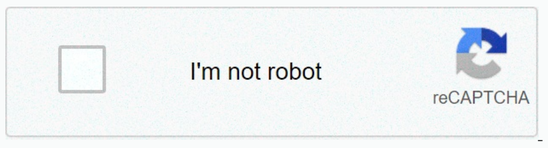

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Operational amplifier notes pdf

High Gain Voltage Amplifier with Differential Input Op Amp A MuA741 Integrated Circuit One Type of Most Successful Op Amp First Production 1967 Pin Configuration V +: Non-Inverted Input V-: Inverted Input V-out: Output VS+: Plus Power VS-: Negative Power Supply Power Terminal (VS+ and VS-) Power Pins (see IC Power Pins) can be labeled separately. In many cases, these pins are left out of the diagram for clarity, and the power configuration is described or assumed from the circuit. For electronic symbol schematic symbols op amplifiers. The pin is labeled above. Op amps (op amps and op amps) are DC-coupled high-interest electronic voltage amplifiers with differential inputs and usually single-ended outputs. [1] In this configuration, the op amp generates an output potential (for circuit grounding) and is usually 100,000 times the potential difference between the input terminals. Op amps originated in analog computers and were used to perform mathematical operations on linear, nonlinear, and frequency-dependent circuits. The popularity of op amps as building blocks of analog circuits is due to their versatility. By using negative feedback, the characteristics of the op amp circuit, its gain, input and output impedance, bandwidth, etc. are determined by the external components and are almost independent of the temperature coefficients and engineering tolerances of the op amp itself. Op amplifiers are widely used in electronic devices today, including a vast array of consumer, industrial and scientific instruments. Many standard IC op amps cost only a few cents. However, some integrated or hybrid op amps with special performance specifications may cost more than USD 100 in small quantities. [2] Op amps can be packaged as a component or used as an element of a more complex integrated circuit. Op amps are one type of differential amplifier. Other types of differential amplifiers include full differential amplifiers (similar to op amps, but with two outputs), instrumentation amplifiers (usually built from three op amps), insulated amplifiers (usually tolerances for common mode voltages that destroy normal op amps), and negative feedback amplifiers (usually built from one or more op amps and resistance networks). Operation The differential input of an op amp (comparator) amplifier without negative feedback consists of a non-inverting input (+) with a voltage V+ and an inverted input (-) with a voltage V-. Ideally, the op amp amplifies only the difference in voltage between the two, called the differential input voltage. The output voltage of the op amp Vout is given by the formula Vout, which is the open loop gain of the expression V out , A OL (V + - V -), the display style V_ V_ A_ V_ . . . .(The term open loop refers to the lack of an external feedback loop from output to input.) The size of the open-loop amplifier AOL is generally very large (more than 100,000 for integrated circuit op amps), so even between V+ and V-, the amplifier output is close to the supply voltage. A situation in which the output voltage is greater than or greater than the supply voltage is called the saturation of the amplifier. Since the size of the AOL is not sufficiently controlled in the manufacturing process, it is not practical to use an open loop amplifier as a stand-alone differential amplifier. Without negative feedback, and perhaps with positive feedback for playback, the op amp will function as a comparator. If the inverted input is held directly on the ground (0 V) or by the resistor Rg, and the input voltage Vin applied to the non-inverted input is positive, the output is maximum positive. If Vin is negative, the output is maximum negative. Since there is no feedback on either input from the output, it is an open loop circuit that functions as a comparator. If the operation amplifier having a closed-loop amplification (non-inverting amplifier) (non-inverting amplifier) predictable operation is desirable, negative feedback is used, applying a portion of the output voltage to the inverted input. Closed-loop feedback significantly reduces the gain of the circuit. With negative feedback, the gain and response of the entire circuit is determined by the feedback network, not by the op amp characteristics. If the feedback network consists of components with a lower value for the input impedance of the op amp, the value of the open loop response AOL of the op amp does not seriously affect the performance of the circuit. The response of the op amp circuit to the input input, the output, and the feedback circuit is mathematically characterized by the transfer function. Designing an op amp circuit with the desired transmission function is in the field of electrical engineering. The transfer function is important for most applications of op amps, such as analog computers. High input impedance at the input terminal and low output impedance at the output terminal are particularly useful functions of the op amp. In the right non-inverting amplifier, the presence of negative feedback via the voltage divider Rf, Rg determines the closed-loop gain ACL.Vout/Vin. If Vout is sufficient to reach and pull the inverted input to the same voltage as Vin, equilibrium is established. The voltage gain of the entire circuit is therefore 1 + Rf /Rg. As a simple example, if Vin is 1 V and Rf is Rg, Vout is 2 V, which is the same amount that is required to keep V- at 1 V. For feedback provided by the Rf, Rg network, this is a closed-loop circuit. Another method of analyzing this circuit proceeds by performing the following (usually valid) assumptions: [3] If the op amp operates in linear (i.e., not saturated) mode, the difference is as follows.The difference between the inverted pin (+) and the inverted (-) pin is very small. The input impedance between the (+) and (-) pins is much greater than the other resistors in the circuit. The input signal Vin appears on both the (+) and (-) pins, resulting in currents i through Rg equal to Vin/Rg: i In the current method of Kirthhoff, the same current must leave the node when the node is entered, and (-) because the impedance to the pin is close to infinity. It can be assumed that the current i flows through Rf, the output voltage V out , V in + i R f , V in + R R f V_ iR_ V_) . . . . V_ V_ R_ R_ V_ R_ V_V_ V_ R_ V_ V_ V_ V_ <a0></a0>R_ R_ R_ V_ R_ R_ R_<a1></a1><a2></a2><a3></a3><a4><a5></a5><a5></a5><a5></a5></a5><a5></a5><a5></a5></a5> R_ V_ R_ R_ the following terms: A CL : V out V in , 1 + R f R g, by combining the terms V_ the following terms: <a0></a0><a1></a1><a2></a2><a4></a4><a5></a5></a5><a5></a5></a1><a5></a5></a1><a5></a5></a1></a0> The equivalence of the op amp that