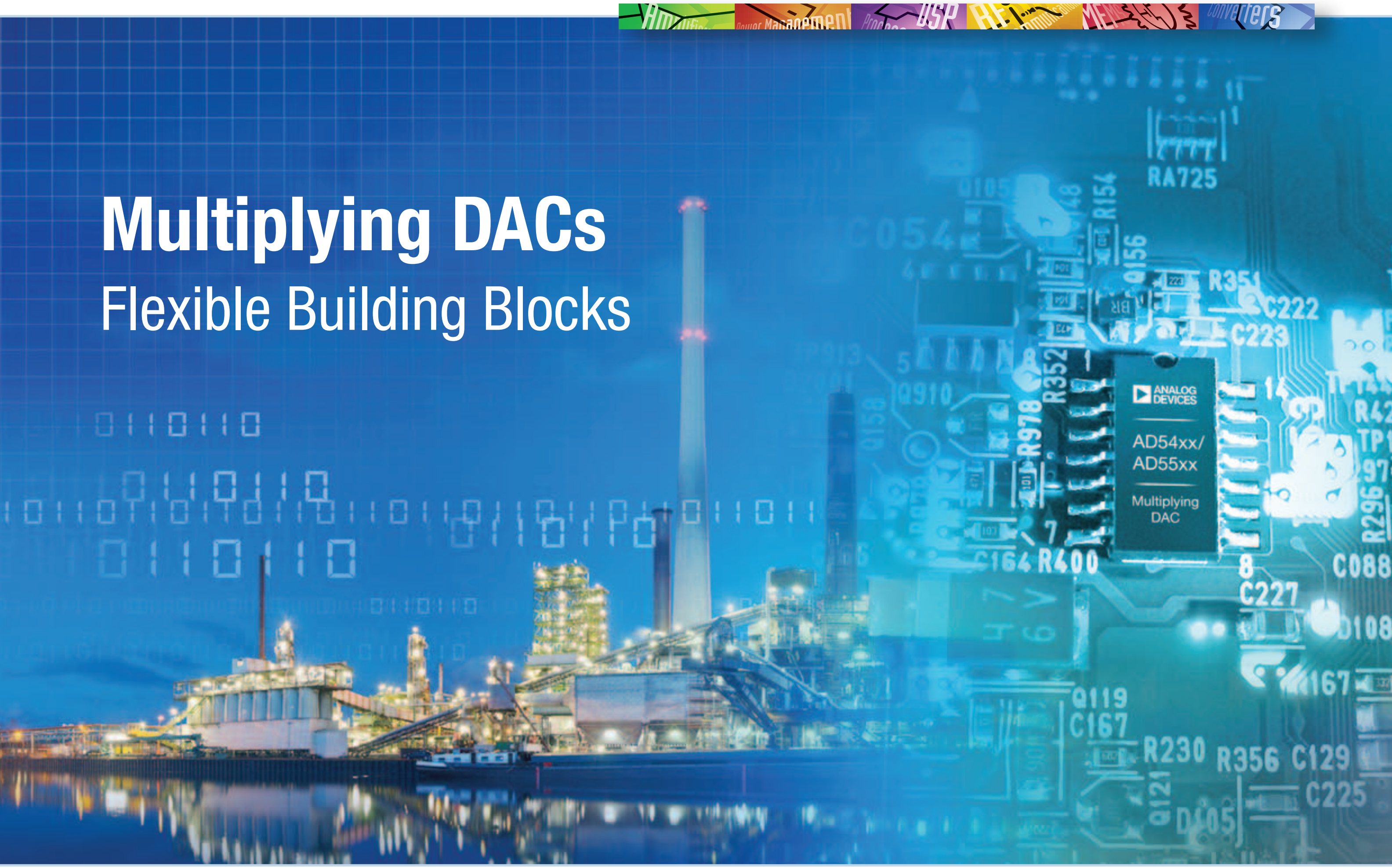


Multiplying DACs

Flexible Building Blocks

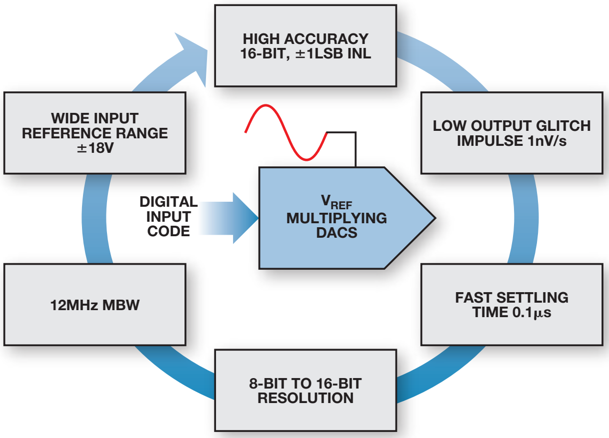
Analog Devices has a comprehensive family of 8-/10-/12-/14-/16-bit multiplying digital-to-analog converters. As a result of manufacture on a CMOS submicron process, these DACs offer excellent 4-quadrant multiplication characteristics. By offering flexibility and simplicity, multiplying DAC products are an ideal building block in a broad range of both fixed and varying input reference applications.

These parts can handle up to ±18 V inputs on the reference, despite operating from a single-supply power supply of up to 2.5 V to 5.5 V. An integrated feedback resistor (RFB) provides temperature tracking and full-scale voltage output when combined with an external current-to-voltage precision amplifier.

Analog Devices has now revamped its portfolio of high resolution 14-/16-bit current output products to include:

- Improved linearity of ±1 LSB INL
- Improved analog THD, multiplying feedthrough, and higher multiplying bandwidth performance for varying reference voltage multiplication
- Improved digital THD, midscale glitch, and digital feedthrough for fixed reference voltage multiplication

With the launch of the improved AD55xx products, ADI has added to the already high performance 8-/10-/12-bit AD54xx family of current output DACs. These updated current output DAC products enable analog designers to address an even wider range of both fixed and varying reference multiplying applications.



Multiplying DACs

By offering both flexibility and simplicity, multiplying DACs can be used in a broad range of applications. The benefit of a discrete DAC and op amp solution is that the op amp selection can be custom tailored to suit the application requirements. Multiplying DACs are ideal building blocks for fixed reference applications, where the user wants to generate a waveform from a fixed dc voltage. They are also ideally suited for varying reference applications, where the user wants to digitally condition an ac or arbitrary reference voltage. The AD54xx and revamped AD55xx families of multiplying DACs have been designed to target both these application spaces.

