XK-1A Development Board Tutorial

IN THIS DOCUMENT

1 Introduction

The XK-1A is a low-cost development board based on the XMOS XS1-L1 device. It includes a single L1, four LEDs, two press-buttons, SPI flash memory, two 16-way IDC connectors and an XSYS debugging interface.

This tutorial shows you how to write some simple XC programs that control and respond to the XK-1A board components. In this tutorial you learn how to:

- illuminate the LEDs
- flash the LEDs at a fixed rate
- flash the LEDs in sequence
- respond to a button press
- connect multiple boards together

2 Illuminate an LED

This part of the tutorial shows you how to illuminate an LED on your XK-1A, using an XC port and an output statement.

2.1 Create a project

2.2 Add the application code

The program below illuminates an LED on an XK-1A.

```
#include <xs1.h>

out port led = XS1_PORT_4F;
```

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```
int main () {
  led <: 0b0001;
  while (1)
    ;
  return 0;
}
```

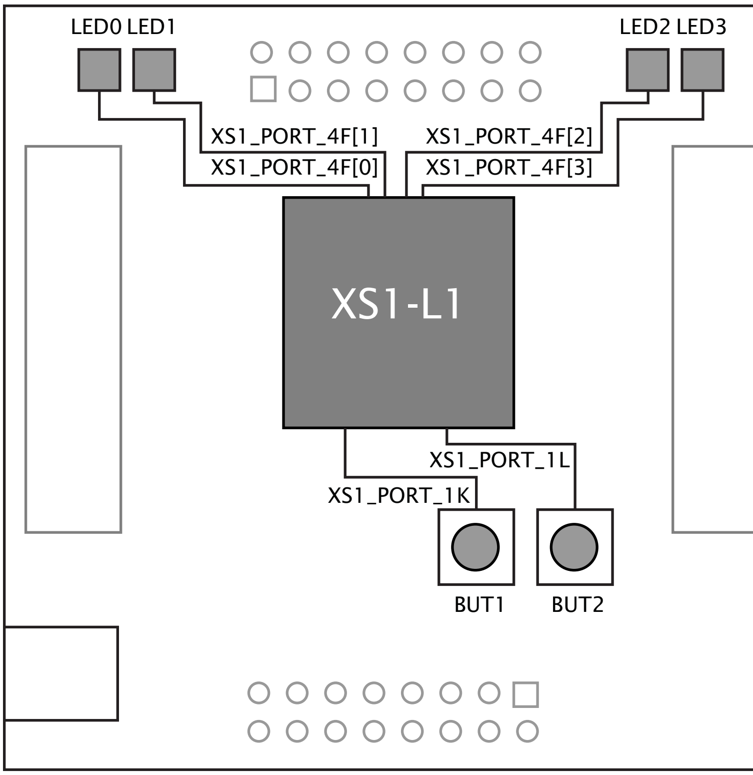
Copy and paste the code into your project, and then choose **File ▶ Save** () to save your changes to file.

2.3 Examine the code

Take a look at the code in the editor. The declaration

```
    out port led = XS1_PORT_4F;
```

declares an output port named `led`, which refers to the 4-bit port 4F. On the XK-1A, the I/O pins of port 4F are connected to the LEDs labeled LED0, LED1, LED2 and LED3.



Show image of port map..

XC input and output statements make it easy to express I/O operations on ports. The statement

