Celoxica

DK2

Handel-C and PSL basics

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Conventions

A number of conventions are used in this document. These conventions are detailed below.

Warning Message. These messages warn you that actions may damage your hardware.

Handy Note. These messages draw your attention to crucial pieces of information.

Hexadecimal numbers will appear throughout this document. The convention used is that of prefixing the number with '0x' in common with standard C syntax.

Sections of code or commands that you must type are given in typewriter font like this:

```
void main();
```

Information about a type of object you must specify is given in italics like this:

copy ***SourceFileName DestinationFileName***

Optional elements are enclosed in square brackets like this:

```
struct [type_Name]
```

Curly brackets around an element show that it is optional but it may be repeated any number of times.

string ::= "{***character***}"

1 Tutorial: Handel-C and PSL basics

The following examples illustrate basic use of the common Handel-C operators which are not present in C or C++. The first example involves creating a driver for an off-chip peripheral, and uses the Celoxica PSL API for this. A brief overview of PSL and PAL is also given, for further information consult the relevant manuals and tutorial guides. Later examples use the Celoxica PAL API, allowing them to be used in simulation as well as with any supported board. The examples given can be used with any FPGA based board, but are shown configured for the Celoxica RC200.

New users are recommended to work through the following topics in order:

Platform Support Library (see page 4)

Seven-segment device driver (see page 6)

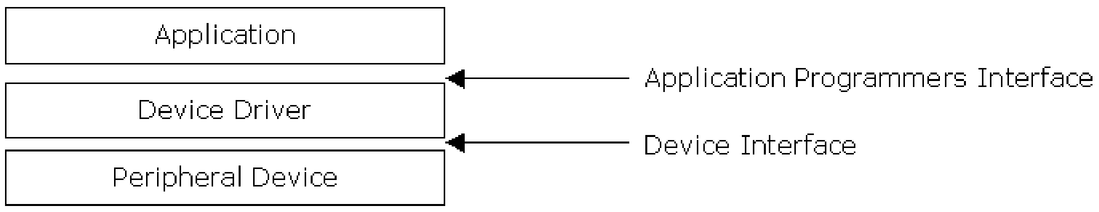
Setting up a PAL workspace (see page 9)

Handel-C language basics (see page 17)

2 Handel-C basics: Platform Support Library

A Platform Support Library (PSL) is a Handel-C library containing functions for communicating with peripheral devices on an FPGA/PLD platform. A collection of functions for a particular device is referred to as a device driver. This document describes techniques and considerations for implementing device drivers in Handel-C, and thereby creating a PSL.

A device driver has two interfaces, one for the device and one for the application programmer. The device interface is defined by the device manufacturer, whereas the Application Programmers Interface (API) is defined by the author of the device driver. Where possible, a device driver presents an API which is less complex than the device interface by encapsulating device command timing and command sequences.

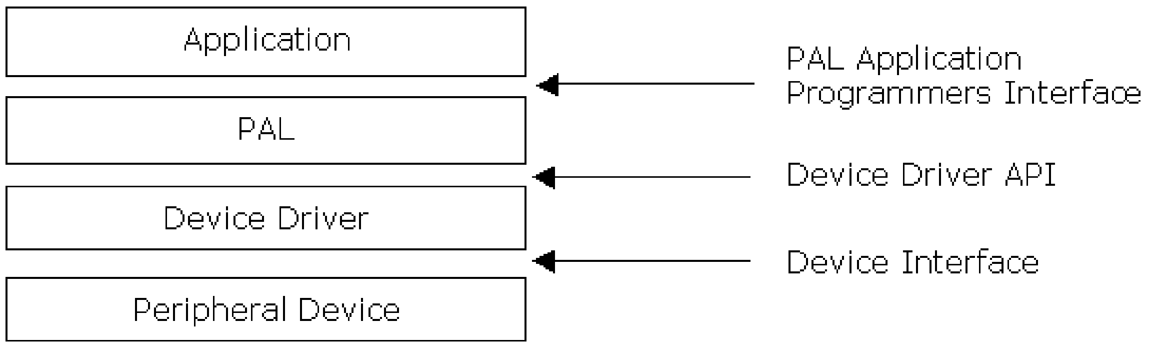


SYSTEM HIERARCHY

3 Handel-C basics: Platform Abstraction Layer

The functions presented in a device driver API reflect the characteristics of the device. For example, an API function which reads data from a device will return data of a specific bit-width that corresponds to that device. Different devices that achieve the same purpose but have different characteristics (such as data width) will have APIs that reflect these differences.

Celoxica's Platform Abstraction Layer (PAL) offers a way to abstract over the differences in device driver APIs. PAL sits between the application and the device driver layer and translates calls to functions in the PAL API into the calls in the device drivers API.



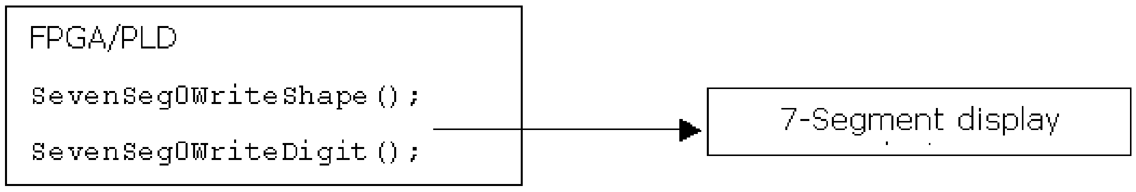
SYSTEM HIERARCHY WITH PAL

PAL performs generalization of device driver APIs with auxiliary functions that can report the device characteristics from within an application. For example, there are PAL functions for determining the data width of a resource.

When you write a device driver you should make the API specific to the device and then use PAL to make the device driver compatible with existing portable applications.

