Operational Amplifiers (Op Amps) – Quick Reference Guide

In today's digital world, many signals start as an analog one. Most sensors already have their own analog signal conditioning circuit, but an operational amplifier is still a key device when you need more complex amplification and filtering, or just for interfacing analog signals with an ADC or a microcontroller. This reference guide provides you information about ST's most recent operational amplifiers and their characteristics.

How do I pick the right op amp for an application?

Even though some may consider op amps as a commodity, they are not. Modern high-performance devices have a wide range of variable parameters. One device can have almost ideal parameters, while another may be little worse and others can be completely different. The main key performance indicators for operational amplifiers can be listed as following:

- Supply voltage [V]
- Quiescent current [uA]
- Input offset voltage [mV]
- Input bias current [pA]
- Gain bandwidth product [MHz]
- Slew rate [V/us]
- Rail-to-rail input and output
- Noise level [nV/√Hz]

Typical op amp applications and key parameters

Each application has different key requirements for operational amplifier performance. Generally, we can divide applications into several different categories.

Amplification of low voltage signals

When amplifying low-voltage signals, you definitely need high precision op amps since the input offset voltage directly affects your measurement. On the other hand, most low-voltage signals come from low-impedance sources; therefore, the input bias current is not critical. A differential amplifier or an instrumentation amplifier is a typical circuit. Current sensing is a typical application where you usually need low- or high-rail features and possibly an appropriate bandwidth with a slew rate to track PWM. Other applications include Wheatstone bridges circuits e.g. strain gauges, RTD sensors or resistive sensors. In such applications, rail-to-rail inputs are not needed in most cases, but you may require a low-noise device. The same can be applied to thermocouples.

Small current amplification

Sensors providing a small current will require an op amp with a low input bias current. All of these applications use a transimpedance amplifier where the input offset voltage is not usually critical.

A typical application is a photodiode current sensing circuit used in communications, light curtains, smoke detectors, electrochemical gas sensors or optical heart rate monitors. In this case, the device is quite often powered from a battery so power consumption can be important or the device needs to be fast and a high slew rate may be required.

ADC buffering

Interfacing an analog signal with an ADC can be tricky since the ADC requires a high current within a short time to charge input capacitors. Often an additional capacitor is used at the op amp output which may cause stability issues and may require the use of compensation techniques. In any case, errors caused by an op amp should be less than one LSB of the ADC. Additionally, an op amp can be used as a basic antialiasing filter.

