

# DAC1003D160

Dual 10 bits DAC, up to 160 MHz, 2 x interpolation

Rev. 02 — 13 August 2008

Product data sheet

## 1. General description

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The DAC1003D160 is optimized to reduce architecture complexity and overall system cost. The Digital-to-Analog Converter (DAC) leads dynamic performance in multi-carrier support because of its direct IF conversion capabilities. With an internal sampling rate up to 160 MHz, the DAC1003D160 is an extremely competitive solution for broadband wireless systems transmitters, as well as a wide range of applications.

## 2. Features

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- Dual 10-bit resolution
- Spurious Free Dynamic Range (SFDR) = 80 dBc at 2.5 MHz
- Input data rate up to 80 MHz
- 2 × interpolation filter
- Output data rate up to 160 Mhz
- Single 3.3 V power supply
- Low noise capacitor free integrated Phase-Locked Loop (PLL)
- Low power dissipation
- HTQFP80 package
- Ambient temperature from -40 °C to +85 °C

## 3. Applications

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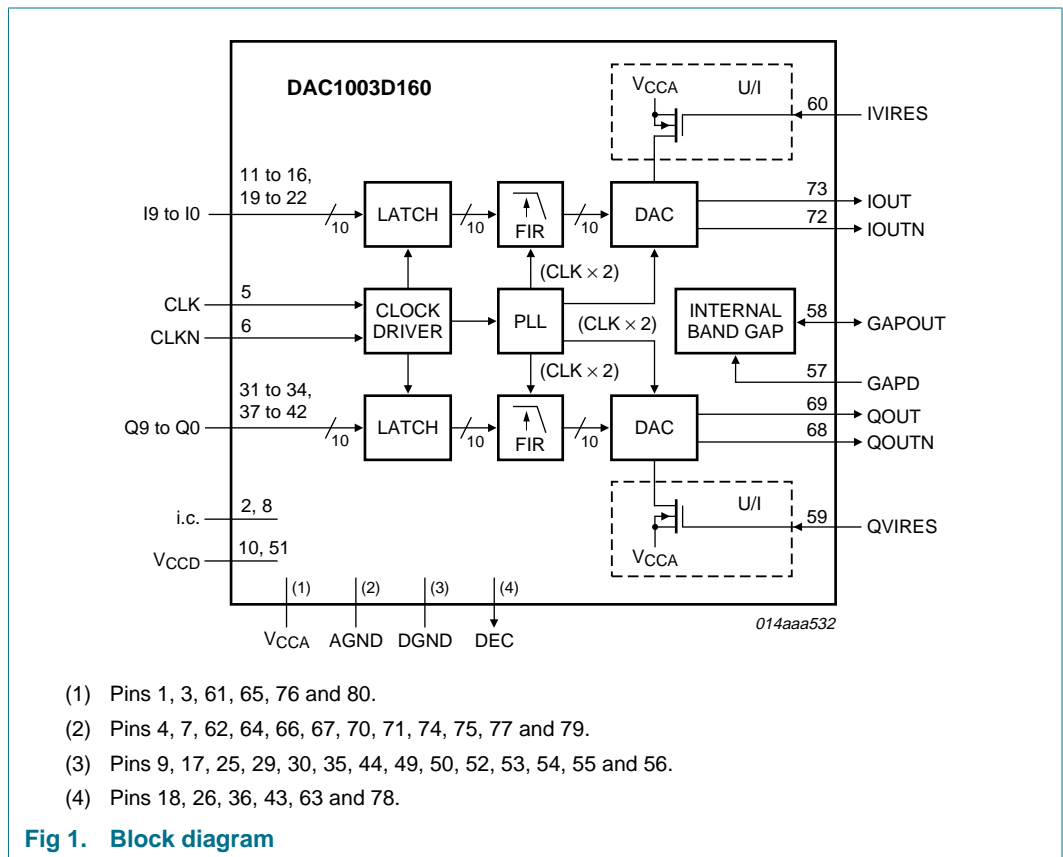
- Broadband wireless systems
- Digital radio links
- Cellular base stations
- Instrumentation
- Cable modems
- Cable Modem Termination System (CMTS)/Data Over Cable Service Interface Specification (DOCSIS)

### 4. Ordering information

Table 1. Ordering information

Type number	Package		Version
	Name	Description	
DAC1003D160HW	HTQFP80	plastic thermal enhanced thin quad flat package; 80 leads; body 12 × 12 × 1 mm; exposed die pad	SOT841-1

