

DAC1205D650

Dual 12-bit DAC, up to 650 Msps; 2× 4× and 8× interpolating

Rev. 01 — 28 July 2009

Product data sheet

1. General description

The DAC1205D650 is a high-speed 12-bit dual-channel Digital-to-Analog Converter (DAC) with selectable 2×, 4× or 8× interpolating filters optimized for multi-carrier wireless transmitters.

Thanks to its digital on-chip modulation, the DAC1205D650 allows the complex I and Q inputs to be converted up from BaseBand (BB) to IF. The mixing frequency is adjusted using a Serial Peripheral Interface (SPI) with a 32-bit Numerically Controlled Oscillator (NCO). The phase is controlled by a 16-bit register.

Two modes of operation are available: separate data ports or a single interleaved high-speed data port. In the Interleaved mode, the input data stream is demultiplexed into its original I and Q data and then latched.

The DAC1205D650 also includes a 2×, 4× and 8× clock multiplier which provides the appropriate internal clocks and an internal regulator to adjust the output full-scale current.

2. Features

- Dual 12-bit resolution
- 650 Msps maximum update rate
- Selectable 2×, 4× or 8× interpolation filters
- Input data rate up to 160 Msps
- Very low noise cap-free integrated PLL
- 32-bit programmable NCO frequency
- Dual-port or Interleaved data modes
- 1.8 V and 3.3 V power supplies
- LVDS compatible clock
- Two's complement or binary offset data format
- 3.3 V CMOS input buffers
- IMD3: 79 dBc; $f_s = 640$ Msps; $f_o = 96$ MHz
- ACPR: 68 dB; 2 carriers WCDMA; $f_s = 614.4$ Msps; $f_o = 115.2$ MHz; PLL on
- Typical 0.95 W power dissipation at 4× interpolation
- Power-down and Sleep modes
- Differential scalable output current from 1.6 mA to 22 mA
- On-chip 1.25 V reference
- External analog offset control (10-bit auxiliary DACs)
- Internal digital offset control
- Inverse (sin x) / x function
- Fully compatible SPI port
- Industrial temperature range from -40 °C to $+85$ °C



3. Applications

- Wireless infrastructure: LTE, WiMAX, GSM, CDMA, WCDMA, TD-SCDMA
- Communication: LMDS/MMDS, point-to-point
- Direct Digital Synthesis (DDS)
- Broadband wireless systems
- Digital radio links
- Instrumentation
- Automated Test Equipment (ATE)

4. Ordering information

Table 1. Ordering information

| Type number | Package | | |
|------------------|----------|--|----------|
| | Name | Description | Version |
| DAC1205D650HW/C1 | HTQFP100 | plastic thermal enhanced thin quad flat package; 100 leads; body 14 × 14 × 1 mm; exposed die pad | SOT638-1 |

5. Block diagram

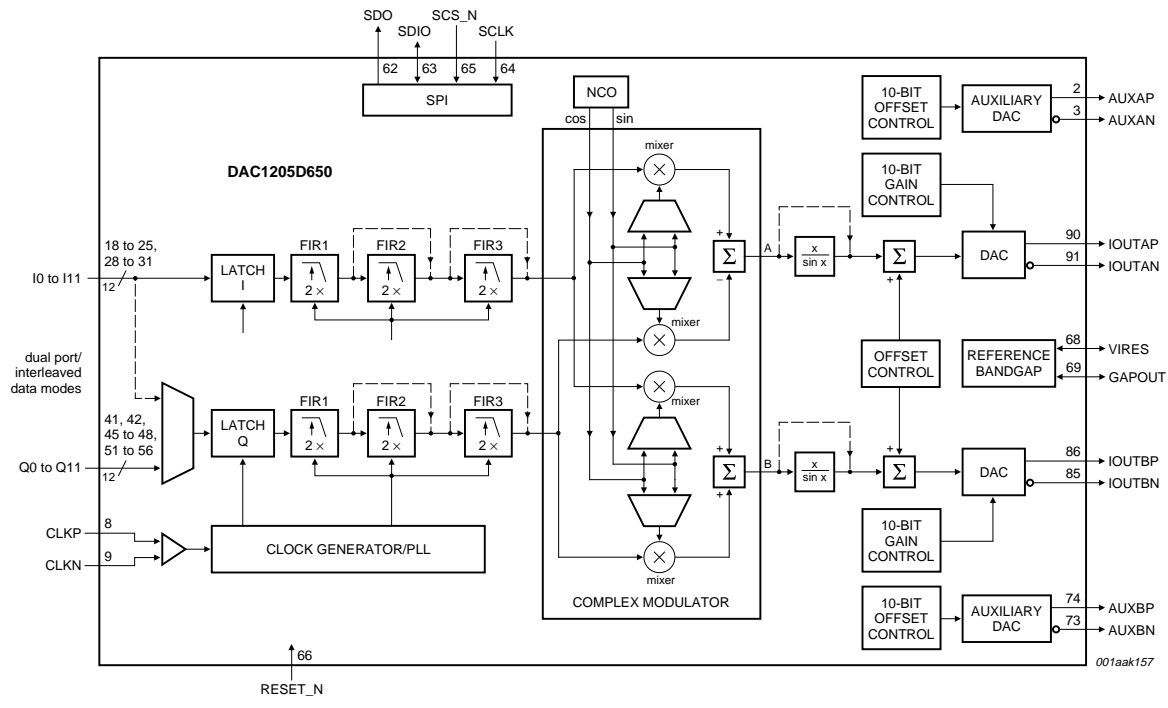
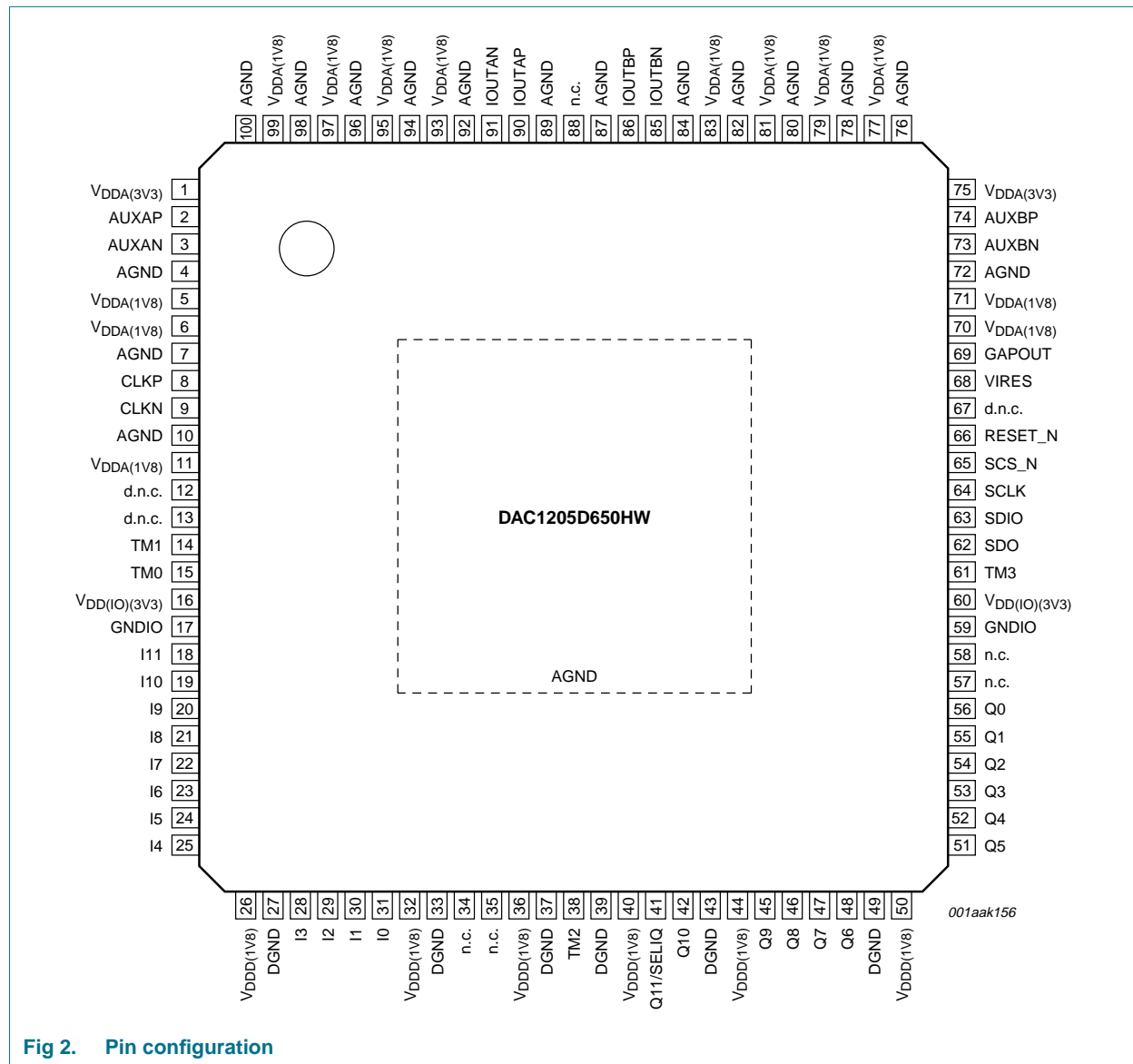


Fig 1. Block diagram

6. Pinning information

6.1 Pinning



6.2 Pin description

Table 2. Pin description

| Symbol | Pin | Type ^[1] | Description |
|--------------------------|-----|---------------------|--|
| V _{DDA(3V3)} | 1 | P | analog supply voltage 3.3 V |
| AUXAP | 2 | O | auxiliary DAC B output current |
| AUXAN | 3 | O | complementary auxiliary DAC B output current |
| AGND | 4 | G | analog ground |
| V _{DDA(1V8)} | 5 | P | analog supply voltage 1.8 V |
| V _{DDA(1V8)} | 6 | P | analog supply voltage 1.8 V |
| AGND | 7 | G | analog ground |
| CLKP | 8 | I | clock input |
| CLKN | 9 | I | complementary clock input |
| AGND | 10 | G | analog ground |
| V _{DDA(1V8)} | 11 | P | analog supply voltage 1.8 V |
| d.n.c. | 12 | - | do not connect |
| d.n.c. | 13 | - | do not connect |
| TM1 | 14 | I/O | test mode 1 (to connect to DGND) |
| TM0 | 15 | I/O | test mode 0 (to connect to DGND) |
| V _{DD(IO)(3V3)} | 16 | P | input/output buffers supply voltage 3.3 V |
| GNDIO | 17 | G | input/output buffers ground |
| I11 | 18 | I | I data input bit 11 (MSB) |
| I10 | 19 | I | I data input bit 10 |
| I9 | 20 | I | I data input bit 9 |
| I8 | 21 | I | I data input bit 8 |
| I7 | 22 | I | I data input bit 7 |
| I6 | 23 | I | I data input bit 6 |
| I5 | 24 | I | I data input bit 5 |
| I4 | 25 | I | I data input bit 4 |
| V _{DDD(1V8)} | 26 | P | digital supply voltage 1.8 V |
| DGND | 27 | G | digital ground |
| I3 | 28 | I | I data input bit 3 |
| I2 | 29 | I | I data input bit 2 |
| I1 | 30 | I | I data input bit 1 |
| I0 | 31 | I | I data input bit 0 (LSB) |
| V _{DDD(1V8)} | 32 | P | digital supply voltage 1.8 V |
| DGND | 33 | G | digital ground |
| n.c. | 34 | I | not connected |
| n.c. | 35 | I | not connected |
| V _{DDD(1V8)} | 36 | P | digital supply voltage 1.8 V |
| DGND | 37 | G | digital ground |
| TM2 | 38 | - | test mode 2 (to connect to DGND) |
| DGND | 39 | G | digital ground |

