KCPSM6 Reference Design for the KC705 Evaluation Board

XADC Interface, Communication & Sampling Conversions

including…

PicoTerm Graph of Die Temperature

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This Document and Reference Design

The primary purpose of this document is to provide images to supplement the descriptions contained in the source VHDL and PSM code provided with this reference design.

It is assumed that you already have a copy of the KCPSM6 variant of PicoBlaze and are familiar with using it. In particular, this reference design builds on the UART based reference designs provided in the KCPSM6 package so this document focuses on the additions specific to XADC interfacing and communication and then the subsequent conversion and presentation of the samples relating to analogue measurements.

The reference design is presented on the Kintex-7 KC705 Evaluation Kit. Although this makes the design somewhat specific to the hardware arrangement of the KC705 board, the reference design itself should provide a valid starting point for any 7-Series based design using KCPSM6 with XADC and it is hoped that you will readily adopt sections of both the hardware and PSM source files provided.

XADC is a dual 12-bit, 1-MSPS analog-to-digital converter with up to 17 external analog inputs (depending on device, package and hardware platform) and the ability sample internal power supply rails and measure die temperature. Please refer to the XADC User Guide UG480 for full descriptions and technical details.

The source code provided with this reference design configures XADC such that it will automatically sequence through a subset of the analogue channels taking samples of die temperature, the VCCINT, VCCBRAM and VCCAUX power supplies and 3 of the external analog inputs accessible from the XADC Header (J46) on the KC705 board. KCPSM6 is able to read samples from XADC and convert them into meaningful temperature and voltages which are presented to the user.

This reference design must be used with PicoTerm (provided with PicoBlaze). The main terminal window is used to present the user with a simple menu allowing various XADC information to be read and displayed. It is hoped that the information presented will help you to understand and experiment with XADC as much as it enables you to learn more about KCPSM6. For example, the information presented in the terminal window will appear to be rather plain but behind these figures are different conversion routines (in PSM code) to convert the raw XADC samples into a meaningful values depending on which analogue source is being processed. All these routines have the potential for reuse in your own designs.

In order to make this reference design a little more interesting it also presents a graphical plot of die temperature over time in the PicoTerm Graphic Display. As such, this is also a reference design showing how to display points, lines, boxes and text in this special feature window.

I do hope you find this reference design useful. Please provide any feedback related to this reference design (good or bad) to…

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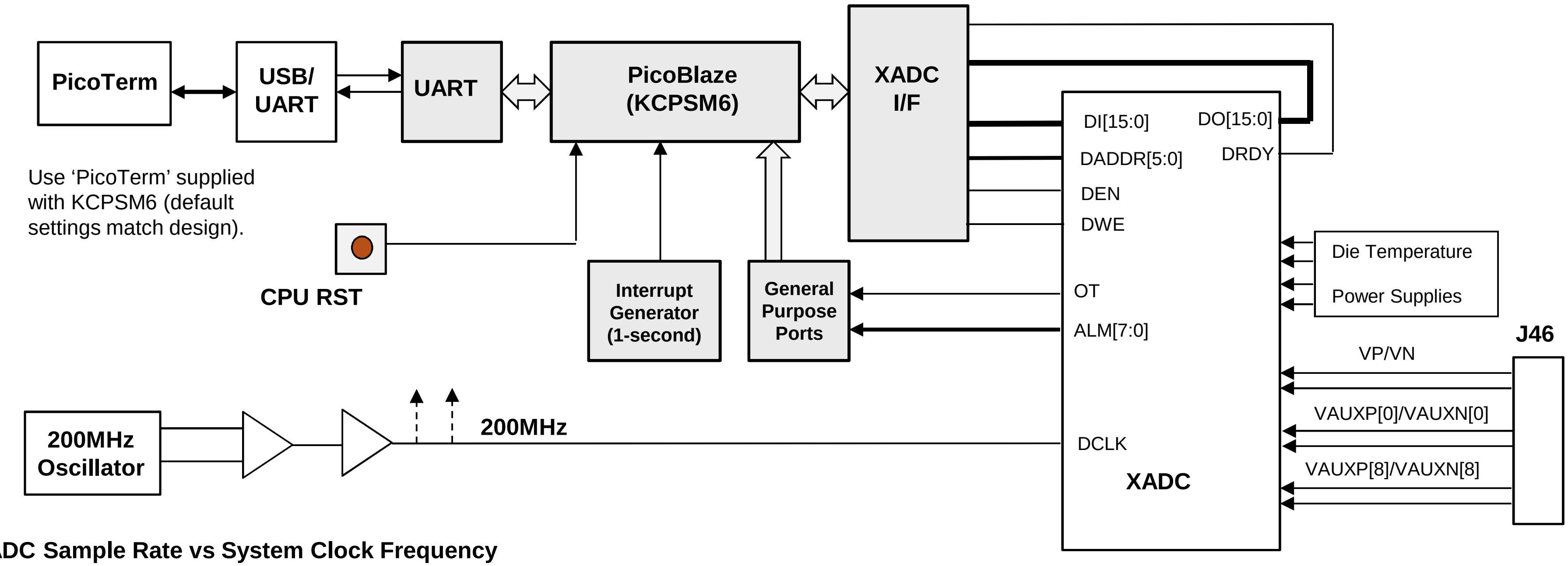
Overview of Reference Design

