1.6 V, Micropower 12-/10-/8-Bit ADCs in 6-Lead SOT-23

AD7466/AD7467/AD7468*

FEATURES

Specified for V_{DD} of 1.6 V to 3.6 V
Low Power:
- **0.62 mW Typ at 100 kSPS with 3 V Supplies**
- **0.48 mW Typ at 50 kSPS with 3.6 V Supplies**
- **0.12 mW Typ at 100 kSPS with 1.6 V Supplies**

Fast Throughput Rate: 200 kSPS
Wide Input Bandwidth:
- **71 dB SNR at 30 kHz Input Frequency**

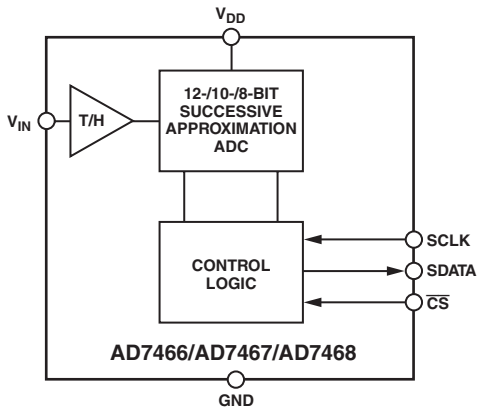
Flexible Power/Serial Clock Speed Management
No Pipeline Delays
High Speed Serial Interface
- **SPI®/QSPI™/MICROWIRE™/DSP Compatible**

Automatic Power Down
Power-Down Mode: 8 nA Typ
6-Lead SOT-23 Package
8-Lead MSOP Package

APPLICATIONS

Battery-Powered Systems
Medical Instruments
Remote Data Acquisition
Isolated Data Acquisition

FUNCTIONAL BLOCK DIAGRAM



GENERAL DESCRIPTION

The AD7466/AD7467/AD7468 are 12-/10-/8-bit, high speed, low power, successive approximation ADCs, respectively. The parts operate from a single 1.6 V to 3.6 V power supply and feature throughput rates up to 200 kSPS. The parts contain a low noise, wide bandwidth track-and-hold amplifier that can handle input frequencies in excess of 3 MHz.

The conversion process and data acquisition are controlled using $\overline{CS}$ and the serial clock, allowing the devices to interface with microprocessors or DSPs. The input signal is sampled on the falling edge of $\overline{CS}$, and the conversion is also initiated at this point. There are no pipeline delays associated with the part.

The AD7466/AD7467/AD7468 use advanced design techniques to achieve very low power dissipation at high throughput rates.

The reference for the part is taken internally from V_{DD}. This allows the widest dynamic input range to the ADC. Thus, the analog input range for the part is 0 V to V_{DD}. The conversion rate is determined by the SCLK.

PRODUCT HIGHLIGHTS

1. Specified for supply voltages of 1.6 V to 3.6 V.
2. 12-/10-/8-Bit ADCs in a SOT-23 package.
3. High throughput rate with low power consumption. Power consumption in normal mode of operation at 100 kSPS and 3 V is 0.9 mW max.
4. Flexible power/serial clock speed management. The conversion rate is determined by the serial clock, allowing the conversion time to be reduced through the serial clock speed increase. Automatic power-down after conversion allows the average power consumption to be reduced when in power-down. Current consumption is 0.1 μA max and 8 nA typically when in power-down.
5. Reference derived from the power supply.
6. No pipeline delay. The part features a standard successive approximation ADC with accurate control of the conversions via a $\overline{CS}$ input.

*Patent pending

REV. 0

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AD7466–SPECIFICATIONS[1] (V_{DD} = 1.6 V to 3.6 V, f_{SCLK} = 3.4 MHz, f_{SAMPLE} = 100 kSPS, unless otherwise noted; $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.)

Parameter	B Version	Unit	Test Conditions/Comments
DYNAMIC PERFORMANCE			f_{IN} = 30 kHz sine wave
Signal-to-Noise + Distortion (SINAD)[2]	69	dB min	1.8 V ≤ V_{DD} ≤ 2 V
	70	dB min	2.5 V ≤ V_{DD} ≤ 3.6 V
	70	dB typ	V_{DD} = 1.6 V
Signal-to-Noise Ratio (SNR)[2]	70	dB min	1.8 V ≤ V_{DD} ≤ 2 V
	71	dB typ	1.8 V ≤ V_{DD} ≤ 2 V
	71	dB min	2.5 V ≤ V_{DD} ≤ 3.6 V
	70.5	dB typ	V_{DD} = 1.6 V
Total Harmonic Distortion (THD)[2]	–83	dB typ	
Peak Harmonic or Spurious Noise (SFDR)[2]	–85	dB typ	
Intermodulation Distortion (IMD)[2]			fa = 29.1 kHz, fb = 29.9 kHz
Second Order Terms	–84	dB typ	
Third Order Terms	–86	dB typ	
Aperture Delay	10	ns typ	
Aperture Jitter	40	ps typ	
Full Power Bandwidth	3.2	MHz typ	@ 3 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	1.9	MHz typ	@ 3 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V
	750	kHz typ	@ 0.1 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	450	kHz typ	@ 0.1 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V
DC ACCURACY			Maximum specifications apply as typical figures when V_{DD} = 1.6 V
Resolution	12	Bits	
Integral Nonlinearity[2]	±1.5	LSB max	
Differential Nonlinearity[2]	–0.9/+1.5	LSB max	Guaranteed no missed codes to 12 bits
Offset Error[2]	±1	LSB max	
Gain Error[2]	±1	LSB max	
Total Unadjusted Error (TUE)[2]	±2	LSB max	
ANALOG INPUT			
Input Voltage Ranges	0 to V_{DD}	V	
DC Leakage Current	±1	μA max	
Input Capacitance	20	pF typ	
LOGIC INPUTS			
Input High Voltage, V_{INH}	0.7 × V_{DD}	V min	1.6 V ≤ V_{DD} < 2.7 V
	2	V min	2.7 V ≤ V_{DD} ≤ 3.6 V
Input Low Voltage, V_{INL}	0.2 × V_{DD}	V max	1.6 V ≤ V_{DD} < 1.8 V
	0.3 × V_{DD}	V max	1.8 V ≤ V_{DD} < 2.7 V
	0.8	V max	2.7 V ≤ V_{DD} ≤ 3.6 V
Input Current, I_{IN}, $\overline{\text{SCLK}}$ Pin	±1	μA max	Typically 20 nA, V_{IN} = 0 V or V_{DD}
Input Current, I_{IN}, $\overline{\text{CS}}$ Pin	±1	μA typ	
Input Capacitance, C_{IN}[3]	10	pF max	
LOGIC OUTPUTS			
Output High Voltage, V_{OH}	V_{DD} – 0.2	V min	I_{SOURCE} = 200 μA; V_{DD} = 1.6 V to 3.6 V
Output Low Voltage, V_{OL}	0.2	V max	I_{SINK} = 200 μA
Floating-State Leakage Current	±1	μA max	
Floating-State Output Capacitance[3]	10	pF max	
Output Coding	Straight (Natural) Binary		
CONVERSION RATE			
Conversion Time	4.70	μs max	16 SCLK cycles with SCLK at 3.4 MHz
Throughput Rate	200	kSPS max	See Serial Interface section

AD7466–SPECIFICATIONS[1] (continued)

Parameter	B Version	Unit	Test Conditions/Comments
POWER REQUIREMENTS			
V_{DD}	1.6/3.6	V min/max	
I_{DD}			Digital I/Ps = 0 V or V_{DD}
Normal Mode (Operational)[4]	300	µA max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	110	µA typ	V_{DD} = 3 V, f_{SAMPLE} = 50 kSPS
	20	µA typ	V_{DD} = 3 V, f_{SAMPLE} = 10 kSPS
	240	µA max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	80	µA typ	V_{DD} = 2.5 V, f_{SAMPLE} = 50 kSPS
	16	µA typ	V_{DD} = 2.5 V, f_{SAMPLE} = 10 kSPS
	165	µA max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
	50	µA typ	V_{DD} = 1.8 V, f_{SAMPLE} = 50 kSPS
	10	µA typ	V_{DD} = 1.8 V, f_{SAMPLE} = 10 kSPS
Power-Down	0.1	µA max	SCLK on or off, typically 8 nA
Power Dissipation[5]			
Normal Mode (Operational)	0.9	mW max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	0.6	mW max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	0.3	mW max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
Power-Down	0.3	µW max	V_{DD} = 3 V

NOTES
[1]Temperature range for B Version –40°C to +85°C.
[2]See Terminology section.
[3]Sample tested at 25°C to ensure compliance.
[4]See TPC 10.
[5]See Power Consumption section.

Specifications subject to change without notice.

AD7467–SPECIFICATIONS[1] (V_{DD} = 1.6 V to 3.6 V, f_{SCLK} = 3.4 MHz, f_{SAMPLE} = 100 kSPS, unless otherwise noted; $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.)

Parameter	B Version	Unit	Test Conditions/Comments
DYNAMIC PERFORMANCE			Maximum/minimum specifications apply as typical figures when V_{DD} = 1.6 V f_{IN} = 30 kHz sine wave
Signal-to-Noise + Distortion (SINAD)[2]	61	dB min	
Total Harmonic Distortion (THD)[2]	–72	dB max	
Peak Harmonic or Spurious Noise (SFDR)[2]	–74	dB max	
Intermodulation Distortion (IMD)[2]			fa = 29.1 kHz, fb = 29.9 kHz
Second Order Terms	–83	dB typ	
Third Order Terms	–83	dB typ	
Aperture Delay	10	ns typ	
Aperture Jitter	40	ps typ	
Full Power Bandwidth	3.2	MHz typ	@ 3 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	1.9	MHz typ	@ 3 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V
	750	kHz typ	@ 0.1 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	450	kHz typ	@ 0.1 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V
DC ACCURACY			Maximum specifications apply as typical figures when V_{DD} = 1.6 V.
Resolution	10	Bits	
Integral Nonlinearity[2]	±0.5	LSB max	
Differential Nonlinearity[2]	±0.5	LSB max	Guaranteed no missed codes to 10 bits
Offset Error[2]	±0.2	LSB max	
Gain Error[2]	±0.2	LSB max	
Total Unadjusted Error (TUE)[2]	±1	LSB max	
ANALOG INPUT			
Input Voltage Ranges	0 to V_{DD}	V	
DC Leakage Current	±1	µA max	
Input Capacitance	20	pF typ	

AD7467–SPECIFICATIONS[1] (continued)

Parameter	B Version	Unit	Test Conditions/Comments
LOGIC INPUTS			
Input High Voltage, V_{INH}	$0.7 \times V_{DD}$	V min	$1.6\ V \le V_{DD} < 2.7\ V$
	2	V min	$2.7\ V \le V_{DD} \le 3.6\ V$
Input Low Voltage, V_{INL}	$0.2 \times V_{DD}$	V max	$1.6\ V \le V_{DD} < 1.8\ V$
	$0.3 \times V_{DD}$	V max	$1.8\ V \le V_{DD} < 2.7\ V$
	0.8	V max	$2.7\ V \le V_{DD} \le 3.6\ V$
Input Current, I_{IN}, SCLK Pin	±1	μA max	Typically 20 nA, V_{IN} = 0 V or V_{DD}
Input Current, I_{IN}, $\overline{CS}$ Pin	±1	μA typ	
Input Capacitance, C_{IN}[3]	10	pF max	
LOGIC OUTPUTS			
Output High Voltage, V_{OH}	$V_{DD} - 0.2$	V min	I_{SOURCE} = 200 μA; V_{DD} = 1.6 V to 3.6 V
Output Low Voltage, V_{OL}	0.2	V max	I_{SINK} = 200 μA
Floating-State Leakage Current	±1	μA max	
Floating-State Output Capacitance[3]	10	pF max	
Output Coding	Straight (Natural) Binary		
CONVERSION RATE			
Conversion Time	3.52	μs max	12 SCLK cycles with SCLK at 3.4 MHz
Throughput Rate	275	kSPS max	See Serial Interface section
POWER REQUIREMENTS			
V_{DD}	1.6/3.6	V min/max	
I_{DD}			Digital I/Ps = 0 V or V_{DD}
Normal Mode (Operational)	210	μA max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	170	μA max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	140	μA max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
Power-Down	0.1	μA max	SCLK on or off, typically 8 nA
Power Dissipation[4]			
Normal Mode (Operational)	0.63	mW max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	0.42	mW max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	0.25	mW max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
Power-Down	0.3	μW max	V_{DD} = 3 V

NOTES
[1]Temperature range for B Version –40°C to +85°C.
[2]See Terminology section.
[3]Sample tested at 25°C to ensure compliance.
[4]See Power Consumption section.

