

# ADC1413S series

Single 14-bit ADC; 65 Msps, 80 Msps, 105 Msps or 125 Msps;  
serial JESD204A interface

Rev. 03 — 2 July 2012

Product data sheet

## 1. General description

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The ADC1413S is a single channel 14-bit Analog-to-Digital Converter (ADC) optimized for high dynamic performance and low power at sample rates up to 125 Msps. Pipelined architecture and output error correction ensure the ADC1413S is accurate enough to guarantee zero missing codes over the entire operating range. Supplied from a 3 V source for analog and a 1.8 V source for the output driver, it outputs data in serial mode via a single differential lane, which complies with the JESD204A standard. The integration of Serial Peripheral Interface (SPI) allows the user to easily configure the ADCs and the serial output modes. The device also includes a programmable full-scale SPI to allow a flexible input voltage range from 1 V (p-p) to 2 V (p-p).

Excellent dynamic performance is maintained from the baseband to input frequencies of 170 MHz or more, making the ADC1413S ideal for use in communications, imaging, and medical applications.

## 2. Features and benefits

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- SNR, 72.1 dBFS; SFDR, 86 dBc
- Sample rates up to 125 Msps
- Single channel, 14-bit pipelined ADC core
- 3 V, 1.8 V power supplies
- Flexible input voltage range: 1 V (p-p) to 2 V (p-p)
- serial output
- Compliant with JESD204A serial transmission standard
- Pin compatible with the ADC1613S series, ADC1213S series, and ADC1113S125
- Input bandwidth, 600 MHz
- Power dissipation, 550 mW at 80 Msps
- SPI register programming
- Duty cycle stabilizer
- High Intermediate Frequency (IF) capability
- Offset binary, two's complement, gray code
- Power-down mode and Sleep mode
- HVQFN32 package

## 3. Applications

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- Wireless and wired broadband communications
- Spectral analysis
- Ultrasound equipment
- Portable instrumentation
- Imaging systems





## 6. Pinning information

### 6.1 Pinning

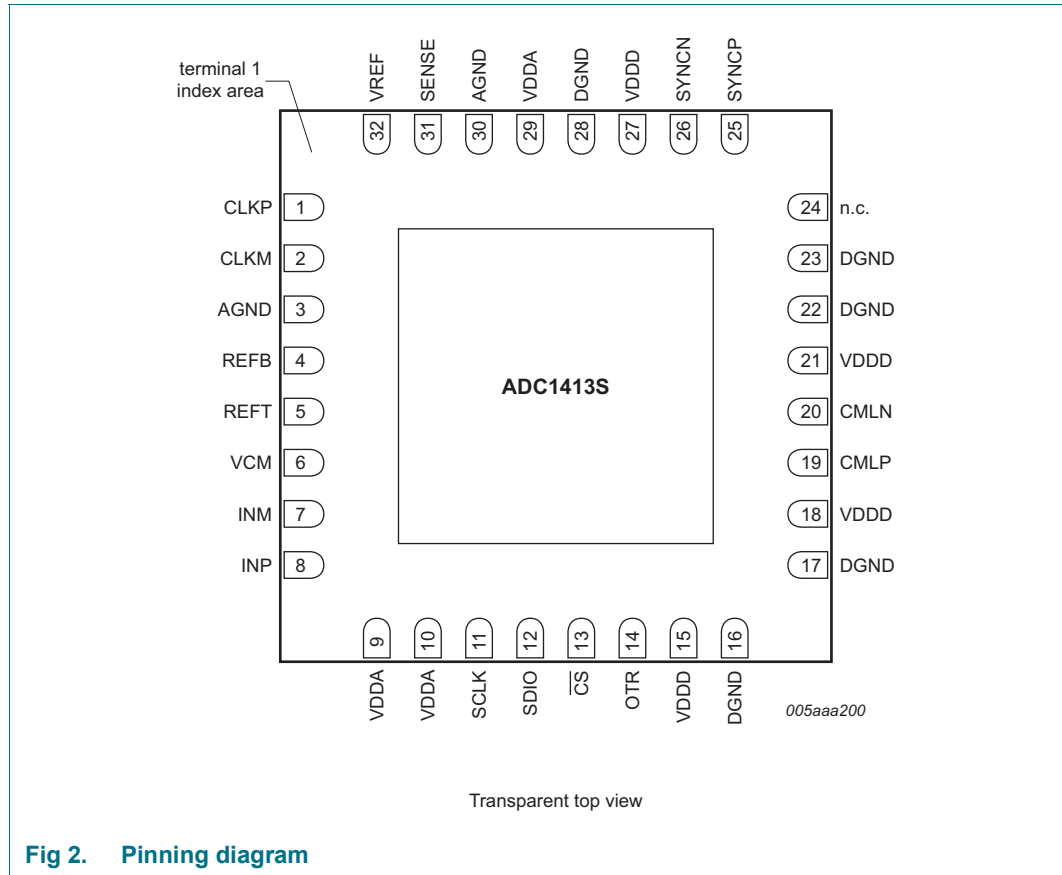


Fig 2. Pinning diagram

### 6.2 Pin description

Table 2. Pin description

Symbol	Pin	Type <sup>[1]</sup>	Description
CLKP	1	I	clock input
CLKM	2	I	complementary clock input
AGND	3	G	analog ground
REFB	4	O	ADC bottom reference
REFT	5	O	ADC top reference
VCM	6	O	ADC output common voltage
INM	7	I	ADC complementary analog input
INP	8	I	ADC analog input
VDDA	9	P	analog power supply 3 V
VDDA	10	P	analog power supply 3 V
SCLK	11	I	SPI clock
SDIO	12	I/O	SPI data input/output
$\overline{\text{CS}}$	13	I	chip select

Table 2. Pin description ...continued

Symbol	Pin	Type <sup>[1]</sup>	Description
OTR	14	O	out-of-range information
VDDD	15	P	digital power supply 1.8 V
DGND	16	G	digital ground
DGND	17	G	digital ground
VDDD	18	P	digital power supply 1.8 V
CMLP	19	O	serial output
CMLN	20	O	serial complementary output
VDDD	21	P	digital power supply 1.8 V
DGND	22	G	digital ground
DGND	23	G	digital ground
n.c.	24	-	not connected
SYNCP	25	I	positive synchronization signal from the receiver
SYNCPN	26	I	negative synchronization signal from the receiver
VDDD	27	P	digital power supply 1.8 V
DGND	28	G	digital ground
VDDA	29	P	analog power supply 3 V
AGND	30	G	analog ground
SENSE	31	I	reference programming pin
VREF	32	I/O	voltage reference input/output

[1] P: power supply; G: ground; I: input; O: output; I/O: input/output.

## 7. Limiting values

Table 3. Limiting values

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V <sub>DDA</sub>	analog supply voltage		-0.4	+4.6	V
V <sub>DDD(1V8)</sub>	digital supply voltage (1.8 V)		-0.4	+2.5	V
T <sub>stg</sub>	storage temperature		-55	+125	°C
T <sub>amb</sub>	ambient temperature		-40	+85	°C
T <sub>j</sub>	junction temperature		-	125	°C

## 8. Thermal characteristics

**Table 4. Thermal characteristics**

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient		[1] 25.6	K/W
$R_{th(j-c)}$	thermal resistance from junction to case		[1] 8.6	K/W

[1] Value for six layers board in still air with a minimum of 25 thermal vias.

## 9. Static characteristics

**Table 5. Static characteristics [1]**

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Supplies</b>						
$V_{DDA}$	analog supply voltage		2.85	3.0	3.4	V
$V_{DDD(1V8)}$	digital supply voltage (1.8 V)		1.65	1.8	1.95	V
$I_{DDA}$	analog supply current	$f_{clk} = 125$ Msps; $f_i = 70$ MHz	-	185	-	mA
$I_{DDD(1V8)}$	digital supply current (1.8 V)	$f_{clk} = 125$ Msps; $f_i = 70$ MHz	-	75	-	mA
$P_{tot}$	total power dissipation	$f_{clk} = 125$ Msps	-	690	-	mW
		$f_{clk} = 105$ Msps	-	625	-	mW
		$f_{clk} = 80$ Msps	-	550	-	mW
		$f_{clk} = 65$ Msps	-	495	-	mW
P	power dissipation	Power-down mode	-	30	-	mW
		Standby mode	-	150	-	mW
<b>Digital inputs</b>						
<b>Clock inputs: pins CLKP and CLKM (AC-coupled)</b>						
<b>Low-Voltage Positive Emitter-Coupled Logic (LVPECL)</b>						
$V_{i(clk)dif}$	differential clock input voltage	peak-to-peak	-	1.6	-	V
<b>Sine</b>						
$V_{i(clk)dif}$	differential clock input voltage	peak	$\pm 0.8$	$\pm 3.0$	-	V
<b>Low Voltage Complementary Metal Oxide Semiconductor (LVCMOS)</b>						
$V_{IL}$	LOW-level input voltage		-	-	$0.3V_{DDA}$	V
$V_{IH}$	HIGH-level input voltage		$0.7V_{DDA}$	-	-	V
<b>SPI: pins CS, SDIO, and SCLK</b>						
$V_{IL}$	LOW-level input voltage		0	-	$0.3V_{DDA}$	V
$V_{IH}$	HIGH-level input voltage		$0.7V_{DDA}$	-	$V_{DDA}$	V
$I_{IL}$	LOW-level input current		-10	-	+10	$\mu$ A
$I_{IH}$	HIGH-level input current		-50	-	+50	$\mu$ A
$C_i$	input capacitance		-	4	-	pF

Table 5. Static characteristics ...continued<sup>[1]</sup>

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Analog inputs: pins INP and INM</b>						
$I_I$	input current	track mode	-5	-	+5	$\mu\text{A}$
$R_I$	input resistance	track mode	-	15	-	$\Omega$
$C_I$	input capacitance	track mode	-	5	-	pF
$V_{I(\text{cm})}$	common-mode input voltage	track mode	1.1	1.5	2	V
$B_I$	input bandwidth		-	600	-	MHz
$V_{I(\text{dif})}$	differential input voltage	peak-to-peak	1	-	2	V
<b>Voltage controlled regulator output: pin VCM</b>						
$V_{O(\text{cm})}$	common-mode output voltage		-	$0.5V_{\text{DDA}}$	-	V
$I_{O(\text{cm})}$	common-mode output current		-	4	-	mA
<b>Reference voltage input/output: pin VREF</b>						
$V_{\text{VREF}}$	voltage on pin VREF	output	0.5	-	1	V
		input	0.5	-	1	V
<b>Data outputs: CMLP, CMLN</b>						
Output levels, $V_{\text{DD}(1\text{V}8)} = 1.8\text{ V}$ ; $\text{SWING\_SEL}[2:0] = 000$						
$V_{\text{OL}}$	LOW-level output voltage	DC-coupled; output	-	1.5	-	V
		AC-coupled	-	1.35	-	V
$V_{\text{OH}}$	HIGH-level output voltage	DC-coupled; output	-	1.8	-	V
		AC-coupled	-	1.65	-	V
Output levels, $V_{\text{DD}(1\text{V}8)} = 1.8\text{ V}$ ; $\text{SWING\_SEL}[2:0] = 001$						
$V_{\text{OL}}$	LOW-level output voltage	DC-coupled; output	-	1.45	-	V
		AC-coupled	-	1.275	-	V
$V_{\text{OH}}$	HIGH-level output voltage	DC-coupled; output	-	1.8	-	V
		AC-coupled	-	1.625	-	V
Output levels, $V_{\text{DD}(1\text{V}8)} = 1.8\text{ V}$ ; $\text{SWING\_SEL}[2:0] = 010$						
$V_{\text{OL}}$	LOW-level output voltage	DC-coupled; output	-	1.4	-	V
		AC-coupled	-	1.2	-	V
$V_{\text{OH}}$	HIGH-level output voltage	DC-coupled; output	-	1.8	-	V
		AC-coupled	-	1.6	-	V
Output levels, $V_{\text{DD}(1\text{V}8)} = 1.8\text{ V}$ ; $\text{SWING\_SEL}[2:0] = 011$						
$V_{\text{OL}}$	LOW-level output voltage	DC-coupled; output	-	1.35	-	V
		AC-coupled	-	1.125	-	V
$V_{\text{OH}}$	HIGH-level output voltage	DC-coupled; output	-	1.8	-	V
		AC-coupled	-	1.575	-	V
Output levels, $V_{\text{DD}(1\text{V}8)} = 1.8\text{ V}$ ; $\text{SWING\_SEL}[2:0] = 100$						
$V_{\text{OL}}$	LOW-level output voltage	DC-coupled; output	-	1.3	-	V
		AC-coupled	-	1.05	-	V
$V_{\text{OH}}$	HIGH-level output voltage	DC-coupled; output	-	1.8	-	V
		AC-coupled	-	1.55	-	V

