

FEATURES

Analog input/output

Multichannel, 12-bit, 1 MSPS analog-to-digital converter (ADC)

Up to 16 ADC input channels

0 V to VREF analog input range

Single-ended modes

AVDD and IOVDD monitors

12-bit voltage output digital-to-analog converters (VDACs)

8 VDACs with a range of 0 V to 2.5 V or AVDD outputs

Voltage comparator

Microcontroller

ARM Cortex-M3 processor, 32-bit RISC architecture

Serial wire port supports code download and debug

Clocking options

80 MHz phase-locked loop (PLL) with programmable divider

Trimmed on-chip oscillator ($\pm 3\%$)

External 16 MHz crystal option

External clock source up to 80 MHz

Memory

2 × 128 kB independent Flash/EE memories

10,000 cycle Flash/EE endurance

20-year Flash/EE retention

32 kB SRAM

Software triggered in-circuit reprogrammability via management data input/output (MDIO)

On-chip peripherals

MDIO slave up to 4 MHz

2 × I²C, 2 × SPI, UART

Multiple general-purpose input/output (GPIO) balls: 3.6 V compliant

7 × 1.2 V compatible when used for MDIO

32-element programmable logic array (PLA)

3 general-purpose timers

Wake-up timer

Watchdog timer

16-bit pulse width modulator (PWM)

Power

Supply range: 2.9 V to 3.6 V

Flexible operating modes for low power applications

Packages and temperature range

6 mm × 6 mm, 96-ball CSP_BGA package

Fully specified for -40°C to $+105^{\circ}\text{C}$ ambient operation

Tools

QuickStart development system

Full third-party support

APPLICATIONS

Optical networking

FUNCTIONAL BLOCK DIAGRAM

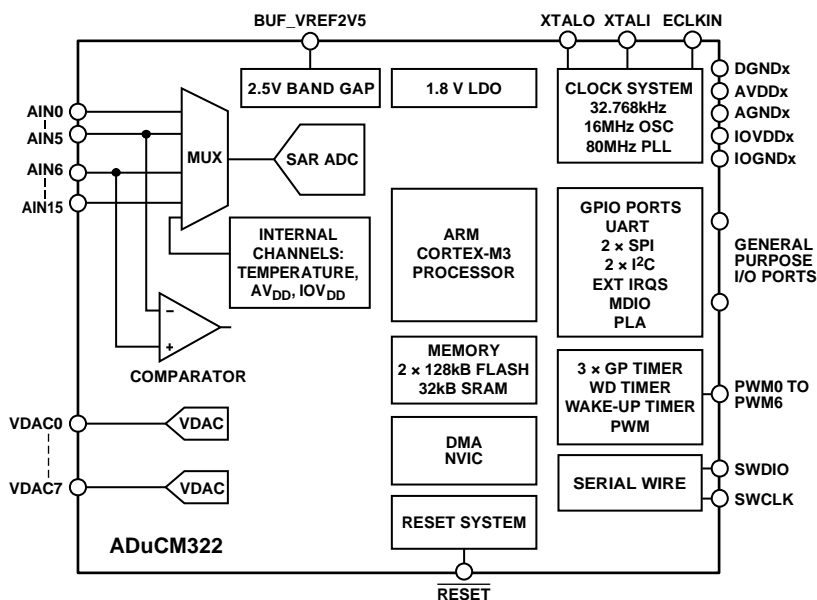


Figure 1.

Rev. A

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REVISION HISTORY

4/2018—Rev. 0 to Rev. A

| | |
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| Changes to Table 1..... | 4 |
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2/2016—Revision 0: Initial Version

GENERAL DESCRIPTION

The [ADuCM322](#) is a fully integrated, single package device that incorporates high performance analog peripherals together with digital peripherals controlled by an 80 MHz ARM® Cortex™-M3 processor and integral flash for code and data.

The ADC on the [ADuCM322](#) provides 12-bit, 1 MSPS data acquisition on up to 16 input balls. Additionally, chip temperature and supply voltages can be measured.

The ADC input voltage range is 0 V to VREF. A sequencer is provided, which allows a user to select a set of ADC channels to measure in sequence without software involvement during the sequence. The sequence can optionally repeat automatically at a user selectable rate. Up to eight VDACS are provided with output ranges that are programmable to one of two voltage ranges.

The [ADuCM322](#) can be configured so that the digital and analog outputs retain their output voltages through a watchdog or software reset sequence. Thus, a product can remain functional even while the [ADuCM322](#) is resetting itself.

The [ADuCM322](#) has a low power ARM Cortex-M3 processor and a 32-bit RISC machine that offers up to 100 MIPS peak performance. Also integrated on-chip are 2 × 128 kB Flash/EE memory blocks and 32 kB of SRAM. The flash comprises two separate 128 kB blocks supporting execution from one flash block and simultaneous writing/erasing of the other flash block.

The [ADuCM322](#) operates from an on-chip oscillator or a 16 MHz external crystal and a PLL at 80 MHz. This clock can optionally be divided down to reduce current consumption. Additional low power modes can be set via software. In normal operating mode, the [ADuCM322](#) digital core consumes about 300 µA per MHz.

The device includes an MDIO interface capable of operating at up to 4 MHz. The capability to simultaneously execute from one flash block and write/erase the other flash block makes the [ADuCM322](#) ideal for 10G, 40G, and 100G optical applications. In addition, the nonerasable kernel code plus flags in user flash provide assistance by allowing user code to robustly switch between the two blocks of user flash code and data spaces.

The [ADuCM322](#) integrates a range of on-chip peripherals that can be configured under software control, as required in the application. These peripherals include 1 × UART, 2 × I²C, and 2 × SPI serial input/output communication controllers, GPIO, 32-element PLA, three general-purpose timers, plus a wake-up timer and system watchdog timer. A 16-bit PWM with seven output channels is also provided.

GPIO balls on the device power up in high impedance input mode. In output mode, the software chooses between open-drain mode and push-pull mode. The pull-up resistors can be disabled and enabled in software. In GPIO output mode, the inputs can remain enabled to monitor the balls. The GPIO balls can also be programmed to handle digital or analog peripheral signals; in such cases, the ball characteristics are matched to the specific requirement.

A large support ecosystem is available for the ARM Cortex-M3 processor to ease product development of the [ADuCM322](#). Access is via the ARM serial wire debug port (SW-DP). On-chip factory firmware supports in-circuit serial download via MDIO. These features are incorporated into a QuickStart™ development system, supporting this precision analog microcontroller family.

SPECIFICATIONS

MICROCONTROLLER ELECTRICAL SPECIFICATIONS

AVDD = IOVDD = VDD1 = 2.9 V to 3.6 V (see Figure 12), maximum difference between supplies = 0.3 V, VREF = 2.5 V internal reference, $f_{CORE} = 80$ MHz, $T_A = -40^{\circ}\text{C}$ to $+105^{\circ}\text{C}$, unless otherwise noted. The power-up sequence must be VDD1, IOVDDx, and AVDDx, but no delays in the sequence are required.

Table 1.

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions/Comments |
|--|--------------|-------|------------|---------|--------------------------------|--|
| ADC BASIC SPECIFICATIONS | | | | | | |
| ADC Power-Up Time | | | 5 | | μs | Single-ended mode, unless otherwise stated |
| Data Rate | f_{SAMPLE} | | | 1 | MSPS | |
| DC Accuracy ¹ | | 12 | | | Bits | |
| Resolution ¹ | | 16 | | | Bits | |
| Integral Nonlinearity | INL | | ± 1.75 | | LSB | |
| | | | ± 1.75 | | LSB | |
| Differential Nonlinearity | DNL | -0.99 | ± 0.75 | +1.5 | LSB | |
| | | | ± 0.75 | | LSB | |
| DC Code Distribution | | | ± 3 | | LSB | ADC input 1.25 V; 1 LSB = $2.5 \text{ V}/2^{12}$ |
| ADC ENDPOINT ERRORS | | | | | | |
| Offset Error | | | ± 200 | | μV | Using 2.5 V external reference |
| Drift ¹ | | -3.92 | 0.3 | +1.21 | $\mu\text{V}/^{\circ}\text{C}$ | |
| Match | | | ± 1 | | LSB | |
| Full-Scale Error | | | ± 400 | | μV | |
| Gain Drift ¹ | | -4 | | +5 | $\mu\text{V}/^{\circ}\text{C}$ | Full-scale error drift minus offset error drift |
| | | | | ± 1 | | |
| ADC DYNAMIC PERFORMANCE | | | | | | |
| Signal-to-Noise Ratio | SNR | | 80 | | dB | $f_{IN} = 665.25$ Hz sine wave, $f_{SAMPLE} = 100$ kSPS; input filter = 15Ω , $C_L = 2$ nF Includes distortion and noise components |
| Total Harmonic Distortion | THD | | -86 | | dB | |
| Peak Harmonic or Spurious Noise | | | -88 | | dB | |
| Channel-to-Channel Crosstalk | | | -90 | | dB | |
| ADC INPUT | | | | | | |
| Input Voltage Ranges | | | | | | At 1 MSPS ≤ 800 kSPS 500 kSPS, ADCCNVC, Bits[25:16] = 0x1E During ADC acquisition |
| Single-Ended Mode ¹ | | AGND | | VREF | | |
| Compliance ¹ | | AGND4 | | AVDD4 | | |
| Leakage Current | | | ± 1.5 | | nA | |
| Input Current | | | ± 9 | | $\mu\text{A}/\text{V}$ | |
| | | | ± 6 | | $\mu\text{A}/\text{V}$ | |
| | | | ± 4 | | $\mu\text{A}/\text{V}$ | |
| Input Capacitance | | | 20 | | pF | |
| ON-CHIP VOLTAGE REFERENCE | | | | | | |
| Accuracy | | | 2.51 | | V | 0.47 μF from VREF_1V2 to AGND4; reference is measured with all ADC and VDACS enabled $T_A = 25^{\circ}\text{C}$ |
| Reference Temperature Coefficient ¹ | | | | ± 5 | mV | |
| Power Supply Rejection Ratio | PSRR | -59 | ± 15 | 38 | ppm/ $^{\circ}\text{C}$ | |
| Internal VREF Power-On Time | | | 60 | | dB | |
| | | | 50 | | ms | |

