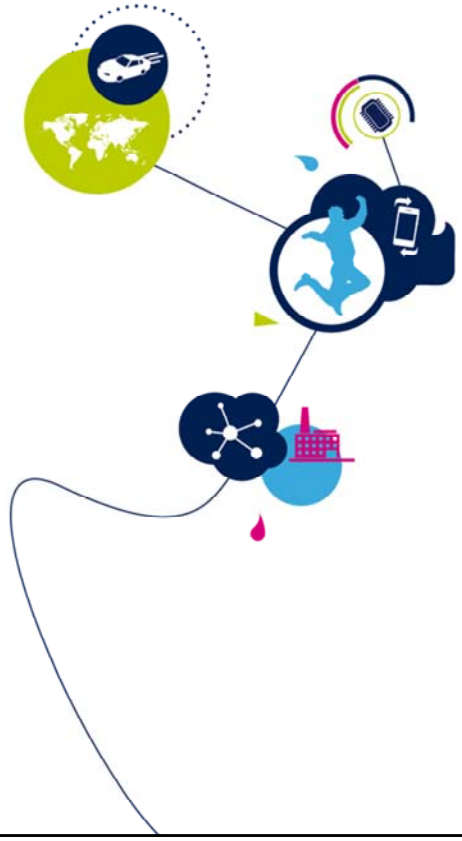
STM32G4 – OPAMP

Operational amplifier

Revision 1.0



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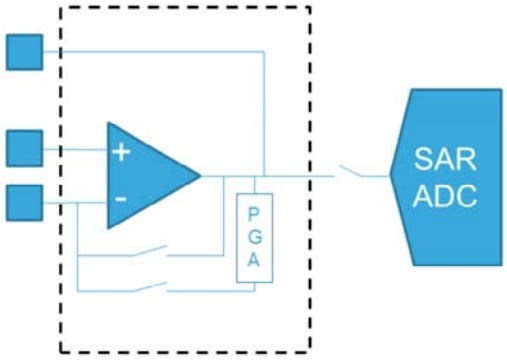
Hello, and welcome to this presentation of the STM32G4 embedded operational amplifier. It covers the features of this IP, which is widely used for conditioning analog signals.

