ADC121S625,DAC101S101,LPV511,LPV531

A Voltage-Controlled Filter

Literature Number: SNOA830

ANALOG edge[SM]
Expert tips, tricks, and techniques for analog designs
Vol. IV, Issue 6

DESIGN | idea

A Voltage-Controlled Filter

By Walter Bacharowski, Applications Engineer

In the area of sound and music synthesis, voltage-controlled filters are used to shape the envelope of the sound being generated. A web search on the term "voltage controlled filter" will locate many commercially available products for use with music synthesizers and sound effects generators. Most of what is available is not suitable for embedded systems because of the cost and number of components used. An alternative to these types of circuits is an amplifier which has the feature that its supply current is continuously variable over a range of 1 µA to 400 µA. One of the side effects of this is that the gain bandwidth of the amplifier is a function of the supply current. The graph in ***Figure 1*** shows the effect of supply current on the gain bandwidth and phase margin, using the LPV531 as an example.

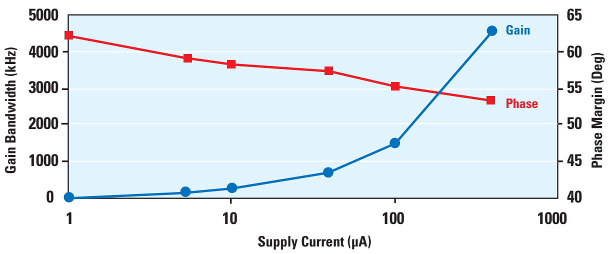


Figure 1. LPV531 Gain Bandwidth vs Supply Current

Controlling the Supply Current

The total supply current is dynamically controlled by the current flowing out of its I_{SEL} control pin (***Figure 4***). The supply current is 40 times higher than the I_{SEL} current. An internal 110 mV reference voltage, that is referred to the negative supply voltage, and an 11 kΩ internal resistor, determine the maximum current that can flow from the I_{SEL} pin when the I_{SEL} is connected to the negative supply voltage. Inserting additional resistance between the I_{SEL} pin and the negative supply voltage will reduce the current from the I_{SEL} pin.

The supply current can be calculated, approximately, by the following equation:

$$I_S = 1\,\mu A + 40\left[\frac{110\,mV}{R_{EXT} + 11\,k\Omega}\right]$$

Equation 1

The graph in ***Figure 2*** shows the relationship between R_{EXT} and I_{SEL} while ***Figure 3*** shows the relationship between the I_{SEL} current and the amplifier's supply current.

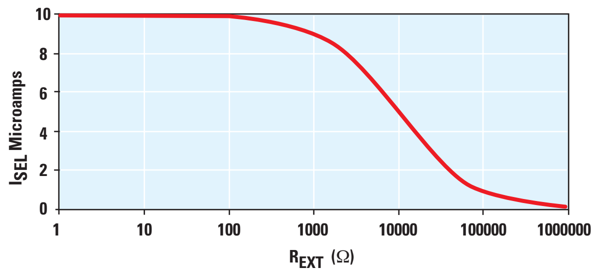


Figure 2. I_{SEL} vs R_{EXT}

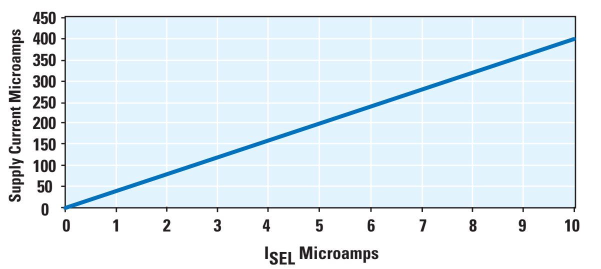


Figure 3. Supply Current vs I_{SEL}

To implement a voltage controlled filter, the I_{SEL} current must be made dependent on voltage rather then a resistor.

