MKT1132 ELEKTRİK DEVRE TEMELLERİ DÖNEM PROJESİ

PROJE NO:2

Microchip AN682– Using Single Supply Operational Amplifiers in Embedded SYSTEMS

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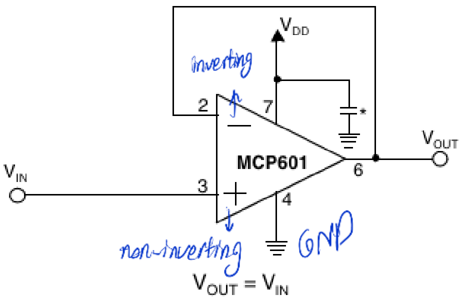
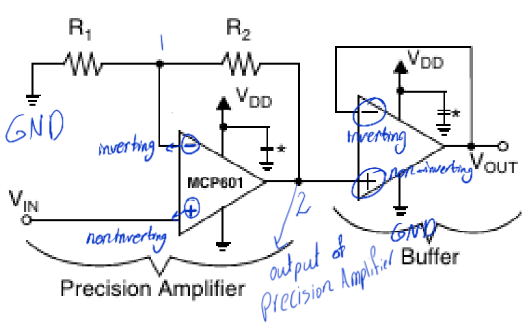
2406A914

Voltage Follower Amplifier



In this figure, we have a Voltage Follower Amplifier (Buffer Amplifier) using a MCP601 op-amp. Our output, which is at node 6, is connected directly to the inverting input at node 2, and its signal is applied to the non-inverting input at node 3. We also have a bypass capacitor (1 μF) connected between VDD at node 7 and ground at node 4, which stabilizes power and prevents oscillations that are not needed. This circuit is mainly used for impedance matching, capacitor load driving, and unity gain linear amplification. As the operating principle of this circuit we have a unity gain configuration VOUT=VIN. The non-inverting input receives the signals, and then the op-amp adjusts it to match the inverting and non-inverting input. Also output is directly fed back to the inverting input. The operation of our op-amp is closed-loop, which tracks the input voltage exactly.

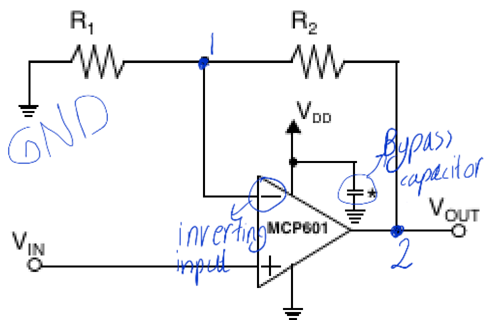
In this circuit, we have a MCP601 Op-Amp because it is used for single supply operations, low power, and high input impedance (up to 10^13Ω) CMOS input stage. These features make it suitable for buffering with no loading of previous stages. We also have a Bypass Capacitor (1 μF), which stabilizes our power supply. It is used when we have high-frequency or sensitive analog signals. This capacitor is designed to prevent oscillations and improve transient response. The voltage gain is $A_v = \frac{V_{out}}{V_{in}} = 1$, meaning no amplification because the purpose is signal buffering, not amplification. High input impedance (10^13Ω) makes a minimal current draw from the source, which is useful in sensor circuits and audio buffers, while low output impedance (<10Ω) allows the op-amp to drive heavy or capacitive loads with almost no voltage drop.



This figure's circuit contains two op-amps (both MCP601). First, we have a precision amplifier with a non-inverting configuration and a resistive gain network of R1 and R2. Second, there is a voltage follower (buffer amplifier)connected after the precision amplifier. The main purpose of these connections is to maintain accuracy in small-signal amplifications (100 μV) and isolate the load with the help of the buffer to prevent heating or loading effects on the precision op-amp. The bypass capacitor is used for supply decoupling. All of this allows it to do hight accuracy amplification of very small input signals. The operating principle for the first op-amp (Precision Amplifier) is a non-inverting configuration $V_{out} = V_{in}(1 + \frac{R2}{R1})$, it amplifies very small signals with high precision. The second op-amp (Buffer) is a voltage follower(unity-gain) $V_{out2} = V_{out1}$,which drives the load while preserving the amplified signal integrity from the previous op-amp. Buffer also prevents loading and self-heating issues that would affect accuracy.

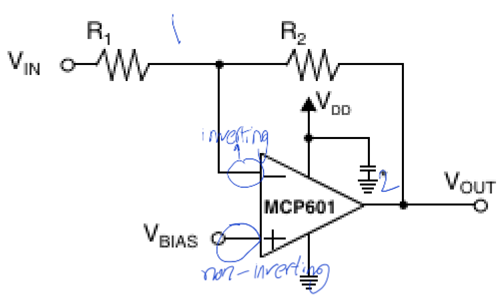
Again, here, we have an MCP601 used in both precision and buffering stages. It is CMOS-based, which allows it to provide high input impedance and low offset voltage. We have resistor R1 connected to the inverting input(-) of the op-amp at node1 and the ground from the other end, and R2 connected to the inverting input of the MCP601 at node1 and its output at node2. Together, they define the gain of the precision amplifier. We also have a Bypass Capacitor (1 μF) stabilizing power supply to prevent unwanted oscillations. The gain of the precision amplifier is $A_v = 1 + \frac{R2}{R1}$, which provides controlled voltage gain to amplify the input. It is needed for measuring very small signals (100 μV). The output of buffer is $V_{out} = V_{in}(1 + \frac{R2}{R1})$. As you can see, the buffer does not change this voltage, but it isolates the load. Input impedance is very high in MCP601, making it ideal for signal sourcing, and the output impedance of buffer is low, ensuring effective load driving. All the above is for impedance matching.

