Thomas Kuehl Jan 15, 2016

Other Parts Discussed in Post: TLV2620, TLV2332

In my last blog, I described how a customer had been operating their op amp circuit with a power supply voltage level that was too high for the amplifier and the consequences of doing this. Recently, while meeting with other customers, I've had similar conversations about voltage that is too low and I want to share my advice to them in this blog post.

This may be surprising, but I have come across instances where a customer discovered that the supply voltage they selected to power their application turned out to be lower than the minimum rated operating voltage of the operational amplifiers (op amps) used in their circuit design.

I expect this happens due to an oversight that occurs over the time it takes to develop and design a product and put it into manufacturing. I can imagine a scenario where a designer identifies and selects a particular op amp for its electrical performance and ability to meet the low-end supply-voltage requirement.

For example, let's say that the minimum voltage requirement is 2.7V and you select an op amp that meets that requirement. Then later, someone decides to use a different op amp due to lower cost or availability, but no one noticed its minimum supply voltage is higher, such as 3V. Initially the circuit performs as expected in production. But later, when the customer receives another different batch of the op amps, the circuit performance doesn't meet the necessary levels. An investigation into the performance issue brings the supply-voltage discrepancy to light.

An undervoltage scenario does not sound too scary. That is because the bad things that can happen when an op amp is exposed to a high overvoltage are unlikely to occur. The main concern then becomes how the op amp performs electrically when subjected to an undervoltage condition.

When examining the lower end of the supply-voltage scale shown in Figure 1, you'll see that for this complementary metal-oxide semiconductor CMOS op amp, the minimum specified operating voltage is 2.7V. The op amp's design team takes into consideration its design and semiconductor process guardbands when establishing the amplifier's lower supply limit. The process guardband compensates for normal semiconductor process variances that affect the op amp's internal operating points and provides assurance that every one of that particular op amp operates at 2.7V, (if observing the stated datasheet conditions).

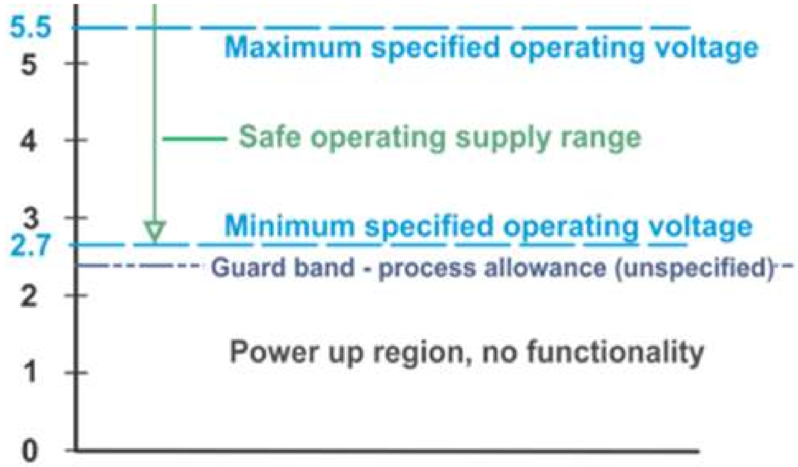


Figure 1: An example of the low operating voltage end for a CMOS op amp

In fact, because of the guardbanding, the op amp actually continues to operate with a supply voltage level somewhat less than 2.7V. Casual checks made in the lab on some low-voltage CMOS op amps show that their lower supply functional limit can be a few tenths of a volt to almost a volt below the minimum specified voltage.

You can see why some op amps continue to operate with a small undervoltage by viewing a set of curves commonly found in the datasheet. Figure 2 is a graph of supply current, I_{DD}, vs. supply voltage, V_{DD}, from the TLV2620 data sheet. The TLV2620 is a wideband CMOS op amp with an 11MHz unity-gain bandwidth. Its recommended supply range is 2.7 to 5.5V, but it is usable to 6V on the high end.