Specifications subject to change without notice.

AD7468–SPECIFICATIONS[1] (V_{DD} = 1.6 V to 3.6 V, f_{SCLK} = 3.4 MHz, f_{SAMPLE} = 100 kSPS, unless otherwise noted; $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.)

Parameter	B Version	Unit	Test Conditions/Comments
DYNAMIC PERFORMANCE			Maximum/minimum specifications apply as typical figures when V_{DD} = 1.6 V f_{IN} = 30 kHz sine wave
Signal-to-Noise + Distortion (SINAD)[2]	49	dB min	
Total Harmonic Distortion (THD)[2]	–66	dB max	
Peak Harmonic or Spurious Noise (SFDR)[2]	–66	dB max	
Intermodulation Distortion (IMD)[2]			fa = 29.1 kHz, fb = 29.9 kHz
Second Order Terms	–77	dB typ	
Third Order Terms	–77	dB typ	
Aperture Delay	10	ns typ	
Aperture Jitter	40	ps typ	
Full Power Bandwidth	3.2	MHz typ	@ 3 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	1.9	MHz typ	@ 3 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V
	750	kHz typ	@ 0.1 dB, 2.5 V ≤ V_{DD} ≤ 3.6 V
	450	kHz typ	@ 0.1 dB, 1.6 V ≤ V_{DD} ≤ 2.2 V

AD7468–SPECIFICATIONS[1] (continued)

Parameter	B Version	Unit	Test Conditions/Comments
DC ACCURACY			Maximum specifications apply as typical figures when V_{DD} = 1.6 V
Resolution	8	Bits	
Integral Nonlinearity[2]	±0.2	LSB max	
Differential Nonlinearity[2]	±0.2	LSB max	Guaranteed no missed codes to 8 bits
Offset Error[2]	±0.1	LSB max	
Gain Error[2]	±0.1	LSB max	
Total Unadjusted Error (TUE)[2]	±0.3	LSB max	
ANALOG INPUT			
Input Voltage Ranges	0 to V_{DD}	V	
DC Leakage Current	±1	µA max	
Input Capacitance	20	pF typ	
LOGIC INPUTS			
Input High Voltage, V_{INH}	0.7 × V_{DD}	V min	1.6 V ≤ V_{DD} < 2.7 V
	2	V min	2.7 V ≤ V_{DD} ≤ 3.6 V
Input Low Voltage, V_{INL}	0.2 × V_{DD}	V max	1.6 V ≤ V_{DD} < 1.8 V
	0.3 × V_{DD}	V max	1.8 V ≤ V_{DD} < 2.7 V
	0.8	V max	2.7 V ≤ V_{DD} ≤ 3.6 V
Input Current, I_{IN}, SCLK Pin	±1	µA max	Typically 20 nA, V_{IN} = 0 V or V_{DD}
Input Current, I_{IN}, $\overline{CS}$ Pin	±1	µA typ	
Input Capacitance, C_{IN}[3]	10	pF max	
LOGIC OUTPUTS			
Output High Voltage, V_{OH}	V_{DD} – 0.2	V min	I_{SOURCE} = 200 µA; V_{DD} = 1.6 V to 3.6 V
Output Low Voltage, V_{OL}	0.2	V max	I_{SINK} = 200 µA
Floating-State Leakage Current	±1	µA max	
Floating-State Output Capacitance[3]	10	pF max	
Output Coding	Straight (Natural) Binary		
CONVERSION RATE			
Conversion Time	2.94	µs max	10 SCLK cycles with SCLK at 3.4 MHz
Throughput Rate	320	kSPS max	See Serial Interface section
POWER REQUIREMENTS			
V_{DD}	1.6/3.6	V min/max	
I_{DD}			Digital I/Ps = 0 V or V_{DD}
Normal Mode (Operational)	190	µA max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	155	µA max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	120	µA max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
Power-Down	0.1	µA max	SCLK on or off, typically 8 nA
Power Dissipation[4]			
Normal Mode (Operational)	0.57	mW max	V_{DD} = 3 V, f_{SAMPLE} = 100 kSPS
	0.4	mW max	V_{DD} = 2.5 V, f_{SAMPLE} = 100 kSPS
	0.2	mW max	V_{DD} = 1.8 V, f_{SAMPLE} = 100 kSPS
Power-Down	0.3	µW max	V_{DD} = 3 V

NOTES
[1]Temperature range for B Version –40°C to +85°C.
[2]See Terminology section.
[3]Sample tested at 25°C to ensure compliance.
[4]See Power Consumption section.

Specifications subject to change without notice.

TIMING SPECIFICATIONS[1] (V_{DD} = 1.6 V to 3.6 V; $T_A = T_{MIN}$ to T_{MAX}, unless otherwise noted.)

Parameter	Limit at T_{MIN}, T_{MAX} AD7466/AD7467/AD7468	Unit	Description
f_{SCLK}[2]	3.4	MHz max	
	10	kHz min[3]	1.6 V ≤ V_{DD} ≤ 3 V
	20	kHz min[3]	V_{DD} = 3.3 V
	150	kHz min[3]	V_{DD} = 3.6 V
$t_{CONVERT}$	16 × t_{SCLK}		AD7466
	12 × t_{SCLK}		AD7467
	10 × t_{SCLK}		AD7468
Acquisition Time[4]			Acquisition time/power-up time from power-down
	780	ns max	V_{DD} = 1.6 V
	640	ns max	1.8 V ≤ V_{DD} ≤ 3.6 V
t_{QUIET}	10	ns min	Minimum quiet time required between bus relinquish and start of next conversion
t_1	10	ns min	Minimum $\overline{CS}$ pulsewidth
t_2[5]	55	ns min	$\overline{CS}$ to SCLK setup time
t_3[6]	55	ns max	Delay from $\overline{CS}$ until SDATA three-state disabled
t_4[6]	140	ns max	Data access time after SCLK falling edge
t_5	0.4 t_{SCLK}	ns min	SCLK low pulsewidth
t_6	0.4 t_{SCLK}	ns min	SCLK high pulsewidth
t_7[6]	10	ns min	SCLK to data valid hold time
t_8[7]	60	ns max	SCLK falling edge to SDATA three-state
	7	ns min	SCLK falling edge to SDATA three-state

NOTES

[1]Sample tested at 25°C to ensure compliance. All input signals are specified with tr = tf = 5 ns (10% to 90% of V_{DD}) and timed from a voltage level of 1.4 V.

[2]Mark/space ratio for the SCLK input is 40/60 to 60/40.

[3]Minimum f_{SCLK} at which specifications are guaranteed.

[4]See Terminology section. The acquisition time is the time required for the part to acquire a full-scale step input value within ±1 LSB or a 30 kHz ac input value within ±0.5 LSB.

[5]If V_{DD} = 1.6 V and f_{SCLK} = 3.4 MHz, t_2 has to be 192 ns minimum in order to meet the maximum figure for the acquisition time.

[6]Measured with the load circuit of Figure 1 and defined as the time required for the output to cross the V_{IH} or V_{IL} voltage.

[7]t_8 is derived from the measured time taken by the data outputs to change 0.5 V when loaded with the circuit of Figure 1. The measured number is then extrapolated back to remove the effects of charging or discharging the 50 pF capacitor. This means that the time, t_8, quoted in the timing characteristics is the true bus relinquish time of the part and is independent of the bus loading.

Specifications subject to change without notice.

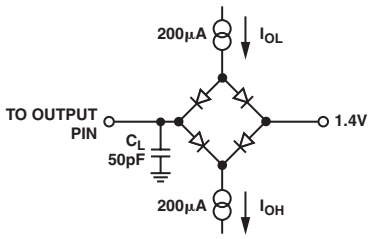


Figure 1. Load Circuit for Digital Output Timing Specifications

Figures 2 and 3 show some of the timing parameters from the Timing Specifications section.

Timing Example 1

From Figure 3, having f_{SCLK} = 3.4 MHz and a throughput of 100 kSPS gives a cycle time of $t_{CONVERT} + t_8 + t_{QUIET}$ = 10 µs. Assuming V_{DD} = 1.8 V, $t_{CONVERT} = t_2 + 15(1/f_{SCLK})$ = 55 ns + 4.41 µs = 4.46 µs, and t_8 = 60 ns max, then t_{QUIET} = 5.48 µs, which satisfies the requirement of 10 ns for t_{QUIET}. The part is fully powered up and the signal is fully acquired at Point A. This means that the acquisition/power-up time is $t_2 + 2(1/f_{SCLK})$ = 55 ns + 588 ns = 643 ns, satisfying the maximum requirement of 640 ns for the power-up time.

Timing Example 2

The AD7466 can also operate with slower clock frequencies. From Figure 3, assuming V_{DD} = 1.8 V, f_{SCLK} = 2 MHz, and a throughput of 50 kSPS gives a cycle time of $t_{CONVERT} + t_8 + t_{QUIET}$ = 20 µs. With $t_{CONVERT} = t_2 + 15(1/f_{SCLK})$ = 55 ns + 7.5 µs = 7.55 µs, and t_8 = 60 ns max, this leaves t_{QUIET} to be 12.39 µs, which satisfies the requirement of 10 ns for t_{QUIET}. The part is fully powered up and the signal is fully acquired at Point A, which means the acquisition/power-up time is $t_2 + 2(1/f_{SCLK})$ = 55 ns + 1 µs = 1.05 µs, satisfying the maximum requirement of 640 ns for the power-up time. As in this example and with other slower clock values, the part will be fully powered up and the signal will already be acquired before the third SCLK falling edge; however, the track-and-hold will not go into hold mode until that point. In this example, the part may be powered up and the signal may be fully acquired at approximately point B in Figure 3.