Table 5. Static characteristics ...continued<sup>[1]</sup>

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Serial configuration: SYNCp, SYNCn</b>						
V <sub>IL</sub>	LOW-level input voltage	differential; input	-	0.95	-	V
V <sub>IH</sub>	HIGH-level input voltage	differential; input	-	1.47	-	V
<b>Accuracy</b>						
INL	integral non-linearity		-5	-	+5	LSB
DNL	differential non-linearity	guaranteed no missing codes	-0.95	±0.5	+0.95	LSB
E <sub>offset</sub>	offset error		-	±2	-	mV
E <sub>G</sub>	gain error	full-scale	-	± 0.5	-	%
<b>Supply</b>						
PSRR	power supply rejection ratio	200 mV (p-p) on pin VDDA; f <sub>i</sub> = DC	-	-54	-	dB

[1] Typical values measured at V<sub>DDA</sub> = 3 V, V<sub>DDD(1V8)</sub> = 1.8 V, T<sub>amb</sub> = 25 °C. Minimum and maximum values are across the full temperature range T<sub>amb</sub> = -40 °C to +85 °C at V<sub>DDA</sub> = 3 V, V<sub>DDD(1V8)</sub> = 1.8 V; V<sub>i(INP)</sub> - V<sub>i(INM)</sub> = -1 dBFS; internal reference mode; 100 Ω differential applied to serial outputs; unless otherwise specified.

## 10. Dynamic characteristics

### 10.1 Dynamic characteristics

Table 6. Dynamic characteristics [1]

Symbol	Parameter	Conditions	ADC1413S065			ADC1413S080			ADC1413S105			ADC1413S125			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
$\alpha_{2H}$	second harmonic level	$f_i = 3$ MHz	-	87	-	-	87	-	-	86	-	-	88	-	dBc
		$f_i = 30$ MHz	-	86	-	-	86	-	-	86	-	-	87	-	dBc
		$f_i = 70$ MHz	-	85	-	-	85	-	-	84	-	-	85	-	dBc
		$f_i = 170$ MHz	-	82	-	-	82	-	-	81	-	-	83	-	dBc
$\alpha_{3H}$	third harmonic level	$f_i = 3$ MHz	-	86	-	-	86	-	-	85	-	-	87	-	dBc
		$f_i = 30$ MHz	-	85	-	-	85	-	-	85	-	-	86	-	dBc
		$f_i = 70$ MHz	-	84	-	-	84	-	-	83	-	-	84	-	dBc
		$f_i = 170$ MHz	-	81	-	-	81	-	-	80	-	-	82	-	dBc
THD	total harmonic distortion	$f_i = 3$ MHz	-	83	-	-	83	-	-	82	-	-	84	-	dBc
		$f_i = 30$ MHz	-	82	-	-	82	-	-	82	-	-	83	-	dBc
		$f_i = 70$ MHz	-	81	-	-	81	-	-	80	-	-	81	-	dBc
		$f_i = 170$ MHz	-	78	-	-	78	-	-	77	-	-	79	-	dBc
ENOB	effective number of bits	$f_i = 3$ MHz	-	11.7	-	-	11.7	-	-	11.6	-	-	11.6	-	bits
		$f_i = 30$ MHz	-	11.6	-	-	11.5	-	-	11.5	-	-	11.5	-	bits
		$f_i = 70$ MHz	-	11.5	-	-	11.5	-	-	11.4	-	-	11.4	-	bits
		$f_i = 170$ MHz	-	11.4	-	-	11.4	-	-	11.3	-	-	11.3	-	bits
SNR	signal-to-noise ratio	$f_i = 3$ MHz	-	72.1	-	-	72.0	-	-	71.8	-	-	71.4	-	dBFS
		$f_i = 30$ MHz	-	71.3	-	-	71.2	-	-	71.2	-	-	71.1	-	dBFS
		$f_i = 70$ MHz	-	70.7	-	-	70.7	-	-	70.6	-	-	70.5	-	dBFS
		$f_i = 170$ MHz	-	70.2	-	-	70.1	-	-	70.0	-	-	69.9	-	dBFS
SFDR	spurious-free dynamic range	$f_i = 3$ MHz	-	86	-	-	86	-	-	85	-	-	87	-	dBc
		$f_i = 30$ MHz	-	85	-	-	85	-	-	85	-	-	86	-	dBc
		$f_i = 70$ MHz	-	84	-	-	84	-	-	83	-	-	84	-	dBc
		$f_i = 170$ MHz	-	81	-	-	81	-	-	80	-	-	82	-	dBc



**Table 6. Dynamic characteristics ...continued<sup>[1]</sup>**

Symbol	Parameter	Conditions	ADC1413S065			ADC1413S080			ADC1413S105			ADC1413S125			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
IMD	intermodulation distortion	$f_i = 3 \text{ MHz}$	-	89	-	-	89	-	-	88	-	-	89	-	dBc
		$f_i = 30 \text{ MHz}$	-	88	-	-	88	-	-	88	-	-	88	-	dBc
		$f_i = 70 \text{ MHz}$	-	87	-	-	87	-	-	86	-	-	86	-	dBc
		$f_i = 170 \text{ MHz}$	-	84	-	-	85	-	-	83	-	-	84	-	dBc
$\alpha_{ct(ch)}$	channel crosstalk	$f_i = 70 \text{ MHz}$	-	100	-	-	100	-	-	100	-	-	100	-	dBc

[1] Typical values measured at  $V_{DDA} = 3 \text{ V}$ ,  $V_{DDD(1V8)} = 1.8 \text{ V}$ ,  $T_{amb} = 25 \text{ }^\circ\text{C}$  and  $C_L = 5 \text{ pF}$ . Minimum and maximum values are across the full temperature range  $T_{amb} = -40 \text{ }^\circ\text{C}$  to  $+85 \text{ }^\circ\text{C}$  at  $V_{DDA} = 3 \text{ V}$ ,  $V_{DDD(1V8)} = 1.8 \text{ V}$ ;  $V_{i(INP)} - V_{i(INM)} = -1 \text{ dBFS}$ ; internal reference mode;  $100 \text{ } \Omega$  differential applied to serial outputs; unless otherwise specified.

## 10.2 Clock and digital output timing

**Table 7. Clock and digital output timing characteristics <sup>[1]</sup>**

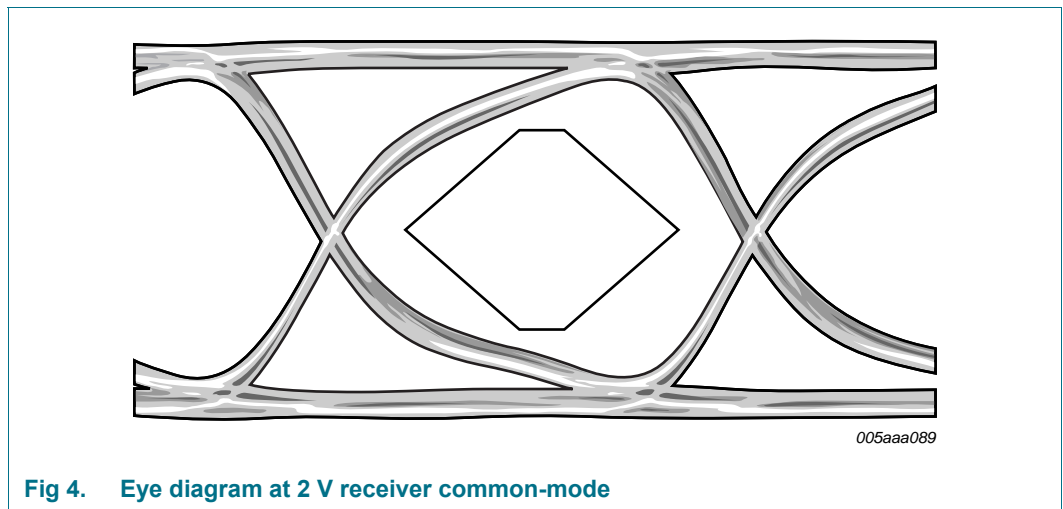
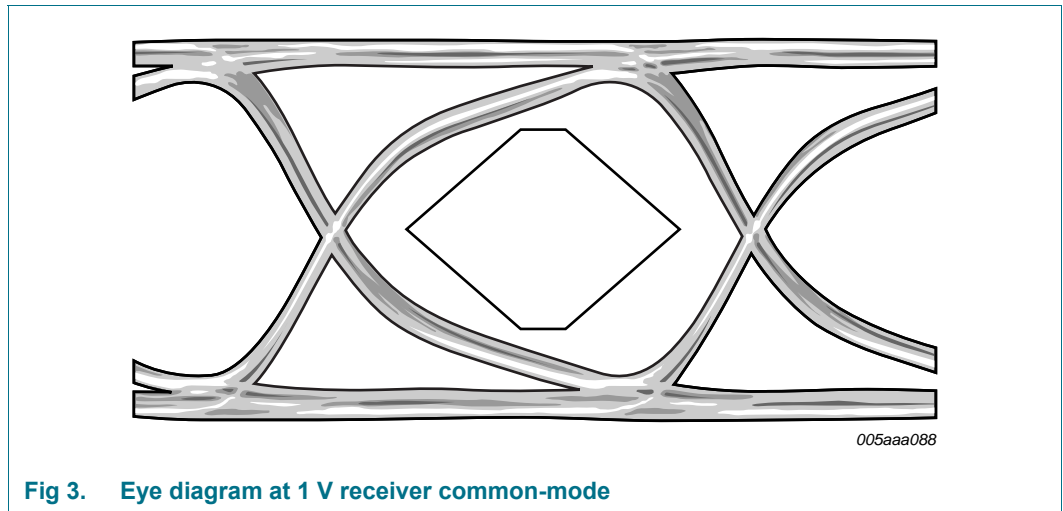
Symbol	Parameter	Conditions	ADC1413S065			ADC1413S080			ADC1413S105			ADC1413S125			Unit
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
<b>pins CLKP and CLKM</b>															
$f_{clk}$	clock frequency		45	-	65	60	-	80	75	-	105	100	-	125	MspS
$t_{lat(data)}$	data latency time	clock cycles	307	-	850	250	-	283	190	-	226	160	-	170	ns
$\delta_{clk}$	clock duty cycle	DCS_EN = 1: en	30	50	70	30	50	70	30	50	70	30	50	70	%
$t_{d(s)}$	sampling delay time		-	0.8	-	-	0.8	-	-	0.8	-	-	0.8	-	ns
$t_{wake}$	wake-up time		-	76	-	-	76	-	-	76	-	-	76	-	ns

[1] Typical values measured at  $V_{DDA} = 3 \text{ V}$ ,  $V_{DDD(1V8)} = 1.8 \text{ V}$ ,  $T_{amb} = 25 \text{ }^\circ\text{C}$ . Minimum and maximum values are across the full temperature range  $T_{amb} = -40 \text{ }^\circ\text{C}$  to  $+85 \text{ }^\circ\text{C}$  at  $V_{DDA} = 3 \text{ V}$ ,  $V_{DDD(1V8)} = 1.8 \text{ V}$ ;  $V_{i(INP)} - V_{i(INM)} = -1 \text{ dBFS}$ ; internal reference mode;  $100 \text{ } \Omega$  differential applied to serial outputs; unless otherwise specified.