```
led <: 0b0001;
```

causes the value specified to the right of `<:` to be output to the port specified to its left (`led`). The port then drives LED0 high and the other LEDs low, causing LED0 to illuminate yellow and the other LEDs to remain off.

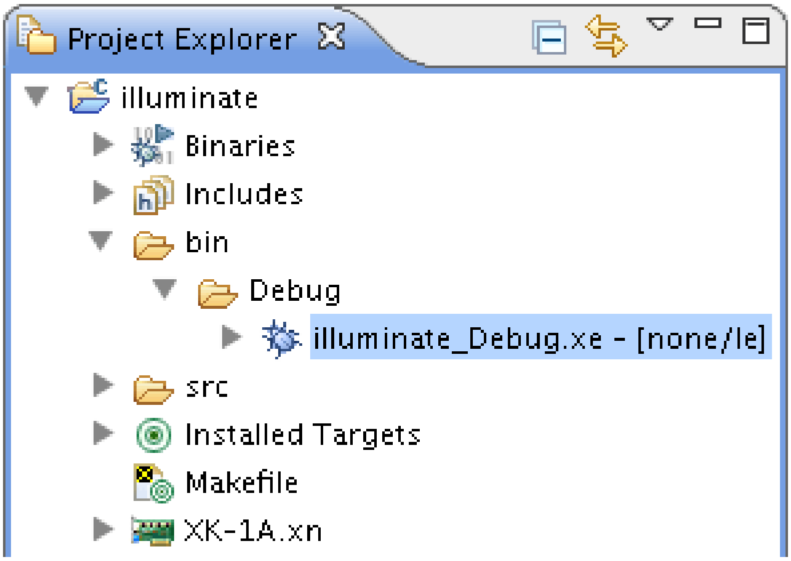
The empty `while` loop prevents the program from terminating, which ensures that the LED remains illuminated.

2.4 Build and run your project

To build and run your project, follow these steps:

1. In the **Project Explorer**, click your project to select it, and then choose the menu option **Project ▶ Build Project** ( ).

   The XDE displays its progress in the **Console**. When the build is complete, the XDE adds the compiled binary file to the subfolder `bin/Debug`.

2. Choose **Run ▶ Run Configurations**.

3. In the **Run Configurations** dialog, in the left panel, double-click **XCore Application**.

4. In the right panel, in **Name**, enter the name `illuminate`.

5. In **Project**, ensure that your project is displayed. If not, click **Browse** to open the **Project Selection** dialog, select your project, and then click **OK**.
6. In **C/C++ Application**, click **Search Project** to open the **Program Selection** dialog, select your application binary, and then click **OK**.
7. In **Device options**, in **Run on**, select the option **hardware**, and in **Target**, ensure that the option “XMOS XTAG-2 connected to L1[0]” is selected.

   If your hardware is not displayed, ensure that your XK-1A is connected to your PC, and then click **Refresh list**.
8. Click **Run** to save your configuration and run it.

   The XDE loads the binary onto your XK-1A, displaying its progress in the **Console**. When the binary is loaded, the **Console** is cleared.
9. On your XK-1A, verify that LED0 is illuminated yellow.
10. In the **Console**, click the **Terminate** button () to stop your application running.

2.5 Exercise

To complete this part of the tutorial, perform the following steps:

1. Modify your application so that it illuminates all four LEDs.

   Show a tip..

   You should change the value output to the port `led` so that all four LEDs are driven high.

   Show a sample answer..

```
#include <xs1.h>

out port led = XS1_PORT_4F;

int main () {
  led <: 0b1111;
  while (1)
    ;
  return 0;
}
```

2. Click the **Run** button () to reload your last Run Configuration.

   The XDE determines that your source code has been updated and re-builds it, displaying progress in the **Console**.

   If your application contains errors, the XDE displays a dialog asking if you want to continue launching the application. Click **No**, locate the first error in the **Console** and double-click it to go to the offending line in the editor. When you have fixed all errors, re-run your application.

3. On your XK-1A, verify that all four LEDs are illuminated, and then click the **Terminate** button () to stop your application running.

3 Flash an LED

This part of the tutorial shows you how to flash an LED at a fixed rate, using an XC timer and an input statement.

3.1 Create a new project

3.2 Add the application code

The program below flashes a single LED on an XK-1A.

