5.7: CMRR and PSRR

CMRR stands for Common Mode Rejection Ratio. It is a measure of how well the two halves of the input differential amplifier stage are matched. A common-mode signal is a signal that is present on both inputs of the diff amp. Ideally, a differential amplifier completely suppresses or rejects common-mode signals. Common-mode signals should not appear at the circuit output. Due to the non-perfect matching of transistors, some portion of the common-mode signal will make it to the output. Exactly how much this signal is reduced relative to desired signals is measured by the CMRR.

Ideally, CMRR is infinite. A typical value for CMRR would be 100 dB. In other words, if an op amp had both desired (i.e., differential) and common-mode signals at its input that were the same size, the common-mode signal would be 100 dB smaller than the desired signal at the output.

CMRR is particularly important when using the op amp in differential mode (Chapter Four) or when making an instrumentation amplifier (Chapter Six). There are two broad uses for these circuits. First, the amplifier may be receiving a low level, balanced signal over a considerable distance. Good examples of this are a microphone cable in a recording studio and an instrumentation cable on a factory floor. Interference signals tend to be induced into the cable in-phase (i.e., commonmode). Because the desired signal is presented out-of-phase (i.e., differential), a high CMRR will effectively remove the interference signal. Second, the op amp may be used as part of a bridge-type measurement system. Here, the desired signal is seen as a small variation between two DC potentials. The op amp must amplify the difference signal, but suppress the DC outputs of the bridge circuit.

Example 5.12

An amplifier has a closed loop voltage gain of 20 dB and a CMRR of 90 dB. If a common-mode signal is applied to the input at -60 dBV, what is the output?
If the input signal were differential instead of common-mode, the output would be:

\[ V_{out}^{'} = A_v^{'} + V_{in}^{'} \notag \]
\[ V_{out}^{'} = 20 \text{ dB}+(−60 \text{ dBV}) \notag \]
\[ V_{out}^{'} = −40 \text{ dBV} \notag \]

Because this is a common-mode signal, it is reduced by the CMRR

\[ V_{out}^{'} = −40 \text{ dBV}−90 \text{ dB} \notag \]
\[ V_{out}^{'} = −130 \text{ dBV} \notag \]

This signal is so small that it is probably overshadowed by the circuit noise.

One final note concerning CMRR is that it is specified for DC. In truth, CMRR is frequency dependent. The shape of its curve is reminiscent of the open loop gain curve. The stated CMRR may remain at its DC level up to perhaps 100 or 1000 Hz, and then fall off as frequency increases. For example, the 741 data sheet found in the Appendix states a typical CMRR of 90 dB. By looking at the CMRR graph, though, you can see that it starts to roll off noticeably around 1 kHz. By the time it hits 1 MHz, only 20 dB of rejection remains. A more gentle rolloff is exhibited by the 411. At 1 MHz, almost 60 dB of rejection remains. What this means is that the op amp cannot suppress high frequency interference signals as well as it suppresses low frequency interference.

Similar to CMRR is PSRR, or Power Supply Rejection Ratio. Ideally, all ripple, hum, and noise from the power supply will be prevented from reaching the output of the op amp. PSRR is a measure of exactly how well the op amp reaches this ideal. Typical values for PSRR are in the 100 dB range. Like CMRR, PSRR is frequency dependent and shows a rolloff as frequency increases. If an op amp is powered by a 60 Hz source, the ripple frequency from a standard full-wave rectifier will be 120 Hz. At the output, this ripple will be reduced by the PSRR. Higher frequency noise components on the power supply line are not reduced as much because PSRR rolls off. Normally, PSRR is consistent between power rails. Sometimes, there is a marked performance difference between the positive and negative PSRR. One good example of this is the 411. The positive rail exhibits about a 30 dB improvement over the negative rail. Note that PSRR is only a few decibels for the negative rail by the time it reaches 1 MHz.

Example 5.13

An op amp is operated off a power supply that has a peak to peak ripple voltage of 0.5 V. If the op amp's PSRR is 86 dB, how much of this ripple is seen at the circuit output?

First, determine the PSRR as an ordinary value.

\[ PSRR = \log_{10}(\frac{\text{PSRR}}{20}) \notag \]
\[ PSRR = \log_{10}(\frac{86 \text{ dB}}{20}) \notag \]
\[ PSRR = 20,000 \notag \]
Divide the ripple voltage by the PSRR to find the amount that is seen at the output.

\[ V_{\text{out-ripple}} = \frac{V_{\text{ripple}}}{\text{PSRR}} \]
\[ V_{\text{out-ripple}} = \frac{0.5 \text{ Vpp}}{20,000} \]
\[ V_{\text{out-ripple}} = 25 \mu \text{Vpp} \]