Multiplying DACs have a number of extra features to assist designers in generating the desired output signal. Some multiplying DACs, such as the AD5405 and AD5545, include uncommitted matched resistors, whereby a positive output can be obtained simply by connecting an additional op amp (A2 in Figure 2), which could be the companion op amp within a dual device. Some generics of the family, including the AD5546 and AD5544, have the added feature of resetting to midscale or zero scale, which is useful in bipolar applications. The required op amp to support these applications can be selected for particular specifications, for example, high gain bandwidth, high slew rate, low noise, etc.

Key Advantages of AD55xx DACs for Multiplying AC/Arbitrary Reference Applications

- High multiplying bandwidth—signals can be multiplied up to this frequency before they are attenuated by more than 3 dB. The AD5544/AD5554 can multiply signals up to 12 MHz. See Figure 1.
- Low multiplying feedthrough—this is the error due to capacitive feedthrough from the reference input to the DAC output, when all 0's are loaded to the DAC. This measures the amount of possible distortion in the multiplied signal—the AD5544 measures as low as –65 dB at 100 kHz.
- Excellent analog THD—a mathematical representation of the harmonic content in the multiplied waveform signal. It is the rms sum of the harmonics (V2, V3, V4, and V5) of the DAC output to the fundamental value, V1, given by Equation 1. Measures as low as –103 dB on the AD5543.

$$THD = 20 \log \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2}}{V_1} \quad (1)$$

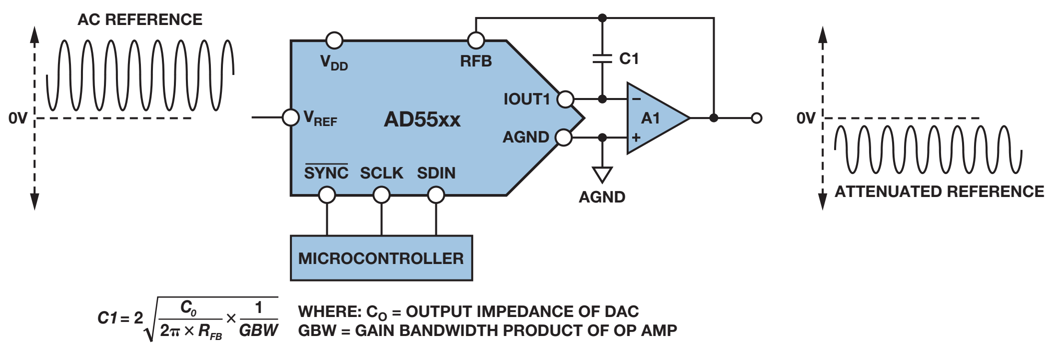


Figure 1. Multiplying DAC—varying reference—positive reference in/negative out configuration.