4 Seven-segment device driver

A device driver for a seven-segment display provides control of the display state. It is possible to write a raw shape to the display, or a digit which will be interpreted by the driver to display the correct shape. The source code for the driver should be in a separate .hcc file, with a .hch header file containing prototypes for the API. These files can then be used directly in a project, or compiled into a library.



Block Diagram

4.1 Hardware interface

First define macro expressions for the pins which the seven-segment displays are connected to. The example shown is for the RC200:

```
static macro expr SevenSeg0Pins = {"L5", "G4", "F3", "K3", "L4", "L3",
"H4", "G3"};
static macro expr SevenSeg1Pins = {"K4", "G5", "H3", "L6", "F5", "H5",
"J3", "J4"};
```

Now define registers to hold the values to be displayed, initialising them to zero. The example shown is for the RC200, which has two seven-segment displays, hence the array of two 8-bit unsigned integers.

```
static unsigned 8 SevenSeg[2] = {0, 0};
```

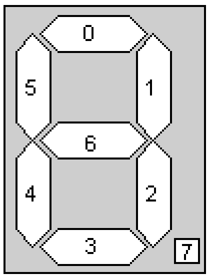
Now define a Handel-C interface to attach the pins to the variables. Use the Handel-C bus_out interface as the pins are outputs from the device driver.

```
static interface bus_out () SevenSeg0Out (SevenSeg[0]) with {data =
SevenSeg0Pins};
static interface bus_out () SevenSeg1Out (SevenSeg[1]) with {data =
SevenSeg1Pins};
```

Note that making the SevenSeg variable and the various macros static prevents them from being visible outside the file they are defined in.

Now implement a macro procedure to display a ‘shape’ on the seven-segment display. The figure below shows how the segments of the display are numbered, so that when an 8-bit data value is written to the display, bit 0 is the top segment, and bit 7 is the decimal point.

```
macro proc SevenSeg0WriteShape (Shape)
{
    SevenSeg[0] = Shape;
}
```



NUMBERING OF DISPLAY SEGMENTS

Now implement a macro procedure which accepts a 4-bit unsigned integer and displays the corresponding hexadecimal digit on the seven-segment display. The decimal point is set according to a further 1-bit unsigned integer parameter. The required shapes to display hexadecimal digits have been provided in the ROM `TranslationROM0` in the example project (**TutorialSevenSeg1**).

```
macro proc SevenSeg0WriteDigit (Value, DecimalPoint)
{
    SevenSeg[0] = DecimalPoint @ TranslationROM0[Value];
}
```

The two macros shown for displaying a shape and a digit are for a single seven-segment display, and a further copy of each will be required for each additional display.

4.2 Source file organization and example project

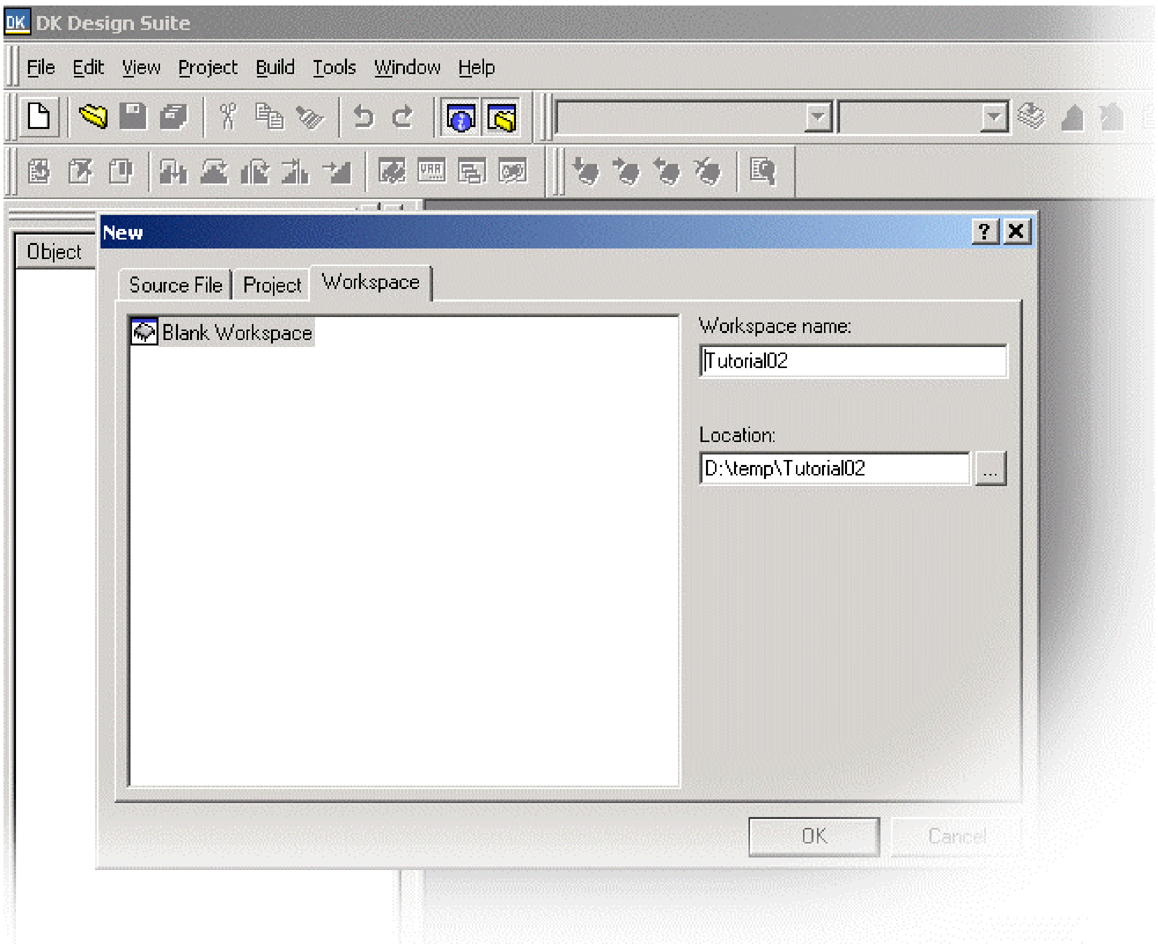
To allow the driver for the seven segment display to be easily included in a library, as part of a PSL for a board, the source code should be organized in a certain way. All the Handel-C source code for interfacing to the hardware should be in a single file, and the prototypes for the macros should be in a separate header file. By doing this the header and source file can be included directly in projects during their development, and later the Handel-C file can be linked into a PSL library, and the prototypes for the macros pasted into the PSL library header.