models some non-ideal parameters of the Op-amp characteristic ideal op amp, which is the ideal op amp for the display style A_ R_ R_ V_. V_ The ideal op amp is usually considered to have the following characteristics: [4][5] Infinite Open Loop Gain G - vout /vin Infinite Input Impedance Phosphorus, Zero Input Zero Input Voltage Infinite Output Voltage Range Bandwidth Zero Phase Shift and Infinite Slew Rate Zero Output Impedance Zero Noise Infinite Common Mode Rejection Ratio (CMRR) Infinite Power Rejection Ratio. These ideals can be summarized by two golden rules: in a closed loop the output will try to do whatever is necessary to zero the voltage difference between the inputs. The input does not draw current. [6]:177 The first rule applies only if op amp is normally used in a closed-loop design (negative feedback, returns some signal path from the output to the inverted input). These rules are commonly used as the first approximation suitable for the analysis and design of op amp circuits. [6]:177 None of these ideals can be fully realized. The actual op amp can be modeled with non-infinite or non-zero parameters using the equivalent resistance and capacitor of the op amp model. Designers can include these effects in the overall performance of the final circuit. Some parameters have a ignorable effect on the final design, while others represent the actual limits of final performance that need to be evaluated. Real Op Real Op Amps are different from ideal models in many ways. DC Imperfection The actual op amp suffers from some non-ideal effects: the finite gain open loop gain is infinite in the ideal op amp, but finite in the actual op amp. A typical device shows an open loop DC gain in the range of 100,000 to more than 1 million. AsThe loop gain (i.e., the product of open loop and feedback gain) is very large, and the circuit gain is completely determined by the amount of negative feedback (i.e., independent of the open loop gain). If the closed loop gain must be very high, the feedback gain is very low and the low feedback gain causes a low loop gain. In these cases, the op amp will not work ideally. Finite input impedance The differential input impedance of an op amp is defined as the impedance between the two inputs. The common mode input impedance is the impedance from each input to the ground. Because moSFET input amplifiers have a protection circuit that effectively short-circuits input differences larger than small thresholds, some tests may appear to have very low input impedance. However, as long as these op amps are used in a typical high gain negative feedback application, these protection circuits will be deactivated. The input bias and leakage currents described below are more important design parameters for typical op amp applications. Non-zero output impedance Low output impedance is important for low impedance loads. For these loads, the voltage drop across the output impedance effectively reduces the open loop gain. In a configuration with voltage sensing negative feedback, the output impedance of the amplifier is effectively reduced. Therefore, in linear applications, the op amp circuit typically shows a very low output impedance. Low impedance output typically require high static (idle) current at the output stage and dissipates more power, which can intentionally sacrifice low output impedance in low-power designs. The input current flows into the input with a small amount of current (typically about 10 nanoamps, nA, bipolar op amps, tens of picoa amps, pA, for the JFET input stage, and several pA for the MOSFET input stage) due to bias requirements and leakage. When using a source with a large resistor or high output impedance in the circuit, these small currents may result in a large non-modeling voltage drop. If the input currents match and the impedance looking out of both inputs matches, the voltage generated by each input is equal. These matching voltages have no effect because the op amp operates against the difference between inputs. It is more common for the input current to be a little mismatched. The difference is called the input offset current, and even a matched resistor can produce a small offset voltage (different from the input offset voltage below). This offset voltage allows you to create offsets and drifts in the op amp. Input offset voltage This is the voltage required across the input terminal of the op amp to drive the output voltage to zero. [7] [nb 1] In a perfect amplifier, there is no input offset voltage. But it's present in the actual op ampAmplifiers that make up the input phase for the majority of these devices. The input offset voltage causes two problems: first, the amplifier's high voltage gain effectively ensures that the amplifier output is saturated if it operates without negative feedback, even when the input terminals are wired. Second, in the closed loop, the negative feedback configuration, the input offset voltage is amplified with the signal, if high-precision DC amplification is required, or may cause problems when the input signal is very small. [nb 2] Common mode gain Perfect op amp amplifies only the voltage difference between the two inputs and completely rejects all voltages common to both. However, since the differential input stage of the op amp is not perfect, these common voltages are amplified to some extent. The standard measure of this defect is called the common mode rejection rate (called CMRR). Minimizing common-mode gain is usually important for non-inverting amplifiers that operate at high amplification (see below). The output of the power denied perfect op amp is completely independent of its power supply. All actual op amps have a finite power removal ratio (PSRR) that reflects how well the op amp can reject changes in the supply voltage. Temperature effect All parameters vary depending on the temperature. The temperature drift of the input offset voltage is particularly important. Drift real op amp parameters may receive slow changes in temperature, input conditions, etc. over time. The gain of the op amp calculated by the defective DC of the AC does not apply at higher frequencies. Therefore, for fast operation, more advanced considerations should be used in the op-amp circuit design. Finite bandwidth All amplifiers have finite bandwidth. To the first approximation, the op amp has a frequency response of the integrator with gain. In other words, the gain of a typical op amp is inversely proportional to the frequency and is characterized by its gain bandwidth product (GBWP). For example, an op amp with a 1 MHz GBWP has a gain of 5 at 200 kHz and a gain of 1 at 1 MHz. Combined with the very high DC gain of the op amp, this dynamic response is the characteristics of the first low-pass filter with very high DC gain and