### 5. Block diagram



## 6. Pinning information

### 6.1 Pinning

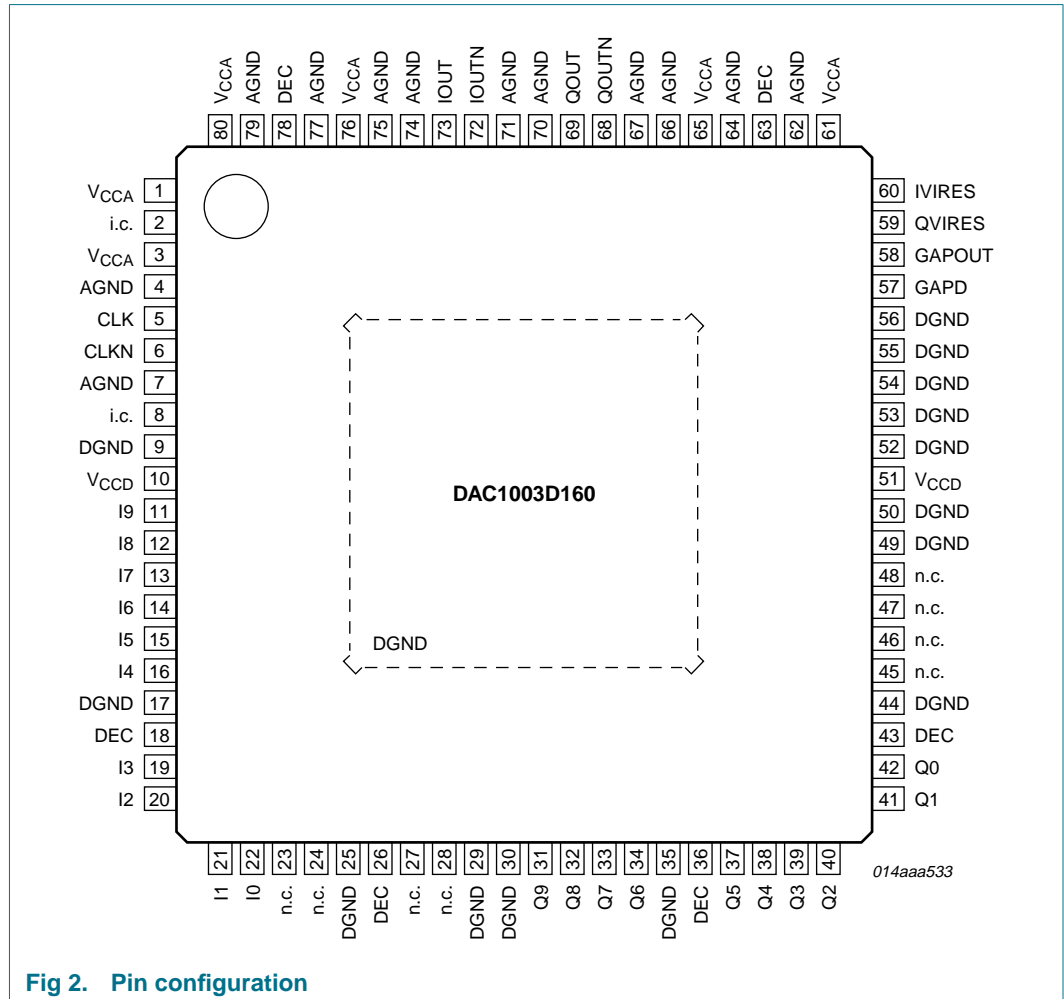


Fig 2. Pin configuration

### 6.2 Pin description

Table 2. Pin description

Symbol	Pin	Type <sup>[1]</sup>	Description
V <sub>CCA</sub>	1	S	analog supply voltage
i.c.	2	I/O	internally connected; leave open
V <sub>CCA</sub>	3	S	analog supply voltage
AGND	4	G	analog ground
CLK	5	I	clock input
CLKN	6	I	complementary clock input
AGND	7	G	analog ground
i.c.	8	O	internally connected; leave open
DGND	9	G	digital ground

Table 2. Pin description ...continued

Symbol	Pin	Type <sup>[1]</sup>	Description
V <sub>CCD</sub>	10	S	digital supply voltage
I9	11	I	I data input bit 9 (Most Significant Bit (MSB))
I8	12	I	I data input bit 8
I7	13	I	I data input bit 7
I6	14	I	I data input bit 6
I5	15	I	I data input bit 5
I4	16	I	I data input bit 4
DGND	17	G	digital ground
DEC	18	O	decoupling node
I3	19	I	I data input bit 3
I2	20	I	I data input bit 2
I1	21	I	I data input bit 1
I0	22	I	I data input bit 0 (Least Significant Bit (LSB))
n.c.	23	I	not connected
n.c.	23	I	not connected
DGND	25	G	digital ground
DEC	26	O	decoupling node
n.c.	27	I	not connected
n.c.	28	I	not connected
DGND	29	G	digital ground
DGND	30	G	digital ground
Q9	31	I	Q data input bit 9 (MSB)
Q8	32	I	Q data input bit 8
Q7	33	I	Q data input bit 7
Q6	34	I	Q data input bit 6
DGND	35	G	digital ground
DEC	36	O	decoupling node
Q5	37	I	Q data input bit 5
Q4	38	I	Q data input bit 4
Q3	39	I	Q data input bit 3
Q2	40	I	Q data input bit 2
Q1	41	I	Q data input bit 1
Q0	42	I	Q data input bit 0 (LSB)
DEC	43	O	decoupling node
DGND	44	G	digital ground
n.c.	45	I	not connected
n.c.	46	I	not connected
n.c.	47	I	not connected
n.c.	48	I	not connected
DGND	49	G	digital ground
DGND	50	G	digital ground

Table 2. Pin description ...continued

Symbol	Pin	Type <sup>[1]</sup>	Description
V <sub>CCD</sub>	51	S	digital supply voltage
DGND	52	G	digital ground
DGND	53	G	digital ground
DGND	54	G	digital ground
DGND	55	G	digital ground
DGND	56	G	digital ground
GAPD	57	I	internal band gap power disable input
GAPOUT	58	I/O	band gap output voltage
QVIRES	59	I	Q DAC biasing resistor
IVIRES	60	I	I DAC biasing resistor
V <sub>CCA</sub>	61	S	analog supply voltage
AGND	62	G	analog ground
DEC	63	O	decoupling node
AGND	64	G	analog ground
V <sub>CCA</sub>	65	S	analog supply voltage
AGND	66	G	analog ground
AGND	67	G	analog ground
QOUTN	68	O	complementary Q DAC output current
QOUT	69	O	Q DAC output current
AGND	70	G	analog ground
AGND	71	G	analog ground
IOUTN	72	O	complementary I DAC output current
IOUT	73	O	I DAC output current
AGND	74	G	analog ground
AGND	75	G	analog ground
V <sub>CCA</sub>	76	S	analog supply voltage
AGND	77	G	analog ground
DEC	78	O	decoupling node
AGND	79	G	analog ground
V <sub>CCA</sub>	80	S	analog supply voltage

[1] Type description: S: Supply; G: Ground; I: Input; O: Output.

