

## MKT1132 INTRODUCTION TO ELECTRIC CIRCUITS

### PROJECT NUMBER:2

#### Microchip AN682– Using Single Supply Operational Amplifiers in Embedded Systems

##### Voltage Follower Amplifier

Figure 1(Buffer Amplifier; also called a voltage follower) allows driving large loads while resolving impedance differences and acting as protection barriers between weak and strong circuits. It provides an output signal of equal magnitude to its input without creating any amplification effect.

The circuit has an MCP601 operational amplifier as its main component because it delivers low-power operation and rail-to-rail output while having high input impedance. The power supply receives stabilization and noise reduction capability through a  $1\mu\text{F}$  bypass capacitor. No external resistors are used here. The buffer amplifier produces an output voltage equivalent to the input voltage to create isolation thus protecting against signal deterioration.

In Figure 2(Load isolation is achieved using a buffer amplifier), circuit functions to isolate measurement systems from heavy load control. The circuit protects amplifiers from experiencing load-induced performance fluctuations which ensures proper signal amplification.

This circuit employs MCP601 precision op-amps for buffering and exact amplification. R1 and R2 resistors establish the gain factor yet bypass capacitors sustain a stable power supply and minimize noise disturbances. The precision amplifier delivers precise amplification of tiny signals whereas the buffer allows driving heavy loads without distorting measurement accuracy.

##### Gaining Analog Signals

Circuit in Figure 3(Operational amplifier configured in a non-inverting gain circuit) amplifies signals without signal inversion. It is well-suited for boosting signals that must preserve their original polarity within single-supply amplifier designs.

In this picture, we have an MCP0601 Op-Amp, which amplifies the input signal and offers rail-to-rail output. We also have two resistors (R1 and R2) and a Bypass Capacitor with  $1\mu\text{F}$ . R1 and R2 set the amplifier's gain, and R2 determines the signal relative to R1. The general working principle of this circuit is the fact that its input goes to the non-inverting terminal, and output is the same phase amplified version of input. Gain is set by two resistors, R1 and R2.

Circuit shown in Figure 4(Operational amplifier configured in an inverting gain circuit. In single supply environments a VBIAS is required to insure the output stays above ground) is used to

amplify and invert input signals and is commonly used in signal supply systems with no negative voltage. It also uses VBIAS to keep the output signal positive or above ground.

In this circuit we have two resistors (R1 and R2) controlling the gain of the amplifier, a MCP0601 Op-Amp amplifying the voltage and requiring power supply VDD, VBIAS adding a DC offset to shift output above ground, a Bypass Capacitor(1 $\mu$ F) to stabilize voltage at VBIAS and blocking AC signals. The general working principle is the op-amp inverting and amplifying input signals while the capacitor keeps VBIAS stable, which its job is to maintain the output above 0V.

### Single Supply Circuits and Supply Splitters

The circuit shown in Figure 5(A supply splitter is constructed using one operational amplifier. This type of function is particularly useful in single supply circuits) is used in a single supply circuits and for providing a stable reference to Analog-to-Digital (A/D) converter. This circuit shifts voltage to keep signal between negative (ground) and positive supply pins, it also keeps VREF stable using op-amp, resistors, and capacitor thus it prevents ADC conversion errors due to voltage changes.

The components include the resistors R1 and R2 which create a voltage divider to the level shift, capacitor (C<sub>1</sub>) acts as a charge reservoir in the AC domain and also stabilizes the VREF voltage, op-amp which buffers and maintains the VREF voltage ensuring low output impedance and stable voltage. The resistors divide VDD to set VREF and also create a level shift to keep the signal above ground. The op-amp buffers and stabilizes VREF, and the Capacitor keeps VREF steady.

### The Difference Amplifier

The circuit in Figure 6 (Operational amplifier configured in a difference amplifier circuit.) combines Figures 3 and 4 into a single block that subtracts two signals and amplifies the difference based on the resistor's ratio. Additionally, it allows gains equal to or higher than one, and is a useful signal source impedance is low.

