

# New Complete, High Resolution, and Multifunctional Bipolar DACs: an Easy to Use, Universal Solution

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With current market dynamics constantly driving toward shorter design cycles, enhanced system functionality, and more portable end systems, the need for new methodology to simplify these challenges without adding design complexity, is a must. This article will address some key system challenges for control and measurement that are topical across a multitude of applications, including data acquisition systems, industrial automations, programmable logic controllers, and motor controls. It will explore the latest advances in bipolar digital-to-analog converter (DAC) architectures and how these topologies can address end system challenges, such as by adding even more functionality and intelligence within the same or reduced space. This article will explore discrete and more functionally complete solutions. Finally it will outline a number of alternatives to traditional design topology that support higher flexibility in design reuse and system modularity.

It should be noted that the following figures are not the actual schematics, but illustrations on how applications could be achieved with multifunctional DACs and other components. While it does not include aspects such as circuits for power

supplies, bypassing, and other passive components, these diagrams illustrate how applications can be implemented in general.

## Data Acquisition Systems

Data acquisition systems (DAQs) are used to measure an electrical or physical singularity such as voltage, current, or pressure with a microcontroller or microprocessor (MPU) for data processing capability. DAQs consist of sensors, amplifiers, data converters, and a controller with embedded software that controls the acquisition process.

In a process control application, it is critical that the sensor is sensitive enough to preserve the quality of the signal to be measured. But even if the sensor is sensitive enough, the signal chain errors such as gain and offset could still interfere with the signal quality. High performance applications employ DACs in automatic calibration of the conditioning circuits in data acquisition systems. Figure 1 shows the block diagram of a pressure sensing system. It illustrates how bipolar DACs such as [AD5761R](#) and its product family can be used in an automated gain and offset calibration scheme.