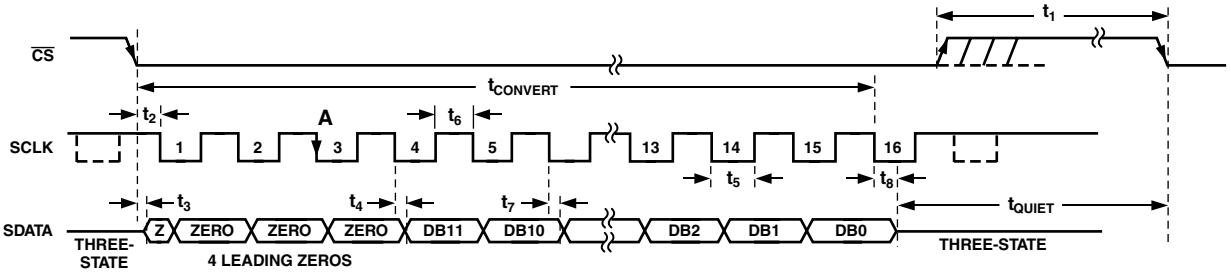


Figure 2. AD7466 Serial Interface Timing Diagram

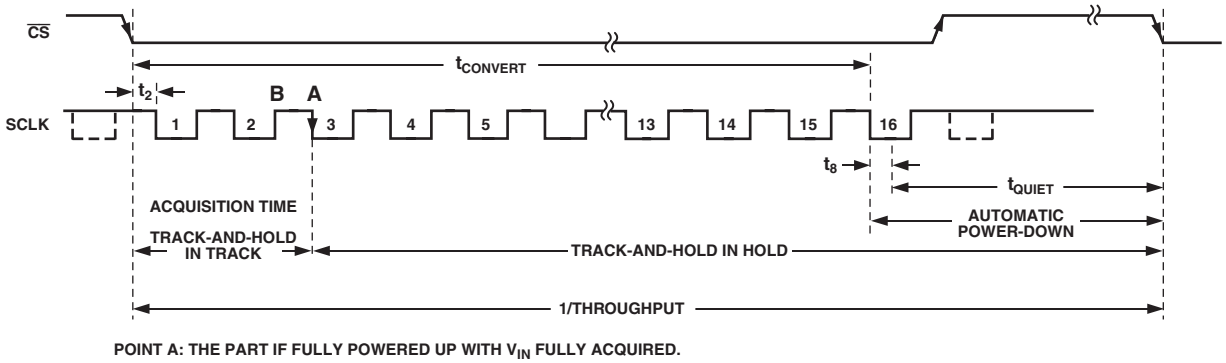


Figure 3. AD7466 Serial Interface Timing Example

ABSOLUTE MAXIMUM RATINGS[1]

(T_A = 25°C, unless otherwise noted.)

V_{DD} to GND . . . . . –0.3 V to +7 V
Analog Input Voltage to GND . . . . . –0.3 V to V_{DD} + 0.3 V
Digital Input Voltage to GND . . . . . –0.3 V to +7 V
Digital Output Voltage to GND . . . . . –0.3 V to V_{DD} + 0.3 V
Input Current to Any Pin Except Supplies[2] . . . . . ±10 mA
Operating Temperature Range
  Commercial (B Version) . . . . . –40°C to +85°C
  Storage Temperature Range . . . . . –65°C to +150°C
  Junction Temperature . . . . . +150°C
SOT-23 Package
  θ_{JA} Thermal Impedance . . . . . 229.6°C/W
  θ_{JC} Thermal Impedance . . . . . 91.99°C/W
MSOP Package
  θ_{JA} Thermal Impedance . . . . . 205.9°C/W
  θ_{JC} Thermal Impedance . . . . . 43.74°C/W
Lead Temperature, Soldering
  Vapor Phase (60 sec) . . . . . 215°C
  Infared (15 sec) . . . . . 220°C
ESD . . . . . 3.5 kV

NOTES
[1]Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those listed in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.
[2]Transient currents of up to 100 mA will not cause SCR latch-up.

ORDERING GUIDE

Model	Temperature Range	Linearity Error (LSB)[1]	Package Option[2]	Branding
AD7466BRT-REEL	–40°C to +85°C	±1.5 max	RT-6	CLB
AD7466BRT-REEL7	–40°C to +85°C	±1.5 max	RT-6	CLB
AD7466BRT-RL2	–40°C to +85°C	±1.5 max	RT-6	CLB
AD7466BRM	–40°C to +85°C	±1.5 max	RM-8	CLB
AD7466BRM-REEL	–40°C to +85°C	±1.5 max	RM-8	CLB
AD7466BRM-REEL7	–40°C to +85°C	±1.5 max	RM-8	CLB
AD7467BRT-REEL	–40°C to +85°C	±0.5 max	RT-6	CMB
AD7467BRT-REEL7	–40°C to +85°C	±0.5 max	RT-6	CMB
AD7467BRT-RL2	–40°C to +85°C	±0.5 max	RT-6	CMB
AD7467BRM	–40°C to +85°C	±0.5 max	RM-8	CMB
AD7467BRM-REEL	–40°C to +85°C	±0.5 max	RM-8	CMB
AD7467BRM-REEL7	–40°C to +85°C	±0.5 max	RM-8	CMB
AD7468BRT-REEL	–40°C to +85°C	±0.2 max	RT-6	CNB
AD7468BRT-REEL7	–40°C to +85°C	±0.2 max	RT-6	CNB
AD7468BRT-RL2	–40°C to +85°C	±0.2 max	RT-6	CNB
AD7468BRM	–40°C to +85°C	±0.2 max	RM-8	CNB
AD7468BRM-REEL	–40°C to +85°C	±0.2 max	RM-8	CNB
AD7468BRM-REEL7	–40°C to +85°C	±0.2 max	RM-8	CNB
EVAL-AD7466CB[3]			Evaluation Board	
EVAL-AD7467CB[3]			Evaluation Board	
EVAL-CONTROL BRD2[4]				

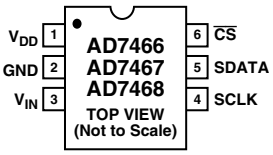
NOTES
[1]Linearity error here refers to integral nonlinearity.
[2]RT = SOT-23, RM = MSOP.
[3]This can be used as a standalone evaluation board or in conjunction with the EVAL-CONTROL BRD2 for evaluation/demonstration purposes.
[4]This board is a complete unit that allows a PC to control and communicate with all Analog Devices evaluation boards ending in the CB designator. To order a complete evaluation kit, you will need to order a particular ADC evaluation board, e.g., EVAL-AD7466CB, the EVAL-CONTROL BRD2, and a 12 V ac transformer. See relevant evaluation board technical note for more information.

CAUTION

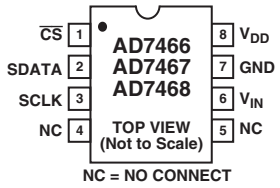
ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD7466/AD7467/AD7468 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION

6-Lead SOT-23



8-Lead MSOP



PIN FUNCTION DESCRIPTION

Mnemonic	Function
$\overline{CS}$	Chip Select. Active low logic input. This input provides the dual function of initiating conversions on the AD7466/AD7467/AD7468 and frames the serial data transfer.
V_{DD}	Power Supply Input. The V_{DD} range for the AD7466/AD7467/AD7468 is from 1.6 V to 3.6 V.
GND	Analog Ground. Ground reference point for all circuitry on the AD7466/AD7467/AD7468. All analog input signals should be referred to this GND voltage.
V_{IN}	Analog Input. Single-ended analog input channel. The input range is 0 V to V_{DD}.
SDATA	Data Out. Logic output. The conversion result from the AD7466/AD7467/AD7468 is provided on this output as a serial data stream. The bits are clocked out on the falling edge of the SCLK input. The data stream from the AD7466 consists of four leading zeros followed by the 12 bits of conversion data, provided MSB first. The data stream from the AD7467 consists of four leading zeros followed by the 10 bits of conversion data, provided MSB first. The data stream from the AD7468 consists of four leading zeros followed by the eight bits of conversion data, provided MSB first.
SCLK	Serial Clock. Logic input. SCLK provides the serial clock for accessing data from the part. This clock input is also used as the clock source for the AD7466/AD7467/AD7468's conversion process.
NC	No Connect.

TERMINOLOGY

Integral Nonlinearity (INL)
This is the maximum deviation from a straight line passing through the endpoints of the ADC transfer function. For the AD7466/AD7467/AD7468 the endpoints of the transfer function are zero scale, a point 1 LSB below the first code transition, and full scale, a point 1 LSB above the last code transition.

Differential Nonlinearity (DNL)
This is the difference between the measured and the ideal 1 LSB change between any two adjacent codes in the ADC.

Offset Error
This is the deviation of the first code transition (00 . . . 000) to (00 . . . 001) from the ideal, i.e., AGND + 1 LSB.

Gain Error
This is the deviation of the last code transition (111 . . . 110) to (111 . . . 111) from the ideal (i.e., VREF – 1 LSB) after the offset error has been adjusted out.

Track-and-Hold Acquisition Time
The track-and-hold acquisition time is the time required for the part to acquire a full-scale step input value within ±1 LSB or a 30 kHz ac input value within ±0.5 LSB. For the AD7466/AD7467/AD7468, the part enters track mode on the $\overline{CS}$ falling edge, and returns to hold mode on the third SCLK falling edge. The part remains in hold mode until the following $\overline{CS}$ falling edge. See Figure 3 and the Serial Interface section for more details.

Signal-to-Noise Ratio (SNR)
This is the measured ratio of signal to noise at the output of the A/D converter. The signal is the rms value of the sine wave input. Noise is the rms quantization error within the Nyquist bandwidth ($f_S/2$). The rms value of the sine wave is one half its peak-to-peak value divided by $\sqrt{2}$ and the rms value for the quantization noise is $q/\sqrt{12}$. The ratio is dependent on the number of quantization levels in the digitization process; the more levels, the smaller the quantization noise.

For an ideal N-bit converter, the *SNR* is defined as:

$$SNR = 6.02N + 1.76\ dB$$

Thus, for a 12-bit converter, this is 74 dB; for a 10-bit converter, it is 62 dB; and for an 8-bit converter, it is 50 dB.

Practically, though, various error sources in the ADC cause the measured SNR to be less than the theoretical value. These errors occur due to integral and differential nonlinearities, internal ac noise sources, and so on.

Signal-to-(Noise + Distortion) Ratio (SINAD)
This is the measured ratio of signal-to-(noise + distortion) at the output of the A/D converter. The signal is the rms value of the sine wave and noise is the rms sum of all nonfundamental signals up to half the sampling frequency ($f_S/2$), including harmonics, but excluding dc.

Total Unadjusted Error (TUE)
This is a comprehensive specification that includes gain error, linearity error, and offset error.

Total Harmonic Distortion (THD)
Total harmonic distortion is the ratio of the rms sum of harmonics to the fundamental. For the AD7466/AD7467/AD7468, it is defined as

$$THD\ (dB) = 20\log\frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + V_5^2 + V_6^2}}{V_1}$$

where V_1 is the rms amplitude of the fundamental, and V_2, V_3, V_4, V_5, and V_6 are the rms amplitudes of the second through sixth harmonics.