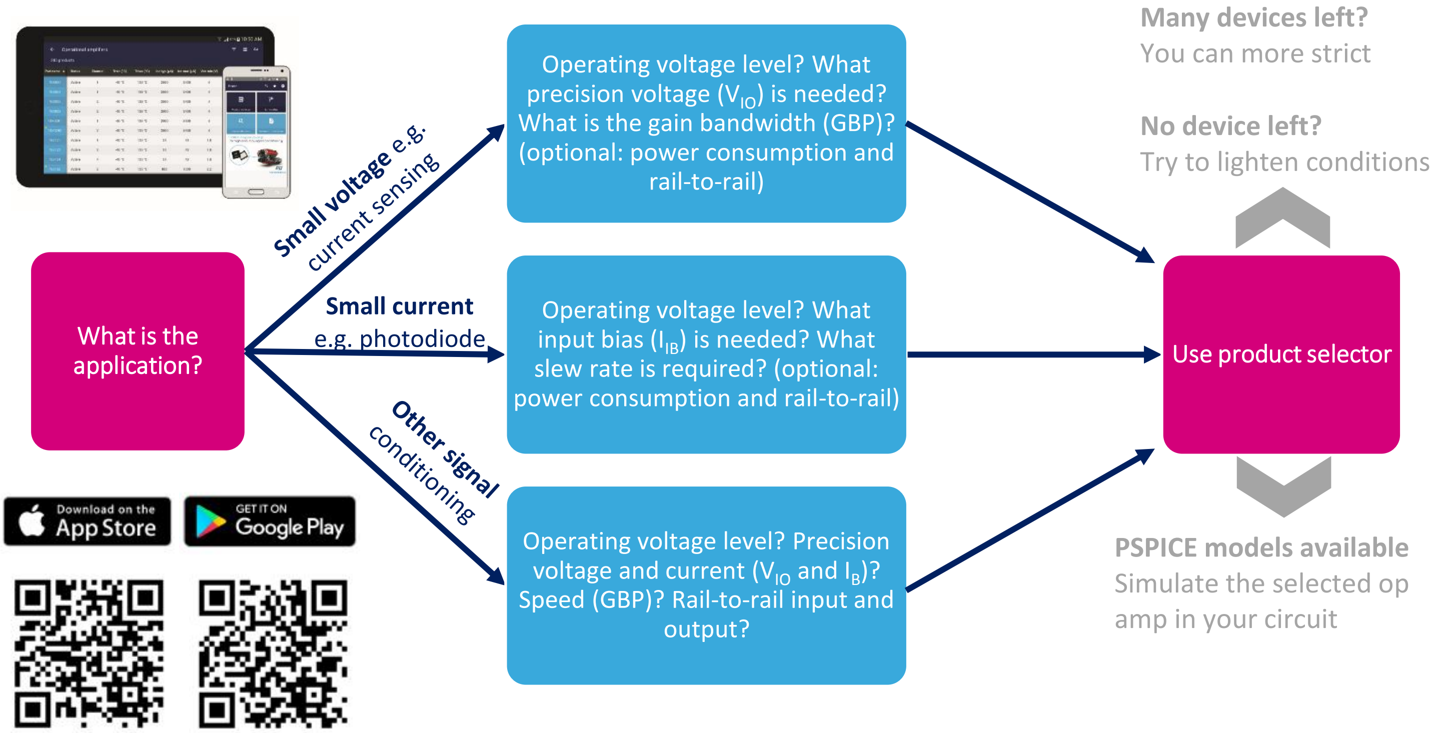
Other signal conditioning

More complex signal conditioning circuits have different requirements and designers should keep in mind all the above-mentioned parameters and how they each affect functionality and performance.

