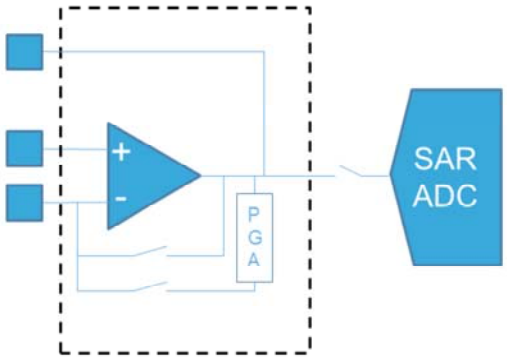
Hello, and welcome to this presentation of the STM32L4 embedded Operational Amplifier. It covers the features of this IP, which is widely used for conditioning analog signals.

Overview



- Provides analog amplifier function for MCU applications
  - general-purpose operational amplifiers
    - x2 on STM32L47x/48x/49x/4Ax devices
    - x1 on STM32L41x/42x/43x/44x/45x/46x devices
  - 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

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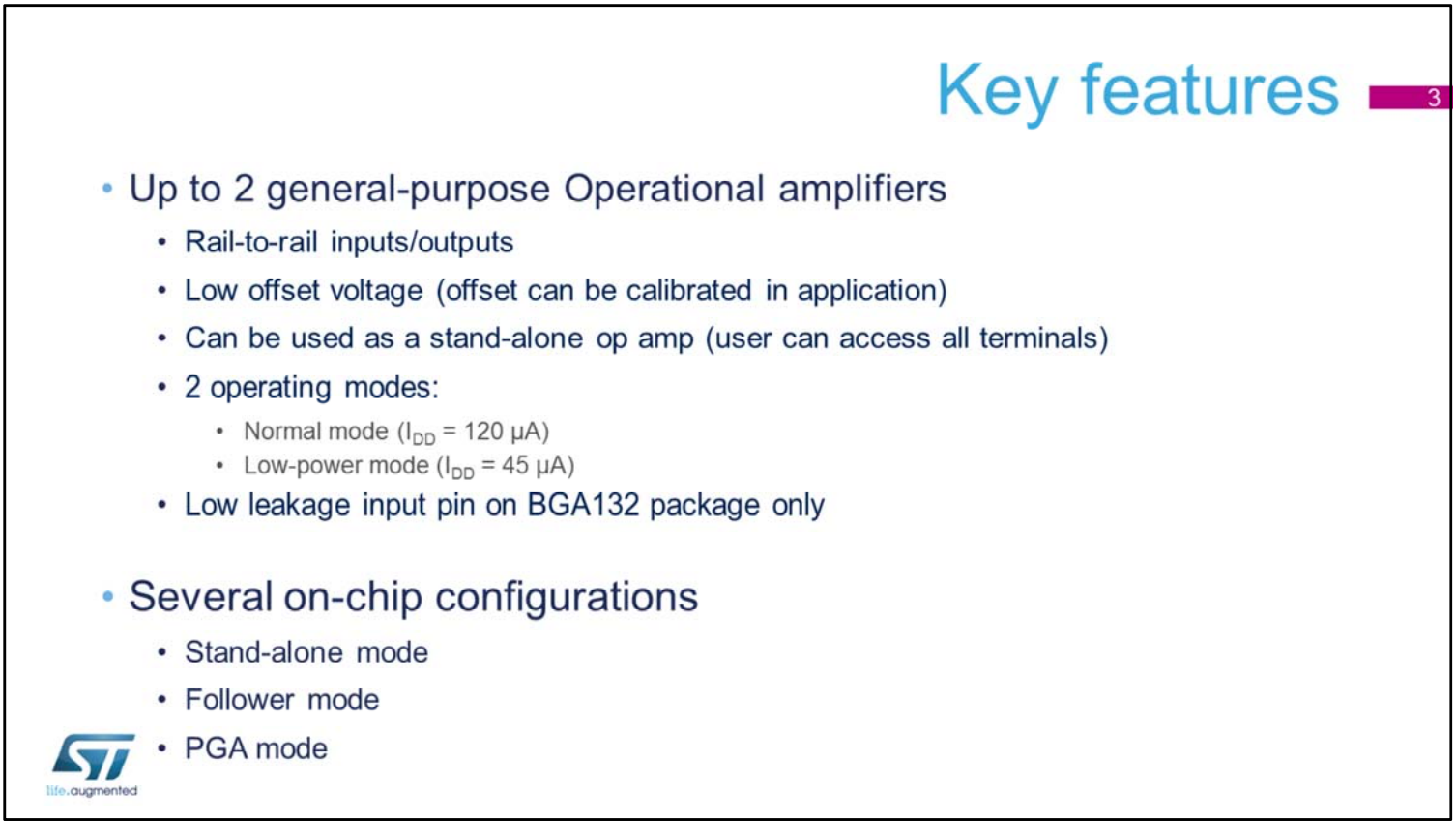
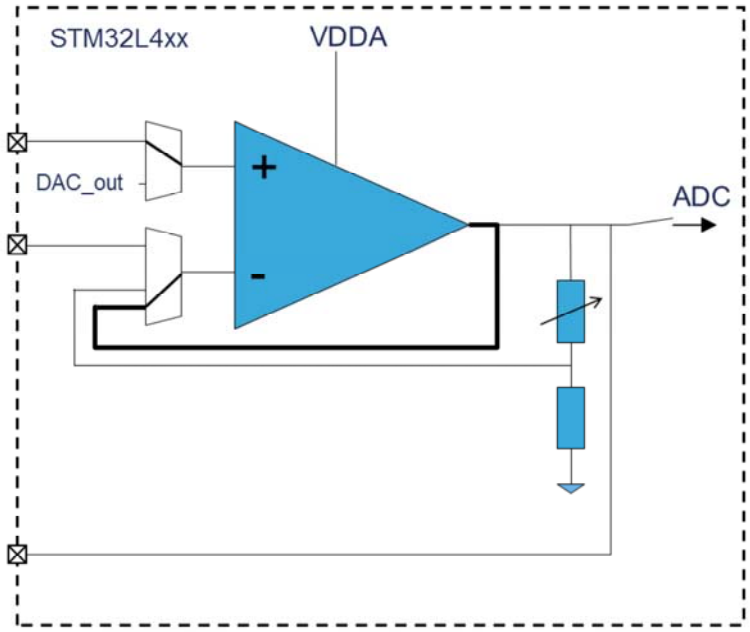
Each operational amplifier inside STM32L4 products functions as a general-purpose analog amplifier, which may reduce the need for an external stand-alone op amp.
As these op amps can be configured in stand-alone mode with all terminals available for the user, it is possible to use them as a voltage follower, 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 STM32L4 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. For low-power applications which do not need high bandwidth, a low-power mode is available which only consumes 45 micro amps from VDDA. For current sense applications, a dedicated low-leakage input pad is available on the BGA 132 package.
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