Peak Harmonic or Spurious Noise (SFDR)
Peak harmonic or spurious noise is the ratio of the rms value of the next largest component in the ADC output spectrum (up to $f_S/2$ and excluding dc) to the rms value of the fundamental. Normally, the value of this specification is determined by the largest harmonic in the spectrum, but for ADCs where the harmonics are buried in the noise floor, it will be a noise peak.

Intermodulation Distortion (IMD)
With inputs consisting of sine waves at two frequencies, fa and fb, any active device with nonlinearities will create distortion products at sum and difference frequencies of mfa ± nfb where m, n = 0, 1, 2, 3, and so on. Intermodulation distortion terms are those for which neither m nor n are equal to zero. For example, the second order terms include (fa + fb) and (fa – fb), while the third order terms include (2fa + fb), (2fa – fb), (fa + 2fb), and (fa – 2fb).

The AD7466/AD7467/AD7468 are tested using the CCIF standard where two input frequencies are used. In this case, the second order terms are usually distanced in frequency from the original sine waves, while the third order terms are usually at a frequency close to the input frequencies. As a result, the second and third order terms are specified separately. The calculation of the intermodulation distortion is as per the THD specification, where it is the ratio of the rms sum of the individual distortion products to the rms amplitude of the sum of the fundamentals, expressed in dBs.

PERFORMANCE CURVES

Dynamic Performance Curves

TPC 1, TPC 2, and TPC 3 show typical FFT plots for the AD7466, AD7467, and AD7468, respectively, at 100 kSPS sample rate and 30 kHz input tone.

TPC 4 shows the Signal-to-(Noise + Distortion) Ratio performance versus input frequency for various supply voltages while sampling at 100 kSPS with a SCLK frequency of 3.4 MHz for the AD7466.

TPC 5 shows the Signal-to-Noise Ratio (SNR) performance versus input frequency for various supply voltages while sampling at 100 kSPS with a SCLK frequency of 3.4 MHz for the AD7466.

TPC 6 shows a graph of the Total Harmonic Distortion versus analog input signal frequency for various supply voltages while sampling at 100 kSPS with a SCLK frequency of 3.4 MHz for the AD7466.

TPC 7 shows a graph of the Total Harmonic Distortion versus analog input frequency for different source impedances when using a supply voltage of 2.7 V, a SCLK frequency of 3.4 MHz, and sampling at a rate of 100 kSPS for the AD7466. See the Analog Input section.

DC Accuracy Curves

TPC 8 and TPC 9 show typical INL and DNL performance for the AD7466.

Power Requirements Curves

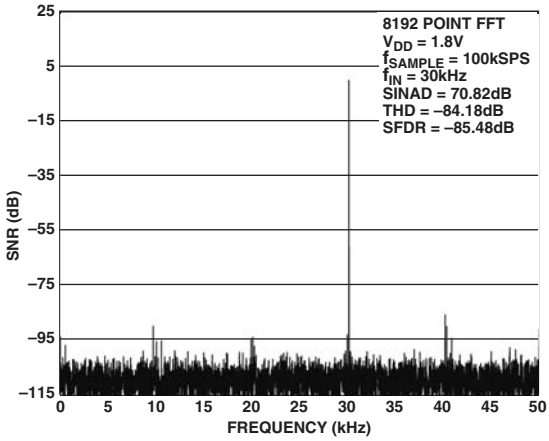
TPC 10 shows the supply current versus supply voltage for the AD7466 at –40°C, +25°C, and +85°C, with SCLK frequency of 3.4 MHz and a sampling rate of 100 kSPS.

TPC 11 shows the maximum current versus supply voltage for the AD7466 with different SCLK frequencies.

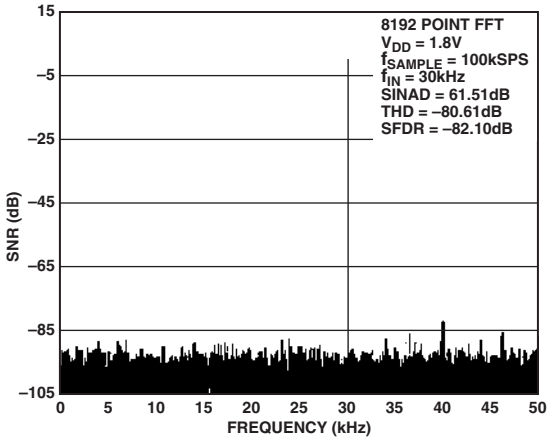
TPC 12 shows the shutdown current versus supply voltage.

TPC 13 shows the power consumption versus throughput rate for the AD7466 with a SCLK of 3.4 MHz and different supply voltages.

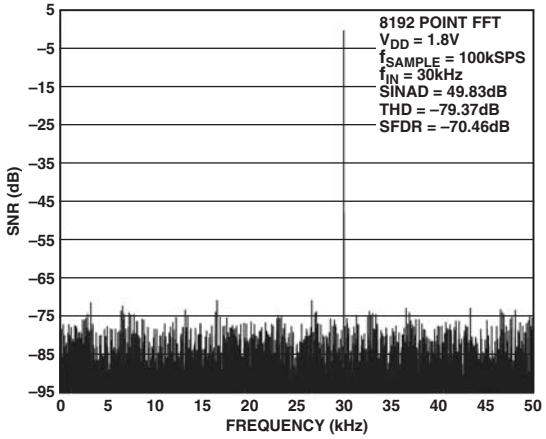
See the Power Consumption section for more details.



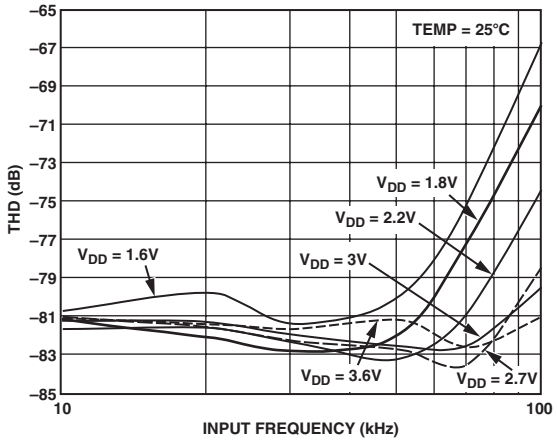
TPC 1. AD7466 Dynamic Performance at 100 kSPS



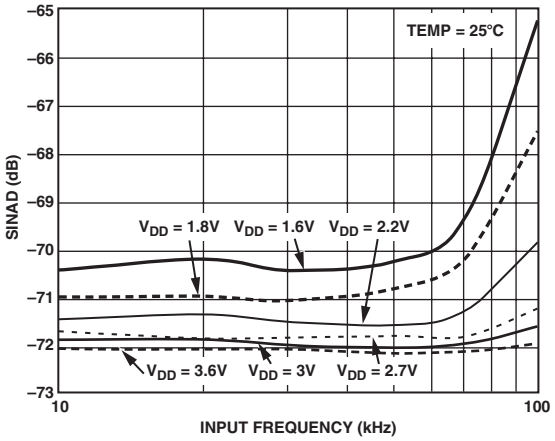
TPC 2. AD7467 Dynamic Performance at 100 kSPS



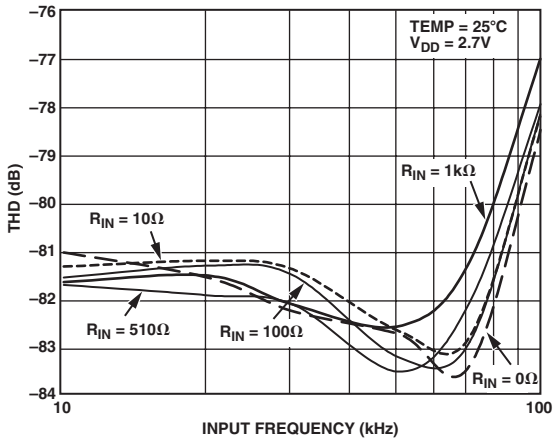
TPC 3. AD7468 Dynamic Performance at 100 kSPS



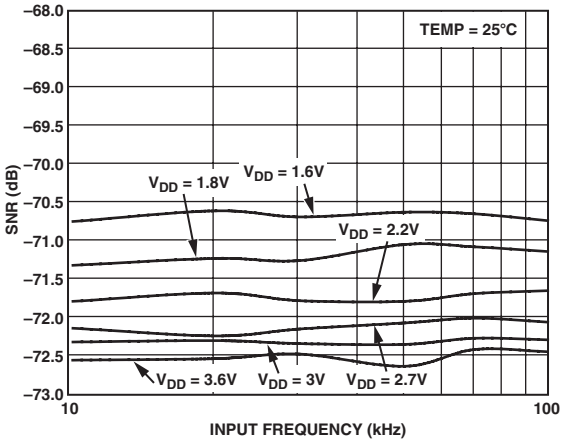
TPC 6. THD vs. Analog Input Frequency at 100 kSPS for Various Supply Voltages



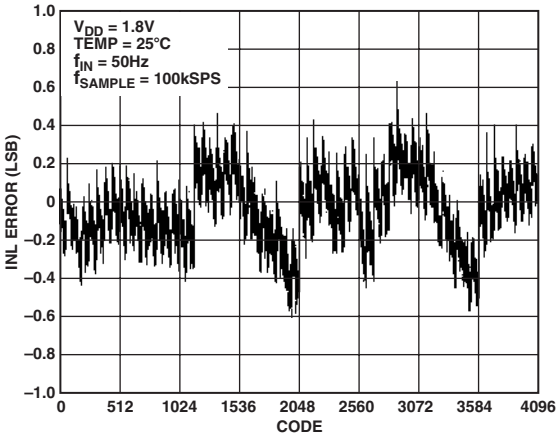
TPC 4. AD7466 SINAD vs. Analog Input Frequency at 100 kSPS for Various Supply Voltages



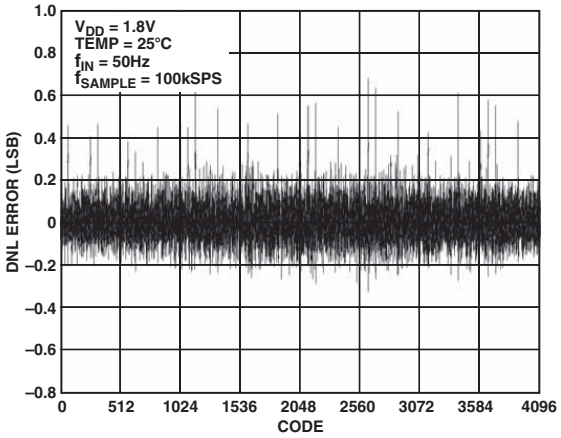
TPC 7. THD vs. Analog Input Frequency for Various Source Impedances