Table 2. Pin description ...continued

| Symbol | Pin | Type ^[1] | Description |
|--------------------------|-----|---------------------|--|
| V _{DD(1V8)} | 40 | P | digital supply voltage 1.8 V |
| Q11/SELIQ | 41 | I | Q data input bit 11 (MSB) select IQ in Interleaved mode |
| Q10 | 42 | I | Q data input bit 10 |
| DGND | 43 | G | digital ground |
| V _{DD(1V8)} | 44 | P | digital supply voltage 1.8 V |
| Q9 | 45 | I | Q data input bit 9 |
| Q8 | 46 | I | Q data input bit 8 |
| Q7 | 47 | I | Q data input bit 7 |
| Q6 | 48 | I | Q data input bit 6 |
| DGND | 49 | G | digital ground |
| V _{DD(1V8)} | 50 | P | digital supply voltage 1.8 V |
| Q5 | 51 | I | Q data input bit 5 |
| Q4 | 52 | I | Q data input bit 4 |
| Q3 | 53 | I | Q data input bit 3 |
| Q2 | 54 | I | Q data input bit 2 |
| Q1 | 55 | I | Q data input bit 1 |
| Q0 | 56 | I | Q data input bit 0 (LSB) |
| n.c. | 57 | I | not connected |
| n.c. | 58 | I | not connected |
| GNDIO | 59 | G | input/output buffers ground |
| V _{DD(IO)(3V3)} | 60 | P | input/output buffers supply voltage 3.3 V |
| TM3 | 61 | I/O | test mode 3 (to connect to DGND) |
| SDO | 62 | O | SPI data output |
| SDIO | 63 | I/O | SPI data input/output |
| SCLK | 64 | I | SPI clock |
| SCS_N | 65 | I | SPI chip select (active LOW) |
| RESET_N | 66 | I | general reset (active LOW) |
| d.n.c. | 67 | - | do not connect |
| VIRES | 68 | I/O | DAC biasing resistor |
| GAPOUT | 69 | I/O | bandgap input/output voltage |
| V _{DDA(1V8)} | 70 | P | analog supply voltage 1.8 V |
| V _{DDA(1V8)} | 71 | P | analog supply voltage 1.8 V |
| AGND | 72 | G | analog ground |
| AUXBN | 73 | O | complementary auxiliary DAC B output current |
| AUXBP | 74 | O | auxiliary DAC B output current |
| V _{DDA(3V3)} | 75 | P | analog supply voltage 3.3 V |
| AGND | 76 | G | analog ground |
| V _{DDA(1V8)} | 77 | P | analog supply voltage 1.8 V |
| AGND | 78 | G | analog ground |
| V _{DDA(1V8)} | 79 | P | analog supply voltage 1.8 V |

Table 2. Pin description ...continued

| Symbol | Pin | Type ^[1] | Description |
|-----------------------|------------------|---------------------|------------------------------------|
| AGND | 80 | G | analog ground |
| V _{DDA(1V8)} | 81 | P | analog supply voltage 1.8 V |
| AGND | 82 | G | analog ground |
| V _{DDA(1V8)} | 83 | P | analog supply voltage 1.8 V |
| AGND | 84 | G | analog ground |
| IOUTBN | 85 | O | complementary DAC B output current |
| IOUTBP | 86 | O | DAC B output current |
| AGND | 87 | G | analog ground |
| n.c. | 88 | - | not connected |
| AGND | 89 | G | analog ground |
| IOUTAP | 90 | O | DAC A output current |
| IOUTAN | 91 | O | complementary DAC A output current |
| AGND | 92 | G | analog ground |
| V _{DDA(1V8)} | 93 | P | analog supply voltage 1.8 V |
| AGND | 94 | G | analog ground |
| V _{DDA(1V8)} | 95 | P | analog supply voltage 1.8 V |
| AGND | 96 | G | analog ground |
| V _{DDA(1V8)} | 97 | P | analog supply voltage 1.8 V |
| AGND | 98 | G | analog ground |
| V _{DDA(1V8)} | 99 | P | analog supply voltage 1.8 V |
| AGND | 100 | G | analog ground |
| AGND | H ^[2] | G | analog ground |

[1] P = power supply
 G = ground
 I = input
 O = output.

[2] H = heatsink (exposed die pad to be soldered).

7. Limiting values

Table 3. Limiting values

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

| Symbol | Parameter | Conditions | Min | Max | Unit |
|--------------------|-------------------------------------|---|------|------|------|
| $V_{DD(I/O)(3V3)}$ | input/output supply voltage (3.3 V) | | -0.5 | +4.6 | V |
| $V_{DDA(3V3)}$ | analog supply voltage (3.3 V) | | -0.5 | +4.6 | V |
| $V_{DDA(1V8)}$ | analog supply voltage (1.8 V) | | -0.5 | +3.0 | V |
| $V_{DDD(1V8)}$ | digital supply voltage (1.8 V) | | -0.5 | +3.0 | V |
| V_I | input voltage | pins CLKP, CLKN, VIRES and GAPOUT referenced to AGND | -0.5 | +3.0 | V |
| | | pins I11 to I0, Q11 to Q0, SDO, SDIO, SCLK, SCS_N and RESET_N referenced to GNDIO | -0.5 | +4.6 | V |
| V_O | output voltage | pins IOUTAP, IOUTAN, IOUTBP, IOUTBN, AUXAP, AUXAN, AUXBP and AUXBN referenced to AGND | -0.5 | +4.6 | V |
| T_{stg} | storage temperature | | -55 | +150 | °C |
| T_{amb} | ambient temperature | | -45 | +85 | °C |
| T_j | 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] 19.8 | K/W |
| $R_{th(j-c)}$ | thermal resistance from junction to case | | [1] 7.7 | K/W |

[1] In compliance with JEDEC test board, in free air.

9. Characteristics

Table 5. Characteristics

$V_{DDA(1V8)} = V_{DDD(1V8)} = 1.8\text{ V}$; $V_{DDA(3V3)} = V_{DD(IO)(3V3)} = 3.3\text{ V}$; AGND, DGND and GNDIO shorted together; $T_{amb} = -40\text{ °C}$ to $+85\text{ °C}$; typical values measured at $T_{amb} = 25\text{ °C}$; $R_L = 50\ \Omega$; $I_{O(fs)} = 20\text{ mA}$; maximum sample rate; PLL on unless otherwise specified.

| Symbol | Parameter | Conditions | Test [1] | Min | Typ | Max | Unit |
|--|-------------------------------------|--|----------|------|------|-----|------|
| $V_{DD(IO)(3V3)}$ | input/output supply voltage (3.3 V) | | I | 3.0 | 3.3 | 3.6 | V |
| $V_{DDA(3V3)}$ | analog supply voltage (3.3 V) | | I | 3.0 | 3.3 | 3.6 | V |
| $V_{DDA(1V8)}$ | analog supply voltage (1.8 V) | | I | 1.7 | 1.8 | 1.9 | V |
| $V_{DDD(1V8)}$ | digital supply voltage (1.8 V) | | I | 1.7 | 1.8 | 1.9 | V |
| $I_{DD(IO)(3V3)}$ | input/output supply current (3.3 V) | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO on | I | - | 5 | 13 | mA |
| $I_{DDA(3V3)}$ | analog supply current (3.3 V) | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO on | I | - | 48 | 26 | mA |
| $I_{DDD(1V8)}$ | digital supply current (1.8 V) | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO on | I | - | 270 | 309 | mA |
| $I_{DDA(1V8)}$ | analog supply current (1.8 V) | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO on | I | - | 330 | 358 | mA |
| I_{DDD} | digital supply current | for x / (sin x) function only | I | - | 67 | - | mA |
| P_{tot} | total power dissipation | $f_o = 19\text{ MHz}$; $f_s = 320\text{ Msps}$; 4× interpolation; NCO off; DAC B off | C | - | 0.53 | - | W |
| | | $f_o = 19\text{ MHz}$; $f_s = 320\text{ Msps}$; 4× interpolation; NCO off | C | - | 0.82 | - | W |
| | | $f_o = 19\text{ MHz}$; $f_s = 320\text{ Msps}$; 4× interpolation; NCO on | C | - | 0.94 | - | W |
| | | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO off | C | - | 0.95 | - | W |
| | | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO on; All V_{DD} | I | - | 1.18 | 1.4 | W |
| | | $f_o = 19\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation; NCO low-power on | C | - | 1.07 | - | W |
| | | Power-down mode | | | | | |
| full power-down; all V_{DD} | I | - | 0.08 | 0.13 | W | | |
| DAC A and DAC B Sleep mode; 8× interpolation; NCO on | I | - | 0.88 | - | W | | |

Table 5. Characteristics ...continued

$V_{DDA(1V8)} = V_{DDD(1V8)} = 1.8\text{ V}$; $V_{DDA(3V3)} = V_{DD(IO)(3V3)} = 3.3\text{ V}$; AGND, DGND and GNDIO shorted together; $T_{amb} = -40\text{ °C}$ to $+85\text{ °C}$; typical values measured at $T_{amb} = 25\text{ °C}$; $R_L = 50\text{ }\Omega$; $I_{O(fs)} = 20\text{ mA}$; maximum sample rate; PLL on unless otherwise specified.

| Symbol | Parameter | Conditions | Test [1] | Min | Typ | Max | Unit |
|--|--------------------------------------|--|----------|----------|------|-------------------|---------------|
| Clock inputs (CLKP and CLKN)[2] | | | | | | | |
| V_i | input voltage | CLKP; or CLKN $ V_{gpdl} < 50\text{ mV}$ | C | [3] 825 | - | 1575 | mV |
| V_{idth} | input differential threshold voltage | $ V_{gpdl} < 50\text{ mV}$ | C | [3] -100 | - | +100 | mV |
| R_i | input resistance | | D | - | 10 | - | M Ω |
| C_i | input capacitance | | D | - | 0.5 | - | pF |
| Digital inputs (I0 to I11, Q0 to Q11) | | | | | | | |
| V_{IL} | LOW-level input voltage | | C | GNDIO | - | 1.0 | V |
| V_{IH} | HIGH-level input voltage | | C | 2.3 | - | $V_{DD(IO)(3V3)}$ | V |
| I_{IL} | LOW-level input current | $V_{IL} = 1.0\text{ V}$ | I | - | 40 | - | μA |
| I_{IH} | HIGH-level input current | $V_{IH} = 2.3\text{ V}$ | I | - | 80 | - | μA |
| Digital inputs (SDO, SDIO, SCLK, SCS_N and RESET_N) | | | | | | | |
| V_{IL} | LOW-level input voltage | | C | GNDIO | - | 1.0 | V |
| V_{IH} | HIGH-level input voltage | | C | 2.3 | - | $V_{DD(IO)(3V3)}$ | V |
| I_{IL} | LOW-level input current | $V_{IL} = 1.0\text{ V}$ | I | - | 20 | - | nA |
| I_{IH} | HIGH-level input current | $V_{IH} = 2.3\text{ V}$ | I | - | 20 | - | nA |
| Analog outputs (IOUTAP, IOUTAN, IOUTBP and IOUTBN) | | | | | | | |
| $I_{O(fs)}$ | full-scale output current | register value = 00h | C | - | 1.6 | - | mA |
| | | default register | C | - | 20 | - | mA |
| V_O | output voltage | compliance range | C | 1.8 | - | $V_{DDA(3V3)}$ | V |
| R_O | output resistance | | D | - | 250 | - | k Ω |
| C_O | output capacitance | | D | - | 3 | - | pF |
| $N_{DAC(mon)}$ | DAC monotonicity | guaranteed | D | - | 8 | - | bit |
| ΔE_O | offset error variation | | C | - | 6 | - | ppm/°C |
| ΔE_G | gain error variation | | C | - | 18 | - | ppm/°C |
| Reference voltage output (GAPOUT) | | | | | | | |
| $V_{O(ref)}$ | reference output voltage | $T_{amb} = 25\text{ °C}$ | I | 1.2 | 1.25 | 1.29 | V |
| $\Delta V_{O(ref)}$ | reference output voltage variation | | C | - | 117 | - | ppm/°C |
| $I_{O(ref)}$ | reference output current | external voltage 1.25 V | D | - | 40 | - | μA |

Table 5. Characteristics ...continued

$V_{DDA(1V8)} = V_{DDD(1V8)} = 1.8\text{ V}$; $V_{DDA(3V3)} = V_{DD(I/O)(3V3)} = 3.3\text{ V}$; AGND, DGND and GNDIO shorted together; $T_{amb} = -40\text{ °C}$ to $+85\text{ °C}$; typical values measured at $T_{amb} = 25\text{ °C}$; $R_L = 50\text{ }\Omega$; $I_{O(fs)} = 20\text{ mA}$; maximum sample rate; PLL on unless otherwise specified.