The components of this circuit are resistors (R1 and R2) which set the gain of the amplifier, capacitor (Bypass Capacitor, 1 $\mu$ F) that stabilizes the power supply and reduces noise, Operational Amplifier (MCP601) amplifies the difference between V1 and V2 and also is configured to handle both inverting and non-inverting inputs. This circuit takes the difference between two input signals, amplifies the difference by a factor then adds the reference voltage term VREF by the same factor.

### Summing Amplifier

Figure 7 (Operational amplifier configured in a summing amplifier circuit) shows a summing amplifier, which is used when multiple signals need to be combined by addition or subtraction. It accepts any number of inputs with resistors of the same value as their equivalent resistors.

Here we have resistors R1 connecting each input signal to the op-amp to ensure equal weighting, while R2 sets the overall gain of the output. Operational Amplifier (MCP601), which is configured for summing and subtracting signals here. The working principle is adding and subtracting multiple input values making sure all inputs are passing through equal resistors to the op-amp.

### Current to Voltage Conversion

The circuit in Figure 8 (Current to voltage converter using an amplifier and one resistor. The top light scanning circuit is appropriate for precision applications. The bottom circuit is appropriate for high-speed applications) and is used in systems with sensors that output current (photodetector). Additionally, it is used in precise or high-speed sensing applications. Its main function is converting sensor current ( $I_{D1}$ ) into voltage, but it also uses an op amp with resistors in a feedback loop. This circuit also maintains the diode at low voltage or ground for accurate current flow.

This circuit includes resistor R2 converting photodiode current ( $I_{D1}$ ) into voltage, capacitor (C2) optionally used in feedback loops helping with stability and precision in slow light-scanning applications, Operational Amplifier (MCP601) amplifying voltage developed across R2, a photodiode (D1) which is a light-sensitive component generating current when exposed to light. This circuit converts photodiode current to voltage, the top circuit is for precision sensing and the bottom circuit is for high-speed sensing.

### Instrumentation Amplifier

The circuit shown in Figure 9 (An instrumentation amplifier can be designed using three amplifiers. The input operational amplifiers provide signal gain. The output operational amplifier converts the signal from two inputs to a single-ended output with a difference amplifier) is used in medical instruments and process controls. When high input impedance and accurate signal differences are needed, we use this circuit, it is also suitable for single-supply systems. It amplifies the difference between two signals, rejecting input impedance, and also uses three op-amps to improve accuracy and gain control, resulting in a single-ended signal from two inputs as output.

Here we have resistors  $R_G$  controlling overall gain, R1 and R2 as a part of the gain stage, R3 and R4 used in the output difference amplifier, two input op-amps amplifying each input signal, One output op-amp forming difference amplifier stages, capacitor (Bypass Capacitor,  $1\mu F$ ) stabilizing power supply (VDD). The first two op-amps amplify the input signals with high input impedance; however, the third op-amp subtracts the two signals.

Figure 10 (An instrumentation amplifier can be designed using two amplifiers. This configuration is best suited for higher gains. ( $\text{gain} > 3 \text{ V/V}$ )) is used in applications requiring high gain ( $\text{gain} > 3 \text{ V/V}$ ) and is suitable for single supply environments. Additionally, it is used

in single gain, load isolation, and differential signal processing. It isolates and processes signals using two op-amps, adding reference voltage  $V_{REF}$  to the output.

In Figure 10, we have resistors  $R1$  and  $R2$  setting gain and scaling,  $R_G$  controlling gain adjustment, the first op-amp provides signal gain and isolation, the second op-amp subtracts input signals, a capacitor (Bypass Capacitor,  $0.1\mu F$ ) filters noise on the power supply ( $V_{DD}$ ) and ensures stable operation. The working principle here is that the first op-amp gives gain and isolation, and the second op-amp subtracts signals while the gains are set by resistors. We also have the addition of offset  $V_{REF}$  to the output.