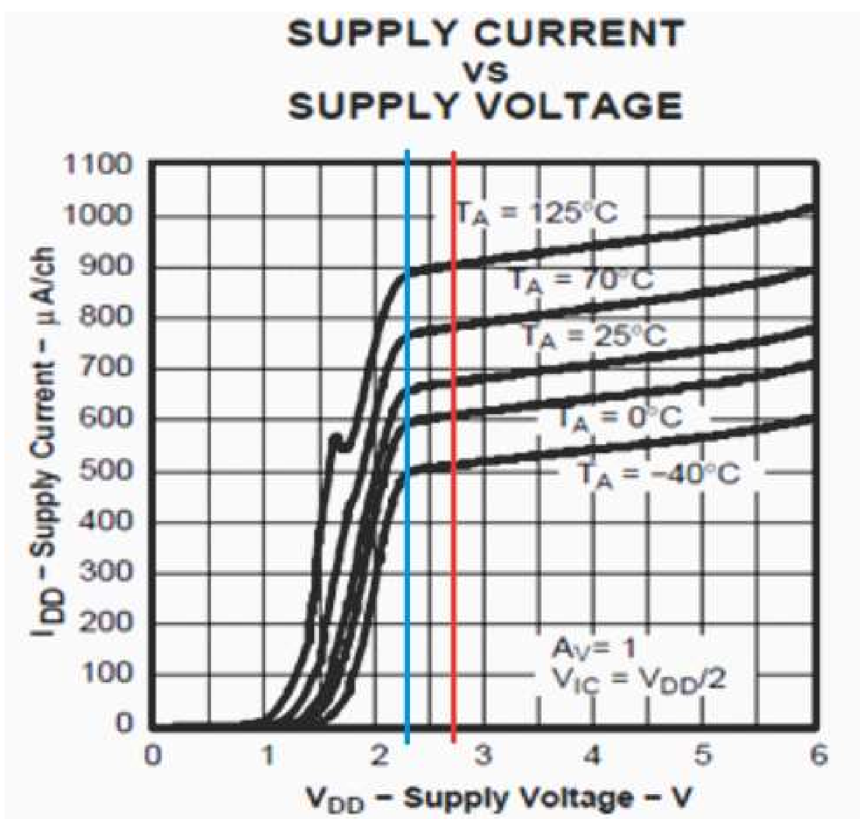


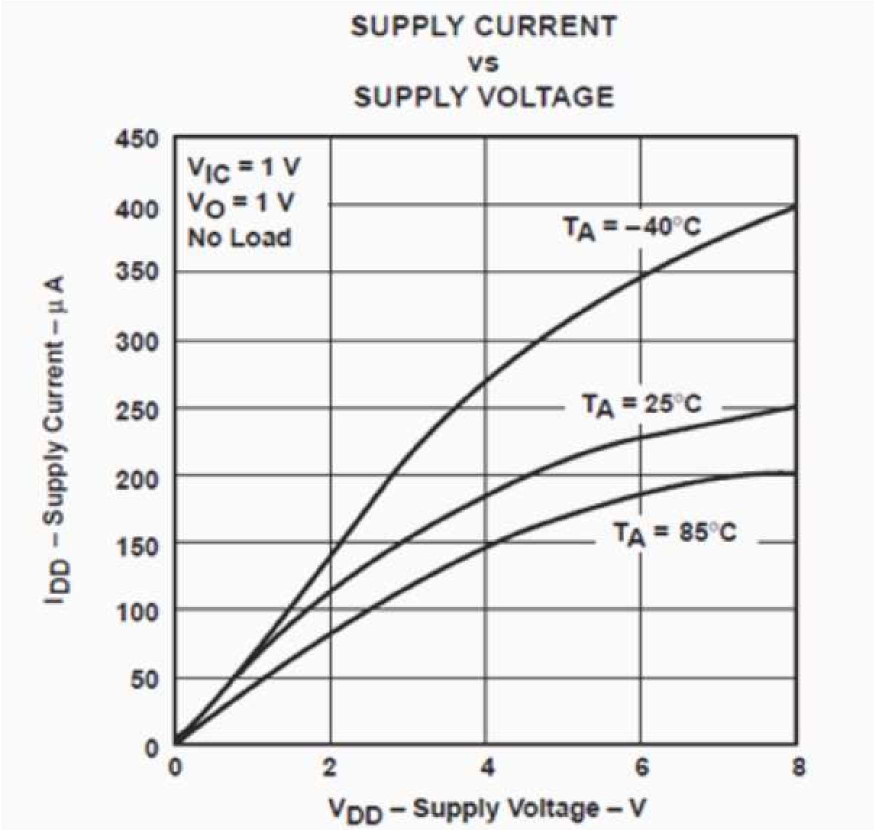
Figure 2: TLV2620 CMOS op amp I_{DD} vs V_{DD} and temperature

Figure 2 provides information on how the TLV2620 I_{DD} is a function of both supply voltage and temperature. Of particular interest for this discussion is the minimum specified 2.7V V_{DD} level indicated by the vertical red line in Figure 2. The temperature curves show that I_{DD} has the same slope on both sides of the 2.7V line. The op amp has only slightly less I_{DD} at 2.3V or 2.4V (shown as the blue line) than it does at 2.7V. Since there isn't an abrupt change in current at this lower voltage, the op amp is very likely operational.