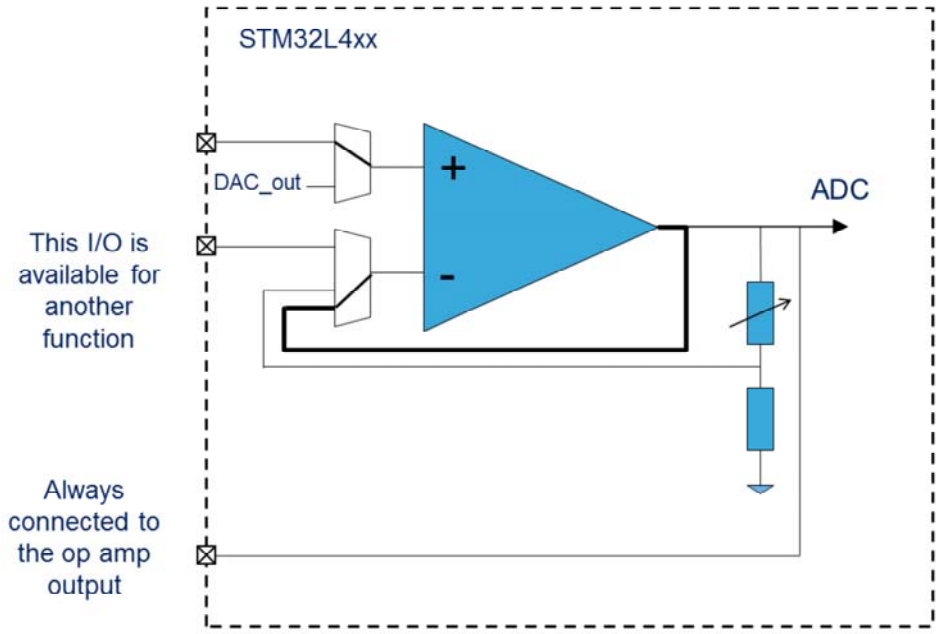


Up to x2

This slide shows the block diagram of the operational amplifiers. The STM32L4 integrates up to two Operational Amplifiers. Several switches are used to configure different functions. Each op amp can be configured differently.