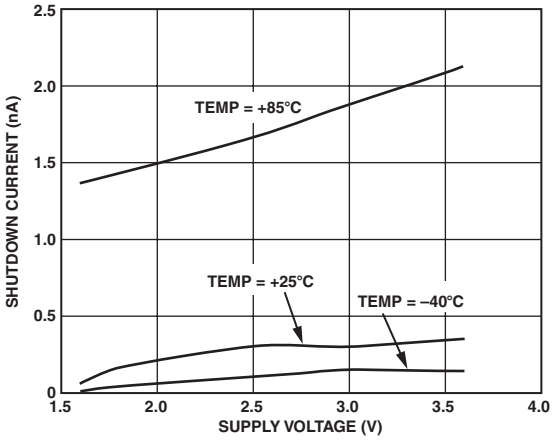
TPC 5. AD7466 SNR vs. Analog Input Frequency at 100 kSPS for Various Supply Voltages



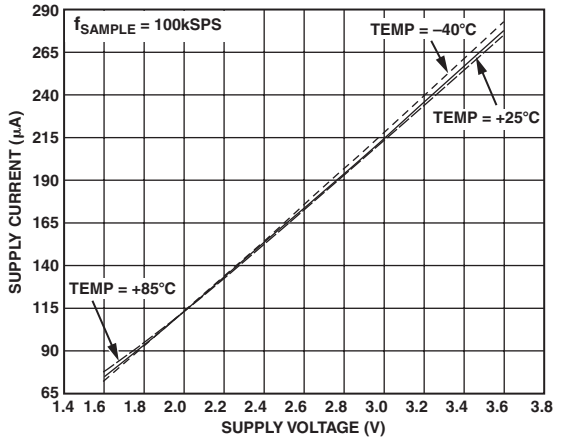
TPC 8. AD7466 INL Performance



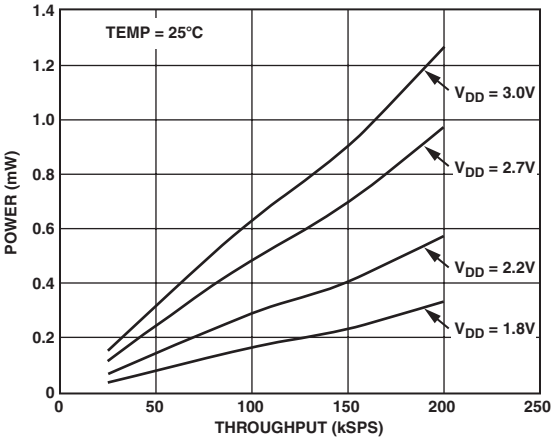
TPC 9. AD7466 DNL Performance



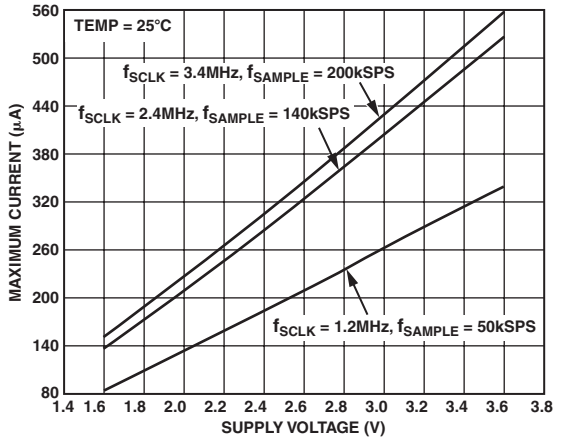
TPC 12. Shutdown Current vs. Supply Voltage



TPC 10. Supply Current vs. Supply Voltage, SCLK 3.4 MHz



TPC 13. Power Consumption vs. Throughput Rate, SCLK 3.4 MHz



TPC 11. Maximum Current vs. Supply Voltage, for Different SCLK Frequencies

CIRCUIT INFORMATION

The AD7466/AD7467/AD7468 are fast, micropower, 12-/10-/8-bit, A/D converters respectively. The parts can be operated from a 1.6 V to 3.6 V supply. When operated from any supply voltage within this range, the AD7466/AD7467/AD7468 are capable of throughput rates of 200 kSPS when provided with a 3.4 MHz clock.

The AD7466/AD7467/AD7468 provide the user with an on-chip track-and-hold, an A/D converter, and a serial interface housed in a tiny 6-lead SOT-23 or 8-lead MSOP package, which offer the user considerable space savings advantages over alternative solutions. The serial clock input accesses data from the part but also provides the clock source for the successive approximation A/D converter. The analog input range is 0 V to V_{DD}. An external reference is not required for the ADC and there is no on-chip reference. The reference for the AD7466/AD7467/AD7468 is derived from the power supply, thus giving the widest possible dynamic input range.

The AD7466/AD7467/AD7468 also features an Automatic Power-Down mode option to allow power savings between conversions. The power-down feature is implemented across the standard serial interface, as described in the Mode of Operation section.

CONVERTER OPERATION

The AD7466/AD7467/AD7468 is a successive approximation analog-to-digital converter based around a charge redistribution DAC. Figures 4 and 5 show simplified schematics of the ADC. Figure 4 shows the ADC during its acquisition phase. SW2 is closed and SW1 is in position A, the comparator is held in a balanced condition, and the sampling capacitor acquires the signal on V_{IN}.

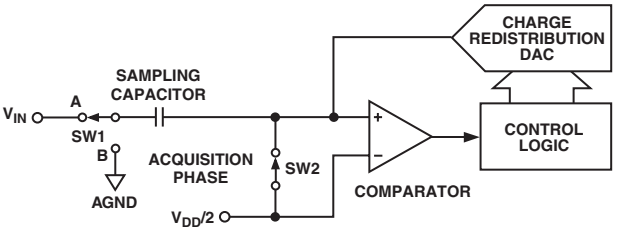


Figure 4. ADC Acquisition Phase

When the ADC starts a conversion (see Figure 5), SW2 will open and SW1 will move to Position B, causing the comparator to become unbalanced. The control logic and the charge redistribution DAC are used to add and subtract fixed amounts of charge from the sampling capacitor to bring the comparator back into a balanced condition. When the comparator is rebalanced, the conversion is complete. The control logic generates the ADC output code. Figure 6 shows the ADC transfer function.

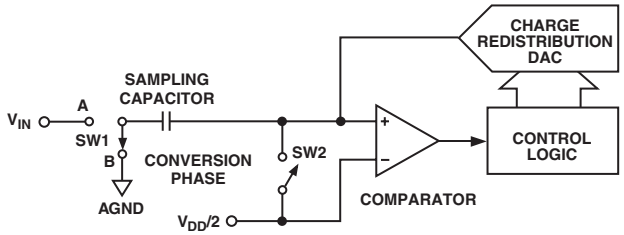


Figure 5. ADC Conversion Phase

ADC TRANSFER FUNCTION

The output coding of the AD7466/AD7467/AD7468 is straight binary. The designed code transitions occur at successive integer LSB values (i.e., 1 LSB, 2 LSB, and so on). The LSB size is $V_{DD}/4096$ for the AD7466, $V_{DD}/1024$ for the AD7467, and $V_{DD}/256$ for the AD7468. The ideal transfer characteristic for the AD7466/AD7467/AD7468 is shown in Figure 6.

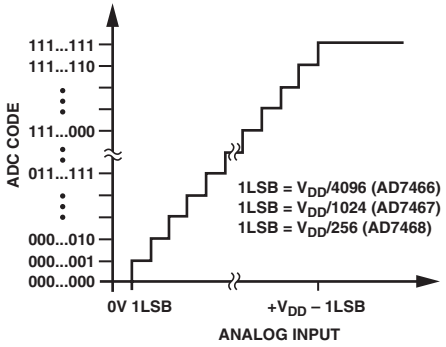


Figure 6. AD7466/AD7467/AD7468 Transfer Characteristic

TYPICAL CONNECTION DIAGRAM

Figure 7 shows a typical connection diagram for the AD7466/AD7467/AD7468. V_{REF} is taken internally from V_{DD} and therefore V_{DD} should be well decoupled. This provides an analog input range of 0 V to V_{DD}.

The conversion result consists of four leading zeros followed by the MSB of the 12-bit, 10-bit, or 8-bit result from the AD7466, AD7467, or AD7468, respectively. See the Serial Interface section. Alternatively, because the supply current required by the AD7466/AD7467/AD7468 is so low, a precision reference can be used as the supply source to the AD7466/AD7467/AD7468.

The REF19x series devices are precision micropower, low dropout voltage references. For the AD7466/AD7467/AD7468 voltage range operation, the REF193, REF192 , and REF191 can be used to supply the required voltage to the ADC delivering 3 V, 2.5 V, and 2.048 V, respectively (see Figure 7). This configuration is especially useful if the power supply is quite noisy or if the system supply voltages are at some value other than 3 V or 2.5 V (e.g., 5 V). The REF19x will output a steady voltage to the AD7466/AD7467/AD7468. If the low dropout REF192 is used, when the AD7466 is converting at a rate of 100 kSPS, the REF192 will need to supply a maximum of 240 μA to the AD7466. The load regulation of the REF192 is typically 10 ppm/mA (REF192, V_S = 5 V), which results in an error of 2.4 ppm (6 μV) for the 240 μA drawn from it. This corresponds to a 0.0098 LSB error for the AD7466 with V_{DD} = 2.5 V from the REF192. For applications where power consumption is important, the automatic power-down mode of the ADC and the sleep mode of the REF19x reference should be used to improve power performance. See the Mode of Operation section.

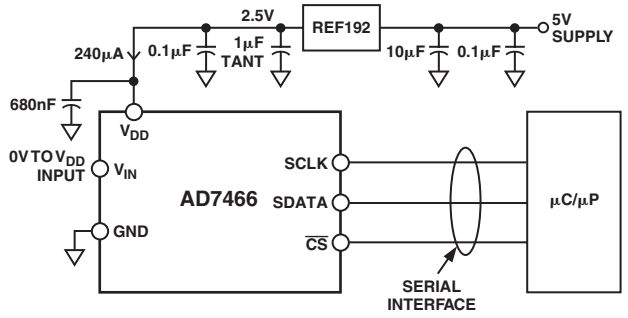


Figure 7. REF192 as Power Supply to AD7466

Table I provides some typical performance data with various references used as a V_{DD} source under the same setup conditions. The ADR318, for instance, is a 1.8 V band gap voltage reference. Its tiny footprint, low power consumption, and the additional shutdown capability make the ADR318 ideal for battery-powered applications.

Table I. AD7466 Performance for Various Voltage Reference ICs

Reference Tied to V_{DD}	AD7466 SNR Performance (dB)
ADR318 @ 1.8 V	70.73
ADR370 @ 2.048 V	70.72
ADR421 @ 2.5 V	71.13
ADR423 @ 3 V	71.44

Analog Input

Figure 8 shows an equivalent circuit of the AD7466/AD7467/AD7468 analog input structure. The two diodes, D1 and D2, provide ESD protection for the analog inputs. Care must be taken to ensure that the analog input signal never exceeds the supply rails by more than 300 mV. This will cause these diodes to become forward biased and start conducting current into the substrate. Capacitor C1 in Figure 8 is typically about 4 pF and can primarily be attributed to pin capacitance. The resistor R1 is a lumped component made up of the on resistance of a switch. This resistor is typically about 200 Ω. The capacitor C2 is the ADC sampling capacitor and has a capacitance of 20 pF typically.