| Symbol | Parameter | Conditions | Test [1] | Min | Typ | Max | Unit |
|--|--|---|----------|-----|-------|------------------|------|
| Analog auxiliary outputs (AUXAP, AUXAN, AUXBP and AUXBN) | | | | | | | |
| $I_{O(aux)}$ | auxiliary output current | differential outputs | I | - | 2.2 | - | mA |
| $V_{O(aux)}$ | auxiliary output voltage | compliance range | C | 0 | - | 2 | V |
| $N_{DAC(aux)mono}$ | auxiliary DAC monotonicity | guaranteed | D | - | 10 | - | bit |
| Input timing (see Figure 10) | | | | | | | |
| f_{data} | data rate | Dual-port mode input | C | - | - | 160 | MHz |
| $t_{w(CLK)}$ | CLK pulse width | | C | 1.5 | - | $T_{data} - 1.5$ | ns |
| $t_{h(i)}$ | input hold time | | C | 1.1 | - | - | ns |
| $t_{su(i)}$ | input set-up time | | C | 1.1 | - | - | ns |
| Output timing | | | | | | | |
| f_s | sampling frequency | | C | - | - | 650 | MSPS |
| t_s | settling time | to ± 0.5 LSB | D | - | 20 | - | ns |
| NCO frequency range; $f_s = 640$ Msps | | | | | | | |
| f_{NCO} | NCO frequency | register value = 00000000h | D | - | 0 | - | MHz |
| | | register value = FFFFFFFFh | D | - | 640 | - | MHz |
| f_{step} | step frequency | | D | - | 0.149 | - | Hz |
| Low-power NCO frequency range; $f_{DAC} = 640$ MHz | | | | | | | |
| f_{NCO} | NCO frequency | register value = 00000000h | D | - | 0 | - | MHz |
| | | register value = F8000000h | D | - | 620 | - | MHz |
| f_{step} | step frequency | | D | - | 20 | - | MHz |
| Dynamic performance; PLL on | | | | | | | |
| SFDR | spurious-free dynamic range | $f_{data} = 80\text{ MHz}$; $f_s = 320\text{ Msps}$; $B = f_{data} / 2$; $f_o = 35\text{ MHz}$ at 0 dBFS | C | - | 84 | - | dBc |
| | | $f_{data} = 80\text{ MHz}$; $f_s = 640\text{ Msps}$; $B = f_{data} / 2$ | | | | | |
| | | $f_o = 4\text{ MHz}$ at 0 dBFS | I | - | 76 | - | dBc |
| | | $f_o = 19\text{ MHz}$ at 0 dBFS | I | - | 76 | - | dBc |
| | | $f_{data} = 160\text{ MHz}$; $f_s = 640\text{ Msps}$; $B = f_{data} / 2$; $f_o = 70\text{ MHz}$ at 0 dBFS | C | - | 83 | - | dBc |
| SFDR _{RBW} | restricted bandwidth spurious-free dynamic range | $f_s = 640\text{ Msps}$; $f_o = 96\text{ MHz}$ at 0 dBFS; $B = 30\text{ kHz}$ | | | | | |
| | | $2.51\text{ MHz} \leq f_{offset} \leq 2.71\text{ MHz}$ | I | - | -91 | -84 | dBc |
| | | $2.71\text{ MHz} \leq f_{offset} \leq 3.51\text{ MHz}$ | I | - | -92 | - | dBc |
| | | $3.51\text{ MHz} \leq f_{offset} \leq 4\text{ MHz}$ | I | - | -93 | -85 | dBc |
| | | $f_s = 640\text{ Msps}$; $f_o = 96\text{ MHz}$ at 0 dBFS; $B = 1\text{ MHz}$ | | | | | |
| $4\text{ MHz} \leq f_{offset} \leq 40\text{ MHz}$ | I | - | -84 | -65 | dBc | | |

Table 5. Characteristics ...continued

$V_{DDA(1V8)} = V_{DDD(1V8)} = 1.8\text{ V}$; $V_{DDA(3V3)} = V_{DD(I/O)(3V3)} = 3.3\text{ V}$; AGND, DGND and GNDIO shorted together; $T_{amb} = -40\text{ °C}$ to $+85\text{ °C}$; typical values measured at $T_{amb} = 25\text{ °C}$; $R_L = 50\text{ }\Omega$; $I_{O(f_s)} = 20\text{ mA}$; maximum sample rate; PLL on unless otherwise specified.

| Symbol | Parameter | Conditions | Test [1] | Min | Typ | Max | Unit |
|--------|--|---|-----------------------------|------------------------|------|-----|--------|
| IMD3 | third-order intermodulation distortion | $f_{o1} = 49\text{ MHz}$; $f_{o2} = 51\text{ MHz}$; $f_s = 320\text{ Msps}$; 4× interpolation | C | [4] - | 82 | - | dBc |
| | | $f_{o1} = 95\text{ MHz}$; $f_{o2} = 97\text{ MHz}$; $f_s = 320\text{ Msps}$; 4× interpolation | C | [4] - | 80 | - | dBc |
| | | $f_{o1} = 95\text{ MHz}$; $f_{o2} = 97\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation | I | [4] 66 | 79 | - | dBc |
| | | $f_{o1} = 152\text{ MHz}$; $f_{o2} = 154\text{ MHz}$; $f_s = 640\text{ Msps}$; 8× interpolation | C | [4] - | 77 | - | dBc |
| ACPR | adjacent channel power ratio | $f_{data} = 76.8\text{ MHz}$; $f_s = 614.4\text{ Msps}$; $f_o = 96\text{ MHz}$ | | | | | |
| | | 1 carrier; B = 5 MHz | I | - | 70 | - | dB |
| | | 2 carriers; B = 10 MHz | C | - | 68 | - | dB |
| | | 4 carriers; B = 20 MHz | C | - | 67 | - | dB |
| | | $f_{data} = 153.6\text{ MHz}$; $f_s = 614.4\text{ Msps}$; $f_o = 115.2\text{ MHz}$ | | | | | |
| | | 1 carrier; B = 5 MHz | C | - | 70 | - | dB |
| | | 2 carriers; B = 10 MHz | C | - | 68 | - | dB |
| | | 4 carriers; B = 20 MHz | C | - | 66 | - | dB |
| | | $f_{data} = 153.6\text{ MHz}$; $f_s = 614.4\text{ Msps}$; $f_o = 153.6\text{ MHz}$ | | | | | |
| | | 1 carrier; B = 5 MHz | C | - | 68 | - | dB |
| | | 2 carriers; B = 10 MHz | C | - | 66 | - | dB |
| | | 4 carriers; B = 20 MHz | C | - | 65 | - | dB |
| NSD | noise spectral density | $f_s = 640\text{ Msps}$; 8× interpolation; $f_o = 19\text{ MHz}$ at 0 dBFS | | | | | |
| | | noise shaper disabled | C | - | -149 | - | dBm/Hz |
| | | noise shaper enabled | C | - | -150 | - | dBm/Hz |

[1] D = guaranteed by design; C = guaranteed by characterization; I = 100 % industrially tested.

[2] CLKP and CLKN inputs are at differential LVDS levels. An external differential resistor with a value of between 80 Ω and 120 Ω should be connected across the pins (see [Figure 8](#)).

[3] $|V_{gpd}|$ represents the ground potential difference voltage. This is the voltage that results from current flowing through the finite resistance and the inductance between the receiver and the driver circuit ground.

[4] IMD3 rejection with -6 dBFS/tone.

10. Application information

10.1 General description

The DAC1205D650 is a dual 12-bit DAC operating at up to 650 Msps. Each DAC consists of a segmented architecture, comprising a 6-bit thermometer sub-DAC and an 6-bit binary weighted sub-DAC.

With an input data rate of up to 160 MHz, and a maximum output sampling rate of 650 Msps, the DAC1205D650 allows more flexibility for wide bandwidth and multi-carrier systems. Combined with its quadrature modulator and its 32-bit NCO, the DAC1205D650 simplifies the frequency selection of the system. This is also possible because of the 2×, 4× and 8× interpolation filters that remove undesired images.

Two modes are available for the digital input. In the Dual-port mode, each DAC uses its own data input line. In Interleaved mode, both DACs use the same data input line.

Each DAC generates two complementary current outputs on pins IOUTAP/IOUTAN and IOUTBP/IOUTBN. This provides a full-scale output current ($I_{O(fs)}$) up to 20 mA. An internal reference is available for the reference current which is externally adjustable using pin VIRES.

There are embedded features which provide analog offset correction (internal auxiliary DACs), digital offset control and gain adjustment. All the functions can be set using a SPI.

The DAC1205D650 operates at both 3.3 V and 1.8 V using separate digital and analog power supplies. The digital input is 3.3 V compliant and the clock input is LVDS compliant.

10.2 Serial interface (SPI)

10.2.1 Protocol description

The DAC1205D650 serial interface is a synchronous serial communication port allowing easy interfacing with many industry microprocessors. It provides access to the registers that define the operating modes of the chip in both write and read modes.

This interface can be configured as a 3-wire type (SDIO as bidirectional pin) or a 4-wire type (SDIO and SDO as unidirectional pin, input and output port respectively). In both configurations, SCLK acts as the serial clock, and SCS_N acts as the serial chip select bar.

Each read/write operation is sequenced by the SCS_N signal and enabled by a LOW assertion to drive the chip with between 2 to 5 bytes, depending on the content of the instruction byte (see [Table 7](#)).

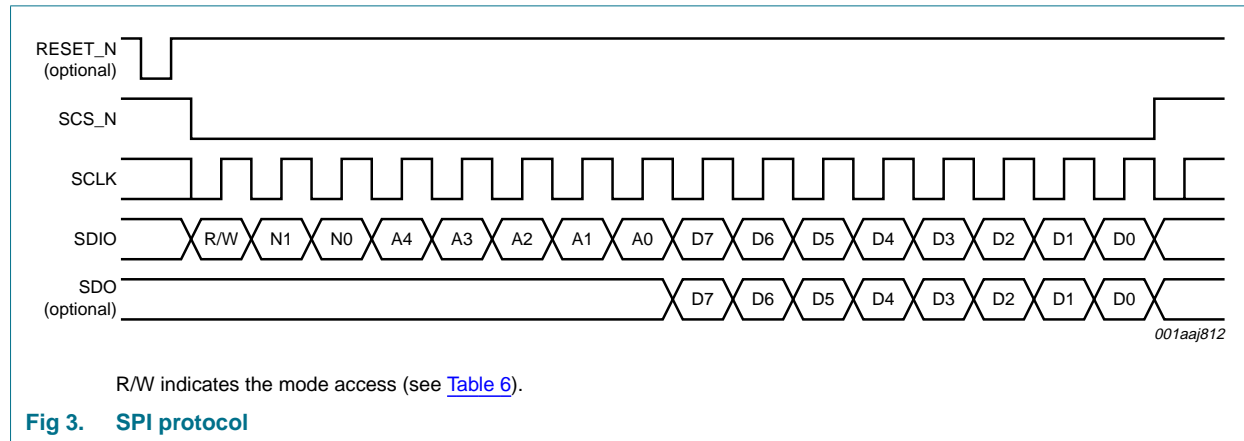


Table 6. Read or Write mode access description

| R/W | Description |
|-----|----------------------|
| 0 | Write mode operation |
| 1 | Read mode operation |

In [Table 7](#) N1 and N0 indicate the number of bytes transferred after the instruction byte.

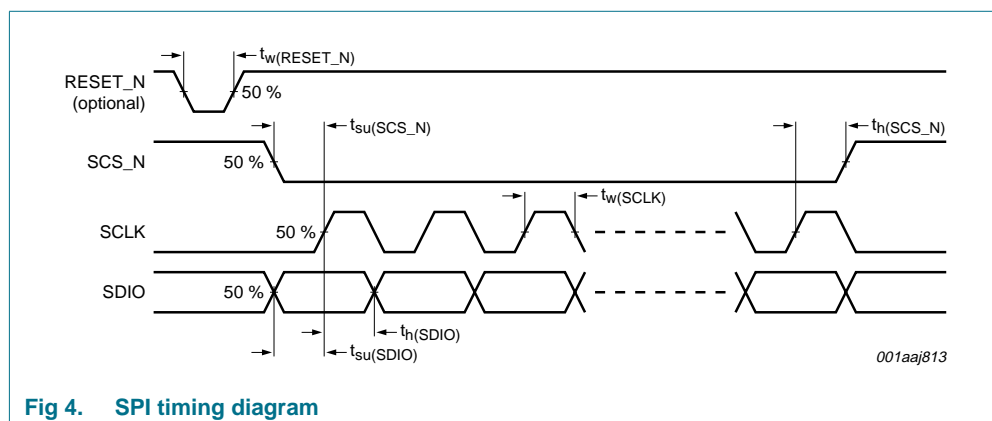
Table 7. Number of bytes to be transferred

| N1 | N0 | Number of bytes |
|----|----|---------------------|
| 0 | 0 | 1 byte transferred |
| 0 | 1 | 2 bytes transferred |
| 1 | 0 | 3 bytes transferred |
| 1 | 1 | 4 bytes transferred |

A0 to A4: indicates which register is being addressed. In the case of a multiple transfer, this address concerns the first register after which the next registers follow directly in decreasing order according to [Table 9 “Register allocation map”](#).

10.2.2 SPI timing description

The SPI interface can operate at a frequency of up to 15 MHz. The SPI timing is shown in [Figure 4](#).



The SPI timing characteristics are given in [Table 8](#).

Table 8. SPI timing characteristics

| Symbol | Parameter | Min | Typ | Max | Unit |
|---------------------------------|---------------------|-----|-----|-----|------|
| f_{SCLK} | SCLK frequency | - | - | 15 | MHz |
| $t_{\text{w}}(\text{SCLK})$ | SCLK pulse width | 30 | - | - | ns |
| $t_{\text{su}}(\text{SCS_N})$ | SCS_N set-up time | 20 | - | - | ns |
| $t_{\text{h}}(\text{SCS_N})$ | SCS_N hold time | 20 | - | - | ns |
| $t_{\text{su}}(\text{SDIO})$ | SDIO set-up time | 10 | - | - | ns |
| $t_{\text{h}}(\text{SDIO})$ | SDIO hold time | 5 | - | - | ns |
| $t_{\text{w}}(\text{RESET_N})$ | RESET_N pulse width | 30 | - | - | ns |

10.2.3 Detailed descriptions of registers

An overview of the details for all registers is provided in [Table 9](#).