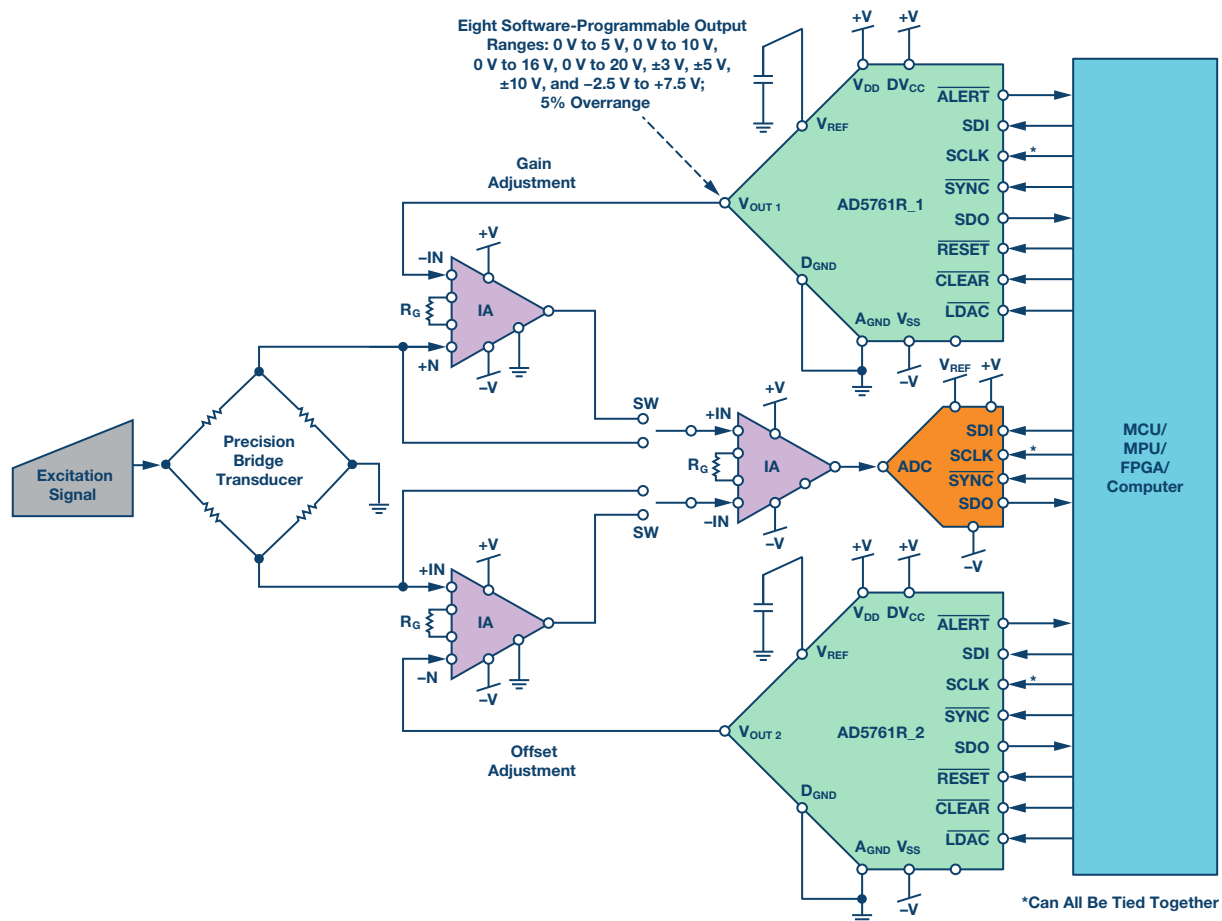


Figure 1. Automated calibration of a pressure sensing system.

The precision bridge transducer receives an excitation signal from a pressure sensor and produces an output voltage. Due to the low amplitude of the transducer's signal, an instrumentation amplifier is typically used as a signal multiplier. This low amplitude signal is susceptible to errors. Such errors are usually contributed by drift due to changes in temperature, parasitic errors across circuit boards, and tolerances of passive components.

With the use of AD5761R, gain and offset calibrations can be implemented into the system to dynamically correct the errors as the system operates over time. Depending on the level of adjustment and the polarity required, a complete, high resolution, and multifunctional bipolar DAC can greatly simplify the calibration process. The AD5761R can be programmed through a high speed, 4-wire SPI interface with a serial data output (SDO) line available to facilitate daisy-chain and read-back operation.

## Industrial Automation

The applications for industrial automation are diverse. But regardless of what applications there may be, the functionality and performance of such automated systems lie in their signal acquisition and control units. On the acquisition side, the sensitivity of the sensors, adaptability of the conditioning circuits, and the speed of acquiring correct information from low level signals is very important. On the control side, the flexibility to adapt to the requirement of various actuators and drivers is vital.

Figure 2 shows an example of an industrial automated system. A thermocouple with cold-junction compensation is used to

measure the temperature of industrial equipment such as a laser machine or heavy duty motor. The voltage is gained up, filtered, and sent to an integrated analog front-end (AFE) IC for conversion and the digital data is passed into the processor for analysis. Based on the processed data, the processor sends signal to a control DAC, which is also fully isolated, to drive an industrial fan, activate a cooling apparatus such as a Peltier, or open the valve of a water cooling system. Additionally, the user can input an override command via a control interface device.

The same system can be adopted for pressure and vibration measurement and control. A pressure sensor system can typically be used for oil and chemical tank monitoring, while a gyroscope system can typically be used for vibration monitoring of fast moving machine heads. These applications share the same AFE that is fully isolated from the external environment.

The AD5761R, a high voltage, high resolution, bipolar DAC with a low drift internal reference and software-selectable output range is a practical replacement for multiple DACs or a single multiplexed DAC. It provides unipolar and bipolar voltages while maintaining the same accuracy with an option of overrange output. This bipolar DAC supports the different needs that actuators require, including the adjustment of the control unit through software avoiding hardware modifications.

AD5761R and its product family come in small packages—a 3 mm × 3 mm, lead frame chip scale package (LFCSP) and 16-lead thin shrink outline package (TSSOP)—and support a wide operating temperature range of -55°C to +125°C. This new industrial control approach essentially helps to minimize board space and reduce cost.