### 10.3 Serial output timing

The eye diagram of the serial output is shown in Figure 3 and Figure 4. Test conditions are:

- 3.125 Gbps data rate
- $T_{amb} = 25\text{ }^{\circ}\text{C}$
- DC-coupling with two different receiver common-mode voltages



10.4 SPI timing

Table 8. SPI timing characteristics [1]

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$t_{w(SCLK)}$	SCLK pulse width		-	40	-	ns
$t_{w(SCLKH)}$	SCLK HIGH pulse width		-	16	-	ns
$t_{w(SCLKL)}$	SCLK LOW pulse width		-	16	-	ns
$t_{su}$	set-up time	data to SCLK HIGH	-	5	-	ns
		$\overline{CS}$ to SCLK HIGH	-	5	-	ns
$t_h$	hold time	data to SCLK HIGH	-	2	-	ns
		$\overline{CS}$ to SCLK HIGH	-	2	-	ns
$f_{clk(max)}$	maximum clock frequency		-	25	-	MHz

[1] Typical values measured at  $V_{DDA} = 3\text{ V}$ ,  $V_{DDD(1V8)} = 1.8\text{ V}$ ,  $T_{amb} = 25\text{ }^\circ\text{C}$ . Minimum and maximum values are across the full temperature range  $T_{amb} = -40\text{ }^\circ\text{C}$  to  $+85\text{ }^\circ\text{C}$  at  $V_{DDA} = 3\text{ V}$ ,  $V_{DDD(1V8)} = 1.8\text{ V}$ ;  $V_{i(INP)} - V_{i(INM)} = -1\text{ dBFS}$ ; internal reference mode;  $100\text{ }\Omega$  differential applied to serial outputs; unless otherwise specified.

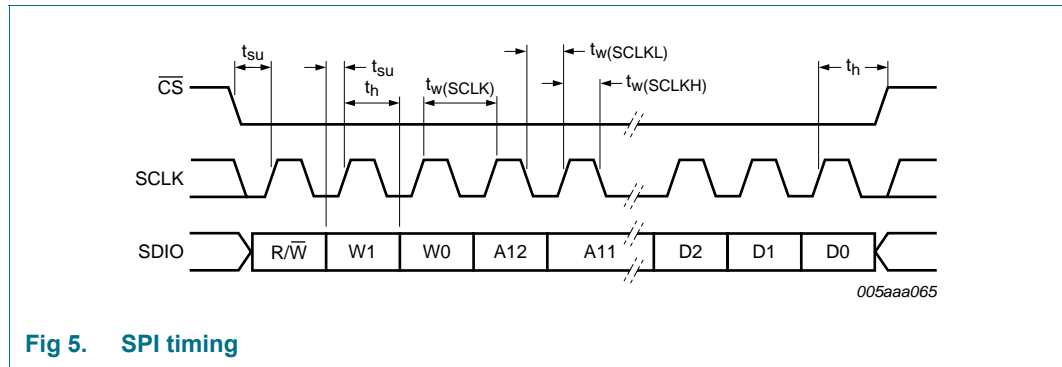


Fig 5. SPI timing

## 11. Application information

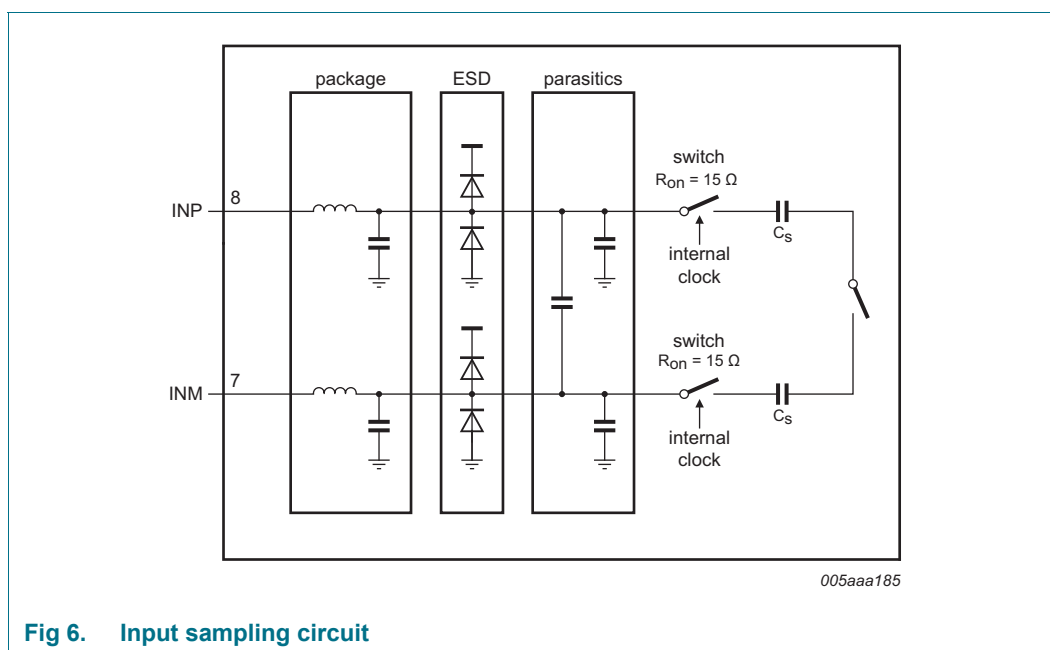
### 11.1 Analog inputs

#### 11.1.1 Input stage description

The analog input of the ADC1413S supports a differential or a single-ended input drive. Optimal performance is achieved using differential inputs with the common-mode input voltage ( $V_{I(cm)}$ ) on pins INP and INM set to  $0.5V_{DDA}$ .

The full-scale analog input voltage range is configurable between 1 V (p-p) and 2 V (p-p) via a programmable internal reference (see Section 11.2 and Table 21).

Figure 6 shows the equivalent circuit of the sample-and-hold input stage, including ElectroStatic Discharge (ESD) protection and circuit and package parasitics.



**Fig 6. Input sampling circuit**

The sample phase occurs when the internal clock (derived from the clock signal on pin CLKP/CLKM) is HIGH. The voltage is then held on the sampling capacitors. When the clock signal goes LOW, the stage enters the hold phase and the voltage information is transmitted to the ADC core.

11.1.2 Anti-kickback circuitry

Anti-kickback circuitry (RC filter in Figure 7) is needed to counteract the effects of a charge injection generated by the sampling capacitance.

The RC filter is also used to filter noise from the signal before it reaches the sampling stage. The value of the capacitor should be chosen to maximize noise attenuation without degrading the settling time excessively.

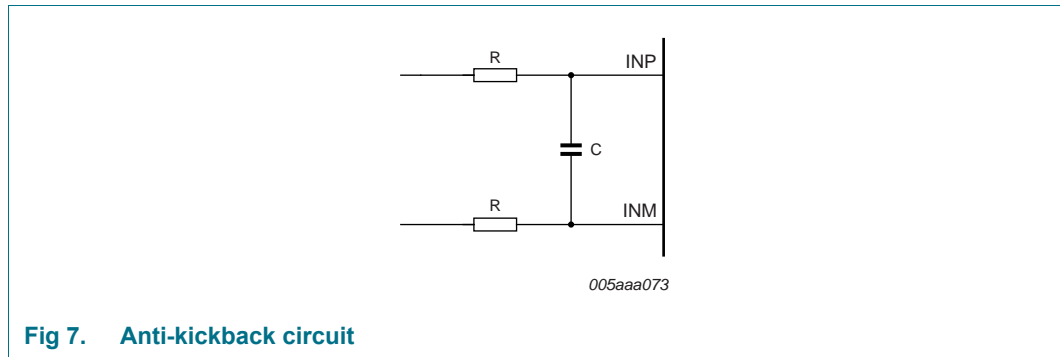


Fig 7. Anti-kickback circuit

The component values are determined by the input frequency and should be selected so as not to affect the input bandwidth.

Table 9. RC coupling versus input frequency, typical values

Input frequency (MHz)	Resistance ( $\Omega$ )	Capacitance (pF)
3	25	12
70	12	8
170	12	8

11.1.3 Transformer

The configuration of the transformer circuit is determined by the input frequency. The configuration shown in Figure 8 would be suitable for a baseband application.

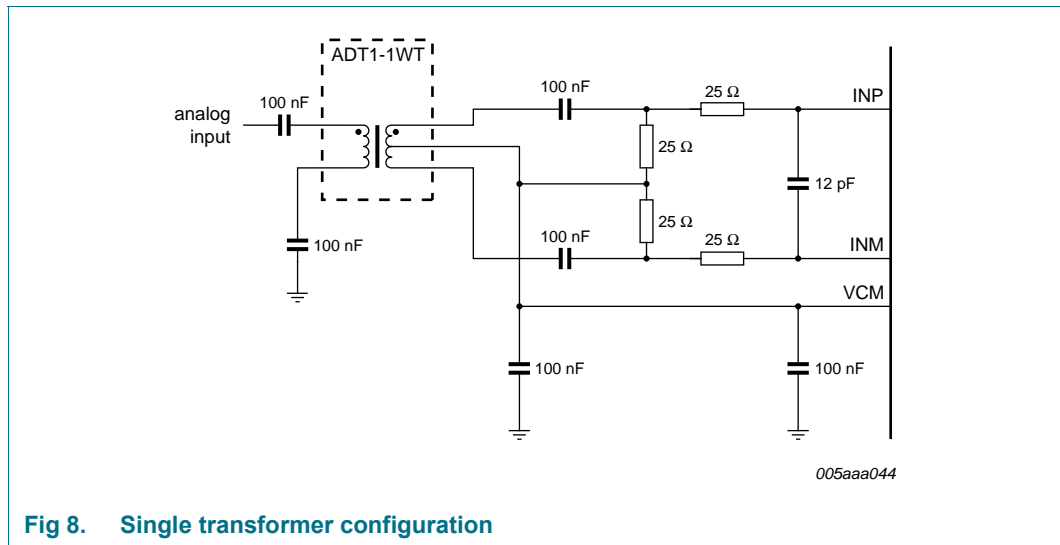


Fig 8. Single transformer configuration

The configuration shown in Figure 9 is recommended for high frequency applications. In both cases, the choice of transformer is a compromise between cost and performance.

