UCC23513 Input Resistor Selection Guide

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ABSTRACT
The UCC23513 is a 3-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 note 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. UCC23513 targets industrial motor control drives, industrial power supplies, solar inverters and uninterruptible power supplies.

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1 Introduction
The input stage of a gate driver is made up of either a high impedance structure e.g. CMOS or TTL or a low impedance structure e.g. 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.
In order to pass information through the reinforced isolation barrier, the e-diode must be forward biased and requires between 7mA to 16mA 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 33V max output drive with a peak current rating of 3A 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 will present 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:

- $V_{SUP} = 5V$ (5% tolerance)
- $V_F = 1.8 \sim 2.2V$
- $R_{M1} = 0.25 \sim 1.0\Omega$
- Manufacture’s tolerance for $R_{EXT} = +/- 3\%$
- Target current for $I_F = 11mA$

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.
The current is set by the series resistance $R_{\text{EXT}}$ 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 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.

$$R_{\text{EXT}} = \frac{[V_{\text{SUP}} - V_F]}{I_F} - R_{M1}$$  \hspace{1cm} (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, $R_{\text{DSON}}$ in order to minimize power dissipation across the switch.

For the assumptions given in the introduction, Equation 1 recommends a value for $R_{\text{EXT}}$ of 266Ω with a range of 222Ω ~ 352Ω.

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

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

$$R_{\text{EXT}} = \frac{[V_{\text{SUP}} - V_F]}{I_F} - R_{\text{OH}_{\text{buf}}}$$  \hspace{1cm} (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 $R_{\text{EXT}}$ of 249Ω with a range of 208Ω to 332Ω.

4 Input Drive Architecture - Configuration 3 (Two Buffers)

The interlock configuration in Figure 4 takes advantage of the e-diode's minimum reverse breakdown voltage of 8V. 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 5V 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](image-url)

The forward current for both opto-emulated devices will be 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 $V_{\text{SUP}}$ through the pull-up resistance $R_{\text{OH}}$, the external resistance $R_{\text{EXT}}$ and $R_{\text{OL}}$ of the buffer as shown in Equation 3.

$$R_{\text{EXT}} = \frac{V_{\text{SUP}} - V_F}{I_F} - (R_{\text{OH, buf}} + R_{\text{OL, buf}})$$
For the assumptions given in the introduction, Equation 3 recommends a value of 235Ω with a range of 198Ω ~ 315Ω.

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 \( R_{\text{EXT}} \) 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 manufacturer’s tolerance for \( R_{\text{EXT}} \) before placing it at the input of UCC23513. A large tolerance will affect the desired forward current and may set the forward current outside the recommended range of 7mA ~ 16mA.

Table 1. \( R_{\text{EXT}} \) Calculator Example for UCC23513

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode to Cathode Clamp ( V_F ) (V)</td>
<td>1.8</td>
<td>2.07</td>
<td>2.2</td>
<td>Datasheet Specification</td>
</tr>
<tr>
<td>Supply Voltage ( V_{\text{SUP}} ) (V)</td>
<td>4.75</td>
<td>5</td>
<td>5.25</td>
<td>Adjustable</td>
</tr>
<tr>
<td>( R_{\text{M1}} ) (discrete NFET resistance)</td>
<td>0.25</td>
<td>0.5</td>
<td>1</td>
<td>Adjustable</td>
</tr>
<tr>
<td>Buffer ( R_{\text{OH}} ) (Ω)</td>
<td>13</td>
<td>18</td>
<td>22</td>
<td>Adjustable</td>
</tr>
<tr>
<td>Buffer ( R_{\text{OL}} ) (Ω)</td>
<td>10</td>
<td>14</td>
<td>17</td>
<td>Adjustable</td>
</tr>
<tr>
<td>Manf. tolerance for ( R_{\text{EXT}} ) (+/- %)</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>Adjustable</td>
</tr>
<tr>
<td>Recommended ( I_F ) range (mA)</td>
<td>7</td>
<td>11</td>
<td>16</td>
<td>Adjustable only (between 7 mA &amp; 16 mA)</td>
</tr>
</tbody>
</table>
Table 2. Calculated $R_{\text{EXT}}$ Values

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Recommended $R_{\text{EXT}}$ (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>min</td>
</tr>
<tr>
<td>One discrete NMOS driving cathode</td>
<td>222</td>
</tr>
<tr>
<td>Single buffer</td>
<td>208</td>
</tr>
<tr>
<td>Dual buffer</td>
<td>198</td>
</tr>
</tbody>
</table>

6 References
UCC23513 Datasheet link here

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