Internal follower mode

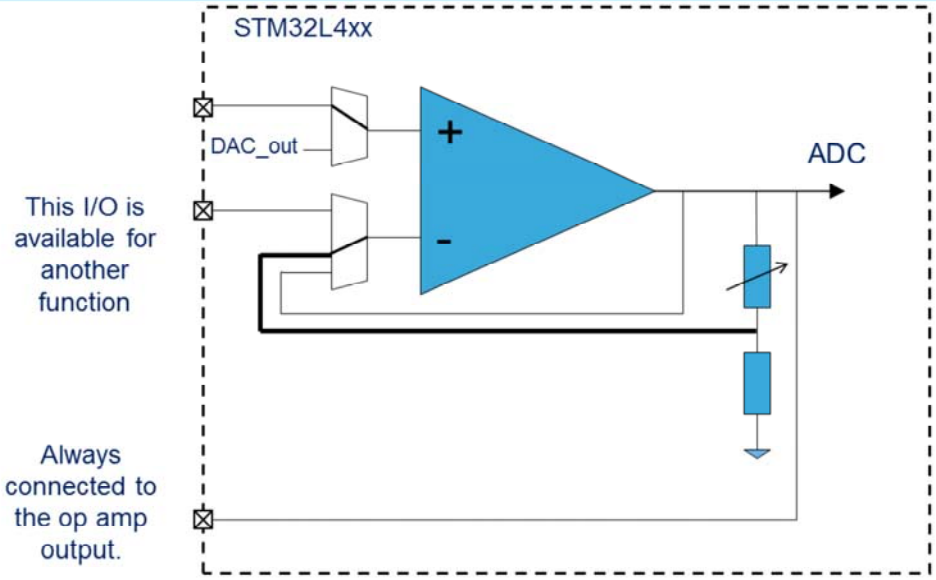
- Flexible configuration



The Operational Amplifier 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 is free, so that it may be used with a different functions as subsequently assigned in the GPIO selection process.

PGA Mode, Internal Gain setting (Gain= 2/4/8/16)

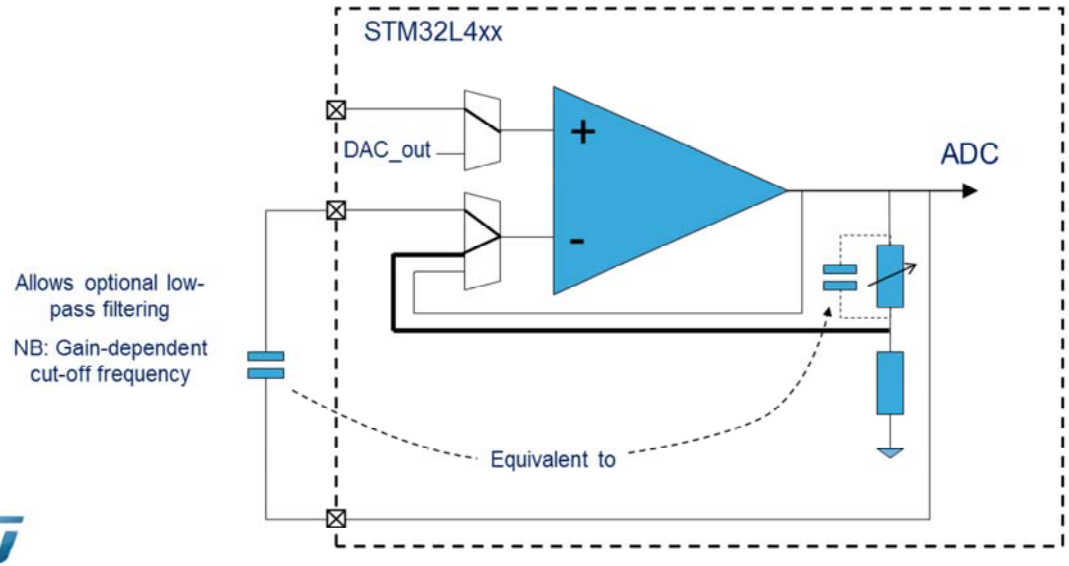
- Flexible configuration



This STM32L4's op amps support non-inverting amplifier mode with four fixed gains available. The feedback resistors can be selected to have gain of 2, 4, 8 or 16 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
(gain = 2/4/8/16) with inverting input used for filtering

