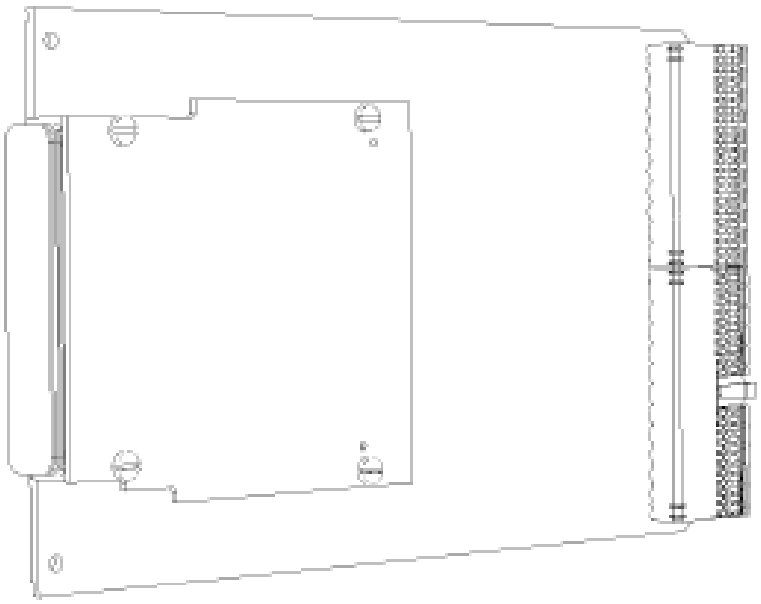
FMC230
User Manual



4DSP, USA

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Revision History

Date	Description	Revision
2012-12-19	Release	1.0
2013-02-05	Corrected pin assignments in Appendix A	1.1
2013-03-22	Updated analog output range in Table 2 and added a FMC700 requirement information for KC705	1.2
2013-08-15	Updated analog output bandwidth in Table 2. Added a signal description in Appendix A.	1.3
2014-01-30	Removed incorrect reference to analog input gain and over range in Chapter 2	1.4
2014-04-07	Revised some descriptions and fixed typos. Changed external reference input characteristics.	1.5
2014-05-30	Corrected analog output power range in Table 2	1.6
2014-07-03	Added DACx_SYNC signals in Appendix A	1.7
2014-10-02	Updated external reference input characteristics	1.8
2015-02-27	Clarified external clock frequency range	1.9
2015-06-22	Updated analog output and external sample clock input characteristics	1.10
2015-09-30	Updated Figure 4: Wideband balun output option, to reflect board schematic, added section 4.4.1.	1.11

Table of Contents

1 Acronyms and related documents

1.1 Acronyms

ADC	Analog-to-Digital Converter
DDR	Double Data Rate
DSP	Digital Signal Processing
EPROM	Erasable Programmable Read-Only Memory
FBGA	Fineline Ball Grid Array
FMC	FPGA Mezzanine Card
FPGA	Field Programmable Gate Array
JTAG	Join Test Action Group
LED	Light Emitting Diode
LVTTL	Low Voltage Transistor Logic level
LSB	Least Significant Bit(s)
LVDS	Low Voltage Differential Signaling
MGT	Multi-Gigabit Transceiver
MSB	Most Significant Bit(s)
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect
PCIe	PCI Express
PLL	Phase-Locked Loop
PMC	PCI Mezzanine Card
PSSR	Power Supply Rejection Ratio
QDR	Quadruple Data rate
SDRAM	Synchronous Dynamic Random Access memory
SRAM	Synchronous Random Access memory
TTL	Transistor Logic level
XMC	PCIe Mezzanine card

Table 1: Glossary

1.2 Related Documents

- FPGA Mezzanine Card (FMC) standard ANSI/VITA 57.1-2010
- Datasheet AD9129, Rev C, Analog Devices
- Datasheet AD9517 Rev A, Analog Devices
- Datasheet AD7291 Rev B, Analog Devices
- FMC700 User Manual, 4DSP

2 General description

The FMC230 is a two channel DAC FMC daughter card. The card provides two 14-bit up to 5.7 GSPS DAC channels which can be clocked by an internal clock source (optionally locked to an external reference) or an externally supplied sample clock. There is one trigger input for customized sampling control. The FMC daughter card is mechanically and electrically compliant to FMC standard (ANSI/VITA 57.1). The FMC has a high-pin count connector, front panel I/O, and can be used in a conduction-cooled environment.

The design is based on Analog Devices AD9129 single-channel 14-bit 5.7 GSPS DAC with DDR LVDS inputs. The analog output signals are AC-coupled and connect to MMCX coax connectors on the front panel.

The FMC allows flexible control of sampling frequency through serial communication busses. Furthermore, the card is equipped with power supply and temperature monitoring, and it offers several power-down modes to switch off unused functions or protect the card from overheating.

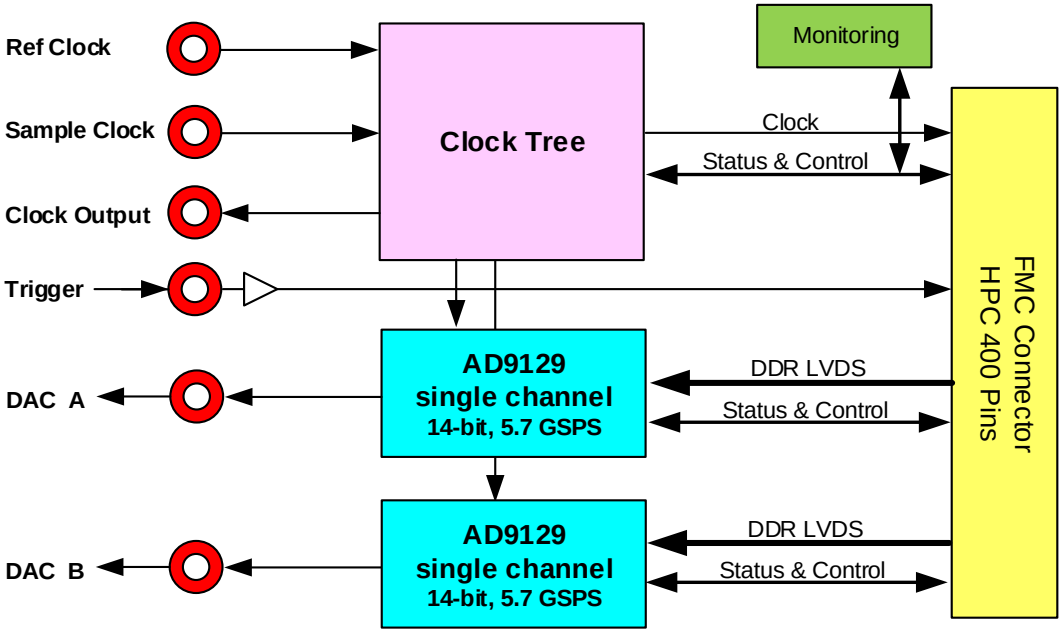


Figure 1: FMC230 block diagram

3 Installation

3.1 Requirements and handling instructions

- Prevent electrostatic discharges by observing ESD precautions when handling the card.
- Do not flex the card.
- The FMC daughter card must be installed on a carrier card compliant to the FMC standard.
- The FMC carrier card must support the high-pin count connector (400-pins) to support all channels. A low-pin count connector is supported but may result in limited features.
- The FMC carrier card may support a VADJ/VIO_B voltage of +1.2V to +3.3V.
- The FMC700 is required in order to use the FMC230 on KC705.