Gaining Analog Signal



This circuit is a non-inverting amplifier, meaning the input is amplified without phase inversion. It operates in single supply mode, making it practical in systems lacking negative voltage. The R1 and R2 create a resistive feedback network connecting the output back to the inverting input, and in the end the the bypass capacitor supplies decoupling. The main operational principle uses negative feedback through R1 and R2 to stabilize the gain. The op-amp internally adjusts the voltage at both inputs to make them equal, this ensures linear amplification. The signal remains in-phase, meaning no polarity change occurs from input to output.

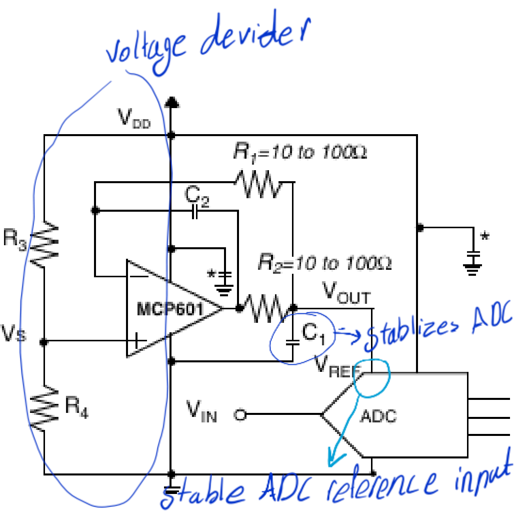
This circuit contains two resistors, R1 connected from the inverting input in node1 to ground, and R2 connected from the op-amp output in node 2 to the inverting input at node1. R1 is used to determine the gain with R2, and R2 is used as a part of the gain-setting divider. Again, we have as MCP601which performs signal amplification with a high impedance input and a low output one. The bypass capacitor here decouples supply noise to prevent unwanted oscillations. The voltage gain formula is $V_{OUT} = \left(1 + \frac{R2}{R1}\right) V_{IN}$ which is derived using voltage and op-amp feedback theory, which forces the op-amp to make $V_{-} = V_{+}$. In here, we make sure that gain is always greater than or equal to 1. This ensures that no phase shift is happening and amplifies V_{IN}.



This figure represents an inverting amplifier with bias. Like all the above circuits, we use a single supply op-amp, MCP601. The input signal V_{IN} is applied through R1 to the inverting input of the op-amp at node1. At the same time, R2 provides feedback from the output to the inverting input at nodes1 and 2. To prevent the output from going below the ground, which is very important in single supply applications, the non-inverting input is biased to a fixed DC voltage V_{BIAS}. Again, our boy capacitor is used to stabilize the op-amp supply voltage. The operating principle of this circuit is that its op-amp inverts and amplifies the input signals. A bias voltage V_{BIAS} It is applied to the non-inverting input to shift the signal into the op-amp output range. In here, we have negative feedback, and due to this, the op-amp forces $V_{-} = V_{+} = V_{BIAS}$ creating a virtual ground. The op-amp adjusts the voltage difference between its two inputs to nearly 0.

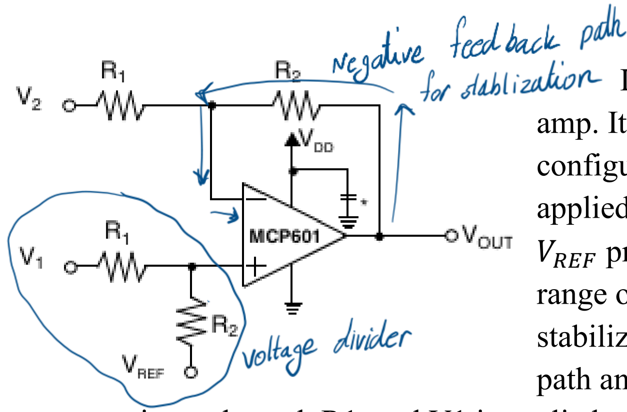
R2 resistor is connected to the inverting input of the amplifier and to its output at nodes 1 and 2, R1 is connected to the inverting input of the amplifier from one end, but from the other end it is connected to the input signal V_{IN} determining the gain with R2. We also have V_{BIAS}which is a DC bias applied to the non-inverting input. It centers the output swing within the single-supply range. We also have MCP601, which is a low-power op-amp used for single-supply use. As usual, the bypass capacitor stabilizes the power supply and filters high-frequency noises. The full output voltage formula here is: $V_{OUT} = -\left(\frac{R2}{R1}\right) V_{IN} + \left(1 + \frac{R2}{R1}\right) V_{BIAS}$. The first term gives the amplified and inverted version of the input signal, providing a negative sign because the op-amp is in an inverting configuration, so it's entering the inverting input, making it negative, so the output is going to be 180 degrees out of phase. The second term adds a DC offset to keep the output above ground. By applying a superposition of one, the op-amp output is influenced by both the signal applied to the inverting input and the DC bias applied to the non-inverting input. Typically, the average output voltage should be designed to be Equal to $V_{DD}/2$.

