Rarely Asked Questions—Issue 119
The Ingenious Gentleman and the Mysterious Paddle

By Gustavo Castro

Question:

Shouldn't the exposed paddle of an IC amplifier always be connected to ground?

Answer:

In a village of La Mancha, the name of which I have no desire to recall, there lived not long since one of those gentlemen that keep a lance in the lance rack, an old buckler, a lean hack, and a greyhound for coursing. You must know then, that this gentleman, whenever he was at work, gave himself up to connect all exposed paddles in ICs to ground with such ardor and avidity that he almost entirely neglected the pursuit of reading data sheets, unsuspecting of its actual internal connection. Until one day, to his unfortunate surprise, a fuse was blown and all he was left was a board worth not more than a pile of rocks.

This heroic gentleman—an electrical engineer no less, had embarked himself in numerous battles, from which he came triumphant after jostling with proper PCB design, but this one had been an exception. He had understood the importance of providing solid ground connections through the exposed paddle or E-Pad, just like most people would after reading Rob Reeder's[1] and David Buchanan's[2] *RAQ* articles on the topic. However, he failed to realize that for amplifiers, there is no universal rule regarding the potential to which the E-Pad should be connected.

Most amplifiers don't have a ground terminal, so there is no practical meaning in saying that the E-Pad should be connected to ground. One might argue that the exception to the rule is when they are powered from a single supply, in which case the negative rail becomes ground. But even then, the recommended potential of the E-Pad could differ from that of the most negative rail, depending on the IC process technology and package assembly. This is can be a challenge to those seeking to use the E-Pad for thermal management.

For example, there are junction and oxide insulated processes. For the former, conduction is possible through p-n junctions formed from the back side of the chip to any other terminal; for the latter, a barrier of silicon oxide will prevent it. Since the back side of the chip is "glued" to the exposed pad with a die attach material (which is by no means an insulator), an electrical connection is formed, and proper biasing of the paddle becomes important for the junction isolated process. But even if the back side is $Si0_2$, there may be down bonds if the designer deemed them necessary.[2] As a consequence, the exposed paddle on several IC amplifiers has a specific bias requirement. The problem is that it does not always have to be the most negative potential available to the part (as in the negative rail), but it can be the most positive instead.

So, how's anybody supposed to know what to do with the mysterious paddle? Read the data sheet. If the part in question is available in a package with an exposed paddle, instructions are provided there. For example, the AD8224, an n-channel JFET input in-amp must have its paddle connected to the most positive potential available to the chip (that is, the positive supply)[3], while the ADA4610-2 p-channel JFET input op amp must have its paddle connected to the same potential as the negative rail.[4] In contrast, the ADA4807-2 can have the paddle connected to ground or either power plane,[5] in which case it makes sense to connect it to the ground plane if power dissipation is a concern.

If our fictitious gentleman had used an amplifier on a dielectrically isolated process (and without down bonds), he would have been spared, and the omission would have gone unnoticed. But instead, like Don Quixote, he chose to tilt at the windmills (and connect to ground planes) before listening to his loyal squire.

References

[1] Reeder, Rob. "Considerations on High Speed Converter PCB Design, Part 3: The E-Pad Low Down." *RAQ*—Issue 69.

[2] Buchanan, David. "Exposed Paddles and Downbonds Improve Performance and Reduce Pin Count." *RAQ*—Issue 112.

[3] AD8224 Data Sheet.

[4] ADA4610-2 Data Sheet.

[5] ADA4807-2 Data Sheet.

Gustavo Castro [gustavo.castro@analog.com] is an applications engineer in the Linear and Precision Technology Group in Wilmington, MA. His main interests are analog and mixed-signal design for precision signal conditioning and electronic instrumentation. Prior to joining Analog Devices in 2011, he worked for 10 years designing high performance digital multimeters and precision dc sources at National Instruments. Gustavo received a bachelor's degree in electronics engineering in 2000 from Tecnológico de Monterrey, Mexico. He holds three patents.

Gustavo Castro

Also by this Author:

Rarely Asked Questions—Issue 116, April 2015

Muntzing Can Save Cost, Components, and Even Your Sanity