There as an example workspace set up in **TutorialSevenSeg1,** which contains a library project with the seven segment code in it, with the interface pins set up for the Celoxica RC200 board. There is also an example project using the library, again set up for the RC200.

5 Setting up a PAL workspace

Rather than using the ***seven-segment PSL driver*** (see page 6), the tutorial will continue using the standard PAL seven-segment displays instead. This will allow a range of boards to be used with the tutorial, and also simulation using the PAL Virtual Platform. Each platform which is going to be supported can have its own *configuration* created in DK, to allow easy customization.

First, select the **File->New** menu and create a new workspace, as shown below.

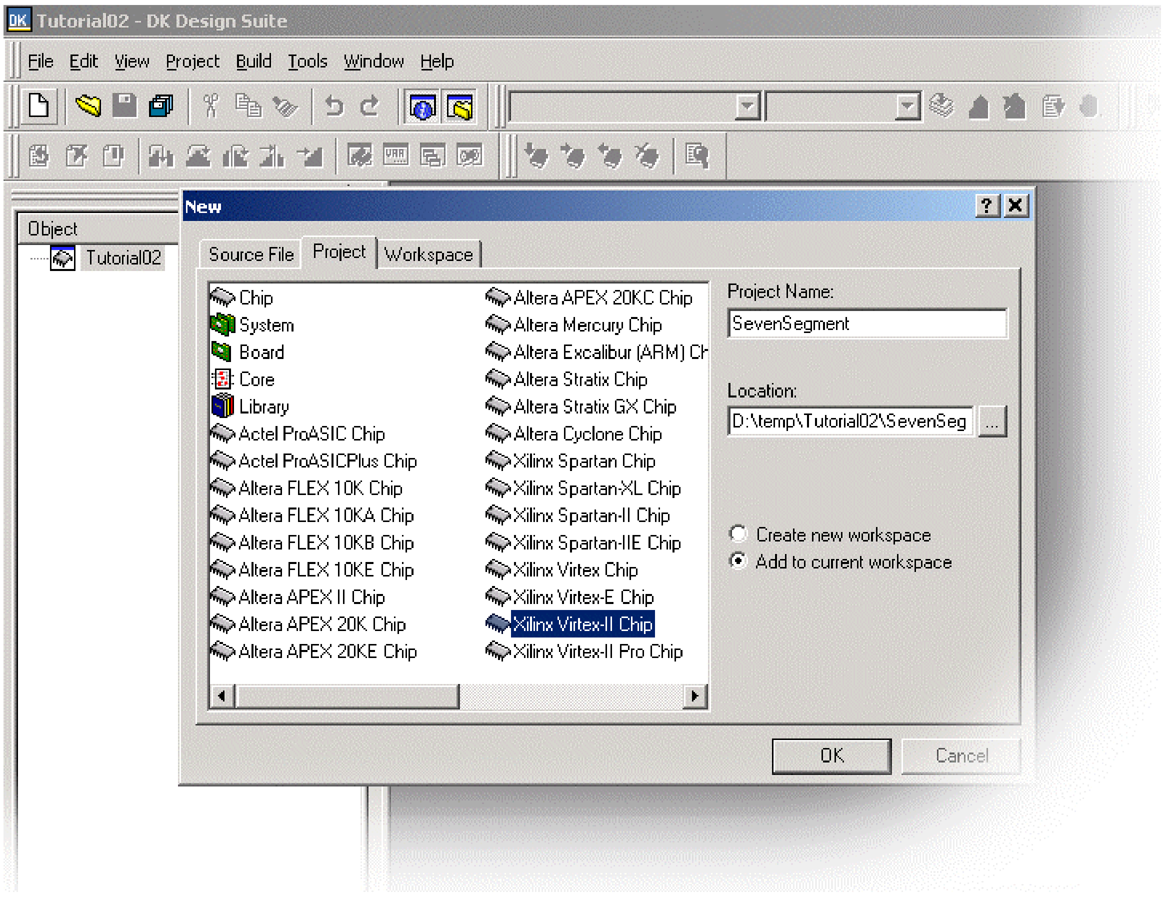


Workspace name: Tutorial02

Location: D:\temp\Tutorial02

CREATING A NEW WORKSPACE

Then, select the **File->New** menu again and create a new project in the workspace, as shown below. If you are targeting a board, the chip type must be set correctly – the figure below shows the setting for the Celoxica RC200. For simulation, the chip type is irrelevant.