low cutoff frequency divided by DC gain. Finite bandwidth of the op amp may cause several problems, such as: associated with the limit of the stability bandwidth is a phase difference between the input signal and the amplifier output, which may lead to oscillation in some feedback circuits. For example, when 180 degrees late to form a positive feedback, sine wave output signal which means that interferes destructively with the input signal of the same frequency is constructively interfered. In such cases, the feedback circuit can be stabilized in the following ways:Correction increases the gain or phase margin of the open loop circuit. Circuit designers can implement this correction externally using a different circuit component. Alternatively, compensation can be made within the op amp by adding a dominant pole that sufficiently attenuates the high-frequency gain of the op amp. The position of the pole can be configured by the circuit designer using either internally fixed by the manufacturer or using a method specific to the op amp. In general, dominant polar frequency compensation further reduces the bandwidth of the op amp. If the desired closed-loop gain is high, op amp frequency compensation is often not required because the required open loop gain is low enough. Therefore, applications with high closed-loop gain can take advantage of op amps with higher bandwidth. Distortion and other effectsSevered bandwidth outputs impedance as the skewness increases and the frequency increases because of the low amount of feedback at higher frequencies. A typical low-cost, general-purpose op amp shows GBWP of several megahertz. There are special and high-speed op amps that can achieve GBWP of hundreds of megahertz. Current feedback amplifiers are often used in very high frequency circuits. The noise amplifier generates a random voltage at output, even if no signal is applied. This may be due to the thermal noise and flickering noise of the device. Noise is a very important consideration for high-gain or high-bandwidth applications. It is most important for high-frequency operation because it reduces the input capacity input impedance and can cause phase shift. Common mode gain See DC imperfections above. As the power-denied frequency increases, the power rejection usually worsens. Therefore, it is important to keep the signal supply clean with higher frequency ripples, such as the use of bypass capacitors. Nonlinear Defects Inverted Amplifier Saturation Amplifier Saturated Op amp inputs (yellow) and output (green) are limited to a minimum and maximum value close to the supply voltage. [nb 3] The output of the old op amp can reach within one or two bolts of the power rail. The output of the new so-called rail-to-rail op amp can reach within the millivolt of the power rail when supplying low output current. The output voltage of the through amplifier usually reaches the slew rate, which is the maximum rate of change specified in the number of volts per microsecond (V/mus). further increases in the input signal will no longer affect the rate of change in the output. through is usually caused by the saturation of the input stage. As a result, there is a constant current driving the capacitane C (especially the capacitane used to implement frequency compensation) in the amplifier. The slew rate is limited by dv/dt- i/C. slewing and is associated with the large signal performance of the op amp.For example, an op amp with a gain of 10. Make the input a 1 V, 100 kHz serrated wave. In other words, the amplitude is 1 V and the duration is 10 microseconds. Therefore, the rate of change in the input (i.e., slope) is 0.1V per microsecond. After × 10-inch amplification, the output must be 10 V, 100 kHz serrated and must have a corresponding slew rate of 1V per microsecond. However, the classic 741 op amp has a microsecond slew rate specification of 0.5 V so that its output can be increased to 5 V or less in a period of 10 microseconds of saws. Therefore, when measuring the output, it will cost 5 V, 100 kHz, rather than a 10 V, 100 kHz saw. Next, consider the same amplifier and 100 kHz sawtooth, but the input amplitude is now 100 mV instead of 1V. The × output is a 1V, 100kHz sawtooth with a corresponding slew rate of 0.1V per microsecond. In this case, 741 with a microsecond slew rate of 0.5V properly amplifies the input. Modern high-speed op amps can have slew rates of more than 5,000 V per microsecond. However, it is common for the slew rate of the op amp to be in the range of 5 to 100 V per microsecond. For example, a general-purpose TL081 op amp has a slew rate of 13V per microsecond. As a rule, low power and low bandwidth op amps have a low slew rate. For example, the LT1494 micropower op amp consumes 1.5 microamps, but has a gain bandwidth product of 2.7 kHz and 0.001 V per microsecond slew rate. Nonlinear input output relationship The output voltage may not be exactly proportional to the difference between the input voltages. If the input signal is a waveform, it is commonly referred to as distortion. This effect is very small in practical circuits where substantial negative feedback is used. Phase inversion In some integrated op amps, if the exposed common mode voltage is violated (for example, by one of the inputs driven to one of the supply voltages), the output may turn to the opposite polarity as expected in normal operation. [8] [9] Under such conditions, negative feedback is positive, which may cause the circuit to lock up in that state. Power considerations Limited output current Output current must be finite. In practice, most op amps are designed to limit the output current to about 25 mA for the type of 741 IC op amp, protecting the op amp and related circuits from damage. The latest design is more electronically robust than the previous implementation, and some designs can maintain a direct short circuit without damaging its output. Output sink current The output sink current is the maximum current that flows into the output stage. Some manufacturers display an output voltage and output sink current plot to inform the output voltage when current flows from another source to the output pin. Limited dissipation force Output current flows through the internal output of the op ampIt causes heat that must be dissipated. If the op amp dissipates too much power, its temperature will increase beyond some safety limits. The op amp may enter a thermal shutdown or be destroyed. The latest integrated FET or MOSFET op amp approximates an op amp that is more ideal than bipolar ICs when it comes to input impedance and input bias current. Bipolars are generally superior in regard to input voltage offsets and often have low noise. In general, FET and MOSFET op amps provide better performance when using fairly large