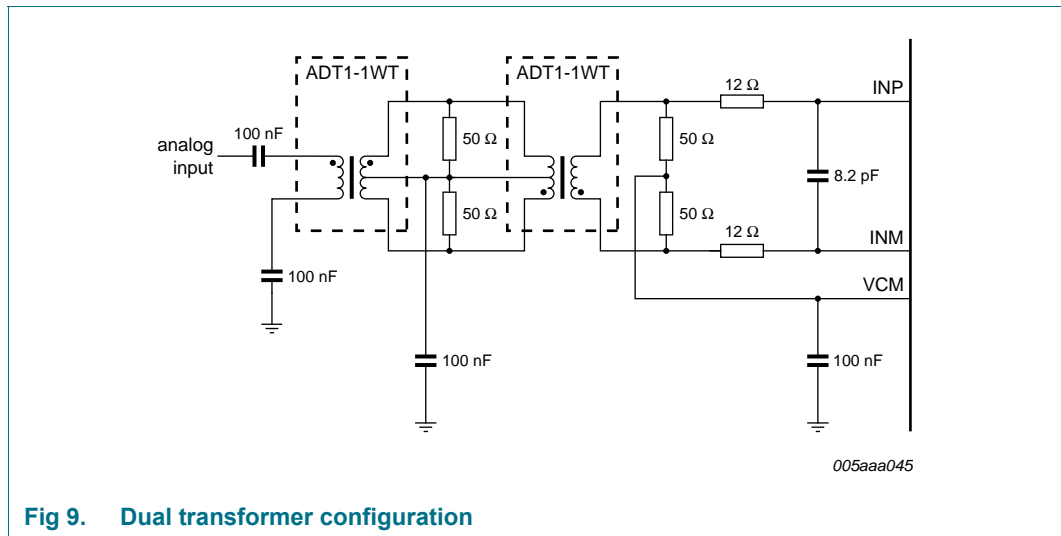


Fig 9. Dual transformer configuration

## 11.2 System reference and power management

### 11.2.1 Internal/external reference

The ADC1413S has a stable and accurate built-in internal reference voltage to adjust the ADC full-scale. This reference voltage can be set internally via SPI or with pins VREF and SENSE (see Figure 11 to Figure 14), in 1 dB steps between 0 dB and -6 dB, via SPI control bits INTREF[2:0] (when bit INTREF\_EN = logic 1; see Table 21). The equivalent reference circuit is shown in Figure 10. External reference is also possible by providing a voltage on pin VREF as described in Figure 14.

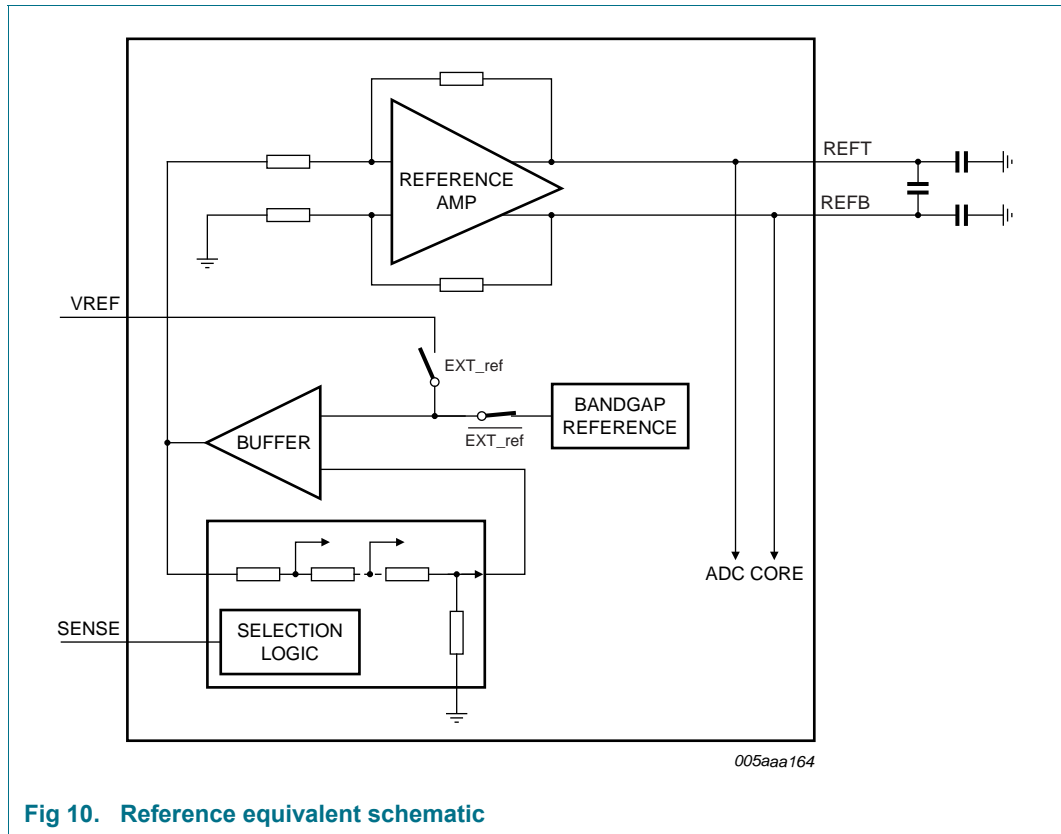


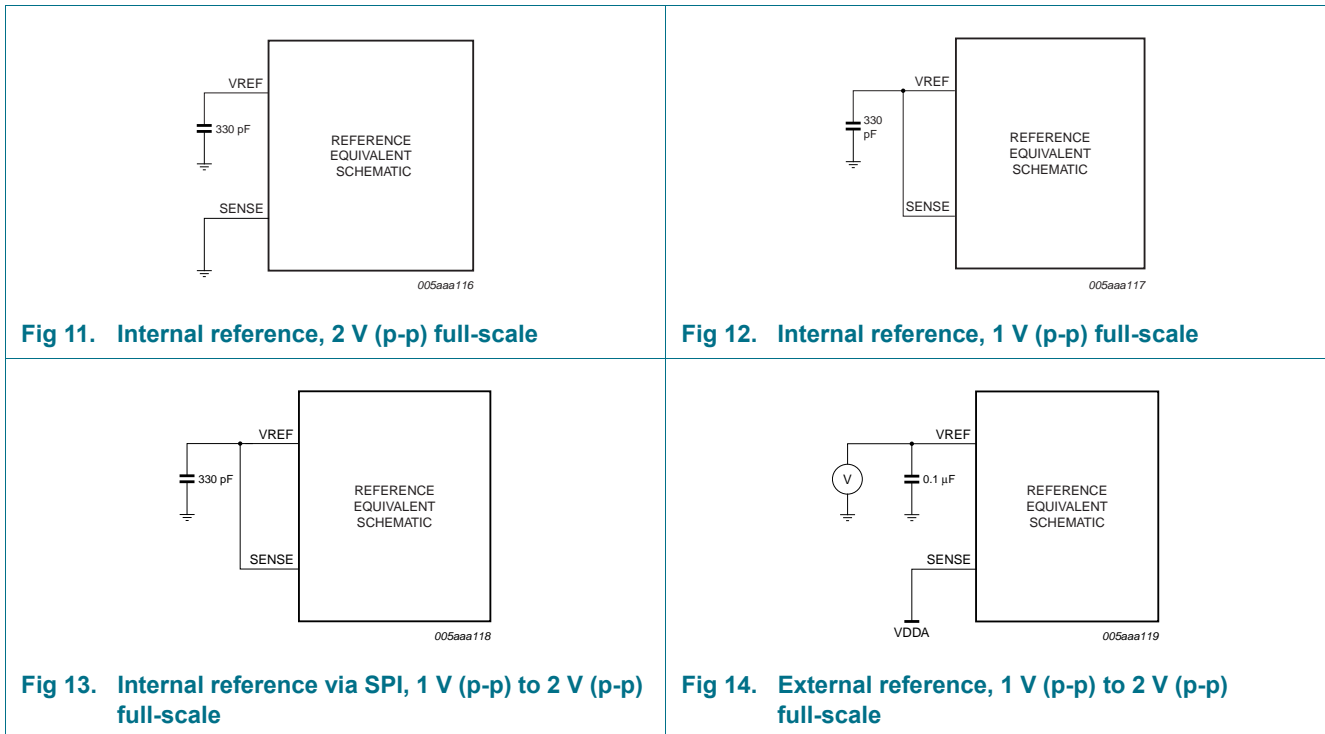
Fig 10. Reference equivalent schematic

Table 10 shows how to choose between the different internal/external modes:

Table 10. Reference modes

Mode	SPI bit, "Internal reference"	SENSE pin	VREF pin	Full-scale, (V (p-p))
Internal (Figure 11)	0	GND	330 pF capacitor to GND	2
Internal (Figure 12)	0	VREF pin = SENSE pin and 330 pF capacitor to GND		1
Internal, SPI mode (Figure 13)	1	VREF pin = SENSE pin and 330 pF capacitor to GND		1 to 2
External (Figure 14)	0	V <sub>DDA</sub>	External voltage from 0.5 V to 1 V	1 to 2

Figure 11 to Figure 14 illustrate how to connect the SENSE and VREF pins to select the required reference voltage source.



11.2.2 Programmable full-scale

The full-scale is programmable between 1 V (p-p) to 2 V (p-p) (see Table 11).

Table 11. Reference modes

INTREF[2:0]	Level	Full-scale (V (p-p))
000	0 dB	2
001	-1 dB	1.78
010	-2 dB	1.59
011	-3 dB	1.42
100	-4 dB	1.26
101	-5 dB	1.12
110	-6 dB	1
111	not used	x



### 11.2.3 Common-mode output voltage ( $V_{O(cm)}$ )

An 0.1  $\mu\text{F}$  filter capacitor should be connected between pin VCM and ground to ensure a low-noise common-mode output voltage. When AC-coupled, these pins can be used to set the common-mode reference for the analog inputs, for instance via a transformer middle point.

