ADC121S101,ADC121S625,DAC081S101, DAC082S085,DAC084S085,DAC101S101, DAC102S085,DAC104S085,DAC121S101, DAC122S085,DAC124S085,LM4866,LM4875, LMP7701,LMP7702,LMP7704

Optimizing Portable Applications with D/A Converters

Literature Number: SNAA108

ANALOG edge℠
Expert tips, tricks, and techniques for analog designs
Vol. IV, Issue 9
DESIGN idea

Optimizing Portable Applications with D/A Converters

By Chuck Sins, Applications Engineer

Designers of portable electronic devices have several methods available for using general-purpose Digital-to-Analog Converters (DACs) to digitally adjust voltages and enhance the performance of portable devices.

DACs are most easily understood by examining a simplified DAC block diagram. As shown in *Figure 1*, the architecture of a one-channel DAC consists of a resistor array (each of equal value R) followed by a rail-to-rail voltage output amplifier. The voltage applied to the reference pin is the voltage at the top of the resistor array and a switch is connected between each pair of resistors and one to ground. The voltage is tapped off by closing one of the switches and connecting this point on the array to the amplifier. The resistor array and output amplifier consume very little power and emit no switching noise since the DAC is static once the specified resistor tap has been connected to the amplifier. In addition, multi-channel DACs packaged in a 3 mm by 3 mm Leadless Leadframe Package (LLP®) occupy very little board space in portable applications. An alternative to using a DAC is a resistive trim potentiometer. However, these devices are large in size, suffer from mechanical wear, and are not digitally controllable.

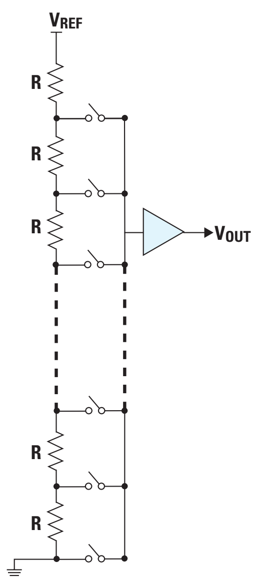


Figure 1. 1-Channel DAC Architecture

Over the last couple of years, the audio capability and LCD display quality of cell phones have improved tremendously, while the size and cost of the phones have gone down. Most phones today have a headphone jack, an earpiece, and a built in loudspeaker. All three of these audio outputs require some type of volume control. One way a DAC can provide volume control is when it is used in conjunction with an audio amplifier that has a built-in DC volume control. A micro-controller that receives input from soft keys on the display or push buttons on the case causes the DAC's output voltage to step up or down (*Figure 2*). Another way to control volume is to use a DAC as a single quadrant multiplier. This configuration consists of an amplifier gain stage that feeds the amplified audio input into the reference pin of the DAC (*Figure 3*). The Serial Peripheral Interface (SPI) of the DAC is used to digitally attenuate the amplified audio input anywhere from full scale (0 dB) to zero volts. This is accomplished without adding any noticeable level of noise or distortion to the audio signal.

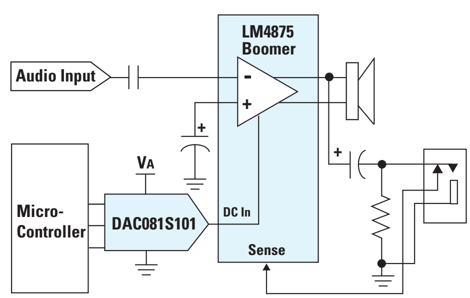


Figure 2. DC-Control of an Audio Amplifier

NEXT ISSUE:
Closed-Loop Bandwidth Accuracy

National Semiconductor
The Sight & Sound of Information

Featured Products

1-Channel, Pin- and Function-Compatible DACs Across Resolutions

The 1-channel, pin- and function-compatible 8-, 10-, and 12-bit DACs each provide rail-to-rail output swing and input clock rates of 30 MHz over the entire supply range of 2.7V to 5.25V. The reference for each is derived from the power supply, resulting in the widest possible dynamic output range. A power-down feature reduces power consumption to less than 0.2 µW, which is especially important for portable, battery-powered applications.

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 and is compatible with standard SPI™, QSPI, MICROWIRE, and DSP interfaces. The supply voltage serves as its voltage reference, providing the widest possible output dynamic range.

Features

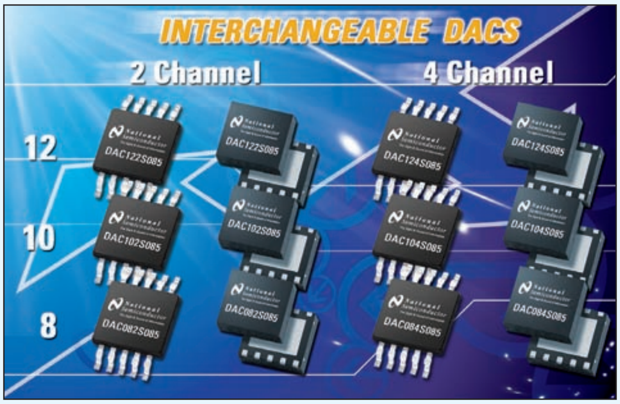
- Settling time: 10 µs
- Guaranteed monotonicity
- Low-power operation
- Rail-to-rail voltage output
- Power-on reset to zero volts output
- SYNC interrupt facility
- Wide power supply range: 2.7V to 5.5V
- Power down feature

Operating over the extended industrial temperature range of -40°C to +105°C, these DACs are ideal for battery-power instruments, digital gain and offset adjustment, programmable voltage and current sources, and programmable attenuators. The DAC121S101, DAC101S101, and DAC081S101 are available in TSOT-6 and MSOP-8 packaging.