signals at room temperature and bandwidth is limited. The internal circuit of type 741 op amp A is a component level diagram of a typical 741 op amp. Dotted outline: current mirror; An example of a bipolar transistor op amp, procured by many manufacturers and several similar products, is a 741 integrated circuit designed in 1968 by Fairchild Semiconductor's David Flagger after Bob Widdler's LM301 integrated circuit design. In this discussion, the parameters of the hybrid pie model are used to characterize the small signal and ground emitter characteristics of transistors. In this model, the current gain of the transistor is more commonly called hfe called hfe, which is called β, and the 741 op amp, a small integrated circuit, shares with most operations and amplifies the internal structure consisting of three gain stages: [12] Differential amplification (dark blue contour) - common mode signal, low noise, Provides high differential amplification (gain) with rejection of high input impey impey. Drives voltage amplifiers (magenta outlines), provides high voltage gain, single-pole frequency roll-off, and provides output amplifier (output impedance) with output current limit, high current gain (low output impedance), and output short circuit protection. It also includes a current mirror (red contour) bias circuit and a compensation capacitor (30 pF). Differential Amplifier The input phase consists of a cascaded differential amplifier (shown in blue) and an active load on the current mirror. It consists of a transconductance amplifier, which converts the differential voltage signal into a current signal and converts it to a Q15 base at the base of Q1 and Q2. Two cascading transistor pairs are required to meet conflicting requirements. The first phase consists of a matched NPN emitter follower pair Q1, Q2 that provides high input impedance. The second is the matched PNP common base pairs Q3 and Q4, which eliminate undesirable mirror effects. Drives the active load Q7 and matching pairs Q5 and Q6. Its active load will be implemented as the modified Wilson's current mirror. Its role is to convert the (differential) input current signal into a single-ended signal without having to lose 50% of the attendant (increase the open loop gain of the op amp by 3 dB). [nb 4] Therefore, micro signal differential currents of the third and fourth quarters appear(2x) At the base of the Q15, input of the voltage gain stage. The Voltage Amplifier (Class A) Voltage Gain Stage (outlined in Magenta) consists of two NPN transistors Q15/Q19 connected in a Darlington configuration, which uses the output side of the current mirror Q12/Q13 as a collector (dynamic) load to achieve high voltage gain. The output sink transistor Q20 receives the base drive from the common collectors of Q15 and Q19. The LevelShifter Q16 provides the base drive of the output source transistor Q14. Transistor Q22 prevents this stage from supplying excessive current to the Q20 and limits the output sink current. The output amplifier output stage (outlined in Q14, Q20, cyan) is a Class AB complementary symmetry amplifier. It provides an output drive with a current gain, essentially, an impedance of up to 50 ohms. Transistor Q16 (shown in green) provides the quiescent current of the output transistor, and Q17 provides the output current limit. Bias circuit Provides appropriate quiescent current for each stage of the op amp. (Diode connection) The resistor for connecting Q11 and Q12 (39 k ohms) and the given supply voltage (VS+-VS-) determine the current of the current mirror in (match pairs) Q10/Q11 and Q12/Q13. The collector current × Q11, i11 is 39 k ohms - VS+ - VS- - 2 VBE. For a typical VS ± 20 V, the standing current for Q11/Q12 is 1 mA. Typical supply current of about 2 mA 741 agrees with the idea that these two bias currents dominate the quiescent supply current. Transistors Q11 and Q10 form a Widler current mirror, ln (i11× / i10) . In this case, the i10 ≈ 20 .mu.A. Differential amplification The bias circuit at this stage is set by a feedback loop that (almost) matches the collector currents of Q10 and Q9. Small differences in these currents provide a common base drive for Q3/Q4 (note that the base drive of the input transistor Q1/Q2 is an input bias current and must be supplied externally). The total quiescent current for Q1/Q3 and Q2/Q4 is reflected in Q8 through Q9, sumned with the collector current in Q10, and the result is applied to the Q3/Q4 base. The quiescent current of Q1/Q3(resp., Q2/Q4) i1 is half of i10 and is approximately 10 .mu.A. The input bias current at the base of Q1 (Q2) corresponds to the β i1/Q1. Usually between -50 nA and the current gain of Q1(Q2) means hfe ≈ 200. This feedback circuit tends to draw a common base node of Q3/Q4 into the voltage Vcom- 2 VBE where Vcom is the input common mode voltage. At the same time, the magnitude of the quiescent current is relatively sensitive to the characteristics of components Q1 through Q4, such as hfe, causing temperature dependence and variation between parts. Transistor Q7 conducts Q5 and Q6 to (equivalent)The current matches the current in Q1/Q3 and Q2/Q4. The quiescent current of Q7 has matching operating points as well as VBE/50 k ohms, about 35 .mu.A, and Q15 quiescent currents. Therefore, the quiescent current matches the Q1/Q2, Q3/Q4, Q5/Q6, and Q7/Q15. The voltage amplifiers quiescent currents of Q16 and Q19 are set by the current mirror Q12/Q13 and operate at approximately 1 mA. Through several [ambiguous] mechanisms, the collector current of Q19 tracks its standing current. For circuits containing the output amplifier Q16 (various rubber diodes or VBE numbers), the 4.5 k ohm resistor is approximately 100 [mu] A and the Q16 VBE is about 700 mV. The VCB must be approximately 0.45 V and VCE at approximately 1.0 V. Because the Q16 collector is driven by a current source and the Q16 emitter is driven to the Q19 collector current sink, the Q16 transistor set the voltage difference between Q14-based and Q20-based to -1V, regardless of the Q14/Q20-based common-mode voltage. The standing current of Q14/Q20 is ≈ factor exp (100 mV/VT), which is 36 smaller than the 1mA quiescent current in class A portion of the op amp. This (small) standing current of the output transistor establishes the output stage of the Operation of Class AB and reduces the cross-distortion of this stage. Small signal differential mode A small differential input voltage signal rises to a much larger voltage signal at output through multiple stages of current amplification. The input stages for input impedances Q1 and Q3 are similar to emitter-coupled pairs (long tail pairs), and Q2 and Q4 add some weird impedance. The input impedance is relatively high due to the small current up to Q1-Q4. A typical 741 op amp