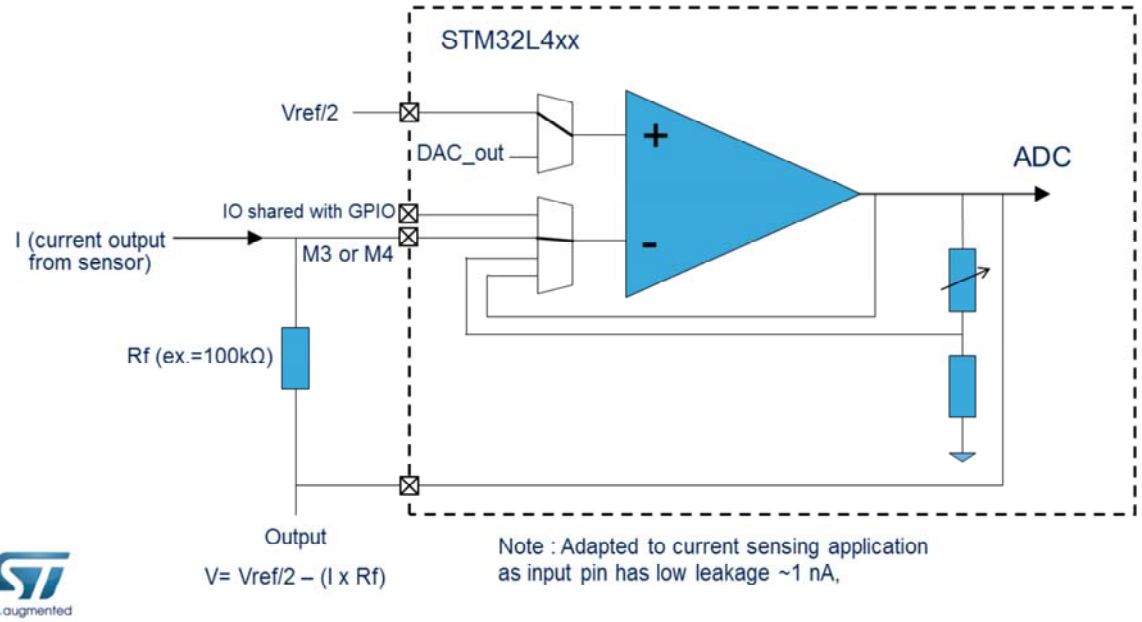
- **Flexible configuration**



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

Transimpedance amplifier

- BGA132 and BGA169 packages only



The op amps have a very low leakage inverting input pin to support the current sensing application. The dedicated pads are only available on the BGA132 and BGA169 packages and have 1 nA leakage which allows for a current to voltage conversion with high precision.

Low-power modes

Mode	Description
Run	Active.
Sleep	Active.
Low-power run	Active.
Low-power sleep	Active.
Stop 0/Stop 1	Active.
Stop 2	Not available. Peripheral registers' content is kept.
Standby	Powered-down. The peripheral must be reinitialized after exiting Standby mode.
Shutdown	Powered-down. The peripheral must be reinitialized after exiting Shutdown mode.

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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 Stop2 mode, the op amp is not available, but its registers' content is kept. In Standby or Shutdown modes, the op amp is powered-down and must be reinitialized for use if returning to one of the higher powered modes.

Performance

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SYMBOL	Parameter	Condition	Typical value	Unit
VDDA	Analog voltage supply		1.8 ~ 3.6	V
CMIR	Common mode input range		0 ~VDDA	V
Vos	Offset voltage		1.5	mV
GBW	Normal mode		1.6	MHz
	Low power mode		0.42	MHz
SlewRate	Normal mode	10~90% output range	0.7	V/us
	Low power mode		0.18	V/us
Output Current	Normal mode		500	uA
	Low power mode		100	uA
PSRR	Normal mode		85	dB
	Low power mode		90	dB
WakeUp Time	Normal mode		10 (max)	us
	Low power mode		30 (max)	us

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Note: All values are for V_{DDA} = 3.0 V, C_{LOAD} (max) = 50 pF

The following table shows performance parameters for the STM32L4's op amp. The op amp can work from 1.8 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 normal and low-power operating modes. Normal mode can have a gain bandwidth of 1.6 MHz while low-power mode only has 0.42 MHz of gain bandwidth, but comes with the added benefit of reducing power consumption. Thanks to its fast wake-up time of 10 to 30 micro seconds, it is not needed to keep it always enable but only when the functionality is necessary.

Application examples

- Pre-amplifier for the ADC
- Dynamic range control (PGA) for input to the ADC
- Voltage follower for impedance changes
- Current-to-voltage converter

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The STM32L4'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. It is handy to use as an on-chip voltage follower instead of using an off-chip stand-alone op amp. Its low bias current allows it to properly perform as a current-to-voltage converter for the current sensing function.

Related peripherals

- Refer to these trainings for the peripherals related to the STM32L4's operational amplifiers if needed:
  - ADC
  - DAC
  - GPIO

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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.