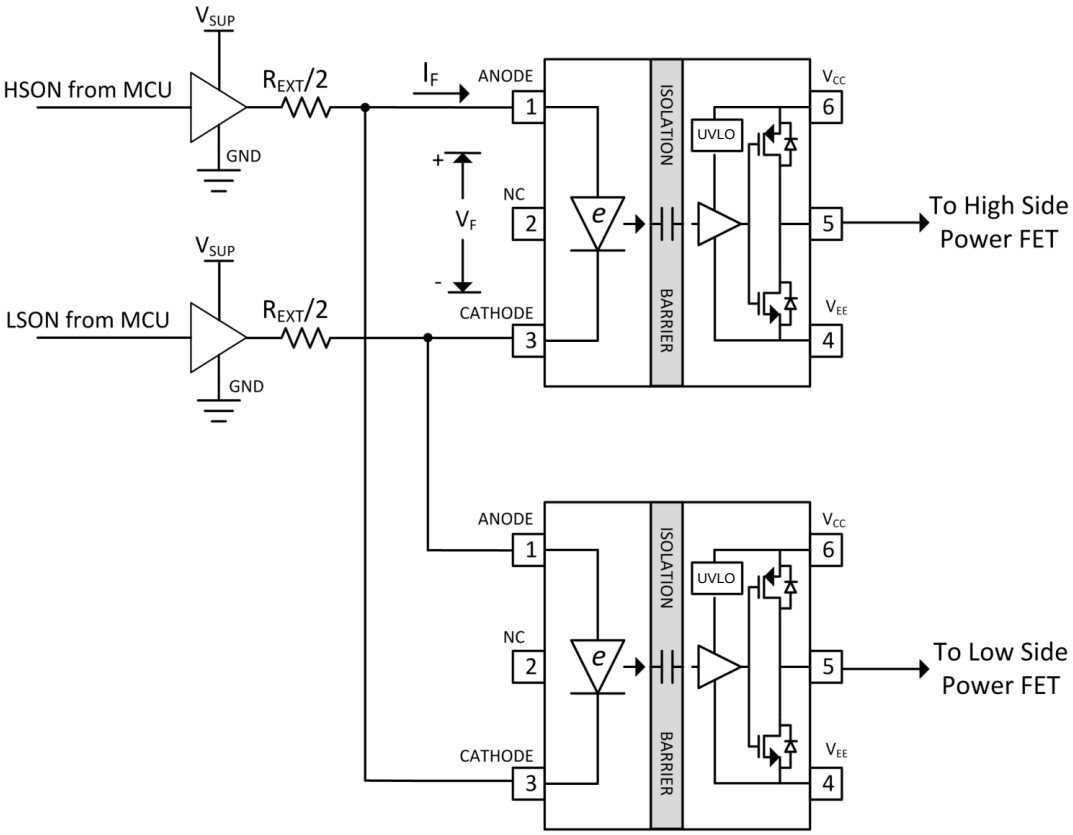


**Figure 4. Interlock Configuration Using Two Buffers**

The forward current for both opto-emulated devices is the same as long as the internal resistance of the buffers and the selected external resistance are matched. If true, the forward current $I_F$ is sourced from $V_{SUP}$ through the pullup resistance $R_{OH}$, the external resistance $R_{EXT}$ , and $R_{OL}$ of the buffer as shown in Equation 3.

$$R_{EXT} = \frac{[V_{SUP} - V_F]}{I_F} - (R_{OH\_buf} + R_{OL\_buf}) \quad (3)$$

For the assumptions given in the introduction, Equation 3 recommends a value of 259 Ω with a range of 194 Ω ~ 294 Ω.

Figure 5 demonstrates the interlock functionality between two UCC23513 devices. Two buffers drive the high-side anode, IN_AN1, and cathode, IN_CAT1, high or low which forces the cathode and anode of the low-side UCC23513 low or high, respectively.