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions/Comments |
|--|--------|--------|-------|--------------|--------|--|
| EXTERNAL REFERENCE INPUT | | | | | | |
| Range ¹ | | 1.8 | | 2.5 | V | ADC |
| Input Current | | | 200 | | μA | |
| BUFFERED REFERENCE OUTPUT | | | | | | |
| Output Voltage | | | 2.504 | | V | |
| Accuracy | | | ±8 | | mV | T _A = 25°C, load = 1.2 mA |
| Reference Temperature Coefficient ¹ | | -115 | ±15 | 115 | μV/°C | 100 nF from BUF_VREF2V5 to AGND4 |
| Output Impedance | | | 10 | | Ω | T _A = 25°C |
| Load Current ¹ | | | | 1.2 | mA | |
| VDAC CHANNEL SPECIFICATIONS | | | | | | R _L = 5 kΩ, C _L = 100 pF ² |
| DC Accuracy ¹ | | 12 | | | Bits | 1 LSB = 2.5 V/2 ¹² |
| Resolution ¹ | | 12 | | | Bits | Number of data bits |
| Relative Accuracy ³ | INL | | ±4 | | LSB | 1 LSB = 2.5 V/2 ¹² |
| Differential Nonlinearity ³ | DNL | -0.99 | | +1 | LSB | Guaranteed monotonic, 1 LSB = 2.5 V/2 ¹² |
| Offset Error | | | ±3 | ±15 | mV | 2.5 V internal reference, DAC Output Code 0 |
| Drift | | | ±18 | | μV/°C | |
| Gain Error ⁴ | | | ±0.3 | ±0.85 | % | 0 V to internal V _{REF} range |
| Drift | | | ±0.4 | ±1 | % | 0 V to AVDD range |
| Mismatch | | | 6.5 | | ppm/°C | Excluding reference drift |
| Analog Outputs | | | | | | % of full scale on DAC0 |
| Output Voltage Range 1 ¹ | | 0.15 | | 2.5 | V | |
| Output Voltage Range 2 ¹ | | 0.15 | | AVDDx - 0.15 | V | |
| Output Impedance | | | 2 | | Ω | |
| DAC AC Characteristics | | | | | | |
| Output Settling Time | | | 10 | | μs | Settled to ±1 LSB |
| Glitch Energy | | | ±20 | | nV-sec | 1 LSB change when the maximum number of bits changes simultaneously in the DACxDAT register |
| COMPARATOR | | | | | | |
| Input | | | | | | |
| Offset Voltage | | | ±10 | | mV | |
| Bias Current | | | 1 | | nA | |
| Voltage Range ¹ | | AGNDx | | AVDDx - 1.2 | V | |
| Capacitance | | | 7 | | pF | |
| Hysteresis ¹ | | 8.5 | | 15 | mV | When enabled in software |
| Response Time | | | 7 | | μs | AFECOMP, Bits[2:1] = 0 |
| TEMPERATURE SENSOR | | | | | | |
| Resolution | | | 0.5 | | °C | Indicates die temperature, see Figure 9 |
| Accuracy ¹ | | 1.34 | | 1.43 | V | When precision calibrated by the user ⁵ |
| | | | | | | ADC measured voltage for temperature sensor channel without calibration, T _A = 25°C |
| POWER-ON RESET | POR | | 2.85 | 2.9 | V | |
| WATCHDOG TIMER | WDT | | | | | |
| Timeout Period | | | 32 | | sec | Default at power-up |
| FLASH/EE MEMORY | | | | | | |
| Endurance ¹ | | 10,000 | | | Cycles | |
| Data Retention ¹ | | 20 | | | Years | T _J = 85°C |

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions/Comments |
|--|-----------|-----------------------------|-----------|-----------------------------|---------------|--|
| DIGITAL INPUTS | | | | | | |
| Input Leakage Current | | | | | | |
| Logic 1 GPIO | | | 1 | | nA | $V_{IH} = V_{DD}$, pull-up resistor disabled |
| Logic 0 GPIO | | | 10 | | nA | $V_{IL} = 0\text{ V}$, pull-up resistor disabled |
| PRTADDRx | | | | | | |
| Input Leakage Current | | | 16 | | μA | $V_{IN} = 0\text{ V}$ to 1.8 V, due to weak pull-up resistors to 1.8 V |
| Input Voltage | | 0.84 | | 1.5 | V | External resistor $91\text{ k}\Omega \pm 1\%$ to ground; range for CFP MSA high ¹ |
| Input Capacitance, All Balls Except MCK, MDIO, PRTADDRx, and XTALx | | | 10 | | pF | |
| Input Capacitance | | | | | | |
| MCK, PRTADDRx | | | 6.5 | | pF | |
| MDIO | | | 8.5 | | pF | |
| Ball Capacitance | | | | | | |
| XTALI | | | 5 | | pF | |
| XTALO | | | 5 | | pF | |
| LOGIC INPUTS | | | | | | |
| GPIO Input Voltage | | | | | | |
| Low | V_{INL} | | | $0.25 \times \text{IOVDDx}$ | V | |
| High | V_{INH} | $0.58 \times \text{IOVDDx}$ | | | V | |
| MDIO | | | | | | |
| PRTADDRx Input Voltage | | | | | | |
| Low | V_{INL} | | | 0.36 | V | |
| High | V_{INH} | 0.84 | | | V | |
| MCK, MDIO Input Voltage | | | | | | |
| Low | V_{INL} | | | 0.36 | V | |
| High | V_{INH} | 0.84 | | | V | |
| XTALI Input Voltage | | | | | | |
| Low | V_{INL} | | 1.1 | | V | |
| High | V_{INH} | | 1.7 | | V | |
| Pull-Up Current | | 30 | | 120 | μA | $V_{IN} = 0\text{ V}$, see Figure 10 |
| Pull-Down Current | | 30 | | 100 | μA | $V_{IN} = 3.3\text{ V}$, see Figure 10 |
| LOGIC OUTPUTS | | | | | | |
| GPIO Output Voltage ⁶ | | | | | | |
| High | V_{OH} | $\text{IOVDDx} - 0.4$ | | | V | $I_{SOURCE} = 2\text{ mA}$ |
| Low | V_{OL} | | | 0.4 | V | $I_{SINK} = 2\text{ mA}$ |
| GPIO Short-Circuit Current ¹ | | | 11 | | mA | See Figure 11 |
| MDIO | | | | | | |
| Output Voltage | | | | | | |
| High | V_{OH} | 1.0 | | | V | $I_{SOURCE} = 4\text{ mA}$ |
| Low | V_{OL} | | | 0.2 | V | $I_{SINK} = 4\text{ mA}$ |
| Delay Time | | | | 100 | ns | MCK to MDIO out |
| OSCILLATORS | | | | | | |
| Internal System Oscillator | | | 16 | | MHz | |
| Accuracy | | | ± 0.5 | ± 3 | % | |
| System PLL | | | 80 | | MHz | Main system clock |
| External Crystal Oscillator | | | 16 | | MHz | Can be selected in place of the internal oscillator |
| 32 kHz Internal Oscillator | | | 32.768 | | kHz | Use for watchdog |
| Accuracy | | | ± 5 | ± 20 | % | |
| External Clock | | 0.05 | | 80 | MHz | Can be selected in place of PLL |