Overview

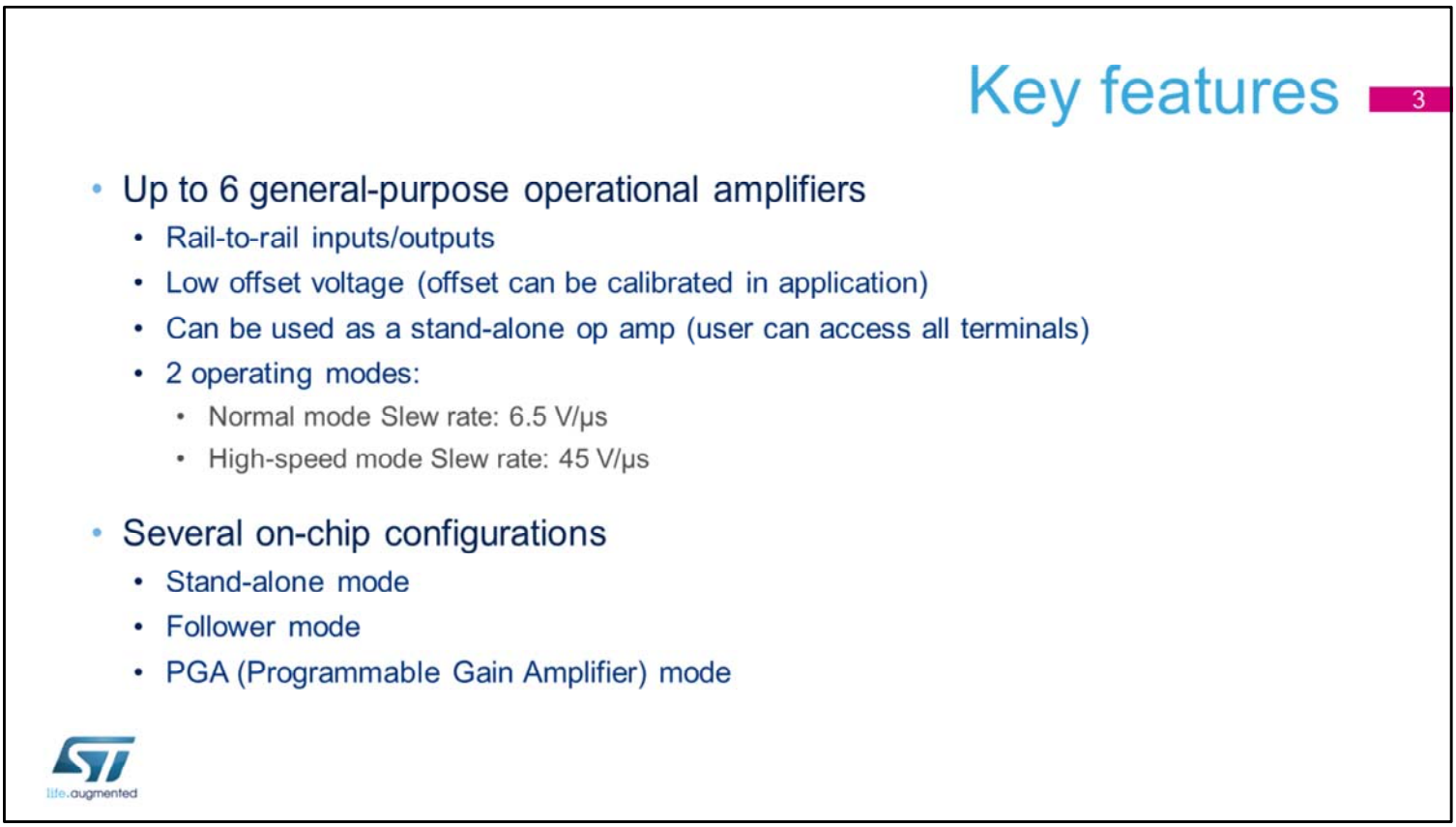
- Provides analog amplifier function for MCU applications
  - Up to 6 general-purpose operational amplifiers
  - Rail-to-rail input/output
  - Designer has access to all terminals



Application benefits

- Pre-amplifier for the ADC input
- May replace an external op amp

Up to four operational amplifiers inside STM32G4 products functions as a general-purpose analog amplifier, which may reduce the need for an external stand-alone op amp.
As these op amps can be configured in stand-alone mode with all terminals available for the user, it is possible to use them as a voltage follower, non-inverting and inverting amplifiers, as well as analog filters such as low- or high-pass filters. They can also act as a pre-amplifier for the ADC input.

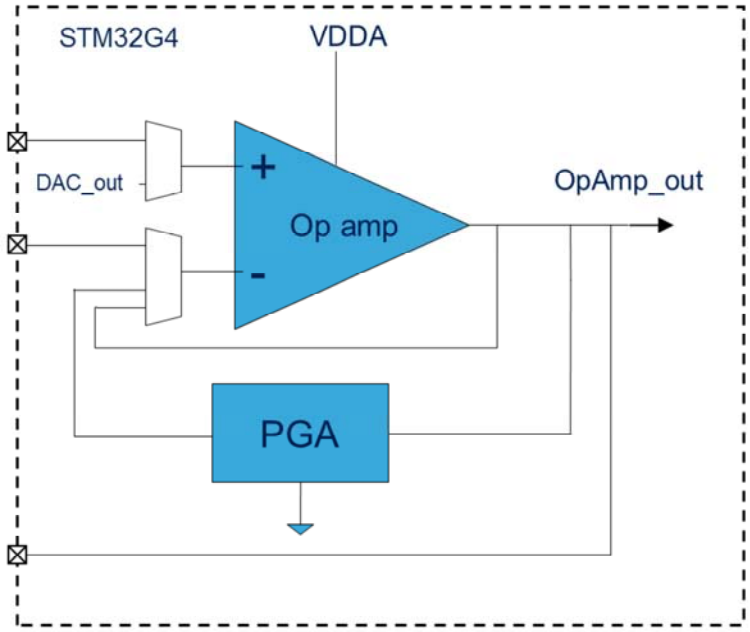


The operation amplifier inside STM32G4 products offers general-purpose rail-to-rail inputs and outputs. The input offset voltage can be calibrated in the application to achieve minimal offset. All the terminals are accessible by the user so that any operational amplifier function can be configured with external passive components.

