Bruce Trump *May 8, 2012*

We often receive applications questions relating to the power supply, input and output voltage range capabilities of our op amps. It can be confusing so here is an attempt to sort it out:

First, common op amps don't have ground terminals. A standard op amp does not "know" where ground is so it cannot know whether it is operating from a dual supply (±) or from a single power supply. As long as the power supply, input and output voltages are within their operating ranges, all is good.

Here are the three critical voltage ranges to consider:

1. The total supply voltage range. This is total voltage between the two supply terminals. For example, ±15V is a total of 30V. The operating voltage range for an op amp might be, for example, 6V to 36V. At the low voltage extreme this could be ±3V or +6V. At maximum, ±18V or +36V or even -6V/+30V. Yes, unbalanced supplies are okay if you heed points 2 and 3 below.
2. The input common-mode voltage range (C-M range) is generally specified relative to the positive and negative supply voltages, shown graphically in figure 1. In some equation-like form, C-M range of this hypothetical op amp would be described as 2V above the negative rail to 2.5V below the positive rail. Something like this… (V-)+2V to (V+)–2.5V.
3. The output voltage range (or output swing capability) is. again, commonly specified relative to the rail voltages. In this case, (V-)+1V to (V+)–1.5V.

These examples (figures 1, 2, 3) are shown in a G=1 buffer configuration. A key point here… the output capability **of this example in figure 1** will be limited to 2V from the negative rail and 2.5V from the positive rail and due to the limited input C-M range. This op amp would need to be configured in a higher gain to deliver its full output voltage range.

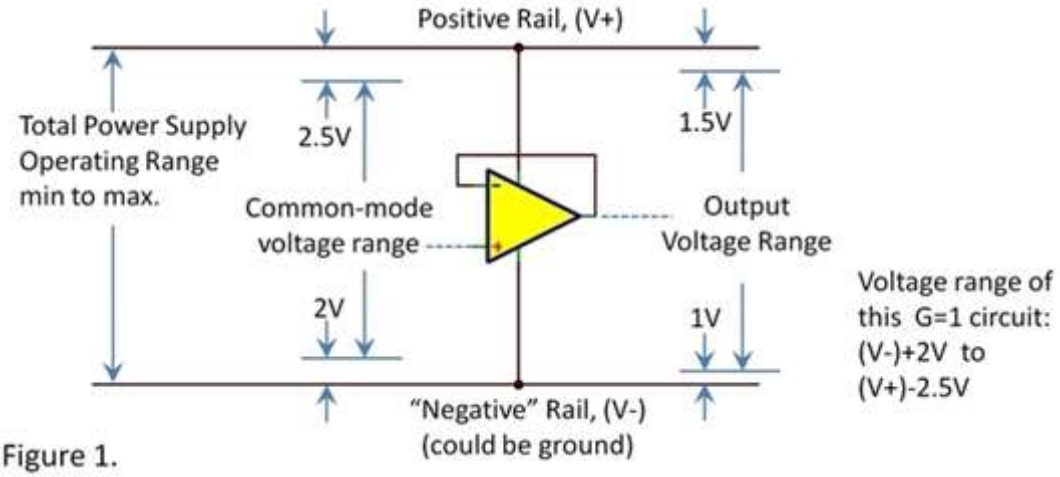

Figure 1.

- The example in Figure 1 is typical of an op amp generally used on dual ± supplies. It would not be called a “single supply” type but it certainly could be operated on a single supply just by staying within these ranges.

Figure 2 shows a so-called single supply op amp. It has a C-M range that extends to, and often slightly below the negative rail. This allows its use in a wider range of circuits that operate close to ground. So an op amp that is not called “single supply” could be used in some single supply circuits but a true single-supply type is more versatile in these applications.

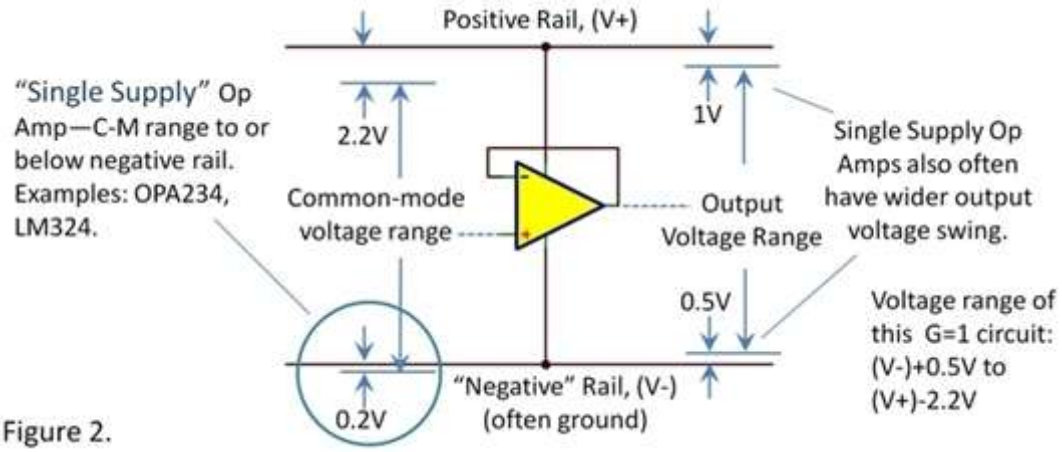

Figure 2.