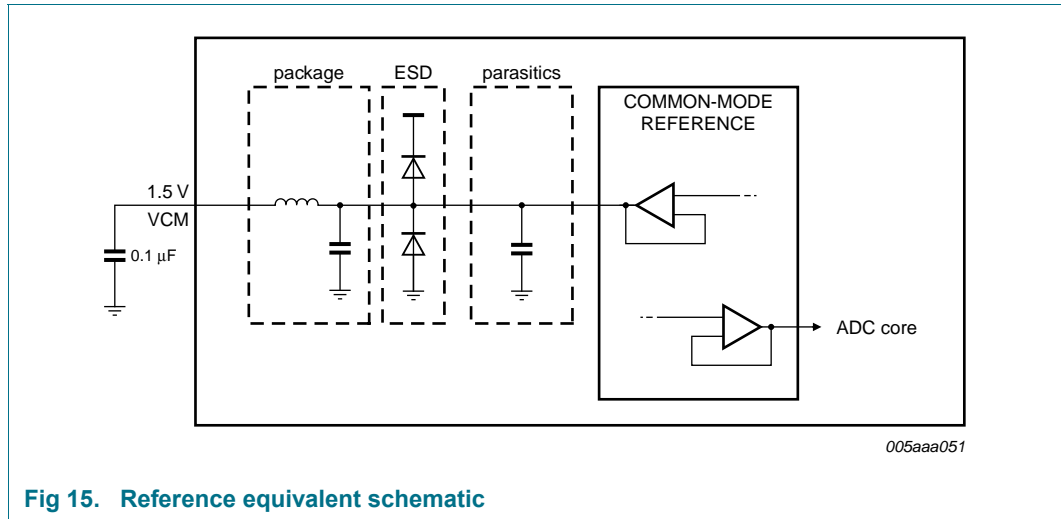


Fig 15. Reference equivalent schematic

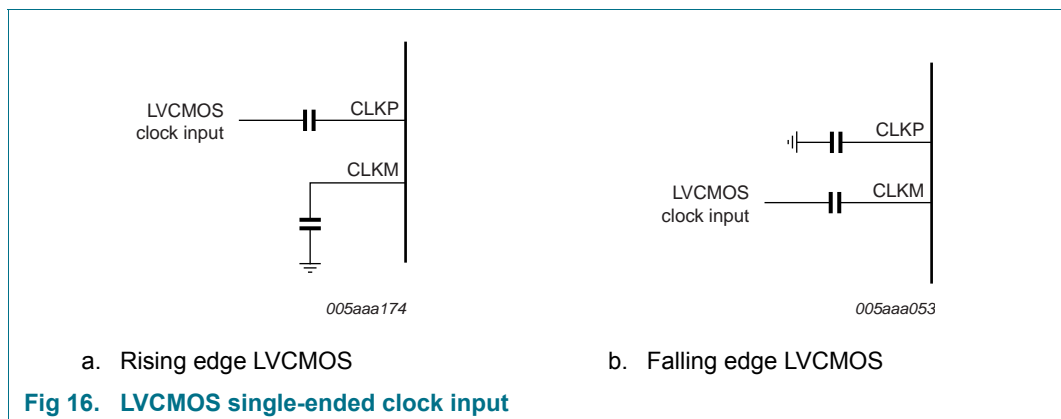
### 11.2.4 Biasing

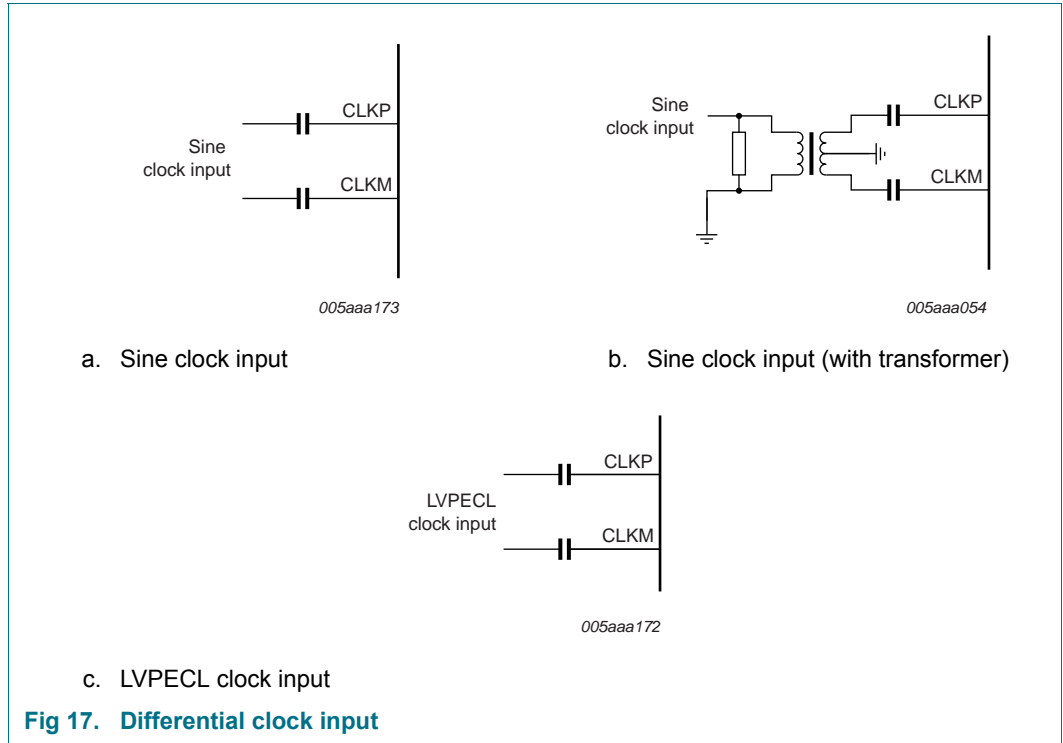
The common-mode input voltage ( $V_{I(cm)}$ ) on pins INP and INM should be set externally to  $0.5V_{DDA}$  for optimal performance and should always be between 0.9 V and 2 V.

## 11.3 Clock input

### 11.3.1 Drive modes

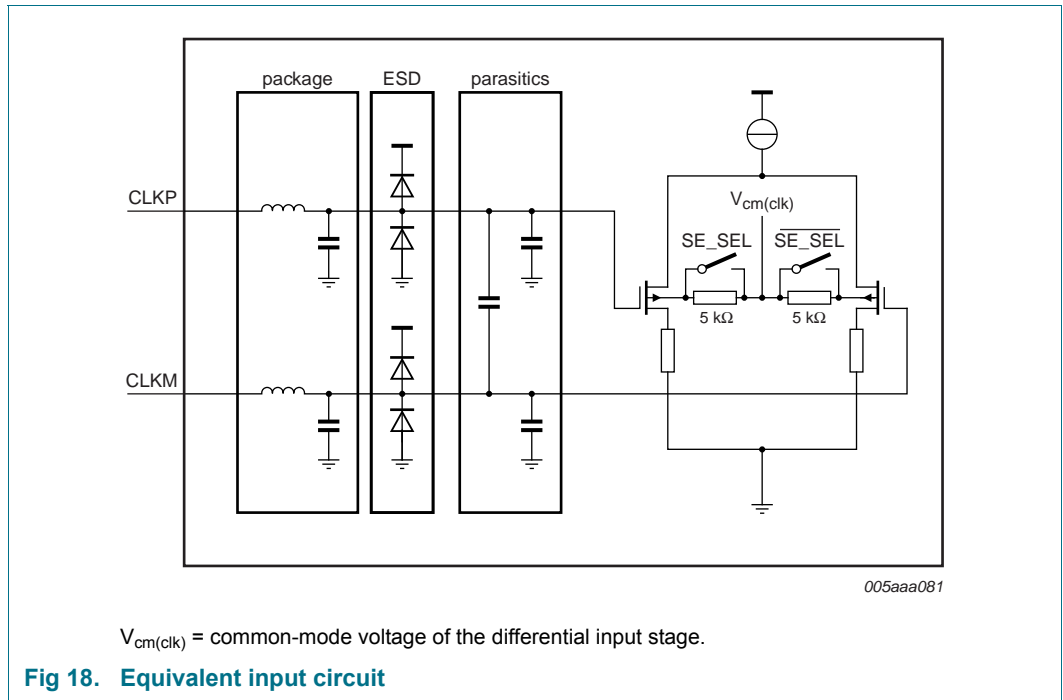
The ADC1413S can be driven differentially (LVPECL). It can also be driven by a single-ended LVCMOS signal connected to pin CLKP (CLKM should be connected to ground via a capacitor).





11.3.2 Equivalent input circuit

The equivalent circuit of the input clock buffer is shown in Figure 18. The common-mode voltage of the differential input stage is set via internal 5 kΩ resistors.



Single-ended or differential clock inputs can be selected via the SPI (see Table 20). If single-ended is selected, the input pin (CLKM or CLKP) is selected via control bit SE\_SEL.

If single-ended is implemented without setting bit SE\_SEL accordingly, the unused pin should be connected to ground via a capacitor.

### 11.3.3 Duty cycle stabilizer

The duty cycle stabilizer can improve the overall performance of the ADC by compensating the input clock signal duty cycle. When the duty cycle stabilizer is active (bit DCS\_EN = logic 1; see Table 20), the circuit can handle signals with duty cycles of between 30 % and 70 % (typical). When the duty cycle stabilizer is disabled (DCS\_EN = logic 0), the input clock signal should have a duty cycle of between 45 % and 55 %.

Table 12. Duty cycle stabilizer

bit DCS_EN	Description
0	duty cycle stabilizer disable
1	duty cycle stabilizer enable

### 11.3.4 Clock input divider

The ADC1413S contains an input clock divider that divides the incoming clock by a factor of 2 (when bit CLKDIV2\_SEL = logic 1; see Table 20). This feature allows the user to deliver a higher clock frequency with better jitter performance, leading to a better SNR result once acquisition has been performed.

## 11.4 Digital outputs

### 11.4.1 Serial output equivalent circuit

The JESD204A standard specifies that if the receiver and the transmitter are DC-coupled both must be fed from the same supply.

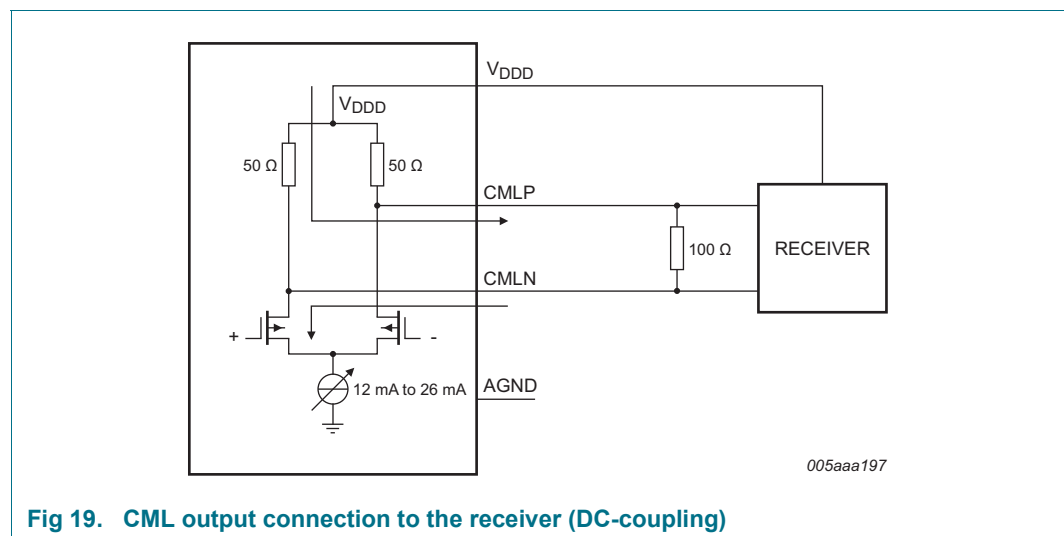


Fig 19. CML output connection to the receiver (DC-coupling)

The output should be terminated when 100 Ω (typical) is reached at the receiver side.