For FREE samples, datasheets, and more, visit
www.national.com/pf/DA/DAC121S101.html
www.national.com/pf/DA/DAC101S101.html
www.national.com/pf/DA/DAC081S101.html

Ultra Low-Power, 2-Channel, 8-/10-/12-Bit DACs

These general purpose DACs are full-featured and can operate from a single 2.7V to 5.5V supply and use 210 µA at 3V and 320 µA at 5V. The on-chip output amplifier allows rail-to-rail output swing and the three-wire serial interface operates at clock rates up to 40 MHz over the entire supply voltage range.



Features

- INL (max)
  - ±0.5 LSB (DAC082S085)
  - ±2 LSB (DAC102S085)
  - ±8 LSB (DAC122S085)
- DNL (max)
  - +0.18 / -0.13 LSB (DAC082S085)
  - +0.35 / -0.25 LSB (DAC102S085)
  - +0.7 / -0.5 LSB (DAC122S085)
- Settling time (max)
  - 4.5 µs (DAC082S085)
  - 6 µs (DAC102S085)
  - 8.5 µs (DAC122S085)
- Zero code error: +15 mV (max)
- Full-scale error: -0/75% FS (max)
- Wide power supply range: 2.7V to 5.5V

The 2-channel, 8-/10-/12-bit DACs are ideal for use in battery-powered instruments, digital gain and offset adjustments, programmable voltage and current sources, and programmable attenuators. The DAC082S085, DAC102S085, and DAC122S085 are available in MSOP-10 and LLP-10 packaging.

For FREE samples, datasheets, and more, visit
www.national.com/pf/DA/DAC082S085.html
www.national.com/pf/DA/DAC102S085.html
www.national.com/pf/DA/DAC122S085.html

Optimizing Portable Applications with DACs

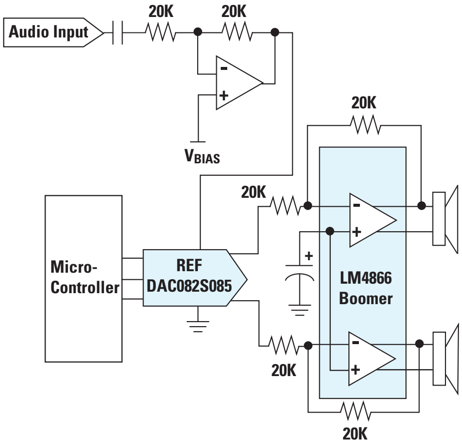


Figure 3. Single Quadrant Multiplying DAC

Many microprocessors can operate at a lower supply voltage to save power, and then operate at a higher supply voltage to increase their processing speed. Switching between these modes requires adjusting the output voltage of a DC-to-DC converter. Similar to microprocessors, LCD displays utilize DACs to control their contrast ratio. As the temperature of the display changes, the voltage applied to the display by the DC-to-DC converter must be adjusted to maintain the proper contrast ratio (***Figure 4***). Since neither of these applications require high speed adjustments, general purpose DACs are the ideal solution for digitally optimizing their performance.

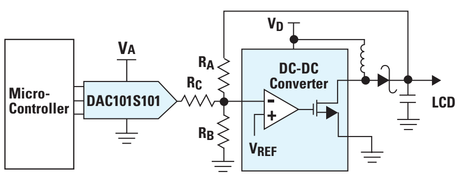


Figure 4. DAC Controlling a DC-DC Converter

Portable devices that utilize sensors can also be enhanced with the use of general purpose DACs. ***Figure 5*** illustrates a pressure sensor that is amplified and then monitored by a general purpose Analog-to-Digital Converter (ADC). Since the output of the amplifier stage has a large voltage range, the ADC requires a reference voltage equal or greater to the largest possible output voltage. While this is fine for measuring the sensor's output when it is at its maximum voltage, it is less than ideal for measuring the sensor's minimum output voltage. If a DAC was utilized as the reference voltage, the DAC could be digitally adjusted based on the input to the ADC. This technique maximizes the accuracy of the ADC and allows the full range of codes to be utilized. The alternative solution is to use a more expensive ADC with a higher resolution in order to improve the system's accuracy. As a result, using a DAC in the circuit reduces the overall system cost while still providing the required accuracy.