Single Supply Circuits and Supply Splitters



This circuit is called a supply splitter or level shifter. It is used in single supply systems to generate a mid-supply reference voltage. It also creates a stable DC voltage (V_{REF}) which is often needed in inverting op-amp stages or analog-to-digital converters (A_{DC}) that needs a reference centered between the ground and V_{DD}. In single supply systems, signals cannot swing below ground level, but in this circuit, we have a shift of the reference point to allow AC-coupling or bipolar-like behavior. In operating principles, we have DC behavior, which follows the voltage divider rule. Resistors R3 and R4 form a voltage divider generating an intermediate voltage. This DC voltage is applied to the non-inverting input of the op-amp. We also have an AC behavior following the capacitive theory. The capacitor C1 smooths the reference voltage, acting as a charged reservoir, reducing the AC impedance at the reference node, while C2 provides bypass filtering.

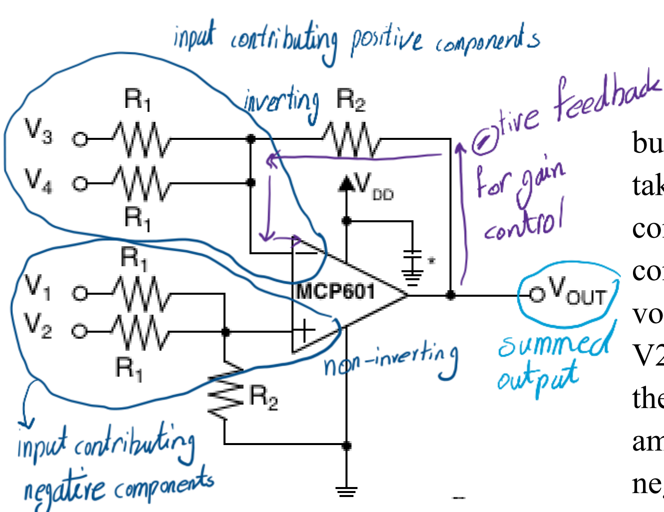
We have a MCP601 op-amp, which has the same rule as previous examples, and it has been explained already. We have R3 and R4 as a voltage divider setting a DC reference level, and C1 as a reference capacitor and C2 as a bypass capacitor, which were explained in detail in the previous paragraph. R1 and R2 are isolation resistors that prevent instability with capacitive loads. The formula used for calculating the output voltage is:$V_{OUT} = V_{DD}.\left(\frac{R4}{R3+R4}\right)$. In here, R3 and R4 determine the proportional reference voltage. If R3=R4, we have $V_{OUT} = \frac{1}{2}V_{DD}$ which is ideal for mid-supply reference, like 2.5V for a 5V supply. This results in an accurate and noise-isolated reference voltage.



The Difference Amplifier

In here, we have a difference amplifier using the MCP601 op-amp. It combines the non-inverting and inverting amplifier configurations to subtract two input signals. Inputs V1 and V2 are applied to a balanced resistor network, allowing signal subtraction and V_{REF} provides a DC offset for shifting the signal into the operating range of single-supply systems. And again, the bypass capacitor stabilizes the power supply of the op-amp. In here, we have a single path and configuration, which means V2 is applied to the inverting input through R1, and V1 is applied to a voltage divider consisting of R1 and R2 and enters the non-inverting input. The op-amp uses negative feedback through resistor R2 from the output to the inverting input. We also have a virtual short principle because of the feedback op-amp maintains $(V_+ = V_-)$, ensuring accurate differential behavior.

The components of this circuit are two R1 which set gain and balances the subtracting function also it is equal in both positions for symmetry to ensures linear subtraction and equal gain, two R2 which sets the gain and completes the voltage divider shown in the figure they also must match for unity gain symmetry to dictate final output level. We have a MCP601, which was explained in previous figures, and a V_{REF}, which is a reference offset voltage used in single-supply systems to keep the output above 0V. Lastly, we have a bypass capacitor, which helps power decoupling and stabilizes the op-amp. The output voltage formula in here is $V_{OUT} = (V_1 - V_2).\left(\frac{R2}{R2}\right) + V_{REF}.\left(\frac{R2}{R1}\right)$. The first term represents the differential input voltage amplified by the gain factor. If R1=R2, this term reduces to $(V_1 - V_2)$. Second term shifts the output upwards, ensuring that the output stays within the positive supply rail when using a single-supply op-amp.