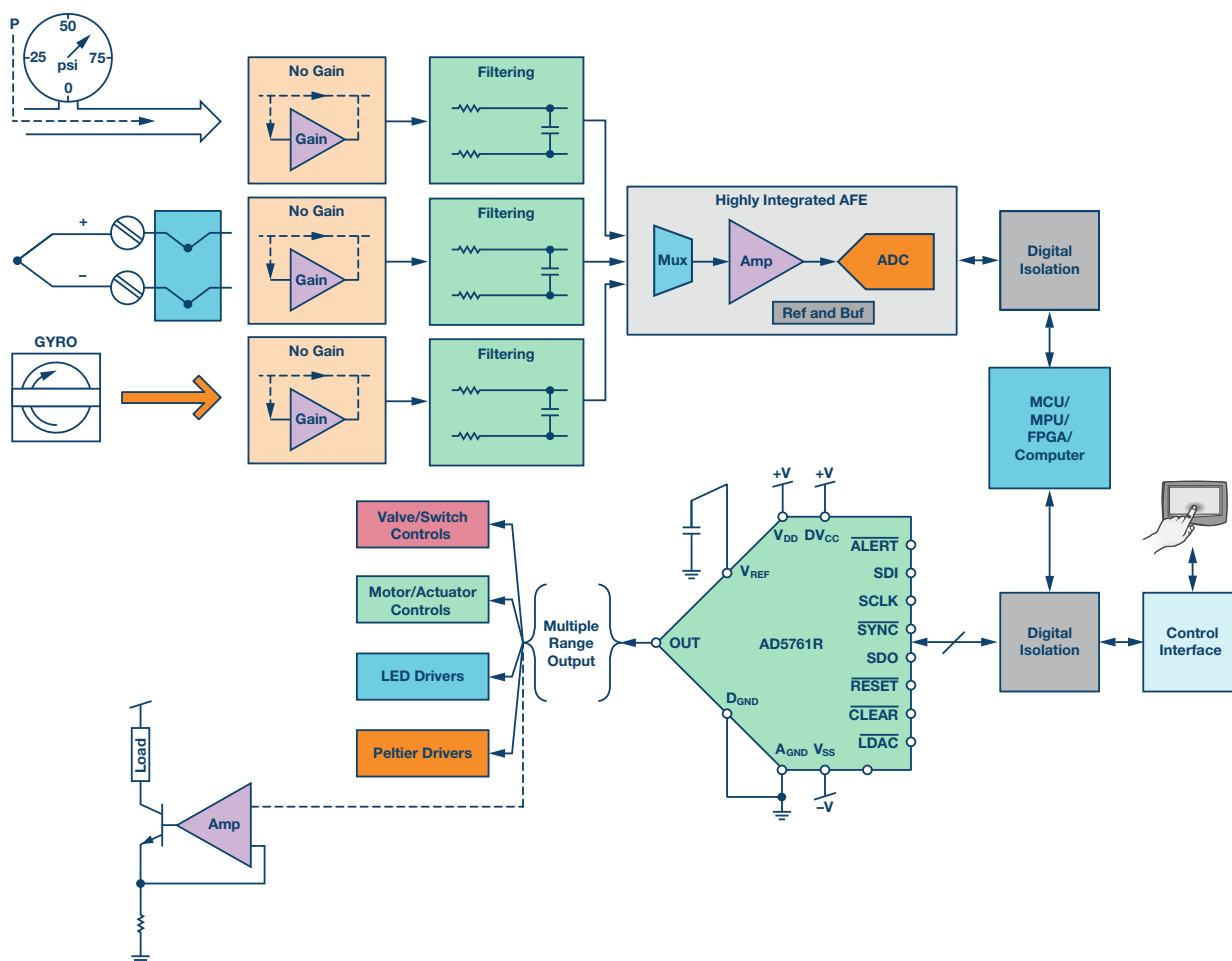


Figure 2. Simplified diagram of an industrial automated system.

## Programmable Logic Controllers

Programmable logic controllers (PLCs) incorporate power supplies, central processing units, and several analog and digital I/O modules in order to control, actuate, and monitor complex machine variables. PLCs are widely used across industries and they offer extended temperature ranges, immunity to [electrical noise](#), and resistance to vibration and impact. A fundamental process control system building block is shown in Figure 3. An input signal reporting on the status of a process variable is monitored via the input module and transferred to the MCU to be analyzed. Based on the results of this analysis, a response containing the necessary arrangements is managed by the output module to control the devices in the system.