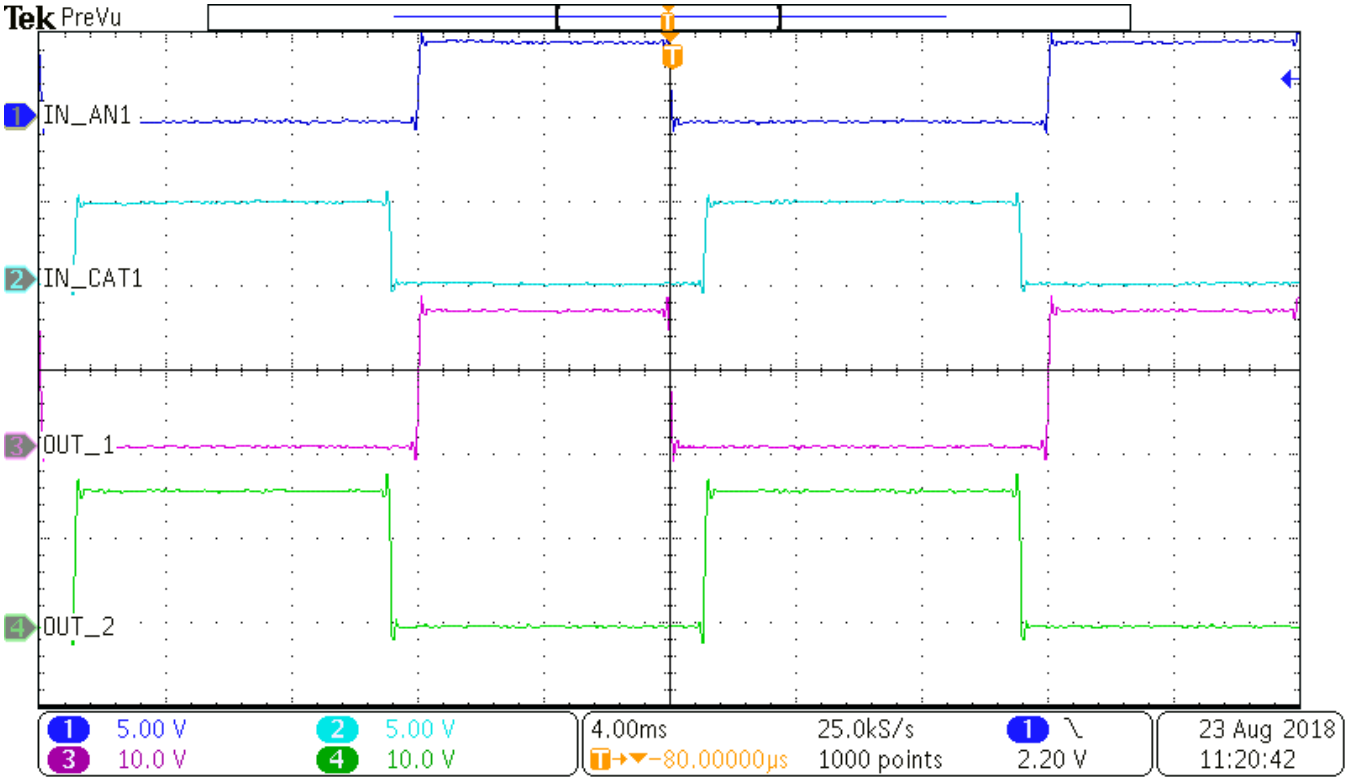


**Figure 5. Interlock Functionality**

## 5 $R_{EXT}$ Results

Using the assumptions in Table 1, Table 2 displays the calculated values for the three configurations presented in the previous sections. Take note of the tolerance of the manufacturer for $R_{EXT}$ before placing it at the input of UCC23513. A large tolerance affects the desired forward current and may set the forward current outside the recommended range of 7 mA ~ 16 mA.

**Table 1. $R_{EXT}$ Calculator Example for UCC23513**

| | PARAMETER | MIN | TYP | MAX | COMMENTS |
|---|---|---|---|---|---|
| **Assumptions** | Anode to Cathode Clamp $V_F$ (V) | 1.8 | 2.1 | 2.4 | Datasheet Specification |
| | Supply Voltage $V_{SUP}$ (V) | 4.75 | 5 | 5.25 | Adjustable |
| | $R_{M1}$ (discrete NFET resistance) | 0.25 | 0.5 | 1.0 | Adjustable |
| | Buffer $R_{OH}$ (Ω) | 13 | 18 | 22 | Adjustable |
| | Buffer $R_{OL}$ (Ω) | 10 | 14 | 17 | Adjustable |
| | Manf. tolerance for $R_{EXT}$ (+/- %) | - | 1 | - | Adjustable |
| | Recommended $I_F$ range (mA) | 7 | 10 | 16 | Adjustable only (between 7 mA and 16 mA) |

**Table 2. Calculated $R_{EXT}$ Values**

| CONFIGURATION | Recommended $R_{EXT}$ (Ω) | | |
|---|---|---|---|
| | MIN | TYP | MAX |
| One discrete NMOS driving cathode | 218 | 290 | 331 |
| Single buffer | 204 | 272 | 311 |
| Dual buffer | 194 | 259 | 294 |

## 6 References


- *UCC23513 5-kV Single Channel Isolated Gate Driver with Opto Compatible Input Datasheet*
- *UCC23513 Product Folder*
- *UCC23513 Evaluation Module User's Guide*

## Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Original (October 2018) to A Revision | Page |
|---|---|
| • Edited application report for clarity. | 1 |
| • Changed from 3 A to 4 A | 2 |
| • Changed from 2.2 V to 2.4 V | 5 |
| • Changed from 5% to 1% | 5 |
| • Changed from 11 mA to 10 mA | 5 |
| • Changed from 222 Ω, 266 Ω, 352 Ω to 218 Ω, 290 Ω, 331 Ω | 6 |
| • Changed from 208 Ω, 249 Ω, 332 Ω to 204 Ω, 272 Ω, 311 Ω | 6 |
| • Changed from 198 Ω, 235 Ω, 315 Ω to 194 Ω, 259 Ω, 294 Ω | 6 |

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