Table 9. Register allocation map

| Address | Register name | R/W | Bit definition | | | | | | | | | Default | | | |
|---------|---------------|---------------|----------------|------------------------|-------------|-------------------|----------------------|----------|----------------|--------------------|-------------|----------|----------|-----|---|
| | | | b7 | b6 | b5 | b4 | b3 | b2 | b1 | b0 | Bin | Hex | Dec | | |
| 0 | 00h | COMMon | R/W | 3W_SPI | SPI_RST | CLK_SEL | - | MODE_SEL | CODING | IC_PD | GAP_PD | 10000000 | 80 | 128 | |
| 1 | 01h | TXCFG | R/W | NCO_ON | NCO_LP_SEL | INV_SIN_SEL | MODULATION[2:0] | | | INTERPOLATION[1:0] | | 10000111 | 87 | 135 | |
| 2 | 02h | PLLCFG | R/W | PLL_PD | - | PLL_DIV_PD | PLL_DIV[1:0] | | PLL_PHASE[1:0] | | PLL_POL | 00010000 | 10 | 16 | |
| 3 | 03h | FREQNCO_LSB | R/W | FREQ_NCO[7:0] | | | | | | | | 01100110 | 66 | 102 | |
| 4 | 04h | FREQNCO_LISB | R/W | FREQ_NCO[15:8] | | | | | | | | 01100110 | 66 | 102 | |
| 5 | 05h | FREQNCO_UISB | R/W | FREQ_NCO[23:16] | | | | | | | | 01100110 | 66 | 102 | |
| 6 | 06h | FREQNCO_MSB | R/W | FREQ_NCO[31:24] | | | | | | | | 00100110 | 26 | 38 | |
| 7 | 07h | PHINCO_LSB | R/W | PH_NCO[7:0] | | | | | | | | 00000000 | 00 | 0 | |
| 8 | 08h | PHINCO_MSB | R/W | PH_NCO[15:8] | | | | | | | | 00000000 | 00 | 0 | |
| 9 | 09h | DAC_A_Cfg_1 | R/W | DAC_A_PD | DAC_A_SLEEP | DAC_A_OFFSET[4:0] | | | | | - | 00000000 | 00 | 0 | |
| 10 | 0Ah | DAC_A_Cfg_2 | R/W | DAC_A_GAIN_COARSE[1:0] | | | DAC_A_GAIN_FINE[5:0] | | | | | 01000000 | 40 | 64 | |
| 11 | 0Bh | DAC_A_Cfg_3 | R/W | DAC_A_GAIN_COARSE[3:2] | | | DAC_A_OFFSET[10:5] | | | | | 11000000 | C0 | 192 | |
| 12 | 0Ch | DAC_B_Cfg_1 | R/W | DAC_B_PD | DAC_B_SLEEP | DAC_B_OFFSET[4:0] | | | | | - | 00000000 | 00 | 0 | |
| 13 | 0Dh | DAC_B_Cfg_2 | R/W | DAC_B_GAIN_COARSE[1:0] | | | DAC_B_GAIN_FINE[5:0] | | | | | 01000000 | 40 | 64 | |
| 14 | 0Eh | DAC_B_Cfg_3 | R/W | DAC_B_GAIN_COARSE[3:2] | | | DAC_B_OFFSET[10:5] | | | | | 11000000 | C0 | 192 | |
| 15 | 0Fh | DAC_Cfg | R/W | - | | | | | | MINUS_3DB | NOISE_SHPER | 11000000 | C0 | 0 | |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | |
| 26 | 1Ah | DAC_A_Aux_MSB | R/W | AUX_A[9:2] | | | | | | | | 10000000 | 80 | 128 | |
| 27 | 1Bh | DAC_A_Aux_LSB | R/W | AUX_A_PD | - | | | | | | AUX_A[1:0] | | 00000000 | 00 | 0 |
| 28 | 1Ch | DAC_B_Aux_MSB | R/W | AUX_B[9:2] | | | | | | | | 10000000 | 80 | 128 | |
| 29 | 1Dh | DAC_B_Aux_LSB | R/W | AUX_B_PD | - | | | | | | AUX_B[1:0] | | 00000000 | 00 | 0 |

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10.2.4 Registers detailed description

Please refer to [Table 9](#) for a register overview and their default values. In the following tables, all the values highlighted are the default values.

Table 10. COMMON register (address 00h) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|-----|----------|--------|-------|--|
| 7 | 3W_SPI | R/W | | serial interface bus type |
| | | | 0 | 4 wire SPI |
| | | | 1 | 3 wire SPI |
| 6 | SPI_RST | R/W | | serial interface reset |
| | | | 0 | no reset |
| | | | 1 | performs a reset on all registers except 00h |
| 5 | CLK_SEL | R/W | | data input latch |
| | | | 0 | at CLK rising edge |
| | | | 1 | at CLK falling edge |
| 3 | MODE_SEL | R/W | | input data mode |
| | | | 0 | dual-port |
| | | | 1 | interleaved |
| 2 | CODING | R/W | | coding |
| | | | 0 | binary |
| | | | 1 | two's compliment |
| 1 | IC_PD | R/W | | power-down |
| | | | 0 | disabled |
| | | | 1 | all circuits (digital and analog, except SPI) are switched off |
| 0 | GAP_PD | R/W | | internal bandgap power-down |
| | | | 0 | power-down disabled |
| | | | 1 | internal bandgap references are switched off |

Table 11. TXCFG register (address 01h) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|-----|-------------|--------|-------|--|
| 7 | NCO_ON | R/W | | NCO |
| | | | 0 | disabled (the NCO phase is reset to 0°) |
| | | | 1 | enabled |
| 6 | NCO_LP_SEL | R/W | | low-power NCO |
| | | | 0 | disabled |
| | | | 1 | NCO frequency and phase given by the five MSBs of the registers 06h and 08h respectively |
| 5 | INV_SIN_SEL | R/W | | x / (sin x) function |
| | | | 0 | disabled |
| | | | 1 | enabled |

Table 11. TXCFG register (address 01h) bit description ...continued
 Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|------------------------|--------|------------|---|
| 4 to 2 | MODULATION[2:0] | R/W | | modulation |
| | | | 000 | dual DAC: no modulation |
| | | | 001 | positive upper single sideband up-conversion |
| | | | 010 | positive lower single sideband up-conversion |
| | | | 011 | negative upper single sideband up-conversion |
| | | | 100 | negative lower single sideband up-conversion |
| 1 to 0 | INTERPOLATION [1:0] | R/W | | interpolation |
| | | | 01 | 2× |
| | | | 10 | 4× |
| | | | 11 | 8× |

Table 12. PLLCFG register (address 02h) bit description
 Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|----------------|--------|-----------|--|
| 7 | PLL_PD | R/W | | PLL |
| | | | 0 | switched on |
| | | | 1 | switched off |
| 5 | PLL_DIV_PD | R/W | | PLL divider |
| | | | 0 | switched on |
| | | | 1 | switched off |
| 4 to 3 | PLL_DIV[1:0] | R/W | | PLL divider factor |
| | | | 00 | $f_s = 2 \times f_{clk}$ |
| | | | 01 | $f_s = 4 \times f_{clk}$ |
| | | | 10 | $f_s = 8 \times f_{clk}$ |
| 2 to 1 | PLL_PHASE[1:0] | R/W | | PLL phase shift of f_s |
| | | | 00 | 0° |
| | | | 01 | 120° |
| | | | 10 | 240° |
| 0 | PLL_POL | R/W | | DAC clock edge (f_s) |
| | | | 0 | normal |
| | | | 1 | inverted |

Table 13. FREQNCO_LSB register (address 03h) bit description

| Bit | Symbol | Access | Value | Description |
|--------|---------------|--------|-------|--|
| 7 to 0 | FREQ_NCO[7:0] | R/W | - | lower 8 bits for the NCO frequency setting |

Table 14. FREQNCO_LISB register (address 04h) bit description

| Bit | Symbol | Access | Value | Description |
|--------|----------------|--------|-------|---|
| 7 to 0 | FREQ_NCO[15:8] | R/W | - | lower intermediate 8 bits for the NCO frequency setting |

Table 15. **FREQNCO_UIB register (address 05h) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|-----------------|--------|-------|---|
| 7 to 0 | FREQ_NCO[23:16] | R/W | - | upper intermediate 8 bits for the NCO frequency setting |

Table 16. **FREQNCO_MSB register (address 06h) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|-----------------|--------|-------|---|
| 7 to 0 | FREQ_NCO[31:24] | R/W | - | most significant 8 bits for the NCO frequency setting |

Table 17. **PHINCO_LSB register (address 07h) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|-------------|--------|-------|--|
| 7 to 0 | PH_NCO[7:0] | R/W | - | lower 8 bits for the NCO phase setting |

Table 18. **PHINCO_MSB register (address 08h) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|--------------|--------|-------|---|
| 7 to 0 | PH_NCO[15:8] | R/W | - | most significant 8 bits for the NCO phase setting |

Table 19. **DAC_A_Cfg_1 register (address 09h) bit description**

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|-------------------|--------|----------|-----------------------------------|
| 7 | DAC_A_PD | R/W | | DAC A power |
| | | | 0 | on |
| | | | 1 | off |
| 6 | DAC_A_SLEEP | R/W | | DAC A Sleep mode |
| | | | 0 | disabled |
| | | | 1 | enabled |
| 5 to 1 | DAC_A_OFFSET[4:0] | R/W | - | lower 5 bits for the DAC A offset |

Table 20. **DAC_A_Cfg_2 register (address 0Ah) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|------------------------|--------|-------|---|
| 7 to 6 | DAC_A_GAIN_COARSE[1:0] | R/W | - | least significant 2 bits for the DAC A gain setting for coarse adjustment |
| 5 to 0 | DAC_A_GAIN_FINE[5:0] | R/W | - | the 6 bits for the DAC A gain fine adjustment setting |

Table 21. **DAC_A_Cfg_3 register (address 0Bh) bit description**

| Bit | Symbol | Access | Value | Description |
|--------|------------------------|--------|-------|--|
| 7 to 6 | DAC_A_GAIN_COARSE[3:2] | R/W | - | most significant 2 bits for the DAC A gain setting for coarse adjustment |
| 5 to 0 | DAC_A_OFFSET[10:5] | R/W | - | most significant 6 bits for the DAC A offset |

Table 22. DAC_B_Cfg_1 register (address 0Ch) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|-------------------|--------|----------|-----------------------------------|
| 7 | DAC_B_PD | R/W | | DAC B power |
| | | | 0 | on |
| | | | 1 | off |
| 6 | DAC_B_SLEEP | R/W | | DAC B Sleep mode |
| | | | 0 | disabled |
| | | | 1 | enabled |
| 5 to 1 | DAC_B_OFFSET[4:0] | R/W | | lower 5 bits for the DAC B offset |

Table 23. DAC_B_Cfg_2 register (address 0Dh) bit description

| Bit | Symbol | Access | Value | Description |
|--------|------------------------|--------|-------|--|
| 7 to 6 | DAC_B_GAIN_COARSE[1:0] | R/W | - | less significant 2 bits for the DAC B gain setting for coarse adjustment |
| 5 to 0 | DAC_B_GAIN_FINE[5:0] | R/W | - | the 6 bits for the DAC B gain setting for fine adjustment |

Table 24. DAC_B_Cfg_3 register (address 0Eh) bit description

| Bit | Symbol | Access | Value | Description |
|--------|------------------------|--------|-------|--|
| 7 to 6 | DAC_B_GAIN_COARSE[3:2] | R/W | - | most significant 2 bits for the DAC B gain setting for coarse adjustment |
| 5 to 0 | DAC_B_OFFSET[10:5] | R/W | - | most significant 6 bits for the DAC B offset |

Table 25. DAC_Cfg register (address 0Fh) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|-----|-------------|--------|----------|-----------------|
| 1 | MINUS_3DB | R/W | | NCO gain |
| | | | 0 | unity |
| | | | 1 | -3 dB |
| 0 | NOISE_SHPER | R/W | | noise shaper |
| | | | 0 | disabled |
| | | | 1 | enabled |

Table 26. DAC_A_Aux_MSB register (address 1Ah) bit description

| Bit | Symbol | Access | Value | Description |
|--------|------------|--------|-------|---|
| 7 to 0 | AUX_A[9:2] | R/W | - | most significant 8 bits for the auxiliary DAC A |

Table 27. DAC_A_Aux_LSB register (address 1Bh) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|------------|--------|----------|--------------------------------------|
| 7 | AUX_A_PD | R/W | | auxiliary DAC A power |
| | | | 0 | on |
| | | | 1 | off |
| 1 to 0 | AUX_A[1:0] | R/W | | lower 2 bits for the auxiliary DAC A |

Table 28. DAC_B_Aux_MSB register (address 1Ch) bit description

| Bit | Symbol | Access | Value | Description |
|--------|------------|--------|-------|---|
| 7 to 0 | AUX_B[9:2] | R/W | - | most significant 8 bits for the auxiliary DAC B |

Table 29. DAC_B_Aux_LSB register (address 1Dh) bit description

Default settings are shown highlighted.

| Bit | Symbol | Access | Value | Description |
|--------|------------|--------|----------|--------------------------------------|
| 7 | AUX_B_PD | R/W | 0 | auxiliary DAC B power on |
| | | | 1 | off |
| 1 to 0 | AUX_B[1:0] | R/W | | lower 2 bits for the auxiliary DAC B |

10.3 Input data

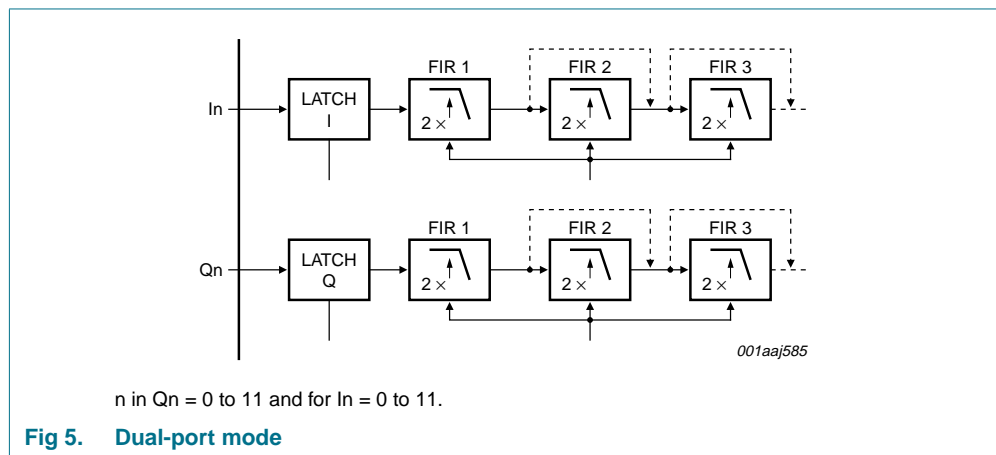
The setting applied to MODE_SEL (register 00h[3]; see [Table 10 on page 17](#)) defines whether the DAC1205D650 operates in the Dual-port mode or in the Interleaved mode (see [Table 30](#)).