The design implements a bridge between the user of a terminal (PicoTerm) and XADC within the Kintex-7 device on the KC705 board. The KC705 board has an 'XADC Header' (J46) which provides the ability to connect analogue signals to VP/VN, VAUXP[0]/VAUXN[0] and VAUXP[8]/VAUXN[8] which XADC will sample and KCPSM6 will read, convert and present as voltages on the PicoTerm Terminal. Obviously you would need to connect something to this header before you will observe anything meaningful. Hint – Placing a wire link between a differential pair should at least result in zero (or very close).

Please be aware that the PSM code provided contains a total of 1726 instructions but the vast majority of these are related to user interaction. In fact, over 1000 instructions are directly associated with the generation of text messages. For this reason it is useful to know that only 74 instructions are directly involved with XADC communication and all conversions of raw samples into meaningful temperature and voltage values. These XADC specific routines are contained in their own 'xadc_routines.psm' file ready to be reused in your own designs.



XADC Sample Rate vs System Clock Frequency

All elements in this design are provided with a 200MHz for no other reason than it is the frequency of the differential oscillator on the KC705 board. This 200MHz clock is provided to XADC as 'DCLK'. Internally to XADC this has been divided by 8 to form an 'ADCCLK' of 25MHz resulting in a raw A/D sample rate of 961.538KHz. Please read the descriptions included in 'kc705_kcpsm6_xadc.vhd' relating to the setting of the CD[7:0] bits within XADC Configuration Register 2 (INIT_42) and the channel sequencer. UG480 is the XADC User Guide and should be your primary reference to learn more.

Reference Design Files

All source files contain detailed descriptions and comments. In fact, the descriptions and comments in the source code should be considered the *main* documentation for this reference design with this PDF mainly used to provide an introduction and complementary graphics.

Hardware Definition

kc705_kcpsm6_xadc.vhd

- kc705_kcpsm6_xadc.ucf
- kcpsm6.vhd
- xadc_monitor.vhd
- uart_tx6.vhd
- uart_rx6.vhd

KCPSM6 Assembler

Software Definition

xadc_monitor.psm

- xadc_routines.psm
- PicoTerm_routines.psm
- soft_delays_200mhz.psm

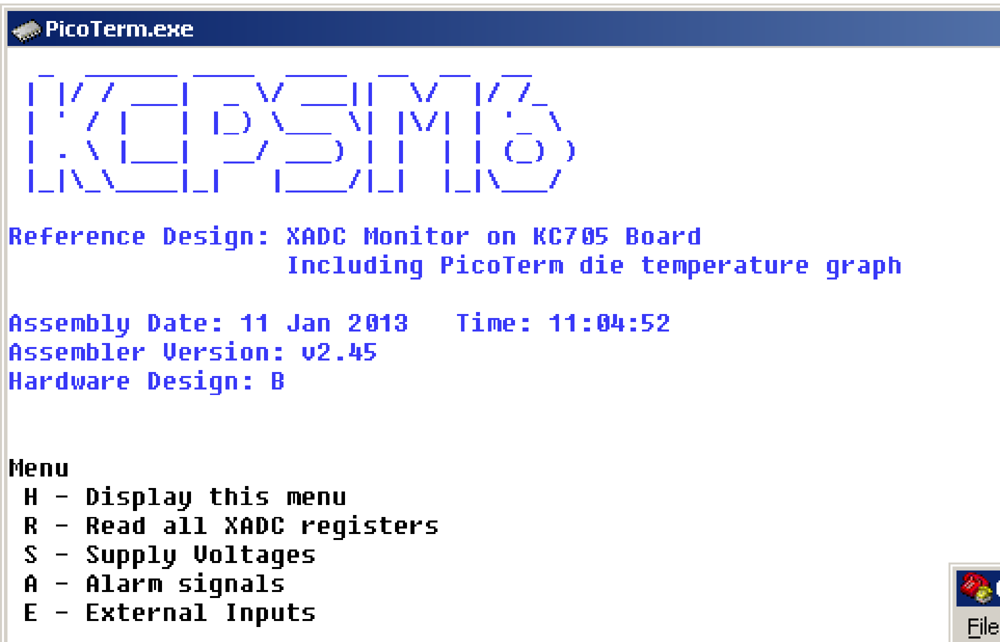
XADC interface and sample conversion routines.