## 7. Functional description

The DAC1003D160 is a segmented architecture composed of a 7-bit thermometer sub-DAC and the remaining 3-bit in a binary weighted sub-DAC.

The device produces two complementary current outputs on both channels, respectively pins IOUT/IOUTN and QOUT/QOUTN which need to be connected via a load resistor to the ground.

[Figure 3](#) shows the equivalent analog output circuit of one DAC, which consists of a parallel combination of PMOS current sources and associated switches for each segment.

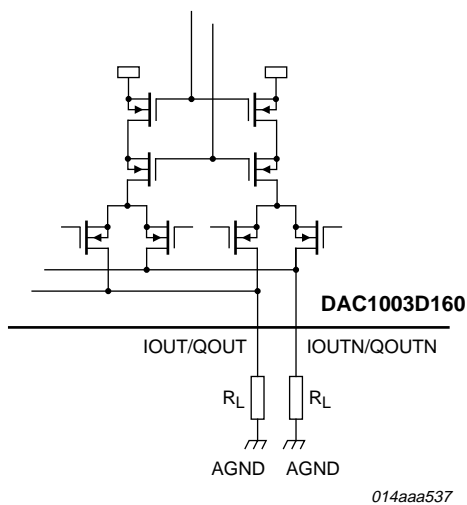
The cascade source configuration enables the increase of the output impedance of the source and the improvement of the dynamic performance of the DAC by introducing less distortion.

[Figure 4](#) shows the internal reference configuration. In this case the bias current is given by the output of the internal regulator connected to the inverting input of the internal operational amplifiers, while external resistors  $R_I$  and  $R_Q$  are connected respectively to pins IVIRES and QVIRES. Thus the output current of the two DACs is typically fixed to 20 mA with an appropriate choice of these resistors. This configuration is optimal for temperature drift compensation because the band gap can be matched with the voltage on the feedback resistors.

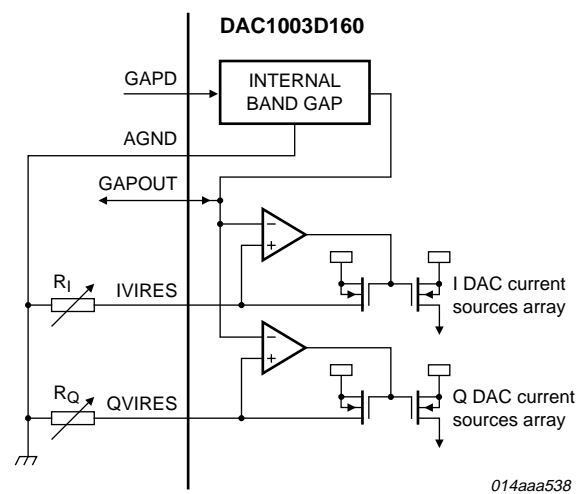
The relation between full-scale output current  $I_{O(fs)}$  and the  $R_I$  ( $R_Q$ ) is:

$$R_I = \frac{2048 \times V_{GAPOUT}}{82 \times I_{O(FS)}} \Omega$$

The output current can also be adjusted by imposing an external reference voltage to the inverting input pin GAPOUT and disabling the internal band gap with pin GAPD set to HIGH. At a voltage lower than 1.2 V the current can be set at values lower than 20 mA. The input references at pins IVIRES and QVIRES may also be driven by separate reference voltages to adjust independently the two DAC currents.



**Fig 3. Equivalent analog output circuit**



**Fig 4. Internal reference configuration**

## 8. Limiting values

**Table 3. Limiting values**

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

Symbol	Parameter	Conditions	Min	Max	Unit
$V_{CCD}$	digital supply voltage		[1] -0.3	+3.9	V
$V_{CCA}$	analog supply voltage		[1] -0.3	+3.9	V
$\Delta V_{CC}$	supply voltage difference	between the analog and digital supply voltages	-150	+150	mV
$V_I$	input voltage	pins Qn and In referenced to DGND	-0.3	$V_{CCD} + 0.3$	V
		pins IVIRES, QVIRES, GAPD, CLK and CLKN referenced to AGND	-0.3	$V_{CCA} + 0.3$	V
$V_O$	output voltage	pins IOUT, IOUTN, QOUT and QOUTN referenced to DAGND	-0.3	$V_{CCA} + 0.3$	V
$T_{stg}$	storage temperature		-55	+150	°C
$T_{amb}$	ambient temperature		-40	+85	°C
$T_j$	junction temperature		-	125	°C

[1] All supplies are connected together.