Circuits from the Lab™

Circuit Note CN-0025, *Precision, AC Reference Signal Attenuator Using the AD5546/AD5556 Multiplying DAC.* *www.analog.com/CN0025*

AN-1094 Application Note, *Multiplying DACs—Fixed Reference, Waveform Generation Applications.* *www.analog.com/AN-1094*

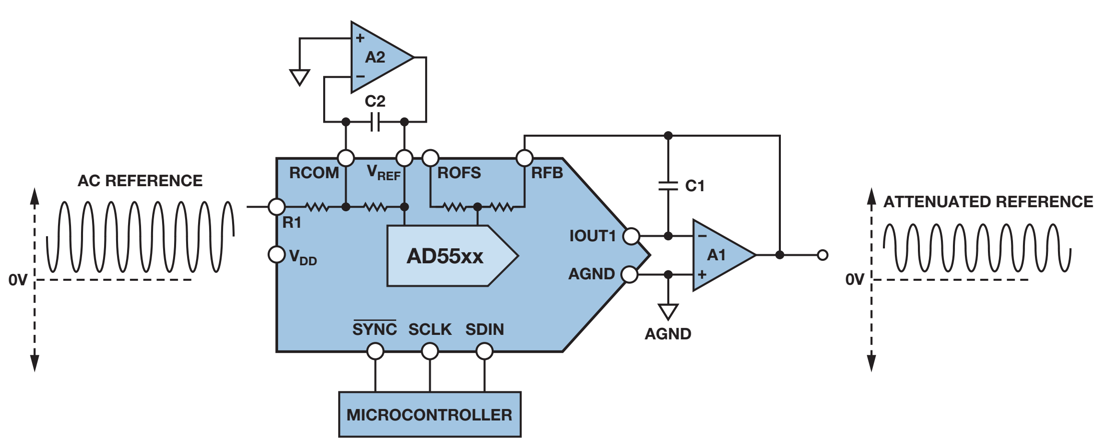


Figure 2. Multiplying DAC—varying reference—positive reference in/positive out configuration.

Key Advantages of AD55xx DACs for Multiplying DC Reference Applications

- Fast settling time—the AD55xx benefit from a 0.5 µs settling time from zero scale to full scale within ±0.1%. The AD54xx have zero scale to full scale settling time of sub 0.1 µs to within ±0.1%.
- High slew rate—due to fast switching architecture of the AD54xx and AD55xx families, an operational amplifier with a slew rate of >100 V/µs is sufficient to not limit the DAC performance.
- Low glitch—low in R2R structures due to the fact that the current is steered either to ground or virtual ground. The worst case is the midscale glitch, which can measure as low as –1 nV/s for the AD55xx parts.
- Low noise—the AD54xx and AD55xx family of I_{OUT} DACs utilize low impedance architectures. These are inherently low noise architectures dominated by the thermal noise of the RDAC resistor.

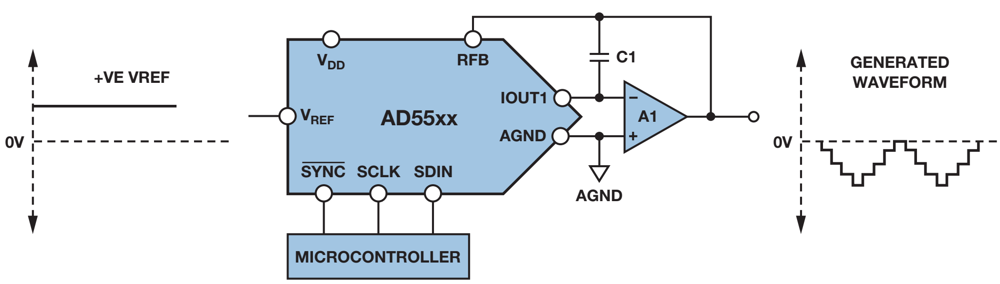


Figure 3. Multiplying DAC—fixed reference—unipolar operation.