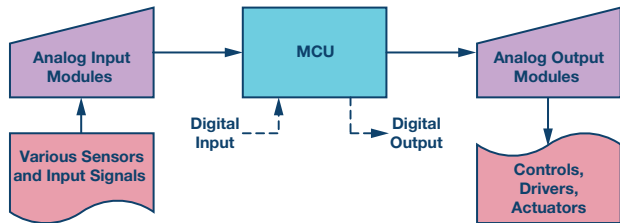


Figure 3. Process control system building block.

Figure 4 shows a more complete industrial PLC system including an embedded controller/processor as the main system controller interfacing to the fully isolated input and output modules. Excluding the power supply module, the system is divided into four subsystems that differentiate the analog input, analog output, digital input, and analog output

modules. Several types of sensors are deployed to acquire analog signals of different amplitudes and frequencies. These signals need to be preprocessed and converted into digital form for further analysis. Programmable gain amplifiers condition the small input signals such that they can be accurately measured and converted into their digital representation by analog-to-digital converters (ADCs). Isolation is required to protect the controller or processor from possible unexpected overvoltage coming from the field, for which optical or integrated isolators are placed among the processor and the input and output modules.

The accuracy and resolution requirements for the input and output modules are considerably distinct. While the input modules are required to monitor highly precise and accurate data acquisitions from the process, the output modules essentially adjust the output with a 16-bit resolution and accuracy in high end applications. As a result of these conditions,  $\Sigma\text{-}\Delta$  ADCs are commonly used for input modules in PLC systems from which a wide range of isolated, single-channel/multichannel, and simultaneous sampling ADCs are available in the market.

Output modules may offer precision voltage DACs, precision current DACs, or a combination of both. Several methods allow current and voltage levels to be generated for the PLC's analog output. The evolution of precision bipolar DACs such as the AD5761R, providing extra functionality and a high level of integration, significantly benefit PLC systems from reduction of system complexity, board size, and cost.