### Floating Current Source

Figure 11 circuit (A floating current source can be constructed using two operational amplifiers and a precision voltage reference) is mainly used for driving variable resistive loads like RTD, and in applications needing a precise constant current source. It generates a constant output current independent of the load resistor.

The components are  $R1$  forming a voltage drop to control the op-amp input,  $R_F$  used in the feedback path for gain control, and  $R_L$  as a load resistor that determines output current. Here, the top op-amp is used to amplify the voltage drop across  $R1$  and the bottom op-amp is used to maintain correct output voltage for constant currents, a capacitor (Bypass Capacitor,  $1\mu F$ ) stabilizing power supply ( $V_{DD}$ ), and voltage reference ( $V_{REF} = 2.5V$ ) providing a stable reference voltage for current generation. As a working principle, we have a drop of  $V_{REF}$  across  $R1$  to create a controlled voltage while the top op-amps amplify this voltage, and the bottom one adjusts the output to maintain a constant current.

### Filters

Figure 12 (Low pass, 2-pole, active filters are easily designed with one operational amplifier. The resistors and capacitors can be adjusted to implement other filter types, such as Bessel and Chebyshev) circuit is used before A/D converters to eliminate unwanted signals, and is also used in anti-aliasing applications to remove high-frequency noise. This circuit acts as a low-pass filter with a defined cut-off frequency it also removes high-frequency components above the needed rate, providing a flat gain response in the passbands.

Resistors  $R1$  and  $R2$  set the frequency of the filter while  $R3$  and  $R4$  set the gain. Capacitors ( $C1$ ,  $C2$ ) define the corner frequency of the low-pass filter. Additionally works with resistors to shape the filter response. Operational Amplifier (MCP601) amplifies the filtered signal and forms part of the Sallen-Key topology. A Bypass Capacitor ( $1\mu F$ ) stabilizes the power supply ( $V_{DD}$ ). This circuit uses resistors and capacitors to form a 2-pole low-pass filter that also passes low-frequency signals and attenuates high-frequency ones. It is usually designed for anti-aliasing before A/D conversion.

## Putting it Together

Figure 13 (Bandpass filters can be implemented with one operational amplifier designed to perform the high pass function and a second amplifier to perform the low pass function) and Figure 14 (Complete single supply temperature measurement circuit) are used in single-supply temperature measurement systems and for RTD (Resistive Temperature Device) sensor signal conditioning, before a 12-bit ADC for accurate digital conversion. Figure 13 acts as a bandpass filter with high-pass and low-pass sections, while Figure 14 completes the signal chain, including excitation, gain, filtering, and ADC input.

Resistors (R1, R2, R3, etc.) are used to set gain and filter characteristics and control signal scaling and matching for ADC. Capacitors (e.g., C1, C2, C3...) here are used to form high-pass and low-pass filter sections, also controlling cut-off frequency. Operational Amplifiers MCP602 is for a dual op-amp used in filtering, and MCP604 is for a quad op-amp used in a complete signal chain. RTD (Resistive Temperature Device) senses temperature by varying resistance. A/D Converter (PIC12C509 with internal ADC) converts the filtered analog signal to digital. Figure 13 filters out unwanted low or high frequencies using two op-amps for high-pass and low-pass stage. it also sends clean signals to ADC. Figure 14 measures RTD sensor signal and also applies current source, amplifies, and filters the signal.

The circuits covered such as inverting and non-inverting amplifiers, instrumentation amplifiers, current-to-voltage converters, summing and difference amplifiers, supply splitters, low-pass and bandpass filters, and RTD-based measurement systems have the key characteristic of precision signal processing using operational amplifiers, voltage and current scaling for compatibility with ADCs and temperature sensing using RTDs with current sources.

## List of sources

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