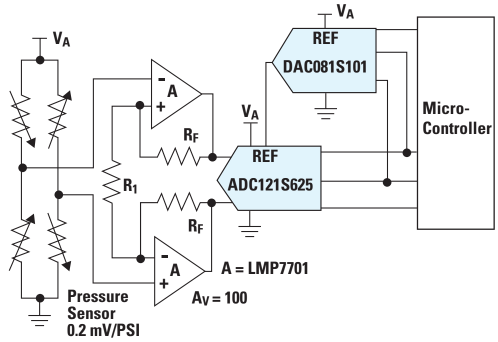


Figure 5. Pressure Sensor Monitoring by an ADC

A similar application with a DAC enhancing system performance is a system that requires calibration for higher conversion accuracy. For example, a humidity sensor can be calibrated to a known ADC output code with the circuit in ***Figure 6***. The sensor's output is applied to the negative input of the op-amp while a DAC output is connected to the positive terminal. The desired output code of the ADC can be achieved by digitally adjusting the DAC output voltage to the appropriate level. Higher resolution DACs deliver higher precision in the output reading.

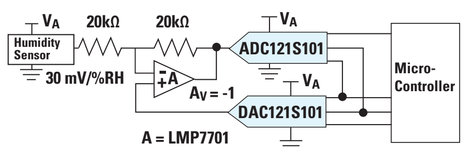


Figure 6. Humidity Sensor Application

In all of these examples, general purpose DACs optimized a product's performance by digitally adjusting a voltage in the circuit without impacting the product's size, cost, or power consumption. ■

Featured Products

Precision, CMOS Input, RRIO Amps

The LMP7701/02/04 are single, dual, and quad low offset voltage, rail-to-rail input and output precision amplifiers with CMOS input stage and wide supply voltage range. The rail-to-rail input stage significantly reduces the CMRR glitch commonly associated with rail-to-rail input amplifiers.

Features

- Input offset voltage (max)
  - ±200 µV (LMP7701)
  - ±220 µV (LMP7702/04)
- Input bias current: ±200 fA
- Input voltage noise: 9 nV/$\sqrt{\text{Hz}}$
- 130 dB CMRR
- 130 dB open loop gain
- 2.5 MHz unity gain bandwidth
- Supply current
  - 715 µA (LMP7701)
  - 1.5 mA (LMP7702)
  - 2.9 mA (LMP7704)
- Supply voltage range: 2.7V to 12V

The LMP7701/02/04 are ideal for high impedance sensor interfaces, battery-powered instrumentation, high gain amplifiers, DAC buffers, instrumentation amplifiers, and active filters. The LMP7701 is available in SOT23-5 packaging, the LMP7702 is available in MSOP-8 packaging, and the LMP7704 is available in TSSOP-14 packaging.

For FREE samples, datasheets, and more, visit
www.national.com/pf/LM/LMP7701.html
www.national.com/pf/LM/LMP7702.html
www.national.com/pf/LM/LMP7704.html

Ultra Low-Power, 4-Channel, 8-/10-/12-Bit DACs

These 4-channel, 8-/10-/12-bit DACs are full-featured and can operate from a single 2.7V to 5.5V supply and use 360 µA at 3V and 480 µA at 5V. The on-chip output amplifier allows rail-to-rail output swing and the three-wire serial interface operates at clock rates up to 40 MHz over the entire supply voltage range.

The reference serves all four channels and can vary in voltage between 1V and VA, providing the widest possible output dynamic range. A power-down feature reduces power consumption to less than a microWatt with three different termination options.

Features

- INL (max)
  - ±0.5 LSB (DAC084S085)
  - ±2 LSB (DAC104S085)
  - ±8 LSB (DAC124S085)
- DNL (max)
  - +0.18 / -0.13 LSB (DAC084S085)
  - +0.35 / -0.25 LSB (DAC104S085)
  - +0.7 / -0.5 LSB (DAC124S085)
- Settling time (max)
  - 3 µs (DAC084S085)
  - 4.5 µs (DAC104S085)
  - 6 µs (DAC124S085)
- Zero code error: +15 mV (max)
- Full-scale error: -0/75% FS (max)
- Wide power supply range: 2.7V to 5.5V

The 4-channel, 8-/10-/12-bit DACs are ideal for use in battery-powered instruments, digital gain and offset adjustments, programmable voltage and current sources, and programmable attenuators. These DACs are available in MSOP-10 and LLP-10 packaging.

For FREE samples, datasheets, and more, visit
www.national.com/pf/DA/DAC084S085.html
www.national.com/pf/DA/DAC104S085.html
www.national.com/pf/DA/DAC124S085.html

National Semiconductor
The Sight & Sound of Information

570102-037

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Communications and Telecom	www.ti.com/communications
Amplifiers	amplifier.ti.com	Computers and Peripherals	www.ti.com/computers
Data Converters	dataconverter.ti.com	Consumer Electronics	www.ti.com/consumer-apps
DLP® Products	www.dlp.com	Energy and Lighting	www.ti.com/energy
DSP	dsp.ti.com	Industrial	www.ti.com/industrial
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Security	www.ti.com/security
Logic	logic.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Power Mgmt	power.ti.com	Transportation and Automotive	www.ti.com/automotive
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
		TI E2E Community Home Page	e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265