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Application Note AN010

Low-cost Bidirectional Mixed-voltage Interfacing

Abstract: The Propeller P8X32A multicore microcontroller's I/O pins feature oversized internal ESD protection diodes. With the appropriate over-current protection, these diodes allow the Propeller to interface with voltage levels above VDD and below Vss.

Introduction

The Propeller P8X32A's I/O pins operate at 0 to V_{DD}, usually 3.3 volts; however, in many cases, a simple resistor may be all that is needed for bidirectional communication between the Propeller chip and a higher voltage device. This application note will focus on choosing the correct current-limiting series resistor value for different voltage levels.

Propeller P8X32A I/O Pin ESD Protection Diodes

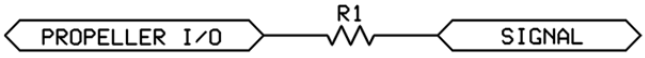
Each of the P8X32A's I/O pins contain oversized ESD protection diodes that allow the input to exceed V_{DD}, or fall below V_{SS}, as long as the current sourced or sunk is limited. Using an external current-limiting resistor in series with an I/O pin, a Propeller pin can function as an over-voltage and under-voltage tolerant input. When the I/O pin is operating as an output, this circuitry will have a minimal effect.

When a P8X32A I/O pin is operating as an input and is driven by a signal with a voltage higher than V_{DD} or lower than V_{SS}, the internal ESD protection diodes will clamp to the respective supply rail. The current must not exceed a maximum of 500 µA under the worst-case operating conditions. ***ESD protection diode exposure to current over 500 µA may cause damage to the Propeller chip.***

Choosing a Current-limiting Resistor Value

Figure 1 shows a Propeller I/O pin interfaced with an external signal via a series resistor R1.

Figure 1: R1 serves as a current-limiting resistor, providing over-current protection to the Propeller P8X32A's ESD protection diodes



To choose a resistance value for R1, consider the following equation:

$$Minimum\ Resistance\ R1 = \frac{|Signal\ Maximum\ \Delta\ V|}{Maximum\ allowed\ ESD\ diode\ current}$$

The $|Signal\ Maximum\ \Delta V|$ is the largest absolute value of the difference in interface-to-Propeller voltages on the high-side and low-side (positive-to-positive and negative-to-negative). Note that worst-case voltages for both devices must be considered when calculating this value. For the P8X32A the minimum operating voltage is 2.7 V.

The *Maximum allowed ESD diode current* is 500 µA.

Example #1: 5-volt Signal

A 5-volt device may output a signal that transitions from 5 V (high) to 0 V (low). When compared to the Propeller's I/O pin (with a 2.7 V worst-case supply voltage), the high-side absolute Δ voltage is 2.3 V.

$$|5\ V_{SIGNAL}|\ -\ |2.7\ V_{PROPELLER}| = 2.3\ V$$

The low-side absolute Δ voltage is 0 V.

$$|0\ V_{SIGNAL}|\ -\ |0\ V_{PROPELLER}| = 0\ V$$

The greater of the absolute values of low-side and high-side is 2.3 V.

$$\begin{aligned} & 0\ V\ ?\ \ 2.3\ V \\ \rightarrow\ & 0\ V\ <\ 2.3\ V \\ =\ & 2.3\ V\ (greatest) \end{aligned}$$

So the *Minimum Resistance* equation above becomes:

$$Minimum\ Resistance\ \mathrm{R1} = \frac{2.3\ V}{500\ \mu A}$$

$$2.3\ V\ \div 500\ \mu A\ = 4.6\ k\Omega$$

Choose a resistor value for R1 that is at least 4.6 kΩ.

Example #2: RS-232 Device

An RS-232 compliant input must accept voltages from 25 V (high) to -25 V (low). When compared to the Propeller I/O pin's (with a 2.7 worst-case supply voltage), the high-side absolute Δ voltage is 22.3 V.

$$|25\ V_{SIGNAL}|\ -\ |2.7\ V_{PROPELLER}| = 22.3\ V$$

The low-side absolute Δ voltage is 25 V.

$$|-25\ V_{SIGNAL}|\ -\ |0\ V_{PROPELLER}| = 25\ V$$

The greater of the absolute values of low-side and high-side is 25 V.

$$\begin{aligned} & 25\ V\ ?\ \ 22.3\ V \\ \rightarrow\ & 25\ V\ >\ 22.3\ V \\ =\ & 25\ V\ (greatest) \end{aligned}$$

So, the *Minimum Resistance* equation above becomes:

$$Minimum\ Resistance\ \mathrm{R1} = \frac{25\ V}{500\ \mu A}$$

$$25\ V\ \div 500\ \mu A\ = 50\ k\Omega$$

Choose a resistor value for R1 that is at least 50 kΩ.

Revision History

Version 1.0: Original document.