4 Design

4.1 Physical specifications

4.1.1 Board Dimensions

The FMC card complies with the FMC standard known as ANSI/VITA 57.1. The card is a single-width, conduction-cooled mezzanine module (with region 1 and front panel I/O). There may be a mechanical conflict with the front rib on a carrier card. The stacking height is 10mm, and the PCB thickness is 1.6mm.

4.1.2 Front panel

There are six MMCX connectors available from the front panel. From top to bottom:

- Analog outputs B (D1) and A (D0)
- Trigger in (TR)
- Clock Input (CI)
- Reference Input (RI)
- Clock Output (CO)

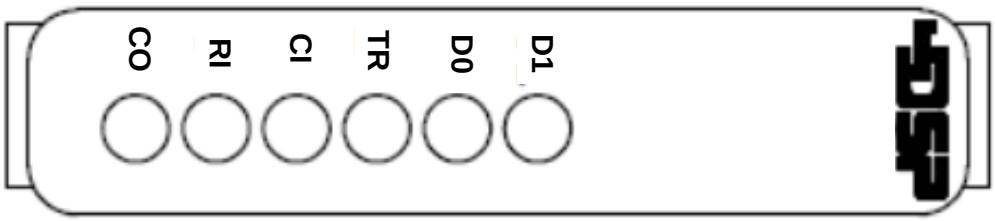


Figure 2: Front panel layout

4.2 Electrical specifications

The DAC devices use DDR LVDS signals mapped to the regular FMC pins. Each channel has two 14-bit wide DDR LVDS busses.

Control signals operate in LVCMOS mode. A VADJ range of 1.2V to 3.3V is supported. The voltage on VIO_B pins will follow the voltage on VADJ.

The CLKx pins are required to be LVDS by the FMC standard. CLK2 and CLK3 are not used for best compatibility with Xilinx development platforms. CLK0 is connected to a spare clock output of the clock tree. CLK1 is connected to the external trigger.

4.2.1 EEPROM

The FMC card has a small serial EEPROM (M24C02) which is accessible from the carrier card through the I^2C bus. The EEPROM is powered by 3P3VAUX. The standby current is only 0.01µA when SCL and SDA are kept at 3P3VAUX level. These signals may also be left floating since pull-up resistors are present on the FMC. The EEPROM is write-protected by default.

4.2.1 FMC Connector

FMC Top Connector

The top connector is the main connector to the FMC carrier board. The pin-out is defined in the appendix. The connector is a HPC connector.

FMC Bottom Connector

The high-pin count connector enables FMC card stacking. The following connections are available between the top and bottom FMC connector:

- Unused gigabit data signals (DP[4..9]_M2C_P/N, DP[0..9]_C2M_P/N)
- All gigabit reference clocks (GBTCLK[0..1]_M2C_P/N)
- RES0
- 3P3VAUX, 3P3V, 12P0V, VADJ
- JTAG (see section 4.2.1)

The bottom connector is not mounted by default.

4.2.1 JTAG

In a stacked environment, the TDI pin will be decoupled from the TDO pin by the PRST_M2C_L signal coming from the bottom connector. TRST#, TCK, TMS, TDI, and TDO are directly connected between top to bottom connector.

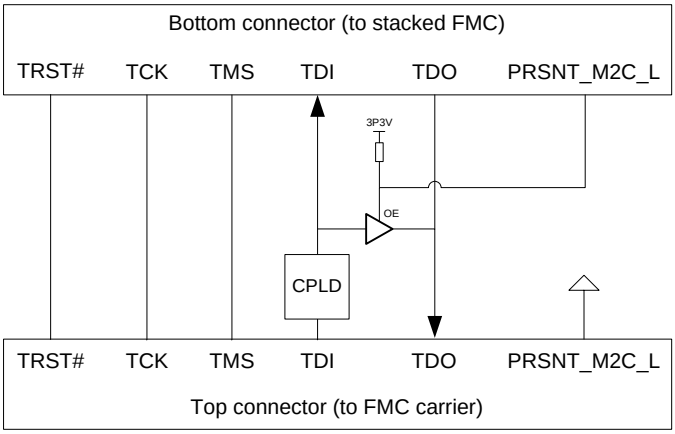


Figure 3: JTAG Connection

4.3 Main characteristics

Analog outputs	
Number of channels	2
Channel resolution	14-bit
Output voltage range	1.12 Vpp (5 dBm)
Output impedance	50Ω (optimized output impedance for mixed-mode operation)

Analogue output bandwidth	1.4GHz, please refer to AD9129 datasheet for details
External sampling clock input	
Input Level	-10dBm < Clock In Level < 10dBm 0dBm typical (LVTTL level supported[1])
Input impedance	50Ω
Input range	4.5 MHz to 2850 MHz [2]
External reference clock input	
Serial numbers FMC230-0000 to FMC230-0186	
Input Level	LVTTL: 3.6 > V_{IH} > 2.0V, -0.3 < V_{IL} < 0.8V
Input impedance	50Ω (DC-coupled)
Input range	0MHz to 250MHz
Serial numbers FMC230-0187 and above	
Input Level	LVTTL: 3.6 > V_{IH} > 2.0V, -0.3 < V_{IL} < 0.8V Input is DC-coupled and self-biased to 1.5V, refer to 4.7
Input impedance	5KΩ
Input range	0MHz to 250MHz
External clock output	
Output Level	800mVp-p into 50Ω typical (LVCMOS output available as build option, contact 4DSP)
External Trigger input	
Format	LVTLL/LVCMOS33 Logic '0' → max 0.8V / Logic '1' → min 2.0V
Frequency range	Up to 300 MHz
Internal sampling clock	
Format	LVPECL
Frequency Range	DAC: up to 5300MHz (Software selectable, contact 4DSP for frequencies higher frequencies up to 5700MHz)

Table 2 : FMC daughter card main characteristics

[1] 3.3V LVTTL into 50Ohm would result in 14dBm, a 1A Schottky diode in the clock input circuit protects the clock input from overvoltage when driving the input with a LVTTL signal.

[2] AD9517 device does support up to 2850MHz with a clock input level of 0dB and higher.

4.4 Analog output channels

The DAC output circuit is constructed such that different build options are available. The default configuration is a wideband balun ETC1-1-13 (MACOM; 4.5 to 3000MHz) as shown in Figure 4. This configuration is the recommended output circuit for mixed-mode operation of the DAC, for details refer to the AD9129 datasheet.. Please contact 4DSP for custom configurations.

4.4.1 Analog output phase

While not intuitively obvious from the representative schematic below, the analog output voltage tracks the data written to the DAC. The analog output signal at its maximum when the DAC is set to full scale.

