I'm not a robot

The "common mode" of a differential amplifier is the average ground-referenced voltage of the two input signals.Let's take a typical load cell as an example. These devices are made of variable-resistance strain gauges in a bridge configuration. You apply an excitation voltage at one end, and ground at the other, and under no load, both sensor leads output exactly half the excitation voltage: simulate this circuit Schematic created using CircuitLabUnder load, though, the variable resistors change resistance, producing a "differential" (read: "different") voltage on each of the two output wires. Now, instead of 5.000 V on both, we have one at 4.975 V and one at 5.025 V.But the average voltage of the two is still 5 V, and more importantly, we don't care about that. The signal of interest is the difference between the two sides, i.e. 5.025 V - 4.975 V = 50 mV. So we use a differential amplifier to take the difference (and probably multiply it by some gain factor).Unfortunately, real amplifiers don't simply take the difference of two signals. Different average ("common-mode") voltages will have an effect on the output. In the ideal case, input voltages of 10.025 and 9.975 should still produce 50 mV at the output, but in reality they will produce a slightly different value from our 5.025 and 4.975 example. How different? That's determined by the common-mode rejection ratio (CMRR) of the amp. For example, if a differential input change of \$Y\$ volts produces a change of 1 V at the output, and a common-mode change of \$X\$ volts produces a similar change of 1 V, then the CMRR is \$X/Y\$. Often you'll see this expressed in decibels, and quality modern op-amps can have ratios in the 100-150 dB range.Amplifiers will also be specified with a minimum and maximum input voltage, as referenced to ground, that can be applied to any one pin. If your common-mode voltages exceed this spec, the amplifier will not function properly. For example, even though they're still only 50 mV different, applying 200.025 V and 199.975 V will probably not have acceptable results.In general, differential amplifiers are designed to reject as much of the common-mode voltage as possible, and amplify only the differential voltage. The formula to calculate Common Mode Gain is: $$ A_{cm} = \frac{V_{od}}{V_{id}} $$ The Common Mode Gain (Acm) refers to the amplification given to signals that appear on both inputs relative to the common (typically ground). Differential Output Voltage (Vod) is defined as a measure of the voltage between two distinct output signals. Differential Input Voltage (Vid) is defined as a signal input circuit where SIGNAL LO and SIGNAL HI are electrically floating with respect to ANALOG GROUND. Using the following values: Differential Output Voltage (Vod) = 16 Volt Differential Input Voltage (Vid) = 7.5 Volt Using the formula: $$ A_{cm} = \frac{16}{7.5} \approx 2.13333333333333 $$ The Common Mode Gain is approximately 2.13333333333333. Common Mode Gain is the amplification factor for signals that appear simultaneously and in-phase on both inputs of a differential amplifier. 2. Why is Common Mode Gain important? It's important because it measures how well a differential amplifier rejects common-mode signals (noise that appears equally on both inputs). 3. What is the ideal Common Mode Gain? The ideal Common Mode Gain is zero, meaning the amplifier completely rejects common-mode signals. 4. How is Common Mode Gain different from Differential Gain? Differential Gain amplifies the difference between inputs, while Common Mode Gain amplifies what's common to both inputs. 5. What affects Common Mode Gain in BJT amplifiers? It's affected by transistor matching, emitter resistance, and the current source quality in the differential pair. Calculator - All Rights Reserved 2025 The formula to calculate the Common Mode Gain is: $$ A_{cm} = \left(\frac{R4}{R4 + R3}\right) \times \left(1 - \frac{R2 \times R3}{R1 \times R4}\right) $$ The Common Mode Gain (Acm) is typically much smaller than the differential gain. Acm is the gain given to a voltage that appears on both input terminals with respect to the ground. Resistance 1 (R1) is a measure of the opposition to current flow in an electrical circuit. Resistance 2 (R2) is a measure of the opposition to current flow in an electrical circuit. Resistance 3 (R3) is a measure of the opposition to current flow in an electrical circuit. Resistance 4 (R4) is a measure of the opposition to current flow in an electrical circuit. Let's assume the following values: Resistance 1 (R1) = 12500 Ohm Resistance 2 (R2) = 8750 Ohm Resistance 3 (R3) = 9250 Ohm Resistance 4 (R4) = 10350 Ohm Using the formula: $$ A_{cm} = \left(\frac{10350}{10350 + 9250}\right) \times \left(1 - \frac{8750 \times 9250}{12500 \times 10350}\right) \approx 0.197704081632653 $$ The Common Mode Gain is approximately 0.197704081632653. Common Mode Gain (Acm) is the amplification given to signals that appear simultaneously and in-phase on both inputs of a differential amplifier. 