One Technology Way • P.O. Box 9106 • Norwood, MA 02062-9106, U.S.A. • Tel: 781.329.4700 • Fax: 781.461.3113 • www.analog.com

Additional Details, Background, and Examples of the AD5770R Features
by Ivan Santos

INTRODUCTION

The AD5770R is a 6-channel, 14-bit resolution, programmable current output, digital-to-analog converter (DAC) used in applications such as photonics control and current mode biasing. This application note explains the most relevant AD5770R features, such as output current ranges, output current scaling, and thermal monitoring. Single-supply configuration, minimum headroom and footroom, and bipolar current configuration with an inductive load are also discussed in this application note.

For full details on the AD5770R, see the AD5770R data sheet. Consult the data sheet in conjunction with this application note when using the AD5770R.

TABLE OF CONTENTS

REVISION HISTORY

9/2019—Revision 0: Initial Version

MAIN FEATURES OF THE AD5770R

POWERING THE AD5770R USING A SINGLE SUPPLY

Using a common, positive supply source for the AVDD pin, the DVDD pin, and the PVDDx pins on the AD5770R is the-most straightforward way of powering the device. Only a few of the supply conditions required to meet the specified performance of the device require the DVDD pin voltage (DV_{DD}) to equal the AVDD pin voltage (AV_{DD}). The PVDDx pin voltage (PV_{DDx}) must not exceed $AV_{DD} − 0.4$ V. Given these conditions, the AVDD pin and the DVDD pin can be shorted. To meet the $PV_{DDx} \leq AV_{DD} − 0.4$ V requirement, place a diode between the AV_{DD} supply and the PV_{DDx} supply, as shown in Figure 1. In this single-supply configuration, the supply voltage must be in the range of 2.9 V to 5.5 V, and the voltage at the cathode of the diode at the PVDDx pins must be ≥0.8 V.
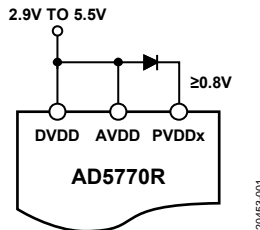
2.9V TO 5.5V

≥0.8V

DVDD   AVDD   PVDDx

AD5770R

Figure 1. Single-Supply Configuration Using Diode

The main specifications to consider when selecting a diode include the following:

- Forward voltage drop (V_F) is ≥0.4 V. Set this specification to ensure that the PV_{DDx} supplies do not exceed $AV_{DD} − 0.4$ V.
- Forward current rating ≥ the sum of all IDACx currents (I_{IDACx}). Place a derating factor of no more than 80% across all operating temperatures for extra margin.
- Low dynamic resistance. Select the diode with lower dynamic resistance to prevent large PV_{DDx} supply variation with respect to the change in output currents.

Based on these specification considerations, a Diodes, Inc., S1MSWF diode, which has a forward current rating of 1 A, is acceptable for use. The S1MSWF V_F value satisfies the requirement, even at very low forward currents and high ambient temperatures. The relationship between I_{IDACx}, V_F, and the effect they have on the headroom must also be considered when selecting the supply values and the diode. Increasing I_{IDACx} settings results in an increased V_F value, which decreases the available headroom at the output.

The AD5770R has a dc power supply rejection ratio (PSRR) performance of 17 µA/V to ensure minimal effect of supply change to the output current. To further reduce the effect of crosstalk due to dynamic changes in the load and output currents, isolate the PVDDx pin of those particular channels with a dedicated diode, as shown in Figure 2, depending on the number of diodes required. A Diodes, Inc., BAV23A diode contains two diodes in a single package to save board space, and is acceptable for use. Decoupling capacitors are required in any

power supply configuration, and it is recommended to place a 10 µF tantalum capacitor in parallel with a 0.1 µF ceramic capacitor. These capacitors must be located as close as possible to the package to provide a low impedance path to ground for high frequency noise present at the supplies. For unused DAC channels, the PVDDx pins, CDAMP_IDACx pins, and IDACx pins can be left floating.
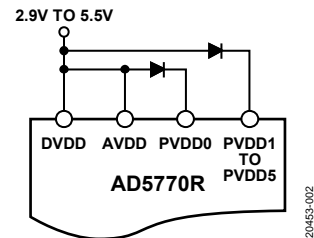
2.9V TO 5.5V