As shown in the schematic, the analog output connector X8 is directly connected to the DACs IOUTN (labeled DAC1_IN) signal thru the balun T4, this results in the output voltage tracking the voltage on the IOUTN pin.

From the perspective of the output connector and IOUTN, the analog output is formed by a voltage divider consisting of the high side pulled up to +1.8V by R89 and L13, and the low side pulled down to -1.5V by the DACs programmable current source.

When 0x0000 is written to the DAC, IOUTN will be sourcing its maximum current thru the pullups resulting in a negative output voltage.

When the full scale value is written to the DAC, the current thru IOUTN and the pullups will be at its minimum resulting in the maximum positive voltage on the output.

The complementary output signal IOUTP performs in a similar manner except that it is 180 degrees out of phase with the value written to the DAC, The IOUTP and IOUTN signals are combined by the transformer action of the balun T4.

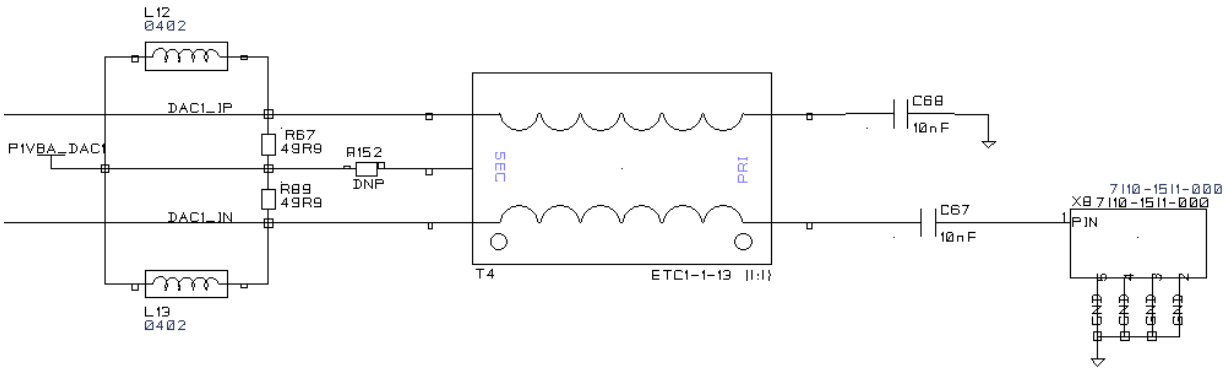


Figure 4: Wideband balun output option

4.5 External trigger input

An external trigger is available on the front panel (MMCX connector). The trigger signal connects to a buffer (NB6N11S) before being sent to the carrier card. The buffer translates the external LVTTL signal to LVDS and connects to the FMC connector. The trigger input is terminated to ground with 4.7kΩ.

4.6 External clock input

There is one MMCX clock input on the front panel that can serve as sampling clock input. Refer also to section 4.9 for more information about the clock tree.

Note: When internal clock is enabled and there is no need for an external reference, it is highly recommended to leave the clock input unconnected to prevent interference with the internal clock.

4.7 External reference input

There is one MMCX reference input on the front panel that can serve as reference clock input. Refer also to section 4.9 for more information about the clock tree.

Note: When internal clock is enabled and there is no need for an external reference, it is highly recommended to terminate the reference input with 50Ω to ground, to prevent interference with the internal clock.

The external reference input connects to the single ended, high-impedance, REF2 input of the AD9517 clock generator. The input is DC-coupled to support reference frequencies below 20MHz. The AD9517 has got an internal self-bias voltage of 1.5V. The single ended input characteristics of the clock generator specify V_{IL} < 0.8V and V_{IH} > 2.0V.

If the external reference source is DC-coupled, make sure that the V_{IL} < 0.8V and V_{IH} > 2.0V levels are met. If the external reference source is AC-coupled, the clock generator uses its self-bias to pull its reference input to the offset level of 1.5V. The required AC voltage swing ranges from $1.4V_{pk-pk}$ to $2.2V_{pk-pk}$.

4.8 External clock output

There is one MMCX clock input on the front panel that can serve as sampling/reference clock output. Refer also to section 4.9 for more information about the clock tree.

4.9 Clock tree

The FMC offers a clock architecture that combines flexibility and high performance. Components have been chosen to minimize jitter and phase noise and reduce degradation of the data conversion performance. The user may choose to use an external sampling clock or an internal sampling clock.

The clock tree has a PLL and clock distribution section. The PLL ensures locking of the internal VCO clock to an external supplied reference. There is an onboard reference which is used if no external reference is present. The onboard reference is a QuartzCom TX3-801 30.72MHz.

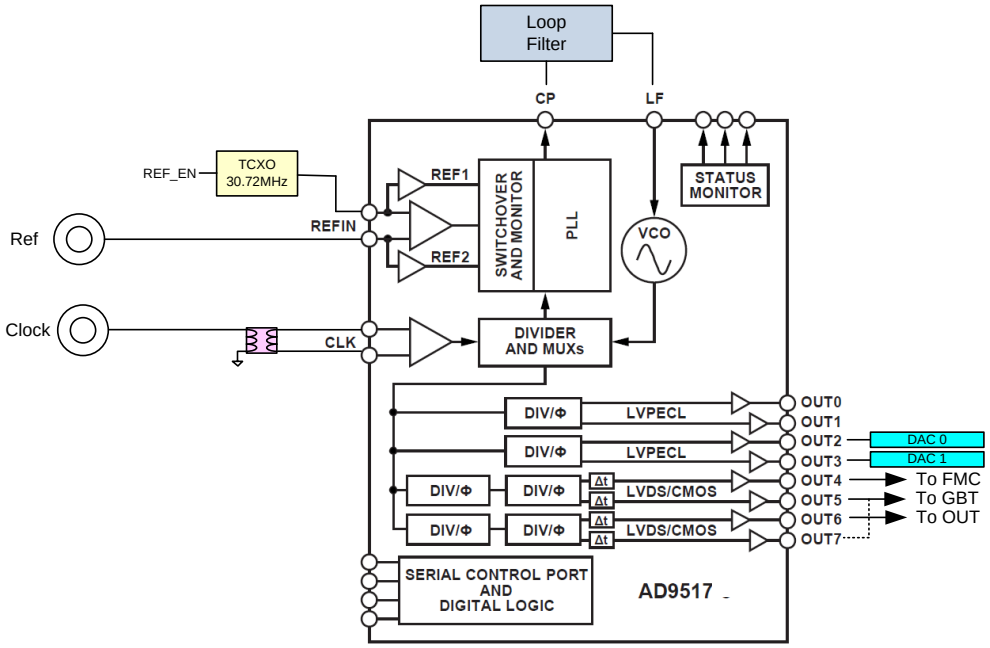


Figure 5: Clock tree

The AD9517 has four LVPECL outputs. OUT2 and OUT3 are used for clocking the DAC devices. The other four clock outputs can be programmed either as LVDS or LVCMOS33. These outputs have the ability to enable a programmable delay. OUT4 is connected to the FMC connector for test and monitoring purposes. OUT5 connects to the gigabit transceiver reference clock on the FMC connector (as a build option it can be connected to OUT7). OUT6 connects to the clock output on a MMCX connector.