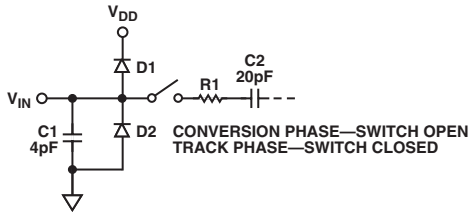


Figure 8. Equivalent Analog Input Circuit

For ac applications, removing high frequency components from the analog input signal by using band-pass filter on the relevant analog input pin is recommended. In applications where harmonic distortion and signal-to-noise ratio are critical, the analog input should be driven from a low impedance source. Large source impedances will significantly affect the ac performance of the ADC. This may necessitate the use of an input buffer amplifier. The choice of the op amp will be a function of the particular application.

Table II provides typical performance data for various op amps used as the input buffer under constant setup conditions.

Table II. AD7466 Performance for Various Input Buffers

Op Amp in the Input Buffer	AD7466 SNR Performance (dB) 30 kHz Input, V_{DD} = 1.8 V
AD8510	70.75
AD8610	71.45
AD797	71.42

When no amplifier is used to drive the analog input, the source impedance should be limited to low values. The maximum source impedance will depend on the amount of total harmonic distortion (THD) that can be tolerated. The THD will increase as the source impedance increases and performance will degrade. TPC 7 shows a graph of the total harmonic distortion versus analog input signal frequency for different source impedances when using a supply voltage of 2.7 V and sampling at a rate of 100 kSPS.

Digital Inputs

The digital inputs applied to the AD7466/AD7467/AD7468 are not limited by the maximum ratings that limit the analog inputs. Instead, the digital inputs applied can go to 7 V and are not restricted by the V_{DD} + 0.3 V limit as on the analog input. For example, if the AD7466/AD7467/AD7468 were operated with a V_{DD} of 3 V, 5 V logic levels could be used on the digital inputs. However, it is important to note that the data output on SDATA will still have 3 V logic levels when V_{DD} = 3 V. Another advantage of SCLK and $\overline{CS}$ not being restricted by the V_{DD} + 0.3 V limit is the fact that power supply sequencing issues are avoided. If $\overline{CS}$ or SCLK is applied before V_{DD}, there is no risk of latch-up as there would be on the analog inputs if a signal greater than 0.3 V were applied prior to V_{DD}.

MODE OF OPERATION

The AD7466/AD7467/AD7468 automatically enters power-down at the end of each conversion. This mode of operation is designed to provide flexible power management options and to optimize the power dissipation/throughput rate ratio for low power application requirements. Figure 9 shows the general diagram of the operation for the AD7466/AD7467/AD7468. On the $\overline{CS}$ falling edge, the part begins to power up and the track-and-hold, which was in hold while the part was in power down, will go into track mode. The conversion is also initiated at this point. On the third SCLK falling edge after the $\overline{CS}$ falling edge, the track-and-hold will return to hold mode.

For the AD7466, 16 serial clock cycles are required to complete the conversion and access the complete conversion result. The AD7466 will automatically enter power-down mode on the 16th SCLK falling edge.

For the AD7467, 14 serial clock cycles are required to complete the conversion and access the complete conversion result. The AD7467 will automatically enter power-down mode on the 14th SCLK falling edge.

For the AD7468, 12 serial clock cycles are required to complete the conversion and access the complete conversion result. The AD7468 will automatically enter power-down mode on the 12th SCLK falling edge.

The AD7466 will also enter power-down mode if $\overline{CS}$ is brought high any time before the 16th SCLK falling edge. The conversion that was initiated by the $\overline{CS}$ falling edge will be terminated and SDATA will go back into three-state. This also applies for the AD7467 and AD7468; if $\overline{CS}$ is brought high before the conversion is complete (the 14th SCLK falling edge for the AD7467 and the 12th SCLK falling edge for the AD7468), the part will enter power-down, the conversion will be terminated, and SDATA will go back into three-state.

Although $\overline{CS}$ may idle high or low between conversions, to save power, bringing $\overline{CS}$ high once the conversion is complete is recommended.

When supplies are first applied to the AD7466/AD7467/AD7468, a dummy conversion should be performed to ensure that the part is in power-down mode, the track-and-hold is in hold mode, and SDATA is in three-state.

Once a data transfer is complete (SDATA has returned to three-state), another conversion can be initiated after the quiet time, t_{QUIET}, has elapsed by bringing $\overline{CS}$ low again.

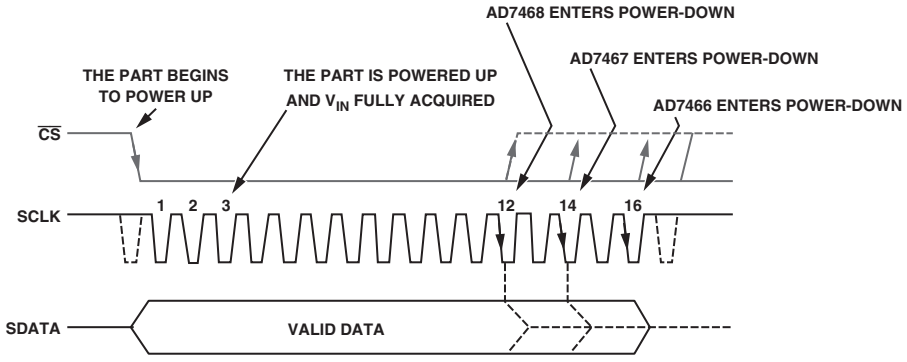


Figure 9. Normal Mode Operation

POWER CONSUMPTION

The AD7466/AD7467/AD7468 automatically enters power-down mode at the end of each conversion or if $\overline{CS}$ is brought high before the conversion is finished.

When the AD7466/AD7467/AD7468 is in power-down mode, all the analog circuitry is powered down and the current consumption is typically 8 nA.

To achieve the lowest power dissipation, there are some considerations the user should keep in mind.

The conversion time is determined by the serial clock frequency; the faster the SCLK frequency, the shorter the conversion time. This implies that as the frequency increases, the part will be dissipating power for a shorter period of time, when the conversion is taking place, and it will remain in power-down mode for a longer percentage of the cycle time or throughput rate.

Figure 11 shows two AD7466s running with two different SCLK frequencies, SCLK A and SCLK B, with SCLK A having the higher SCLK frequency. For the same throughput rate, the AD7466 using SCLK A will have a shorter conversion time than the AD7466 using SCLK B, and it will remain in power-down mode longer. The current consumption in power-down mode is very low; therefore, the average power consumption will be greatly reduced.

This can be seen in Figure 10, which shows the supply current versus SCLK frequency for various supply voltages at a throughput rate of 100 kSPS. For a fixed throughput rate, the supply current (average current) will drop as the SCLK frequency increases because the part will be in power-down mode most of the time. It can also be seen that for a lower supply voltage the supply current drops accordingly.

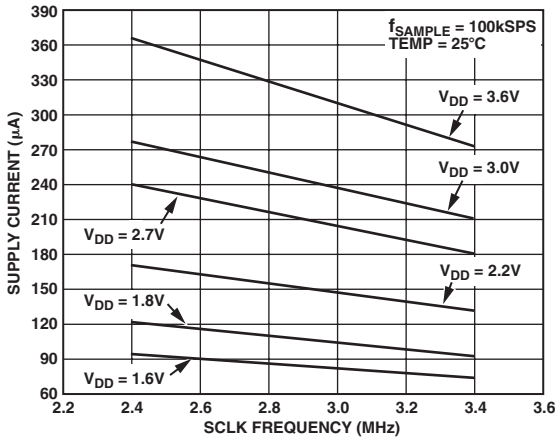


Figure 10. Supply Current vs. SCLK Frequency for a Fixed Throughput Rate and Different Supply Voltages

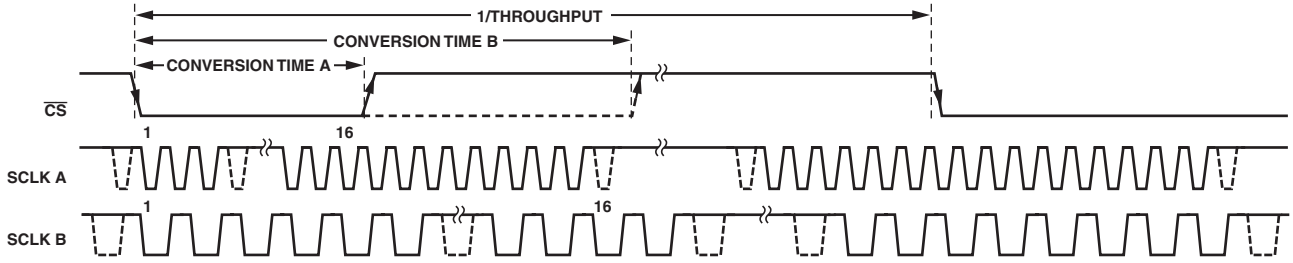


Figure 11. Conversion Time Comparison for Different SCLK Frequencies and a Fixed Throughput Rate

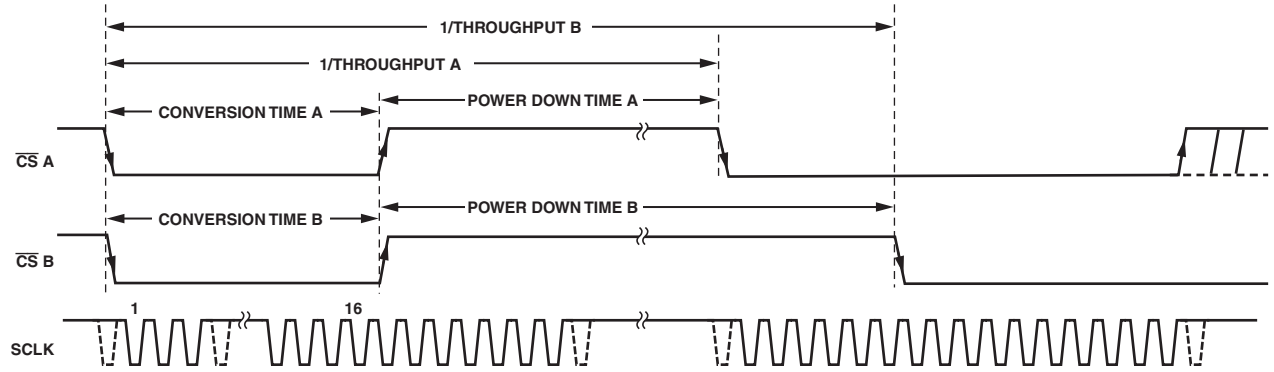


Figure 12. Conversion Time vs. Power-Down Time for a Fixed SCLK Frequency and Different Throughput Rates

TPC 13 shows power consumption versus throughput rate for a 3.4 MHz SCLK frequency. In this case, the conversion time will be the same for all cases because the SCLK frequency is a fixed parameter. Low throughput rates will lead to lower current consumptions, with a higher percentage of the time in power-down mode. Figure 12 shows two AD7466s running with the same SCLK frequency but at different throughput rates. The A throughput rate is higher than the B throughput rate. The slower the throughput rate, the longer the period of time the part will be in power-down mode, and the average power consumption will drop accordingly.