| Parameter | Symbol | Min | Typ | Max | Unit | Test Conditions/Comments |
|---|--------|-----|------|-----|------|---|
| START-UP TIME | | | | | | Processor clock = 80 MHz |
| At Power-On | | | 50 | | ms | POR to first user code execution |
| After Other Reset | | | 1.5 | | ms | Reset to first user code execution |
| From All Power-Down Modes | | | 1.25 | | µs | |
| PROGRAMMABLE LOGIC ARRAY | PLA | | | | | |
| Propagation Delay | | | | | | |
| Ball | | | 17 | | ns | From input ball to output ball |
| Element | | | 1.5 | | ns | Per PLA cell |
| EXTERNAL INTERRUPTS | | | | | | |
| Pulse Width ¹ | | | | | | |
| Level Triggered | | 7 | | | ns | |
| Edge Triggered | | 1 | | | ns | |
| POWER REQUIREMENTS ⁷ | | | | | | |
| Power Supply Voltage Range | | | | | | |
| AVDDx to AGNDx and IOVDDx to DGNDx ¹ | | 2.9 | 3.3 | 3.6 | V | |
| Analog Power Supply Currents | | | | | | |
| AVDDx Current | | | 4.9 | | mA | Analog peripherals in idle mode |
| Digital Power Supply Current | | | | | | |
| IOVDDx Current in Normal Mode | | | 2.7 | | mA | All GPIO pull-up resistors enabled |
| VDDx Current | | | | | | |
| Normal Mode | | | 29 | | mA | Clock divider (CD) = 0 (80 MHz clock), executing typical code |
| | | | 20 | | mA | CD = 1, executing typical code |
| | | | 10 | | mA | CD = 7, executing typical code |
| CORE_SLEEP Mode | | | 16 | | mA | |
| SYS_SLEEP Mode | | | 8 | | mA | |
| Hibernate Mode | | | 4 | | mA | |
| Additional Power Supply Currents | | | | | | |
| ADC | | | 4.1 | | mA | Continuously converting at 100 kSPS |
| DAC | | | 340 | | µA | Per powered up DAC, excluding load current |
| Total Supply Current | | | 37 | | mA | VDD1, IOVDDx, AVDDx connected together; condition when entering user code; peripheral clocks on, peripherals idle, no load currents |
| Thermal Performance | | | | | | |
| Impedance Junction to Ambient | | | 45 | | °C/W | JEDEC 2S2P |

¹ These specifications are not production tested but are guaranteed by design and/or characterization data at production release.

² The data in this section also applies for a load of $R_L = 1 \text{ k}\Omega$ and $C_L = 100 \text{ pF}$ but only an output range of 0 V to 2.5 V. However, this specification is not production tested.

³ DAC linearity is calculated using a reduced code range of 100 to 3900.

⁴ DAC gain error is calculated using a reduced code range of 100 to an internal 2.5 V_{REF} .

⁵ Due to self heating, internal temperature measurements cannot be used to predict external temperatures. This value is only relevant after user calibration and only for internal and external conditions identical to those at calibration.

⁶ The average current from all GPIO balls must not exceed 3 mA per ball.

⁷ Power figures exclude any load currents to external circuits.

TIMING SPECIFICATIONS

I²C Timing

Table 2. I²C Timing in Standard Mode (100 kHz)

| Parameter | Description | Slave | | | Unit |
|---------------------|---|-------|-----|------|------|
| | | Min | Typ | Max | |
| t _L | SCL low pulse width | 4.7 | | | μs |
| t _H | SCL high pulse width | 4.0 | | | ns |
| t _{SHD} | Start condition hold time | 4.0 | | | μs |
| t _{DSU} | Data setup time | 250 | | | ns |
| t _{DHD} | Data hold time (SDA held internally for 300 ns after falling edge of SCL) | 0 | | 3.45 | μs |
| t _{RSU} | Setup time for repeated start | 4.7 | | | μs |
| t _{PSU} | Stop condition setup time | 4.0 | | | μs |
| t _{BUF} | Bus-free time between a stop condition and a start condition | 4.7 | | | μs |
| t _R | Rise time for both SCL and SDA | | | 1 | μs |
| t _F | Fall time for both SCL and SDA | | 15 | 300 | ns |
| t _{VD;DAT} | Data valid time | | | 3.45 | μs |
| t _{VD;ACK} | Data valid acknowledge time | | | 3.45 | μs |

Table 3. I²C Timing in Fast Mode (400 kHz)

| Parameter | Description | Slave | | | Unit |
|---------------------|---|-------|-----|-----|------|
| | | Min | Typ | Max | |
| t _L | SCL low pulse width | 1.3 | | | μs |
| t _H | SCL high pulse width | 0.6 | | | ns |
| t _{SHD} | Start condition hold time | 0.3 | | | μs |
| t _{DSU} | Data setup time | 100 | | | ns |
| t _{DHD} | Data hold time (SDA held internally for 300 ns after falling edge of SCL) | 0 | | | μs |
| t _{RSU} | Setup time for repeated start | 0.6 | | | μs |
| t _{PSU} | Stop condition setup time | 0.3 | | | μs |
| t _{BUF} | Bus-free time between a stop condition and a start condition | 1.3 | | | μs |
| t _R | Rise time for both SCL and SDA | 20 | | 300 | ns |
| t _F | Fall time for both SCL and SDA | | 15 | 300 | ns |
| t _{VD;DAT} | Data valid time | | | 0.9 | μs |
| t _{VD;ACK} | Data valid acknowledge time | | | 0.9 | μs |

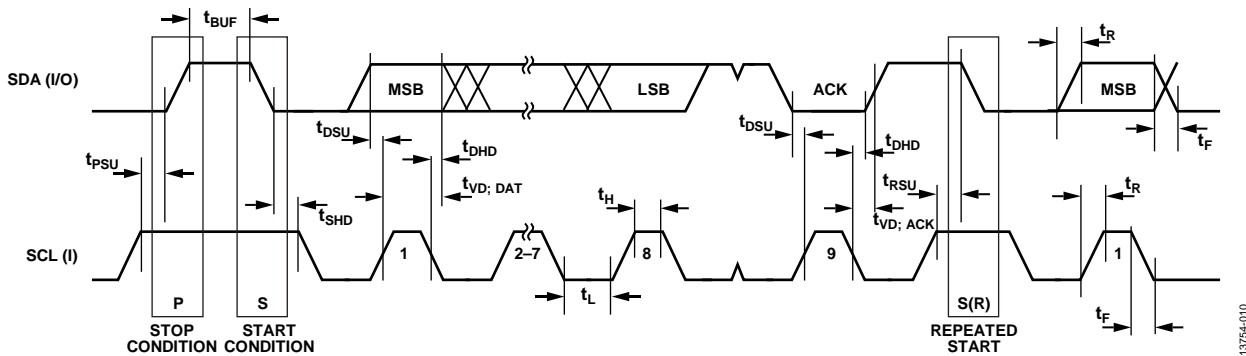


Figure 2. I²C Compatible Interface Timing

SPI Timing

Table 4. SPI Master Mode Timing (Phase Mode = 1)

| Parameter | Description | Min | Typ | Max | Unit |
|-----------|--|-----|----------------------------------|-----|------|
| t_{SL} | SCLK low pulse width | | $(SPIDIV + 1) \times t_{HCLK}/2$ | | ns |
| t_{SH} | SCLK high pulse width | | $(SPIDIV + 1) \times t_{HCLK}/2$ | | ns |
| t_{DAV} | Data output valid after SCLK edge | 0 | 3 | | ns |
| t_{DSU} | Data input setup time before SCLK edge | | $\frac{1}{2}$ SCLK | | ns |
| t_{DHD} | Data input hold time after SCLK edge | | SCLK | | ns |
| t_{DF} | Data output fall time | | SCLK | | ns |
| t_{DR} | Data output rise time | | 25 | | ns |
| t_{SR} | SCLK rise time | | 25 | | ns |
| t_{SF} | SCLK fall time | | 20 | | ns |

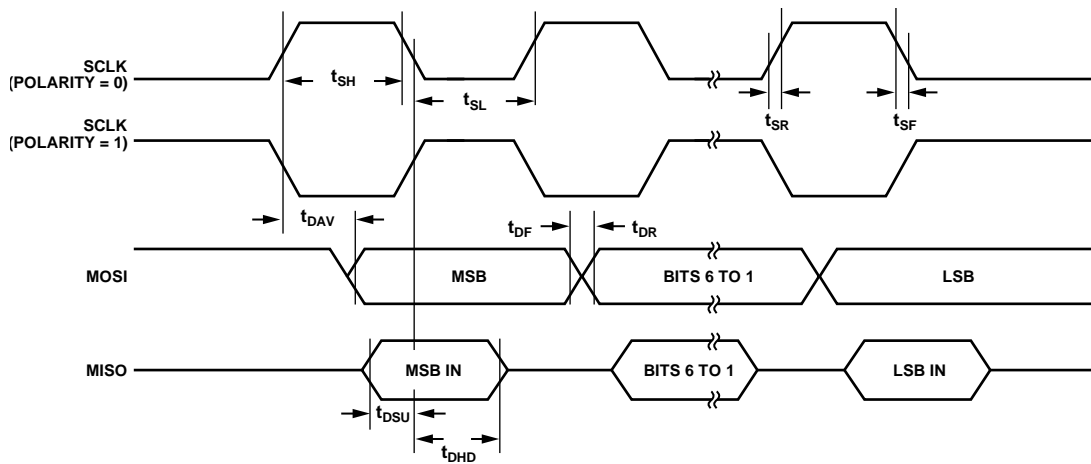


Figure 3. SPI Master Mode Timing (Phase Mode = 1)