Files shown in grey are provided in the KCPSM6 package and should be copied and added to your project directory

Hint – The 'xadc_monitor.vhd' file is not provided. Assemble the PSM code in the normal way to generate this file.

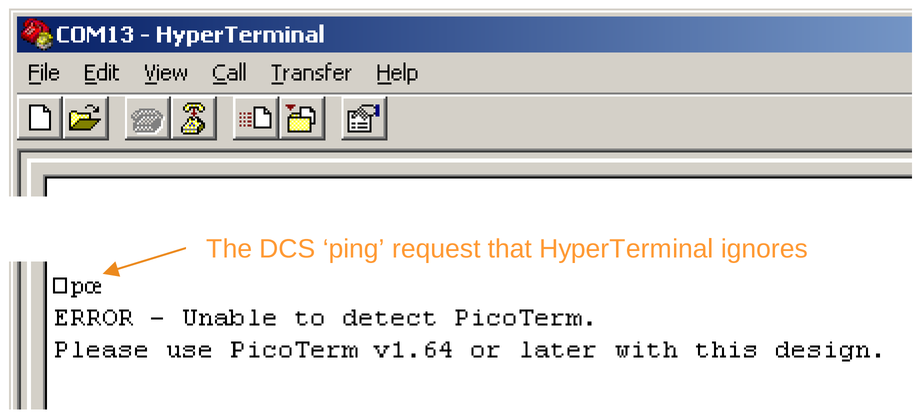
UART Communication and Detecting PicoTerm

KCPSM6 communicates with PicoTerm using the UART macros provided with PicoBlaze (and the UART/USB bridge device on the KC705 board). As long as your USB connection is good and you have installed and specified the appropriate virtual COM port driver on your PC then the design should introduce itself on PicoTerm and present a simple menu of options as shown below.



The UART baud rate has been set to 115200 which matches the PicoTerm default. So you only need to specify the correct virtual COM port when you launch PicoTerm.

The design MUST be used with PicoTerm because KCPSM6 presents a graph of die temperature in the PicoTerm Graphic window. So during the initialisation process, KCPSM6 issues a 'ping' request to PicoTerm and checks for the expected response before continuing. If KCPSM6 does not receive a correct response it sends a message and then halts. Below is an example of this message when HyperTerminal was used.