When the op amps are used for the ADC input, the ADC's sample capacitor must be charged over a very short period. To support ADC input requirements, High-speed mode is available. The slew rate becomes 45 V/µs instead of 6.5 V/µs.

The op amps also provide on-chip functions including voltage follower mode, while their on-die feedback resistance can be used for the Programmable Gain Amplifier function.

Block diagram



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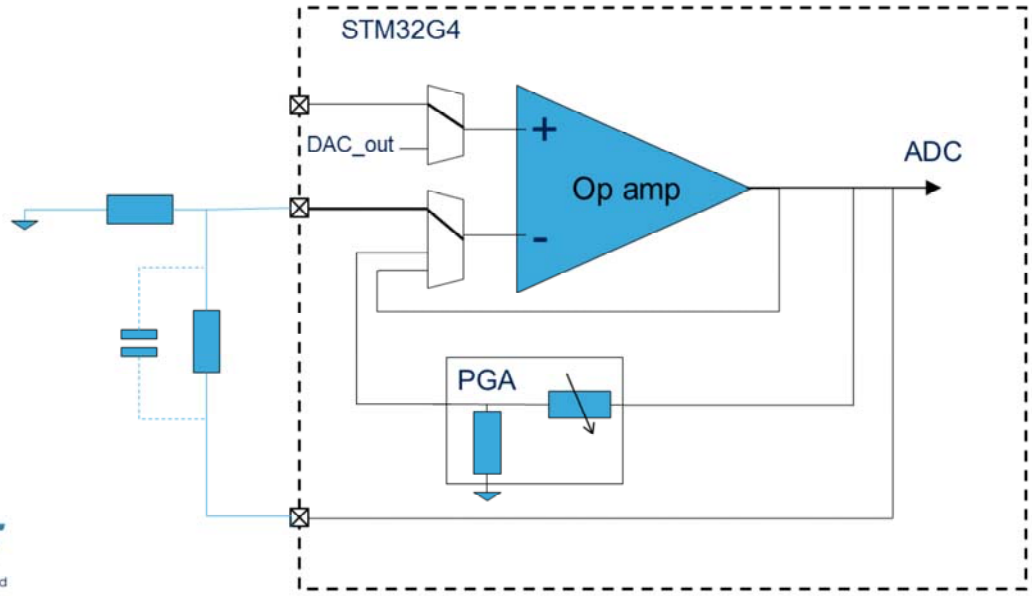
This slide shows the block diagram of the operational amplifiers. The STM32G4 integrates up to six operational amplifiers. Several switches are used to configure different functions. Each op amp can be configured individually.

Standalone mode, external gain setting

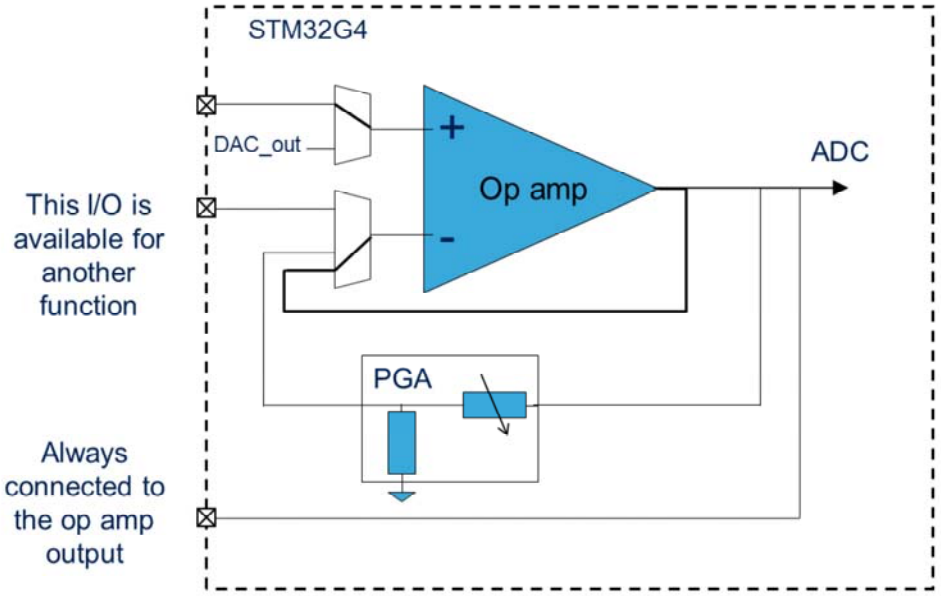
- Flexible configuration



The operational amplifiers support this default configuration using the factory trimming values and operate in normal.