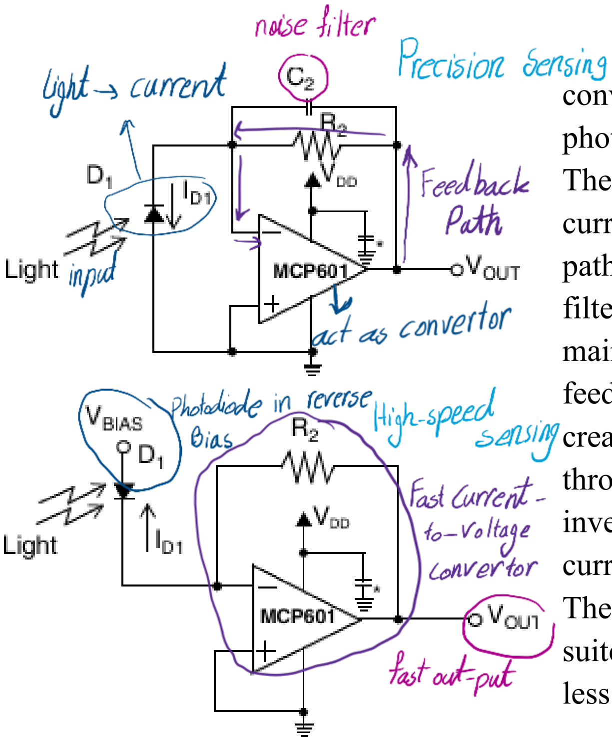


Summing Amplifier

In the following circuit, we have a summing amplifier built using the MCP601 op-amp in an inverting configuration. It takes multiple voltage inputs through identical resistors and combines them algebraically into a single output. This configuration allows both addition and subtraction of input voltages. As for the operating principles, we have inputs V1 and V2 connected to the inverting input and V3 and V4 connected to the non-inverting input. All the voltages are connected to the op-amp through identical, separated resistors R1. We also have negative feedback through resistor R2, creating a virtual ground at the inverting input. Virtual ground is a point that is not physically connected to the ground but is held at ground potential due to negative feedback. With the help of superposition, the output reflects the sum and difference of the input voltages.

The transfer function of this circuit is $V_{OUT} = (V_1 + V_2 - V_3 - V_4).\left(\frac{R2}{R1}\right)$. V1 and V2 are applied to the inverting input, contributing negative currents, while V3 and V4 are applied to the non-inverting input to raise the virtual ground, contributing positive components. All inputs go through equal resistors R1, and the feedback resistors R2 control the overall gain of the summed signal. If R1=R2 output is equal to the algebraic sum of inputs with unity gain.

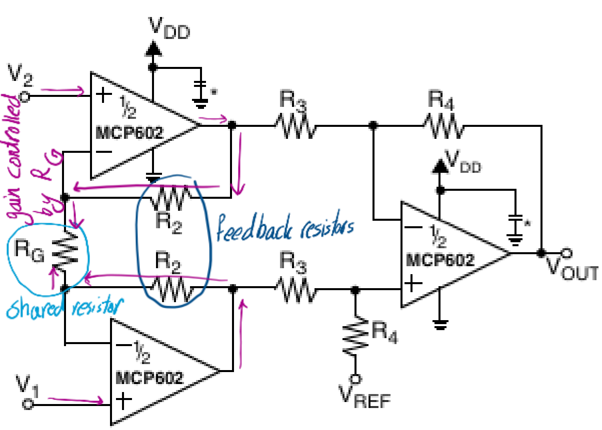
Current to Voltage Conversion



This figure presents two configurations using the MCP601 to convert photocurrent (I_{D1}) to voltage. The signal originates from a photodetector(D1), which generates current when exposed to light. The op-amp is in an inverting amplifier configuration, the input is current, and the output is voltage. The resistor R2 is in the feedback path, and it converts current to voltage. C2 is added for stability and filtering, but it is optional. This circuit is operating by the op-amp maintaining a virtual ground at the inverting input through negative feedback. The photodiode D1 is reverse based, meaning that it would create a current (I_{D1}), when light is hitting it, then the current will flow through R2, creating a voltage drop. In the top circuit, the non-inverting input is tied to the ground, and it is designed for low-bias current and high-accuracy reading using CMOS op-amps (MCP601). The bottom circuit has its non-inverting input based on V_{BIAS}. It is suited for high-speed applications when we need a faster response in less time.

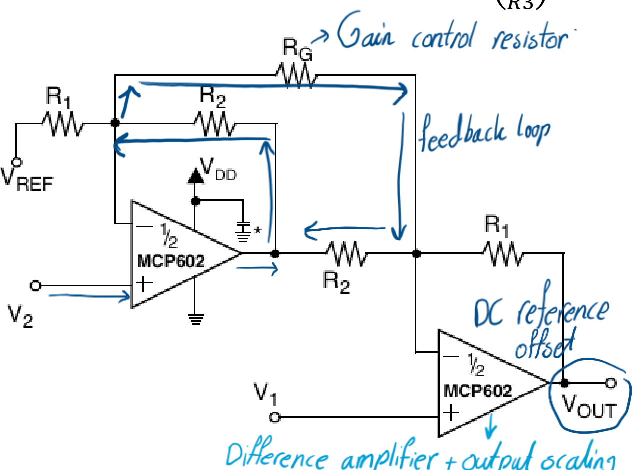
In here, we have a MCP601 op-amp to convert small currents accurately. We have D1, which is a photodetector, and it is used for converting the light into current, used for light intensity output voltages. R2 is used as a feedback resistor, converting current to voltage for determining the gain. C2(top circuit) is a feedback capacitor filtering the noise to improve the precision. V_{BIAS} (bottom circuit) as a bias voltage providing reverse-bias for D1 to enable fast charge collection. The conversion formula is $V_{OUT} = R2. I_{D1}$. R2 controls the sensitivity, a higher R2 means a larger voltage output per μA of light current. I_{D1} photodiode proportional to light intensity.