AN-1085 Application Note, *Multiplying DACs—AC/Arbitrary Reference Applications.*
www.analog.com/AN-1085

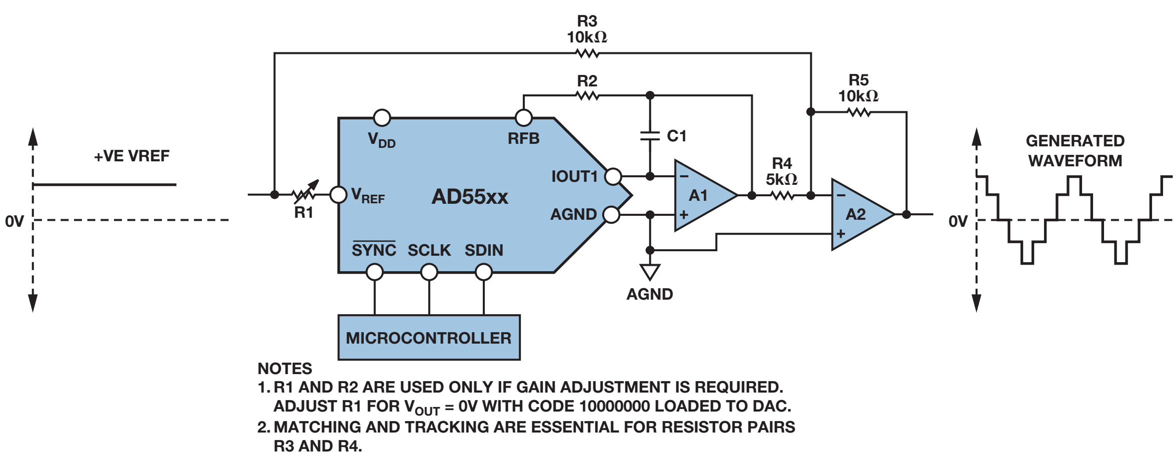
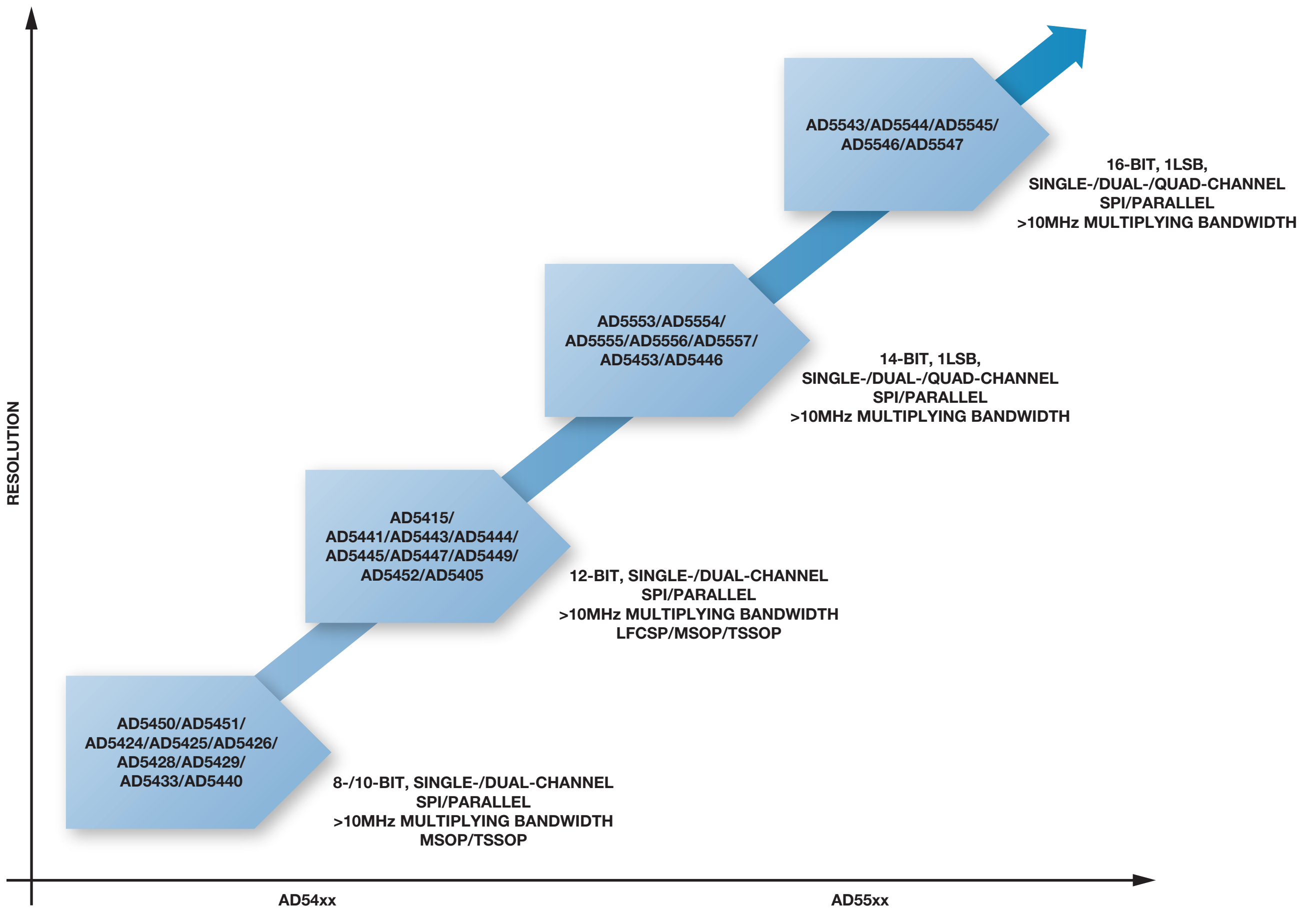