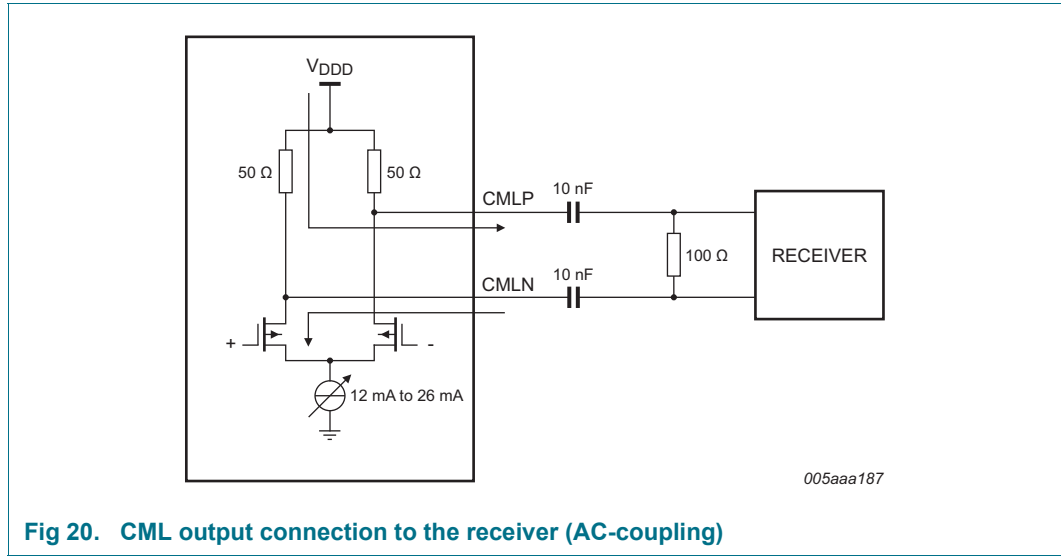


Fig 20. CML output connection to the receiver (AC-coupling)

### 11.5 JESD204A serializer

For more information about the JESD204A standard refer to the JEDEC web site.

#### 11.5.1 Digital JESD204A formatter

The block placed after the ADC cores is used to implement all functions of the JESD204A standard. This ensures signal integrity and guarantees the clock and the data recovery at the receiver side.

The block is highly parameterized and can be configured in various ways depending on the sampling frequency and the number of lanes used.

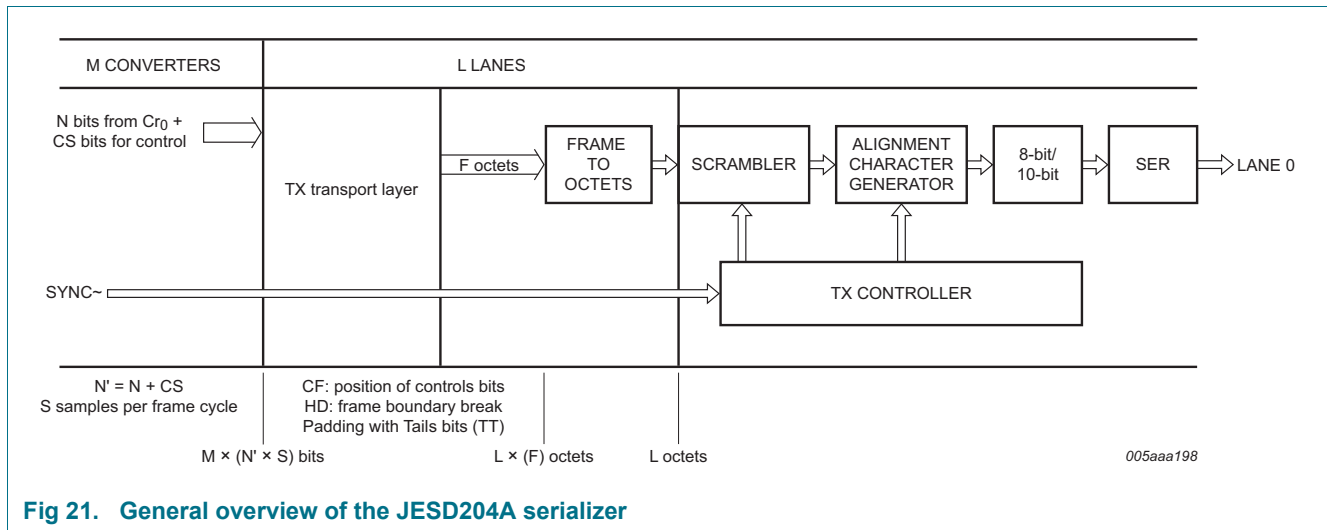


Fig 21. General overview of the JESD204A serializer

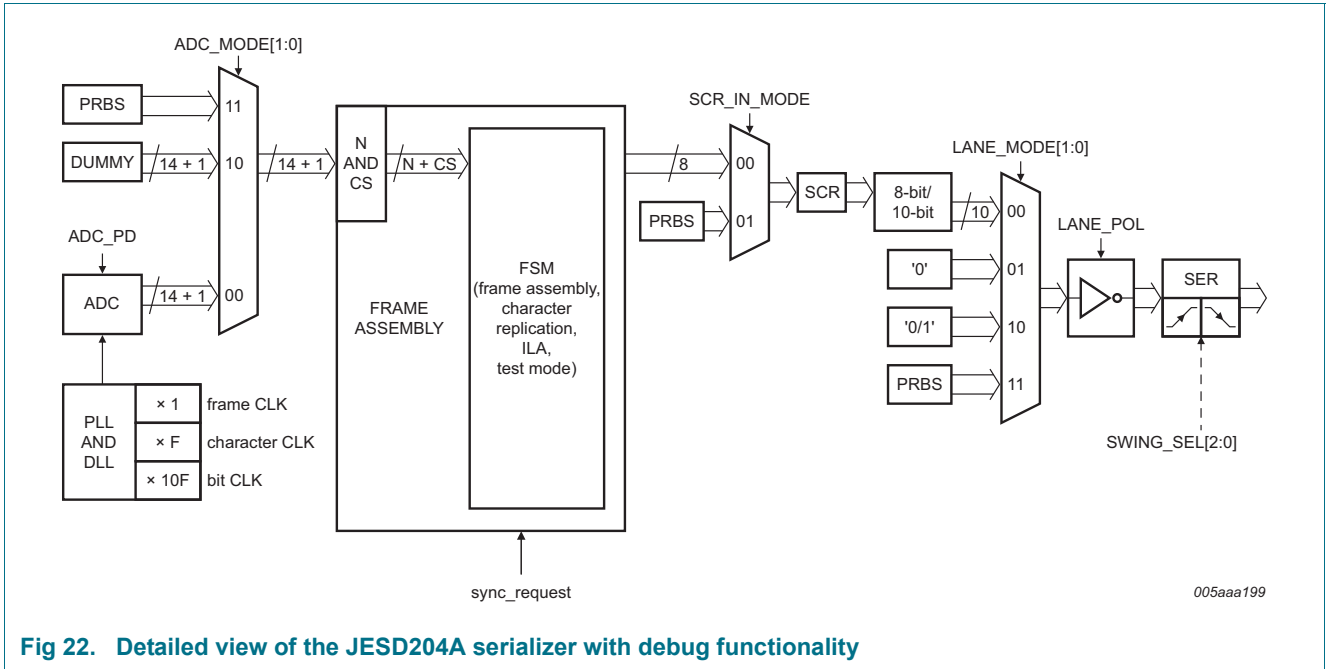


Fig 22. Detailed view of the JESD204A serializer with debug functionality

### 11.5.2 ADC core output codes versus input voltage

Table 13 shows the data output codes for a given analog input voltage.

Table 13. Output codes versus input voltage

INP-INM (V)	Offset binary	Two's complement	OTR
< -1	00 0000 0000 0000	10 0000 0000 0000	1
-1	00 0000 0000 0000	10 0000 0000 0000	0
-0.9998779	00 0000 0000 0001	10 0000 0000 0001	0
-0.9997559	00 0000 0000 0010	10 0000 0000 0010	0
-0.9996338	00 0000 0000 0011	10 0000 0000 0011	0
-0.9995117	00 0000 0000 0100	10 0000 0000 0100	0
....	....	....	0
-0.0002441	01 1111 1111 1110	11 1111 1111 1110	0
-0.0001221	01 1111 1111 1111	11 1111 1111 1111	0
0	10 0000 0000 0000	00 0000 0000 0000	0
+0.0001221	10 0000 0000 0001	00 0000 0000 0001	0
+0.0002441	10 0000 0000 0010	00 0000 0000 0010	0
....	....	....	0
+0.9995117	11 1111 1111 1011	01 1111 1111 1011	0
+0.9996338	11 1111 1111 1100	01 1111 1111 1100	0
+0.9997559	11 1111 1111 1101	01 1111 1111 1101	0
+0.9998779	11 1111 1111 1110	01 1111 1111 1110	0
+1	11 1111 1111 1111	01 1111 1111 1111	0
> +1	11 1111 1111 1111	01 1111 1111 1111	1

## 11.6 Serial Peripheral Interface (SPI)

### 11.6.1 Register description

The ADC1413S serial interface is a synchronous serial communications port allowing easy interfacing with many industry microprocessors. It provides access to the registers that control the operation of the chip in both read and write modes.

This interface is configured as a 3-wire type (SDIO as bidirectional pin).

Pin SCLK acts as the serial clock and pin  $\overline{\text{CS}}$  acts as the serial chip select.

Each read/write operation is sequenced by the  $\overline{\text{CS}}$  signal and enabled by a LOW level to drive the chip with N bytes, depending on the content of the instruction byte (see Table 14).

**Table 14. Instruction bytes for the SPI**

	MSB							LSB
Bit	7	6	5	4	3	2	1	0
Description	R/W <sup>[1]</sup>	W1	W0	A12	A11	A10	A9	A8
	A7	A6	A5	A4	A3	A2	A1	A0

[1] R/W indicates whether a read or write transfer occurs after the instruction byte.

**Table 15. Read or Write mode access description**

R/W <sup>[1]</sup>	Description
0	Write mode operation
1	Read mode operation

[1] Bits W1 and W0 indicate the number of bytes transferred.

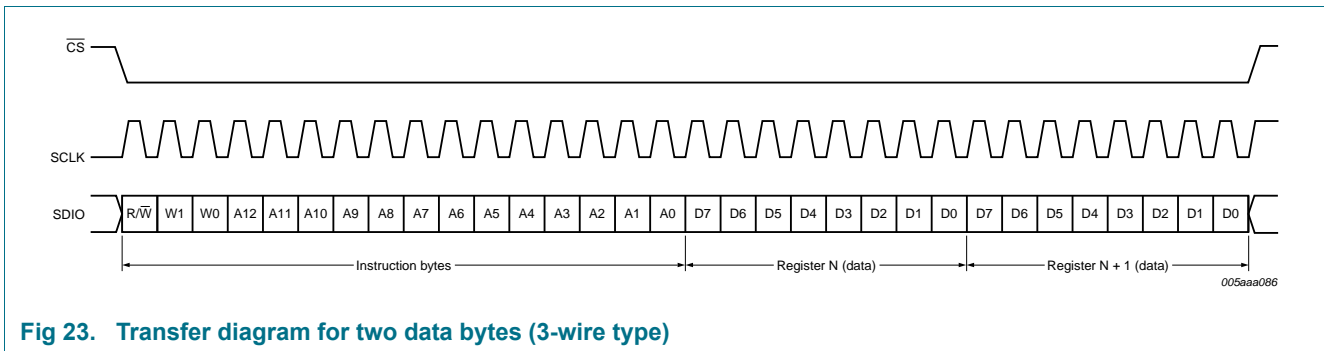
**Table 16. Number of bytes to be transferred**

W1	W0	Number of bytes transferred
0	0	1 byte
0	1	2 bytes
1	0	3 bytes
1	1	4 or more bytes

Bits A12 to A0 indicate the address of the register being accessed. In the case of a multiple byte transfer, this address is the first register to be accessed. An address counter is incremented to access subsequent addresses.

