Operational amplifiers (op amps) quick reference guide

Operational amplifiers, or op amps, are used for their ability to amplify, filter, and perform mathematical operations on analog signals. They are high-gain, differential amplifiers with a range of applications in both analog and digital circuits. Op amps are used to interface analog signals with digital devices, such as microcontrollers and analog-to-digital converters, and for complex signal processing tasks such as filtering, waveform shaping, and signal conditioning.

HOW TO CHOOSE THE RIGHT OPERATIONAL AMPLIFIER?

Op amps provide effective solutions for any market including industrial, automotive, and consumer. Discover the key features for each of the following types of op amps.

Low power	High voltage	High speed	Power operational amplifiers
Low-input bias current	Low offset voltage	Rail-to-rail input and output	Standard

TYPICAL OP AMP APPLICATIONS AND KEY PARAMETERS

Operational amplifiers are used in several applications, each with specific requirements for performance.
These applications can be broadly categorized into the following groups.

Amplification of low-voltage signals

When amplifying low-voltage signals, high-precision op amps are necessary to ensure accurate measurements. Differential amplifiers and instrumentation amplifiers are commonly used in these circuits. For current sensing applications, low- or high-rail features, and an appropriate bandwidth with a slew-rate to track PWM may be required. Wheatstone bridge circuits, such as those used with strain gauges, RTD sensors, or resistive sensors, typically require low-noise devices.

Small current amplification

Sensors that provide a small current require op amps with low-input bias current, such as transimpedance amplifiers. In these applications, the input offset voltage is typically not critical. A common example of this type of application is a photodiode current sensing circuit used in communication equipment, light curtains, smoke detectors, electrochemical gas sensors, and optical heart rate monitors. Since these devices are often powered by batteries, power consumption is an important consideration. Additionally, the device may need to be fast and require a high slew rate to ensure accurate measurements.

ADC buffering

Interfacing an analog signal with an ADC can be challenging because the ADC requires a high current within a short time to charge input capacitors. To address this, an additional capacitor is often used at the op amp output. However, this can cause stability issues and may require the use of compensation techniques. It is important to ensure that errors caused by the op amp are less than one LSB of the ADC to ensure accurate measurements.

In addition to its use in interfacing with ADCs, an op amp can also be used as a basic anti-aliasing filter. This is because op amps can provide high-gain and low-pass filtering, which can help to remove high-frequency noise and prevent aliasing in the ADC.

Other signal conditioning

More complex signal conditioning circuits have different requirements and designers should consider the above-mentioned parameters and how they affect functionality and performance.

OP AMP LONGEVITY COMMITMENT

Most of ST's newly developed high-performance operational amplifiers come with a 10-year longevity commitment. The **list** gets longer every year.

TOOLS AND SOFTWARE

Sample kits

The **KIT24OPAMP** includes a wide range of high-performance op amps, comparators, and current sense amplifiers. It is very useful to test and evaluate the ST operational amplifier's portfolio.

The **KIT2407AUTOSC** contains a selection of AEC-Q100 qualified operational amplifiers, comparators, and current sense amplifiers suitable for automotive applications.

Training kit

The **STEVAL-CCA058V1** kit includes a configurable board and 12 op amp adapter boards for hands-on learning.

Simulation tools

- Use **eDesignSuite** to start your analog circuit design and simulate your project.
- Get a quick preview with fully annotated schematic and BOM.
- Export to **eDSim** for fast and accurate electrical simulations and reliable design validation.

ST'S OP AMP PART NUMBERING SCHEME

TSV	7	7	2	2	A	I	Y	S	T
Series root name	Series root number	I_{CC} and speed	Compensation	Number of channels	Precision	Temperature range	Grade	Package	Tape and reel

Series root name

TSV	High performance 5 V
TSU	Nano power 5 V
TSZ	Zero-drift 5 V
TSX	High performance 16 V
TSB	High performance 36 V
LM	Standard amplifiers

Series root number

1	Family specific
5	High merit factor
6	Micro power
7	High precision
9	High speed

I_{CC} and speed

Higher value means higher power consumption and faster

Compensation

None	Standard device (unity gain stable)
9	Higher GBW (stable for gain >5)
Any	Specific to family

Number of channels

1	Single
2	Dual
4	Quad
With shutdown	
0	Single
3	Dual
5	Quad

Precision

None	Standard device
A	Enhanced Vio

Temperature range

I	Industrial temperature range -40 to 125°C
H	High temperature range -40 to 150°C
H1	Very high temperature range -40 to 175°C