Table 30. Mode selection

| Bit 3 setting | Function | I11 to I0 | Q11 to Q0 |
|---------------|-----------------------------|-----------|-----------|
| 0 | Dual-port mode, pin Q11 | active | active |
| 1 | Interleaved mode, pin SELIQ | active | off |

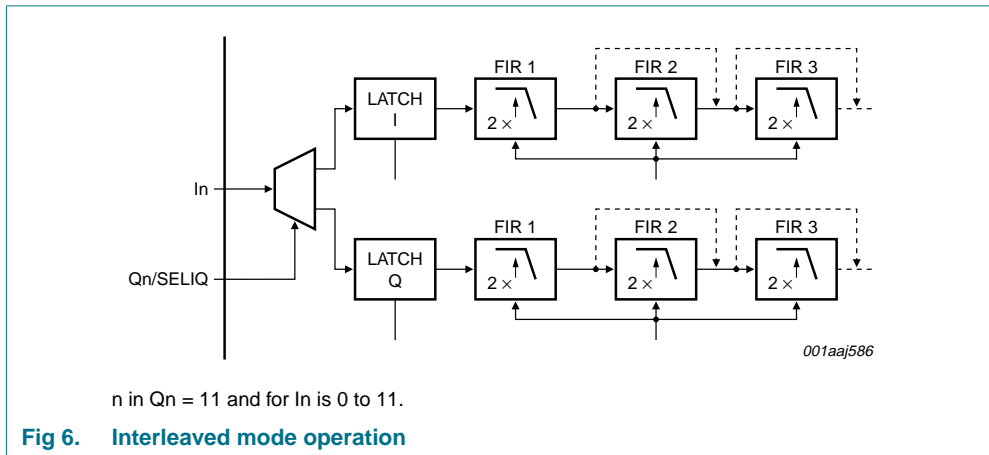
10.3.1 Dual-port mode

The data input for Dual-port mode operation is shown in [Figure 5 “Dual-port mode”](#). Each DAC has its own independent signal data input. The data enters the input latch on the rising edge of the internal clock signal and is transferred to the DAC latch.



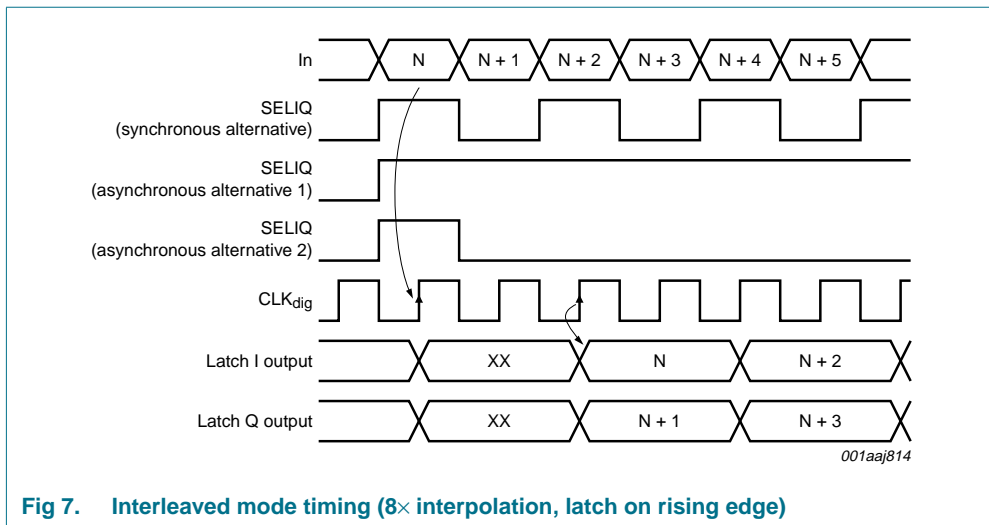
10.3.2 Interleaved mode

The data input for Interleaved mode operation is shown in [Figure 6 “Interleaved mode operation”](#).



In the Interleaved mode, both DACs use the same data input at twice the Dual-port mode frequency. Data enters the latch on the rising edge of the internal clock signal. The data is sent to either latch I or latch Q, depending on the SELIQ signal; see [Figure 7](#).

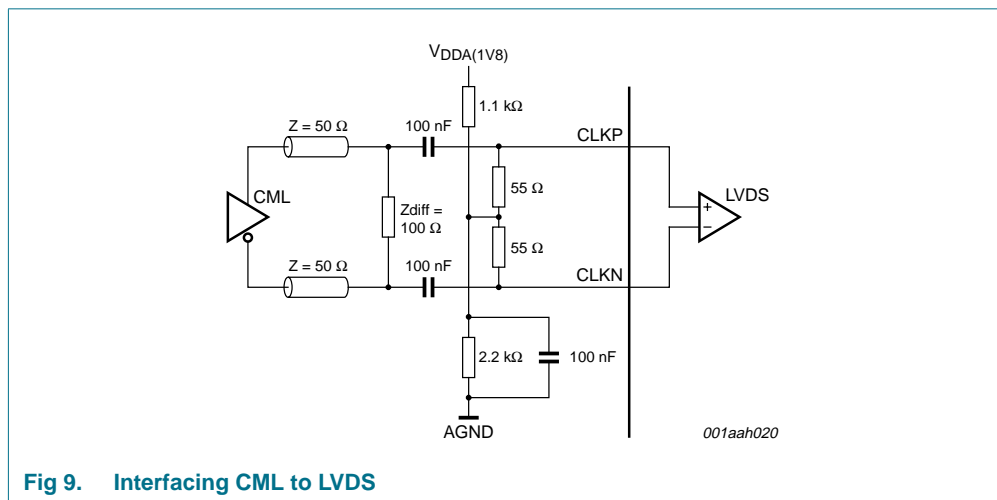
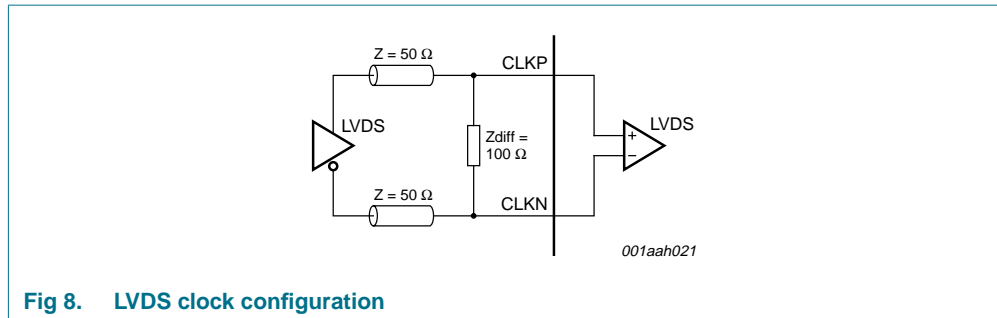
The SELIQ input (pin 41) allows the synchronization of the internally de-multiplexed I and Q channels; see [Figure 7 "Interleaved mode timing \(8× interpolation, latch on rising edge\)"](#).



SELIQ can be either a synchronous or asynchronous (single rising edge, single pulse) signal. The first data bits following the SELIQ rising edge are sent in channel I and following data bits are sent in channel Q. After this, the data is distributed alternately between both channels.

10.4 Input clock

The DAC1205D650 can operate with a clock frequency of 160 MHz in the Dual-port mode and up to 320 MHz in the Interleaved mode. The input clock is LVDS (see [Figure 8](#)) but it can also be interfaced with CML (see [Figure 9](#)).



10.5 Timing

The DAC1205D650 can operate at an update rate (f_s) of up to 650 Msps and with an input data rate (f_{data}) of up to 160 MHz. The input timing is shown in [Figure 10 “Input timing diagram”](#).

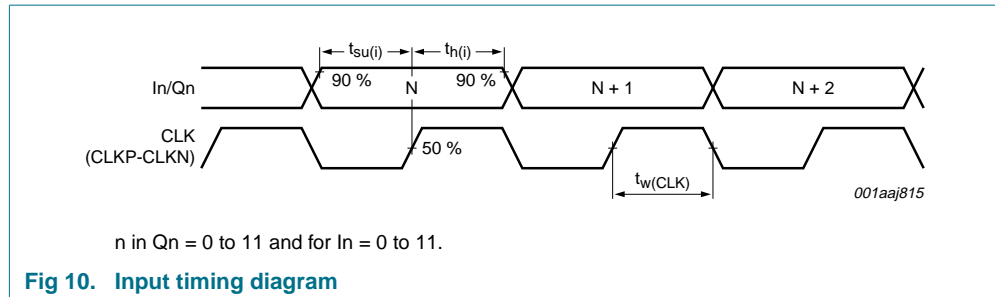


Fig 10. Input timing diagram

The typical performances are measured at 50 % duty cycle but any timing within the limits of the characteristics will not alter the performance.

In [Table 31 “Frequencies”](#), the links between internal and external clocking are defined. The setting applied to PLL_DIV[1:0] (register 02h[4:3]; see [Table 12 “PLLCFG register \(address 02h\) bit description”](#)) allows the frequency between the digital part and the DAC core to be adjusted.

Table 31. Frequencies

| Mode | CLK input (MHz) | Input data rate (MHz) | Interpolation | Update rate (Msps) | PLL_DIV[1:0] |
|-------------|-----------------|-----------------------|---------------|--------------------|--------------|
| Dual-port | 160 | 160 | 2× | 320 | 01 (/4) |
| Dual-port | 160 | 160 | 4× | 640 | 01 (/4) |
| Dual-port | 80 | 80 | 8× | 640 | 10 (/8) |
| Interleaved | 320 | 320 | 2× | 320 | 00 (/2) |
| Interleaved | 320 | 320 | 4× | 640 | 00 (/2) |
| Interleaved | 160 | 160 | 8× | 640 | 01 (/4) |

The settings applied to PLL_PHASE[1:0] (register 02h[2:1]) and PLL_POL (register 02h[0]), allows adjustment of the phase and polarity of the sampling clock. This occurs at the input of the DAC core and depends mainly on the sampling frequency. Some examples are given in [Table 32 “Sample clock phase and polarity examples”](#).

Table 32. Sample clock phase and polarity examples

| Mode | Input data rate (MHz) | Interpolation | Update rate (Msps) | PLL_PHASE [1:0] | PLL_POL |
|-------------|-----------------------|---------------|--------------------|-----------------|---------|
| Dual-port | 80 | 2× | 160 | 01 | 1 |
| Dual-port | 80 | 4× | 320 | 01 | 0 |
| Dual-port | 80 | 8× | 640 | 01 | 1 |
| Interleaved | 160 | 2× | 160 | 01 | 1 |
| Interleaved | 160 | 4× | 320 | 01 | 0 |
| Interleaved | 160 | 8× | 640 | 01 | 1 |

10.6 FIR filters

The DAC1205D650 integrates three selectable Finite Impulse Response (FIR) filters which enable the device to use interpolation rates of 2×, 4× or 8×.

All three interpolation filters have a stop-band attenuation of at least 80 dBc and a pass-band ripple of less than 0.0005 dB.

The coefficients of the interpolation filters are given in [Table 33 "Interpolation filter coefficients"](#).