Internal Follower mode

- **Flexible configuration**

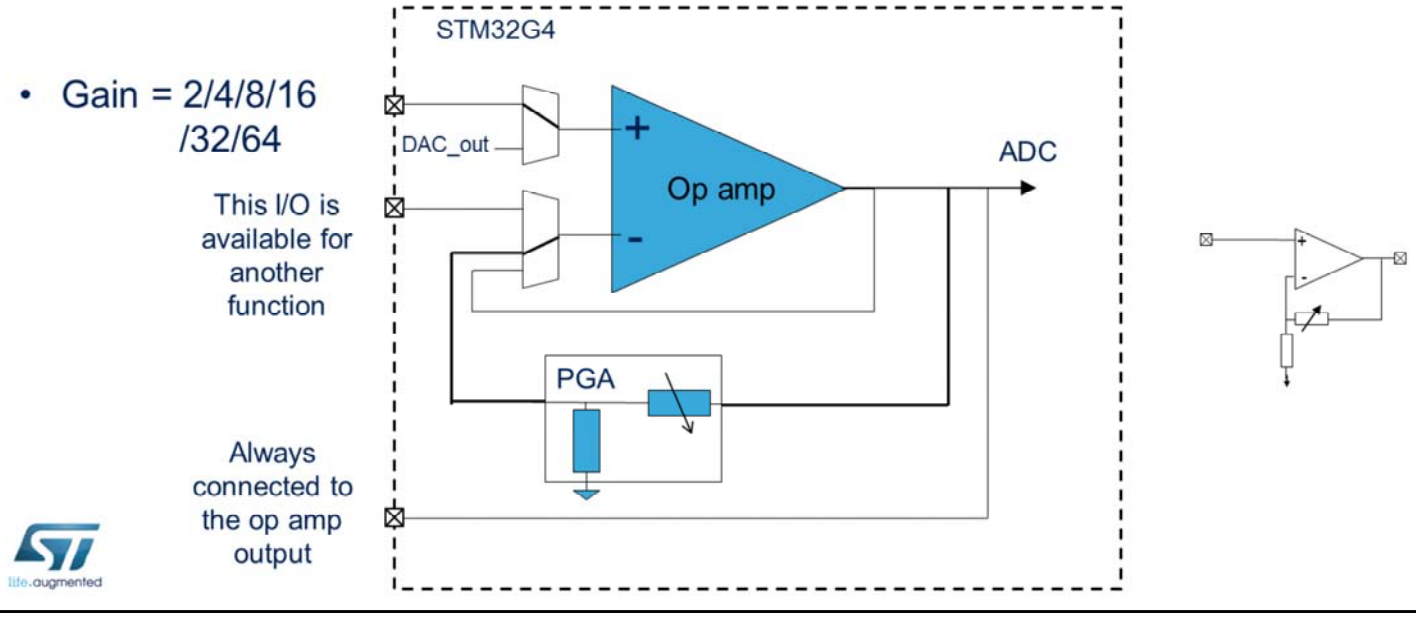


The operational amplifiers can be configured as an internal voltage follower, where the internal switch connects the output to the inverting input. In internal voltage follower mode, the GPIO pad assigned to the op amp's inverting input can be free, so that it may be used with a different functions as subsequently assigned in the GPIO selection process.