Figure 4. Multiplying DAC—fixed reference—bipolar operation.

Circuits from the Lab™

Circuit Note CN-0028, *Precision, Bipolar Configuration for the AD5547/AD5557 DAC.*
www.analog.com/CN0028

I_{OUT} Family Tree



AD5543 Specifications

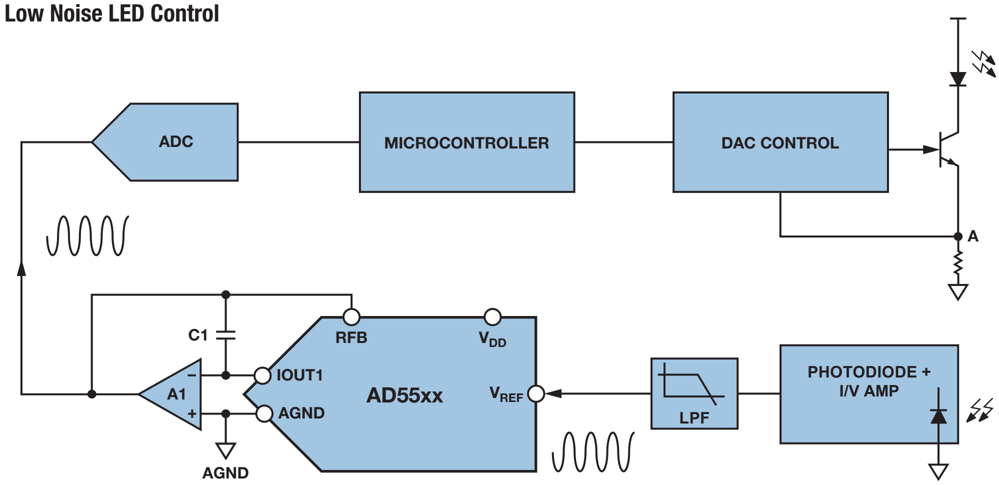
- Single channel
- 16-bit resolution
- ±1 LSB DNL
- ±1 LSB INL
- Low noise: 12 nV/$\sqrt{Hz}$
- Low power: I_{DD} = 10 μA
- 0.5 μs settling time
- 7 MHz multiplying bandwidth
- Analog THD of –103 dB
- 2 mA full-scale current ±20%, with V_{REF} = 10 V
- Built-in RFB facilitates voltage conversion
- SPI-compatible, 3-wire interface
- Temperature range: –40°C to +125°C
- Ultracompact 8-lead MSOP and 8-lead SOIC packages