## 9. Thermal characteristics

**Table 4. Thermal characteristics**

Symbol	Parameter	Conditions	Typ	Unit
$R_{th(j-a)}$	thermal resistance from junction to ambient	in free air	27.1	K/W
$R_{th(c-a)}$	thermal resistance from case to ambient	in free air	11.8	K/W

## 10. Characteristics

**Table 5. Characteristics**

$V_{CCD} = V_{CCA} = 3.0\text{ V to }3.6\text{ V}$ ; AGND and DGND connected together;  $T_{amb} = -40\text{ °C to }+85\text{ °C}$ ; typical values measured at  $V_{CCD} = V_{CCA} = 3.3\text{ V}$ ,  $I_{O(fs)} = 20\text{ mA}$  and  $T_{amb} = 25\text{ °C}$ ; dynamic parameters measured using output schematic given in [Figure 10](#); unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Supplies</b>						
$V_{CCD}$	digital supply voltage		3.0	3.3	3.6	V
$V_{CCA}$	analog supply voltage		3.0	3.3	3.6	V
$I_{CCD}$	digital supply current		-	55	65	mA

**Table 5. Characteristics ...continued**

$V_{CCD} = V_{CCA} = 3.0\text{ V to }3.6\text{ V}$ ; AGND and DGND connected together;  $T_{amb} = -40\text{ °C to }+85\text{ °C}$ ; typical values measured at  $V_{CCD} = V_{CCA} = 3.3\text{ V}$ ,  $I_{O(fs)} = 20\text{ mA}$  and  $T_{amb} = 25\text{ °C}$ ; dynamic parameters measured using output schematic given in [Figure 10](#); unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{CCA}$	analog supply current		-	73	85	mA
$P_{tot}$	total power dissipation	$f_{clk} = 80\text{ MHz}$ ; $f_{IOUT} = f_{QOUT} = 5\text{ MHz}$	-	422	540	mW
<b>Clock inputs (CLK and CLKN)</b>						
$V_{I(cm)}$	common-mode input voltage		-	1.65	-	V
$V_{i(dif)(p-p)}$	peak-to-peak differential input voltage		-	1.0	-	V
<b>Analog outputs (IOUT, IOUTN, QOUT and QOUTN)</b>						
$I_{O(fs)}$	full-scale output current	differential outputs	4	-	20	mA
$R_o$	output resistance		[1]	150	-	k $\Omega$
$C_o$	output capacitance		[1]	3	-	pF
<b>Digital inputs (I0 to I9, Q0 to Q9 and GAPD)</b>						
$V_{IL}$	LOW-level input voltage		DGND	-	$0.3 V_{CCD}$	V
$V_{IH}$	HIGH-level input voltage		$0.7 V_{CCD}$	-	$V_{CCD}$	V
$I_{IL}$	LOW-level input current	$V_{IL} = 0.3 V_{CCD}$	-	5	-	$\mu\text{A}$
$I_{IH}$	HIGH-level input current	$V_{IH} = 0.7 V_{CCD}$	-	5	-	$\mu\text{A}$
<b>Reference voltage output (GAPOUT)</b>						
$V_{GAPOUT}$	voltage on pin GAPOUT		-	1.31	-	V
$I_{GAPOUT}$	current on pin GAPOUT	external voltage	-	1	-	$\mu\text{A}$
$\Delta V_{GAPOUT}$	voltage variation on pin GAPOUT		-	$\pm 133$	-	ppm/ $^{\circ}\text{C}$
<b>Clock timing inputs (CLK and CLKN)</b>						
$f_{clk}$	clock frequency			-	80	MHz
$t_{w(clk)H}$	HIGH clock pulse width		5	-	-	ns
$t_{w(clk)L}$	LOW clock pulse width		5	-	-	ns
<b>Input timing (I0 to I9 and Q0 to Q9); see <a href="#">Figure 5</a></b>						
$t_{h(i)}$	input hold time		1.1	-	3.4	ns
$t_{su(i)}$	input set-up time		-1.5	-	+0.7	ns
<b>Output timing (IOUT, IOUTN, QOUT, QOUTN)</b>						
$t_s$	settling time	$t_o \pm 0.5\text{ LSB}$	[1]	16	-	ns
<b>Digital filter specification (FIR); order N = 42 see <a href="#">Figure 6</a> and <a href="#">7</a> and <a href="#">Table 7</a></b>						
$f_{data}$	data rate		-	-	80	MHz
$\alpha_{ripple(pb)}$	pass-band ripple	$f_{data}/f_{clk}$ ; 0.005 dB attenuation	-	0.405	-	
$B_p$	power bandwidth	$f_{data}/f_{clk}$ ; 3 dB attenuation	-	0.479	-	
$\alpha_{stpb}$	stop-band attenuation	$f_{data}/f_{clk} = 0.6\text{ dB to }1\text{ dB}$	-	69	-	dB
$t_{d(grp)}$	group delay time		-	$11 T_{clk}$	-	ns
<b>Analog signal processing</b>						
INL	integral non-linearity		-	$\pm 0.2$	-	LSB
DNL	differential non-linearity		-	$\pm 0.1$	-	LSB