NEXT ISSUE:
Designing with Sync Separators

Featured Products

Programmable CMOS Input, Rail-to-Rail Output Micropower Op Amp

The LPV531 micropower op amp has adjustable gain-bandwidth control and a power-level adjust feature controlled with only one external resistor. The performance of the LPV531 alternates from standby to full-power mode by varying the bias voltage on this same external resistor. This op amp is capable of operating from 73 kHz, consuming only 5 µA, to as fast as 4.6 MHz, consuming only 425 µA.

The input offset voltage is relatively independent and therefore is not affected by the chosen power level. Using a CMOS input stage, the LPV531 achieves an input bias current of 50 fA and a common mode input voltage which extends from the negative rail to within 1.2V of the positive supply. The LPV531's rail-to-rail class AB output stage enables this op amp to offer maximum dynamic range at low supply voltage.

Features

- 2.7V to 5.5V Supply voltage
- 5 µA to 425 µA Continuously programmable supply current
- Input common mode voltage range: -0.3V to 3.8V
- CMRR of 95 dB
- Rail-to-rail output voltage swing
- 1 mV input offset voltage
- 73 kHz to 4.6 MHz Continuously programmable gain bandwidth product

Available in the space saving SOT23-6 package, the LPV531 is ideal for use in handheld electronics and portable applications. A fixed supply current/gain bandwidth is available upon request. The LPV531 is manufactured using National's award-winning VIP50 process.

For FREE samples, datasheets, and more, visit
www.national.com/pf/LP/LPV531.html

10-Bit Micropower D/A Converter with Rail-to-Rail Output

The DAC101S101 is a full-featured, general purpose 10-bit voltage-output Digital-to-Analog Converter (DAC). It can operate from a single 2.7V to 5.5V supply and consumes just 175 µA of current at 3.6V. The on-chip output amplifier allows rail-to-rail output swing and the three wire serial interface operates at clock rates up to 30 MHz over the specified supply voltage range. The DAC101S101 is compatible with standard SPI™, QSPI, MICROWIRE, and DSP interfaces. Competitive devices are limited to 20 MHz clock rates at supply voltages in the 2.7V to 3.6V range.

Features

- DNL of +0.15, -0.05 LSB
- Output settling time: 8 µs
- Zero code error: 3.3 mV
- Full-scale error: -0.06% FS
- Guaranteed monotonicity
- Low-power operation
- Power-on reset to zero volts output
- SYNC Interrupt facility
- Power down feature

Operating over the extended industrial temperature range of -40°C to +105°C, the DAC101S101 is available in TSOT-6 and MSOP-8 packaging. The low-power consumption and small packaging of the DAC101S101 make it well suited for use in battery-powered instruments, digital gain and offset adjustment, programmable voltage and current sources, and programmable attenuators.

For FREE samples, datasheets, and more, visit
www.national.com/pf/DC/DAC101S101.html

A Voltage Controlled Filter

Figure 4 shows a technique using a voltage source and a resistive divider to control the I_{SEL} current. In this application, the output voltage from a 10-bit Digital-to-Analog Converter (DAC), such as the DAC101S101, is applied to the I_{SEL} pin through a resistive divider made up of R_{SET1} and R_{SET2}. The resistive divider ratio is sized to apply approximately 0.0 to 0.11V to the I_{SEL} pin from the 0 to 5V output of the DAC. The -3 dB frequency now controlled by the voltage that is applied to the I_{SEL} pin.

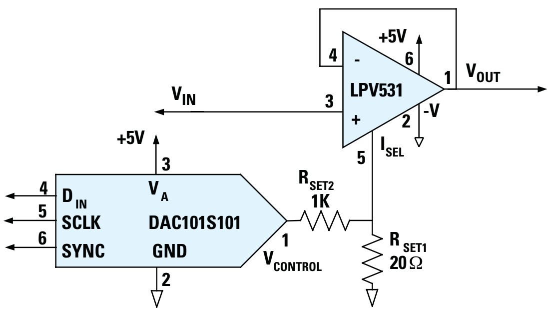


Figure 4. Voltage-Controlled Filter

When the control voltage is near 0V, the I_{SEL} current is determined by the parallel combination of the two resistors R_{SET1} and R_{SET2}. When the control voltage is greater then zero, the Thevenin Equivalent voltage and resistance at the I_{SEL} pin will determine the I_{SEL} current. The following equation can be used to calculate the amplifier's supply current:

$$I_S = 1\,\mu A + 40 \left[\frac{110\,mV - V_{THEVENIN}}{R_{THEVENIN} + 11\,k\Omega} \right]$$