AD5544 Specifications

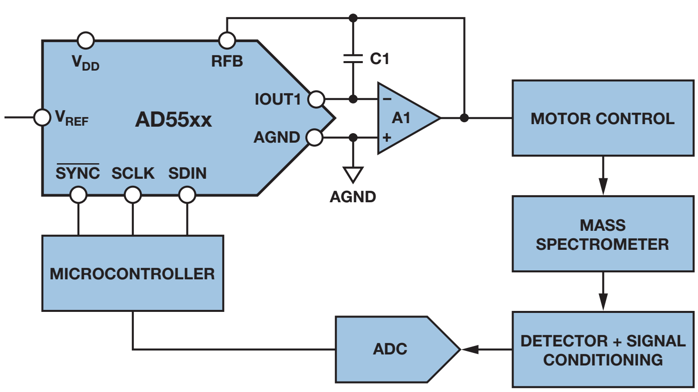
- Quad channel
- 16-bit resolution
- ±1 LSB DNL
- ±1 LSB INL
- 2 mA full-scale current ±20%, with V_{REF} = ±10 V
- 0.9 μs settling time to ±0.1%
- 12 MHz multiplying bandwidth
- Midscale glitch of –1 nV/sec
- Midscale or zero-scale reset
- Four separate, 4-quadrant multiplying reference inputs
- SPI-compatible, 3-wire interface
- Simultaneous multichannel change
- Temperature range: –40°C to +125°C
- Compact 28-lead SSOP; 5 mm × 5 mm, 32-lead LFCSP

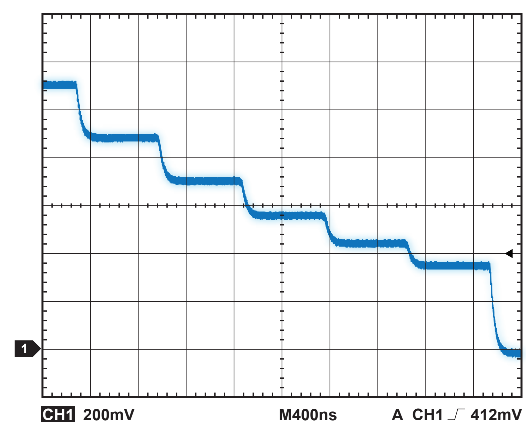
Applications

Low Noise LED Control



Fast Settling Ramp Control on Motors





Circuits from the Lab™ by Analog Devices is a new design assistance resource that provides engineers with tested circuit solutions for many common applications. Circuits from the Lab pairs at least two complementary components, such as an ADC and amplifier, to present a circuit optimized for a targeted application. Each circuit has been built and tested in the lab and can be easily integrated into designs, resulting in reduced design risk and faster time to market.

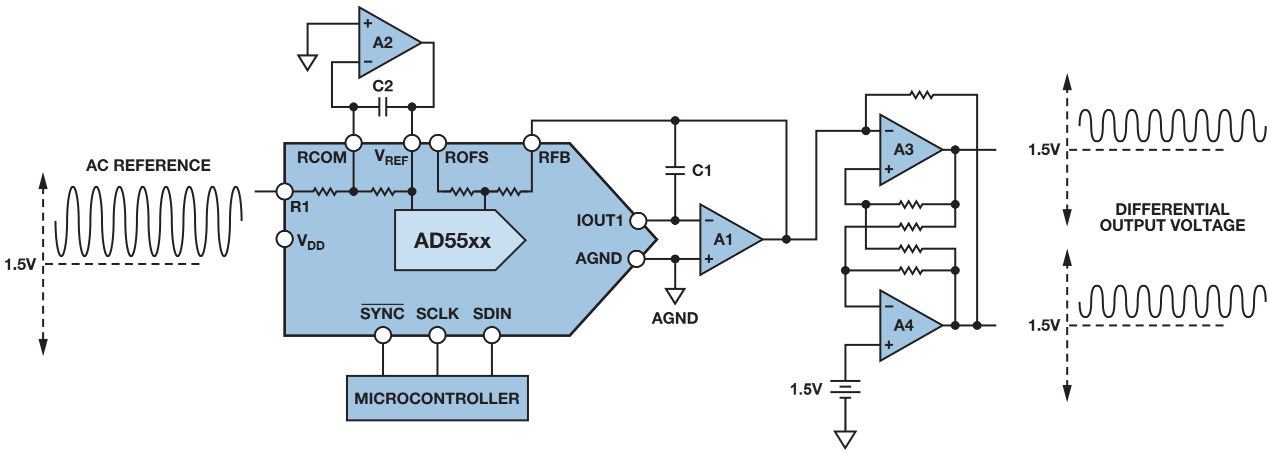
Circuits from the Lab™

Circuit note documentation accompanies each Circuits from the Lab design and describes the circuit function, benefits, and implementation in detail, with common variations noted.

View the collection of circuit notes available for multiplying DAC designs at *www.analog.com/circuits*.