13754-011

Table 5. SPI Master Mode Timing (Phase Mode = 0)

| Parameter | Description | Min | Typ | Max | Unit |
|------------|--|-----|----------------------------------|-----|------|
| t_{SL} | SCLK low pulse width | | $(SPIDIV + 1) \times t_{HCLK}/2$ | | ns |
| t_{SH} | SCLK high pulse width | | $(SPIDIV + 1) \times t_{HCLK}/2$ | | ns |
| t_{DAV} | Data output valid after SCLK edge | 0 | 3 | | ns |
| t_{DOSU} | Data output setup before SCLK edge | | $\frac{1}{2}$ SCLK | | ns |
| t_{DSU} | Data input setup time before SCLK edge | | SCLK | | ns |
| t_{DHD} | Data input hold time after SCLK edge | | SCLK | | ns |
| t_{DF} | Data output fall time | | 25 | | ns |
| t_{DR} | Data output rise time | | 25 | | ns |
| t_{SR} | SCLK rise time | | 20 | | ns |
| t_{SF} | SCLK fall time | | 20 | | ns |

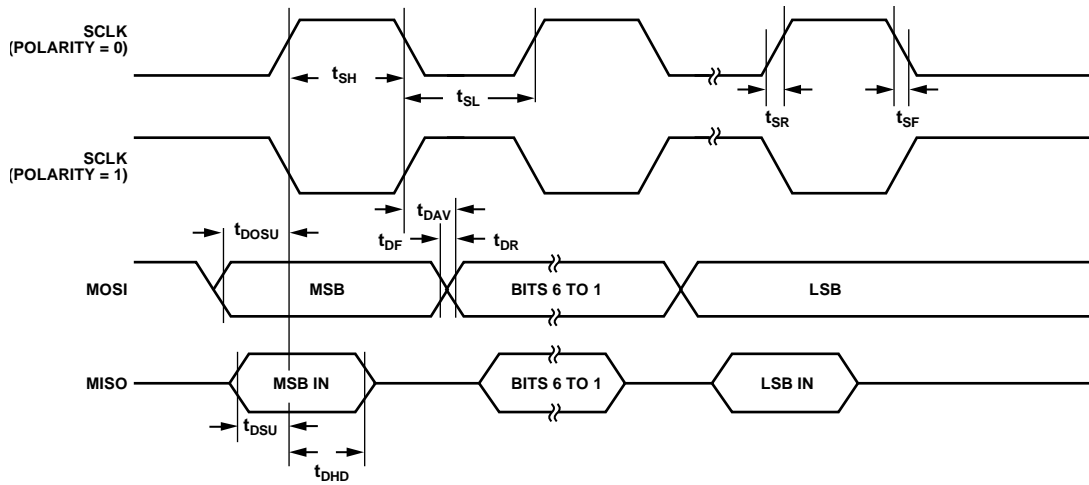


Figure 4. SPI Master Mode Timing (Phase Mode = 0)

13754-012

Table 6. SPI Slave Mode Timing (Phase Mode = 1)

| Parameter | Description | Min | Typ | Max | Unit |
|----------------------|--|-------|--------------------------------|-----|------|
| $t_{\overline{CS}}$ | \overline{CS} to SCLK edge | 10 | | | ns |
| $t_{\overline{CSM}}$ | \overline{CS} high time between active periods | SCLKx | | | ns |
| t_{SL} | SCLK low pulse width | | $(SPIDIV + 1) \times t_{HCLK}$ | | ns |
| t_{SH} | SCLK high pulse width | | $(SPIDIV + 1) \times t_{HCLK}$ | | ns |
| t_{DAV} | Data output valid after SCLK edge | | 20 | | ns |
| t_{DSU} | Data input setup time before SCLK edge | 10 | | | ns |
| t_{DHD} | Data input hold time after SCLK edge | 10 | | | ns |
| t_{DF} | Data output fall time | | 25 | | ns |
| t_{DR} | Data output rise time | | 25 | | ns |
| t_{SR} | SCLK rise time | 1 | | | ns |
| t_{SF} | SCLK fall time | 1 | | | ns |
| t_{SFS} | \overline{CS} high after SCLK edge | 20 | | | ns |

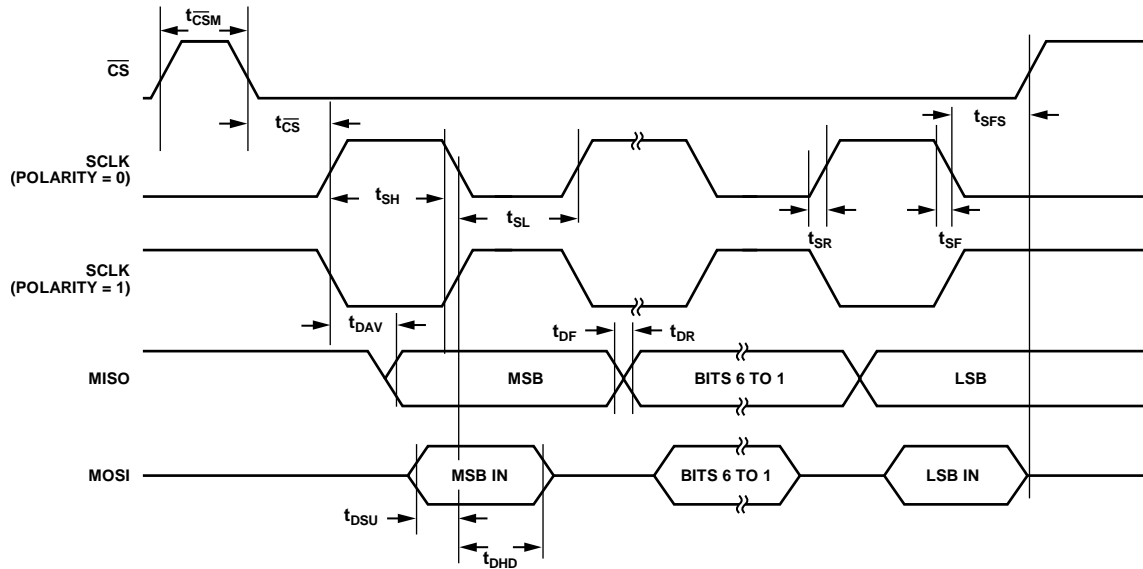


Figure 5. SPI Slave Mode Timing (Phase Mode = 1)

13754-013

Table 7. SPI Slave Mode Timing (Phase Mode = 0)

| Parameter | Description | Min | Typ | Max | Unit |
|----------------------|--|-------|--------------------------------|-----|------|
| $t_{\overline{CS}}$ | \overline{CS} to SCLK edge | 10 | | | ns |
| $t_{\overline{CSM}}$ | \overline{CS} high time between active periods | SCLKx | | | ns |
| t_{SL} | SCLK low pulse width | | $(SPIDIV + 1) \times t_{HCLK}$ | | ns |
| t_{SH} | SCLK high pulse width | | $(SPIDIV + 1) \times t_{HCLK}$ | | ns |
| t_{DAV} | Data output valid after SCLK edge | | 20 | | ns |
| t_{DSU} | Data input setup time before SCLK edge | 10 | | | ns |
| t_{DHD} | Data input hold time after SCLK edge | 10 | | | ns |
| t_{DF} | Data output fall time | | 25 | | ns |
| t_{DR} | Data output rise time | | 25 | | ns |
| t_{SR} | SCLK rise time | 1 | | | ns |
| t_{SF} | SCLK fall time | 1 | | | ns |
| t_{DOCS} | Data output valid after \overline{CS} edge | 20 | | | ns |
| t_{SFS} | \overline{CS} high after SCLK edge | 10 | | | ns |

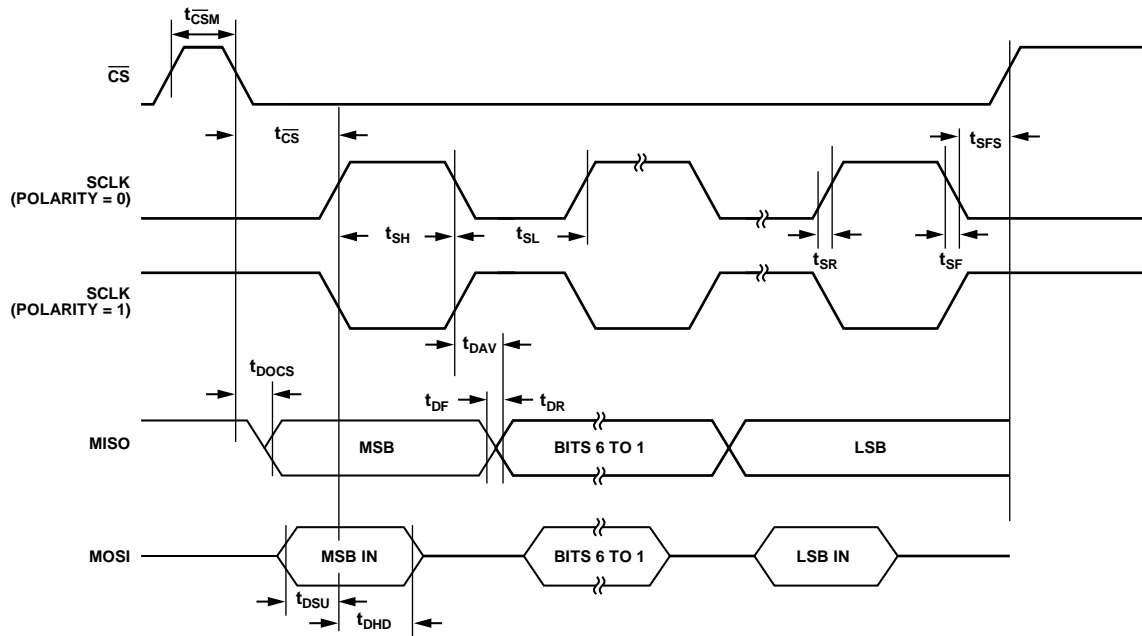


Figure 6. SPI Slave Mode Timing (Phase Mode = 0)