The steps involved in a data transfer are as follows:

1. The falling edge on pin  $\overline{CS}$  in combination with a rising edge on pin SCLK determine the start of communications.
2. The first phase is the transfer of the 2-byte instruction.
3. The second phase is the transfer of the data which can vary in length but is always a multiple of 8 bits. The MSB is always sent first (for instruction and data bytes).
4. A rising edge on pin  $\overline{CS}$  indicates the end of data transmission.



**Fig 23. Transfer diagram for two data bytes (3-wire type)**

11.6.2 Channel control

Table 17. Register allocation map

Address (hex)	Register name	Access <sup>[1]</sup>	Bit definition								Default <sup>[2]</sup> Bin
			Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
<b>ADC control register</b>											
0003	SPI control	R/W	-	-	-	-	-	-	ENABLE	-	1111 1111
0005	Reset and Operating modes	R/W	SW_RST	-	-	-	-	-	PD[1:0]		0000 0000
0006	Clock	R/W	-	-	-	SE_SEL	DIFF_SE	-	CLKDIV2_SEL	DCS_EN	0000 000*
0008	Vref	R/W	-	-	-	-	INTREF_EN	INTREF[2:0]		0000 0000	
0013	Offset	R/W	-	-	DIG_OFFSET[5:0]					0000 0000	
0014	Test pattern 1	R/W	-	-	-	-	-	TESTPAT_1[2:0]		0000 0000	
0015	Test pattern 2	R/W	TESTPAT_2[13:6]								0000 0000
0016	Test pattern 3	R/W	TESTPAT_3[5:0]					-	-	-	0000 0000
<b>JESD204A control</b>											
0801	Ser_Status	R	RXSYNC_ERROR	RESERVED[2:0]			0	0	POR_TST	RESERVED	0100 0000
0802	Ser_Reset	R/W	SW_RST	0	0	0	FSM_SW_RST	0	0	0	0000 0000
0805	Ser_Control1	R/W	0	RESERVED	SYNC_POL	SYNC_SINGLE_ENDED	1	REV_SCR	REV_ENCODER	REV_SERIAL	0100 1001
0808	Ser_Analog_Ctrl	R/W	0	0	0	0	0	SWING_SEL[2:0]		0000 0011	
0809	Ser_ScramblerA	R/W	0	LSB_INIT[6:0]							0000 0000



Table 17. Register allocation map ...continued

Address (hex)	Register name	Access <sup>[1]</sup>	Bit definition								Default <sup>[2]</sup> Bin
			Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
080A	Ser_ScramblerB	R/W	MSB_INIT[7:0]								1111 1111
080B	Ser_PRBS_Ctrl	R/W	0	0	0	0	0	0	PRBS_TYPE[1:0]		0000 0000
0820	Cfg_0_DID	R	DID[7:0]								1110 1101
0821	Cfg_1_BID	R/W*	0	0	0	0	BID[3:0]				0000 1010
0822	Cfg_3_SCR_L	R/W*	SCR	0	0	0	0	0	0	L	0000 0000
0823	Cfg_4_F	R/W*	0	0	0	0	0	F[2:0]			0000 0***
0824	Cfg_5_K	R/W*	0	0	0	K[4:0]				000* ****	
0825	Cfg_6_M	R/W*	0	0	0	0	0	0	0	M	0000 000*
0826	Cfg_7_CS_N	R/W*	0	CS[0]	0	0	N[3:0]				0100 0100
0827	Cfg_8_Np	R	0	0	0	NP[4:0]				0000 1111	
0828	Cfg_9_S	R/W*	0	0	0	0	0	0	0	S	0000 0000
0829	Cfg_10_HD_CF	R/W*	HD	0	0	0	0	0	CF[1:0]		*000 0000
082D	Cfg_02_2_LID	R/W*	0	0	0	LID[4:0]				0001 1100	
084D	Cfg02_13_FCHK	R	FCHK[7:0]								**** ****
0871	Lane_0_Ctrl	R/W	0	SCR_IN_ MODE	LANE_MODE[1:0]		0	LANE_ POL	0	LANE_PD	0000 0000
0891	ADC_0_Ctrl	R/W	0	0	ADC_MODE[1:0]		0	0	0	ADC_PD	0000 0000

[1] an "\*" in the Access column means that this register is subject to control access conditions in Write mode.

[2] an "\*" in the Default column replaces a bit of which the value depends on the binary level of external pins (e.g. CFG[3:0], Swing[1:0], Scrambler).

### 11.6.3 Register description

#### 11.6.3.1 ADC control registers

**Table 18. Register SPI control (address 0003h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 2	-	-	111111	not used
1	ENABLE	R/W		ADC SPI control enable:
			0	ADC does not get the next SPI command
			1	<b>ADC gets the next SPI command</b>
0	-	-	1	not used

**Table 19. Register Reset and Power-down mode (address 0005h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	SW_RST	R/W		reset digital part:
			0	<b>no reset</b>
			1	performs a reset of the digital part
6 to 2	-	-	00000	not used
1 to 0	PD[1-0]	R/W		Power-down mode:
			00	<b>normal (power-up)</b>
			01	full power-down
			10	sleep
			11	normal (power-up)

**Table 20. Register Clock (address 0006h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 5	-	-	000	not used
4	SE_SEL	R/W		select SE clock input pin:
			0	<b>select CLKM input</b>
			1	select CLKP input
3	DIFF_SE	R/W		differential/single-ended clock input select:
			0	<b>fully differential</b>
			1	single-ended
2	-	-	0	not used
1	CLKDIV2_SEL	R/W		select clock input divider by 2:
			0	<b>disable</b>
			1	enable
0	DCS_EN	R/W		duty cycle stabilizer enable:
			0	disable
			1	enable

**Table 21. Register Vref (address 0008h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 4	-	-	0000	not used
3	INTREF_EN	R/W		enable internal programmable VREF mode:
			<b>0</b>	<b>disable</b>
			1	enable
2 to 0	INTREF[2:0]	R/W		programmable internal reference:
			<b>000</b>	<b>0 dB (FS = 2 V)</b>
			001	-1 dB (FS = 1.78 V)
			010	-2 dB (FS = 1.59 V)
			011	-3 dB (FS = 1.42 V)
			100	-4 dB (FS = 1.26 V)
			101	-5 dB (FS = 1.12 V)
			110	-6 dB (FS = 1 V)
			111	not used

**Table 22. Digital offset adjustment (address 0013h)**

Default values are highlighted.

Register offset		
Decimal	DIG_OFFSET[5:0]	
+31	011111	+31 LSB
...	...	...
0	<b>000000</b>	0
...	...	...
-32	100000	-32 LSB

**Table 23. Register Test pattern 1 (address 0014h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 3	-	-	00000	not used
2 to 0	TESTPAT_1[2:0]	R/W		digital test pattern:
			<b>000</b>	<b>off</b>
			001	mid-scale
			010	- FS
			011	+ FS
			100	toggle '1111..1111'/'0000..0000'
			101	custom test pattern, to be written in register 0015h and 0016h
			110	'010101...'
			111	'101010...'

**Table 24. Register Test pattern 2 (address 0015h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 0	TESTPAT_2[13:6]	R/W	<b>00000000</b>	custom digital test pattern (bit 13 to 6)

**Table 25. Register Test pattern 3 (address 0016h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 3	TESTPAT_3[5:0]	R/W	<b>00000</b>	custom digital test pattern (bit 5 to 0)
2 to 0	-	-	000	not used

### 11.6.4 JESD204A digital control registers

**Table 26. SER\_Status (address 0801h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	RXSYNC_ERROR	R/W	0	set to 1 when a synchronization error occurs
6 to 4	RESERVED[2:0]	-	<b>100</b>	reserved
3 to 2	-	-	00	not used
1	POR_TST	-	<b>0</b>	power-on-reset
0	RESERVED	-	0	reserved

**Table 27. SER\_Reset (address 0802h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	SW_RST	R/W	<b>0</b>	initiates a software reset of the JEDEC204A unit
6 to 4	-	-	000	not used
3	FSM_SW_RST	R/W	<b>0</b>	initiates a software reset of the internal state machine of JEDEC204A unit
2 to 0	-	-	000	not used

**Table 28. SER\_Control1 (address 0805h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	-	-	0	not used
6	RESERVED	R/W	0	reserved
5	SYNC_POL	R/W		defines the sync signal polarity:
			<b>0</b>	<b>synchronization signal is active low</b>
			1	synchronization signal is active high
4	SYNC_SINGLE_ENDED	R/W		defines the input mode of the sync signal:
			<b>0</b>	<b>synchronization input mode is set in Differential mode</b>
			1	synchronization input mode is set in Single-ended mode
3	-	-	1	not used
2	REV_SCR	-		LSB are swapped to MSB at the scrambler input:
			<b>0</b>	<b>disable</b>
			1	enable

**Table 28. SER\_Control1 (address 0805h) ...continued**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
1	REV_ENCODER	-		LSB are swapped to MSB at the 8-bit/10-bit encoder input
			<b>0</b>	<b>disable</b>
			1	enable
0	REV_SERIAL	-		LSB are swapped to MSB at the lane input:
			0	disable
			<b>1</b>	<b>enable</b>

**Table 29. SER\_Analog\_Ctrl (address 0808h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 3	-	-	00000	not used
2 to 0	SWING_SEL[2:0]	R/W	<b>011</b>	<b>defines the swing output for the lane pads</b>

**Table 30. SER\_ScramblerA (address 0809h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	-	-	0	not used
6 to 0	LSB_INIT[6:0]	R/W	<b>0000000</b>	<b>defines the initialization vector for the scrambler polynomial (lower)</b>

**Table 31. SER\_ScramblerB (address 080Ah)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 0	MSB_INIT[7:0]	R/W	<b>11111111</b>	<b>defines the initialization vector for the scrambler polynomial (upper)</b>

**Table 32. SER\_PRBS\_Ctrl (address 080Bh)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 2	-	-	000000	not used
1 to 0	PRBS_TYPE[1:0]	R/W		defines the type of Pseudo-Random Binary Sequence (PRBS) generator to be used:
			<b>00</b> (reset)	<b>PRBS-7</b>
			01	PRBS-7
			10	PRBS-23
			11	PRBS-31

**Table 33. Cfg\_0\_DID (address 0820h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 0	DID[7:0]	R	<b>11101101</b>	<b>defines the device (= link) identification number</b>

**Table 34. Cfg\_1\_BID (address 0821h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 4	-	-	0000	not used
3 to 0	BID[3:0]	R/W	<b>1010</b>	<b>defines the bank ID – extension to DID</b>

**Table 35. Cfg\_3\_SCR\_L (address 0822h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7	SCR	R/W	0	scrambling enabled
6 to 1	-	-	000000	not used
0	L	R/W	0	defines the number of lanes per converter device, minus 1

**Table 36. Cfg\_4\_F (address 0823h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 3	-	-	00000	not used
2 to 0	F[2:0]	R/W	<b>***</b>	defines the number of octets per frame, minus 1

**Table 37. Cfg\_5\_K (address 0824h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 5	-	-	000	not used
4 to 0	K[4:0]	R/W	<b>*****</b>	defines the number of frames per multiframe, minus 1

**Table 38. Cfg\_6\_M (address 0825h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 1	-	-	0000000	not used
0	M	R/W	<b>*</b>	defines the number of converters per device, minus 1

**Table 39. Cfg\_7\_CS\_N (address 0826h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7	-	-	0	not used
6	CS[0]	R/W	1	defines the number of control bits per sample, minus 1
5 to 4	-	-	00	not used
3 to 0	N[3:0]	R/W	0100	defines the converter resolution

**Table 40. Cfg\_8\_Np (address 0827h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 5	-	-	000	not used
4 to 0	NP[4:0]	R/W	01111	defines the total number of bits per sample, minus 1

**Table 41. Cfg\_9\_S (address 0828h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 1	-	-	0000000	not used
0	S	R/W	<b>0</b>	<b>defines number of samples per converter per frame cycle</b>

**Table 42. Cfg\_10\_HD\_CF (address 0829h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	HD	R/W	*	defines high density format
6 to 2	-	-	00000	not used
1 to 0	CF[1:0]	R/W	00	defines number of control words per frame clock cycle per link.