Applications

Single-Ended-to-Differential Conditioning

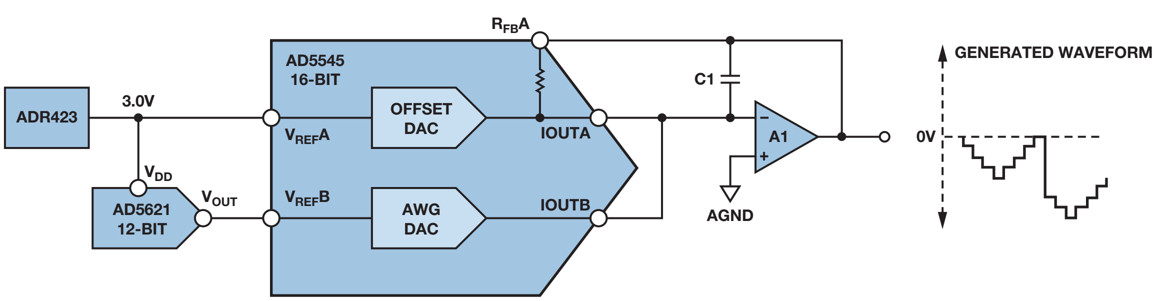


*UNCOMMITTED RESISTOR VERSION

Circuits from the Lab™

Circuit Note CN-0143, *Single-Ended-to-Differential Converters for Voltage Output and Current Output DACs Using the AD8042 Op Amp. www.analog.com/CN0143*

Fast Settling Ramp Generation and Offset Control



For more information on ADI's multiplying DAC portfolio see *www.analog.com/multiplyingDAC.*

Multiplying DACs

Part Number	Bits	Outputs	Interface	Package	Comments
AD5424	8	1	Parallel	16-lead TSSOP, 20-lead LFCSP	>10 MHz BW, ±10 V signals
AD5426	8	1	SPI	10-lead MSOP	>10 MHz BW, ±10 V signals; see also AD5425 fast load
AD5450	8	1	SPI	8-lead SOT-23	Small SOT-23 package; see also AD5425 fast load; pin- and software-compatible family—12 MHz update rate
AD5425	8	1	SPI, 8-bit load	10-lead MSOP	>10 MHz BW, ±10 V signals; see also AD5426
AD5428	8	2	Parallel	20-lead TSSOP	>10 MHz BW, ±10 V signals
AD5429	8	2	SPI	16-lead TSSOP	>10 MHz BW, ±10 V signals
AD5433	10	1	Parallel	20-lead TSSOP, 20-lead LFCSP	>10 MHz BW, ±10 V signals
AD5432	10	1	SPI	10-lead MSOP	>10 MHz BW, ±10 V signals
AD5451	10	1	SPI	8-lead SOT-23	Small SOT-23 package; pin- and software-compatible family
AD5439	10	2	SPI	16-lead TSSOP	>10 MHz BW, ±10 V signals
AD5440	10	2	Parallel	24-lead TSSOP	>10 MHz BW, ±10 V signals
AD5445	12	1	Parallel	20-lead TSSOP, 20-lead LFCSP	>10 MHz BW, ±10 V signals
AD5443	12	1	SPI	10-lead MSOP	>10 MHz BW, ±10 V signals
AD5452	12	1	SPI	8-lead SOT-23, 8-lead MSOP	12 MHz BW, small SOT-23 package; pin- and software-compatible family
DAC8043A	12	1	SPI	8-lead TSSOP	>2 MHz bandwidth; see AD5443, also AD5452 and AD5444
AD5441	12	1	SPI	8-lead LFCSP, 8-lead MSOP	Low noise, 1 LSB, 1 μs settling time, LDAC pin, upgrade to DAC8043A
AD5444	12	1	SPI	10-lead MSOP	Higher accuracy version of AD5443; see also AD5452
AD5447	12	2	Parallel	24-lead TSSOP	>10 MHz BW, ±10 V signals
AD5405	12	2	Parallel	40-lead LFCSP	>10 MHz BW, ±10 V signals, uncommitted resistors
AD5449	12	2	SPI	16-lead TSSOP	>10 MHz BW, ±10 V signals
AD5415	12	2	SPI	24-lead TSSOP	>10 MHz BW, ±10 V signals, uncommitted resistors
AD5556	14	1	Parallel	28-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5453	14	1	SPI	8-lead SOT-23, 8-lead MSOP	Small SOT-23 package; pin- and software-compatible family
AD5553	14	1	SPI	8-lead MSOP, 8-lead SOIC_N	4 MHz BW, ±15 V signals
AD5446	14	1	SPI	10-lead MSOP	MSOP version of AD5453; compatible with AD5443, AD5432, and AD5426
AD5557	14	2	Parallel	38-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5555	14	2	SPI	16-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5554	14	4	SPI	28-lead SOP	±1 LSB, 12 MHz BW, ±15 V signals
AD5546/ AD5546A	16	1	Parallel	28-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5543	16	1	SPI	8-lead MSOP, 8-lead SOIC_N	±1 LSB, 6 MHz BW, ±15 V signals
AD5547	16	2	Parallel	38-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5545	16	2	SPI	16-lead TSSOP	±1 LSB, 6 MHz BW, ±15 V signals
AD5544	16	4	SPI	28-lead SSOP, 32-lead LFCSP	±1 LSB, 12 MHz BW, ±15 V signals