Instrumentation Amplifier



In here we have a classic 3-op-amp instrumentation made using two MCP602 op-amps for the input stage and one for the output stage. It is designed to amplify small voltage differences accurately between V1 and V2, even if they sit on high common-mode voltages. This circuit provides high input impedance, excellent common-mode rejection, and precise and adjustable gains. This design is used in medical sensors, process control systems, and low-noise signal acquisition. The operating principle in this circuit contains two stages. Stage one is about the input buffer and gain stage. The op-amps 1 and 2 buffer the inputs V1 and V2, both inputs are fed to the non-inverting terminals to ensure very high input impedance. The gain of this stage is determined by R_G and R2. The voltage difference between the output of the first two op-amps is proportional to $V_1 - V_2$. In stage two, we have a difference amplifier. The output stage (third op-amp) is a difference amplifier, which subtracts the outputs of the first stage and then applies additional gain via resistors R3 and R4. It also gives a DC reference shift via V_{REF}.

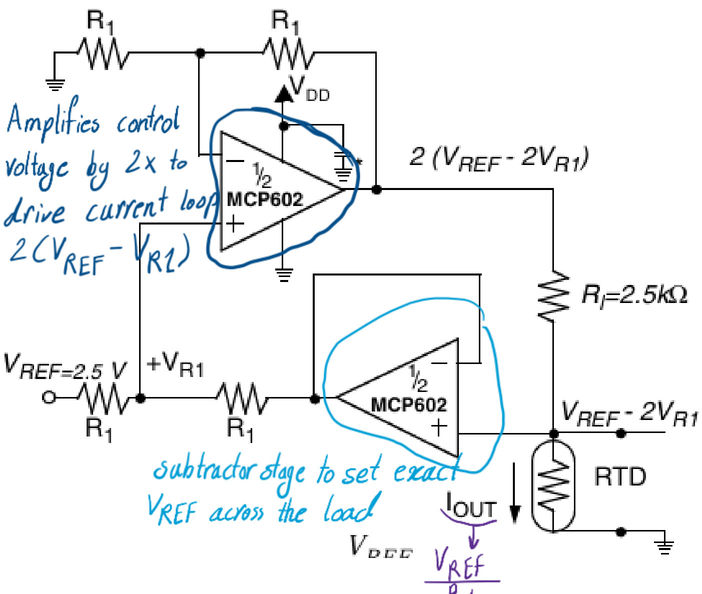
This circuit contains three MCP602, ensuring accurate signal amplification. R_G as a gain resistor setting the gain of input stages (smaller R_G, higher gain). Two R2s, which are symmetric gain resistors and are part of the gain path controlling differential gain. R3 and R4 are feedback and scaling resistors that form a difference amplifier, determining the final gain and common-mode rejection. V_{REF} is a reference voltage setting the output offset and is required for single-supply systems. And the bypass capacitor prevents oscillation by power filtering to maintain oscillations, as usual. The full output voltage formula is $V_{OUT} = (V1 - V2).\left(1 + \frac{2R2}{R_G}\right).\left(\frac{R4}{R3}\right) + V_{REF}\left(\frac{R4}{R3}\right)$. First term $(V1 - V2)$ is a differential input voltage, referring to the voltage difference between two inputs. The second term $\left(1 + \frac{2R2}{R_G}\right)$ is the gain of the input stage, as the R_G decreases the gain increases. $\left(\frac{R4}{R3}\right)$ is the gain of the difference amplifier. $V_{REF}\left(\frac{R4}{R3}\right)$ is the output offset adjustment shifting the entire voltage up or down.



This figure shows a two-op-amp instrumentation amplifier for higher gains. It consists of a first op-amp (left) for buffering and gain, and a second op-amp acting as a differential amplifier. This structure maintains high input impedance while providing isolation between sources and gain stages. This arrangement is the best for higher gains (>3 V/V). In stage one, we have gain and load isolation (left op-amp). V2 is connected to the non-inverting input of the first op-amp, and our feedback path includes resistors R2 and R_G(controlling the gain). Stage 2 is a difference amplifier (right op-amp), in which both V1 and the output of stage 1 are connected to a differential op-amp stage. All the above follow the 2-stage amplification behavior theory, consisting of two stages. Stage 1: voltage follower + gain path, and stage 2, difference amplifier.

This circuit consists of MCP602, which is a dual op-amp used for precise signal amplification. R2 is part of both stages, of gain and feedback, and controls the feedback current. $R_G$is an adjustable gain resistor determining the gain of stage 1, also the smaller it gets, the higher the gain we have. We have an input-output scaling resistor R1, which is part of stage 2, and balances gain and reference shift. V_{REF} which is a reference voltage, offsets the output, and is used for the center signal in a single-supply system. And as usual, our bypass capacitor decouples the power to prevent oscillation. The transfer function of this circuit is $V_{OUT} = (V1 - V2)\left(1 + \frac{R1}{R2} + \frac{2R1}{R_G}\right) + V_{REF}$. $(V1 - V2)$Is the differential input, which is the signal difference, to be amplified. $\left(1 + \frac{R1}{R2} + \frac{2R1}{R_G}\right)$ is the overall gain combining the stage 1 gain $1 + \frac{2R1}{R_G}$ and the stage 2 gain $\frac{R1}{R2}$. V_{REF}Is our offset voltage added to keep the output within the supply range.