Table 33. Interpolation filter coefficients

| First interpolation filter ^[1] | | | Second interpolation filter ^[1] | | | Third interpolation filter ^[1] | | |
|---|-------|-------|--|-------|-------|---|-------|-------|
| Lower | Upper | Value | Lower | Upper | Value | Lower | Upper | Value |
| H(1) | H(55) | -4 | H(1) | H(23) | -2 | H(1) | H(15) | -39 |
| H(2) | H(54) | 0 | H(2) | H(22) | 0 | H(2) | H(14) | 0 |
| H(3) | H(53) | 13 | H(3) | H(21) | 17 | H(3) | H(13) | 273 |
| H(4) | H(52) | 0 | H(4) | H(20) | 0 | H(4) | H(12) | 0 |
| H(5) | H(51) | -34 | H(5) | H(19) | -75 | H(5) | H(11) | -1102 |
| H(6) | H(50) | 0 | H(6) | H(18) | 0 | H(6) | H(10) | 0 |
| H(7) | H(49) | 72 | H(7) | H(17) | 238 | H(7) | H(9) | 4964 |
| H(8) | H(48) | 0 | H(8) | H(16) | 0 | H(8) | - | 8192 |
| H(9) | H(47) | -138 | H(9) | H(15) | -660 | - | - | - |
| H(10) | H(46) | 0 | H(10) | H(14) | 0 | - | - | - |
| H(11) | H(45) | 245 | H(11) | H(13) | 2530 | - | - | - |
| H(12) | H(44) | 0 | H(12) | - | 4096 | - | - | - |
| H(13) | H(43) | -408 | - | - | - | - | - | - |
| H(14) | H(42) | 0 | - | - | - | - | - | - |
| H(15) | H(41) | 650 | - | - | - | - | - | - |
| H(16) | H(40) | 0 | - | - | - | - | - | - |
| H(17) | H(39) | -1003 | - | - | - | - | - | - |
| H(18) | H(38) | 0 | - | - | - | - | - | - |
| H(19) | H(37) | 1521 | - | - | - | - | - | - |
| H(20) | H(36) | 0 | - | - | - | - | - | - |
| H(21) | H(35) | -2315 | - | - | - | - | - | - |
| H(22) | H(34) | 0 | - | - | - | - | - | - |
| H(23) | H(33) | 3671 | - | - | - | - | - | - |
| H(24) | H(32) | 0 | - | - | - | - | - | - |
| H(25) | H(31) | -6642 | - | - | - | - | - | - |
| H(26) | H(30) | 0 | - | - | - | - | - | - |
| H(27) | H(29) | 20756 | - | - | - | - | - | - |
| H(28) | | 32768 | - | - | - | - | - | - |

[1] H(n) is the digital filter coefficient.

10.7 Quadrature modulator and NCO

The quadrature modulator allows the 12-bit I and Q data to be mixed with the carrier signal generated by the Numerically Controlled Oscillator (NCO).

The frequency of the NCO is programmed over 32-bit and allows the sign of the sine component to be inverted in order to operate positive or negative, lower or upper single sideband up-conversion.

10.7.1 NCO in 32-bit

When using the NCO, the frequency can be set by the four registers `FREQNCO_LSB`, `FREQNCO_LISB`, `FREQNCO_UISB` and `FREQNCO_MSB` over 32 bits.

The frequency for the NCO in 32-bit is calculated as follows:

$$f_{NCO} = \frac{M \times f_s}{2^{32}} \quad (1)$$

where M is the decimal representation of `FREQ_NCO[31:0]`.

The phase of the NCO can be set from 0° to 360° by both registers `PHINCO_LSB` and `PHINCO_MSB` over 16 bits.

The default setting is $f_{NCO} = 96$ MHz when $f_s = 640$ Msps and the default phase is 0°.

10.7.2 Low-power NCO

When using the low-power NCO, the frequency can be set by the 5 MSB of register `FREQNCO_MSB`.

The frequency for the low-power NCO is calculated as follows:

$$f_{NCO} = \frac{M \times f_s}{2^5} \quad (2)$$

where M is the decimal representation of `FREQ_NCO[31:27]`.

The phase of the low-power NCO can be set by the 5 MSB of the register `PHINCO_MSB`.

10.7.3 Minus 3dB

During normal use, a full-scale pattern will also be full scale at the output of the DAC. Nevertheless, when the I and Q data are simultaneously close to full scale, some clipping can occur and the `Minus_3dB` function can be used to reduce gain by 3 dB in the modulator. This is to keep a full-scale range at the output of the DAC without added interferers.

10.8 $x / (\sin x)$

Due to the roll-off effect of the DAC, a selectable FIR filter is inserted to compensate for the $(\sin x) / x$ effect. This filter introduces a DC loss of 3.4 dB. The coefficients are represented in [Table 34 "Inversion filter coefficients"](#).

Table 34. Inversion filter coefficients

| First interpolation filter ^[1] | | |
|---|-------|-------|
| Lower | Upper | Value |
| H(1) | H(9) | 2 |
| H(2) | H(8) | -4 |
| H(3) | H(7) | 10 |
| H(4) | H(6) | -35 |
| H(5) | - | 401 |

[1] H(n) is the digital filter coefficient.

10.9 DAC transfer function

The full-scale output current for each DAC is the sum of the two complementary current outputs:

$$I_{O(fs)} = I_{IOUTP} + I_{IOUTN} \quad (3)$$

The output current depends on the digital input data:

$$I_{IOUTP} = I_{O(fs)} \times \left(\frac{DATA}{4095} \right) \quad (4)$$

$$I_{IOUTN} = I_{O(fs)} \times \left(\frac{4095 - DATA}{4095} \right) \quad (5)$$

The setting applied to CODING (register 00h[2]; see [Table 9 “Register allocation map”](#)) defines whether the DAC1205D650 operates with a binary input or a two's complement input.

[Table 35 “DAC transfer function”](#) shows the output current as a function of the input data, when $I_{O(fs)} = 20$ mA.

Table 35. DAC transfer function

| Data (Decimal) | I11/Q11 to I0/Q0 | | IOUTP | IOUTN |
|----------------|------------------|------------------|-------|-------|
| | Binary | Two's complement | | |
| 0 | 0000 0000 0000 | 1000 0000 0000 | 0 mA | 20 mA |
| ... | ... | ... | ... | ... |
| 2048 | 1000 0000 0000 | 0000 0000 0000 | 10 mA | 10 mA |
| ... | ... | ... | ... | ... |
| 4095 | 1111 1111 1111 | 0111 1111 1111 | 20 mA | 0 mA |

10.10 Full-scale current

10.10.1 Regulation

The DAC1205D650 reference circuitry integrates an internal bandgap reference voltage which delivers a 1.25 V reference to the GAPOUT pin. It is recommended to decouple pin GAPOUT using a 100 nF capacitor.

The reference current is generated using an external resistor of 910 Ω (1 %) connected to pin VIRES. A control amplifier sets the appropriate full-scale current ($I_{O(fs)}$) for both DACs (see [Figure 11 “Internal reference configuration”](#)).

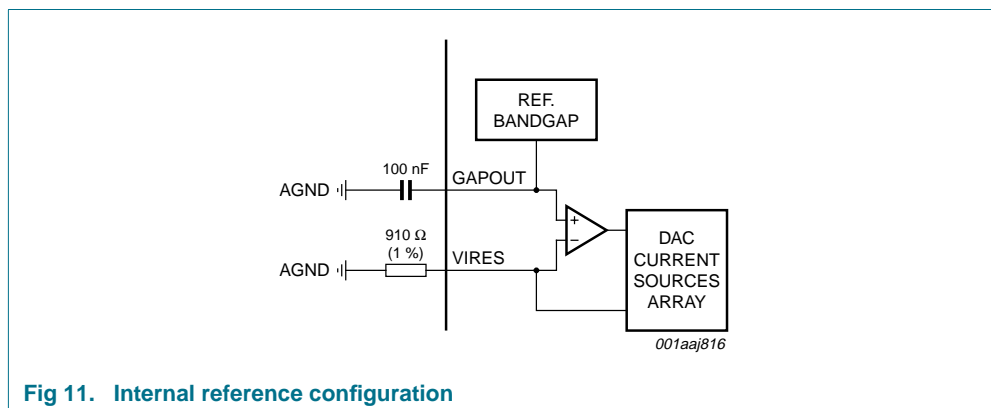


Fig 11. Internal reference configuration

This configuration is optimum for temperature drift compensation because the bandgap reference voltage can be matched to the voltage across the feedback resistor.

The DAC current can also be set by applying an external reference voltage to the non-inverting input pin GAPOUT and disabling the internal bandgap reference voltage with GAP_PD (register 00h[0]; see [Table 10 “COMMON register \(address 00h\) bit description”](#)).

10.10.2 Full-scale current adjustment

The default full-scale current ($I_{O(fs)}$) is 20 mA. It can be further adjusted for each DAC using SPI. The adjustment range is between 1.6 mA and 22 mA, $\pm 10\%$.

The settings applied to DAC_A_GAIN_COARSE[3:0] (register 0Ah; see [Table 20 “DAC_A_Cfg_2 register \(address 0Ah\) bit description”](#) and register 0Bh; see [Table 21 “DAC_A_Cfg_3 register \(address 0Bh\) bit description”](#)) and to DAC_B_GAIN_COARSE[3:0] (register 0Dh; see [Table 23 “DAC_B_Cfg_2 register \(address 0Dh\) bit description”](#) and register 0Eh; see [Table 24 “DAC_B_Cfg_3 register \(address 0Eh\) bit description”](#)) define the coarse variation of the full-scale current (see [Table 36 “ \$I_{O\(fs\)}\$ coarse adjustment”](#)).

Table 36. $I_{O(fs)}$ coarse adjustment

Default settings are shown highlighted.

| DAC_GAIN_COARSE[3:0] | | $I_{O(fs)}$ (mA) |
|----------------------|--------|------------------|
| Decimal | Binary | |
| 0 | 0000 | 1.6 |
| 1 | 0001 | 3.0 |
| 2 | 0010 | 4.4 |
| 3 | 0011 | 5.8 |
| 4 | 0100 | 7.2 |
| 5 | 0101 | 8.6 |
| 6 | 0110 | 10.0 |
| 7 | 0111 | 11.4 |

Table 36. $I_{O(fs)}$ coarse adjustment ...continued
Default settings are shown highlighted.

| DAC_GAIN_COARSE[3:0] | | $I_{O(fs)}$ (mA) |
|----------------------|-------------|------------------|
| Decimal | Binary | |
| 8 | 1000 | 12.8 |
| 9 | 1001 | 14.2 |
| 10 | 1010 | 15.6 |
| 11 | 1011 | 17.0 |
| 12 | 1100 | 18.5 |
| 13 | 1101 | 20.0 |
| 14 | 1110 | 21.0 |
| 15 | 1111 | 22.0 |

The settings applied to DAC_A_GAIN_FINE[5:0] (register 0Ah; see [Table 20](#) “DAC_A_Cfg_2 register (address 0Ah) bit description”) and to DAC_B_GAIN_FINE[5:0] (register 0Dh; see [Table 23](#) “DAC_B_Cfg_2 register (address 0Dh) bit description”) define the fine variation of the full-scale current (see [Table 37](#) “ $I_{O(fs)}$ fine adjustment”).

Table 37. $I_{O(fs)}$ fine adjustment
Default settings are shown highlighted.

| DAC_GAIN_FINE[5:0] | | Delta $I_{O(fs)}$ |
|--------------------|------------------|-------------------|
| Decimal | Two's complement | |
| -32 | 10 0000 | -10 % |
| ... | ... | ... |
| 0 | 00 0000 | 0 |
| ... | ... | ... |
| +31 | 01 1111 | +10 % |

The coding of the fine gain adjustment is two's complement.

10.11 Digital offset adjustment

When the DAC1205D650 analog output is DC connected to the next stage, the digital offset correction can be used to adjust the common mode level at the output of the DAC. It adds an offset at the end of the digital part, just before the DAC.

The settings applied to DAC_A_OFFSET[10:0] (register 09h; see [Table 19](#) “DAC_A_Cfg_1 register (address 09h) bit description”) and register 0Bh; see [Table 21](#) “DAC_A_Cfg_3 register (address 0Bh) bit description”) and to “DAC_B_OFFSET[10:0]” (register 0Ch; see [Table 22](#) “DAC_B_Cfg_1 register (address 0Ch) bit description”) and register 0Eh; see [Table 24](#) “DAC_B_Cfg_3 register (address 0Eh) bit description”) define the range of variation of the digital offset (see [Table 38](#) “Digital offset adjustment”).