**Table 5. Characteristics ...continued**

$V_{CCD} = V_{CCA} = 3.0\text{ V to }3.6\text{ V}$ ; AGND and DGND connected together;  $T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C}$ ; typical values measured at  $V_{CCD} = V_{CCA} = 3.3\text{ V}$ ,  $I_{O(fs)} = 20\text{ mA}$  and  $T_{amb} = 25\text{ }^{\circ}\text{C}$ ; dynamic parameters measured using output schematic given in [Figure 10](#); unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$I_{n(o)}$	output noise current		-	120	-	$\mu\text{A}/\sqrt{\text{Hz}}$
$E_{\text{offset}}$	offset error	relative to full-scale	-	-0.3	-	%
$E_G$	gain error	relative to full-scale	-5.4	-	+5.4	%
$\Delta G_{IQ}$	IQ gain mismatch	between I and Q, relative to full-scale	-	$\pm 0.2$	-	%
SFDR	spurious free dynamic range	$f_{\text{clk}} = 80\text{ MHz}$ ; B = Nyquist				
		$f_o = 2.5\text{ MHz}$ at 0 dBFS	-	80	-	dBc
		$f_o = 5\text{ MHz}$ at 0 dBFS	-	72	-	dBc
		$f_o = 13\text{ MHz}$ at 0 dBFS	-	64	-	dBc
$\alpha_{2H}$	second harmonic level	$f_o = 5\text{ MHz}$	-	73	-	dBc
		$f_o = 13\text{ MHz}$	-	65	-	dBc
$\alpha_{3H}$	third harmonic level	$f_o = 5\text{ MHz}$	-	88	-	dBc
		$f_o = 13\text{ MHz}$	-	86	-	dBc
IMD2	second-order intermodulation distortion	$f_{\text{clk}} = 80\text{ MHz}$ ; $f_o 1 = 10\text{ MHz}$ ; $f_o 2 = 12\text{ MHz}$ ; B = Nyquist	-	65	-	dBc
IMD3	third-order intermodulation distortion	$f_{\text{clk}} = 80\text{ MHz}$ ; $f_o 1 = 10\text{ MHz}$ ; $f_o 2 = 12\text{ MHz}$	-	84	-	dBc
THD	total harmonic distortion	$f_{\text{clk}} = 80\text{ MHz}$ ; B = Nyquist; $T_{amb} = 25\text{ }^{\circ}\text{C}$				
		$f_o = 2.5\text{ MHz}$	-	75	-	dBc
		$f_o = 5\text{ MHz}$	68	71	-	dBc
NSD	noise spectral density	$f_{\text{clk}} = 80\text{ MHz}$				
		$f_o = 2.5\text{ MHz}$	-	-155	-	dBm/Hz
		$f_o = 5\text{ MHz}$	-	-155	-	dBm/Hz
		$f_o = 19\text{ MHz}$	-	-153	-	dBm/Hz
S/N	signal-to-noise ratio	$f_{\text{clk}} = 80\text{ Msample/s}$ ; B = Nyquist				
		$f_o = 2.5\text{ MHz}$	-	80	-	dBc
		$f_o = 5\text{ MHz}$	70	80	-	dBc
		$f_o = 19\text{ MHz}$	-	78	-	dBc
ACPR	adjacent channel power ratio	baseband; 5 MHz channel spacing; B = 3.84 MHz				
		$f_o = 2.5\text{ MHz}$	-	60	-	dBc
		$f_o = 20\text{ MHz}$	-	61	-	dBc

[1] Guaranteed by design.

**Table 6. Band gap**

Band gap disable (GAPD)	Band gap input/output (GAPOUT)	Internal band gap
LOW	output ( $V_{\text{GAPOUT}} = 1.2\text{ V}$ )	enable
HIGH	input	disable