2. Why is Common Mode Gain important? It's important because in an ideal differential amplifier, the common mode gain would be zero, rejecting any signals common to both inputs. 3. What causes a high Common Mode Gain? Component mismatches in the amplifier circuit, particularly in resistor values, can lead to higher common mode gain. 4. How can I reduce Common Mode Gain? Using precision-matched resistors and maintaining good circuit symmetry helps reduce common mode gain. 5. What is the relationship between CMRR and Common Mode Gain? Common Mode Rejection Ratio (CMRR) is the ratio of differential gain to common mode gain (CMRR = Ad/Acm). Higher CMRR means better rejection of common mode signals. Calculator - All Rights Reserved 2025 Operational amplifiers (op-amps) are fundamental components in modern electronic circuits, they can be found on almost all electronic devices. Op-amp has many critical parameters that need to be considered before using it in a circuit. Those include input Offset Voltage, Input Bias Current, Input Offset Current, Common Mode Rejection Ratio (CMRR), Power Supply Rejection Ratio (PSRR), Slew Rate and many more. In a previous article, we looked into the Slew Rate in Op-Amp. Just like the slew rate, another important parameter of an op-amp is the common mode gain. In this article, we will explore what common mode gain is, why it matters, and how it impacts the functionality of op-amps in various applications. What is Common Mode Gain? Common mode gain (Acm) refers to the amplification of signals that are common to both inputs of an operational amplifier. Ideally, an op-amp should only amplify the difference between the two input signals, which is called differential gain Ad, and completely reject any signals that are common to both inputs. That is ideally the output of an opamp must be zero Acm. However, in practical scenarios, op-amps do exhibit some amplification of the common mode signal, which is called the common mode gain. Importance of Common Mode Gain Understanding common mode gain is crucial because it directly impacts the performance and accuracy of an op-amp in real-world applications. High common mode gain can introduce errors in the output signal, affecting the integrity of the amplified signal. It is also important to effectively reject the common mode signals, including noise and interference, for the accurate amplification of differential signals. In precision measurement and instrumentation, even small amounts of common mode gain can lead to significant measurement errors. Calculating Common Mode Gain If we want to calculate the common mode gain of an op-amp, all we have to do is drive both the inverting and non-inverting inputs from the same source and then find the ratio between the output voltage Vout and the common mode voltage, since both inputs are driven by the same voltage. The image below shows the circuit diagram for the same experiment. This can be expressed with the formula, Common mode gain Acm=VoutVcm The common mode gain of an op-amp is typically very small compared to its differential gain. It can be quantified using the common mode rejection ratio (CMRR), which is defined as the ratio of the differential gain (Ad) to the common mode gain (Acm): CMRR=AdAcm A high CMRR indicates a good rejection of common mode signals, which is desirable in most applications. Factors Affecting Common Mode Gain Several factors influence the common mode gain of an op-amp: Op-Amp Design: The internal architecture and design of the op-amp, including transistor matching and biasing, play a significant role. Power Supply: Variations in the power supply voltage can affect the common mode gain. Temperature: Changes in temperature can impact the characteristics of the internal components of the op-amp, thereby