13754-014

Table 8. MDIO vs. MDC Timing

| Parameter | Description | Min | Typ | Max | Unit |
|-------------|----------------------------|-----|-----|-----|------|
| t_{SETUP} | MDIO setup before MCK edge | 10 | | | ns |
| t_{HOLD} | MDIO valid after MCK edge | 10 | | | ns |
| t_{DELAY} | Data output after MCK edge | | | 100 | ns |

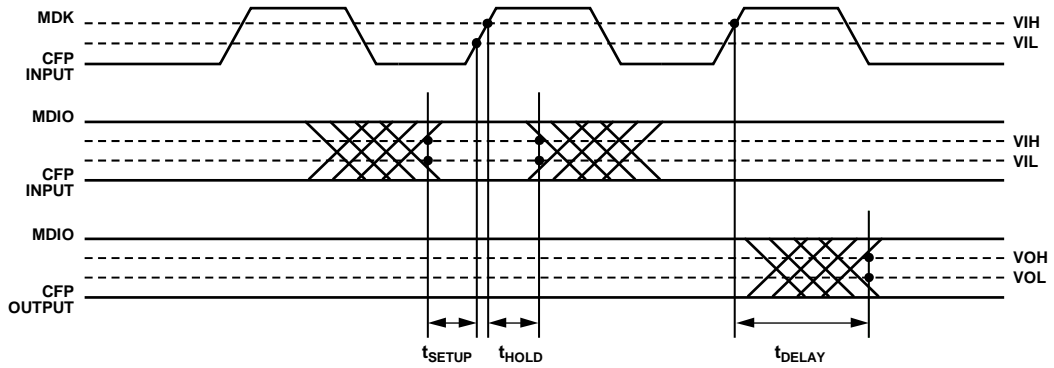


Figure 7. MDIO Timing

13754-015

ABSOLUTE MAXIMUM RATINGS

Table 9.

| Parameter | Rating |
|---|--------------------------|
| Any Ball to GND | -0.3 V to +3.9 V |
| Any RES1 Type Ball to GND | -0.3 V to +2.8 V |
| MDIO, ¹ MCK and PRTADDR0 to PRTADDR4 in MDIO Mode to GND | -0.3 V to +2.1 V |
| Between Any of AVDDx, IOVDDx, and VDD1 Balls | -0.3 V to +0.3 V |
| Any I Type Ball to GND ² | -0.3 V to IOVDDx + 0.3 V |
| Any RES Type, AI Type, or AO Type Ball to GND ³ | -0.3 V to AVDDx + 0.3 V |
| ADC_REFP to GND | -0.3 V to AVDDx + 0.3 V |
| Total Positive GPIO Ball Currents | 0 mA to 30 mA |
| Total Negative GPIO Ball Currents | -30 mA to 0 mA |
| Maximum Power Dissipation | 1 W |
| Operating Ambient Temperature Range | -40°C to +105°C |
| Storage Temperature Range | -65°C to +160°C |
| Operating Junction Temperature Range | -40°C to +150°C |
| Electrostatic Discharge (ESD) | |
| Human Body Model (HBM) | 2 kV |
| Field Induced Charged Device Mode (FICDM) | 1 kV |

¹ Note this ball is always in MDIO mode.

² This limit does not apply if no current can be drawn by external circuits on IOVDDx, because then IOVDD follows to a suitable level.

³ This limit does not apply if no current can be drawn by external circuits on AVDDx, because then AVDD follows to a suitable level.

Stresses at or above those listed under Absolute Maximum Ratings may cause permanent damage to the product. This is a stress rating only; functional operation of the product at these or any other conditions above those indicated in the operational section of this specification is not implied. Operation beyond the maximum operating conditions for extended periods may affect product reliability.

All requirements applicable to each ball must be met. Where multiple limits apply to a ball, each one must be met individually. The limits apply according to the functionality of the balls at the time. Balls that can be either analog or digital, that is, that have two types indicated in the ball descriptions, must meet the limits for both types. For ball types, see Table 10.

When powered up, it is required that all ground balls and ADC_REFN be connected together to a node referred to as GND in Table 9. The limits that are listed must be reduced by any difference between any GNDs. Also, it is required that AVDD3 is connected to AVDD4 and that IOVDD1 to IOVDD3 are connected together.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

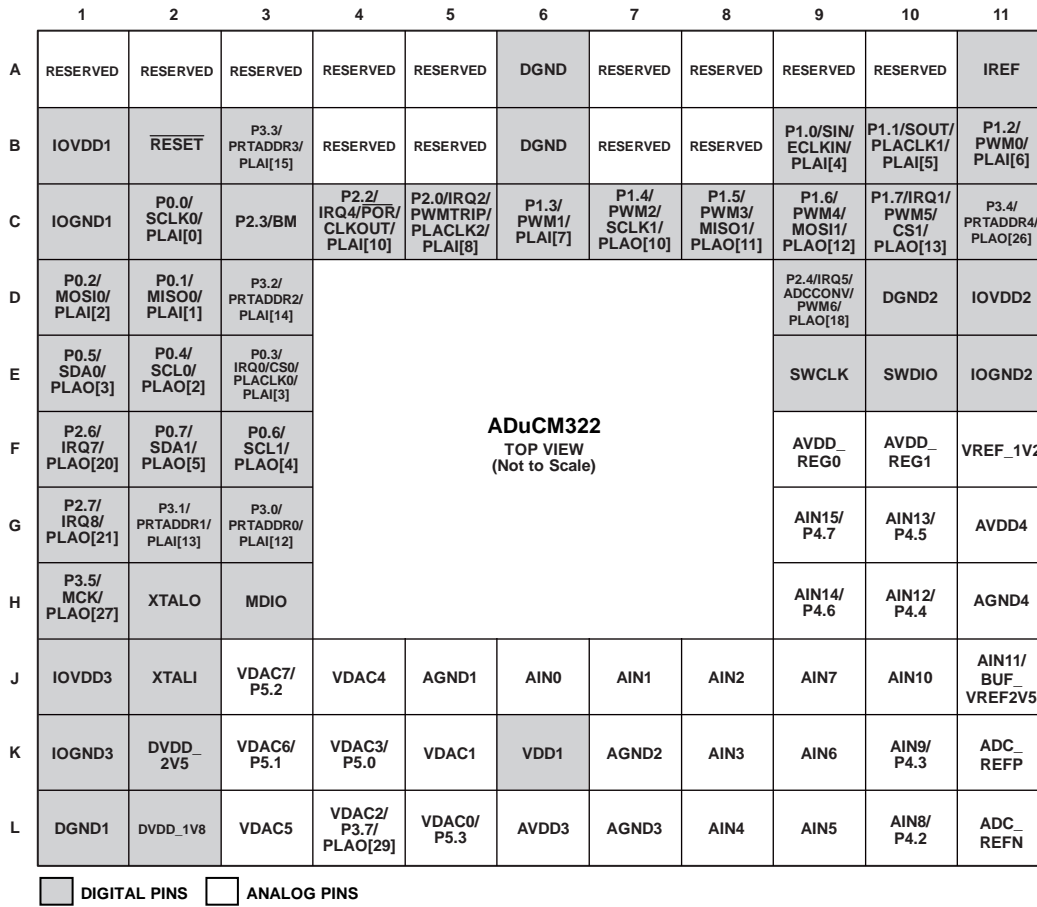


Figure 8. Pin Configuration

13754-002

Table 10. Pin Function Descriptions

| Pin No. | Mnemonic | Type ¹ | Description |
|---------|------------------------|-------------------|---|
| A1 | RESERVED | RES | No Connect. Leave this ball unconnected. |
| A2 | RESERVED | RES | Connect to AGND. |
| A3 | RESERVED | RES1 | Connect to AVDD_REG1. |
| A4 | RESERVED | RES1 | Connect to AVDD_REG1. |
| A5 | RESERVED | RES | Connect to AGND. |
| A6 | DGND | S | Power Supply Ground. |
| A7 | RESERVED | RES | Connect to AGND. |
| A8 | RESERVED | RES1 | Connect to AVDD_REG1. |
| A9 | RESERVED | RES1 | Connect to AVDD_REG1. |
| A10 | RESERVED | RES | Connect to AGND. |
| A11 | IREF | AI | Reference Current. This ball generates the reference current and is set by an external resistor, R _{EXT} . Connect a 3.3 kΩ R _{EXT} from IREF to DGND. |
| B1 | IOVDD1 | S | 3.3 V GPIO Supply. |
| B2 | RESET | I | Reset Input (Active Low). An internal pull-up resistor is included. |
| B3 | P3.3/PRTADDR3/PLAI[15] | I/O | Digital Input/Output Port 3.3 (P3.3). MDIO Port Address Bit 3 (PRTADDR3). See the Digital Inputs parameter in Table 1 for details. Output of PLA Element 15 (PLAI[15]). |
| B4 | RESERVED | RES | No Connect. Leave this ball unconnected. |
| B5 | RESERVED | RES | No Connect. Leave this ball unconnected. |
| B6 | DGND | S | Power Supply Ground. |