DVDD   AVDD   PVDD0   PVDD1 TO PVDD5

AD5770R

Figure 2. Multiple Diode Configuration

AD5770R OUTPUT CURRENT RANGES WITH MINIMUM HEADROOM AND FOOTROOM

Figure 3, Figure 4, and Figure 5 show the output current ranges available for the different current output channels (IDACx), the minimum headroom, and the minimum footroom, respectively.
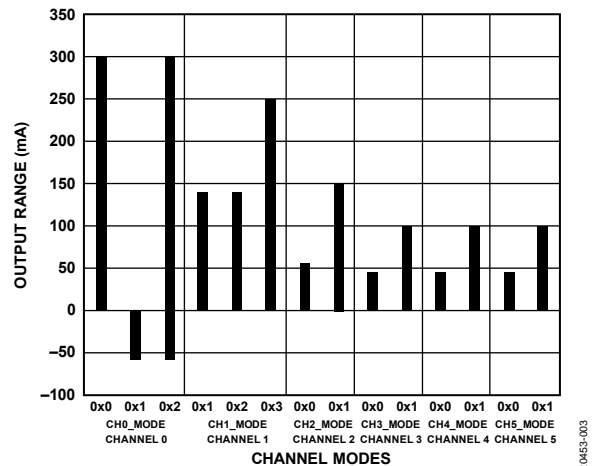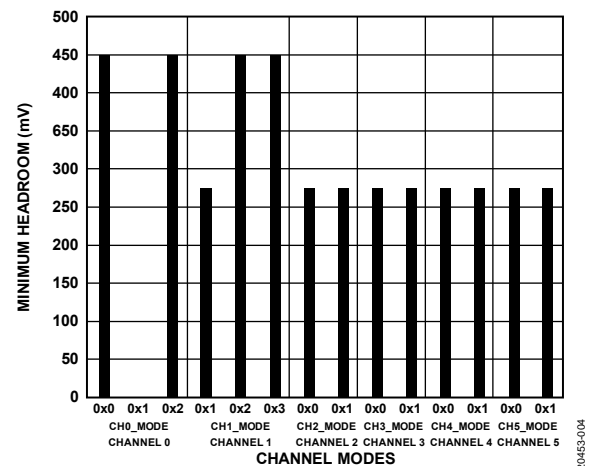
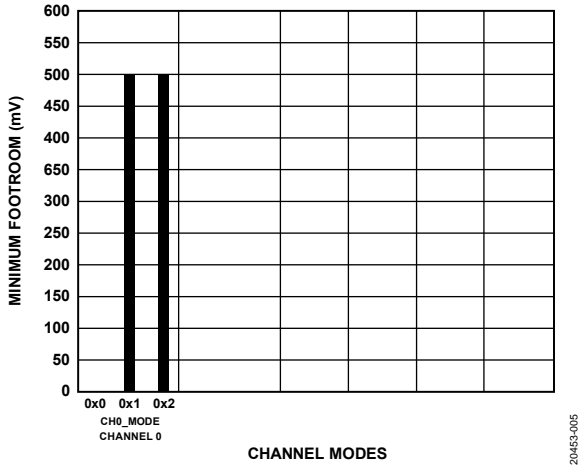*Figure 3. Output Current Ranges*

Figure 4. Minimum Headroom

Figure 5. Minimum Footroom

The minimum headroom for the AD5770R is defined as the minimum allowable voltage difference between the PV_{DDx} and the corresponding IDACx pin voltage (V_{IDACx}) with the output current error within 0.1% full-scale range (FSR). This requirement determines the maximum load resistance for a given I_{IDACx} setting. For diode loads, this requirement determines the maximum number of diodes loaded in series while maintaining accuracy. When efficiency is the priority, the compliance voltage can be increased with a small expense in accuracy at high output current settings.