Equation 2

Where: $R_{THEVENIN} = \dfrac{R_{SET1} \bullet R_{SET2}}{R_{SET1} + R_{SET2}}$

and $V_{THEVENIN} = \dfrac{V_{CONTROL} \bullet R_{SET1}}{R_{SET1} + R_{SET2}}$

The selection of R_{SET1} and R_{SET2} can be simplified by assuming that the value of R_{SET1} will be much smaller than the value of R_{SET2}. In this case, when the control voltage is 0V, resistor R_{SET1} dominates the maximum value of the I_{SEL} current. Additionally, the current from the I_{SEL} is small, less then 10 µA, compared to the current flowing from the voltage source. The value of R_{SET2}, given R_{SET1} and the maximum control voltage, can be calculated from *Equation 3*.

$$R_{SET2} = \frac{R_{SET1}\,(V_{CONTROL\_MAX} - 110\,mV)}{110\,mV}$$

Equation 3

Figure 4 shows the LPV531 being used as a unity gain buffer. In this type of application, the amplifier can also be connected as an inverting or noninverting amplifier with gain suitable for the input and output signal levels.

Figures 5 and 6 are open-loop gain phase plots for a control voltage of 0.5V and 3.0V, respectively.

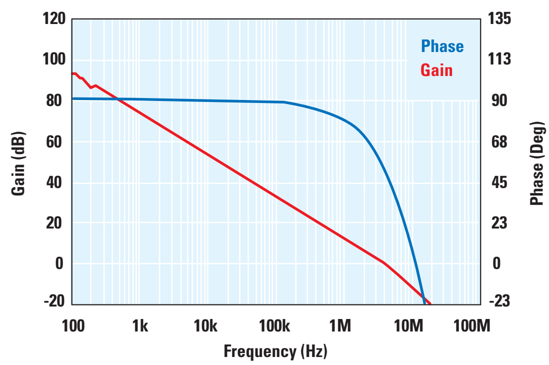


Figure 5. Open-Loop Gain Phase at 0.5V

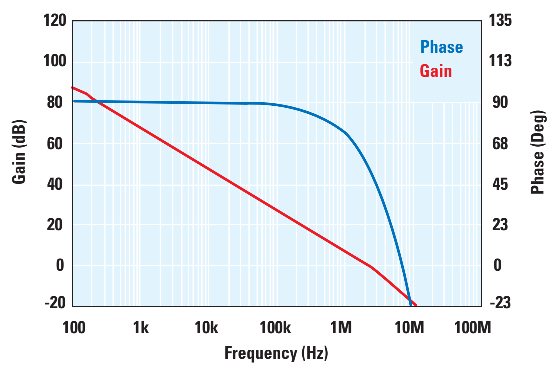
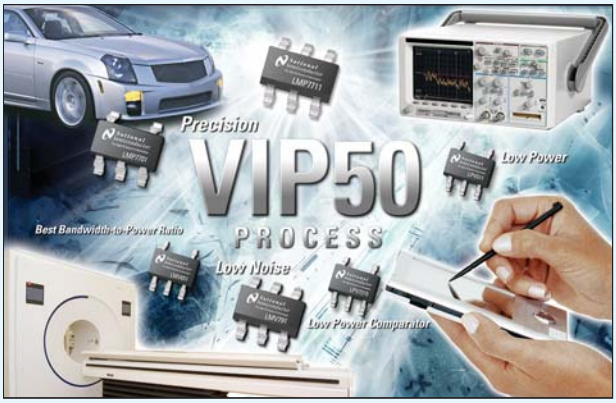