| Pin No. | Mnemonic | Type ¹ | Description |
|---------|---|-------------------|--|
| B7 | RESERVED | RES | No Connect. Leave this ball unconnected. |
| B8 | RESERVED | RES | No Connect. Leave this ball unconnected. |
| B9 | P1.0/SIN/ECLKIN/PLAI[4] | I/O | Digital Input/Output Port 1.0 (P1.0). UART Input (SIN). External Input Clock (ECLKIN). Input to PLA Element 4 (PLAI[4]). |
| B10 | P1.1/SOUT/PLACK1/PLAI[5] | I/O | Digital Input/Output Port 1.1 (P1.1). UART Output (SOUT). PLA Clock 1(PLACK1). Input to PLA Element 5 (PLAI[5]). |
| B11 | P1.2/PWM0/PLAI[6] | I/O | Digital Input/Output Port 1.2 (P1.2). PWM Output 0 (PWM0). Input to PLA Element 6 (PLAI[6]). |
| C1 | IOGND1 | S | Ground for IOVDD1. |
| C2 | P0.0/SCLK0/PLAI[0] | I/O | Digital Input/Output Port 0.0 (P0.0). SPI0 Clock (SCLK0). Input to PLA Element 0 (PLAI[0]). |
| C3 | P2.3/BM | I/O | Digital Input/Output Port 2.3 (P2.3). Boot Mode (BM). This ball determines the start-up sequence after every reset. Pull-up is enabled at power-up. |
| C4 | P2.2/IRQ4/ $\overline{\text{POR}}$ /CLKOUT/PLAI[10] | I/O | Digital Input/Output Port 2.2 (P2.2). External Interrupt 4 (IRQ4). Reset Output ($\overline{\text{POR}}$). This ball function is an output and it is the default for Ball C4. Clock Output (CLKOUT). Input to PLA Element 10 (PLAI[10]). |
| C5 | P2.0/IRQ2/PWMTRIP/PLACK2/PLAI[8] | I/O | Digital Input/Output Port 2.0 (P2.0). External Interrupt 2 (IRQ2). PWM Trip (PWMTRIP). PLA Input Clock 2 (PLACK2). Input to PLA Element 8 (PLAI[8]). |
| C6 | P1.3/PWM1/PLAI[7] | I/O | Digital Input/Output Port 1.3 (P1.3). PWM Output 1 (PWM1). Input to PLA Element 7 (PLAI[7]). |
| C7 | P1.4/PWM2/SCLK1/PLAO[10] | I/O | Digital Input/Output Port 1.4 (P1.4). PWM Output 2 (PWM2). SPI1 Clock (SCLK1). Output of PLA Element 10 (PLAO[10]). |
| C8 | P1.5/PWM3/MISO1/PLAO[11] | I/O | Digital Input/Output Port 1.5 (P1.5). PWM Output 3 (PWM3). SPI1 Master In, Slave Out (MISO1). Output of PLA Element 11 (PLAO[11]). |
| C9 | P1.6/PWM4/MOSI1/PLAO[12] | I/O | Digital Input/Output Port 1.6 (P1.6). PWM Output 4 (PWM4). SPI1 Master Out, Slave Input (MOSI1). Output of PLA Element 12 (PLAO[12]). |
| C10 | P1.7/IRQ1/PWM5/CS1/PLAO[13] | I/O | Digital Input/Output Port 1.7 (P1.7). External Interrupt 1 (IRQ1). PWM Output 5 (PWM5). SPI1 Chip Select 1 (CS1). When using SPI1, configure this ball as CS1. Output of PLA Element 13 (PLAO[13]). |

| Pin No. | Mnemonic | Type ¹ | Description |
|---------|---------------------------------|-------------------|--|
| C11 | P3.4/PRTADDR4/PLAO[26] | I/O | Digital Input/Output Port 3.4 (P3.4). MDIO Port Address Bit 4 (PRTADDR4). See the Digital Inputs parameter in Table 1 for details. Output of PLA Element 26 (PLAO[26]). |
| D1 | P0.2/MOSI0/PLAI[2] | I/O | Digital Input/Output Port 0.2 (P0.2). SPI0 Master Out, Slave In (MOSI0). Input to PLA Element 2 (PLAI[2]). |
| D2 | P0.1/MISO0/PLAI[1] | I/O | Digital Input/Output Port 0.1 (P0.1). SPI0 Master In, Slave Out (MISO0). Input to PLA Element 1 (PLAI[1]). |
| D3 | P3.2/PRTADDR2/PLAI[14] | I/O | Digital Input/Output Port 3.2 (P3.2). MDIO Port Address Bit 2 (PRTADDR2). See the Digital Inputs parameter in Table 1 for details. Input to PLA Element 14 (PLAI[14]). |
| D9 | P2.4/IRQ5/ADCCONV/PWM6/PLAO[18] | I/O | Digital Input/Output Port 2.4 (P2.4). External Interrupt 5 (IRQ5). External Input to Start ADC Conversions (ADCCONV). PWM Output 6 (PWM6). Output of PLA Element 18 (PLAO[18]). |
| D10 | DGND2 | S | Digital Ground 2. Connect to DGND1. |
| D11 | IOVDD2 | S | 3.3 V GPIO Supply. |
| E1 | P0.5/SDA0/PLAO[3] | I/O | Digital Input/Output Port 0.5 (P0.5). I ² C0 Serial Data (SDA0). Output of PLA Element 3 (PLAO[3]). |
| E2 | P0.4/SCL0/PLAO[2] | I/O | Digital Input/Output Port 0.4 (P0.4). I ² C0 Serial Clock (SCL0). Output of PLA Element 2 (PLAO[2]). |
| E3 | P0.3/IRQ0/CS0/PLACLK0/PLAI[3] | I/O | Digital Input/Output Port 0.3 (P0.3). External Interrupt 0 (IRQ0). SPI0 Chip Select 0 (CS0). When using SPI0, configure this ball as CS0. PLA Clock 0 (PLACLK0). Input to PLA Element 3 (PLAI[3]). |
| E9 | SWCLK | I | Serial Wire Debug Clock. |
| E10 | SWDIO | I/O | Serial Wire Bidirectional Data. |
| E11 | IOGND2 | S | Ground for IOVDD2. |
| F1 | P2.6/IRQ7/PLAO[20] | I/O | Digital Input/Output Port 2.6 (P2.6). External Interrupt 7 (IRQ7). Output of PLA Element 20 (PLAO[20]). |
| F2 | P0.7/SDA1/PLAO[5] | I/O | Digital Input/Output Port 0.7 (P0.7). I ² C1 Serial Data (SDA1). Output of PLA Element 5 (PLAO[5]). |
| F3 | P0.6/SCL1/PLAO[4] | I/O | Digital Input/Output Port 0.6 (P0.6). I ² C1 Serial Clock (SCL1). Output of PLA Element 4 (PLAO[4]). |
| F9 | AVDD_REG0 | AO | Analog Regulator 0 Supply. A 470 nF capacitor to AGND4 must be connected to this ball to stabilize the internal 2.5 V regulator that supplies the ADC. |
| F10 | AVDD_REG1 | AO | Analog Regulator 1 Supply. Output of 2.5 V on-chip LDO regulator. A 470 nF capacitor to AGND4 must be connected to this ball. |
| F11 | VREF_1V2 | S | 1.2 V Reference. This ball cannot be used to source current externally. Connect VREF_1V2 to AGNDx via a 470 nF capacitor. |
| G1 | P2.7/IRQ8/PLAO[21] | I/O | Digital Input/Output Port 2.7 (P2.7). External Interrupt 8 (IRQ8). Output of PLA Element 21 (PLAO[21]). |