PGA mode, internal gain setting

- **Flexible configuration**

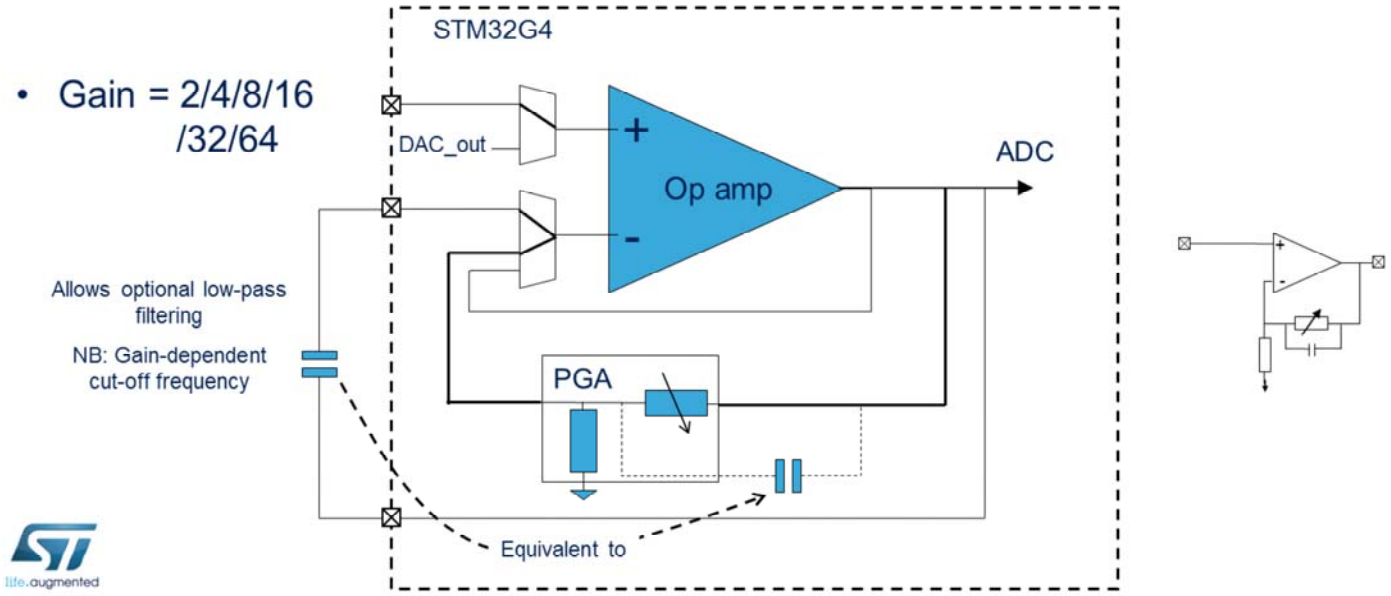
- Gain = 2/4/8/16 /32/64



The op amps support non-inverting amplifier mode with **six** fixed gains available. The feedback resistors can be selected to have gain of 2, 4, 8, 16, 32 or 64 to support the Programmable Gain Amplifier function. It may also be beneficial to use the op amp as an ADC input so that the full dynamic range of the analog-to-digital converter can be applied to signals having a small amplitude.