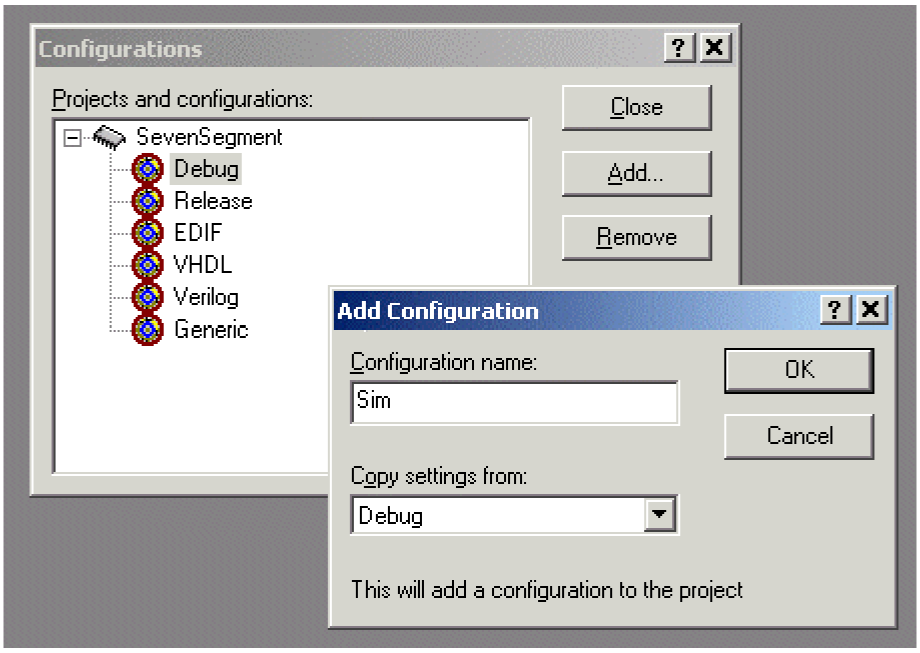
Project Name: SevenSegment

Location: D:\temp\Tutorial02\SevenSeg

Create new workspace [✓ Add to current workspace]

CREATING A NEW PROJECT

Now, select the **Build->Configurations** menu, select the **Debug** configuration, and click the **Add** button. A dialog box will appear, where a new configuration name can be entered, and settings copied from an existing configuration. Create a new configuration called **Sim,** based on the existing **Debug** configuration, as shown below. Also create a configuration called **RC200**, based on the existing **EDIF** configuration.



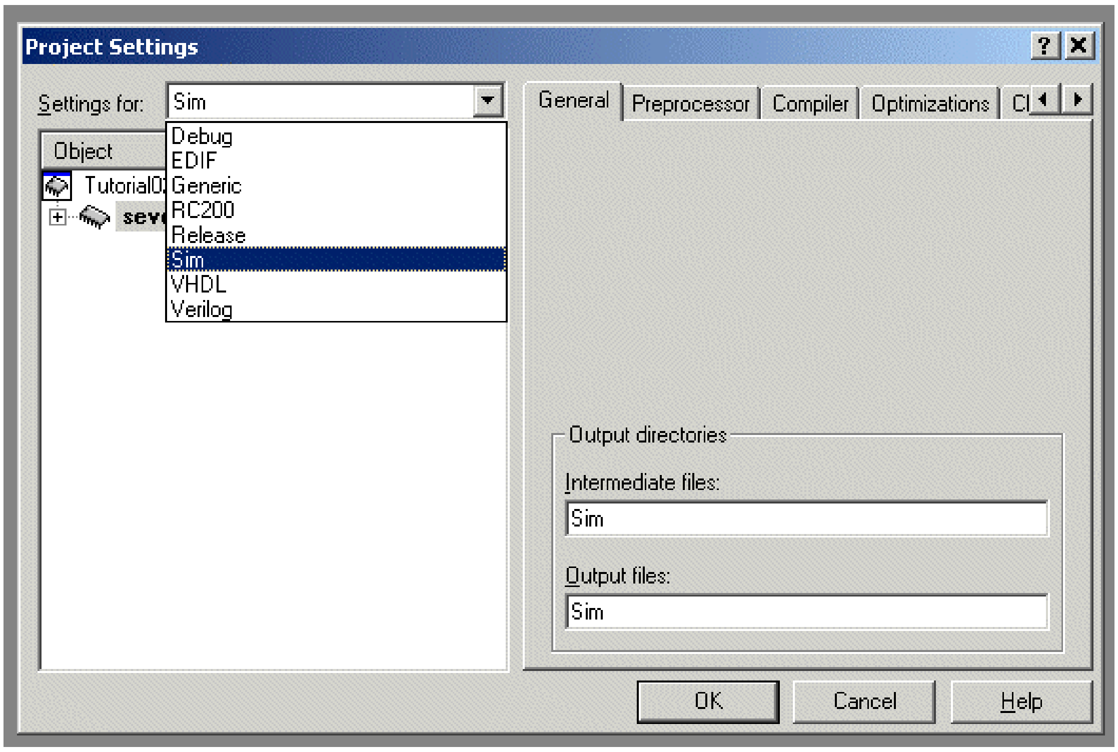
Configuration name: Sim

Copy settings from: Debug

This will add a configuration to the project

CREATING A NEW CONFIGURATION

The two new configurations can now be customized for their particular targets. Select the **Project->Settings** menu, and from the **Settings for** drop-down, select the newly created **Sim** configuration. On the **General** tab, change the output directories to match the configuration name – **Sim** in this case, as shown below.