| Pin No. | Mnemonic | Type ¹ | Description |
|---------|------------------------|-------------------|--|
| G2 | P3.1/PRTADDR1/PLAI[13] | I/O | Digital Input/Output Port 3.1 (P3.1). MDIO Port Address Bit 1 (PRTADDR1). See the Digital Inputs parameter in Table 1 for details. Input to PLA Element 13 (PLAI[13]). |
| G3 | P3.0/PRTADDR0/PLAI[12] | I/O | Digital Input/Output Port 3.0 (P3.0). MDIO Port Address Bit 0 (PRTADDR0). See the Digital Inputs parameter in Table 1 for details. Input to PLA Element 12 (PLAI[12]). |
| G9 | AIN15/P4.7 | AI/I/O | Analog Input 15 (AIN15). Digital Input/Output Port 4.7 (P4.7). |
| G10 | AIN13/P4.5 | AI/I/O | Analog Input 13 (AIN13). Digital Input/Output Port 4.5 (P4.5). |
| G11 | AVDD4 | S | ADC Supply (3.3 V). |
| H1 | P3.5/MCK/PLAO[27] | I/O | Digital Input/Output Port 3.5 (P3.5). MDIO Clock (MCK). See the Digital Inputs parameter in Table 1 for more details. Output of PLA Element 27 (PLAO[27]). |
| H2 | XTALO | O | Output from the Crystal Oscillator Inverter. When not using an external crystal, leave XTALO unconnected. |
| H3 | MDIO | I/O | MDIO Data. |
| H9 | AIN14/P4.6 | AI/I/O | Analog Input 14 (AIN14). Digital Input/Output Port 4.6 (P4.6). |
| H10 | AIN12/P4.4 | AI/I/O | Analog Input 12 (AIN12). Digital Input/Output Port 4.4 (P4.4). |
| H11 | AGND4 | S | Ground for AVDD4, AVDD_REG0, and AVDD_REG1. |
| J1 | IOVDD3 | S | 3.3 V GPIO Supply. |
| J2 | XTALI | I | Input to the Crystal Oscillator Inverter and Input to the Internal Clock Generator Circuits. When not using an external crystal, connect XTALI to DGND. |
| J3 | VDAC7/P5.2 | AO/I/O | Voltage DAC7 Output (VDAC7). Digital Input/Output Port 5.2 (P5.2). |
| J4 | VDAC4 | AO | Voltage DAC4 Output (VDAC4). |
| J5 | AGND1 | S | Analog Ground for VDD1. |
| J6 | AIN0 | AI | Analog Input 0. |
| J7 | AIN1 | AI | Analog Input 1. |
| J8 | AIN2 | AI | Analog Input 2. |
| J9 | AIN7 | AI | Analog Input 7. |
| J10 | AIN10 | AI | Analog Input 10. |
| J11 | AIN11/BUF_VREF2V5 | AI/AO | Analog Input 11 (AIN11). Buffered 2.5 V Bias (BUF_VREF2V5). The maximum load is 1.2 mA. Connect BUF_VREF2V5 to AGNDx via a 100 nF capacitor. |
| K1 | IOGND3 | S | Ground for IOVDD3. |
| K2 | DVDD_2V5 | AO | 2.5 V Digital Supply. A 470 nF capacitor to IOGND3 must be connected to this ball to stabilize the internal 2.5 V regulator that supplies the analog digital control. |
| K3 | VDAC6/P5.1 | AO/I/O | Voltage DAC6 Output (VDAC6). Digital Input/Output Port 5.1 (P5.1). |
| K4 | VDAC3/P5.0 | AO/I/O | Voltage DAC3 Output (VDAC3). Digital Input/Output Port 5.0 (P5.0). |
| K5 | VDAC1 | AO | Voltage DAC1 Output. |
| K6 | VDD1 | S | 3.3 V Supply for Digital Die. |
| K7 | AGND2 | S | ESD Ground for Pad Ring. |
| K8 | AIN3 | AI | Analog Input 3. |
| K9 | AIN6 | AI | Analog Input 6. AIN6 is also the positive input for the comparator. |
| K10 | AIN9/P4.3 | AI/I/O | Analog Input 9 (AIN9). Digital Input/Output Port 4.3 (P4.3). |

| Pin No. | Mnemonic | Type ¹ | Description |
|---------|---------------------|-------------------|--|
| K11 | ADC_REFP | AO/A | Decoupling Capacitor Connection for ADC Reference Buffer. Connect this ball to a 4.7 μ F capacitor to the ADC_REFN ball. ADC_REFP can be overdriven by an external reference. |
| L1 | DGND1 | S | Digital Ground 1 for DVDD_1V8. |
| L2 | DVDD_1V8 | AO | 1.8 V Digital Supply. A 470 nF capacitor to DGND1 must be connected to this ball to stabilize the internal 1.8 V regulator that supplies flash memory and the ARM Cortex-M3 processor. |
| L3 | VDAC5 | AO | Voltage DAC5 Output (VDAC5). |
| L4 | VDAC2/P3.7/PLAO[29] | AO/I/O | Voltage DAC2 Output (VDAC2). Digital Input/Output Port 3.7 (P3.7). Output of PLA Element 29 (PLAO[29]). |
| L5 | VDAC0/P5.3 | AO/I/O | Voltage DAC0 Output (VDAC0). Digital Input/Output Port 5.3 (P5.3). |
| L6 | AVDD3 | S | VDAC Supply (3.3 V). |
| L7 | AGND3 | S | Ground for AVDD3. |
| L8 | AIN4 | AI | Analog Input 4. |
| L9 | AIN5 | AI | Analog Input 5. AIN5 can be the negative input for the comparator. |
| L10 | AIN8/P4.2 | AI/I/O | Analog Input 8 (AIN8). Digital Input/Output Port 4.2 (P4.2). |
| L11 | ADC_REFN | AO/A | Decoupling Capacitor Connection for ADC Reference Buffer. Connect this ball to AGND4. |

¹ RES and RES1 are reserved, S is supply, AI is analog input, I is digital input, I/O is input/output, AO is analog output, and O is digital output.

TYPICAL PERFORMANCE CHARACTERISTICS

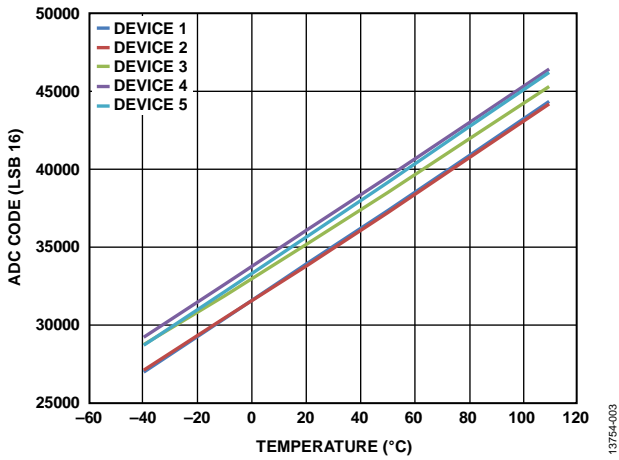


Figure 9. Temperature Measurement vs. Internal Temperature ($V_{DD} = 3.3\text{ V}$, 50 kSPS)

13754-003

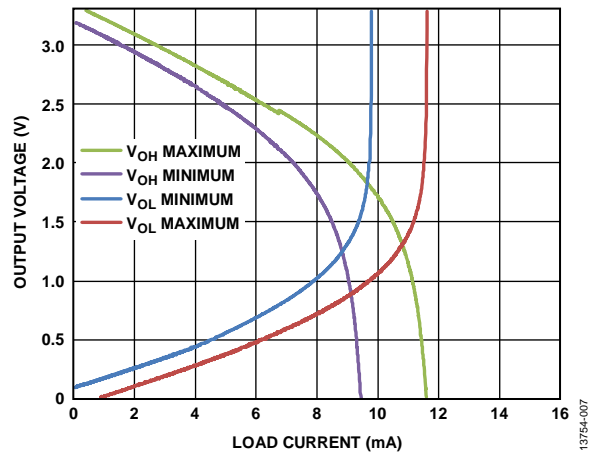


Figure 11. Output Voltage vs. Load Current

13754-007

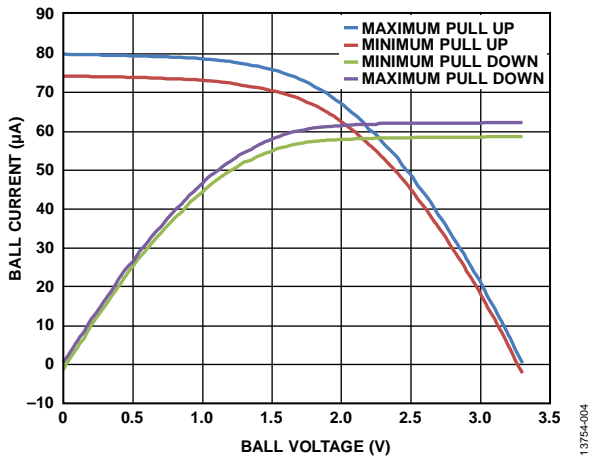


Figure 10. Pull-Up/Pull-Down Ball Current vs. Ball Voltage ($V_{DD} = 3.3\text{ V}$, $T_A = 25^\circ\text{C}$)

13754-004

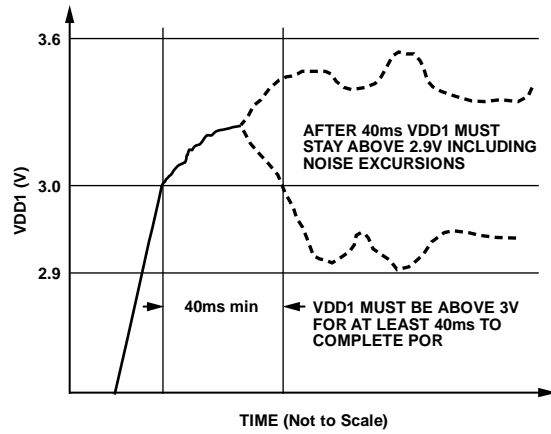


Figure 12. VDD1 Power-On Requirements

13754-008

APPLICATIONS INFORMATION

RECOMMENDED CIRCUIT AND COMPONENT VALUES

Figure 13 shows a typical connection diagram for the [ADuCM322](#).