Hints

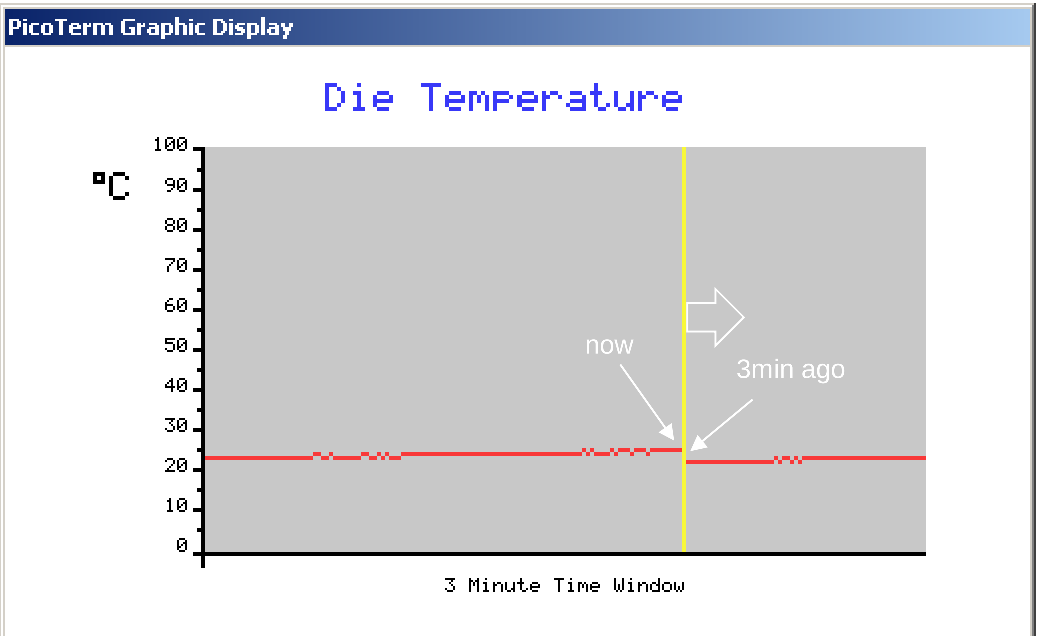
'xadc_monitor.psm' is the main PSM program containing the initialisation process and the text shown above.

Routines to communicate with the UART macros and PicoTerm are provided in 'PicoTerm_routines.psm'.

See 'PicoTerm_README.txt' for descriptions of device control strings (DCS) including the 'ping' request.

Plot of Die Temperature

Almost immediately after KCPSM6 has confirmed that it is in communication with PicoTerm it sends device control strings (DCS) to open a PicoTerm Graphic Display window and initialise a graph which goes on to a plot die temperature over time. KCPSM6 responds to interrupts generated by the hardware at one second intervals and reads the die temperature from XADC which it plots on the graph following suitable conversion of the raw sample value. The plot area presented is 180 pixels wide corresponding with a duration of 180 seconds (180 interrupts). Once the plot has reached the right hand side, KCPSM6 starts over-writing the oldest information on the left. A yellow line marks the boundary between new and old at it moves from left to right.



The temperature range of the plot is consistent with operating range of an extended commercial device.

KCPSM6 reads a die temperature sample from XADC status register 00 (hex) using the 'read_XADC' routine provided in 'xadc_routines.psm'. This raw sample is then converted to a 16-bit fixed point value representing temperature in degrees centigrade using the 'convert_XADC_temperature' routine which is also provided in 'xadc_routines.psm'. A comprehensive description of the conversion process is provided in the source code.

Hints

The graph is set up by the 'graph_setup' routine in 'xadc_monitor.psm'. This sends a series of device control strings (DCS) to PicoTerm which opens the Graphic Display window and draws lines/boxes and adds text labels forming an empty graph. See 'PicoTerm_README.txt' for descriptions of the graphic window and the associated DCS commands (and then have fun generating your own graphs, pictures, patterns etc).

The interrupt service routine (ISR) is the last routine in 'xadc_monitor.psm'. This contains the DCS required to read the die temperature from XADC, plot a point and move the yellow line. As with everything else, please see the descriptions provided in the source code for details.

Voltages and Alarms

The simple menu enables you to monitor supply voltages, external analogue inputs and the alarm signals. In each case, KCPSM6 reads raw information from XADC and performs the conversions necessary to present the values which are displayed. All conversions are provided as PSM routines that are described within the source code and suitable for reuse in your own designs.

```
Menu
 H - Display this menu
 R - Read all XADC registers
 S - Supply Voltages
 A - Alarm signals
 E - External Inputs

> S
        Supply          Present         Minimum         Maximum

        VCCINT          0.999v          0.996v          1.001v
        VCCAUX          1.801v          1.799v          1.807v
        VCCBRAM         0.994v          0.993v          0.997v

> E
        External Input

        VP/VN                    0.371v
        VAUXP[0]/VAUXN[0]       +0.153v
        VAUXP[8]/VAUXN[8]       +0.000v

> A

        0       OT      Over Temperature
        0       ALM(0)  Temperature
        0       ALM(1)  VCCINT
        0       ALM(2)  VCCAUX
        0       ALM(3)  VCCBRAM

>
```