To compute the maximum load resistance, use the equation shown in Figure 6. Using the example shown in Figure 7, when the maximum current to be sourced by the IDAC0 pin is 250 mA, PV_{DDx} = 5 V given that the minimum headroom for the IDAC0 pin, Mode 0x0, is 450 mV. The maximum total load resistance (R_{LOAD}) at the IDAC0 pin must be ≤18.2 Ω.
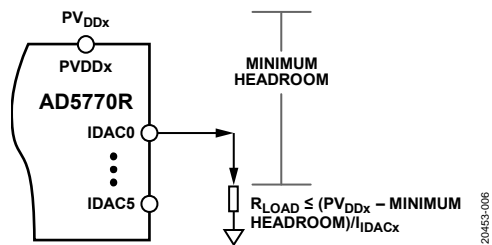

Figure 6. R_{LOAD} Equation as a Function of Minimum Headroom, Supply Voltage, and Output Current
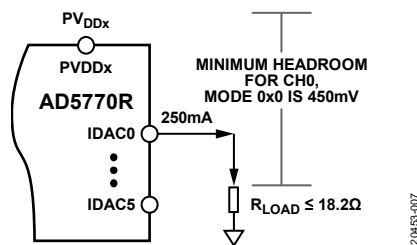

Figure 7. R_{LOAD} Example

For diode loads, use the equations shown in Figure 8 to determine the total number of identical diodes with similar V_F. Using the IDAC0 pin, Mode 0x0, and a PV_{DDx} of 5 V (see Figure 9), the total V_F of the diode or diodes in series (V_{F_TOT}) is ≤4.55 V. If each diode has a V_F of 1.5 V, no more than three identical diodes can be used as a load. The total number of diodes (N) is not dependent on the current for ideal diodes. Adjustments must be made on the actual V_F value depending on the device being used. Note that the actual V_F value also varies according to the operating temperature. Most diode manufacturers provide the characteristics for this particular parameter on the device data sheets.
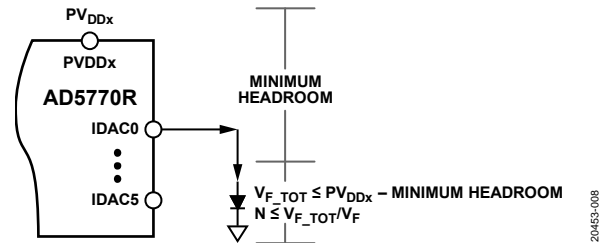

Figure 8. Diode Load Equation as a Function of Minimum Headroom and Supply Voltage
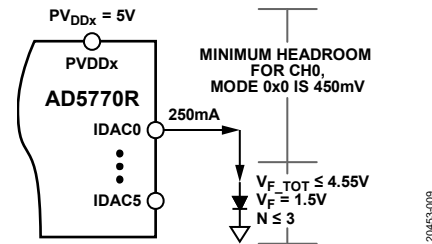

Figure 9. Diode Load Example

The minimum headroom and footroom depend on the actual output current of a given channel (see the AD5770R data sheet for more information). Applications with large load impedance typically require higher supply voltages. In these cases, the recommended device is the LTC2662, for which the supplies can be up to 33 V.

For a given output current, the minimum headroom increases with temperature because of the positive thermal coefficient of the internal resistance of the output current driver. The increase in resistance results in a higher voltage drop across the driver and leaves a smaller margin between the V_{IDACx} and PV_{DDx}. For example, at 25°C, a headroom of about 270 mV allows the device to source up to 250 mA of output current. With a target load resistance that is ground referenced, the minimum supply voltage can be computed using Equation 1. For the IDAC0 current sink mode, use Equation 2 to solve for the maximum PV_{EEx} pin voltage (PV_{EEx}).

$$PV_{DDx} \geq (V_{IDACx} \times R_{LOAD}) + Minimum\ Headroom \qquad (1)$$

$$PV_{EEx} \leq (V_{IDACx} \times R_{LOAD}) - Minimum\ Footroom \qquad (2)$$

AD5770R OUTPUT CURRENT SCALING

Each output shown in Figure 3 can be scaled down to a minimum of 0.5 times the nominal, full-scale current range while maintaining a 14-bit monotonicity, with the exception of the IDAC0 pin, Mode 0x1 and Mode 0x2, where output current scaling is not supported.