Table 38. Digital offset adjustment

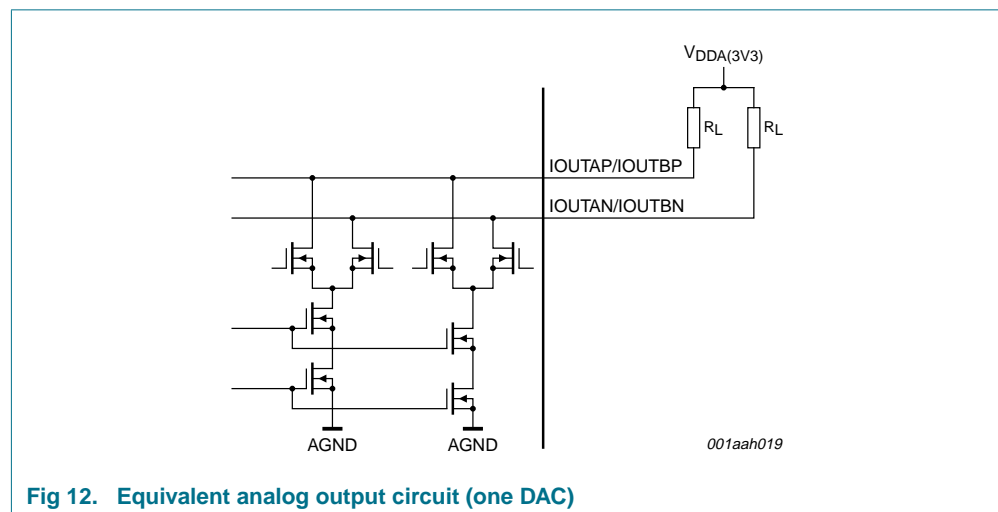
Default settings are shown highlighted.

| DAC_OFFSET[10:0] | | Offset applied |
|------------------|----------------------|----------------|
| Decimal | Two's complement | |
| -1024 | 100 0000 0000 | -1024 |
| -1023 | 100 0000 0001 | -1023 |
| ... | ... | ... |
| -1 | 111 1111 1111 | -1 |
| 0 | 000 0000 0000 | 0 |
| +1 | 000 0000 0001 | +1 |
| ... | ... | ... |
| +1022 | 011 1111 1110 | +1022 |
| +1023 | 011 1111 1111 | +1023 |

10.12 Analog output

The DAC1205D650 has two output channels each of which produces two complementary current outputs. These allow the even-order harmonics and noise to be reduced. The pins are IOUTAP/IOUTAN and IOUTBP/IOUTBN respectively and need to be connected using a load resistor R_L to the 3.3 V analog power supply ($V_{DDA(3V3)}$).

Refer to [Figure 12 "Equivalent analog output circuit \(one DAC\)"](#) for the equivalent analog output circuit of one DAC. This circuit consists of a parallel combination of NMOS current sources, and their associated switches, for each segment.

**Fig 12. Equivalent analog output circuit (one DAC)**

The cascode source configuration increases the output impedance of the source, thus improving the dynamic performance of the DAC by introducing less distortion.

The device can provide an output level of up to $2 V_{o(p-p)}$ depending on the application, the following stages and the targeted performances.

10.13 Auxiliary DACs

The DAC1205D650 integrates two auxiliary DACs that can be used to compensate for any offset between the DAC and the next stage in the transmission path.

Both auxiliary DACs have a resolution of 10-bit and are current sources (referenced to ground). The settings applied to AUX_A[9:0] and AUX_B[9:0] define the offset data:

$$I_{O(AUX)} = I_{AUXP} + I_{AUXN} \quad (6)$$

The output current depends on the auxiliary DAC data:

$$AUXP = I_{O(AUX)} \times \left(\frac{AUX[9:0]}{1023} \right) \quad (7)$$

$$AUXN = I_{O(AUX)} \times \left(\frac{1023 - AUX[9:0]}{1023} \right) \quad (8)$$

[Table 39 “Auxiliary DAC transfer function”](#) shows the output current as a function of the auxiliary DAC data.

Table 39. Auxiliary DAC transfer function

Default settings are shown highlighted.

| Data | AUX_A[9:0] and AUX_B[9:0] (binary) | I _{AUXP} | I _{AUXN} |
|------------|------------------------------------|-------------------|-------------------|
| 0 | 00 0000 0000 | 0 mA | 2.2 mA |
| ... | ... | ... | ... |
| 512 | 10 0000 0000 | 1.1 mA | 1.1 mA |
| ... | ... | ... | ... |
| 1023 | 11 1111 1111 | 2.2 mA | 0 mA |

10.14 Output configuration

10.14.1 Basic output configuration

The use of a differentially-coupled transformer output provides optimum distortion performance (see [Figure 13](#) “Differential output with transformer; $V_{O(dif)(p-p)} = 1\text{ V}$ ”). In addition, it helps to match the impedance and provides electrical isolation.

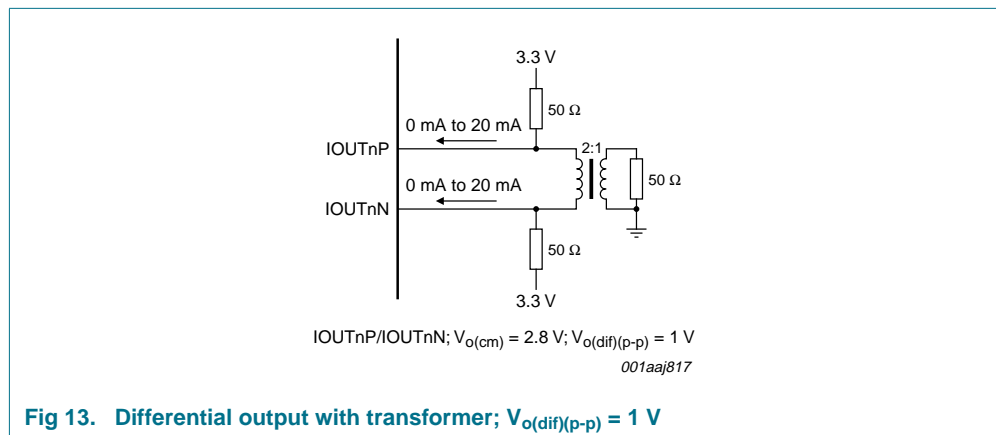


Fig 13. Differential output with transformer; $V_{O(dif)(p-p)} = 1\text{ V}$

The DAC1205D650 can operate up to $2 V_{O(p-p)}$ differential outputs. In this configuration, it is recommended to connect the center tap of the transformer to a $62\ \Omega$ resistor connected to the 3.3 V analog power supply, in order to adjust the DC common mode to approximately 2.7 V (see [Figure 14](#) “Differential output with transformer; $V_{O(dif)(p-p)} = 2\text{ V}$ ”).

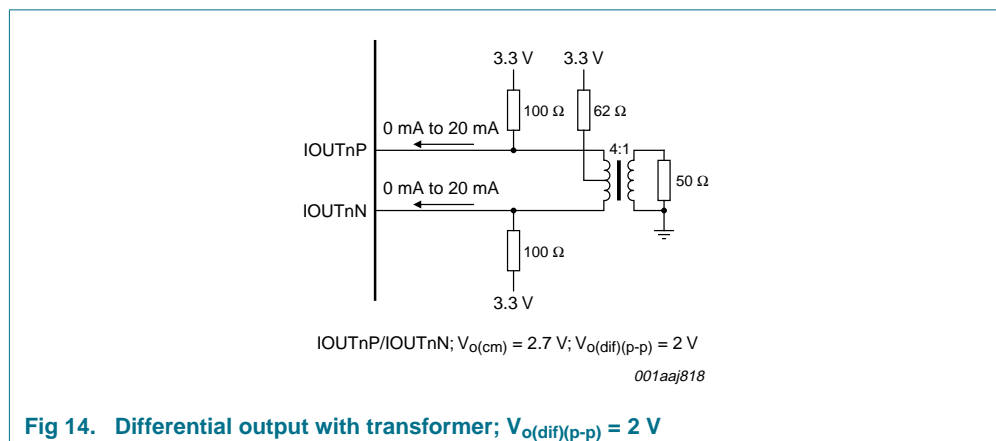


Fig 14. Differential output with transformer; $V_{O(dif)(p-p)} = 2\text{ V}$

10.14.2 DC interface to an AQM

When the system operation requires to keep the DC component of the spectrum, the DAC1205D650 can use a DC interface to connect to an Analog Quadrature Modulator (AQM). In this case, the offset compensation for LO cancellation can be made with the use of the digital offset control in the DAC.

[Figure 15](#) provides an example of a connection to an AQM with a 1.7 V common mode input level.

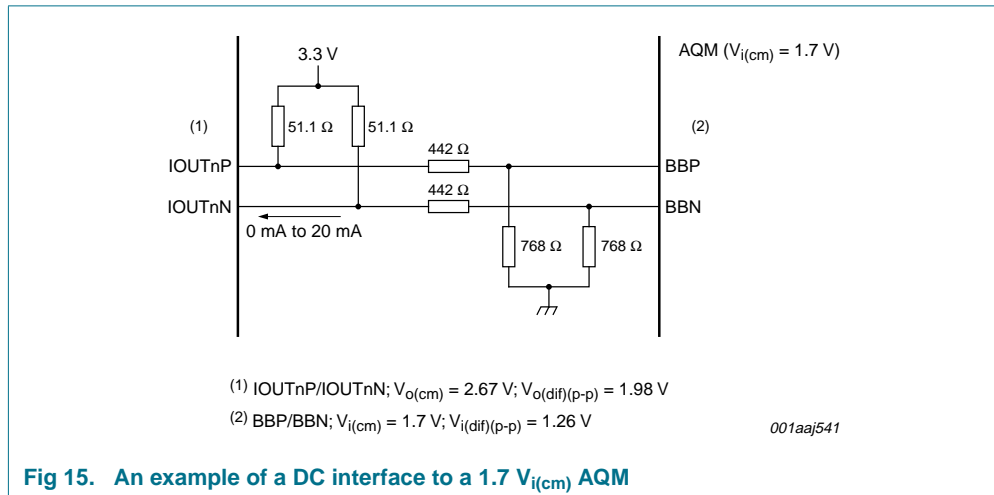


Fig 15. An example of a DC interface to a 1.7 $V_{i(cm)}$ AQM

Figure 16 provides an example of a connection to an AQM with a 3.3 V common mode input level.

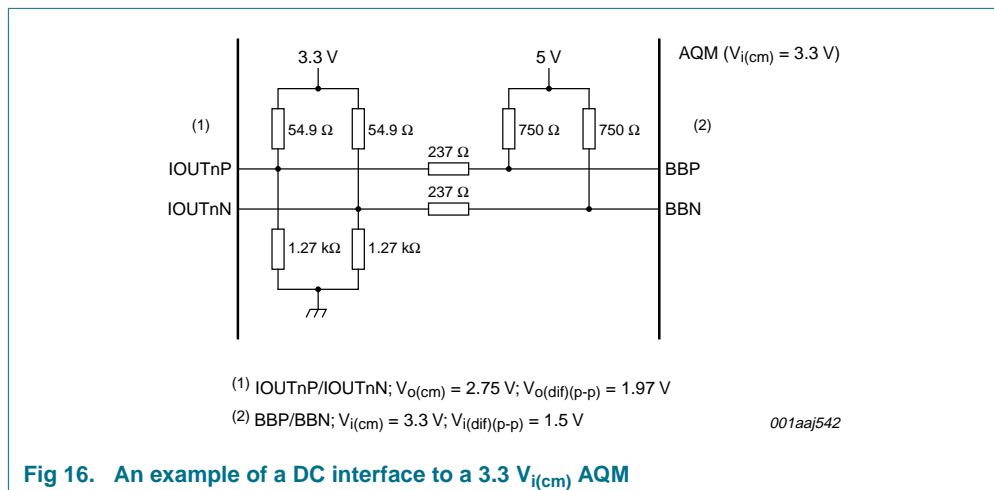


Fig 16. An example of a DC interface to a 3.3 $V_{i(cm)}$ AQM

The auxiliary DACs can be used to control the offset in a precise range or with precise steps.

Figure 17 provides an example of a DC interface with the auxiliary DACs to an AQM with a 1.7 V common mode input level.

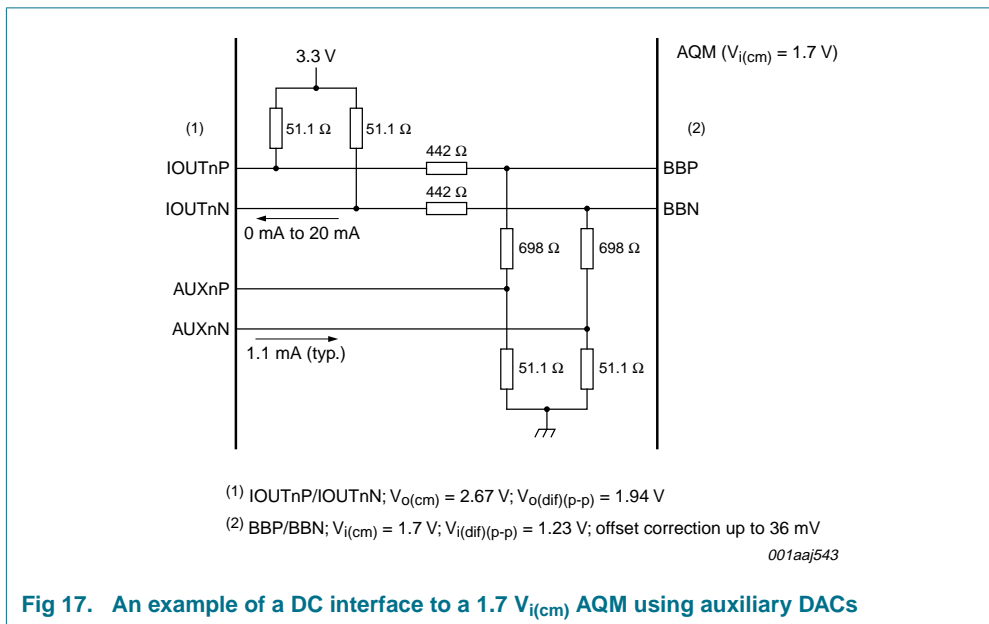


Fig 17. An example of a DC interface to a 1.7 $V_{i(cm)}$ AQM using auxiliary DACs

Figure 18 provides an example of a DC interface with the auxiliary DACs to an AQM with a 3.3 V common mode input level.