affecting the common mode gain. External Components: The design and layout of external circuitry, including resistors and capacitors, can influence the common mode gain. How to Minimize the Implications of Common Mode Gain To minimize the impact of common mode gain in practical applications, we can take several approaches: Use High CMRR Op-Amps: Selecting op-amps with a high CMRR specification can significantly reduce common mode gain issues. Circuit Design: Proper circuit design techniques, such as differential signaling and balanced layouts, can help mitigate common mode interference. Shielding and Grounding: Implementing effective shielding and grounding practices can reduce external noise and interference that contribute to common mode signals. Feedback Networks: Designing appropriate feedback networks can enhance the differential gain while minimizing the common mode gain. Conclusion Common mode gain is a critical parameter in the performance of operational amplifiers, impacting signal integrity, noise rejection, and precision in various applications. By understanding and addressing the factors that influence common-mode gain, we can design more robust and accurate electronic systems. Whether in simple amplification circuits or complex instrumentation, managing common mode gain is essential for achieving optimal performance from op-amps.The "common mode" of a differential amplifier is the average ground-referenced voltage of the two input signals.Let's take a typical load cell as an example. These devices are made of variable-resistance strain gauges in a bridge configuration. You apply an excitation voltage at one end, and ground at the other, and under no load, both sensor leads output exactly half the excitation voltage: simulate this circuit Schematic created using CircuitLabUnder load, though, the variable resistors change resistance, producing a "differential" (read: "different") voltage on each of the two output wires. Now, instead of 5.000 V on both, we have one at 4.975 V and one at 5.025 V.But the average voltage of the two is still 5 V, and more importantly, we don't care about that. The signal of interest is the difference between the two sides, i.e. 5.025 V - 4.975 V = 50 mV. So we use a differential amplifier to take the difference (and probably multiply it by some gain factor).Unfortunately, real amplifiers don't simply take the difference of two signals. Different average ("common-mode") voltages will have an effect on the output. In the ideal case, input voltages of 10.025 and 9.975 should still produce 50 mV at the output, but in reality they will produce a slightly different value from our 5.025 and 4.975 example. How different? That's determined by the common-mode rejection ratio (CMRR) of the amp. 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Then the difference mode gain is R2/R1 and the common mode gain is 0. If you don't do this, I don't think the premise makes sense. Then for the sensitivity analysis, I would pick any single resistor and add in an error term eg. R2 R2 + R. Then recalculate the common mode gain. You may find some discrepancies from their result because of how you introduce the component value error term. Low values of common-mode gain are desirable so that the circuit can reject undesirable signals that are applied equally to both inputs. The common-mode (CM) gain becomes important because undesired common-mode signals may have high-frequency components. The important aspects of the Frequency Response of Common Mode Gain of Differential Amplifier can be calculated with some approximations. Consider the time constant=RTCT, where RT and CT are the equivalent output resistance and capacitance of the tail current source and RT is usually greater than or equal to output resistance of a transistor.Let us assume that the resistance RT is of the order 1 M. The capacitor CT includes capacitance of current source transistor typically CT = 1 pF or less. Thus time constant = RTCT = 1 M x 1 pF = 1 s and the break frequency corresponding to this time constant isBelow this frequency the impedance ZT is dominated by RT, and above this frequency CT dominates. Thus as the operating frequency is increased, the impedance ZTwill exhibit frequency variation before the rest of the circuit.Assume that CT is the only significant capacitance. Since the impedance ZT is high, almost all of vin c appears across ZT if