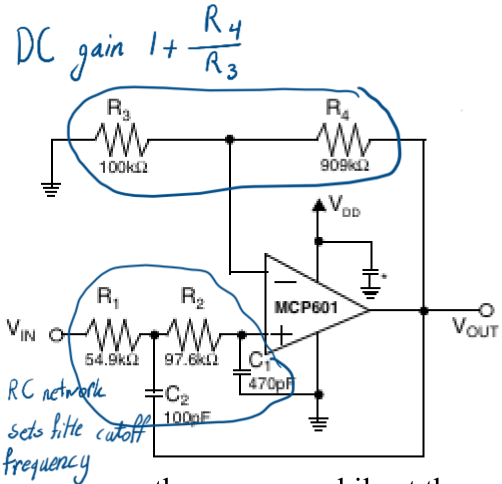
Floating Current Source



This circuit is a floating current source designed for outputting a constant current I_{OUT}into a variable load like an RTD sensor. It uses two MCP602 op-amps, a precision voltage reference V_{REF} and carefully selected resistors. Our current source here is floating because the output current is isolated from the ground, meaning it can be placed across any load. In here, a fixed reference voltage is used to create a precisely controlled current, making it independent of load resistance. This circuit operates with the help of a voltage divider and a gain stage in the top op-amp, and output and current creation on the bottom op-amp. In the voltage divider and gain stage, we have V_{REF}As the reference voltage is applied across R1, generating A voltage drop V_{R1} to calculate its voltage drop at R1, we use Ohm's law $V_{R1} = I.R1$. The voltage at the non-inverting input of the op-amp becomes $V_{REF} - V_{R1}$ This is amplified by gain=2, making the output $2.(V_{REF} - V_{R1})$. In the output and current creation op-amp, we have the voltage presented as $V_{REF} - 2V_{R1}$Subtracting this equation from the top one gives us $2(V_{REF} - V_{R1})$–$(V_{REF} - 2V_{R1})$. The voltage across the resistor R_L(RTD) is exactly V_{RER}.

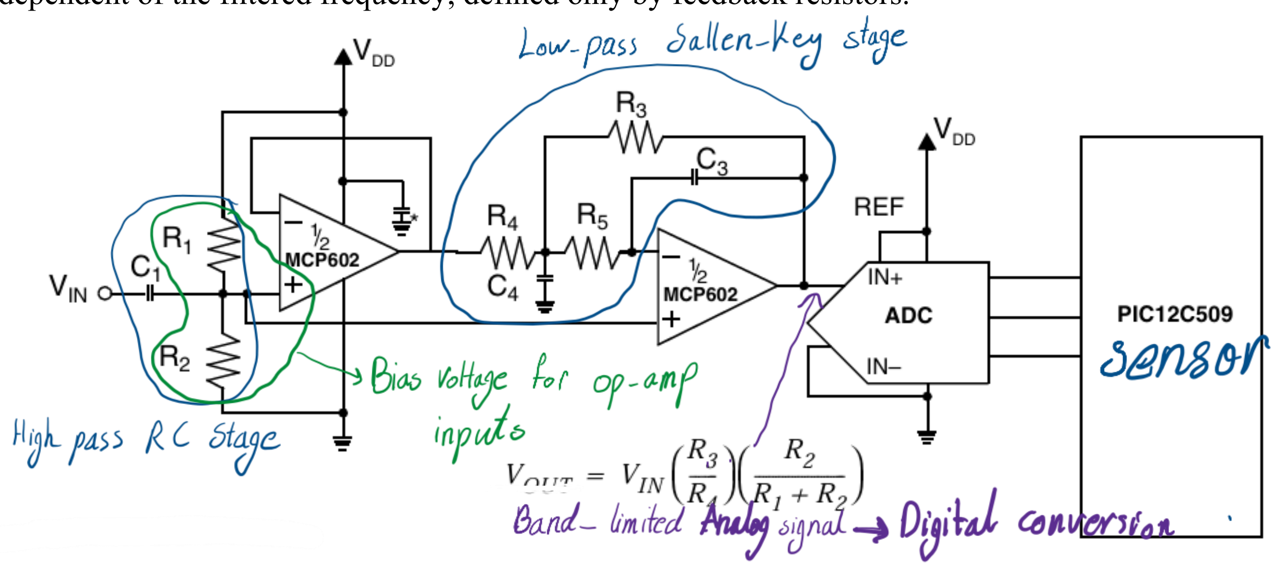
In here, we have two MCP602 op-amps, which provide precision gain and output control to stabilize and maintain the desired current. Resistor R1 is an input resistor forming a voltage drop from V_{REF}For setting the scale of the control loop. RL, which is a load resistor (RTD), is used to receive constant current and it loads whose resistance may change. V_{REF} is a precision reference setting the target current to define the magnitude of I_{OUT}. Like usual, the bypass capacitor filters power noises, preventing oscillation. D transfer function of this circuit is $I_{OUT} = \frac{V_{REF}}{R_L}$. The entire op-amp is designed to ensure that the voltage across the load = V_{REF} So, by Ohm's law, we can say $I_{OUT} = \frac{V}{R} = \frac{V_{REF}}{R_L} = \frac{2.5}{2500} = 1.0mA$.