Unipolar

Bipolar

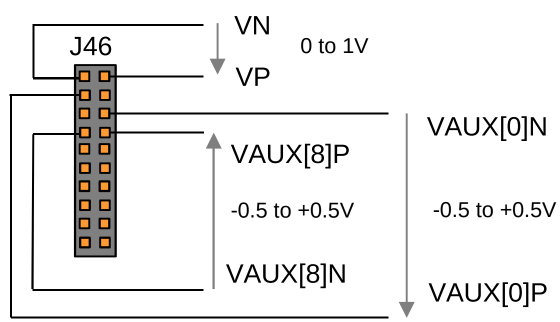
KCPSM6 reads the dedicated alarm signals using the 'read_XADC_status' routine in the 'xadc_routines.psm' file.

XADC samples each of the core supply rails and stores these raw values in a set 'status registers'. It also records the maximum and minimum values observed in another set of 'status registers'. KCPSM6 reads all these raw values from XADC and first converts them into meaningful voltages. Note that internal voltages have a specific transfer function implemented by the 'convert_XADC_supply_voltage' routine provided in the 'xadc_routines.psm' file.

The KC705 board has an 'XADC Header' (J46) which provides connections to three of the differential analogue input channels. As with the internal supplies, XADC samples each of these inputs and stores raw values in a set 'status registers'. KCPSM6 reads these registers and converts the raw values into meaningful voltages. To enhance the reference design the analogue inputs have been configured as a mixture of 'Unipolar' and 'Bipolar' with corresponding conversion routines provided in the 'xadc_routines.psm' file. See…

'convert_XADC_unipolar_voltage'
'convert_XADC_bipolar_voltage'

XADC Header (J46) connections and differential voltage ranges



Recommendations

Before you connect anything to J46, read about the differential analog inputs in UG480. Do not exceed differential input ranges and remain within 0v to 1.8v on any pin. Also refer to UG810 to check the J47 and J48 jumpers on the KC705.

XADC Status and Configuration Registers

XADC has a total of 64 ‘status registers’ and 32 ‘configuration registers’. To help you understand and experiment with XADC the reference design will read and display the raw 16-bit values held in all of them. KCPSM6 reads registers using the ‘read_XADC’ routine in the ‘xadc_routines.psm’ file. A routine called ‘write_XADC’ is also provided and you could use this to write different values to any of the configuration registers (status registers are read only). Please ensure that you read the descriptions contained in HDL and PSM files as well as referring to UG480 to understand the meaning of all registers.

> R

Status Register	Value (Hex)	Examples…	Status Register	Value (Hex)	Configuration Register	Value (Hex)
00	9D6E	← Temperature	20	9DA8	40	B400
01	553A		21	555F	41	2EF0
02	99CE		22	9A13	42	0820
03	05C0	← VP/VN	23	550F	43	0000
04	6AAF		24	9D28	44	0000
05	0003		25	5527	45	0000
06	54E3	← VCCBRAM	26	99A0	46	0000
07	0000		27	54C7	47	0000
08	00B6		28	0000	48	7F01
09	00BC		29	0000	49	0101
0A	0000		2A	0000	4A	4700
0B	0000		2B	0000	4B	0000
0C	0000		2C	FFFF	4C	0000
0D	0000		2D	FFFF	4D	0101
0E	0000		2E	FFFF	4E	0000
0F	0000		2F	0000	4F	0000
10	00E2		30	0000	50	B5ED
11	0000		31	0000	51	57E5
12	0000		32	0000	52	A148
13	0000		33	0000	53	CA3F
14	0000		34	0000	54	A93A
15	0000		35	0000	55	52C6
16	0000		36	0000	56	91EC
17	0000		37	0000	57	AE4F
18	00A2		38	0000	58	57E5
19	0000		39	0000	59	599A
1A	0000		3A	0000	5A	A148
1B	0000		3B	0000	5B	A148
1C	0000		3C	0000	5C	52C6
1D	0000		3D	0000	5D	5111
1E	0000		3E	0000	5E	91EC
1F	0000		3F	0000	5F	6148