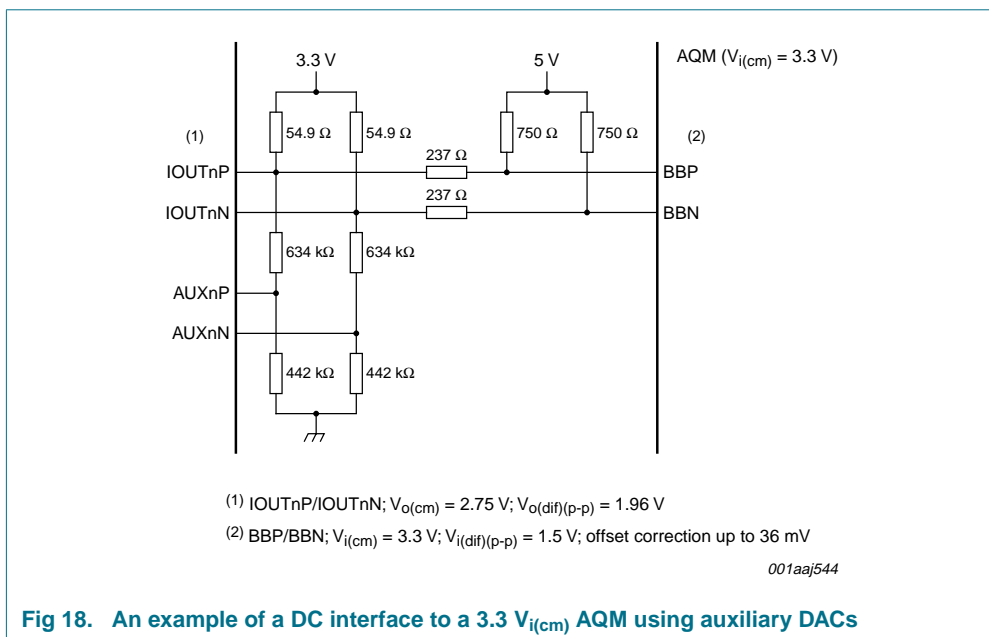


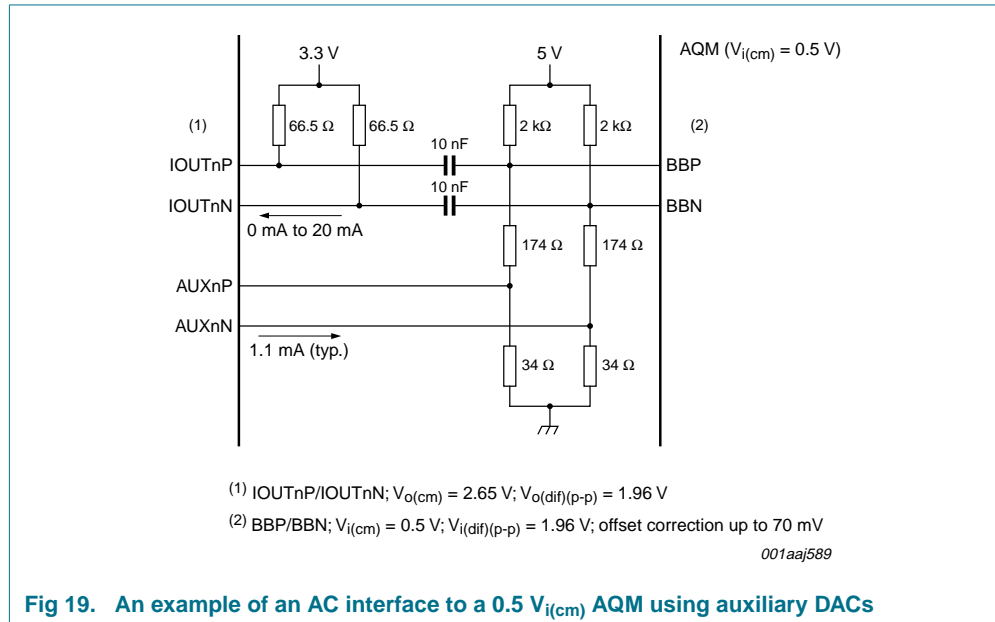
Fig 18. An example of a DC interface to a 3.3 $V_{i(cm)}$ AQM using auxiliary DACs

The constraints to adjust the interface are the output compliance range of the DAC and the auxiliary DACs, the input common mode level of the AQM, and the offset correction range.

10.14.3 AC interface to an AQM

When the Analog Quadrature Modulator (AQM) common mode voltage is close to ground, the DAC1205D650 must be AC-coupled and the auxiliary DACs are needed for offset correction.

Figure 18 provides an example of a connection to an AQM with a 0.5 V common mode input level using auxiliary DACs.



10.15 Power and grounding

In order to obtain optimum performance, it is recommended that the 1.8 V analog power supplies on pins 5, 11, 71, 77 and 99 should not be connected with those on pins 70, 79, 81, 83, 93, 95 and 97 on the top layer.

To optimize the decoupling, the power supplies should be decoupled with the following pins:

- $V_{DD(1V8)}$: pin 26 with 27; pin 32 with 33; pin 36 with 37; pin 40 with 39; pin 44 with 43 and pin 50 with 49.
- $V_{DD(IO)(3V3)}$: pin 16 with 17 and pin 60 with 59.
- $V_{DDA(1V8)}$: pin 5 with 4; pin 6 with 7; pin 11 with 10; pin 71 with 72; pin 77 with 78; pins 79, 81, 83 with 80, 82, 84; pins 93, 95, 97 with 92, 94, 96 and pin 99 with 98.
- $V_{DDA(3V3)}$: pin 1 with 100 and pin 75 with 76.

10.16 Alternative parts

The following alternative parts are available.

Table 40. Alternative parts

| Type number | Description | Sampling frequency |
|-------------|-----------------|--------------------|
| DAC1005D650 | dual 10-bit DAC | up to 650 Msps |
| DAC1405D650 | dual 14-bit DAC | up to 650 Msps |

11. Package outline

HTQFP100: plastic thermal enhanced thin quad flat package; 100 leads; body 14 x 14 x 1 mm; exposed die pad

SOT638-1

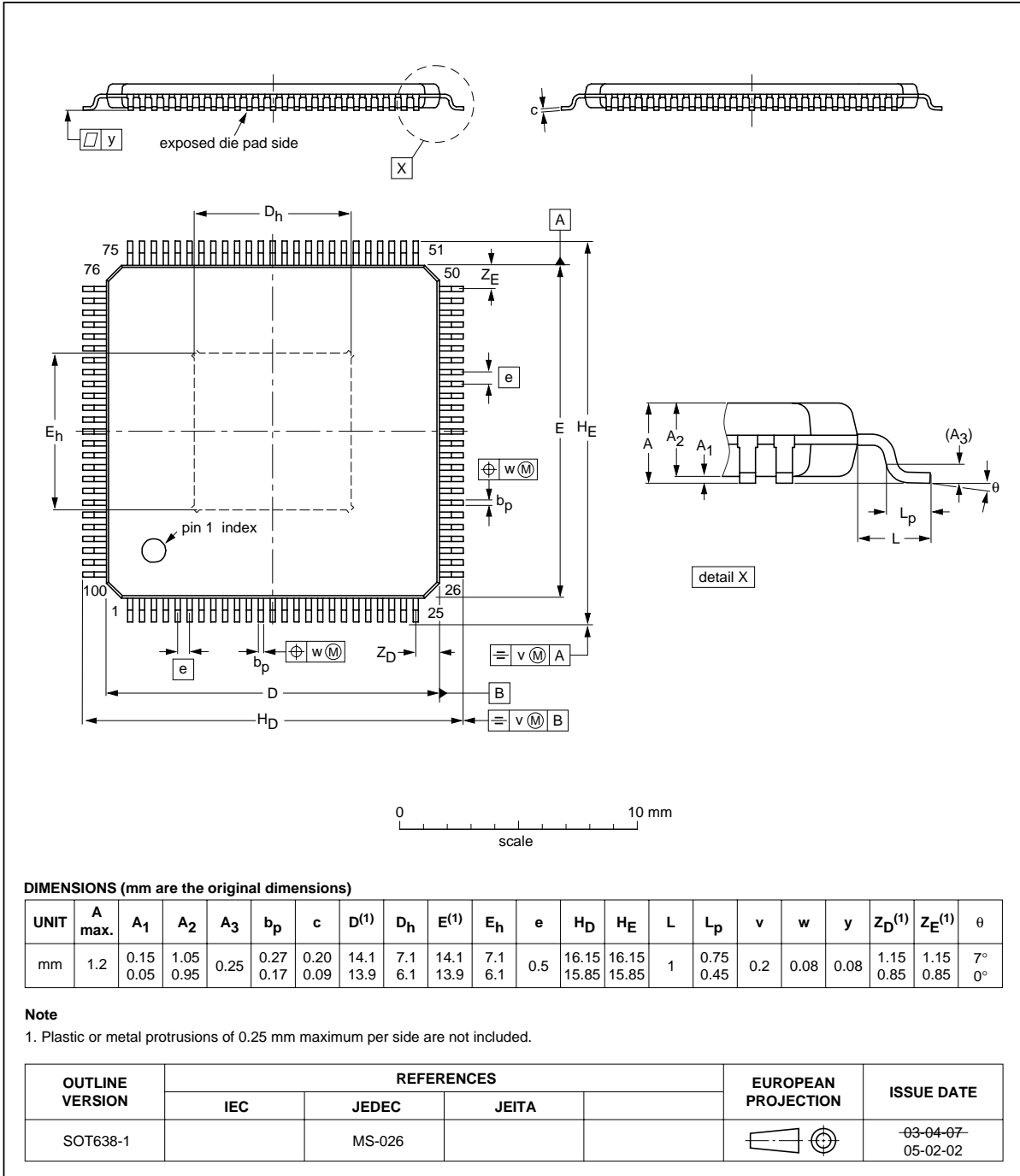


Fig 20. Package outline SOT638-1 (HTQFP100)

12. Abbreviations

Table 41. Abbreviations

| Acronym | Description |
|----------|---|
| CDMA | Code Division Multiple Access |
| CML | Current Mode Logic |
| CMOS | Complementary Metal-Oxide Semiconductor |
| DAC | Digital-to-Analog Converter |
| FIR | Finite Impulse Response |
| GSM | Global System for Mobile communications |
| IF | Intermediate Frequency |
| IMD3 | Third-order Inter Modulation Distortion |
| LISB | Lower Intermediate Significant Byte |
| LMDS | Local Multipoint Distribution Service |
| LSB | Least Significant Bit |
| LTE | Long Term Evolution |
| LVDS | Low-Voltage Differential Signaling |
| MMDS | Multichannel Multipoint Distribution Service |
| MSB | Most Significant Bit |
| NCO | Numerically Controlled Oscillator |
| NMOS | Negative Metal-Oxide Semiconductor |
| PLL | Phase-Locked Loop |
| SFDR | Spurious-Free Dynamic Range |
| SPI | Serial Peripheral Interface |
| TD-SCDMA | Time Division-Synchronous Code Division Multiple Access |
| UISB | Upper Intermediate Significant Byte |
| WCDMA | Wideband Code Division Multiple Access |
| WiMAX | Worldwide Interoperability for Microwave Access |

13. Glossary

Spurious-Free Dynamic Range (SFDR): — 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.

Intermodulation Distortion (IMD): — From a dual-tone digital input sine wave (these two frequencies being close together), the intermodulation distortion products IMD2 and IMD3 (respectively, 2nd and 3rd order components) are defined below.

IMD2 — The ratio of the RMS value of either tone to the RMS value of the worst 2nd order intermodulation product.

IMD3 — The ratio of the RMS value of either tone to the RMS value of the worst 3rd order intermodulation product.

Restricted Bandwidth Spurious-Free Dynamic Range — The ratio of the RMS value of the reconstructed output sine wave to the RMS value of the noise, including the harmonics, in a given bandwidth centered around f_{offset} .

14. Revision history

Table 42. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|---------------|--------------|--------------------|---------------|------------|
| DAC1205D650_1 | 20090728 | Product data sheet | - | - |

15. Legal information

15.1 Data sheet status

| Document status ^{[1][2]} | Product status ^[3] | Definition |
|-----------------------------------|-------------------------------|---|
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| 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".

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Date of release: 28 July 2009

Document identifier: DAC1205D650_1