Filters



This figure illustrates a 2-pole active low-pass single op-amp (MCP601). The design is a Sallen-Key topology, making it very suitable for implementing filters with known gain and cutoff characteristics. This special design is made for a 10 kHz Butterworth, providing a flat passband, controlled roll off, and minimal ripple. All the above description allows the circuit to be used as an anti-aliasing filter before ADCs to prevent high-frequency components from folding into the sampled range. The operating principle of how it filters the signal is by passing the input signal V_{IN} through resistors R1 and R2 before reaching the op-amp, while at the same time, capacitors C1 and C2 form the frequency-selective part of the filter. Also, our op-amp is configured as a non-inverting amplifier providing gain and buffering. The filter's cutoff frequency is dependent on R1, R2, C1, C2 and the formula this frequency is $\frac{1}{2\pi\sqrt{R1.R2.C1.C2}} = 10.03\ kHz$ which is taken from the standard transfer function of a second-order low-pass Sallen-Key filter. At frequencies above the cutoff frequency, the output amplitude drops off quickly, and the gain is set independently by feedback resistors R3 and R4.

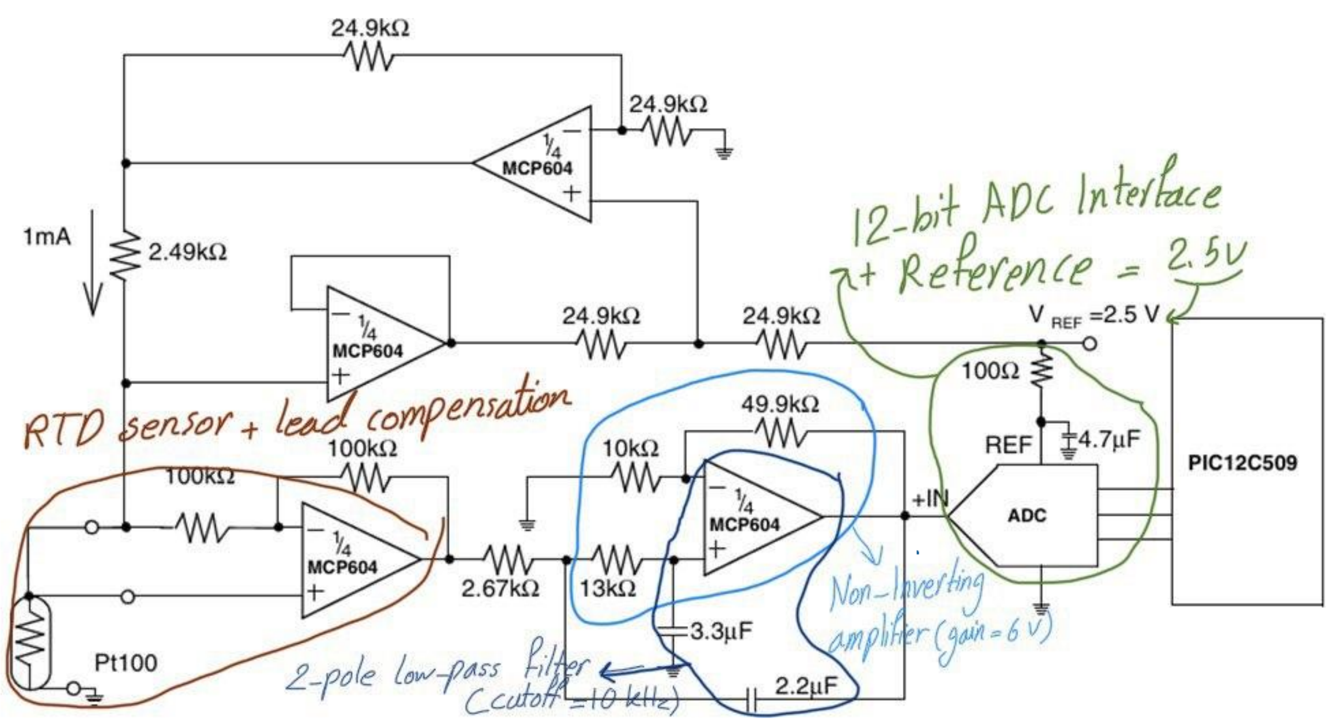
In this figure, we again have a MCP601 op-amp for buffering and gain stages, maintaining the signal integrity and applying gain. R1 and R2 are the input resistors that form part of the RC (resistance-capacitor) network to set the cutoff frequency. C1 and C2 are our capacitors determining the filter's reactive behavior, and their main effect is setting the roll-off (how quickly a filter reduces signal amplitude beyond the cutoff frequency) characteristic. R3 and R4 are feedback resistors setting DC gain (gain = $1 + \frac{R4}{R3}$). Lastly, our bypass capacitor decouples the power to prevent noise and improve stability as usual. The DC gain of this circuit is $\frac{V_{OUT}}{V_{IN}} = \left(1 + \frac{R4}{R3}\right) = 1 + \frac{909k\Omega}{100k\Omega} = 10.09$ and it is independent of the filtered frequency, defined only by feedback resistors.