PGA mode, internal gain setting
with inverting input used for filtering

- **Flexible configuration**

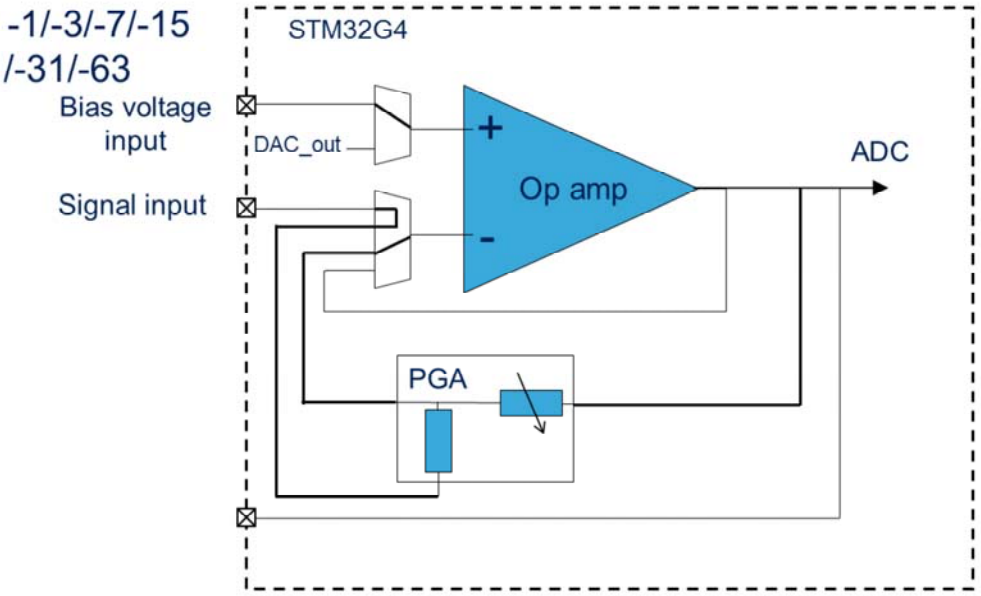


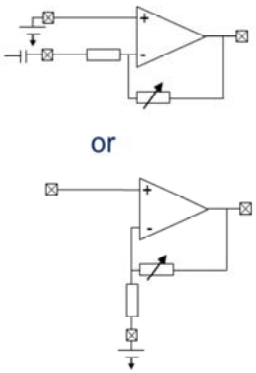
The op amps also support external connections on outputs and the inverting input for the PGA mode. It enables the connection of an external capacitor to add low-pass filter characteristics to the PGA configuration.

PGA mode, inverting configuration

- Flexible configuration

- Gain= -1/-3/-7/-15 /-31/-63



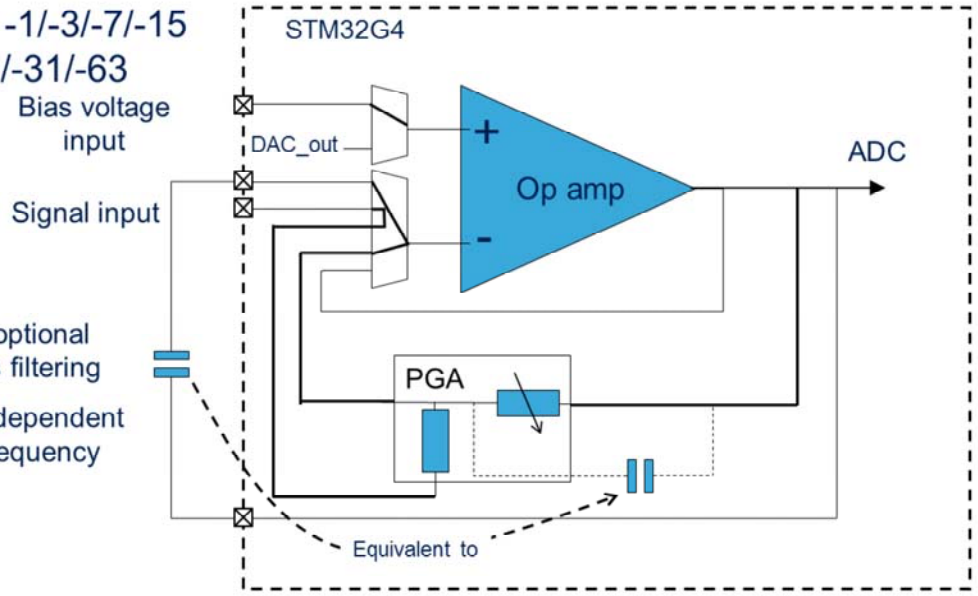


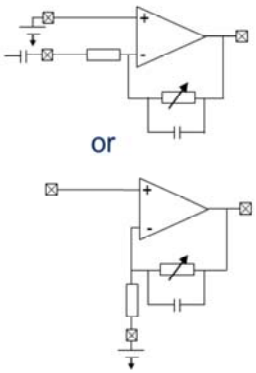
This STM32G4's op amps support inverting amplifier mode with six fixed gains available. The feedback resistors can be selected to have gain of -1, -3, -7, -15, -31 or -63 to support the Programmable Gain Amplifier function. By using this configuration, it is possible to shift the bias voltage of the input signal with AC coupling capacitor. It can also be used as a non-inverting amplifier with a gain of 2, 4, 8, 16, 32 or 64 with bias to a none ground voltage.