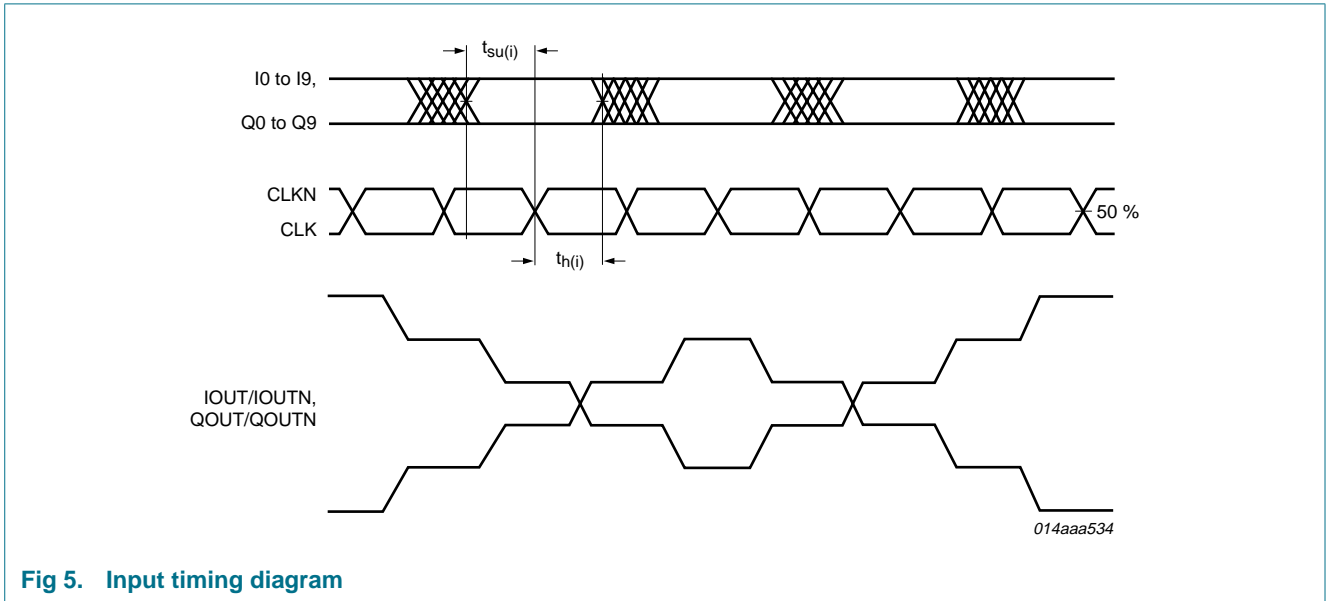


Fig 5. Input timing diagram

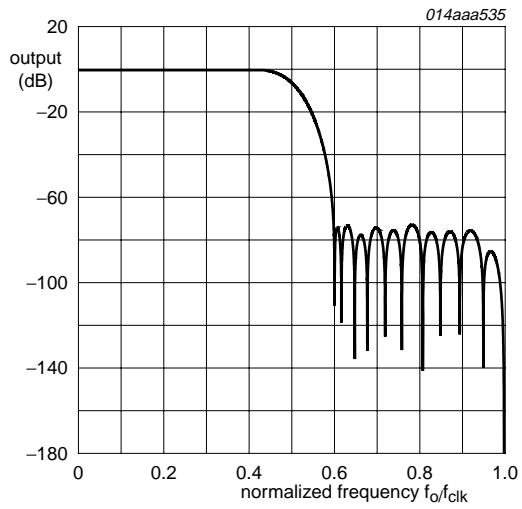


Fig 6. FIR filter frequency response

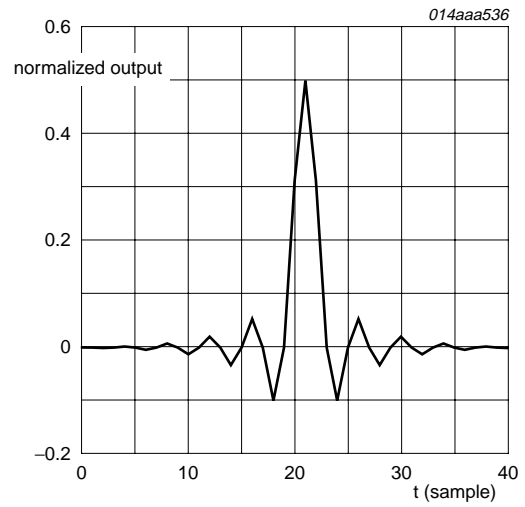
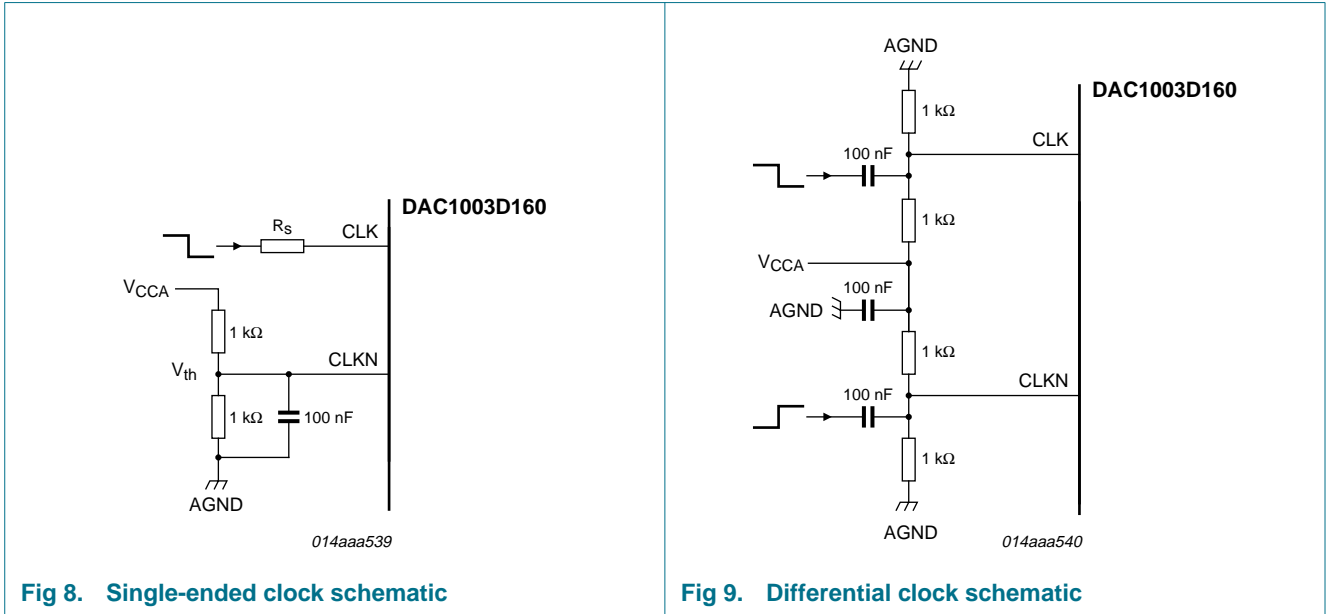