**Table 43. Cfg02\_2\_LID (address 082Dh)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 5	-	-	000	not used
4 to 0	LID[4:0]	R/W	<b>11100</b>	<b>defines lane identification number</b>

**Table 44. Cfg01\_13\_FCHK (address 084Dh)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7 to 0	FCHK[7:0]	R	*****	defines the checksum value for lane checksum corresponds to the sum of all the link configuration parameters module 256 (as defined in JEDEC Standard No.204A)

**Table 45. Lane\_0\_Ctrl (address 0871h)**

Default values are highlighted.

Bit	Symbol	Access	Value	Description
7	-	-	0	not used
6	SCR_IN_MODE	R/W		defines the input type for scrambler and 8-bit/10-bit units:
			<b>0</b> (reset)	<b>(normal mode) = Input of the scrambler and 8-bit/10-bit units is the output of the frame assembly unit.</b>
			1	input of the scrambler and 8-bit/10-bit units is the PRBS generator (PRBS type is defined with "PRBS_TYPE[1:0]" (Ser_PRBS_ctrl register)
5 to 4	LANE_MODE[1:0]	R/W		defines output type of Lane output unit:
			<b>00</b> (reset)	<b>normal mode: Lane output is the 8-bit/10-bit output unit</b>
			01	constant mode: Lane output is set to a constant (0 × 0)
			10	toggle mode: Lane output is toggling between 0 × 0 and 0 × 1
			11	PRBS mode: Lane output is the PRBS generator (PRBS type is defined with "PRBS_TYPE[1:0]" (Ser_PRBS_ctrl register)
3	-	-	0	not used

**Table 45. Lane\_0\_Ctrl (address 0871h) ...continued***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
2	LANE_POL	R/W		defines lane polarity:
			<b>0</b>	<b>lane polarity is normal</b>
			1	lane polarity is inverted
1	RESERVED	R/W	<b>0</b>	reserved
0	Lane_PD	R/W		lane power-down control:
			<b>0</b>	<b>lane is operational</b>
			1	lane is in Power-down mode

**Table 46. ADC\_0\_Ctrl (address 0891h)***Default values are highlighted.*

Bit	Symbol	Access	Value	Description
7 to 6	-	-	00	not used
5 to 4	ADC_MODE[1:0]	R/W		defines input type of JESD204A unit
			<b>00 (reset)</b>	<b>ADC output is connected to the JESD204A input</b>
			01	not used
			10	JESD204A input is fed with a dummy constant, set to: OTR = 0 and ADC[13:0] = "10011011101010"
			11	JESD204A is fed with a PRBS generator (PRBS type is defined with "PRBS_TYPE[1:0]" (Ser_PRBS_ctrl register)
3 to 1	-	-	000	not used
0	ADC_PD	R/W		ADC power-down control:
			<b>0</b>	<b>ADC is operational</b>
			1	ADC is in Power-down mode



12. Package outline

HVQFN32R: plastic thermal enhanced very thin quad flat package; no leads; 32 terminals; resin based; body 7 x 7 x 0.8 mm

SOT1152-1

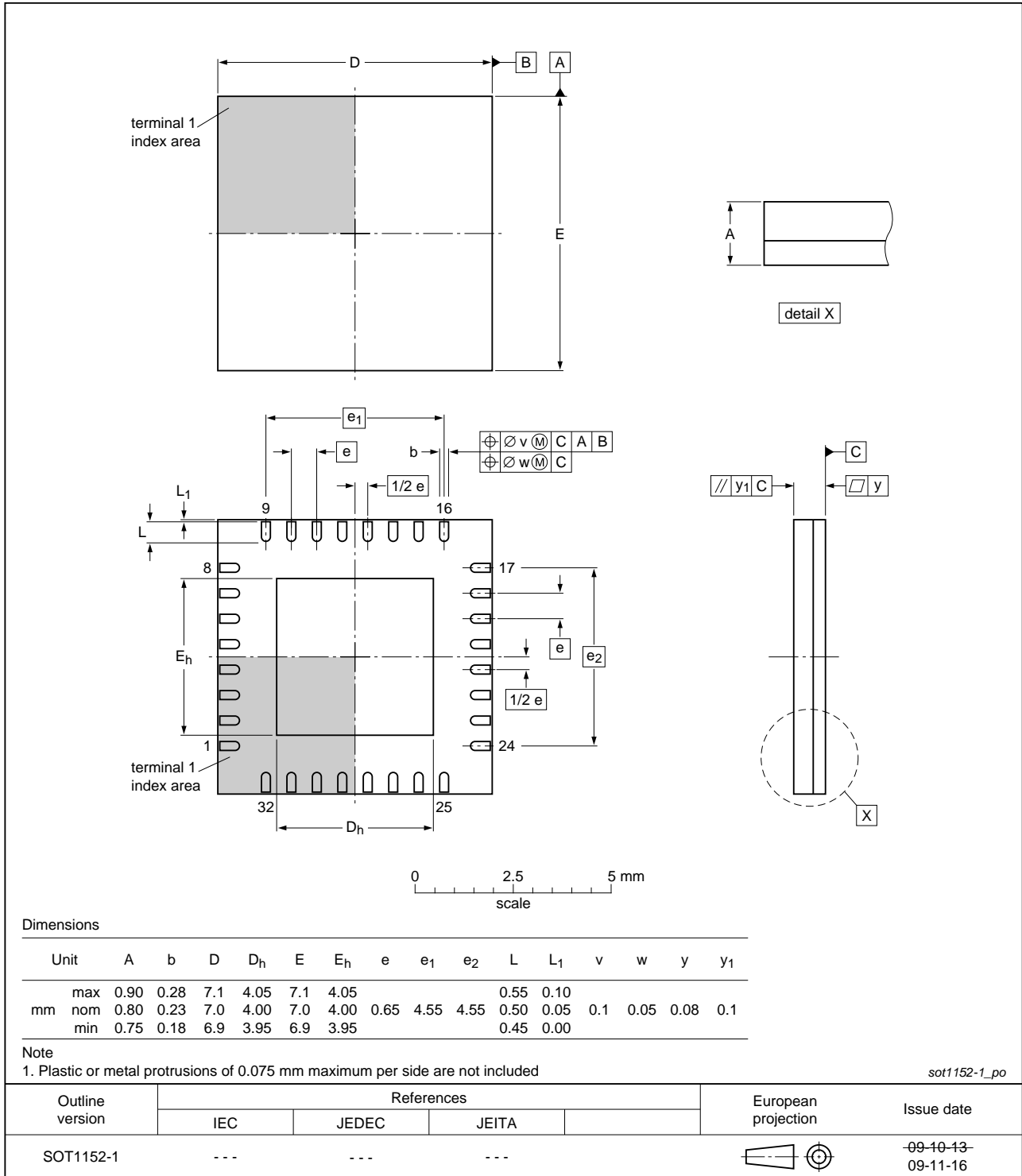


Fig 24. Package outline SOT1152-1 (HVQFN32)

## 13. Abbreviations

Table 47. Abbreviations

Acronym	Description
ADC	Analog-to-Digital Converter
DCS	Duty Cycle Stabilizer
ESD	ElectroStatic Discharge
IF	Intermediate Frequency
IMD	InterModulation Distortion
LSB	Least Significant Bit
LVCMOS	Low-Voltage Complementary Metal-Oxide Semiconductor
LVPECL	Low-Voltage Positive Emitter-Coupled Logic
MSB	Most Significant Bit
OTR	Out-of-Range
PRBS	Pseudo-Random Binary Sequence
SFDR	Spurious-Free Dynamic Range
SNR	Signal-to-Noise Ratio
SPI	Serial Peripheral Interface
TX	Transmitter

## 14. Revision history

Table 48. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
ADC1413S_SER v.3	20120702	Product data sheet	-	ADC1413S_SER v.2
ADC1413S_SER v.2	20110608	Product data sheet	-	ADC1413S_SER v.1
Modifications:	• Section 10.2 “Clock and digital output timing” has been updated.			
ADC1413S_SER v.1	20110314	Product data sheet	-	-

## 15. Contact information

For more information or sales office addresses, please visit: <http://www.idt.com>

## 16. Contents

<b>1</b>	<b>General description</b> . . . . .	<b>1</b>	11.2.2	Programmable full-scale	16
<b>2</b>	<b>Features and benefits</b> . . . . .	<b>1</b>	11.2.3	Common-mode output voltage ( $V_{O(cm)}$ )	17
<b>3</b>	<b>Applications</b> . . . . .	<b>1</b>	11.2.4	Biasing	17
<b>4</b>	<b>Ordering information</b> . . . . .	<b>2</b>	11.3	Clock input	17
<b>5</b>	<b>Block diagram</b> . . . . .	<b>2</b>	11.3.1	Drive modes	17
<b>6</b>	<b>Pinning information</b> . . . . .	<b>3</b>	11.3.2	Equivalent input circuit	18
6.1	Pinning	3	11.3.3	Duty cycle stabilizer	19
6.2	Pin description	3	11.3.4	Clock input divider	19
<b>7</b>	<b>Limiting values</b> . . . . .	<b>4</b>	11.4	Digital outputs	19
<b>8</b>	<b>Thermal characteristics</b> . . . . .	<b>5</b>	11.4.1	Serial output equivalent circuit	19
<b>9</b>	<b>Static characteristics</b> . . . . .	<b>5</b>	11.5	JESD204A serializer	20
<b>10</b>	<b>Dynamic characteristics</b> . . . . .	<b>8</b>	11.5.1	Digital JESD204A formatter	20
10.1	Dynamic characteristics	8	11.5.2	ADC core output codes versus input voltage	21
10.2	Clock and digital output timing	9	11.6	Serial Peripheral Interface (SPI)	22
10.3	Serial output timing	10	11.6.1	Register description	22
<b>10.4</b>	<b>SPI timing</b> . . . . .	<b>11</b>	11.6.2	Channel control	24
<b>11</b>	<b>Application information</b> . . . . .	<b>12</b>	11.6.3	Register description	26
11.1	Analog inputs	12	11.6.3.1	ADC control registers	26
11.1.1	Input stage description	12	11.6.4	JESD204A digital control registers	28
11.1.2	Anti-kickback circuitry	13	<b>12</b>	<b>Package outline</b> . . . . .	<b>33</b>
11.1.3	Transformer	13	<b>13</b>	<b>Abbreviations</b> . . . . .	<b>34</b>
11.2	System reference and power management	14	<b>14</b>	<b>Revision history</b> . . . . .	<b>35</b>
11.2.1	Internal/external reference	14	<b>15</b>	<b>Contact information</b> . . . . .	<b>35</b>
			<b>16</b>	<b>Contents</b> . . . . .	<b>36</b>