PGA mode, inverting configuration with inverting input used for filtering

- **Flexible configuration**

- Gain= -1/-3/-7/-15 /-31/-63

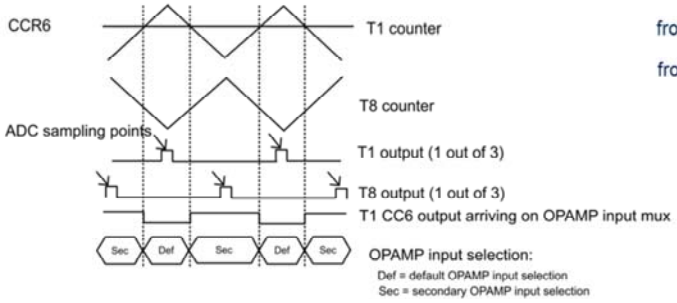


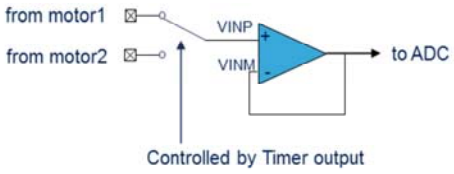


The op amps also support external connections on outputs and on the inverting input also for this PGA mode. It enables the connection of an external capacitor to add low-pass filter characteristics to the PGA configuration.

Timer controlled Multiplexer mode

- VINP/VINM signals selection can be done by hardware timer
  - When many signals need to be monitored by the OPAMP as an ADC input, it is possible to use a switch mechanism controlled by a timer to select the OPAMP input.
  - Useful for dual motor control.
    - Measure the current alternatively on the first motor and then second motor
    - Only one OPAMP can be used instead of two for power efficiency purpose
  - Example





The op amps inputs can be controlled by a timer output. For example when the current levels from two motors have to be measured alternatively, it is possible to use only one Op amp , instead of two, thanks to a switch mechanism triggered by a timer output. By this way, user can reduce the power consumption for the system and use the other Op amps for other purpose.

Low-power modes

Mode	Description
Run	Active.
Sleep	Active.
Low-power run / sleep	Active.
Stop 0 / Stop 1	Active.
Standby	Powered-down. The peripheral must be reinitialized after exiting Standby mode.

The operational amplifiers are active in the following low-power modes: Run, Sleep, Low-power run, Low-power sleep, Stop 0 and Stop 1 modes.
In Standby mode, the op amp is powered-down and must be reinitialized for use if returning to one of the higher powered modes.

Performance (preliminary values)

SYMBOL	Parameter	Condition	Typical value	Unit
VDDA	Analog voltage supply		2.0 ~ 3.6	V
CMIR	Common mode input range		0 ~VDDA	V
Vos	Offset voltage		1.5	mV
GBW	Normal mode		13	MHz
SlewRate	Normal mode	10~90% output range	6.5	V/µs
	High-speed mode		45	V/µs
Output Current			500	µA
PSRR			80	dB
WakeUp Time	Normal mode		6 (max)	µs
Idd	Current consumption		1.3	mA
G error	PGA gain error	Until gain 16	+/- 1	%

Note: All values are for V_{DDA} = 3.3 V, C_{LOAD} (max) = 50 pF

The following table shows performance parameters for the STM32G4's op amp. All values are preliminary. The op amp can work from 2.0 to 3.6 volts from the VDDA supply with rail-to-rail input and output. The offset voltage can be calibrated down to 1.5 mV. It has a gain bandwidth of 13 MHz. Thanks to its High speed mode, the ADC's sample capacitor can be driven very effectively.

Application examples

- Pre-amplifier for the ADC
- Dynamic range control (PGA) for input to the ADC
- Voltage follower for impedance changes
- DC bias voltage shift (signal conditioning)

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The STM32G4's op amps are suitable for the pre-amplification of the ADC input because the integrated PGA can enhance the dynamic range of the analog-to-digital converter. Its high slew rate can drive the sample capacitor of ADC very effectively. It is handy to use as an on-chip voltage follower instead of using an off-chip stand-alone op amp.

Related peripherals

- Refer to these trainings for the peripherals related to the STM32G4's operational amplifiers if needed:
  - Analog-to-digital converter (ADC)
  - Digital-to-analog converter (DAC)
  - General purpose input output (GPIO)
  - Timers (TIM)

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This is a list of peripherals related to the operational amplifiers. Please refer to these peripheral trainings for more information if needed.