```
#include <xs1.h>

#define FLASH_PERIOD 20000000

out port led = XS1_PORT_4F;

int main (void) {
  timer tmr;
  unsigned isOn = 1;
  unsigned t;
  tmr :> t;
  while (1) {
    led <: isOn;
    t += FLASH_PERIOD;
    tmr when timerafter (t) :> void;
    isOn = !isOn;
  }
  return 0;
}
```

Copy and paste the code into your project, and then choose **File** ▶ **Save** () to save your changes to file.

3.3 Examine the code

Take a look at the code in the editor. The declaration

```
timer tmr;
```

declares a variable named `tmr`, and allocates an available hardware timer. The L1 provides 10 timers, which can be used to determine when an event happens, or to delay execution until a particular time. Each timer contains a 32-bit counter that is incremented at 100MHz and whose value can be input at any time.

The statement

```
tmr :> t;
```

inputs the value of `tmr`'s counter into the variable `t`. Having recorded the current time, the statement

```
t += FLASH_PERIOD;
```

increments this value by the required delay, and the statement

```
tmr when timerafter(t) :> void;
```

delays inputting a value until the specified time is reached. The input value is not needed, which is expressed as an input to `void`.

3.4 Build and run your project

To build and run your project, follow these steps:

1. In the **Project Explorer**, click your project to select it, and then choose the menu option **Project ▸ Build Project** (🔨).

   The XDE builds your project, displaying its progress in the **Console**. When the build is complete, the XDE adds the compiled binary file to the application subfolder `bin/Debug`.

2. Create a new Run Configuration for your application named `flash`, and run it.

   Show reminder..

   Follow these steps:

3. Choose **Run ▸ Run Configurations**.

4. In the **Run Configurations** dialog, in the left panel, double-click **XCore Application**.

5. In the right panel, in **Name**, enter the name `flash`.

6. In **Project**, ensure that your project is displayed. If not, click **Browse** to open the **Project Selection** dialog, select your project, and then click **OK**.

7. As there are now two applications in your project, the XDE is unable to select one automatically. To select, in **C/C++ Application**, click **Search Project** to open the **Program Selection** dialog, select your application binary, and then click **OK**.

8. In **Device options**, in **Run on**, select the option **hardware**, and in **Target**, ensure that the option "XMOS XTAG-2 connected to L1[0]" is selected.

   If you did not stop your previous application running, your hardware may be displayed as "XMOS XTAG-2 connected to None".

9. Click **Run** to save your configuration and run it.

   The XDE loads the binary onto your XK-1A, displaying its progress in the **Console**. When the binary is loaded, the **Console** is cleared.

10. On your XK-1A, verify that LED0 is flashing on-off, and then click the **Terminate** button () to stop your application running.

3.5 Switch between projects

The **Run** button (▷) can be used to switch between projects. To complete this part of the tutorial, follow these steps:

1. Click the arrow to the right of the **Run** button and select the Run Configuration named `illuminate`.
2. On your XK-1A, verify that all four LEDs are illuminated.
3. Click the arrow to the right of the **Run** button and select the Run Configuration named `flash`.
4. On your XK-1A, verify that LED0 is flashing on-off.
5. Modify the source of the flashing LED application to change the value of `FLASH_PERIOD` from 20000000 to 40000000.
6. To build and run, just click the **Run** button.

   The XDE launches the Run Configuration you most recently selected.
7. On your XK-1A, verify that LED0 is flashing on-off at half the rate it was flashing previously, and then click the **Terminate** button () to stop your application running.

3.6 Exercise

To complete this part of the tutorial, perform the following steps:

1. Modify your flashing LED application so that both LED0 and LED1 are flashed, with LED0 flashed twice as fast as LED1.

   Show a tip..

   You should output the following pattern to the port `led`: 0b0011, 0b0010, 0b0011, 0b0010, 0b0001, 0b0000, 0b0001 and 0b0000.

   Explain the solution in more detail..

   You can define an array of integers an initialize it with the values 0b0011, 0b0010, 0b0011, 0b0010, 0b0001, 0b0000, 0b0001 and 0b0000. Then use a loop to output this sequence of values to the port 4F.

   Show a sample answer..