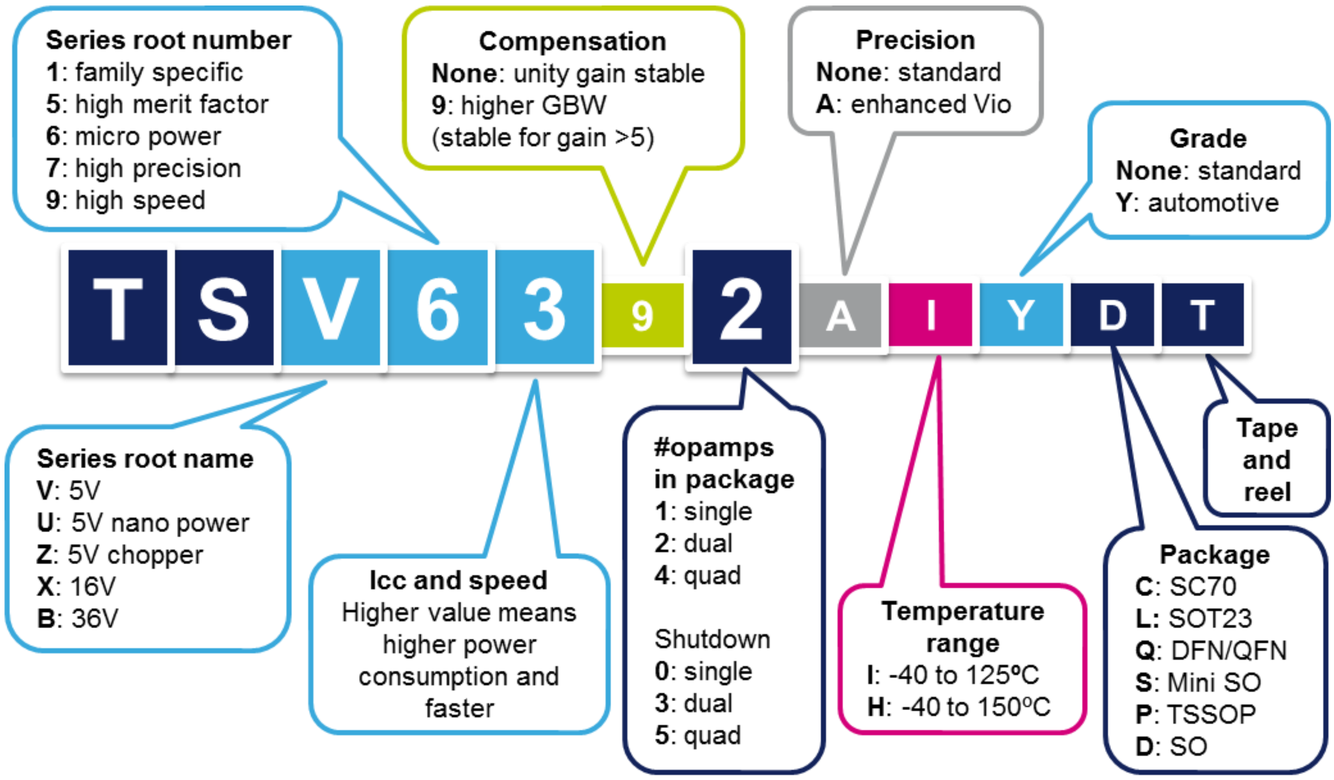
Op amp longevity commitment

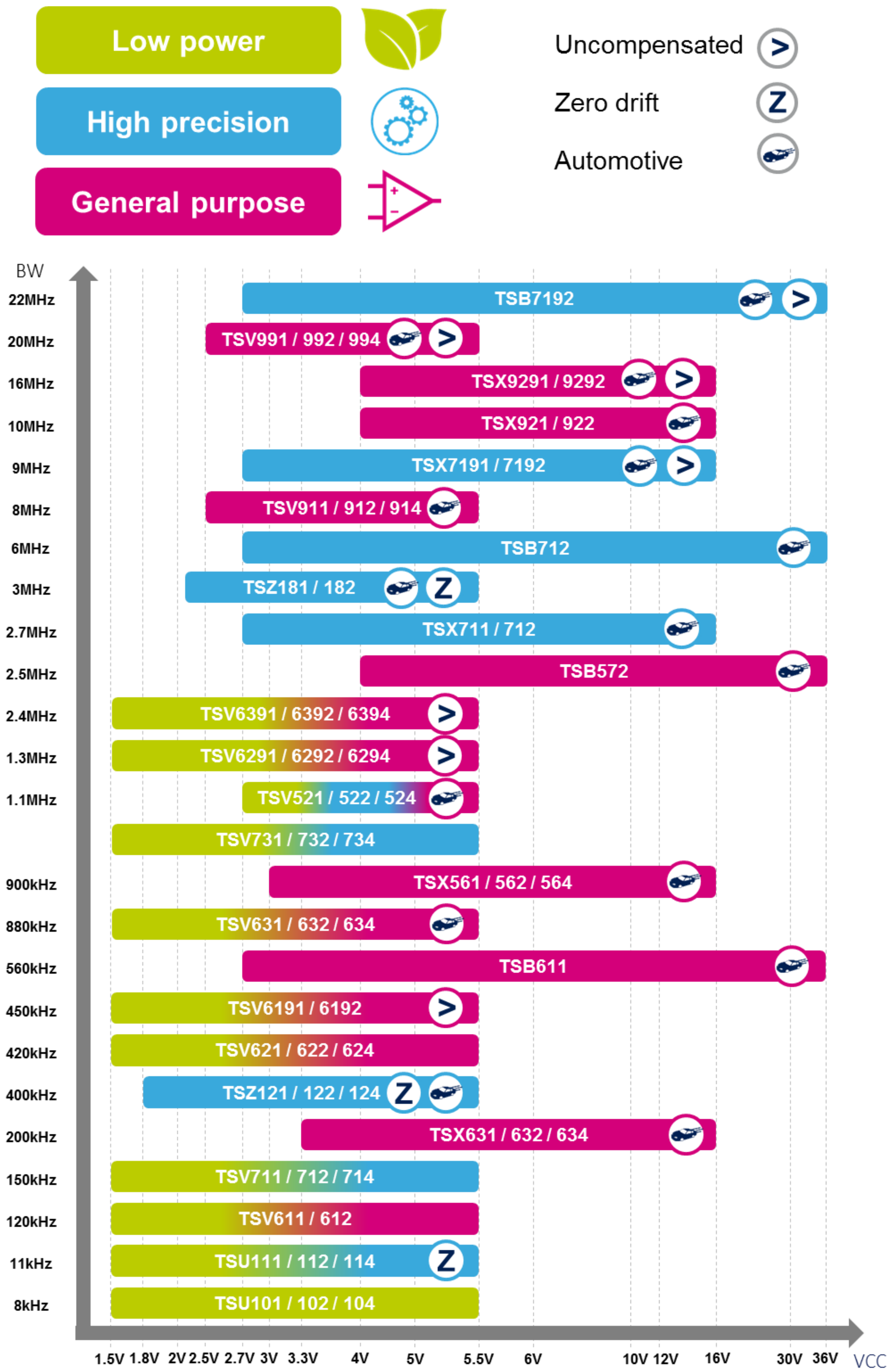
Most of ST's newly developed high-performance op amps come with our 10-year longevity commitment. The list gets longer every year.

Step-by-step op amp selection using the ST Op Amps App



Don't get lost in ST's op amp naming convention!





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Glossary

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

Quiescent current / Supply current (I_{CC}) – Supply current needed for each operational amplifier in the package for its operation.

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 (I_B) – Current flowing through an op amp's inputs. Due to op amp biasing requirements and normal operation leakage, a very small amount of current (pA or nA range, depending on the technology) is flowing through its inputs. This may cause problems when large value resistors or sources with higher output impedances are connected at the op amp inputs. This causes relevant voltage drops at the op amp input and therefore errors.

Gain bandwidth product (GPB) – Product of an op amp's gain and bandwidth. It is measured at 20 dB gain. Defined for small signals.

Slew rate (SR) – How fast an op amp can change voltage on its output. An op amp's output rate of change is limited to the slew rate value. It causes distortion if the signal to be amplified is too fast.

Rail-to-rail input – An op amp with a high rail input is able to deal with input signals up to Vcc+ while a low rail input is able to deal with signals down to Vcc-. Rail-to-rail input op amps can handle input signals from Vcc- to Vcc+.

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. Such noise comes from the thermal noise (white noise) or 1/f noise, also called flicker noise. For applications with high gain or bandwidth, a noise level may become considerable.

Capacitive load – Can cause an op amp to become an oscillator. The op amp output resistance in connection with a capacitive load results in an additional pole in the circuit transfer function. From the Bode, then 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 and also those happening over temperature and over the time. Thanks to their design, zero-drift op amps have their V_{IO} in the range of microvolts and similarly "nano-volt" per Celsius degree drift. Zero-drift op amps have virtually no 1/f noise and also their "aging" over the time is negligible.

Shut down – Op amp operation switch-off. Usually used to reduce the circuit standby current when 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/glass carry core.

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

For more information, visit us on www.st.com/opamps