4.9.1 PLL design

The PLL functionality of the AD9517 is used to operate from an internal sampling clock to enable flexibility in frequency selection while maintaining high performance.

The default loop filter is designed for a phase detector frequency of 7.68MHz ($f_{ref}/4$), loop bandwidth of 10KHz, phase margin of 45 deg, and a charge pump of 4.8mA.

Lower phase detector frequencies might be required to achieve the required output clock frequency (phase detector frequency equals the VCO tuning step size). Whether the loop filter design still works for other configurations should be investigated case by case.

Card Type	Device	VCO Range	VCO	DAC Clock
FMC230	AD9517-1	2300MHz - 2650MHz	2457.60MHz	2457.60MHz

Table 3: FMC default clock configurations

Note: Higher DAC clock frequencies (2850MHz for sampling up to 5700Msps) can be achieved using external clock.

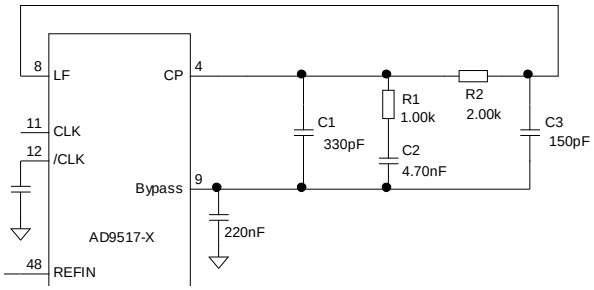


Figure 6: Loop filter design

4.10 Power supply

Power is supplied to the FMC card through the FMC connector. The pin current rating is 2.7A, but the overall maximum is limited according to Table 4.

Voltage	# Pins	Max Amps	Max Watt
+3.3V	4	3 A	10 W
+12V	2	1 A	12 W
VADJ	4	4 A	10 W
VIO_B (VADJ)	2	1.15 A	2.3 W

Table 4: FMC standard power specification

The power provided by the carrier card can be very noisy. Special care is taken with the power supply generation on the FMC card to minimize the effect of power supply noise on clock generation and data conversion.

Clean +1.8V is derived from +3.3V with linear regulators. Clean +3.3V is derived from +12V in two steps for maximum efficiency. The first step uses a highly efficient switched regulator to generate a +3.8V power rail. From this power rail each analog supply is derived with separate low dropout, low noise, and linear regulators.

The regulators have sufficient copper area to dissipate the heat in combination with proper airflow (see section 6.3 Cooling).

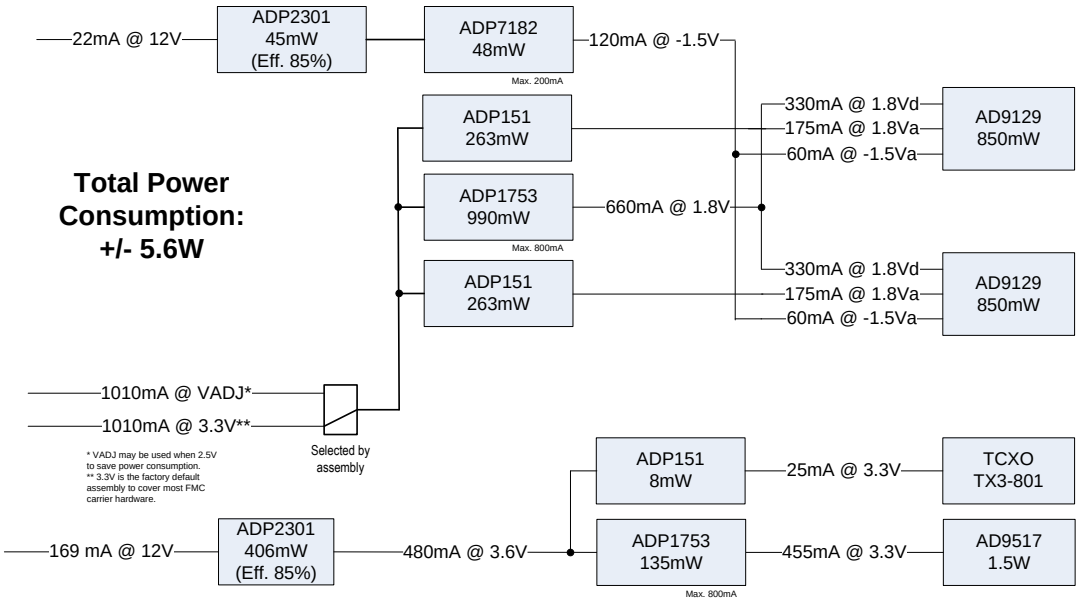


Figure 7: Power supply tree

Power plane	Typical	Maximum
VADJ	0.2A + I_{VIO_B}	-
3P3V	1.0A	1.1A
12P0V	0.2A	0.3A
3P3VAUX (Operating) 3P3VAUX (Standby)	0.1 mA 0.01 µA	3 mA 1 µA

Table 5: Typical / Maximum current drawn from FMC carrier card

5 Controlling the FMC230

5.1 Architecture

The data interface of one DAC channel occupies 31 differential pairs on the FMC connector. Since one DAC channel is available on the LPC connections, there are only six signals left on the LPC connections to control the board. Therefore, the FMC will be controlled from a single SPI interface connecting to an onboard CPLD (Xilinx Coolrunner-II XC2C64A-QFG). Four connections are available between the FMC connector and the CPLD. The CPLD acts as a SPI distribution device and level translator and comes factory programmed. The two remaining signals on the FMC connector are reserved.

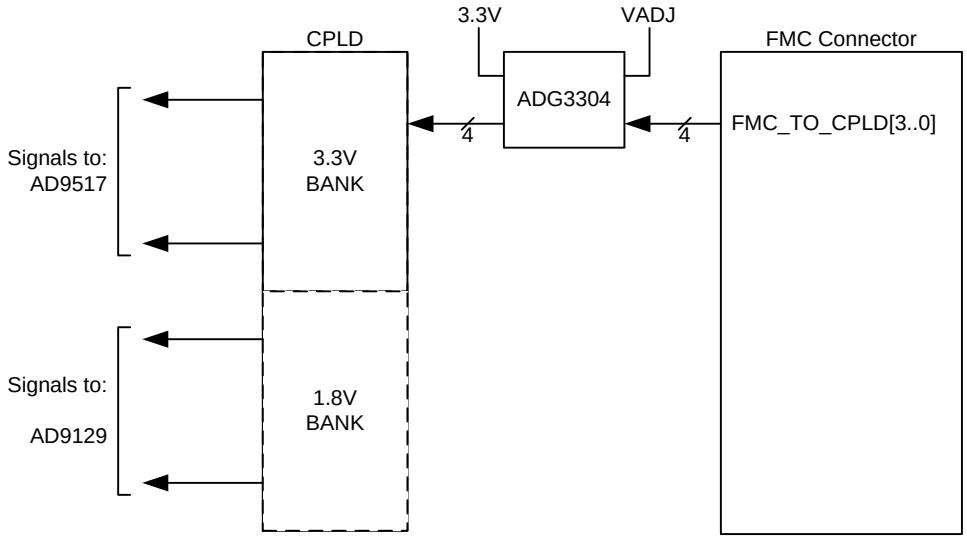


Figure 8: FMC control interface

The FMC is controlled from the carrier hardware through a single SPI communication bus. The SPI communication bus is connected to a CPLD which has the following tasks:

- Distribute SPI access from the carrier hardware along the local devices:
  - 2x AD9129 (D/A converters)
  - 1x AD9517 (Clock Tree)
- Enable/disable internal reference based on a SPI command from the carrier hardware (REF_EN)
- Generate SPI reset for AD9517 (CLK_N_RESET) and both AD9129 (DAC_RST)
- Collect local status signals and store them in a register which can be accessed from the carrier hardware
- Drive a LED according to the level of the status signals

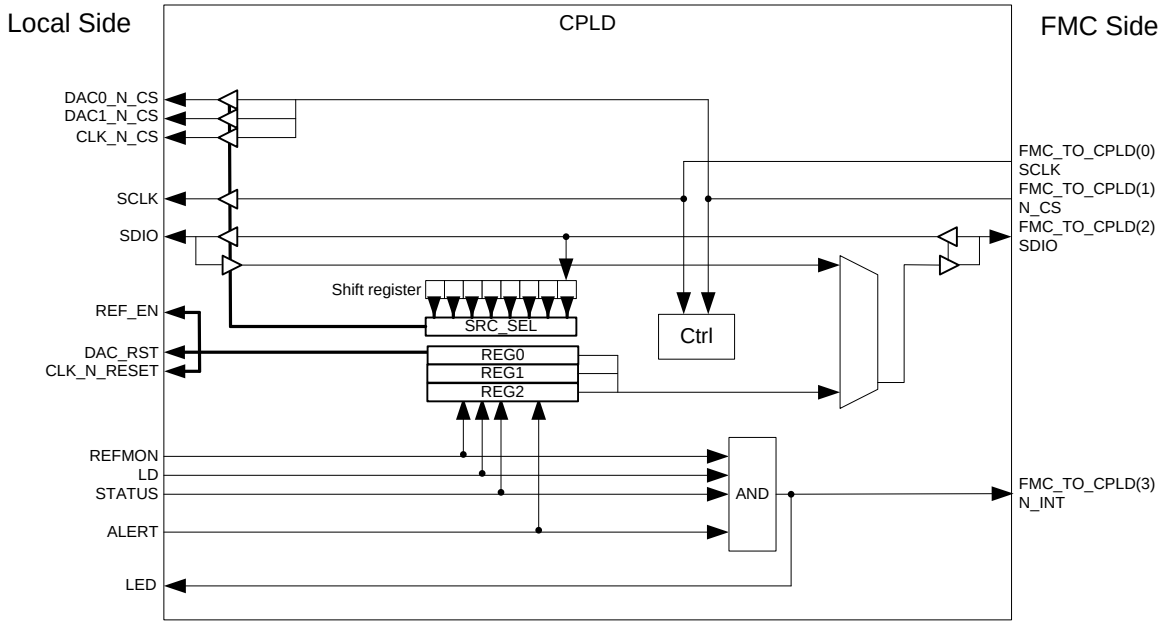


Figure 9: CPLD architecture

Notes:

- SDO on the AD9517 and AD9129 devices is not connected. SDIO is used bidirectional (3-wire SPI).

5.2 SPI Programming

The SPI programmable devices on the FMC can be accessed as described in their datasheet, but each SPI communication cycle needs to be preceded with a pre-selection byte. The pre-selection byte is used by the CPLD to forward the SPI command to the right destination. The pre-selection bytes are defined as follows:

- CPLD 0x00
- AD9129 #1 0x82
- AD9129 #2 0x83
- AD9517 0x84

The CLPD has three internal registers which are described in the Appendix. The registers of the other devices are transparently mapped.