```
#include <xs1.h>

#define FLASH_PERIOD 20000000

out port led = XS1_PORT_4F;
```

```
int pattern[] = {0b0011,
                 0b0010,
                 0b0011,
                 0b0010,
                 0b0001,
                 0b0000,
                 0b0001,
                 0b0000};

int main (void) {
  timer tmr;
  unsigned t;
  unsigned i = 0;
  tmr :> t;
  while (1) {
    t += FLASH_PERIOD;
    tmr when timerafter (t) :> void;
    led <: pattern[i];
    i = (i+1) % 8;
  }
  return 0;
}
```

2. Run your application.
3. On your XK-1A, verify that the two LEDs are flashing at different speeds, and then click the **Terminate** button () to stop your application running.

4 Flash and cycle LEDs at different rates

This part of the tutorial shows you how to flash an LED while cycling it along the LEDs on your XK-1A.

4.1 Create an application

The program below inputs from one of two timers in a loop.

```
#include <xs1.h>

#define FLASH_PERIOD 10000000
#define CYCLE_PERIOD 50000000

out port led = XS1_PORT_4F;

int main (void) {
  timer tmrF, tmrC;
  unsigned timeF, timeC;

  tmrF :> timeF;
  tmrC :> timeC;
  while (1) {
    select {
      case tmrF when timerafter(timeF) :> void :
        /* add code to respond to timeout */
        break;
      case tmrC when timerafter(timeC) :> void :
        /* add code to respond to timeout */
        break;
    }
  }
  return 0;
}
```

Before continuing to the next part of this tutorial, create a new project using this code.

4.2 Examine the application code

Take a look at the application code in the editor. The first statement in `main` inputs the value of the timer `tmrF` into the variable `timeF`, and the second statement inputs the value of the timer `tmrC` into the variable `timeC`.

In the `while` loop, the `select` statement waits for the an input on either `tmrF` or `tmrC` to become ready. It then performs the selected input and executes any code after it up until the keyword `break`.

If more than one input becomes ready at the same time, only one is executed in a single iteration of the loop; the other input is selected on the following iteration.

4.3 Exercise 1

To complete this part of the tutorial, perform the following tasks:

1. Modify the application so that:
   - On each input from `tmrC`, the program changes which LED is flashed, cycling between all four LEDs in sequence.
   - On each input from `tmrF`, the program changes the state of the current LED bewteen on and off.

   Show a sample answer..

```
#include <xs1.h>

#define FLASH_PERIOD 10000000
#define CYCLE_PERIOD 50000000

out port led = XS1_PORT_4F;

int main(void) {

  unsigned ledOn = 1;
  unsigned ledVal = 1;
  timer tmrF, tmrC;
  unsigned timeF, timeC;

  tmrF :> timeF;
  tmrC :> timeC;