has a differential input impedance of about 2 M [Omega]. The common mode input impedance is even higher because the input stage essentially operates at a constant current. Differential voltage Vin in differential amplifiers Op amp inputs (pins 3 and 2) generated minute differential currents on the basis of Q1 and Q2 ≈ Vin/(2hiehfe). This differential base current causes a change in differential current of each leg by inhfe. Introducing the transcondance of Q1, gm-hfe / hiie, (small signal) current at the base of the Q15 (input of the voltage gain stage) is Vingm / 2. This part of the op amp skillfully changes the differential signal of the Op amp input to the single-ended signal at the base of the Q15 to avoid wasting the signal on either leg. Note that a small negative change in voltage at the reverse input (Q2 base) drives it from conduction and this incremental decrease in current passes directly from the Q4 collector to its emitter and leads to a decrease in the base drive of the Q15. On the other hand, a small positive change in voltage at the non-inverted input (Q1 base) drives the transistor to conduction and is reflected in the increase in current in the collector of Q3. This currentQ7 goes into further conduction and turns on the current mirror Q5/Q6. Therefore, the increase in the Q3 emitter current is reflected in the increase in the Q6 collector current. The increased collector current does more shunts from the collector node, reducing the base drive current of the Q15. In addition to not wasting 3 dB gain here, this technology reduces common mode gain and power supply noise feedthrough. Q15 base voltage amplifier A current signal i increases the current in order ibeta2 Q19 (product of each hfe of Q15 and Q19 connected in Darlington pair). This current signal is based on the output transistor Q14/Q20 and generates a voltage proportional to the hee of each transistor. Output amplifier output transistors Q14 and Q20 are configured as emitter followers, so no voltage gain is generated. Instead, this stage provides the current gain equal to the hfe of Q14 (q20). The output impedance is not zero because it is an ideal op amp, but negative feedback approaches zero at low frequencies. Overall open loop voltage gain Net open loop small signal voltage gain of op amp involves the generation of current gain hfe of several 4 transistors. In fact, the voltage gain of a typical 741-style op amp is order 200,000, and the ratio of current gain, input impedance ratio (to 2-6 M ohms) and output impedance (to 50 Ω) provides additional (power) gain. Other linear characteristics small signal common mode gain ideal op amp has an infinite common mode rejection ratio, or zero common mode gain. In this circuit, when the input voltage changes in the same direction, negative feedback causes the Q3/Q4 base voltage to fluctuate (2VBE or less). The output portion of Q10-Q11 (Q10) maintains a constant current through Q9/Q8 even when the voltage changes. The Q3/Q4 collector current and, accordingly, the Q15-based output current, are not changed. In a typical 741 op amp, the rejection ratio of common mode is 90 dB, which means that the open loop common mode voltage gain is about 6. Innovations in frequency compensation Fairchild muA741 are the introduction of frequency compensation via on-chip (monolithic) capacitors, simplifying the application of op amps by eliminating the need for external components of this feature. The 30 pF capacitor stabilizes the amplifier by mirror compensation and functions in a similar way to the op amp integrator circuit. It is also known as dominant pole compensation because it introduces poles that mask (dominate) the effects of other poles in the open loop frequency response. For a 741 op amp, this pole is 10 Hz (-3 dB loss of open loop voltage gain). This internal compensation is provided to achieve unconditional stability of the amplifier in a negative feedback configuration where the feedback network is non-reactive and closed loop gain is unity or higher. In contrast, the <a0>T:SystemIf external compensation is required, such as .mu.A748, the gain of the external compensation or closed loop is significantly higher than that of Unity. The input offset voltage offset null pin can be used to adjust the balance of the Q5/Q6 current mirror by positioning an external resistor (usually a slider connected to the VS- in the form of both ends of the potency meter) parallel to the emitter resistor resistors of Q5 and Q6. The potentiometer adjusts so that the output is null (midrange) when the input is shorted together. Nonlinear characteristics input destructive voltage Transistors Q3 and Q4 help increase reverse VBE ratings: the base emitter junctions of NPN transistors Q1 and Q2 decompose at about 7 V, but PNP transistors Q3 and Q4 50 V. [13] The output stage voltage has a voltage swing and a current limiting current temperature, or a VBE fracture voltage of variation between parts of the same type, so crossover distortion and quiescent current can be affected by significant fluctuations. The output range of the amplifier, depending on the part of the VBE of the output transistors Q14 and Q20, is about 1 volt less than the supply voltage. Q14 The 25-Ω of the emitter, along with the Q17, limits the Q14 current to approximately 25 mA. Otherwise, Q17 does not do any current. The current limit of the Q20 is carried out at the voltage gain stage: Q22 senses the voltage through the emitter resistor resistance of Q19 (50 Ω). When on, the drive current decreases to Q15-based. Later versions of this amplifier schematic may show a slightly different method of output current limit. Applyability considerations 741, which have historically been used in audio and other sensitive devices, are now rare because of the improved noise performance of more modern op amps. In addition to generating noticeable hiss, 741s and other older op amps often introduce other common mode interferences, such as cable-mounted main hams and switch clicks, into sensitive devices because of their poor common mode rejection ratio. 