Fig 7. FIR filter impulse response

Table 7. Interpolation FIR filter coefficient

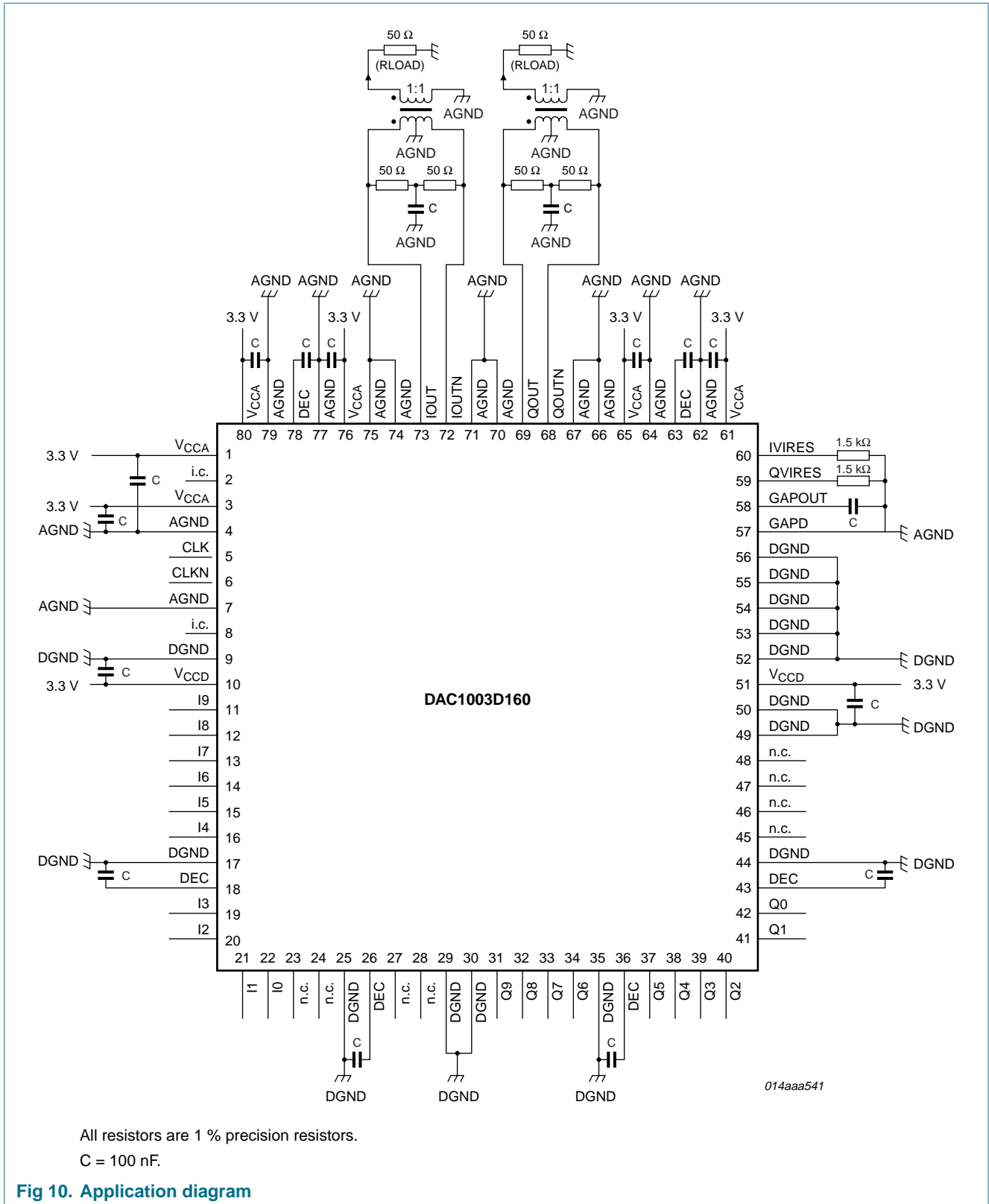
Coefficient	Coefficient	Value
H(1)	H(43)	10
H(2)	H(42)	0
H(3)	H(41)	-31
H(4)	H(40)	0
H(5)	H(39)	69
H(6)	H(38)	0
H(7)	H(37)	-138
H(8)	H(36)	0
H(9)	H(35)	248
H(10)	H(34)	0
H(11)	H(33)	-419
H(12)	H(32)	0
H(13)	H(31)	678
H(14)	H(30)	0
H(15)	H(29)	-1083
H(16)	H(28)	0
H(17)	H(27)	1776
H(18)	H(26)	0
H(19)	H(25)	-3282
H(20)	H(24)	0
H(21)	H(23)	10364
H(22)	-	16384

**11. Application information**



**Fig 8. Single-ended clock schematic**

**Fig 9. Differential clock schematic**



## 11.1 Alternative parts

The following alternative parts are also available:

**Table 8. Alternative parts**

Type number	Description		Sampling frequency
DAC1403D160	Dual 14 bits DAC, with 2 × interpolating	[1]	160 MHz
DAC1203D160	Dual 12 bits DAC, with 2 × interpolating	[1]	160 MHz

[1] Pin to pin compatible

12. Package outline

HTQFP80: plastic thermal enhanced thin quad flat package; 80 leads; body 12 x 12 x 1 mm; exposed die pad SOT841-1