Output current scaling loads the desired value to the output scaling register. The new adjusted, full-scale current range is determined using the following equation:

$$I_{ADJ} = I_{NOM} \times \left(1 - \frac{x}{128}\right) \qquad (3)$$

where:
I_{ADJ} is the adjusted full-scale output current.
I_{NOM} is the nominal full-scale output current.
x is the code loaded into the output scaling register, $0 \leq x$.

To determine the value of x in Equation 3, use the following equation:

$$x = 128 \times \left(1 - \frac{I_{ADJ}}{I_{NOM}}\right) \qquad (4)$$

Using the IDAC0 pin, Mode 0x0, as an example with a nominal, full-scale output current of 300 mA, the code required to achieve an adjusted, full-scale output current of 225 mA is x = 32. The code required to achieve the lowest adjusted, full-scale output current of 150 mA (exactly half of the nominal value) is x = 64.

As shown in Figure 10, increasing the value of x results in decreasing the I_{ADJ}. The zero scale output current is still 0 mA for all cases.
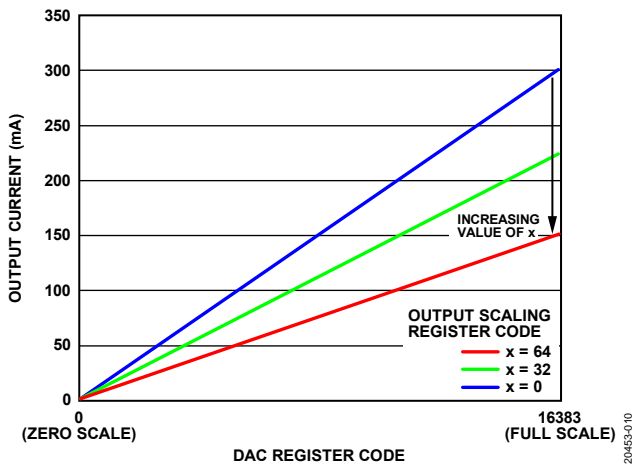
Figure 10. Output Scaling Register Code Effect on Output Current Range

THERMAL MONITORING AND CONSIDERATIONS

The AD5770R offers monitoring of the internal die temperature of the device through an output voltage at the MUX_OUT pin as a representative of the temperature. To monitor the internal die temperature, set up the internal multiplexer first and then select the bias current for the internal diode. The internal diode acts as the temperature sensor. When using the external bias current, bypass the multiplexer (MUX) buffer before enabling the bias current source. See the AD5770R data sheet for details on the configuration of the MUX_OUT pin for this functionality. Figure 11 shows the simplified block diagram of the MUX_OUT section with a focus on the internal die temperature monitoring.
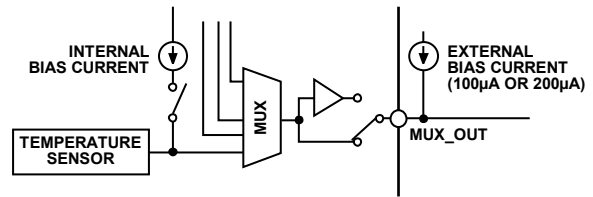
Figure 11. Thermal Monitoring Functional Block Diagram

There are three options for the bias current: the internal bias current, a 100 µA external bias current, and a 200 µA external bias current. Depending on the bias current used, the equivalent temperature in °C is represented by any of the following equations:

$$T = \frac{700\ \text{mV} - V_D}{1.8\ \text{mV}} + 25 \qquad (5)$$

where:
T is the die temperature using the internal bias current.
V_D is the diode voltage.

$$T = \frac{800\ \text{mV} - V_D}{1.3\ \text{mV}} + 25 \qquad (6)$$

where T is the die temperature using a 100 µA external bias current.

$$T = \frac{1.04\ \text{V} - V_D}{0.9\ \text{mV}} + 25 \qquad (7)$$

where T is the die temperature using a 200 µA external bias current.