Op Amp Selection

The performance of a multiplying DAC solution is strongly dependent on the selected op amp to perform the current-to-voltage conversion. In order to maintain the dc accuracy of the signal, it is important to select an op amp with low bias current and low offset voltage so as not to swamp the minimum resolution of the DAC's output. More detail on this is included in the multiplying DAC's data sheet.

For applications where a relatively high speed ac or arbitrary signal needs to be multiplied, a high bandwidth/high slew rate op amp is required to prevent the op amp from degrading the output signal. The gain bandwidth product of an op amp will be limited by the feedback load it sees with the feedback resistor. To determine what GBW is required, the user needs to be conscious of the gain configuration. The higher the gain, the lower the bandwidth. As a rule of thumb, a bandwidth of 10 times the desired frequency for a gain configuration of –1 is generally sufficient.

The slew rate of the op amp is another specification that can limit the multiplying DAC if careful consideration is not given. As a rule of thumb, for the AD54xx and AD55xx family of DACs, an op amp with a slew rate of 100 V/μs is generally sufficient.

The selection tables below list operational amplifiers that can be used for multiplying applications.

Suitable Op Amps for High Precision Applications

Part Number	Supply Voltage (V)	V_{OS} Maximum (μV)	I_B Maximum (nA)	0.1 Hz to 10 Hz Noise (μV p-p)	Supply Current (μA)	Package
OP97	±2 to ±20	25	0.1	0.5	600	8-lead SOIC, 8-lead PDIP
OP1177	±2.5 to ±15	60	2	0.4	500	8-lead MSOP, 8-lead SOIC
AD8675	±5 to ±18	75	2	0.1	2300	8-lead MSOP, 8-lead SOIC
AD8671	±5 to ±15	75	12	0.077	3000	8-lead MSOP, 8-lead SOIC
ADA4004-1	±5 to ±15	125	90	0.1	2000	8-lead SOIC, 5-lead SOT-23
AD8607	1.8 to 5	50	0.001	2.3	40	8-lead MSOP, 8-lead SOIC
AD8605	2.7 to 5	65	0.001	2.3	1000	5-lead WLCSP, 5-lead SOT-23
AD8615	2.7 to 5	65	0.001	2.4	2000	5-lead TSOT
AD8616	2.7 to 5	65	0.001	2.4	2000	8-lead MSOP, 8-lead SOIC

Suitable Op Amps for High Speed Applications

Part Number	Supply Voltage (V)	–3 dB BW (MHz)	Slew Rate (V/μs)	V_{OS} Max (μV)	I_B Max (nA)	Package
AD8065	5 to 24	145	180	1500	0.006	8-lead SOIC, 5-lead SOT-23
AD8066	5 to 24	145	180	1500	0.006	8-lead SOIC, 8-lead MSOP
AD8021	5 to 24	490	120	1000	10,500	8-lead SOIC, 8-lead MSOP
AD8038	3 to 12	350	425	3000	750	8-lead SOIC, 5-lead SC70
ADA4899	5 to 12	600	310	35	100	8-lead LFCSP, 8-lead SOIC
AD8057	3 to 12	325	1000	5000	500	5-lead SOT-23, 8-lead SOIC
AD8058	3 to 12	325	850	5000	500	8-lead SOIC, 8-lead MSOP
AD8061	2.7 to 8	320	650	6000	350	5-lead SOT-23, 8-lead SOIC
AD8062	2.7 to 8	320	650	6000	350	8-lead SOIC, 8-lead MSOP
AD9631	±3 to ±6	320	1300	10,000	7000	8-lead SOIC, 8-lead PDIP

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