Settings for: Sim

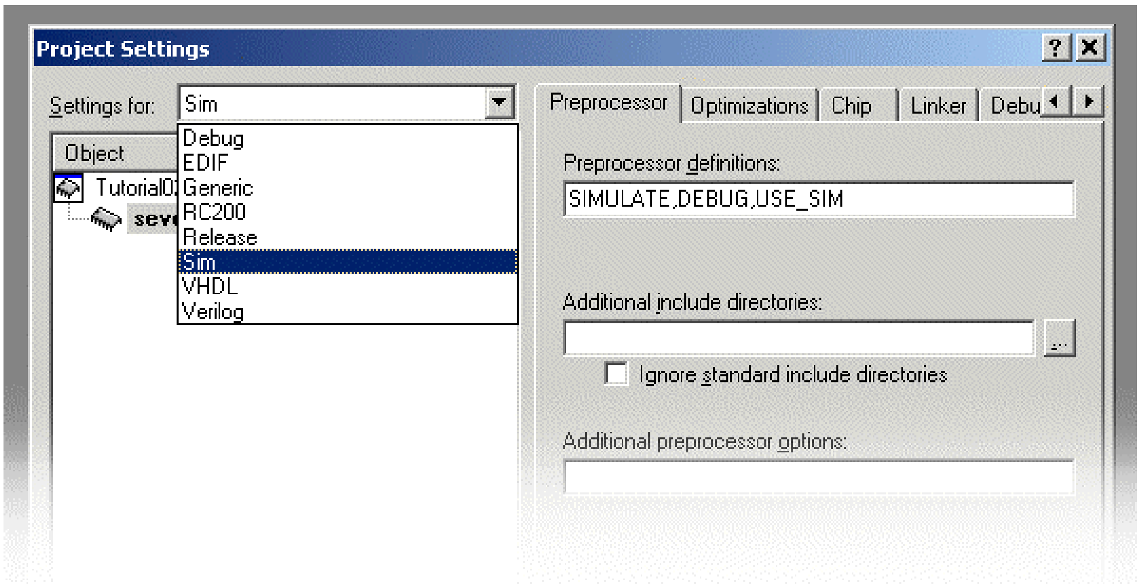
Output directories

Intermediate files: Sim

Output files: Sim

SETTING OUTPUT DIRECTORIES

On the **Preprocessor** tab, add **USE_SIM** to the **Preprocessor definitions** box, as shown below. This definition is used to specify which PAL target is to be used for this configuration.


Project Settings

Settings for: Sim

Debug
EDIF
Generic
RC200
Release
Sim
VHDL
Verilog

Preprocessor definitions: SIMULATE,DEBUG,USE_SIM

Additional include directories:

Ignore standard include directories

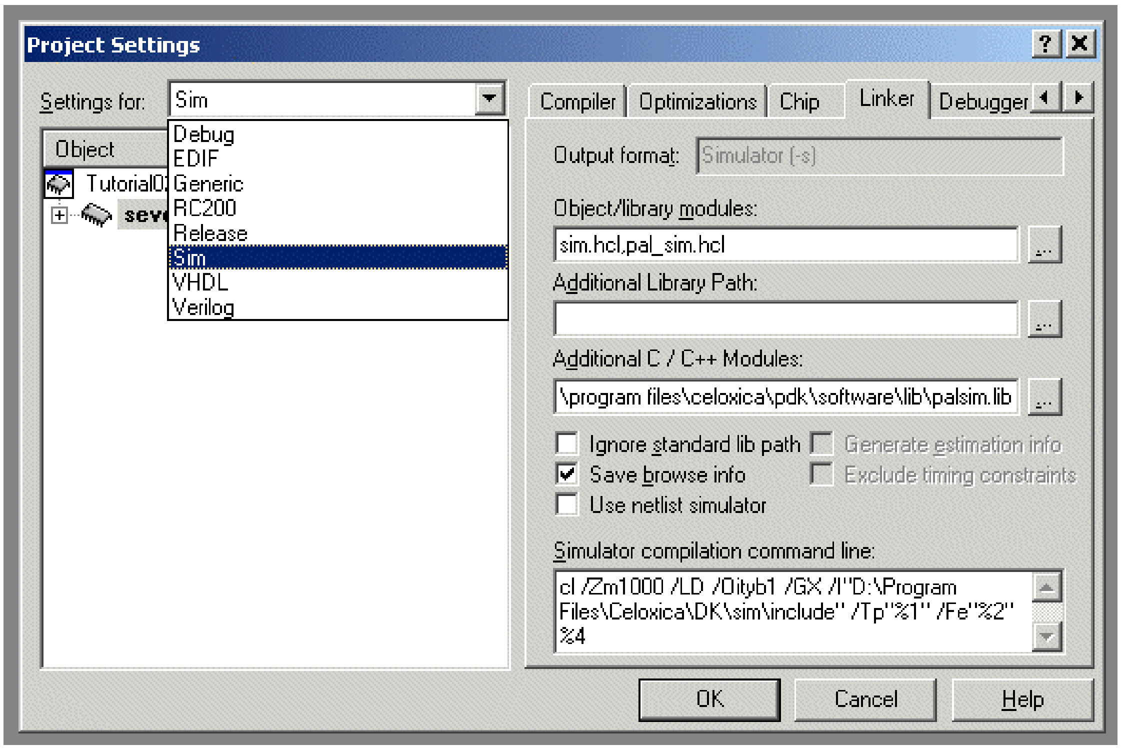
Additional preprocessor options:

SETTING PREPROCESSOR DEFINITIONS

The final step in setting up the new configuration is to go to the **Linker** tab in the **Project Settings**, and add libraries which are required for PAL. For simulation the target is the PalSim Virtual Platform, which requires the Handel-C libraries **sim.hcl** and **pal_sim.hcl** to be added. The C++ library **palSim.lib** is also required, and must be included explicitly in the **Additional C/C++ Modules** box. It is possible to browse to locate the C++ module, the default path would be:

C:\program files\celoxica\pdk\software\lib\palsim.lib

The **Linker** tab with all the libraries set up for simulation is show below.



Output format: Simulator (-s)

Object/library modules: sim.hcl,pal_sim.hcl

Additional Library Path:

Additional C / C++ Modules: \program files\celoxica\pdk\software\lib\palsim.lib

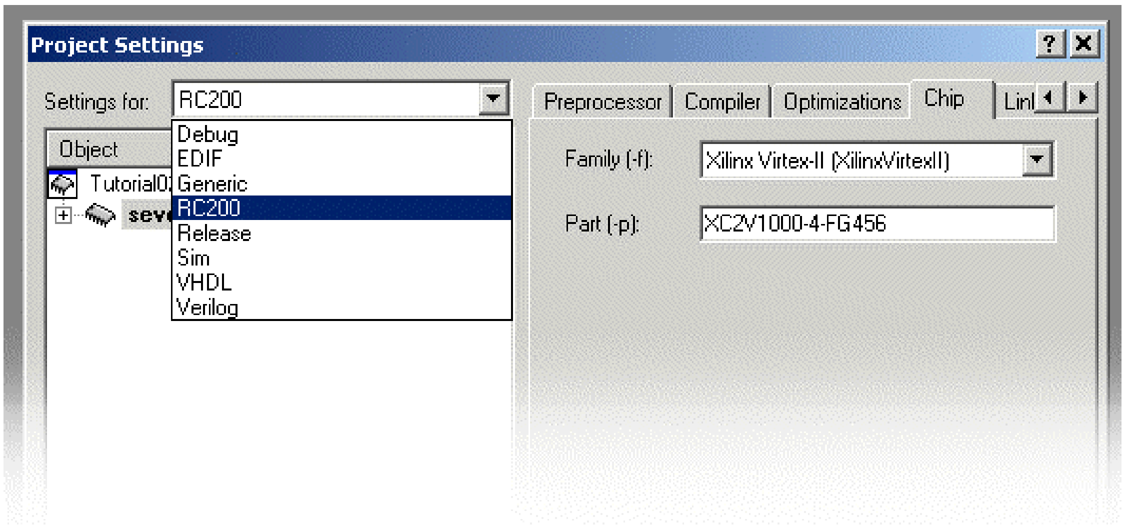
[ ] Ignore standard lib path
[ ] Generate estimation info
[✓] Save browse info
[ ] Exclude timing constraints
[ ] Use netlist simulator

Simulator compilation command line:

```
cl /Zm1000 /LD /Oityb1 /GX /I"D:\Program
Files\Celoxica\DK\sim\include" /Tp"%1" /Fe"%2"
%4
```

LINKER SETTINGS FOR SIMULATION

The RC200 configuration must also be set up in a similar way, but the preprocessor definition should be **USE_RC200**, and the included Handel-C libraries should be **rc200.hcl** and **pal_rc200.hcl**. The **Technology Mapper** should also be enabled, as it allows DK to produce faster circuits. No C++ modules are required to be linked in. As the RC200 is a hardware target, a device type must also be specified. Go to the **Chip** tab in **Project Settings**, make sure that **Family** is set to **Xilinx Virtex-II**, and the **Part** is set to **XC2V1000-4-FG456**, as shown below.


Project Settings

Settings for: RC200

Family (-f): Xilinx Virtex-II (XilinxVirtexII)

Part (-p): XC2V1000-4-FG456

CHIP TYPE SETTINGS FOR RC200

5.1 Seven-segment project in PAL

To use PAL in a project, a target clock rate must be set and the pal_master.hch header file must be included, as shown below. For the seven-segment examples, the clock rate is not very important – a value of 20MHz has been set here.

```
#define PAL_TARGET_CLOCK_RATE 20000000
#include "pal_master.hch"
```

At the start of the project's `main` function, calls should be made to specify what version of PAL is required, and what resources we need to be available. For the seven-segment tutorials we want to use two seven-segment displays, so the required code is as shown below:

```
PalVersionRequire (1, 2);          // require PAL v1.2 or later
PalSevenSegRequire (2);            // require two seven-segment displays
```

Before writing data to the seven-segment displays, they must be enabled using the `PalSevenSegEnable` macro. The parameter to this macro should be a call to the

PalSevenSegCT macro, which itself should be passed a number to index into the requested number of displays, as shown below:

```
PalSevenSegEnable (PalSevenSegCT (0));
PalSevenSegEnable (PalSevenSegCT (1));
```

After enabling the displays, data can be written to them, again using calls to PalSevenSegCT with an index to identify which display to send the data to, as shown below:

```
PalSevenSegWriteDigit (PalSevenSegCT (0), (unsigned 4) 0xE, 0);
PalSevenSegWriteShape (PalSevenSegCT (1), (unsigned 8) 0b11110110);
```

The **TutorialSevenSeg2** workspace has this code in it, set up for **Sim** and **RC200.**

6 Handel-C language basics

The following sections use the PAL seven-segment workspace described above to illustrate the use of some of the Handel-C language operators and constructs which are not present in C or C++. The **TutorialHCBasics** workspace contains the code for this section of the tutorial. Below is a list of the example projects in this section of the tutorial:

Use of parallel code: **ParExample**

Channel communication: **ChanCount**, **ChanCircle**

Bit manipulation: **DropExample**, **TakeExample**, **SelectExample**, **CatExample**

Use of signals: **SignalExample**

6.1 Hardware implementation of examples

The examples in the ***Seven-segment device driver*** (see page 6) and the ***Seven-segment project in PAL*** (see page 15) only wrote static data to the seven-segment displays, but the following examples are going to display continuously changing data. Because the hardware version will be running at tens of MHz, and can not be paused, it will be necessary to slow down some parts of the program so its operation can be observed. To do this the macro shown below will be used. As it uses a call to `log2ceil()`, the `stdlib.hch` header file must be included, and the `stdlib.hcl` library added to the **Linker** tab in the **Project Settings**.

```
/*
 * Sleep for "n" milliseconds
 */
static macro proc Sleep (Milliseconds)
{
    macro expr Cycles = (PAL_ACTUAL_CLOCK_RATE * Milliseconds) / 1000;
    unsigned (log2ceil (Cycles)) Count;

    Count = 0;
    do
    {
        Count++;
    }
    while (Count != Cycles - 1);
}
```

This macro will not be required in simulation, as it will be possible to single-cycle step through the code, so a `#ifndef` will be used, as shown below:

```
#ifndef SIMULATE
Sleep (500);
#endif
```

6.2 Use of parallel code

`par{}` is one of the key Handel-C constructs used to improve the performance of a program. It executes multiple code blocks in parallel. The `seq{}` construct is used to explicitly execute code sequentially, instead of in parallel. Sequential execution is the default if neither `par{}` or `seq{}` is specified.