The AD5770R features an overtemperature warning and overtemperature shutdown alert to flag the application system if the internal die temperature exceeds the warning limit (120°C) or the shutdown temperature limit (145°C). The overtemperature alert feature can also be configured to shut down the output current stages to protect the device from overtemperature.

Approximate the internal junction temperature (T_J) of [AD5770R](#) using the ambient temperature (T_A) given by the following equation:

$$T_J = (\theta_{JA} \times P_{DISS}) + T_A \tag{8}$$

where:
θ_{JA} is the junction to ambient thermal resistance.
P_{DISS} is the power dissipation.

Rearrange Equation 8 to estimate the maximum power dissipation (see Equation 9) or the maximum ambient temperature (see Equation 10). The maximum operating ambient temperature and the power dissipation can be improved by implementing additional copper planes and vias that are directly connected to the device. A heatsink can also be installed on top of the case. Both methods increase the surface area to dissipate heat at a faster rate.

$$P_{DISS}(max) = \frac{T_J(max) - T_A}{\theta_{JA}} \tag{9}$$

$$T_A(max) = T_J(max) - P_{DISS} \times \theta_{JA} \tag{10}$$

BIPOLAR CURRENT SUPPLY AND INDUCTIVE LOADS

Microelectromechanical system (MEMS) actuators driven by Lorentz force are recommended because they are able to provide large displacements at small voltages (3.3 V or 5 V). The resultant force (displacement) is dependent on the magnetic flux density of the magnetic field, and on the amount of current passing through the movable section. Given a fixed magnetic flux density, the actuator current is adjusted to change the displacement. Figure 12 shows the relationship between the current and the displacement.
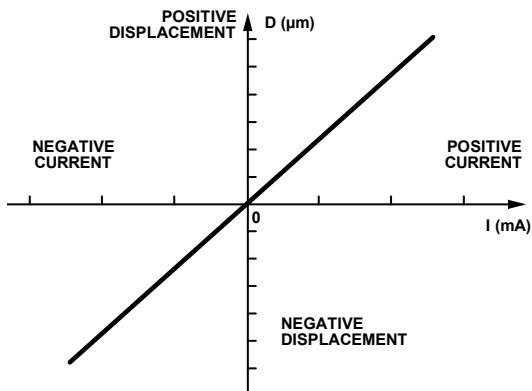

Figure 12. MEMS Actuator Current vs. Displacement

The MEMS actuators require a bipolar drive current to allow the actuators to move in both directions. Only the IDAC0 pin has the capability to source and sink the current. The circuit shown in Figure 13 can be implemented for other channels, which can only source current. This circuit is a classical H-bridge. When the S1 and S4 switches are closed, the S2 and S3 switches are open and the current flows from the left to the right of the MEMS actuator. When the S2 and S3 switches are closed, the S1 and S4 switches are open and the current flows from the right to the left of the MEMS actuator. These two combinations create a bipolar current through the actuator. The inductive nature of MEMS actuators may require a compensating capacitor (C_{COMP}) at the IDACx pins to ensure output stability. A 22 nF capacitor between the IDACx pins and the AGND pin ensures the stability of a 10 µH load. Note that this capacitive component may also result in a slower settling time for the outputs.
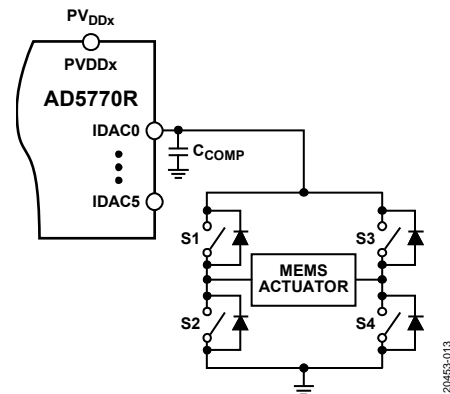

Figure 13. Driving a MEMS Actuator with the [AD5770R](#) in Current Source Mode

www.analog.com