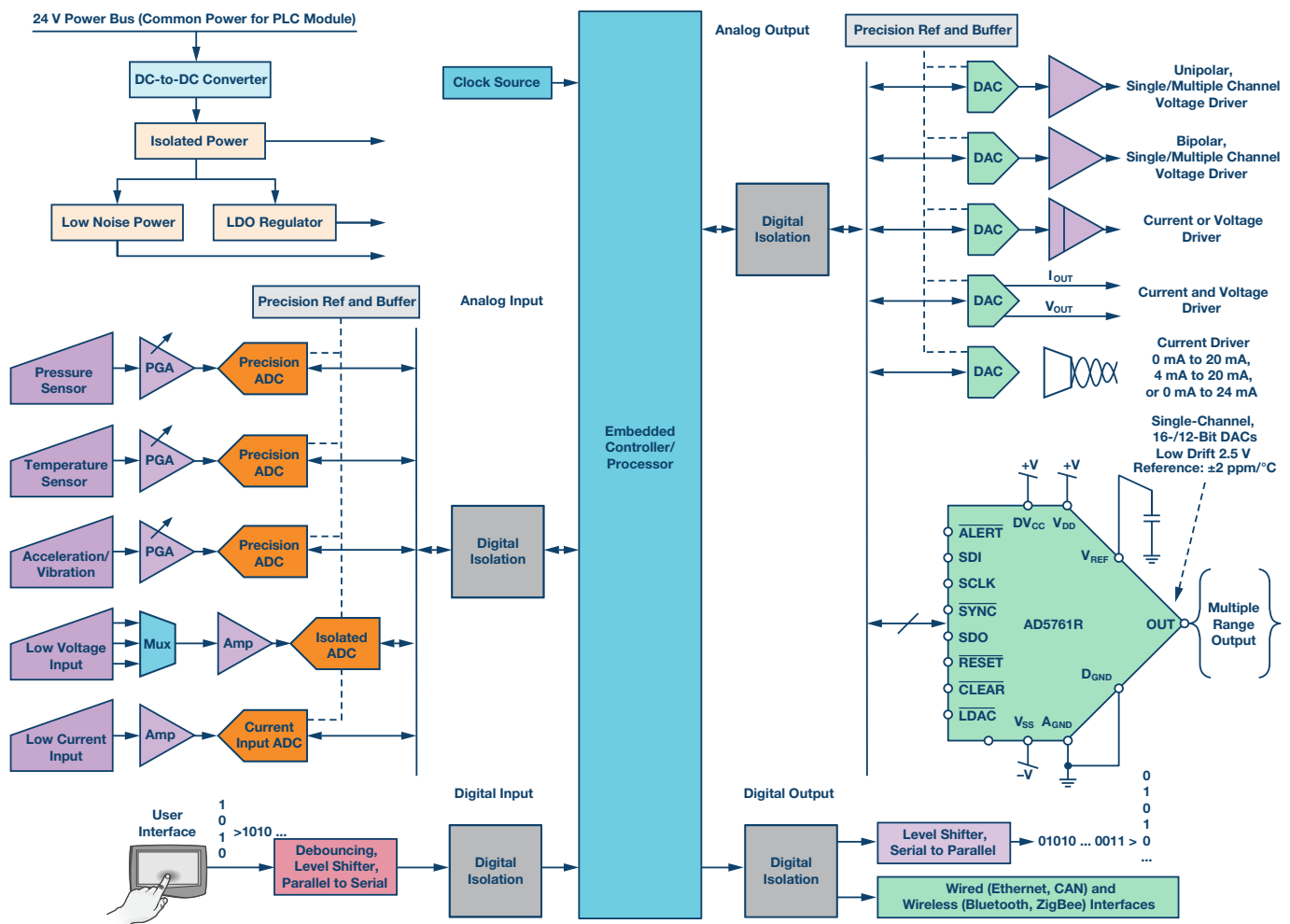


Figure 4. Block diagram of a complete PLC system.