741 often means a more modern alternative, such as a typical op amp IC (e.m.A741, LM301, 558, LM324, TBA221, etc.), or TL071. The description of the 741 output stage is qualitatively similar in many other designs (the input phase may be completely different), but some devices (muA748, LM301, LM308) are not internally compensated (for use in low-closed loop gain applications, an external capacitor from the output to a point in the op amp is required). Some modern devices have a rail-to-rail output function that can range from a few millivolts of positive supply voltages to several millivolts of negative supply voltages. Classification Op amps may be classified by their structure: discrete (manufactured in integrated circuits) IC (built from individual transistors or tubes/valves) - the most common hybrid IC op amps can be classified in many ways.Military, industrial, or commercial grades (e.g., LM301 is a commercial grade version of LM101, LM201 is an industrial version). It allows you to define the operating temperature range and other environmental or quality factors. Classification by package type can also affect the hardness of the environment and manufacturing options. Through-hole packages, such as DIP, tend to be replaced by surface-implemented devices. Classification by internal compensation: Op amps may suffer from high frequency instability in some negative feedback circuits unless a small compensation capacitor changes the phase and frequency responses. An op amp with a built-in capacitor is called compensation so that the circuit above the specified closed loop gain can operate stably without an external capacitor. In particular, an op amp that is stable even if the closed loop gain is 1 is called unity gain correction. Many commercial op amp ICs are available in single, dual, and quad versions, and 1, 2, or 4 op amps are included in the same package. Rail-to-rail input (and/or output) op amps operate on input (and/or output) signals that are very close to the power rail. CMOS op amps (such as CA3140E) provide very high input resistance higher than JFET input op amps, which are usually higher than bipolar input op amps. Other varieties of op amps include programmable op amps (can simply be adjusted by external resistors such as quiescent current, bandwidth, etc.). Manufacturers often aggregate op amps according to their purpose, such as low-noise preamps and broadband amplifiers. DIP Pinout Main Article for Type 741 Op Amps: Applications of Op Amps The use of op amps as electronics system design circuit blocks is much easier and clearer than specifying all individual circuit elements (transistors, resistors, etc.), whether the amplifier used is an integrated or discrete circuit. In the first approximate op amp, it can be used as if it were an ideal differential gain block. At a later stage the limit can be placed in the tolerance of the parameters of each op amp. The circuit design follows the same line for all electronic circuits. A specification is created that specifies what the circuit needs to do, and there is an acceptable limit. For example, the gain might need to be 100 times, with a tolerance of 5% and a drift of less than 1% over the specified temperature range. The input impedance is not more than one megome. Such as. Basic circuits are often designed with the help of circuit modeling (on a computer). Certain commercial op amps and other components are selected to meet the design criteria specified at acceptable costs. If you do not meet all the criteria, you need to change the specification. The prototype will be built and tested. Changes to meet or improve specifications, change functionality, or reduce costsApplications that do not use feedback, i.e., op amps are used as voltage comparators. A device designed primarily as a comparator might be better, for example, if speed is important, or if a wide range of input voltages are found, such devices can be recovered immediately from a full on or full-off (saturated) state. By applying the reference voltage Vref to one of the inputs of the op amp, you can obtain a voltage level detector. This means that the op amp is set as a comparator to detect positive voltages. If the voltage detected, Ei is applied to the op amp (+) input, the result is a non-inverting positive level detector: if Ei exceeds Vref, the VO is equal to +Vsat. If Ei is below Vref, vo is equal to -Vsat. If Ei is applied to the inverted input, the circuit is a positive-level detector that reverses: if Ei exceeds Vref, the VO is equal to -Vsat. The zero voltage level detector (Ei x 0) can, for example, convert the output of a sound wave from a function generator into a variable frequency aerogata wave. If Ei is a sane wave, a triangular wave, or a wave of another shape that is symmetrical around zero, the output of the zero-crossing detector is square. Zero-cross detection can also trigger TRIAC at optimal timings to reduce main interference and current spikes. Another typical configuration of the positive feedback application Schmidt trigger op-amps implemented by the non-inverting comparator is positive feedback that returns some of the output signals to the non-inverted input. An important application of it is a comparator with hysteresis, Schmidt trigger. Some circuits may use positive and negative feedback around the same amplifier (e.g. triangular wave oscillators or active filters). Due to the wide through range and lack of positive feedback, the response of all the above open loop level detectors will be relatively slow. While external overall positive feedback may apply (unlike internal positive feedback, which may be applied within the late stages of the objective-designed comparator), this significantly affects the accuracy of the zero-crossing detection point. For example, if you use a general purpose op amp, the Ei frequency of the harmonic-to-a-positive converter should probably be below 100 Hz. [Quote required] Negative feedback application non-inverting amplifier Non-inverting amplifier In an op amplifier non-inverting amplifier configuration, the output voltage changes in the same direction as the voltage. The gain equation for the op amp is V out , A OL (V + - V -). However, the V-out feature is a feature of V-V_ out due to negative feedback through the R1 R2 network. V_ A_ V_ R1 and R2 form a divider, V- is a high impedance input, so it does not load large. As a result, the V- β V V_ out, the display style V_ β[R_{1}] [R_{1}+R_{2}] We assign this to the gain equation to get V out , A OL (V in - β V out). <a0> V_ A_ β V_ V_ V_ V_ </a0> <a1></a1><a2></a2> <a3></a3><a4></a4><a5></a5><a5></a5><a5></a5><a5></a5><a5></a5><a5></a5></a1><a2></a2><a4></a5><a5></a5></a5></a1> <a2></a2><a3></a4><a5></a5><a5></a5></a5></a1><a2></a2><a4></a5><a5></a5></a5><a5></a5><a5></a5> <A_ {1} {1} V_ a0</a0 V_<a1></a1><a2></a2><a4></a4><a5></a5><a5></a5></a5> This A_ simplifies the ≈ V of the <a0></a0><a1></a1><a2></a2><a3></a3><a4></a4><a5></a5></a5><a5></a5><a5></a5><a5></a5></a5><a5></a5><a5 V_ <R_{2} V_ R_{1} V_ R_{2} R_{1} R_{1} V_ V_ a0</a0><a1></a1><a2></a2> <a3></a3><a4></a4><a5></a5><a5></a5></a5></a5> The dc-to-ground path is required for non-inverted input for the op amp. If the signal source does not supply a DC path, or if the source requires a given load impedance, the circuit requires another resistance from the non-inverting input to the ground. If the input bias current of the op amp is large, it is necessary to balance the DC source resistor that