I_{DD} drops quickly as V_{DD} decreases further. Voltages to the left of the "cliff" where the current falls off quickly are associated with the "power up region" shown in Figure 1. The internal circuits are not fully biased in that region and begin to shut down as the voltage continues lower.

Different op amps exhibit different behaviors in the region around the cliff. Some such as the TLV2620 show an immediate steep drop-off in I_{DD}, while others show a gradual decrease in the operating current as V_{DD} is reduced. In either case, you have no way of knowing at what level the amplifier becomes fully functional. That is until the op amp's minimum specified operating supply voltage is attained.

Other op amps such as the CMOS TLV2332 exhibit much more gradual I_{DD} vs. V_{DD} characteristics. The TLV2332 is a low-voltage, medium-power op amp; its I_{DD} vs. V_{DD} graph is shown in Figure 3. Its electrical characteristics are specified for V_{DD} levels of 3V and 5V; however, its recommended supply range is 2V to 8V, indicating that it is fully functional at 2V.



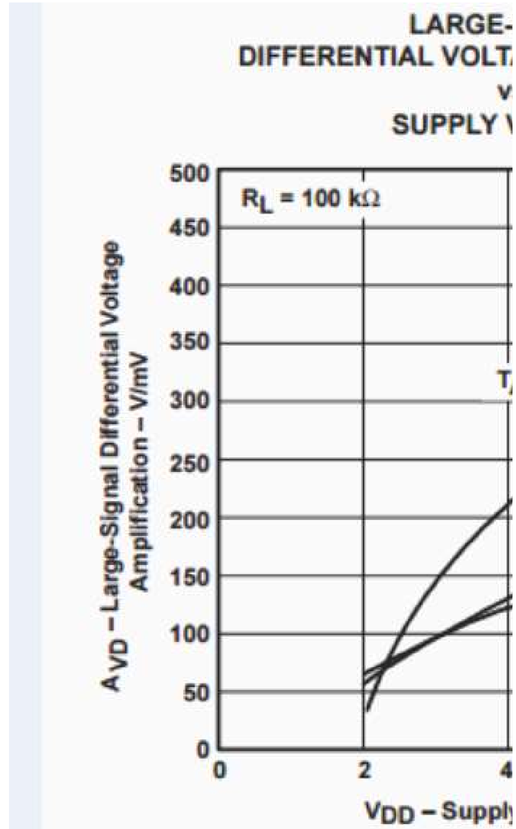


Figure 3: TLV2332 I_{DD} vs V_{DD}

Figure 4: TLV2332 open-loo

Figure 3 shows how I_{DD} follows V_{DD} down and doesn't exhibit an abrupt cliff. Interestingly, the TLV2332 datasheet provides several graphs plotting various DC and AC parameters against V_{DD}. Figure 4 is an example, which plots the large-signal differential-voltage amplification, A_{VD} (also known as open-loop gain, Aol) with V_{DD}. Figure 4 also shows the dramatic effect that V_{DD} has on Aol. Even though it falls off significantly with low V_{DD} to about 50kV/V with a 2V supply level, it is still high enough for less-critical applications.

This low supply-voltage capability is particularly useful in battery-powered applications. If an application is powered from a 3V battery, it can discharge down to 2V and the op amp will remain functional – albeit with reduced performance.

Returning to my original undervoltage topic, it is important to understand the performance implications, should you find yourself with a supply voltage lower than the minimum rated operating voltage of your op amp. Certainly, it is best not to use an op amp with a minimum supply voltage rating that is higher than the application's.

Once you discover this issue, immediately begin searching for a replacement op amp specified for the lower supply-voltage level that also provides the correct electrical performance. If you need help finding

· a suitable replacement, share your requirements via a quick post to the TI E2E™ Community Precision Amplifiers Forum, and we'll provide some options.

Additional resources

- Read the TLV2620 and the TLV2332 datasheets.
- Learn more about TI's precision amplifier portfolio and find technical resources.
- Watch on-demand training courses on input offset voltage and input bias current in TI Precision Labs.