In this G=1 buffer circuit, this op amp would could produce an output swing of 0.5V from the V- rail (limited by output capability) and 2.2V from the V+ rails (limited by the input C-M range).

Figure 3 shows a *“rail-to-rail”* op amp. It can operate with input voltage equal to or even slightly beyond both supply voltage rails as shown in figure 3. *Rail-to-rail output* means that output voltage can swing very close to the rails, often within a 10mV to 100mV from the supply rails. Some op amps claim only a rail-to-rail output, lacking the input characteristics shown in figure 3. Rail-to-rail op amps are very commonly used on single 5V supplies and lower because they maximize signal voltage capability on their limited supply range.

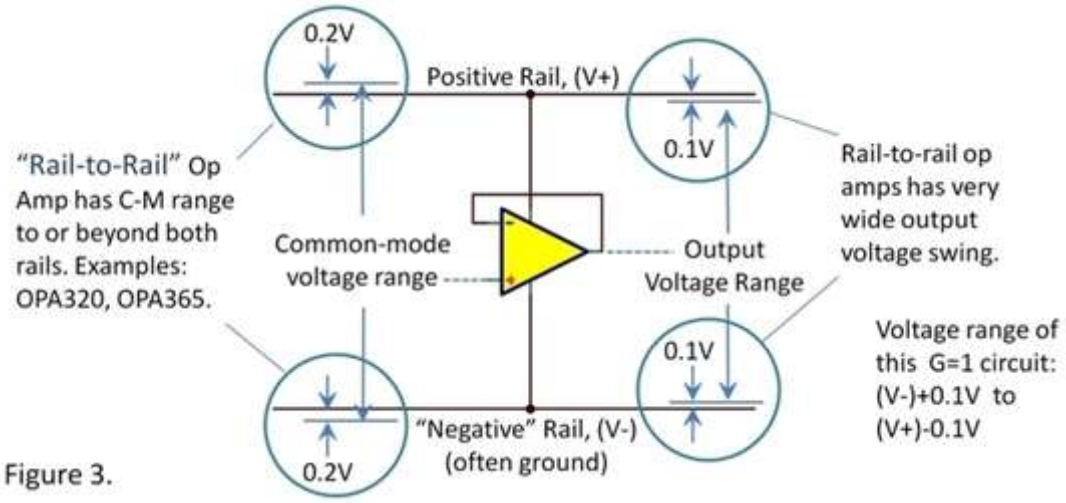

Figure 3.

Rail-to-rail op amps are appealing because they ease signal voltage constraints but they are not always the best choice. Like other of life's choices there are often tradeoffs with other performance attributes. But that's why you are an analog designer. Your life is full of complex issues and tradeoffs and you love it!

Thanks for reading,

Bruce

14 comments 0 members are here

Ken Dillinger *over 12 years ago*

I am curious to know why many manufacturers are marketing their op-amps as "beyond the rails" at the inputs. The outputs cannot reach the rails, so as a buffer there is no issue with violating the input range. Unless it is with the internal design to ensure excellent CMRR, Vos, and Iib from each rail and the byproduct is a little bit of overhead. Amiright?

-Ken

Bruce Trump *over 12 years ago*

Ken-- There are some circuit configurations that require common-mode range that extends to, or beyond the supply rail. These circuits do not require the output of the op amp to swing beyond the rail. This would perhaps make a good future blog topic. I can't attach a figure in this comment but I can describe a simple circuit (not necessarily a common one). Visualize an inverting amplifier with the non-inverting input referenced to a fixed voltage above the rail. With sufficient voltage on the input resistor of the of the circuit, the output of the op amp will be in the linear output range of the op amp.

Regards-- Bruce

Arun Kumar *over 12 years ago*

Thank you Bruce. I had always worried about the difference between dual-supply and single-supply op amps but never found a clear answer, until now.

I love your blog.

. Arun

Vijeendra Nadgir *over 11 years ago*

I wanted to raise this query but I found there is a answer for similar query. Just wanted to confirm on my understanding. I am referring page 3 of OPA 547 - SBOSO56F

OUTPUT Row

If my op-amp is connected to 0V & +12 V, then I can see output only from 1.2V to 10.2V, am I Correct?

Bruce Trump *over 11 years ago*

Vijeendra-- Yes, you are correct. For the OPA547, 100mA sourcing and sinking, the minimum output voltage swing is as you state with 12V single supply. Specific product related questions would best be posted on TI's product support forums. -- Bruce

Gerhard van Rensburg *over 1 year ago in reply to Bruce Trump*

Bruce, From what I understand, the OPA547 should have output swing of -0.2V (perhaps with negative supply), but +9.7V. (V+) −2.3

Not the (V+) −2.3 as Vijeendra asks?

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