The **ParExample** project in the **TutorialHCBasics** workspace runs two counters (`Count` and `Circle`) in parallel. They cycle from 0 to 15 and 0 to 5 respectively. `Count` is displayed on one of the seven-segment displays, while `Circle` is used to index the ROM `CircleDisplayEncode`, which contains the appropriate values to display a lit segment moving around a display. The declaration of the variables is shown below:

```
static rom unsigned 8 CircleDisplayEncode[6] = {0x1,0x2,0x4,0x8,0x10};
unsigned 4 Count;
unsigned 3 Circle;
```

After calling the required PAL functions to request and initialize the seven-segment displays, the `Count` and `Circle` variables are initialized to zero, and the following loop is executed forever:

```
while (1)
{
    /*
     * Run the two displays in parallel
     */
    par
    {
        seq
        {
            /*
             * Increment up to 15, then wrap round to 0
             */
            Count++;

            /*
             * Write Count to display
             */
            PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
        }
        seq
        {
            /*
             * Increment up to 5, then reset to 0
             */
            Circle = (Circle == 5) ? 0 : (Circle + 1);

            /*
             * Look up value in ROM, and set display
             */
            PalSevenSegWriteShape  (PalSevenSegCT (1),
CircleDisplayEncode[Circle]);
        }
    }
}
```

Each iteration of the `while(1)` loop takes two clock cycles to complete, as the `par{}` statement causes the two sequential code blocks within it to be executed in parallel. Without the use of `par{}`, the loop would take four clock cycles to execute.

The execution time can in fact be reduced to a single clock cycle by removing the **seq{}** from around the two code blocks, causing all four lines of code to be executed in parallel. This creates a simple two-stage pipeline, as in Handel-C values are only assigned to variables at the end of a clock cycle. Therefore the value displayed would be that held by the counter during the previous clock cycle.

Try executing the **ParExample** project in the **TutorialHCBasics** workspace in simulation, and changing the code to make each loop iteration take 1 or 4 clock cycles. Use the F11 key to step through the code one cycle at a time, and observe its behaviour. If the **Variables Debug Window** is open, and the **Locals** tab selected, the value of the variables in the project will be visible.

If an RC200 board is available, try compiling the project for it, and using the Xilinx Place & Route tools to create a bitfile to download to the board. Note that the call to **Sleep()** will now be active, slowing the program down in the hardware so it can be observed. The behaviour should be the same as that seen in simulation.

6.2.1 Swapping variable values

The **SwapExample** project in the **TutorialHCBasics** workspace shows how the values of two variables can be exchanged in a single clock cycle without using an intermediate location to store the contents of one of them. This is possible because a variable in Handel-C does not take on the value assigned to it until the end of a clock cycle. By assigning the value of each variable to the other in parallel, the contents are swapped in a single cycle, without any intermediate storage. The source code shown below assigns values to the variables and swaps them back and forth, displaying their values on the two 7-segment displays.

The main point of this demonstration is that it is impossible to achieve this behaviour using C with a conventional compiler.

```
/*
 * Initialise x and y
 */
par
{
    x = 3;
    y = 7;
}

while (1)
{
    /*
     * Swap x and y in a single cycle
     */
    par
    {
        x = y;
        y = x;
    }

    /*
     * Write x and y to displays
     */
    par
    {
        PalSevenSegWriteDigit (PalSevenSegCT (0), x, 0);
        PalSevenSegWriteDigit (PalSevenSegCT (1), y, 0);
    }
}
```

6.3 Channel communications

Channels are used for communication between separate processes. They can be used for synchronization and/or to pass data. Synchronization is enforced because the write to and read from the channel must take place in the same clock cycle. This means that a process writing to a channel must wait until data has been read from the channel before proceeding, and a process reading from a channel must wait for the data to be written.

The **ChannelExample** project in the **TutorialHCBasics** workspace uses two processes, one counting a seven-segment display in hexadecimal, and the other circling a lit segment, as shown below.

```
par
{
    while (1)
    {
        unsigned 1 Temp;

        do
        {
            par
            {
                Count++;
                PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
            }
        } while(Count != 0);

        CountChan ! 0;       /* Write to one channel    */
        CircleChan ? Temp;   /* Read from other channel */
    }

    while (1)
    {
        unsigned 1 Temp;

        CountChan ? Temp;    /* Read from one channel    */

        do
        {
            par
            {
                Circle++;
                PalSevenSegWriteShape  (PalSevenSegCT (1),
CircleDisplayEncode[Circle]);
            }
        } while(Circle != 6);

        Circle = 0;          /* Reset Circle for next loop */
        CircleChan ! 0;      /* Write to other channel     */
    }
}
```

The first process counts from 0x0 to 0xF on its display, writes to the CountChan channel, and then reads from the CircleChan channel, before counting again. The second process reads from the CountChan channel, circles a lit segment around the display, writes to the CircleChan channel, and then waits to read from the CountChan channel again.

The channels are only a single bit wide, and are used for synchronization rather than communication of data. The result is that the two 7-segment displays operate alternately, as the channel synchronization ensures that only one process can be executing its display loop at any time.

When a channel is read, it must be read into a variable, so the example uses Temp to receive the value coming from each of the channels. Because this variable is never read from, the optimizer in DK will be able to remove the hardware used by the variable during compilation.

The **ChannelExample** project in the **TutorialHCBasics** workspace is straightforward to run in hardware, but in simulation breakpoints must be set in each of the two parallel loops. This is necessary because otherwise the Debugger will continue to follow the thread it is currently in, and it will not be possible to step through the code in the other thread. By setting breakpoints on the Circle++ and Count++ lines, it will be possible to step through the code continuously, and see both displays operating cycle-by-cycle.

6.4 Bit manipulation examples

The following examples illustrate how to use the four Handel-C bit manipulation operators which are not used in C/C++.