Figure 13 shows power versus throughput rate for different supply voltages and SCLK frequencies. For this plot, all the elements regarding power consumption that were explained previously (the influence of the SCLK frequency, the influence of the throughput rate, and the influence of the supply voltage) are taken into consideration.

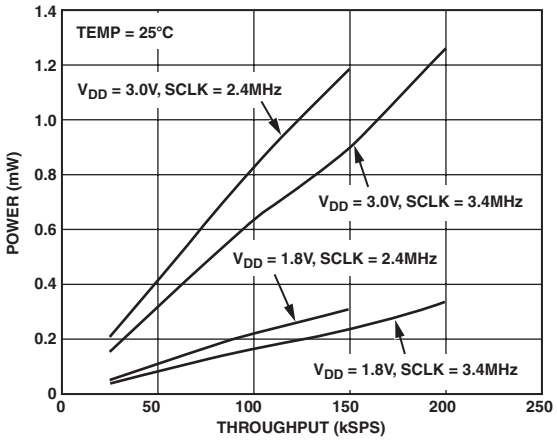


Figure 13. Power vs. Throughput Rate for Different SCLK and Supply Voltages

The following two examples illustrate through calculations what has been explained in this section.

Power Consumption Example 1
This example shows that for a fixed throughput rate, as the SCLK frequency increases, the average power consumption drops. From Figure 11, having SCLK A = 3.4 MHz, SCLK B = 1.2 MHz, and a throughput rate of 50 kSPS, which gives a cycle time of 20 µs, the following values can be obtained:

Conversion Time A = 16 × (1/SCLK A) = 4.7 µs (23.5% of the cycle time)

Power-Down Time A = (1/Throughput) – Conversion Time A = 20 µs – 4.7 µs = 15.3 µs (76.5% of the cycle time)

Conversion Time B = 16 × (1/SCLK B) = 13 µs (65% of the cycle time)

Power-Down Time B = (1/Throughput) – Conversion Time B = 20 µs – 13 µs = 7 µs (35% of the cycle time)

The average power consumption includes the power dissipated when the part is converting and the power dissipated when the part is in power-down mode. The average power dissipated during conversion is calculated as the percentage of the cycle time spent when converting multiplied by the maximum current during conversion. The average power dissipated in power-down mode is calculated as the percentage of cycle time spent in power-down mode multiplied by the current figure for power-down mode. In order to obtain the value for the average power, these terms must be multiplied by the voltage.

Considering the maximum current for each SCLK frequency for V_{DD} = 1.8 V:

Power Consumption A = ((4.7/20) × 186 µA + (15.3/20) × 100 nA) × 1.8 V = (43.71 + 0.076) µA × 1.8 V = 78.8 µW = 0.07 mW

Power Consumption B = ((13/20) × 108 µA + (7/20) × 100 nA) × 1.8 V = (70.2 + 0.035) µA × 1.8 V = 126.42 µW = 0.126 mW

It can be concluded that for a fixed throughput rate, the average power consumption drops as the SCLK frequency increases.

Power Consumption Example 2
This example shows that for a fixed SCLK frequency, as the throughput rate decreases, the average power consumption drops. From Figure 12, for SCLK = 3.4 MHz, Throughput A = 100 kSPS (which gives a cycle time of 10 µs) and Throughput B = 50 kSPS (which gives a cycle time of 20 µs) the following values can be obtained:

Conversion Time A = 16 × (1/SCLK) = 4.7 µs (47% of the cycle time for a throughput of 100 kSPS)

Power-Down Time A = (1/Throughput A) – Conversion Time A = 10 µs – 4.7 µs = 5.3 µs (53% of the cycle time)

Conversion Time B = 16 × (1/SCLK) = 4.7 µs (23.5% of the cycle time for a throughput of 50 kSPS)

Power-Down Time B = (1/Throughput B) – Conversion Time B = 20 µs – 4.7 µs = 15.3 µs (76.5% of the cycle time)

The average power consumption is calculated as explained in Power Consumption Example 1, considering the maximum current for a 3.4 MHz SCLK frequency for V_{DD} = 1.8 V.

Power Consumption A = ((4.7/10) × 186 µA + (5.3/10) × 100 nA) × 1.8 V= (87.42 + 0.053) µA × 1.8 V = 157.4 µW = 0.157 mW

Power Consumption B = ((4.7/20) × 186 µA + (15.3/20) × 100 nA) × 1.8 V = (43.7 + 0.076) µA × 1.8 V = 78.79 µW = 0.078 mW

It can be concluded that for a fixed SCLK frequency, the average power consumption drops as the throughput rate decreases.

SERIAL INTERFACE

Figures 14, 15, and 16 show the detailed timing diagrams for serial interfacing to the AD7466/AD7467/AD7468. The serial clock provides the conversion clock and controls the transfer of information from the ADC during a conversion.

The part begins to power up on the $\overline{CS}$ falling edge. The falling edge of $\overline{CS}$ puts the track-and-hold into track mode and takes the bus out of three-state. The conversion is also initiated at this point. On the third SCLK falling edge after the $\overline{CS}$ falling edge, the part should be fully powered up, as shown in Figure 14 at point B, and the track-and-hold will return to hold.

For the AD7466, the SDATA line will go back into three-state and the part will enter power-down on the 16th SCLK falling edge. If the rising edge of $\overline{CS}$ occurs before 16 SCLKs have elapsed, the conversion will be terminated, the SDATA line will go back into three-state, and the part will enter power-down; otherwise SDATA returns to three-state on the 16th SCLK falling edge, as shown in Figure 14. Sixteen serial clock cycles are required to perform the conversion process and to access data from the AD7466.

For the AD7467, the 14th SCLK falling edge will cause the SDATA line to go back into three-state, and the part will enter power-down. If the rising edge of $\overline{CS}$ occurs before 14 SCLKs have elapsed, the conversion will be terminated, the SDATA line will go back into three-state, and the AD7467 will enter power-down; otherwise SDATA returns to three-state on the 14th SCLK falling edge, as shown in Figure 15. Fourteen serial clock cycles are required to perform the conversion process and to access data from the AD7467.

For the AD7468, the 12th SCLK falling edge will cause the SDATA line to go back into three-state, and the part will enter power-down. If the rising edge of $\overline{CS}$ occurs before 12 SCLKs have elapsed, the conversion will be terminated, the SDATA line will go back into three-state, and the AD7468 will enter power down; otherwise SDATA returns to three-state on the 12th SCLK falling edge, as shown in Figure 16. Twelve serial clock cycles are required to perform the conversion process and to access data from the AD7468.

$\overline{CS}$ going low provides the first leading zero to be read in by the microcontroller or DSP. The remaining data is then clocked out by subsequent SCLK falling edges, beginning with the second leading zero; thus the first clock falling edge on the serial clock has the first leading zero provided and also clocks out the second leading zero. For the AD7466, the final bit in the data transfer is valid on the 16th SCLK falling edge, having been clocked out on the previous (15th) SCLK falling edge.

In applications with a slow SCLK, it is possible to read in data on each SCLK rising edge. In such a case, the first falling edge of SCLK after the $\overline{CS}$ falling edge will clock out the second leading zero and could be read in the following rising edge. If the first SCLK edge after the $\overline{CS}$ falling edge is a falling edge, the first leading zero that was clocked out when $\overline{CS}$ went low will be missed unless it is not read on the first SCLK falling

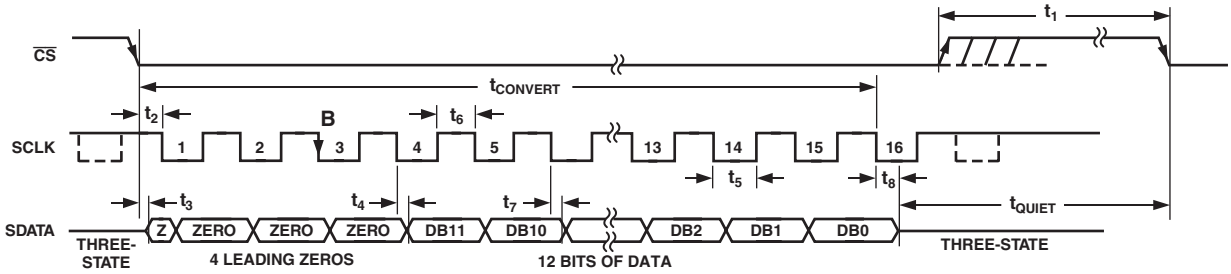


Figure 14. AD7466 Serial Interface Timing Diagram

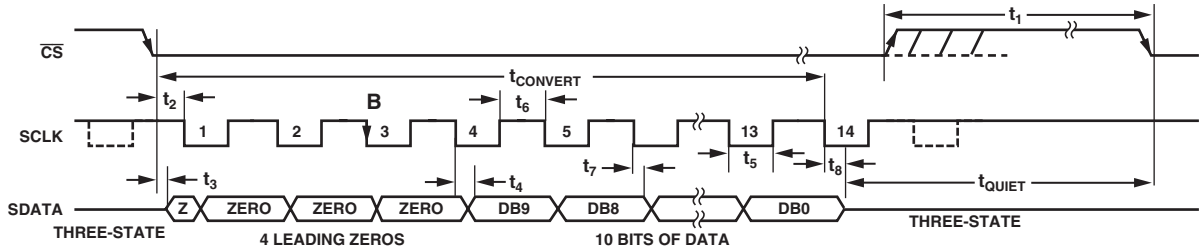


Figure 15. AD7467 Serial Interface Timing Diagram

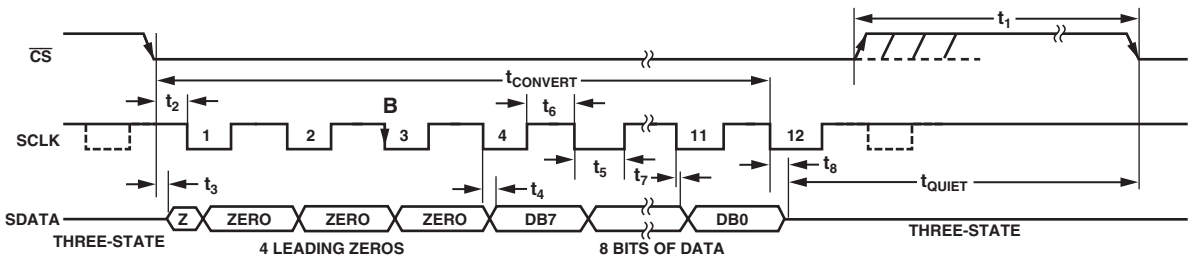


Figure 16. AD7468 Serial Interface Timing Diagram

edge. The 15th falling edge of SCLK will clock out the last bit and it could be read in the following rising SCLK edge.

If the first SCLK edge after $\overline{CS}$ falling edge is a rising edge, $\overline{CS}$ will clock out the first leading zero as before, and it may be read on the SCLK rising edge. The next SCLK falling edge will clock out the second leading zero, and it could be read on the following rising edge.

MICROPROCESSOR INTERFACING

The serial interface on the AD7466/AD7467/AD7468 allows the part to be connected directly to a range of many different microprocessors. This section explains how to interface the AD7466/AD7467/AD7468 with some of the more common microcontroller and DSP serial interface protocols.