  while (1) {
    select {
      case tmrF when timerafter(timeF) :> void:
        ledOn = !ledOn;
        if (ledOn)
          led <: ledVal;
            else
          led <: 0;
        timeF += FLASH_PERIOD;
        break;
      case tmrC when timerafter(timeC) :> void:
        ledVal <<= 1;
        if (ledVal == 0x10)
          ledVal = 1;
        timeC += CYCLE_PERIOD;
        break;
    }
  }
  return 0;
}
```

2. Build your project, create a new Run Configuration, and run it.

   Show reminder..

   Follow these steps:

3. In the **Project Explorer**, click your project to select it, and then choose the menu option **Project** ▶ **Build Project** (🔨).

   If any errors are reported in the **Console**, double-click an error to locate it in the editor, fix the error and then re-build your application.

4. Choose **Run** ▶ **Run Configurations**.

5. In the **Run Configurations** dialog, in the left panel, double-click **XCore Application**.

6. In the right panel, in **Name**, enter a name for the Run Configuration.

7. In **Project**, ensure that your project is displayed. If not, click **Browse** to open the **Project Selection** dialog, select your project, and then click **OK**.

8. In **C/C++ Application**, click **Search Project** to open the **Program Selection** dialog, select your application binary, and then click **OK**.

9. In **Device options**, in **Run on**, select the option **hardware**, and in **Target**, ensure that the option "XMOS XTAG-2 connected to L1[0]" is selected.

10. Click **Run** to save your configuration and run it.

    The XDE loads the application binary onto your XK-1A, displaying its progress in the **Console**. When the binary is loaded, the **Console** is cleared.

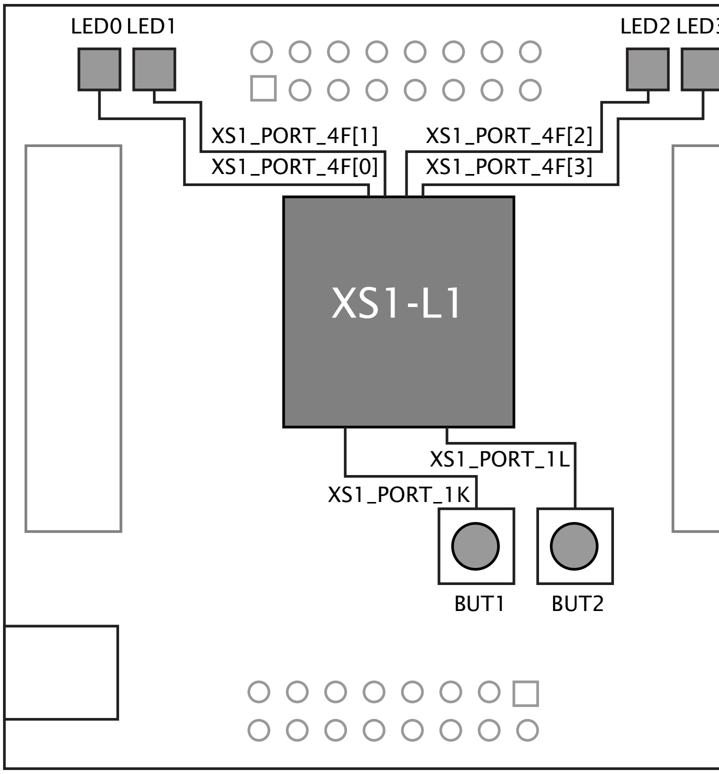
11. On your XK-1A, verify that a flashing LED is cycled between the four LEDs, and then click the **Terminate** button () to stop your project running.

4.4 Exercise 2

To complete this part of the tutorial, perform the following tasks:

1. Add an additional case to the `select` statement that responds to Button 1 being pressed by displaying the string “pressed” on the console, and then waits for Button 1 to be released and displays the string “released”.

   Note that Button 1 drives a 1-bit port high. Pressing the button causes it to stop driving the port, and releasing results in it driving again. You can test for these conditions using the input condition `pinseq(0)` and `pinseq(1)`.



Show image of port map..

To print a message to the console, you can include the standard C library header `stdio.h` and use the the library function `printf`.

Explain the solution in more detail..

Follow these steps:

2. At the top of your source file, include the header file `stdio.h`.
3. Define an input port named `but1` and initialize it with the value `XS1_PORT_1K`.
4. In the `select` statement, add the following case statement:

   `case but1 when pinseq(0) :> void:`
5. In the body of this case, first call the function `printf` to display the first message; then input from the button when the value sampled on the pin equals 1; and then call `printf` again to display the second message.

   Show a sample answer..

```
#include <xs1.h>
#include <stdio.h>

#define FLASH_PERIOD 10000000
#define CYCLE_PERIOD 50000000

out port led = XS1_PORT_4F;
in port but1 = XS1_PORT_1K;

int main(void) {

  unsigned ledOn = 1;
  unsigned ledVal = 1;
  timer tmrF, tmrC;
  unsigned timeF, timeC;

  tmrF :> timeF;
  tmrC :> timeC;

  while (1) {
    select {
      case tmrF when timerafter(timeF) :> void:
        ledOn = !ledOn;
        if (ledOn)
          led <: ledVal;
            else
          led <: 0;
        timeF += FLASH_PERIOD;
        break;
      case tmrC when timerafter(timeC) :> void:
        ledVal <<= 1;
        if (ledVal == 0x10)
          ledVal = 1;
        timeC += CYCLE_PERIOD;
        break;
      case but1 when pinseq(0) :> void:
        printf("Pressed\n");
        but1 when pinseq(1) :> void;
        printf("Released\n");
```

```
          break;
      }
    }
    return 0;
}
```

6. Run your application.

   A flashing LED should cycle between the four LEDs on your XK-1A.

7. Verify that pressing and holding button BUT1 causes the message “pressed” be displayed in the **Console** and the LEDs to stop flashing. Releasing the button should cause the message “released” to be displayed and the flashing LED should continue cycling.

   Note that you may need to push the button down firmly on your XK-1A to operate it.

8. In the **Console**, click the **Terminate** button () to stop your application running.

5 Run tasks concurrently

This part of the tutorial shows you how to run tasks concurrently on different threads, using the XC `par` statement and channel communication.

5.1 Create a project

The program below creates two concurrent threads, which run two separate tasks independently of each other.