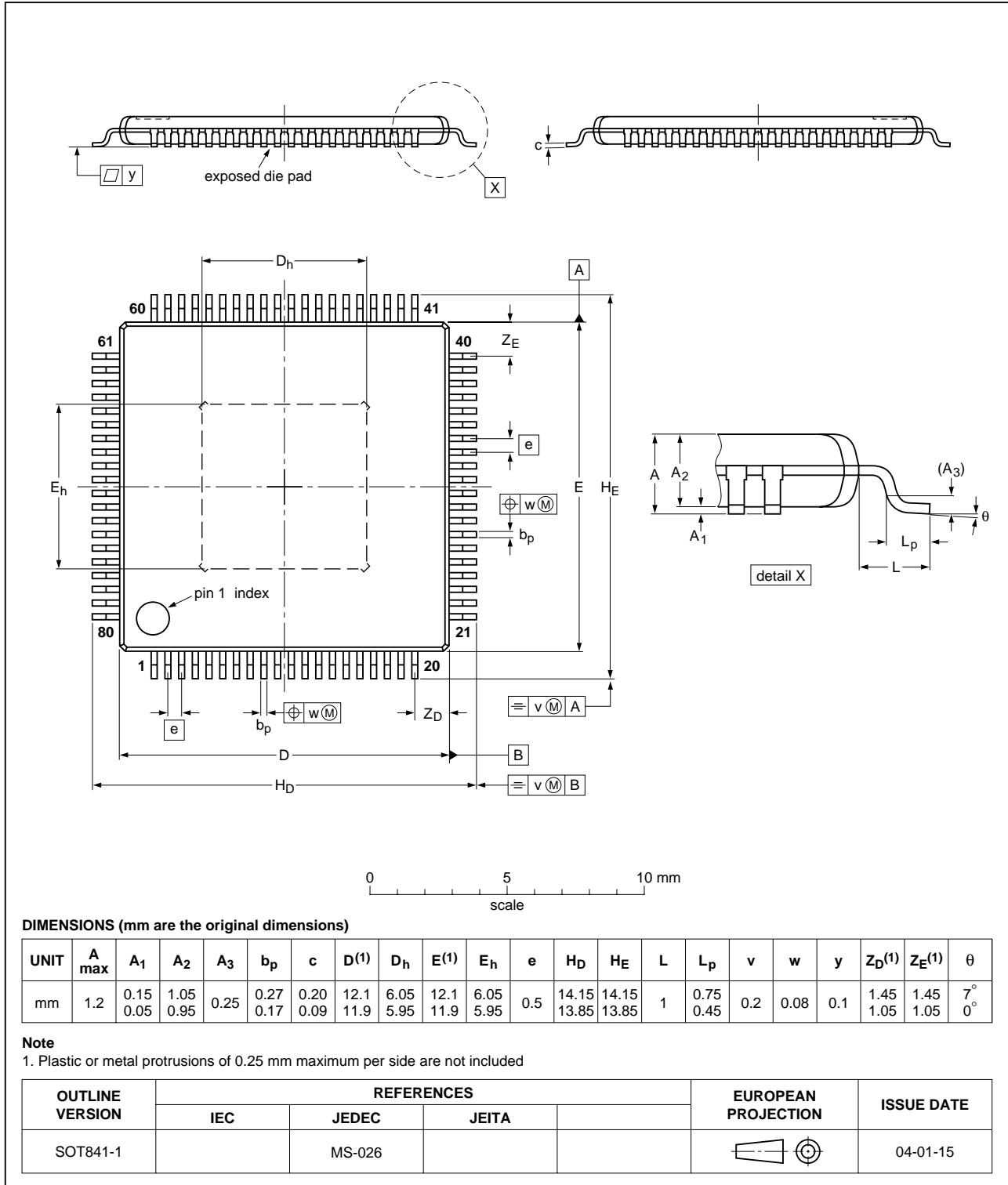


Fig 11. Package outline SOT841-1 (HTQFP80)

## 13. Abbreviations

Table 9. Abbreviations

Acronym	Description
FIR	Finite Impulse Response
IF	Intermediate Frequency
LSB	Least Significant Bit
MSB	Most Significant Bit
PLL	Phase-Locked Loop
PMOS	Positive-Metal Oxide Semiconductor

## 14. Glossary

### 14.1 Static parameters

**DNL** — Differential Non-Linearity. The difference between the ideal and the measured output value between successive DAC codes.

**INL** — Integral Non-Linearity. The deviation of the transfer function from a best-fit straight line (linear regression computation).

### 14.2 Dynamic parameters

**IMD2** — Second-order intermodulation distortion. From a dual-tone digital input sine wave (these two frequencies are close together), the intermodulation distortion product IMD2 is the ratio of the RMS value of either tone and the RMS value of the worst 2nd-order intermodulation product.

**IMD3** — Third-order intermodulation distortion. From a dual-tone digital input sine wave (these two frequencies are close together), the intermodulation distortion product IMD3 is the ratio of the RMS value of either tone and the RMS value of the worst 3rd-order intermodulation product.

**SFDR** — Spurious Free Dynamic Range. The ratio between the RMS value of the reconstructed output sine wave and the RMS value of the largest spurious observed (harmonic and non-harmonic, excluding DC component) in the frequency domain.

**S/N** — Signal-to-Noise ratio. The ratio of the RMS value of the reconstructed output sine wave to the RMS value of the noise excluding the harmonics and the DC component.

**THD** — Total Harmonic Distortion. The ratio of the RMS value of the harmonics of the output frequency to the RMS value of the output sine wave. Usually, the calculation of THD is done on the first 5 harmonics.



## 15. Revision history

Table 10. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
DAC1003D160_2	20080813	Product data sheet	-	DAC1003D160_1
Modifications:	<ul style="list-style-type: none"><li>• Added condition to <math>t_s</math> in <a href="#">Table 5</a>.</li><li>• Correction to <a href="#">Figure 10</a>.</li></ul>			
DAC1003D160_1	20080612	Product data sheet	-	-

## 16. Legal information

### 16.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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**18. Contents**

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Date of release: 13 August 2008

Document identifier: DAC1003D160\_2