AD7466/AD7467/AD7468 to TMS320C541 Interface

The serial interface on the TMS320C541 uses a continuous serial clock and frame synchronization signals to synchronize the data transfer operations with peripheral devices like the AD7466/AD7467/AD7468. The $\overline{CS}$ input allows easy interfacing between the TMS320C541 and the AD7466/AD7467/AD7468 without requiring any glue logic. The serial port of the TMS320C541 is set up to operate in burst mode (FSM = 1 in the serial port control register, SPC) with internal CLKX (MCM = 1 in the SPC register) and internal frame signal (TXM = 1 in the SPC register), so both pins are configured as outputs. For the AD7466, the word length should be set to 16 bits (FO = 0 in the SPC register). The standard synchronous serial port interface in this DSP only allows frames with a word length of 16 bits or 8 bits. Therefore, for the AD7467 and AD7468 where 14 and 12 bits are required, the FO bit also would be set up to 16 bits. In these cases, the user should keep in mind that the last two and four bits for the AD7467 and AD7468, respectively, will be invalid data as the SDATA line goes back into three-state on the 14th and 12th SCLK falling edge.

To summarize, the values in the SPC register are

FO = 0
FSM = 1
MCM = 1
TXM = 1

The connection diagram is shown in Figure 17. Note that for signal processing applications, it is imperative that the frame synchronization signal from the TMS320C541 provides equidistant sampling.

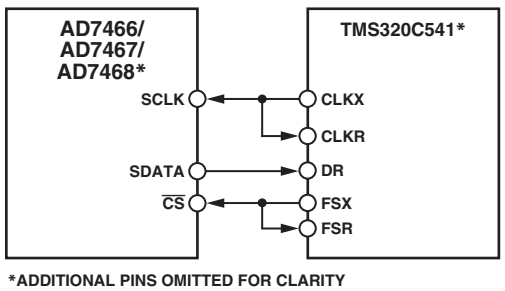


Figure 17. Interfacing to the TMS320C541

AD7466/AD7467/AD7468 to ADSP-218x

The ADSP-218x family of DSPs is interfaced directly to the AD7466/AD7467/AD7468 without any glue logic. The SPORT control register should be set up as follows:

TFSW = RFSW = 1, Alternate Framing
INVRFS = INVTFS = 1, Active Low Frame Signal
DTYPE = 00, Right Justify Data
ISCLK = 1, Internal Serial Clock
TFSR = RFSR= 1, Frame Every Word
IRFS = 0, Sets up RFS as an Input
ITFS = 1, Sets up TFS as an Output
SLEN = 1111, 16 Bits for the AD7466
SLEN = 1101, 14 Bits for the AD7467
SLEN = 1011, 12 Bits for the AD7468

The connection diagram is shown in Figure 18. The ADSP-218x has the TFS and RFS of the SPORT tied together, with TFS set as an output and RFS set as an input. The DSP operates in alternate framing mode, and the SPORT control register is set up as described. The frame synchronization signal generated on the TFS is tied to $\overline{CS}$, and as with all signal processing applications, equidistant sampling is necessary. However, in this example, the timer interrupt is used to control the sampling rate of the ADC and, under certain conditions, equidistant sampling may not be achieved.

The timer registers, for example, are loaded with a value that will provide an interrupt at the required sample interval. When an interrupt is received, a value is transmitted with TFS/DT (ADC control word). The TFS is used to control the RFS and therefore the reading of data. The frequency of the serial clock is set in the SCLKDIV register. When the instruction to transmit with TFS is given, i.e., AX0 = TX0, the state of the SCLK is checked. The DSP will wait until the SCLK has gone high, low, and high again before transmission will start. If the timer and SCLK values are chosen such that the instruction to transmit occurs on or near the rising edge of SCLK, the data may be transmitted or it may wait until the next clock edge.

For example, the ADSP-2111 has a master clock frequency of 16 MHz. If the SCLKDIV register is loaded with the value 3, an SCLK of 2 MHz is obtained, and eight master clock periods will elapse for every SCLK period. If the timer registers are loaded with the value 803, 100.5 SCLKs will occur between interrupts and subsequently between transmit instructions. This situation will result in nonequidistant sampling as the transmit instruction is occurring on a SCLK edge. If the number of SCLKs between interrupts is a whole integer figure of N, equidistant sampling will be implemented by the DSP.

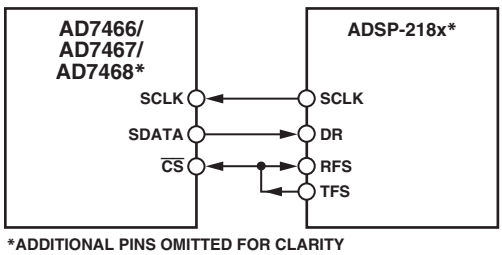


Figure 18. Interfacing to the ADSP-218x

AD7466/AD7467/AD7468 to DSP563xx Interface

The connection diagram in Figure 19 shows how the AD7466/AD7467/AD7468 can be connected to the SSI (synchronous serial interface) of the DSP563xx family of DSPs from Motorola. The SSI is operated in synchronous and normal mode (SYN = 1 and MOD = 0 in the Control Register B, CRB) with an internally generated word frame sync for both Tx and Rx (bits FSL1 = 0 and FSL0 = 0 in the CRB register). Set the word length in the Control Register A (CRA) to 16 by setting bits WL2 = 0, WL1 = 1, and WL0 = 0 for the AD7466. The word length for the AD7468 can be set to 12 bits (WL2 = 0, WL1 = 0, and WL0 = 1). This DSP does not offer the option for a 14-bits word length, so the AD7467 word length will be set up to 16 bits like the AD7466's. In this case, the user should keep in mind that the last two bits will be invalid data as the SDATA goes back into three-state on the 14th SCLK falling edge.

The FSP (frame sync polarity) bit in the CRB register can be set to 1, which means the frame goes low and a conversion starts. Likewise, by means of bits SCD2, SCKD, and SHFD in the CRB register, it will be established that pins SC2 (the frame sync signal) and SCK in the serial port will be configured as outputs and the MSB will be shifted first.

To summarize,

MOD = 0
SYN = 1
WL2, WL1, WL0 depend on the word length
FSL1 = 0, FSL0 = 0
FSP = 1, Negative Frame Sync
SCD2 = 1
SCKD = 1
SHFD = 0

Note that for signal processing applications, it is imperative that the frame synchronization signal from the DSP563xx provides equidistant sampling.

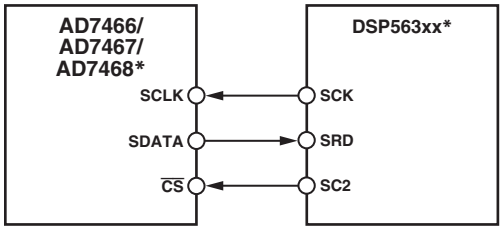


Figure 19. Interfacing to the DSP563xx

APPLICATION HINTS

Grounding and Layout

The printed circuit board that houses the AD7466/AD7467/AD7468 should be designed such that the analog and digital sections are separated and confined to certain areas of the board. This facilitates the use of ground planes that can be separated easily. A minimum etch technique is generally best for ground planes because it gives the best shielding. Digital and analog ground planes should be joined at only one place. If the AD7466/AD7467/AD7468 is in a system where multiple devices require an AGND to DGND connection, the connection should still be made at one point only, a star ground point that should be established as close as possible to the AD7466/AD7467/AD7468.

Avoid running digital lines under the device because these will couple noise onto the die. The analog ground plane should be allowed to run under the AD7466/AD7467/AD7468 to avoid noise coupling. The power supply lines to the AD7466/AD7467/AD7468 should use as large a trace as possible to provide low impedance paths and to reduce the effects of glitches on the power supply line. Fast switching signals like clocks should be shielded with digital ground to avoid radiating noise to other sections of the board, and clock signals should never be run near the analog inputs. Avoid crossover of digital and analog signals. Traces on opposite sides of the board should run at right angles to each other, which will reduce the effects of feedthrough through the board. A microstrip technique is by far the best choice but is not always possible with a double-sided board. With this technique, the component side of the board is dedicated to ground planes while signals are placed on the solder side.

Good decoupling is also very important. All analog supplies should be decoupled with 10 µF tantalum in parallel with 0.1 µF capacitors to AGND. All digital supplies should have a 0.1 µF ceramic disc capacitor to DGND. To achieve the best performance from these decoupling components, the user should attempt to keep the distance between the decoupling capacitor and the V_{DD} and GND pins to a minimum, with short track lengths connecting the respective pins.

Evaluating the AD7466/AD7467 Performance

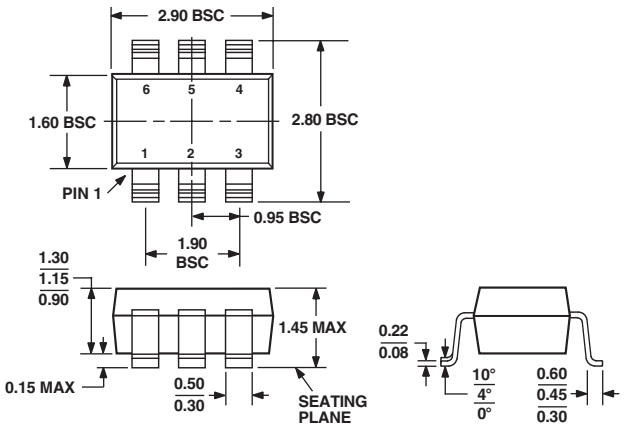
The evaluation board package includes a fully assembled and tested evaluation board, documentation, and software for controlling the board from the PC via the eval-board controller. To demonstrate/evaluate the ac and dc performance of the AD7466/AD7467, the eval-board controller can be used in conjunction with the AD7466/AD7467CB evaluation board, as well as many other Analog Devices evaluation boards ending in the CB designator.

The software allows the user to perform ac (fast Fourier transform) and dc (histogram of codes) tests on the AD7466/AD7467. See the evaluation board application note for more information.

OUTLINE DIMENSIONS

6-Lead Small Outline Transistor Package [SOT-23]
(RT-6)

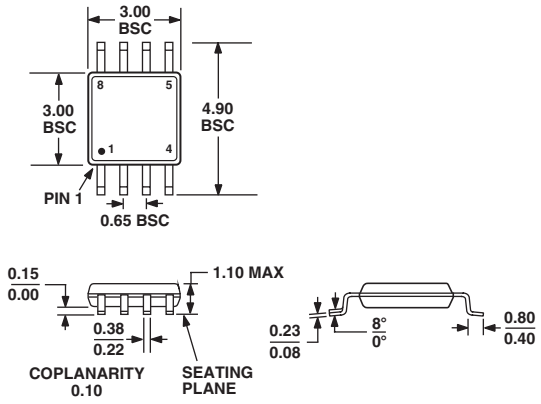
Dimensions shown in millimeters



COMPLIANT TO JEDEC STANDARDS MO-178AB

8-Lead Mini Small Outline Package [MSOP]
(RM-8)

Dimensions shown in millimeters



COMPLIANT TO JEDEC STANDARDS MO-187AA