```
#include <xs1.h>
#include <stdio.h>

#define FLASH_PERIOD 10000000
#define CYCLE_PERIOD 50000000

out port led = XS1_PORT_4F;
in port but1 = XS1_PORT_1K;

void flashLEDs4bitPort(out port led, int flashPeriod, int cyclePeriod) {
  /* Code to flash 4 LEDs connected to a 4-bit port in a cycle */
  unsigned ledOn = 1;
  unsigned ledVal = 1;
  timer tmrF, tmrC;
  unsigned timeF, timeC;

  tmrF :> timeF;
  tmrC :> timeC;

  while (1) {
    select {
      case tmrF when timerafter(timeF) :> void:
        ledOn = !ledOn;
        if (ledOn)
          led <: ledVal;
```

```
            else
              led <: 0;
            timeF += FLASH_PERIOD;
            break;
          case tmrC when timerafter(timeC) :> void:
            ledVal <<= 1;
            if (ledVal == 0x10)
              ledVal = 1;
            timeC += CYCLE_PERIOD;
            break;
        }
    }
}

void respondToButton(in port but) {
  /* Code to respond to a button press */
 while (1) {
    but when pinseq(0) :> void;
    printf("Pressed\n");
    but when pinseq(1) :> void;
    printf("Released\n");
  }
}

int main(void) {
  par {
    flashLEDs4bitPort(led, FLASH_PERIOD, CYCLE_PERIOD);
    respondToButton(but1);
  }
  return 0;
}
```

Before continuing to the next part of this tutorial, create a new project using this code.

5.2 Examine the application code

Take a look at the code in the editor. In `main`, the two statements inside the braces of the `par` are run concurrently: the current thread allocates a new hardware thread; the current thread then runs the function `flashLEDs4bitPort`; and the new thread runs the function `respondToButton`. The L1 device has a total of eight available hardware threads.

To complete this part of the tutorial, perform the following tasks:

1. Build your project, create a new Run Configuration, and run it.
2. Verify that a flashing LED cycles between the four LEDs on your XK-1A. Pressing and holding button BUT1 should cause the message “pressed” be displayed in the **Console** and the LEDs should continue to flash. Releasing the button should cause the message “released” to be displayed.
3. In the **Console**, click the **Terminate** button () to stop your project running.

5.3 Communicate between threads

A **channel** provides a synchronous, bidirectional link between two threads. It consists of two channel ends, which two threads can use to interact on demand using the XC input and output statements.

The program below creates two threads which are connected using a channel, and communicates a value over this channel.

```
void snd(chanend cout) {
  cout <: 1;
}

void rcv(chanend cin) {
  int x;
  cin :> x;
}

int main (void) {
  chan c;

  par {
    snd(c);
    rcv(c);
  }

  return 0;
}
```

The function `snd` declares a channel end parameter `cout`, which refers to one end of a channel. It uses the XC output statement to output the value 1 to a receiving thread.

The function `rcv` declares a channel end parameter `cin` and uses the XC input statement to input a value to the local variable `x`.

The function `main` declares a channel `c`. The locations of its two channel ends are established through its use in two statements of the `par`.

5.4 Exercise 1

To complete this part of the tutorial, perform the following tasks:

1. Modify your application so that after pressing and releasing button BUT1, the flashing LED changes direction. This requires the function `respondToButton` to communicate with the function `flashLEDs4bitPort`.

   Explain the solution in more detail..

   Follow these steps:

2. In the function `respondToButton`:
   - Add a parameter declaration `chanend c`.

- After the button is released, output a value 0 to this channel.

3. In the function `flashLEDs4bitPort`:
   - Add a parameter declaration `chanend c`.
   - Add a variable declaration `unsigned direction` and initialize to 0.
   - Add a case to the `select` statement that inputs from channel `c`, and in the body of this case update the variable `direction`.
   - Modify the body of the case statement that inputs from `tmrC` so that the next LED flashed depends upon the value of the variable `direction`.

   Show a sample answer..