In here, we have a bandpass filter which uses two op-amps (MCP602) to block frequencies below a low-frequency threshold (high-pass behavior) and above a high-frequency threshold (low-pass behavior). This design is ideal for speech processing because we only need to retain in middle band of frequencies (300Hz to 3kHz). The circuit has a high-pass stage (left) and a low-pass stage (right). In the operating principle, we have two stages, stage 1 high-pass filtering (left op-amp) and stage 2 low-pass filtering (right op-amp). In stage 1, we have R1 and R2 as input resistance and C1 as a coupling capacitor. This stage blocks DC and low-frequency noises, passing high frequencies above the high-pass corner frequency. All the above combined resistors also act as a supply splitter at the non-inverting input. In stage 2, we have R3, R4, R5, and capacitors C3 and C4 setting a second-order low-pass corner that blocks high-frequency signals such as RF noise or aliasing frequencies. It operates as a Sallen-Key low-pass filter, which is a type of active filter that uses an op-amp for buffering and gain, two resistors, and two capacitors for frequency selection. It passes low-frequency signals and blocks high-frequency allowing it to start at a cutoff frequency.

The components of this circuit are two MCP602, which are operational amplifiers used when we have high input impedance and active filtering, two resistors R1 and R2 acting as a voltage divider and high pass input setting a high pass cutoff frequency and virtual ground, a C1 coupling capacitor blocking DC, only allowing AC to pass. We also have R3, R4, and R5, which are feedback resistors setting gain and frequency roll-off (how fast a filter reduces the amplitude of signals beyond its cutoff frequency) in the low-pass stage. C3 and C4 are low-pass filter capacitors determining high-frequency cutoff. An ADC block, which is an analog-to-digital converter, receives clean and band-limited signals. Lastly, we have REF, which is an ADC reference voltage(maximum voltage that the Analog-to-Digital Converter (ADC) could accurately measure and convert), ensuring accurate conversion The signal gain of this circuit is $V_{OUT} = V_{IN}\left(\frac{R3}{R4}\right)\left(\frac{R2}{R1+R2}\right)$. $\frac{R2}{R1+R2}$ comes from the voltage divider in the high-pass stage, determining what part of the signal should pass through the op-amp input. $\frac{R3}{R4}$ sets the gain in the low-pass amplifier stage, it also follows the non-inverting op-amp gain rule with additional filtering. Overall, this system is a bandpass response with again based on both stages scaling.

Putting it Together



This circuit measures temperature using a Pt100 RTD (resistance temperature detector) and it includes a constant current source (for RTD), lead wire compensation, an amplification stage, an Anti-aliasing filter, and an Analog-to-digital conversion (ADC) with reference voltage. In this circuit, we have an RTD excitation using a constant current source, meaning using a precision resistor and op-amp, we made a floating current source configuration, which is explained before. Negative feedback is used so that the op-amp can adjust its output so that the voltage drops across the resistor sets the current. We also have a virtual ground theory ensuring the current path is stable. In this circuit, we have an amplification stage that sets the gain to be equal to 6. The theory applied here in here is the non-inverting amplifier theory, and the formula for it is $Gain = 1 + \frac{R_f}{R_g} = 1 + \frac{13k\Omega}{2.67} = 6$. We also have an anti-aliasing filter (2-pole low-pass filter), which is about Sallen-key filter theory and capacitive reactance. The low-pass filter uses $f_c = \frac{1}{2\pi\sqrt{R1R2C1C2}}$ our capacitor slows down in high-frequency changes and filters out frequencies > 10 kHz. In the end, we have an ADA sampling stage, which is about sampling theory (Nyquist). This theory works with ADC Digitalizing the analog signal using a 12-bit resolution, we have $V_{REF} = 2.5V$ so $\frac{2.5V}{2^{12}}$ = 0.61 mV is our resolution.

In this circuit, we have four op-amps (MCP604) acting as buffer, amplifier, filter, and current regulator, and are selected to prevent the high input impedance loads RTD. They also ensure stable amplification and current control across all stages. We have a Pt100 RTD (resistance temperature detector), which senses temperature by changing resistance and is selected for linear, stable response and industry standards. Its resistance at 0°C is 100 Ω, and its sensitivity is 0.385 Ω/°C, allowing it to provide a readable, high-accuracy analog signal for temperature measurements. 24.9 kΩ and 2.49 kΩ resistors (current source), which define current in the 1mA constant current source using Ohm's law, the reason for its selection is precise resistor values for accurate current output, and it helps maintain consistent excitation current to the RTD. Gain resistors (10 kΩ, 13 kΩ, 2.67 kΩ) set the amplifier gain to match RTD signals to the ADC input range to maximize ADC resolution. Filter capacitors (3.3 µF & 2.2 µF) define a low-pass filter cutoff (=10 kHz), making it suitable for ADC anti-aliasing and also removing high-frequency noises. Reference filter (100 Ω + 4.7 µF) smooths the ADC reference voltage by suppressing supply noise on V_{REF} To improve ADC stability and accuracy. PIC12C509 (12-bit ADC MCU) converts analog to digital signals, integrating an ADC to digitize your signal for microcontroller processing. Overall, this circuit is used for microcontroller-based embedded systems in temperature monitoring because it gives accurate temperature sensing and high-resolution digital output.

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