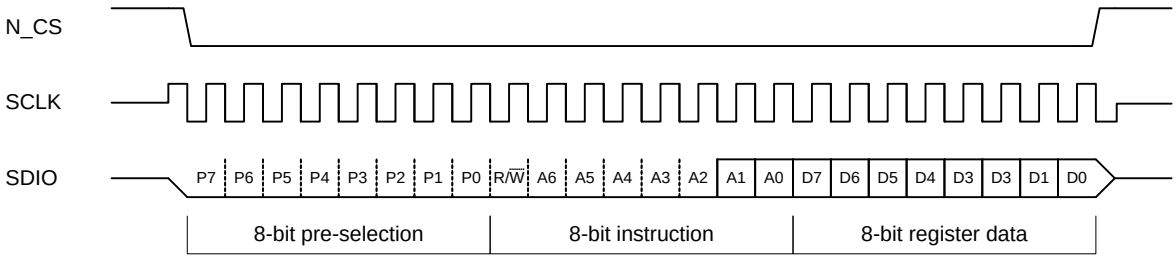


Figure 10: Write instruction to CPLD registers A1:A0

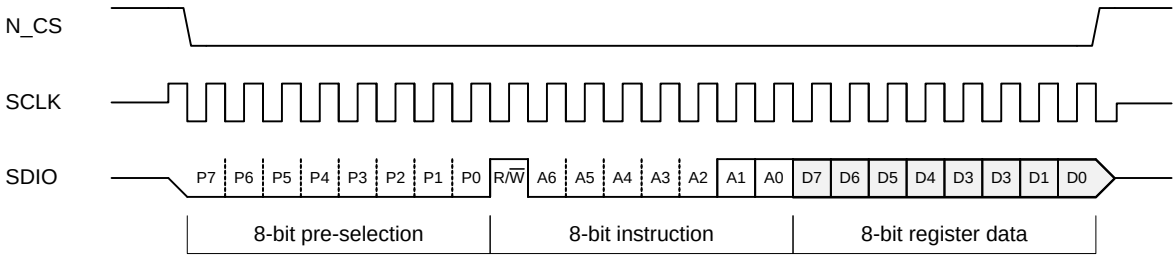


Figure 11: Read instruction to CPLD registers A1:A0

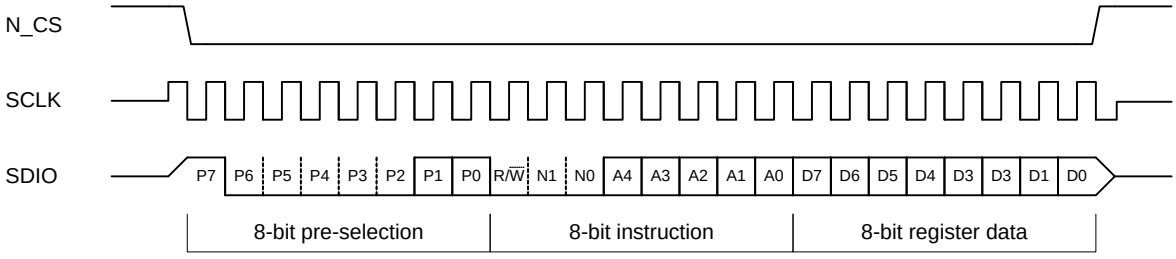


Figure 12: Write instruction to AD9129 registers A4:A0

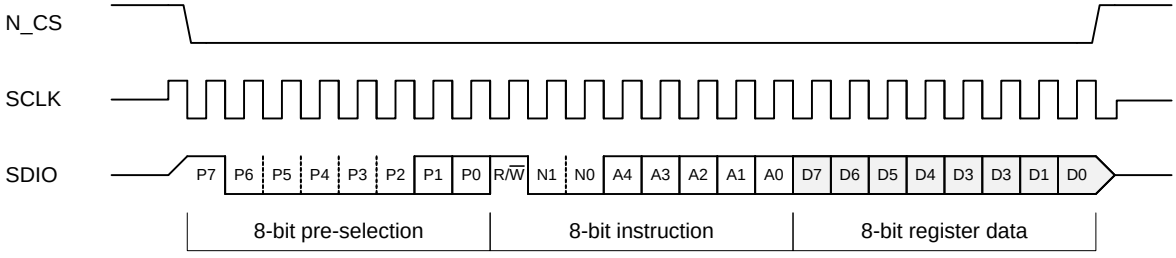


Figure 13: Read instruction to AD9129 registers A4:A0

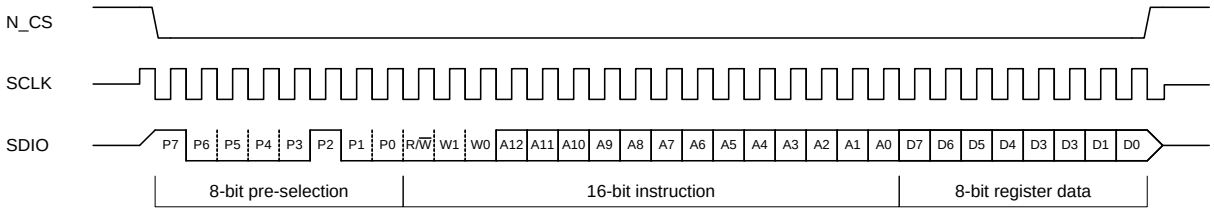


Figure 14: Write instruction to AD9517 registers A12:A0

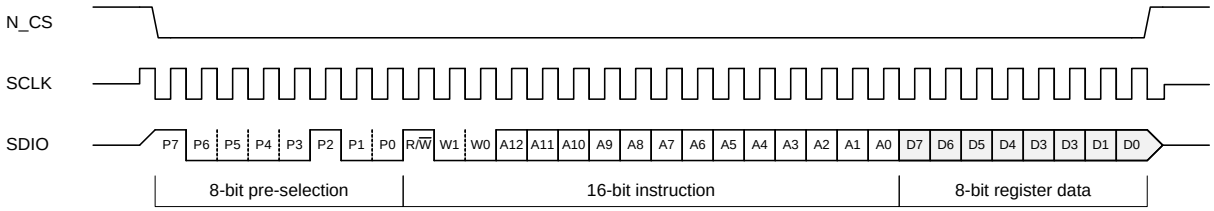


Figure 15: Read instruction to AD9517 registers A12:A0

6 Environment

6.1 Temperature

Operating temperature

- -40˚C to +85˚C (Industrial)

Storage temperature:

- -40˚C to +120˚C

6.2 Monitoring

The FMC holds an AD7291 device for monitoring several power supply voltages on the board as well as the temperature. The device can be programmed and read out through the I^2C bus. Continuously operating the I^2C bus might interfere with the conversion process and result in signal distortion. It is recommended to program the minimum and maximum limits in the monitoring devices and only read from the devices when the interrupt line is asserted. It is recommended that the carrier card and/or host software uses the power-down features in the case the temperature is too high.

Parameter:	**Device 1** **address 010 1111 (GA=00)** **address 010 1100 (GA=01)** **address 010 0011 (GA=10)** **address 010 0000 (GA=11)**	**Formula**
On-chip temperature		
External VIN0	1.8Va DAC	VIN0 * 1
External VIN1	1.8Vd DAC	VIN1 * 1
External VIN2	1.8Va	VIN2 * 1
External VIN3	1.8Vd	VIN3 * 1
External VIN4	3V3 CLK	VIN4 * 2
External VIN5	3V3 TCXO	VIN5 * 2
External VIN6	VADJ	VIN6 * 2
External VIN7	-1V5	3.3 - 2 * VIN7

Table 6: Temperature and voltage parameters

6.3 Cooling

Two different types of cooling are available for the FMC.

6.3.1 Convection cooling

The air flow provided by the fans of the chassis the FMC is enclosed in will dissipate the heat generated by the on board components. A minimum airflow of 300 LFM is recommended.

For standalone operations (such as on a Xilinx development kit), it is highly recommended to blow air across the FMC and ensure that the temperature of the devices is within the allowed range. 4DSP's warranty does not cover boards on which the maximum allowed temperature has been exceeded.

6.3.2 Conduction cooling

In demanding environments, the ambient temperature inside a chassis could be close to the operating temperature defined in this document. It is very likely that in these conditions the junction temperature of power consuming devices will exceed the operating conditions recommended by the device manufacturers (mostly +85°C). While a low profile heat sink coupled with sufficient air flow might be sufficient to maintain the temperature within operating boundaries, some active cooling would yield better results and would certainly help with resuming operations much faster in the case the devices were disabled because of a temperature "over range".

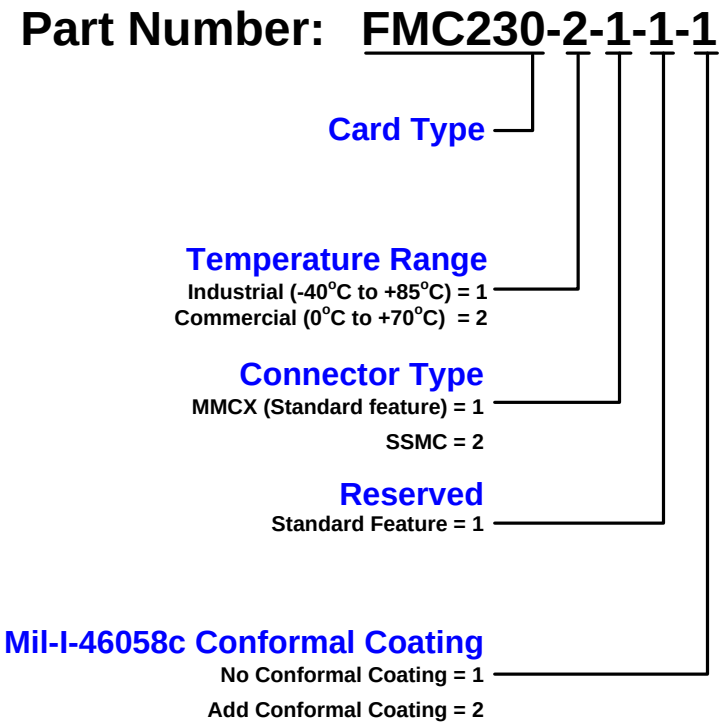
7 Safety

This module presents no hazard to the user.