Supplies and regulators must be adequately decoupled with capacitors connected between the AVDD_x, DVDD_x, AVDD_REG_x, IOVDD_x, and VDD1 balls and their associated GND balls (AGND_x, IOGND_x, and DGND_x). Table 10 indicates which ground balls are paired with which supply balls.

There are four digital supply balls: IOVDD1, IOVDD2, IOVDD3, and VDD1. Decouple these balls with a 100 nF capacitor placed as near as possible to each of the four balls and their associated ground balls (IOGND_x and AGND1, respectively). In addition, place a 10 μF capacitor conveniently near to these balls.

Similarly, the analog supply balls, AVDD3 and AVDD4, each require a 100 nF capacitor placed as near as possible to each ball and its associated AGND_x ball, and place a 10 μF capacitor conveniently near to these balls.

The ADC reference requires a 4.7 μF capacitor placed between ADC_REFP and ADC_REFN and located as near as possible to each ball. ADC_REFN must be connected directly to AGND4.

The [ADuCM322](#) contains four internal regulators. These regulators require external decoupling capacitors. The DVDD_1V8 and DVDD_2V5 balls each require a 470 nF capacitor to DGND1 and IOGND3, respectively. AVDD_REG0 and AVDD_REG1 each require a decoupling capacitor to AGND4. The AVDD_REG1 output ball must be connected to Ball A3, Ball A4, Ball A8, and Ball A9.

Connect the IREF ball to DGND via a standard 3.3 kΩ resistor.

Take care in the layout to ensure that currents flowing from the ground end of each decoupling capacitor to its associated ground ball share as little track as possible with other ground currents on the printed circuit board.

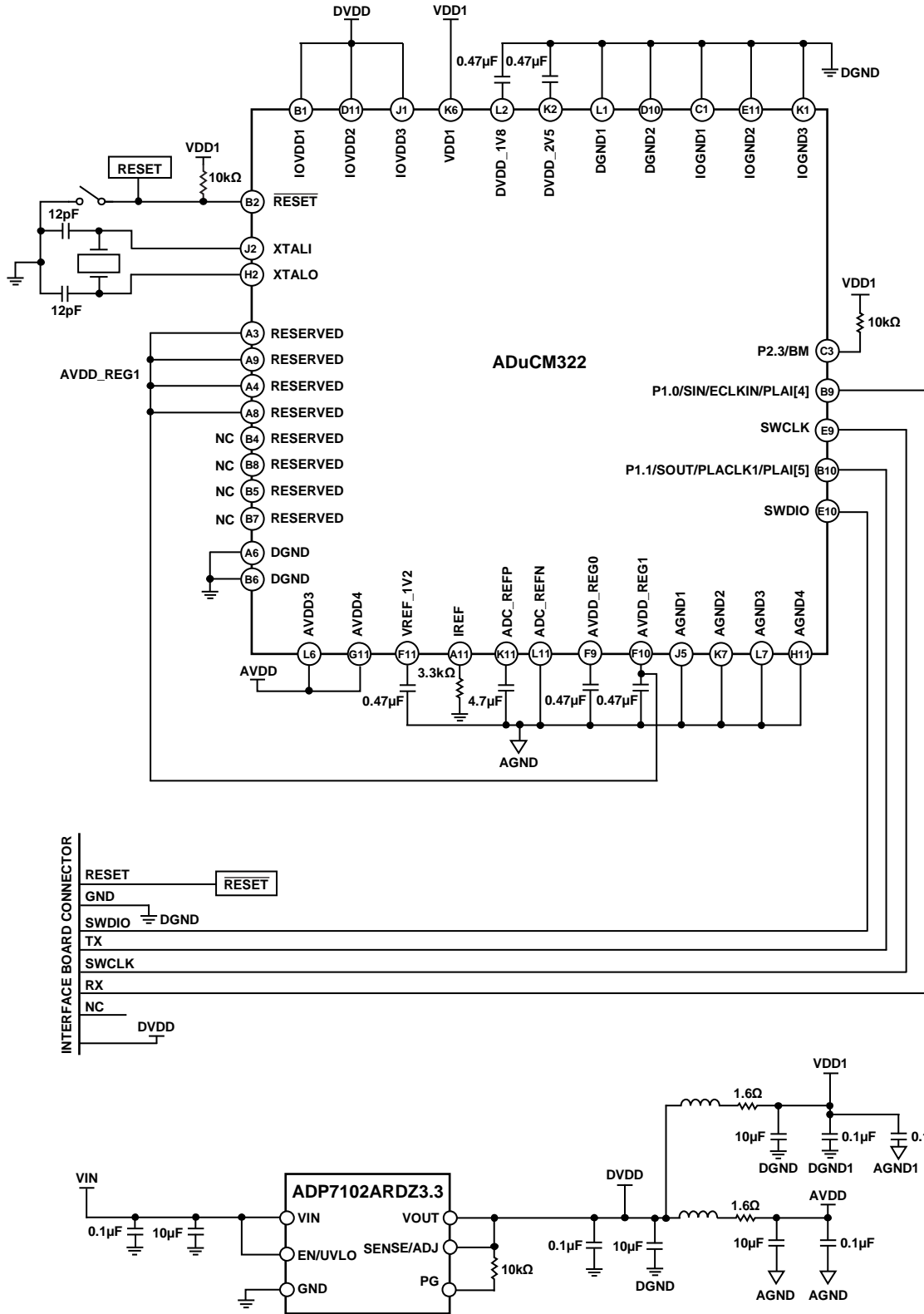
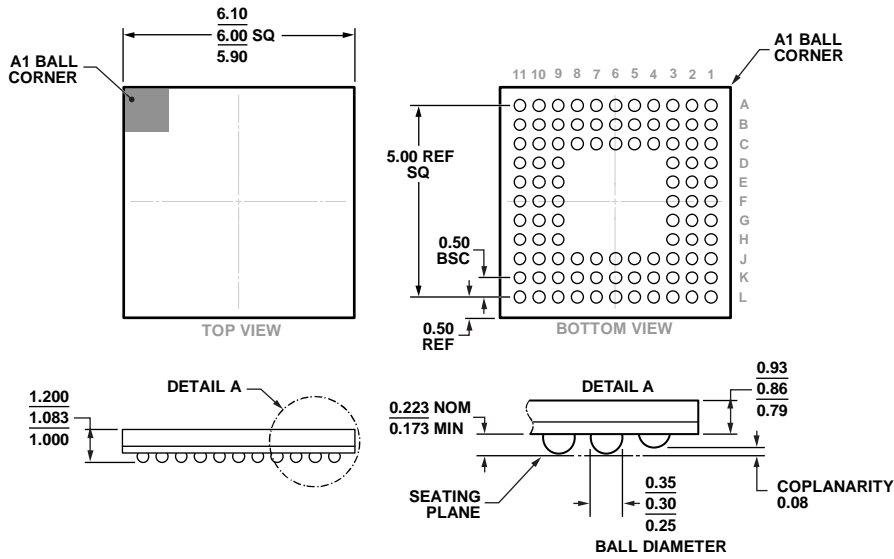


Figure 13. Recommended Circuit and Component Values

13754-009

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MO-195-AC
WITH THE EXCEPTION TO BALL COUNT.
Figure 14. 96-Ball Chip Scale Package Ball Grid Array [CSP_BGA]
(BC-96-2)
Dimensions shown in millimeters

04-02-2013-A

ORDERING GUIDE

| Model ¹ | Temperature Range | Package Description | Package Option | Downloader | Ordering Quantity |
|--------------------|-------------------|---|----------------|------------|-------------------|
| ADuCM322BBCZ | -40°C to +105°C | 96-Ball CSP_BGA | BC-96-2 | MDIO | 429 |
| ADuCM322BBCZ-RL | -40°C to +105°C | 96-Ball CSP_BGA | BC-96-2 | MDIO | 2,500 |
| EV-ADuCM322QSPZ | | Evaluation Board with QuickStart Development System | | MDIO | 1 |

¹ Z = RoHS Compliant Part.

¹C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).