Hint

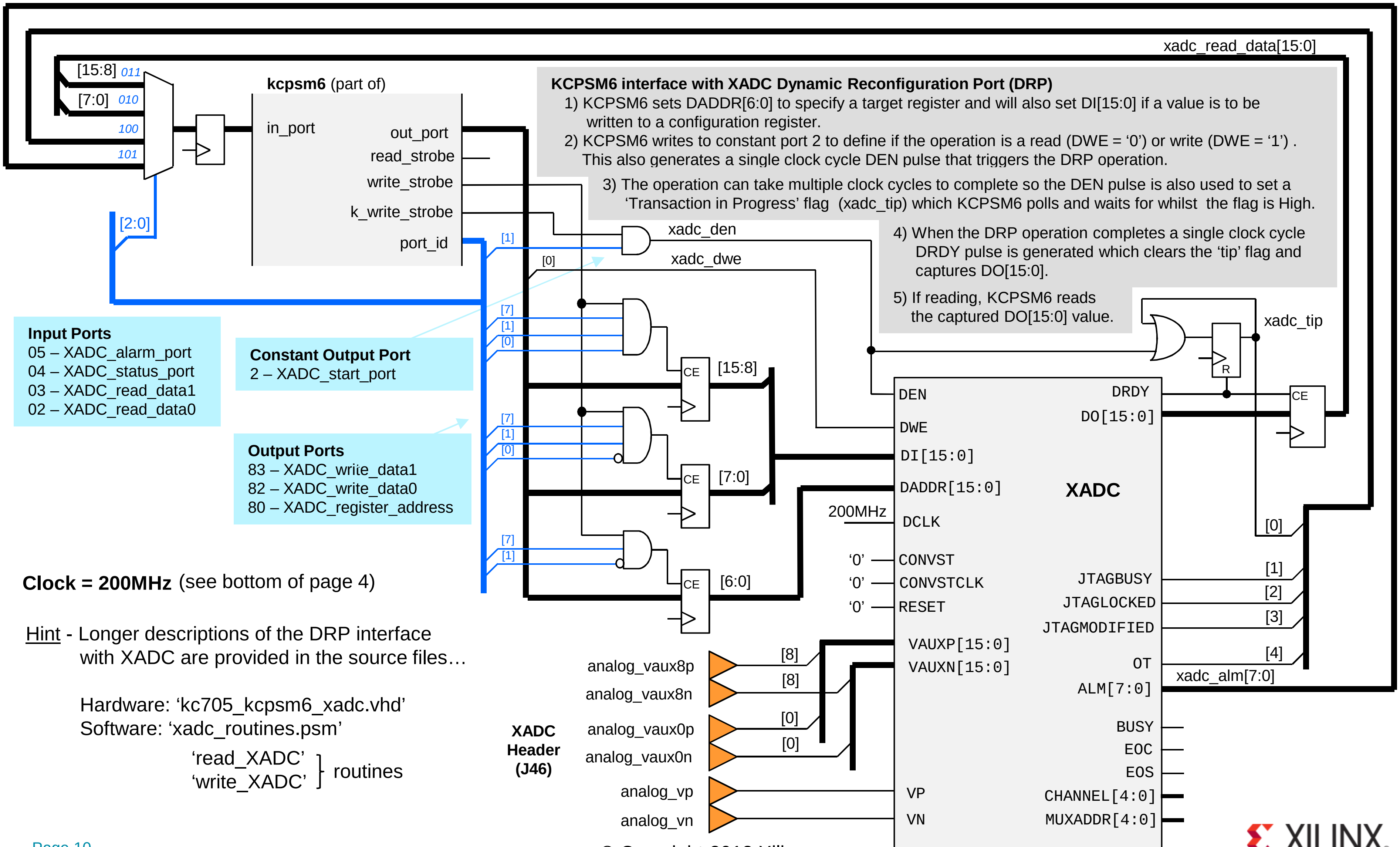
The values in the configuration registers are those defined by the ‘INIT_40’ to ‘INIT_5F’ values set on the XADC primitive in the ‘kc705_kcpsm6_xadc.vhd’ file.

These initial values enabled XADC to automatically start collecting samples from all the active channels as soon as the device was configured. This also meant that KCPSM6 only had to read the appropriate status registers and interpret their values.

KCPSM6 could write or modify the configuration registers to set up or change the behaviour of XADC so why not use JTAG LOADER to experiment?