drives the input. The ideal value of the feedback resistor (to provide a minimum offset voltage) so that the two resistors are parallel to the resistance to the grounding of the non-inverting input pin. This ideal value assumes that the bias currents are exactly the same, which may not be true for all op amps. [15] In the op amp inversion amplifier connected to the inversion amplifier inversion amplifier configuration, the output voltage is changed in the opposite direction to the input voltage. As with non-inverting amplifiers, we start with the gain equation of the op amp: V out . This time, V- is a feature of both Vout and Vin by the divider formed by Rf and Rin. V_ V_ A_ V_ Again, the op amp input does not apply a considerable load, so V - . . . . We're not sure if we're in the same way as we're R_ V_. V_ R_ R_ You can assign it to the V_ V_-gain equation. . . . . {1} R_ Solve : V out - A OL R + A OL R in V in A OL R f R + A OL R . <a0></a0><a1></a1><a2></a2><a3></a3><a4><a5></a5><a5></a5><a5></a5></a5><a5></a5><a5></a5></a1></a0> R_ R_ V_ V_ R_ ' R_ R_ R_ R_ A_ R_ R_ A_ A_ V_ V_ V_ This is simplified to the V-out ≈ V of R f R if it is very large. A_ <a0></R_ V_ R_ V_ a0 V_<a1></a1><a2></a2><a4></a4><a5></a5><a5></a5><a5></a5></a5> The V_ is often inserted between the non-inverting input and the ground (both inputs refer to the same resistance), reducing the input offset voltage due to different voltage drops due to bias current, Some op amps may reduce distortion. If no frequency response is required for the DC and no DC voltage is required for the input, the DC blocking capacitor can be inserted in series with the input resistor. What you meanThe input impedance component inserts DC zero and low frequency poles and gives the circuit bandpath or high pass characteristics. The potential of the op amp input is kept almost constant (near ground) in the inversion configuration. When it is possible to operate at a certain rate, it is usually lower than the strain level that can be achieved in a non-inverting topology. Audio and video frequency preamplimps and buffer differential amplifiers and buffer differential amplifiers and integrators in other applications, precision rectifier precision peak detector voltage and current regulator analog calculator analog-to-digital converter digital-analog converter voltage clamp oscillator Most amplifiers dual and quad op amps with oscillators and waveform generator clipper clampers (DC insur restore or restorer) LOG and ANTILOG have standardized pinouts to be replaced by different types without wiring changes. You can select a specific op amp for open loop gain, bandwidth, noise performance, input impedance, power consumption, or compromise between these factors. Historical Timeline 1941: Tube Op Amp. The op amp is defined as a general purpose DC bond, high gain, and inverted feedback amplifier and is first seen in the U.S. Patent 2,401,779 Samping Amplifier submitted by Carl D. Swerzel Jr. of Bell Labs in 1941. This design uses three vacuum tubes to achieve a gain of 90 dB and operated on ± 350 V voltage rails. As is common in today's op amps, it had a single inverted input instead of a differential inversion input and a non-inverting input. Throughout World War II, Swutzel's design proved its value by being freely used by M9 artillery directors designed in Bell Labs. This artillery director achieved an extraordinary hit ratio (nearly 90%) in cooperation with the SCR584 radar system, otherwise it would not have been possible. [16] GAP/R K2-W: Tube Op Amp (1953) 1947: Op amp with explicit non-inverting input. In 1947, the op amp was first officially defined and named in the paper [17] by John R. Lagazuccini of Columbia University. In this same paper, footnotes mentioned the design of op amps by students, which turned out to be very important. Designed by Loewe Julie, this op amp was excellent in many ways. It had two major innovations. Its input phase used a long-tailed trio-repair with matching loads to reduce output drift, and much more importantly, it was the first op amp design with two inputs (one inverted and the other inverted). Differential input allowed for a full range of new features, but was not used for long periods of time due to the rise of chopper-stabilized amplifiers. [16] 1949: Chopper Stabilization Op Amp.1949, Edwin A. Goldberg designed Chopper Stabilization Op Amp[18] This setup uses a regular op amp with an additional AC amplifier that go with the op amp. Chopper gets AC signal from DC by switchingDC voltage and grounding at high speed (60 Hz or 400 Hz). This signal is amplified, modified, filtered and supplied to the non-inverting input of the op amp. This greatly improved the gain of the op amp while significantly reducing the output drift and DC offset. Unfortunately, designs that use choppers could not use non-inverted inputs for other purposes. Nevertheless, the significantly improved properties of chopper-stabilized op amps have made the dominant way to use op amps. Technology that regularly uses non-inverting inputs was not very popular until the 1960s, when op-amp ICs began to appear in the field. 1953: Commercial op amps .1953, tube op amps were marketed by George A. Philbrick Research Co., Ltd. with the launch of the model K2-W. Specifying GAP/R for the displayed device is an acronyp for the entire company name. The two 9-pin 12AX7 vacuum tubes were installed in an octal package and the model K2-P chopper add-on was available to effectively use up non-inverting inputs. This op amp is based on the descendants of Loebe Julie's 1947 design and, together with its successor, begins extensive use of op amps in the industry. GAP/R Model P45: Solid, Discrete Op Amp (1961). 1961: Discrete IC op amps: Transistors were born in 1947, silicon transistors were born in 1954, and the concept of IC became a reality. Plane processes were introduced in 1959, and transistors and ICs were so stable that they were commercially useful. By 1961, solid, discrete op amps were produced. These op amps were effectively small circuit boards with packages such as edge connectors. They usually had hand-selected resistors to improve voltage offsets, drifts, etc. The P45 (1961) had a gain of 94 dB and ± on the 15 V rail. In 1961± was intended to handle signals in the range of 10 V: Buxter bridge op amps. In the design of the op amp, various directions are taken. Vatactor bridge op amps began to be produced in the early 1960s. [19] [20] They are designed to have very small input currents and are one of the best op amps available in terms of common mode denial with the ability to handle hundreds of volts correctly at the input. GAP/R Model PP65: Potted Module (1962) 1962 Solid State Op Amp: Op Amp with Potted Module. By 1962, several companies were producing modular potted plant packages that could be connected to printed circuit boards. These packages were very important because they could be easily treated as components of a larger circuit in a single black box. 1963: Monolithic IC Op Amp.In 1963, Bob Widdler, the first monolithic IC op amp, released the .mu.A702 designed by Fairchild Semiconductor. A monolithic IC consists of a single chip, as opposed to a connection between a chip and a discreet part (individual IC) or multiple chips.Circuit board (hybrid IC). Almost all the latest op amps are monolithic ICs. However, this first IC was not very successful. Problems such as uneven supply voltage, low gain, and small dynamic range reduced the superiority of monolithic op amps until the release of the muA709[21] (also designed by Bob Widdler). 