Figure 6. Open-Loop Gain Phase at 3V

This article has shown how to use a control voltage to control the supply current of a programmable CMOS input, rail-to-rail output micropower operational amplifier to implement a voltage-controlled filter. ■

Featured Products



880 nA, Rail-to-Rail Input / Output, Micropower Op Amp

The LPV511 is a micropower op amp that operates from a voltage supply range as wide as 2.7V to 12V. This device exhibits an excellent speed-to-power ratio, drawing only 880 nA of supply current with a unity gain bandwidth of 27 kHz. The input range includes both supply rails for ground and high-side battery sensing applications.

The LPV511 output swings within 100 mV of either rail to maximize the signal's dynamic range in low-supply applications. The output is capable of sourcing 650 uA of current when powered by a 12V battery. The high PSRR of 84 dB ensures higher accuracy in battery-powered applications.

Features

- Supply voltage range of 2.7 to 12V
- Slew rate of 7.7 V/µs
- 880 nA Supply current
- 1.35 mA Output short circuit current
- Output voltage swing of 100 mV from rails
- 27 kHz Bandwidth

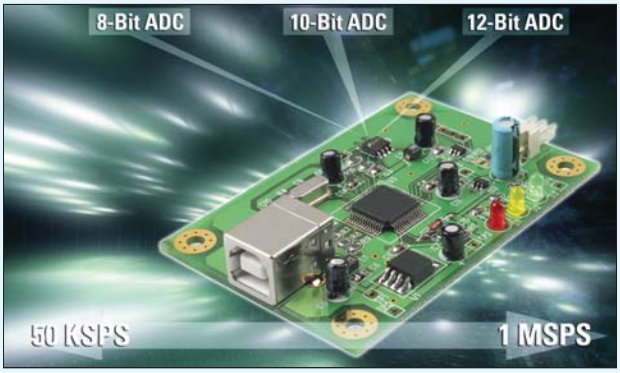
Available in a space-saving SC70-5 package, the LPV511 is ideal for battery-powered systems that require long life through low supply current, such as instrumentation, sensor conditioning, and battery current monitoring. The LPV511 is built on National's award winning VIP50 process.

For FREE samples, datasheets, and more, visit
www.national.com/pf/LP/LPV511.html

12-Bit, 50 kSPS to 200 kSPS, Differential Input, Micropower Sampling A/D Converter

The ADC121S625 features a fully differential, high impedance analog input and an external reference. While best performance is achieved with a reference voltage between 500 mV and 2.5V, the reference voltage can be varied from 100 mV to 2.5V, with a corresponding resolution between 49 µV and 1.22 mV.

The differential input, low power, automatic power down, and small size make the ADC121S625 ideal for direct connection to transducers in battery operated systems or remote data acquisition applications. Operating from a single 5V supply, the normal power consumption is reduced to a few nW in the power-down mode.



Features (typical unless otherwise noted)

- Conversion Rate: 50 to 200 kSPS
- Offset Error: 0.4 LSB
- Gain Error: 0.05 LSB
- INL ± 1 LSB (max)
- DNL ± 0.75 LSB (max)
- CMRR: 82 dB
- Power Consumption
  - Active, 200 kSPS 2.25 mW
  - Active, 50 kSPS 1.33 mW
  - Power Down 60 nW

Operation is guaranteed over the industrial temperature range of -40°C to + 85°C and clock rates of 800 kHz to 3.2 MHz. Available in the MSOP-8 package, the ADC121S625 is ideal for automotive navigation, portable systems, medical instruments, instrumentation and control systems, motor control, and direct sensor interface.

For FREE samples, datasheets, and more, visit
www.national.com/pf/DC/ADC121S625.html

National Semiconductor
The Sight & Sound of Information

570102-034