```
#include <xs1.h>
#include <stdio.h>

#define FLASH_PERIOD 10000000
#define CYCLE_PERIOD 50000000

out port led = XS1_PORT_4F;
in port but1 = XS1_PORT_1K;

void flashLEDs4bitPort(out port led, chanend c, int flashPeriod, int
  ↪ cyclePeriod) {
  /* Code to flash 4 LEDs connected to a 4-bit port in a cycle */
  unsigned ledOn = 1;
  unsigned ledVal = 1;
  unsigned direction = 0;
  timer tmrF, tmrC;
  unsigned timeF, timeC;

  tmrF :> timeF;
  tmrC :> timeC;

  while (1) {
    select {
      case tmrF when timerafter(timeF) :> void:
        ledOn = !ledOn;
        if (ledOn)
          led <: ledVal;
            else
          led <: 0;
        timeF += FLASH_PERIOD;
        break;
      case tmrC when timerafter(timeC) :> void:
        if (direction) {
          ledVal <<= 1;
          if (ledVal == 0b10000)
            ledVal = 1;
        }
        else {
          ledVal >>= 1;
          if (ledVal == 0)
            ledVal = 0b1000;
        }
        timeC += CYCLE_PERIOD;
        break;
      case c :> int x :
        direction = !direction;
        break;
      }
    }
}

void respondToButton(in port but, chanend c) {
  /* Code to respond to a button press */
  while (1) {
    but when pinseq(0) :> void;
    printf("Pressed\n");
    but when pinseq(1) :> void;
    printf("Released\n");
    c <: 0;
  }
}

int main(void) {
  chan c;
  par {
    flashLEDs4bitPort(led, c, FLASH_PERIOD, CYCLE_PERIOD);
    respondToButton(but1, c);
  }
  return 0;
}
```

4. Run your application.

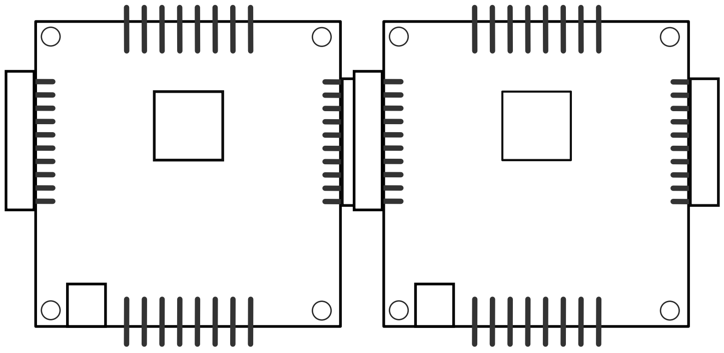
   A flashing LED should cycle between the four LEDs on one of the XK-1As.

5. On your XK-1A, verify that pressing and releasing button BUT1 causes the flashing LED to change direction, and then click the **Terminate** button () to stop your project running.

5.5 Exercise 2

This part of the tutorial shows you how to put ports and threads on different processor cores. It requires you to have two XK-1As available. Follow these steps:

1. Connect the two XK-1As together.



2. Choose **File ▸ New ▸ XDE Source File** ().

3. In the **New XDE Source File** dialog, in **File Name**, enter the name `Dual-XK1A.xn`.
4. In **Location**, ensure that your project folder is selected.
5. Click **Finish**.

   The XDE creates an empty source file, adds it to your application and opens it in the editor.
6. At the bottom left of the editor, click the **Source** tab, copy the code in the window below into your new source file, and then save it.