1968: Release of .mu.A741. The popularity of monolithic op amps has been further improved with the release of LM101 in 1967, which solved a variety of problems, and the release of the muA741 in 1968. The muA741 was very similar to the LM101, except that Fairchild's facilities did not require external compensation, but included a 30 pF compensation capacitor in the chip. This simple difference makes a regular op amp to the 741 and many modern amps are based on their pinouts on the 741s. The .mu.A741 is still in production, popular in electronics, and many manufacturers produce versions of this classic chip, which can be recognized by part numbers, including 741. The same parts are manufactured by several companies. 1970: First high-speed, low-input current FET design. At high speed in the 1970s, the low input current design began to be made using FET. These are mainly replaced by op amps made with MOSFETs in the 1980s. ADI HOS-050: High-speed hybrid IC op amp (1979) 1972: Single-sided supply op amps are produced. One-sided power supply op amps are where the input and output voltages are as low as negative supply voltages and must be at least 2 volts or more. As a result, the negative power pin of the op amp can operate in many applications connected to the signal ground, eliminating the need for another negative power supply. The LM324 (released in 1972) was one such op amp that came into a quad package (four separate op amps in one package) and became an industry standard. In addition to packaging multiple op amps in a single package, an op amp was born in a hybrid package in the 1970s. These op amps were generally improved versions of existing monolithic op amps. As the characteristics of monolithic op amps improved, more complex hybrid ICs were quickly demoted to systems that required very long service lifes and other special systems. Recent trends in op amps in mini DIP packages. Recently, the supply voltage of analog circuits has decreased (as in digital logic), and low-voltage op amps have been introduced to reflect this. The supply of 5 V and increasingly 3.3 V (sometimes 1.8 V lower) is common. To maximize the signal range, modern op amps generally have rail-to-rail output (output signals can range from the lowest supply voltage to the highest voltage) and sometimes rail-to-rail inputs. Electronics Portal Active Filter Analog Computer Bob Widler Current Conveyor Current Feedback Arithmetic Amplifier Differential Amplifier George A. Fill Brick Instrumentation Amplifier See Negative FeedbackOp-amp Swapping Op Amp Application Operational Transcondance AmplifierSallen-Key Topology Note . . . . Many of the old designs of op amps have null inputs for offsets and you can adjust the offset manually. Modern precision op amps can have an internal circuit that automatically cancels this offset using choppers and other circuits that regularly measure the offset voltage and remove it from the input voltage. The inability of the output to reach the supply voltage is usually the result of the limits of the amplifier's output stage transistor. See Output Stages. The same trick was used in the Understanding Single-Ended, Pseudo-Differential and Full Differential ADC Inputs references for muA702 and muA709. Maxim Application Note 1108. Archive from the original of 2007-06-26. Acquired on November 10, 2007. Apex OP PA98.Archived from original on January 1, 2016 Acquired on November 8, 2015. APEX PA98 Op Amp Module, Sale Price: Microelectronics: Digital and analog circuits and systems 523–527.ISBN 0-07-042327-X Lecture 5: Ideal Op Amp (PDF) Archived from original in 2016-11-23. a b Horowitz, Paul Hill, Winfield (1989). The art of electronics. 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It generates an offset voltage of 10 mV with an input bias current of 1 [mu] A through a DC power supply resistor of 10 k ohms. If the other input bias currents are the same and you see the same source resistor, the two input offset voltages disappear. For input bias current, there is no need to balance the DC source resistorThe source resistance product is small. Analog Devices (2009) Op Amp Input Bias Current (PDF). Analog Devices Tutorial MT-038. a b Jung, Walter G(2004). Chapter 8: The History of Op Amps Op Amp Application Handbook. Nunes p. Acquired 777.ISBN 978-0-7506-7844-5.2008-11-15. Ragazini, John R; Randall, Robert H. Russell, FredericK A (May 1947). Analysis of dynamics problems by electronic circuits Minutes of the IRE. Ieee. 35 (5): 444–452.Doi: 10.1109/JRPROC.1947.232616. ISSN 0096-8390. Archived from original (PDF) in 2012-10-07. Acquired 2012-12-27.CS1 Maint: Title Archive Copy (Link) Archived from the original on September 7, 2012. Acquired on April 28, 2018. 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(37 MB PDF) Op Amps - Design and Applications;1st Place Ed;Gerald Graeme, Gene Toby, Lawrence Wellsman;Bar Brown & McGraw Hill;473 pages;1971;ISBN 978-0070649170.Learn the art of electronics with Opamp chapter - Hands-on Lab Course. 1st place Ed; Thomas Hayes, Paul Horowitz; Cambridge; 2016;ISBN 978-0521177238. (Part 3, page 268) The Art of Electronics; 3rd Ed; Paul Horowitz, Winfield Hill; 2015;ISBN 978-0521809269. Lessons from electrical circuits (Chapter 4, page 69) - Volume III - Semiconductors; 528 pages; (Chapter 8 is on page 59) (4 MB PDF) Troubleshooting Analog Circuits; 1991;ISBN 978-0750694995. (Chapter 8, page 19) Analog Application Manual; (Chapter 3 is on page 32) (32 MB PDF) External Link Wikimedia Commons has media related to op amps. 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Philbrick/Research - What's the difference between an op pioneer op amp and an instrumentation amp?, electronic design magazine datasheet / databook LM301, Single BJT OpAmp, Texas Instruments [Permanent DeadLink] LM324, LM324, Quad BJT OpAmp, Texas Instruments LM741, Single BJT OpAmp, Texas Instruments NE5532, Dual BJT Opamp Amplifier (NE5534 is a similar single) TL072, Dual JFET Op, Texas Instruments TL074 is a quad)