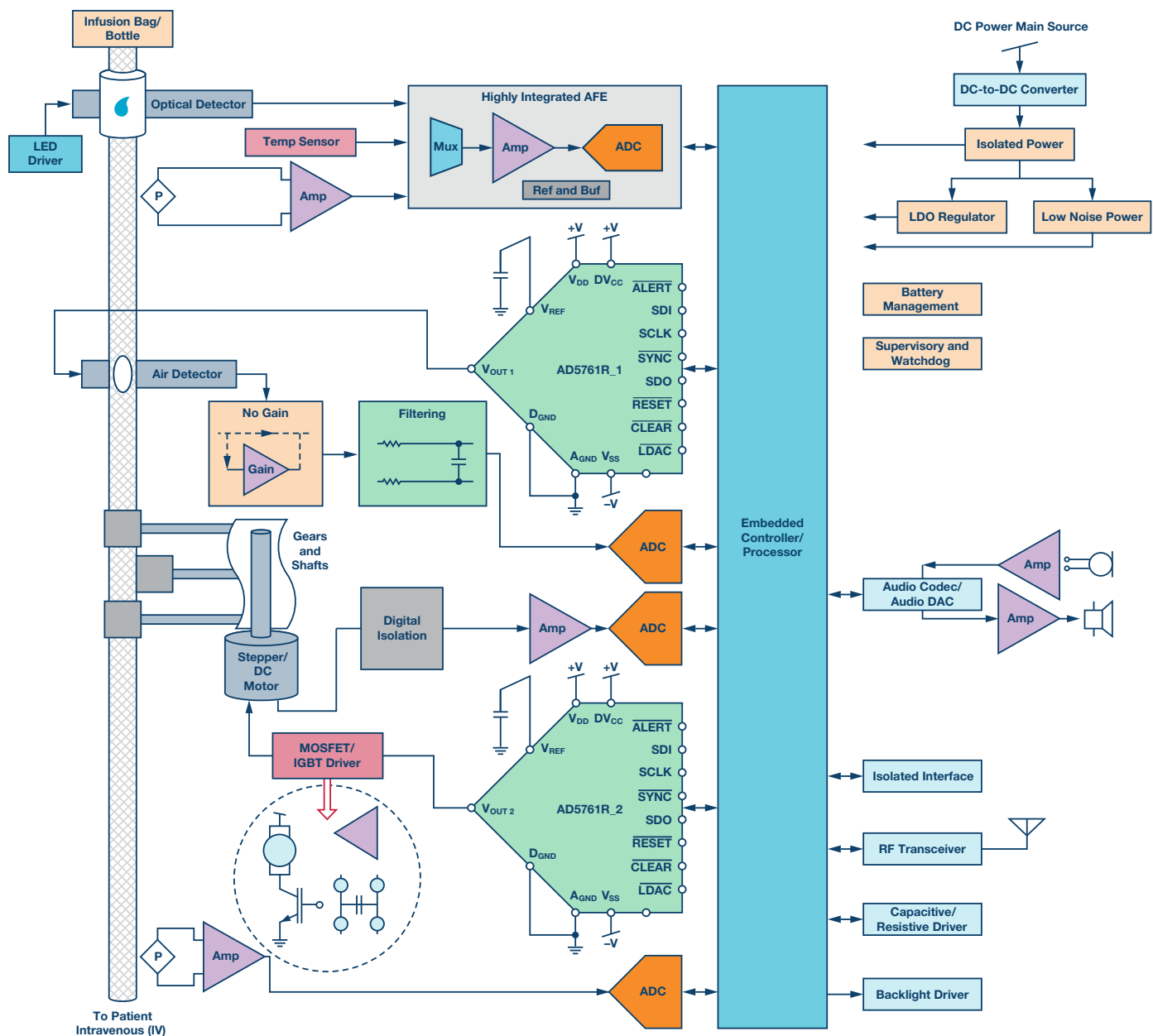


Figure 5. Large volume infusion pump system.

## Motor Controls

DACs perform an integral function in motor control loops; for example, in infusion pump systems. Infusion pumps are widely used in human healthcare to provide medical treatment to patients of all ages. The role of an infusion pump is to deliver fluids, medication, or supplements to the patient's cardiovascular system in an intermittent or continuous procedure.

Although infusion pumps require a qualified user to program the specific parameters for the treatment, the implicated advantages over manual administration influence increasing user confidence. The capability of these instruments to accurately deliver tiny dosages at scheduled intervals in a self-operated mode negates the need for a nurse or doctor to manually control the flow of fluid to the patient. Doctors and medical administrators can depend on the safety of infusion pump systems to display real-time system information on dosage limitations for titration safety, to prevent overdose, as well as the physical delivery mechanism itself to be reliable and accurate.

During operation, the microcontroller receives the monitored speed and direction signals from the dc motor, which are analyzed and adjusted (if required) to meet the setpoint. The DAC in the feedforward path provides the adjustments to the system while the ADC in the feedback path monitors the effect of each adjustment. The desired setpoint voltage set by the DAC is amplified through the driver network to provide the required drive current to the dc motor.

ADI offers high performance analog and mixed-signal processing solutions for detecting, measuring, and controlling sensors and actuators used in chemistry analyzers, flow cytometers, infusion pumps, dialysis equipment, ventilators, catheters, and many more medical instruments. In particular, the AD5761R, a high resolution, bipolar DAC with eight available software selectable output ranges while maintaining a common accuracy is an ideal part for motor control applications, supporting the different voltage swings needed by motors.

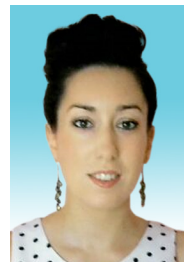
## Conclusion

DACs play a key role in determining the performance and accuracy of many control systems and simple conversion circuits, as well as other complex applications. The AD5761R and its product family, which is a complete 16-bit resolution precision bipolar DAC with multiple programmable output ranges, are suitable for the above applications. The highly configurable ranges of the AD5761R family of DACs (0 V to 5 V, 0 V to 10 V, 0 V to 16 V, 0 V to 20 V,  $\pm 3$  V,  $\pm 5$  V,  $\pm 10$  V, and  $-2.5$  V to  $+7.5$  V; 5% overrange), make this family of DACs a one size fits all solution for data acquisition systems,

industrial automation, programmable logic controllers, and motor controllers. The integration offered within the AD5761R product family, including output buffer and a buffered 2 ppm/ $^{\circ}$ C internal reference, significantly simplifies board design, reduces board size, and minimizes power consumption and cost.



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