```
<?xml version="1.0" encoding="UTF-8"?>

<Network xmlns="http://www.xmos.com"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://www.xmos.com http://www.xmos.com"
     ↪ >

  <Declarations>
    <Declaration>core stdcore[2]</Declaration>
  </Declarations>

  <Packages>
    <Package Id="P1" Type="XS1-L1A-TQ128">
      <Nodes>
        <Node Id="Master" Type="XS1-L1A" InPackageId="0"
              Oscillator="20MHz" SystemFrequency="400MHz">
          <Boot>
            <Source Location="SPI:bootFlash"/>
            <Bootee NodeId="Slave" Core="0"/>
          </Boot>
          <Core Number="0" Reference="stdcore[0]">
            <Port Location="XS1_PORT_1A" Name="PORT_SPI_MISO"/>
            <Port Location="XS1_PORT_1B" Name="PORT_SPI_SS"/>
            <Port Location="XS1_PORT_1C" Name="PORT_SPI_CLK"/>
            <Port Location="XS1_PORT_1D" Name="PORT_SPI_MOSI"/>
            <Port Location="XS1_PORT_4A" Name="PORT_LED"/>
          </Core>
        </Node>
      </Nodes>
    </Package>

    <Package Id="P2" Type="XS1-L1A-TQ128">
      <Nodes>
        <Node Id="Slave" Type="XS1-L1A" InPackageId="0"
              Oscillator="20Mhz" SystemFrequency="400MHz">
          <Boot>
            <Source Location="XMOSLINK"/>
          </Boot>
          <Core Number="0" Reference="stdcore[1]">
            <Port Location="XS1_PORT_1K" Name="PORT_BUTTON"/>
          </Core>
        </Node>
      </Nodes>
    </Package>
  </Packages>

  <Links>
    <Link Encoding="2wire" Delays="4,4">
      <LinkEndpoint NodeId="Master" Link="X0LD"/>
      <LinkEndpoint NodeId="Slave" Link="X0LC"/>
    </Link>
  </Links>

  <ExternalDevices>
    <Device NodeId="Master" Core="0" Name="bootFlash"
            Class="SPIFlash" Type="AT25FS010">
      <Attribute Name="PORT_SPI_MISO" Value="PORT_SPI_MISO"/>
      <Attribute Name="PORT_SPI_SS"   Value="PORT_SPI_SS"/>
      <Attribute Name="PORT_SPI_CLK"  Value="PORT_SPI_CLK"/>
      <Attribute Name="PORT_SPI_MOSI" Value="PORT_SPI_MOSI"/>
    </Device>
  </ExternalDevices>

  <JTAGChain>
    <JTAGDevice NodeId="Master" Position="0"/>
    <JTAGDevice NodeId="Slave" Position="1"/>
  </JTAGChain>

</Network>
```

7. Make it default target
8. In the **Project Explorer**, expand your new file to reveal the header file `platform.h`, and expand this header to reveal the symbols `stdcore[0]` and `stdcore[1]`.

   These symbols name the two processor cores for your new target, which can be referred to in your XC application.
9. In your XC source file, change the header include file `<xs1.h>` to `<platform.h>`.
10. Modify the declaration of the port `led` to place it on the first core, as shown below:

    ```
    on stdcore [0]: out port led = XS1_PORT_4F;
    ```
11. Modify the declaration of the port `but1` to place it on the second core.
12. Modify the call to the function `flashLED` to place it on the first core, as shown below:

    ```
    on stdcore [0]:  flashLED(arguments);
    ```
13. Modify the call to the function `respondToButton` to place it on the second core.
14. In the **Project Explorer**, expand your project and application folder, and then double-click on the file `Makefile`.

15. In the Makefile editor, in **Target**, select the option **Dual-XK1A**, and then choose **File ▶ Save** () to save your changes to file.

16. Run your application.

    A flashing LED should cycle between the four LEDs on one of the XK-1As. Pressing and releasing button BUT1 on the other XK-1A should cause the direction of the flashing LED to change.

6 What to read next

This tutorial provides only a basic introduction the XK-1A hardware.

For more information on the board refer to the XK-1A Hardware Manual[1].

For more information on programming in XC see Programming XC on XMOS Devices[2].

[1] http://www.xmos.com/published/xk1ahw
[2] http://www.xmos.com/published/xc_en