8 EMC

This module is designed to operate within an enclosed host system built to provide EMC shielding. Operation within the EU EMC guidelines is not guaranteed unless it is installed within an adequate host system. This module is protected from damage by fast voltage transients originating from outside the host system which may be introduced through the system.

9 Ordering information



10 Warranty

	Hardware	*Software/Firmware*
Basic Warranty (included)	1 Year from Date of Shipment	90 Days from Date of Shipment
Extended Warranty (optional)	2 Years from Date of Shipment	1 Year from Date of Shipment

Appendix A LPC / HPC pin-out

- Note that FMC700 is required to use the FMC230 on KC705

AV57.1	HPC Pin	FMC230 Signal	AV57.1	HPC Pin	FMC230 Signal	AV57.1	HPC Pin	FMC230 Signal
CLK0_M2C_N	H5	CLK_TO_FPGA_N	HA00_N_CC	F5	DAC1_DCO_N	HB00_N_CC	K26	DAC1_P1_DP05_N
CLK0_M2C_P	H4	CLK_TO_FPGA_P	HA00_P_CC	F4	DAC1_DCO_P	HB00_P_CC	K25	DAC1_P1_DP05_P
CLK1_M2C_N	G3	EXT_TRIGGER_N	HA01_N_CC	E3	DAC1_DCI_N	HB01_N	J25	DAC1_P1_DP04_N
CLK1_M2C_P	G2	EXT_TRIGGER_P	HA01_P_CC	E2	DAC1_DCI_P	HB01_P	J24	DAC1_P1_DP04_P
CLK2_BIDIR_N	K5	N.C.	HA02_N	K8	DAC1_FRM_N	HB02_N	F23	DAC1_P1_DP03_N
CLK2_BIDIR_P	K4	N.C.	HA02_P	K7	DAC1_FRM_P	HB02_P	F22	DAC1_P1_DP03_P
CLK3_BIDIR_N	J3	N.C.	HA03_N	J7	DAC1_P0_DP00_N	HB03_N	E22	DAC1_P1_DP02_N
CLK3_BIDIR_P	J2	N.C.	HA03_P	J6	DAC1_P0_DP00_P	HB03_P	E21	DAC1_P1_DP02_P
LA00_N_CC	G7	DAC0_DCO_N	HA04_N	F8	DAC1_P0_DP01_N	HB04_N	F26	DAC1_P1_DP01_N
LA00_P_CC	G6	DAC0_DCO_P	HA04_P	F7	DAC1_P0_DP01_P	HB04_P	F25	DAC1_P1_DP01_P
LA01_N_CC	D9	DAC0_DCI_N	HA05_N	E7	DAC1_P0_DP02_N	HB05_N	E25	DAC1_P1_DP00_N
LA01_P_CC	D8	DAC0_DCI_P	HA05_P	E6	DAC1_P0_DP02_P	HB05_P	E24	DAC1_P1_DP00_P
LA02_N	H8	DAC0_FRM_N	HA06_N	K11	DAC1_P0_DP04_N	HB06_N_CC	K29	DAC1_P1_DP06_N
LA02_P	H7	DAC0_FRM_P	HA06_P	K10	DAC1_P0_DP04_P	HB06_P_CC	K28	DAC1_P1_DP06_P
LA03_N	G10	DAC0_P0_DP00_N	HA07_N	J10	DAC1_P0_DP03_N	HB07_N	J28	DAC1_P1_DP07_N
LA03_P	G9	DAC0_P0_DP00_P	HA07_P	J9	DAC1_P0_DP03_P	HB07_P	J27	DAC1_P1_DP07_P
LA04_N	H11	DAC0_P0_DP01_N	HA08_N	F11	DAC1_P0_DP05_N	HB08_N	F29	DAC1_P1_DP09_N
LA04_P	H10	DAC0_P0_DP01_P	HA08_P	F10	DAC1_P0_DP05_P	HB08_P	F28	DAC1_P1_DP09_P
LA05_N	D12	DAC0_P0_DP02_N	HA09_N	E10	DAC1_P0_DP06_N	HB09_N	E28	DAC1_P1_DP08_N
LA05_P	D11	DAC0_P0_DP02_P	HA09_P	E9	DAC1_P0_DP06_P	HB09_P	E27	DAC1_P1_DP08_P
LA06_N	C11	DAC0_P0_DP03_N	HA10_N	K14	DAC1_P0_DP09_N	HB10_N	K32	DAC1_P1_DP11_N
LA06_P	C10	DAC0_P0_DP03_P	HA10_P	K13	DAC1_P0_DP09_P	HB10_P	K31	DAC1_P1_DP11_P
LA07_N	H14	DAC0_P0_DP04_N	HA11_N	J13	DAC1_P0_DP08_N	HB11_N	J31	DAC1_P1_DP10_N
LA07_P	H13	DAC0_P0_DP04_P	HA11_P	J12	DAC1_P0_DP08_P	HB11_P	J30	DAC1_P1_DP10_P
LA08_N	G13	DAC0_P0_DP05_N	HA12_N	F14	DAC1_P0_DP07_N	HB12_N	F32	DAC1_P1_DP13_N
LA08_P	G12	DAC0_P0_DP05_P	HA12_P	F13	DAC1_P0_DP07_P	HB12_P	F31	DAC1_P1_DP13_P
LA09_N	D15	DAC0_P0_DP06_N	HA13_N	E13	DAC1_P0_DP10_N	HB13_N	E31	DAC1_P1_DP12_N
LA09_P	D14	DAC0_P0_DP06_P	HA13_P	E12	DAC1_P0_DP10_P	HB13_P	E30	DAC1_P1_DP12_P
LA10_N	C15	DAC0_P0_DP09_N	HA14_N	J16	DAC1_P0_DP11_N	HB14_N	K35	
LA10_P	C14	DAC0_P0_DP09_P	HA14_P	J15	DAC1_P0_DP11_P	HB14_P	K34	
LA11_N	H17	DAC0_P0_DP08_N	HA15_N	F17	DAC1_P0_DP12_N	HB15_N	J34	
LA11_P	H16	DAC0_P0_DP08_P	HA15_P	F16	DAC1_P0_DP12_P	HB15_P	J33	
LA12_N	G16	DAC0_P0_DP07_N	HA16_N	E16	DAC1_P0_DP13_N	HB16_N	F35	
LA12_P	G15	DAC0_P0_DP07_P	HA16_P	E15	DAC1_P0_DP13_P	HB16_P	F34	
LA13_N	D18	DAC0_P0_DP10_N	HA17_N_CC	K17	DAC1_SYNC	HB17_N_CC	K38	
LA13_P	D17	DAC0_P0_DP10_P	HA17_P_CC	K16	DAC0_SYNC	HB17_P_CC	K37	
LA14_N	C19	DAC0_P0_DP13_N	HA18_N	J19		HB18_N	J37	
LA14_P	C18	DAC0_P0_DP13_P	HA18_P	J18		HB18_P	J36	
LA15_N	H20	DAC0_P0_DP12_N	HA19_N	F20		HB19_N	E34	
LA15_P	H19	DAC0_P0_DP12_P	HA19_P	F19		HB19_P	E33	
LA16_N	G19	DAC0_P0_DP11_N	HA20_N	E19		HB20_N	F38	
LA16_P	G18	DAC0_P0_DP11_P	HA20_P	E18		HB20_P	F37	
LA17_N_CC	D21	DAC0_P1_DP00_N	HA21_N	K20		HB21_N	E37	
LA17_P_CC	D20	DAC0_P1_DP00_P	HA21_P	K19		HB21_P	E36	