source resistance Rs is small. Thus common-mode gain can be approximated as whereFrom Eqs. (35.13) and (35.14) we haveAbove Eq. (35.15) reveals that the common-mode gain expression contains a zero, which causes the common-mode gain to rise at 6 dB/octave above a frequency = 1/RTCT. This behavior is undesirable because the common-mode gain should ideally be as small as possible.The CMRR is plotted as a function of frequency in Fig. 35.21(c) by simply taking the magnitude of the ratio of the differential mode (DM) and CM gains. This quantity begins to decrease at frequency f = 1/2RTCTwhen |Acm| begins to increase. The rate of decrease of CMRR further increases when |Ad|begins to fall with increasing frequency. Thus differential amplifiers are far less able to reject CM signals as the frequency of those signals increases. Differential Amplifier, Differential Mode and Common Mode Gain of an amplifier is defined as VOUT/VIN. For the special case of a differential amplifier, the input VIN is the difference between its two input terminals, which is equal to (V1-V2) as shown in the following diagram. So the gain of this differential amplifier is Gain = VOUT/(V1-V2). ---------- (1) We can find the expression of VOUT in term of V1 and V2 by using superposition theorem: VOUT = [R3/(R1+R3)] [(R4 + R2)/R2] V1 - [R4/R2] V2 ---------- (2) However, we will not be able to re-arrange this expression in the form of eqn (1) to find the gain of the amplifier (except in the special case of R1 = R2 and R3 = R4). Instead of applying superposition theorem with V1 and V2 separately, a better way is to first combined V1 and V2 in a different format, viz. (V1-V2). This is known as the differential mode input - Vd. Associated with this differential mode component will be the common mode input - Vcm., which is equal to the average value of V1 and V2. Differential mode component : Vd = (V1-V2) Common mode component : Vcm = (V1+V2)/2 By using these alternate representation of the input components (Vd and Vcm) instead of the original components (V1 and V2), we can re-express eqn (2) in terms of Vd and Vcm as follows. Vcm = (V1+V2)/2 2Vcm = V1 + V2 ---- (3) Since Vd = V1 - V2 ---- (4) Therefore (3) + (4) V1 = Vcm + Vd/2 ---- (5) and (3) - (4) V2 = Vcm - Vd/2 ---- (6) Substitute eqns (5) & (6) into eqn (2) : VOUT = 1/2[R3/(R1+R3)] [(R4 + R2)/R2 + R4/R2] Vd + [R3/(R1+R3)] [(R4 + R2)/R2 - R4/R2] Vcm ---------- (7) From this expression, we can find the gain of the differential amplifier Gain = VOUT/(V1-V2) = VOUT/Vd = 1/2[R3/(R1+R3)] [(R4 + R2)/R2 + R4/R2] This gain is known as the Differential Gain (Ad) as it is based on the differential input alone, i.e. Ad = 1/2[R3/(R1+R3)] [(R4 + R2)/R2 + R4/R2] As there is another component in VOUT due to the common-mode component Vcm of the input, we define another gain for the differential amplifier, the Common Mode Gain (Acm=VOUT/ Vcm). From eqn (7), this is Acm = [R3/(R1+R3)] [(R4 + R2)/R2 - R4/R2] So although a differential amplifier is supposed to amplify the differential component of the input signals, the common component of the input signals (which is the average value of the two input voltages) will also appear at the output. In practice, this common mode component will cause an error in the measurement of the signals. To eliminate the effect of the common mode component, we can either (i) make the input common mode component equal to zero, i.e. make V2 = -V1 such that the average value of the two input signals equal to zero or (ii) choose the resistor values of R1 to R4 in such a way that Acm is zero. (i) is usually not possible in practice due to the constraint of the measuring circuitry used to produce V1 and V2 (e.g. the Bridge circuit). (ii) can be achieved theoretically by making R1 = R2 and R3 = R4. However, this is not feasible in practice due to the tolerance of the resistors used. Because of this imperfection, a figure of merit used to describe differential amplifier is the Common Mode Rejection Ratio (CMRR), which is defined as CMRR = 20 log (Ad/Acm) For a perfect differential amplifier, the CMRR is equal to , as Acm is zero. In practice, a CMRR in excess of 80dB to 100dB will be needed for high accuracy measuring system (e.g. a microcomputer data acquisition system). This is very difficult to achieve if the differential amplifier uses discrete resistors for R1 to R4.

How to calculate the common-mode gain. Common-mode gain.