6.4.1 Drop operator

The **DropExample** project in the **TutorialHCBasics** workspace shows how to use the drop bits \\ operator. The source code is shown below:

```
while (1)
{
    par
    {
        /*
         * Increment up to 15, then wrap round to 0
         */
        Count++;

        /*
         * Write Count and Count \\ 1 to display
         */
        PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
        PalSevenSegWriteDigit (PalSevenSegCT (1), adju( (Count \\ 1), 4),
0);
    }
}
```

The \\ operator returns a value with the least ***n*** significant bits dropped.

The value of `Count` is shown on the first 7-segment display; the second display shows `Count` with the lowest bit dropped. The `adju()` macro (from the Standard Library) is used to adjust the width of the modified value of `Count` to four bits, as this is the width required to be passed to `PalSevenSegWriteDigit()`. The example uses `Count \\ 1` to drop a single bit, so while the first display counts from 0 to 0xF, the second counts from 0 to 7, but at half the rate, as shown in Table 1.

Count	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
Display 1	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Count \\ 1	000	000	001	001	010	010	011	011	100	100	101	101	110	110	111	111
Display 2	0	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7

DROP EXAMPLE DISPLAYS

6.4.2 Take operator

The **TakeExample** project in the **TutorialHCBasics** workspace shows how to use the *take bits* <- operator. The source code is shown below:

```
while (1)
{
    par
    {
        /*
         * Increment up to 15, then wrap round to 0
         */
        Count++;

        /*
         * Write Count and Count <- 3 to display
         */
        PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
        PalSevenSegWriteDigit (PalSevenSegCT (1), adju( (Count <- 3), 4),
0);
    }
}
```

The <- operator returns the ***n*** least significant bits from its operand.

The value of Count is shown on the first 7-segment display, while the second display shows the value of the lowest three bits of Count. The adju() macro is used to adjust the width of the modified value of count to four bits, as this is the width required to be passed to PalSevenSegWriteDigit(). The example uses Count <- 3 to take the lowest 3 bits, so while the first display counts once from 0 to 0xF, the second counts twice from 0 to 7, as shown in the table below.

Count	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
Display 1	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Count<-3	000	001	010	011	100	101	110	111	000	001	010	011	100	101	110	111
Display 2	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7

TAKE EXAMPLE DISPLAYS

6.4.3 Select operator

The **SelectExample** project in the **TutorialHCBasics** workspace shows how to use the *select bits* ***[m:n]*** operator. The source code is shown below:

```
while (1)
{
    par
    {
        /*
         * Increment up to 15, then wrap round to 0
         */
        Count++;

        /*
         * Write Count and Count[2:1] to display
         */
        PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
        PalSevenSegWriteDigit (PalSevenSegCT (1), adju( (Count[2:1]), 4),
0);
    }
}
```

The ***[m:n]*** operator returns bits ***m*** to ***n*** from its operand.

The value of `Count` is shown on the first 7-segment display, while the second display shows the value of the middle two bits of `Count`. The `adju()` macro is used to adjust the width of the modified value of count to four bits, as this is the width required to be passed to `PalSevenSegWriteDigit()`. The example uses `Count[2:1]` to select the middle two of four bits, so while the first display counts once from 0 to 0xF, the second counts twice from 0 to 3 at half the rate, as shown in the table below.

Count	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
Display 1	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Count[2:1]	00	00	01	01	10	10	11	11	00	00	01	01	10	10	11	11
Display 2	0	0	1	1	2	2	3	3	0	0	1	1	2	2	3	3

SELECT EXAMPLE DISPLAY VALUES

6.4.4 Concatenate operator

The **CatExample** project in the **TutorialHCBasics** workspace shows how to use the *concatenate bits* @ operator. The source code is shown below:

```
while (1)
{
    par
    {
        /*
         * Increment up to 15, then wrap round to 0
         */
        Count++;

        /*
         * Write Count and (Count[2:0] @ 0) to display
         */
        PalSevenSegWriteDigit (PalSevenSegCT (0), Count, 0);
        PalSevenSegWriteDigit (PalSevenSegCT (1), Count[2:0] @ 0, 0);
    }
}
```

The @ operator joins together two operands to form a result whose width is equal to the sum of the operand widths. In this case that means the adju() macro does not need to be called, as three bits are selected from Count, and DK will infer that the concatenated zero should be one bit wide, giving the required total of four bits.

The value of Count is shown on the first 7-segment display, while the second display shows the value of the low three bits of Count with zero concatenated at the right. The result is that while the first display counts once from 0 to 0xF, the second counts 0, 2, 4, 6, 8, A, C, E twice, as shown in the table below.

Count	0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111
Display 1	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Count[2:0]@0	0000	0010	0100	0110	1000	1010	1100	1110	0000	0010	0100	0110	1000	1010	1100	1110
Display 2	0	2	4	6	8	A	C	E	0	2	4	6	8	A	C	E

CONCATENATE EXAMPLE DISPLAY VALUES

6.5 Using signals

Signal variables can be assigned to and read from *in the same clock cycle*. They hold their value ONLY for that clock cycle.

The source code for the example shown below sets a signal equal to the value of Count1 + 1, then uses this signal in two separate places, to set counters used to drive the two 7-

segment displays. Although this example is very simple, it illustrates how signals can be used to eliminate common sub-expressions, and make code more readable.

```
unsigned 4 Count1;
unsigned 4 Count2;
unsigned 4 Count3;
signal <unsigned 4> CountSig;

while (1)
{
    /*
     * Increment up to 15, then wrap round to 0
     */
    Count1++;

    par
    {
        CountSig = Count1 * 2;  /* Assign value to the signal,   */
        Count2 = CountSig;      /* use the value from the signal */
        Count3 = CountSig + 1;  /* and use it again here         */
    }

    /*
     * Write Count2 and Count3 to display
     */
    PalSevenSegWriteDigit (PalSevenSegCT (0), Count2, 0);
    PalSevenSegWriteDigit (PalSevenSegCT (1), Count3, 0);
}
```

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