LA18_N_CC	C23	DAC0_P1_DP01_N	HA22_N	J22				
LA18_P_CC	C22	DAC0_P1_DP01_P	HA22_P	J21				
LA19_N	H23	DAC0_P1_DP03_N	HA23_N	K23				
LA19_P	H22	DAC0_P1_DP03_P	HA23_P	K22				
LA20_N	G22	DAC0_P1_DP02_N						
LA20_P	G21	DAC0_P1_DP02_P						
LA21_N	H26	DAC0_P1_DP05_N						
LA21_P	H25	DAC0_P1_DP05_P						
LA22_N	G25	DAC0_P1_DP04_N						
LA22_P	G24	DAC0_P1_DP04_P						
LA23_N	D24	DAC0_P1_DP06_N						
LA23_P	D23	DAC0_P1_DP06_P						
LA24_N	H29	DAC0_P1_DP10_N						
LA24_P	H28	DAC0_P1_DP10_P						
LA25_N	G28	DAC0_P1_DP09_N						
LA25_P	G27	DAC0_P1_DP09_P						
LA26_N	D27	DAC0_P1_DP07_N						
LA26_P	D26	DAC0_P1_DP07_P						
LA27_N	C27	DAC0_P1_DP08_N						
LA27_P	C26	DAC0_P1_DP08_P						
LA28_N	H32	DAC0_P1_DP12_N						
LA28_P	H31	DAC0_P1_DP12_P						
LA29_N	G31	DAC0_P1_DP11_N						
LA29_P	G30	DAC0_P1_DP11_P						
LA30_N	H35	DAC0_P1_DP13_N						
LA30_P	H34	DAC0_P1_DP13_P						
LA31_N	G34	FMC_TO_CPLD(1)						
LA31_P	G33	FMC_TO_CPLD(0)				CLK_DIR	B1	
LA32_N	H38	FMC_TO_CPLD(3)				PG_C2M	D1	PG_C2M
LA32_P	H37	FMC_TO_CPLD(2)				PG_M2C	F1	PG_M2C
LA33_N	G37					I2C_SCL	C30	I2C_SCL
LA33_P	G36					I2C_SDA	C31	I2C_SDA

Table 7: FMC230 Pinout

Signal	Group	Direction	I/O standard	Description
DAC0_DCO_P DAC0_DCO_N	D/A 0	Output	LVDS	Clock coming from the 1st D/A converter.
DAC0_SYNC	D/A 0	Output	1.8V CMOS	Sync output, when enabled this output is DACCLK/8. Only available on r1.2 boards or later
DAC0_DCI_P DAC0_DCI_N	D/A 0	Input	LVDS	Clock going to the 1st D/A converter.
DAC0_FRM_P DAC0_FRM_N	D/A 0	Input	LVDS	Frame going to the 1st D/A converter.

DAC0_P0_P<13..0>	D/A 0	Input	LVDS	Data bus 0 going to the 1st D/A converter.
DAC0_P0_N<13..0>				
DAC0_P1_P<13..0>	D/A 0	Input	LVDS	Data bus 1 going to the 1st D/A converter.
DAC0_P1_N<13..0>				
DAC1_DCO_P	D/A 1	Output	LVDS	Clock coming from the 2nd D/A converter.
DAC1_DCO_N				
DAC1_SYNC	D/A 1	Output	1.8V CMOS	Sync output, when enabled this output is DACCLK/8. Only available on r1.2 boards or later
DAC1_DCI_P	D/A 1	Input	LVDS	Clock going to the 2nd D/A converter.
DAC1_DCI_N				
DAC1_FRM_P	D/A 1	Input	LVDS	Frame going to the 2nd D/A converter.
DAC1_FRM_N				
DAC1_P0_P<13..0>	D/A 1	Input	LVDS	Data bus 0 going to the 2nd D/A converter.
DAC1_P0_N<13..0>				
DAC1_P1_P<13..0>	D/A 1	Input	LVDS	Data bus 1 going to the 2nd D/A converter.
DAC1_P1_N<13..0>				
CLK_TO_FPGA_P	I/O	Output	LVDS	Clock coming from the clock tree. Typically used for debug and monitoring purposes.
CLK_TO_FPGA_N				
EXT_TRIGGER_P	I/O	Output	LVDS	Representation of the external trigger signal.
EXT_TRIGGER_N				
FMC_TO_CPLD<3..0>	CONTROL	Bidir	CMOS VIO	SPI bus to CPLD on the FMC176: FMC_TO_CPLD(0): SPI Clock FMC_TO_CPLD(1): SPI Chip Select (low active) FMC_TO_CPLD(2): SPI Data In/Out FMC_TO_CPLD(3): SPI Alert/Interrupt
CLK_DIR	CONTROL	Output	LVTTL	CLK_DIR is not connected. CLK2 and CLK3 are unused.
PG_C2M	STATUS	Input	LVTTL	Power good indicator from carrier to module.
PG_M2C	STATUS	Output	LVTTL	Power good indicator from module to carrier.
I2C_SCL	I2C	Input	LVTTL	I2C clock line.
I2C_SDA	I2C	Bidir	LVTTL	I2C data line.

Table 8: FMC230 Signal Description

Appendix B CPLD Register map

Register		Description
0x00		**Control register 0**
	Bit 0	'0' for internal reference clock '1' for external reference clock (disable internal reference)
	Bit 1	Reserved
	Bit 2	'0' Release DAC reset '1' Assert DAC reset
	Bit 3	'0' Release CLK reset (AD9517) '1' Assert CLK reset (AD9517)
	Bit 4	'0' Release CLK sync (AD9517) '1' Assert CLK sync (AD9517)
	Bit 6..5	Reserved
	Bit 7	EEPROM write enable. Recommended to write '0'.
0x01		**Control register 1**
	Bit 0	Reserved
R/O	Bit 1	Reserved
R/O	Bit 2	Reserved
	Bit 3	Reserved
R/O	Bit 4	Reserved
R/O	Bit 5	Reserved
	Bit 6	'0' for CLK power enable (AD9517) '1' for CLK power down (AD9517)
	Bit 7	'0' for MONITORING power enable (AD7291 rst_l) '1' for MONITORING power down (AD7291 rst_l)
0x02		**Status register**
	Bit 0	REFMON (AD9517)
	Bit 1	LD (AD9517)
	Bit 2	STATUS (AD9517)
	Bit 3	ALERT (AD7291)
	Bit 4	IRQ (DAC)
	Bit 7..5	CPLD revision (current = b'001')

Table 9: CPLD Register Map