XADC Interface and External Analogue Inputs

For clarity this diagram only shows the KCPSM6 ports assigned to interface with XADC



Clock = 200MHz (see bottom of page 4)

Hint - Longer descriptions of the DRP interface with XADC are provided in the source files…

Hardware: 'kc705_kcpsm6_xadc.vhd'
Software: 'xadc_routines.psm'

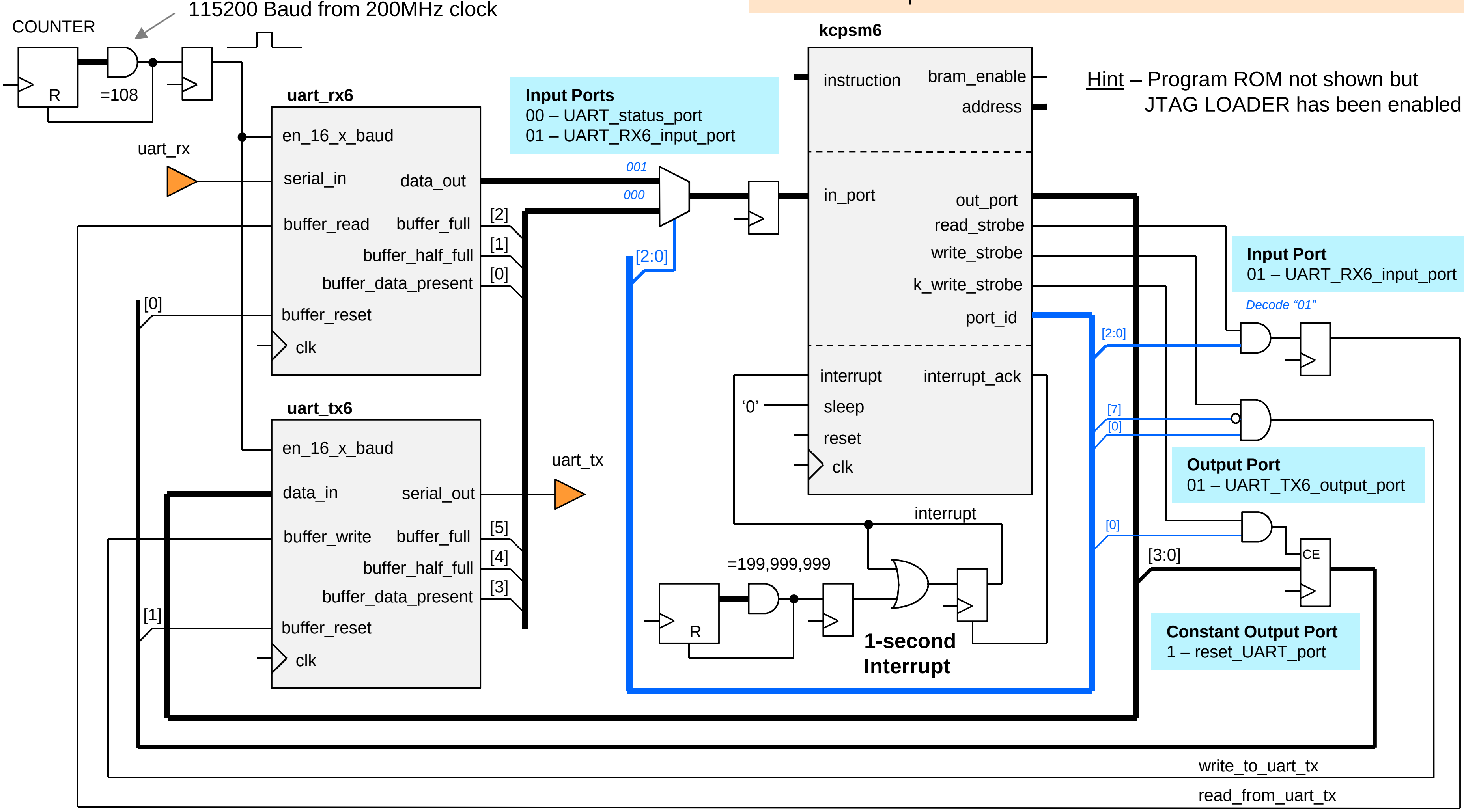
'read_XADC'
'write_XADC' } routines

UART Macros and 1-second Interrupt

For clarity this diagram only shows the ports assigned to connect to the UART macros used to communicate with the user at 115,200 baud.

Clock = 200MHz (see bottom of page 4)

For more information about this part of the design please see the documentation provided with KCPSM6 and the UART6 macros.



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