Grade

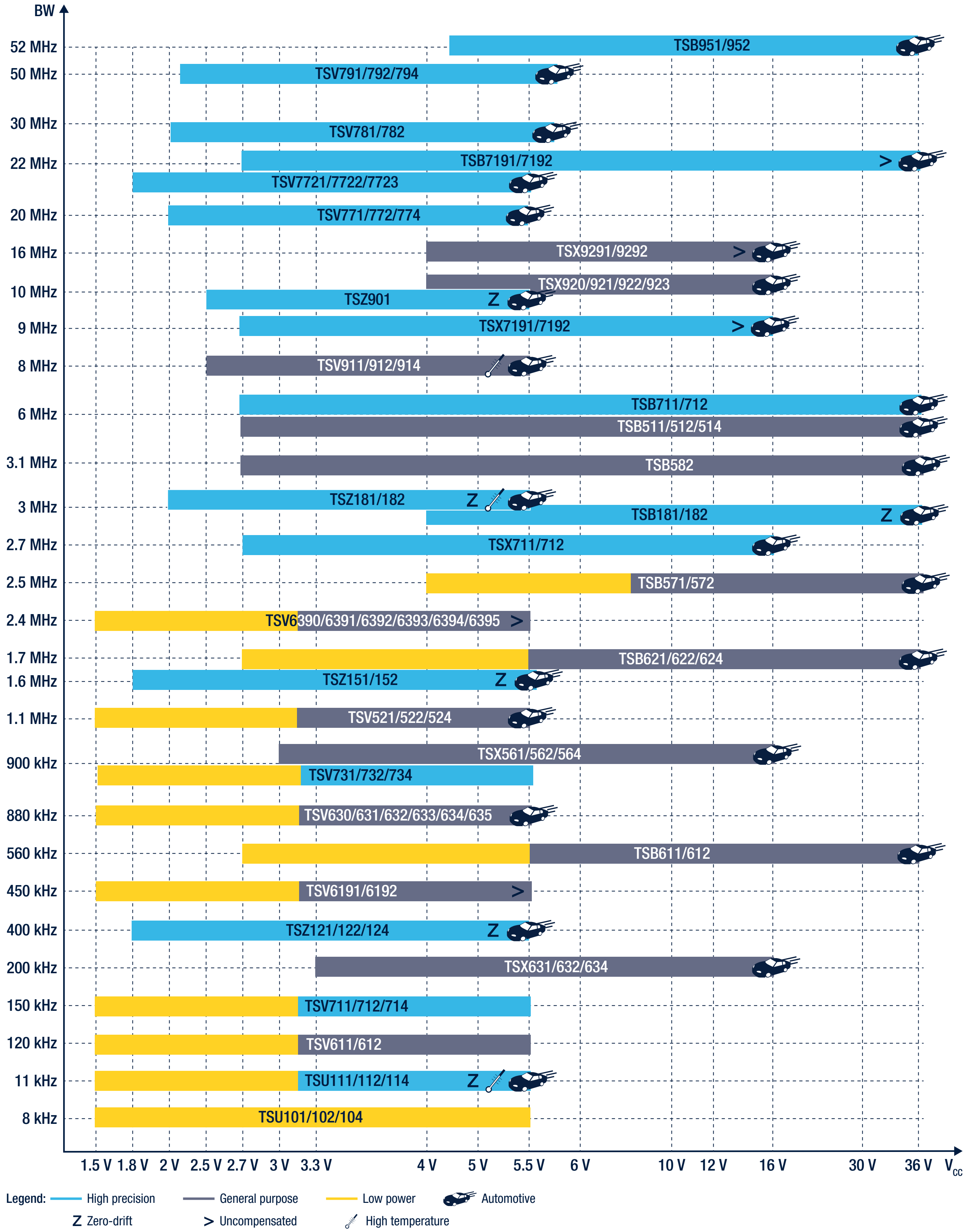
None	Standard qualification
Y	Automotive grade

Package

C	SC70
D	SO
L	SOT23
P	TSSOP
Q	DFN/QFN
S	MiniSO

Tape and reel

ST'S OP AMP PRODUCTS



GLOSSARY

Supply voltage (V_{CC}) – Voltage difference between the two power pins where the op amp works correctly. In ST's portfolio, 5 V, 16 V, and 36 V products are available.

Quiescent current/supply current (I_{CC}) – Supply current needed for each operational amplifier to operate correctly.

Input offset voltage (V_{IO}) – Differential input voltage of the + and - pins to get the output at the mid-range of the supply voltage. It originates from the matching of internal transistors.

Input bias current (IIB) – Current flowing through the inputs of an op amp. Due to op amp biasing requirements and normal operation leakage, a very small amount of current (pA or nA range, depending on the technology) flows through the op amp's inputs. This can cause issues when large value resistors or sources with higher output impedances are connected to the op amp inputs, resulting in significant voltage drops and errors.

Gain bandwidth product (GBP or GBW) – It is the product of an op amp's gain and bandwidth. It is typically measured at 20 dB gain and is defined for small signals.

Slew rate (SR) – How fast an op amp can change the voltage on its output. If the signal being amplified is too fast, the op amp's output rate of change is limited by the slew rate value, which can cause distortion.

Rail-to-rail input – The op amp with a high-rail input can deal with input signals up to V_{cc}+ while a low-rail input can deal with signals down to V_{cc}-. Rail-to-rail input op amps can handle input signals from V_{cc}- to V_{cc}+.

Rail-to-rail output – Capability of an op amp to drive its output very close to the power supply rails.

Noise level – Op amps generate random voltages at the output even when there is no signal applied on its input. This noise is caused by thermal noise (white noise) or 1/f noise, also known as flicker noise. In applications with high gain or bandwidth, the noise level may become considerable and affect the performance of the circuit.

Capacitive load – Can cause an op amp to become an oscillator. When the output resistance of op amp is connected to a capacitive load, it results in an additional pole in the circuit transfer function. From the Bode plot, it is clearly visible under which operating conditions the circuit can become unstable.

Zero-drift – Chopper op amps designed to "self-correct" their V_{IO} errors over temperature and over the time. Thanks to their design, zero-drift op amps have their V_{IO} in the range of microvolts and similar "nanovolt" per Celsius degree drift.
These op amps have virtually no 1/f noise and their "aging" over the time is negligible.

Shutdown – Op amp operation switch-off. Usually used to reduce the circuit standby current when either an application does not run or amplification is not needed. Usually controlled by a dedicated op amp pin.

EMI hardening – An op amp's input pins are very sensitive and might act as a gate for electromagnetic interference in your design. Some op amps embed EMI filters to attenuate high-frequency signals for 60 dB or more.

Strain gauge – A sensor used to measure an object's deformation.

RTD sensor – Resistance temperature detectors. Many RTD sensors are constructed from a fine metal wire which is wrapped around a ceramic or glass core.

Thermocouple – Every transition between different kinds of metals causes a tiny thermoelectrical voltage. This effect is used in some temperature sensors.

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