MCUXpresso IDE LinkServer SWO Trace Guide

Rev. 10.2.0 — 14 May, 2018

User guide

14 May, 2018

1. Trace Overview

There are two different kinds of tracing technologies available directly within MCUXpresso IDE.

- **Instruction Trace** - capturing an instruction stream within onboard RAM of the MCU. This data can then be retrieved, decoded, and displayed within the IDE.
  - Available with any supported debug probe.
- **SWO Trace** - capturing events occurring on a running MCU in real time
  - Only available with LPC-Link2 debug probes (using MCUXpresso IDE's CMSIS-DAP probe firmware).

The Trace functionality available depends on the features supported by your target MCU and the features supported by your debug probe.

The rest of this guide looks at SWO Trace. For information regarding Instruction Trace, see the Instruction Trace Guide.

Compatibility

Use of MCUXpresso IDE's SWO Trace functionality requires connection to the target MCU using an LPC-Link2 with MCUXpresso IDE's CMSIS-DAP firmware (standalone or built into many LPCXpresso development boards). It cannot be used with other CMSIS-DAP based probes or with P&E or SEGGER J-Link debug probes). However, non-LinkServer probes may provide SWO trace capabilities via other software – check the vendors' websites for more details.

Note that SWO Trace may sometimes be referred to as SWV Trace (Serial Wire Viewer). Even the ARM documentation uses the two terms interchangeably.

1.1 Serial Wire Output (SWO)

ARM's Coresight debug architecture allows data to be sampled and streamed from the MCU to the host completely nonintrusively. This scheme allows events such as periodic PC sampling, interrupts, etc. to be captured and transmitted by the debug probe **with no effect on MCU performance** and without the need for any code instrumentation or changes.

The Serial Wire Output (SWO) tools provide access to the memory of a running target, and facilitate Trace without needing to interrupt the target. Support for SWO is generally provided by all Cortex-M3 and M4 based MCUs. It requires just one extra pin in addition to the standard Serial Wire Debug (SWD) connection (but cannot be used if a JTAG debug connection is being used). Cortex-M0 and Cortex-M0+ based MCUs do not have SWO capabilities.

MCUXpresso IDE presents target information collected using SWO from a Cortex-M3/M4 based MCU in several different Views.

Table 1.1. SWO trace feature

Feature	SWO Trace
Data watch	yes
Profile	yes
Interrupt Statistics	yes
Graphical Interrupt Trace	yes
ITM text console	yes
Counters	yes

Note : New in MCUXpresso IDE version 10.2.0 – all trace features are available in the 'Free Edition'. In earlier version of MCUXpresso IDE, certain features such as Graphical Interrupt Trace were restricted to the 'Pro' edition.

1.2 SWO Trace: Views

You can configure SWO Trace and see the collected data in a set of Views.

SWO Config

- Provides quick access to the SWO Trace Views and shows the status of the SWO Trace connection

SWO Profile

- Provides a statistical profile of application activity

SWO ITM Console

- A debug console for reading and writing text to and from your application

SWO Int Stats

- Provides counts and timing information for interrupts and interrupt handlers

SWO Int Trace

- Plots a time-line trace of interrupts

SWO Int Table

- Lists the raw entry, exit, and return SWO events for interrupt handlers

SWO Data

- Provides the ability to monitor (and update) up to four memory locations in real time, without stopping the CPU

SWO Counters

- Displays the target's performance counters

SWO Stats

- Displays Trace channel bandwidth usage and low-level debug information related to the SWO Trace connection

The **SWO Config** View is presented within the **Debug Perspective** or the **Develop Perspective** by default. This View can be used to easily show and hide the other SWO Trace Views. Trace Views that are not required may be closed to simplify the user interface. They may also be opened using the **Window -> Show View -> Other...** menu item.

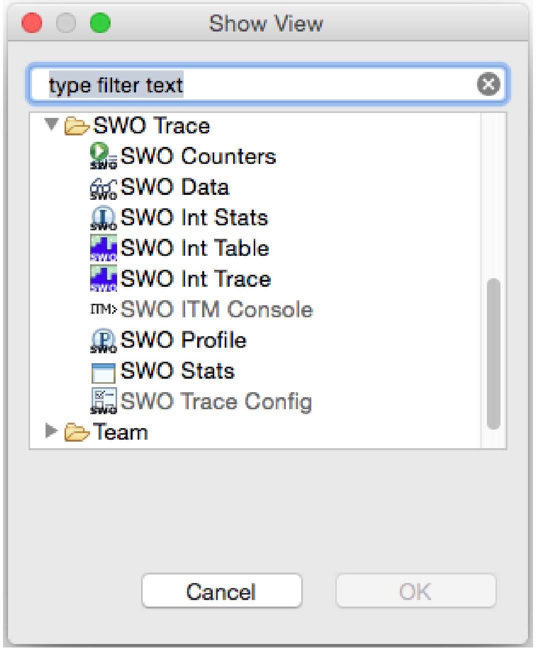


Figure 1.1. Reopening a View

1.3 Starting SWO Trace

To use SWO Trace’s features, you must be debugging an application on a Cortex-M3/M4 based MCU, connected via a supported LPC-Link2 debug probe using the SWD protocol.

You may start SWO Trace at any time while debugging your program. The program does **not** have to be stopped at a breakpoint or paused. Before the collection of data commences, SWO Trace may prompt you to enter the target clock speed.

Trace collection for each View is controlled by the buttons in its toolbar.

- - starts Trace collection for that View
- - stops Trace collection for that View
- - deletes the collected Trace from the View
- - opens the **SWO Config** View

More than one View may be configured to collect Trace at a time. However, the bandwidth of the Trace channel is limited and may become saturated, resulting in data loss. Try disabling other SWO Trace Views if you do not see Trace data coming through. The **SWO Stats** View provides an overview of the SWO channel load.

1.3.1 Target Clock Speed

Due to the way the Trace data is transferred by the Cortex CPU within the MCU, setting the correct clock speed within the SWO Trace interface is essential to determine the correct baud rate for the data transfer. If the clock speed setting does not match the actual clock speed of the processor then data will be lost and/or corrupted. This can result in no data being visualized, or unexpected Trace data.

The first time Trace is used in a project you will be asked to enter the target clock speed. SWO Trace attempts to read the clock speed from the SystemCoreClock global variable and will suggest that value if found. The SystemCoreClock is usually set to the *current* clock speed of the target. Take care to use it *after* the application has set the clock speed for normal operation, otherwise it may provide an inappropriate value. If that variable does not exist or has not been set to the core clock frequency you will need to manually enter the clock frequency.

Once set, the target core clock speed is saved in the project configuration. The saved value can be viewed and changed from the **SWO Config** View.

1.3.2 Part-Specific Configuration for SWO Trace

Most MCUs should not need any special configuration to use SWO Trace. However, some may require additional configuration to enable SWO output, for instance to set up the correct pin muxing or to enable a Trace clock.

Parts that require extra configuration include the LPC13xx, LPC15xx, LPC541xx and LPC546xx families.

Further details on the above parts can be found in the Appendices of this guide. However, it is generally recommended to check the user or reference manual for the MCU being used for details of any required SWO configuration details.

1.3.3 SWO Config View

The **SWO Config** View displays the state of the SWO Trace system. From here you can open and close the other SWO Views using the Show View buttons and Hide View buttons for each SWO component.

Note

The clock speed can be changed from the **SWO Config** View. If the clock speed is entered incorrectly you may see unexpected Trace data or no Trace data.

The status of the SWO connection is also displayed. When SWO Trace is correctly configured all lights will be green.

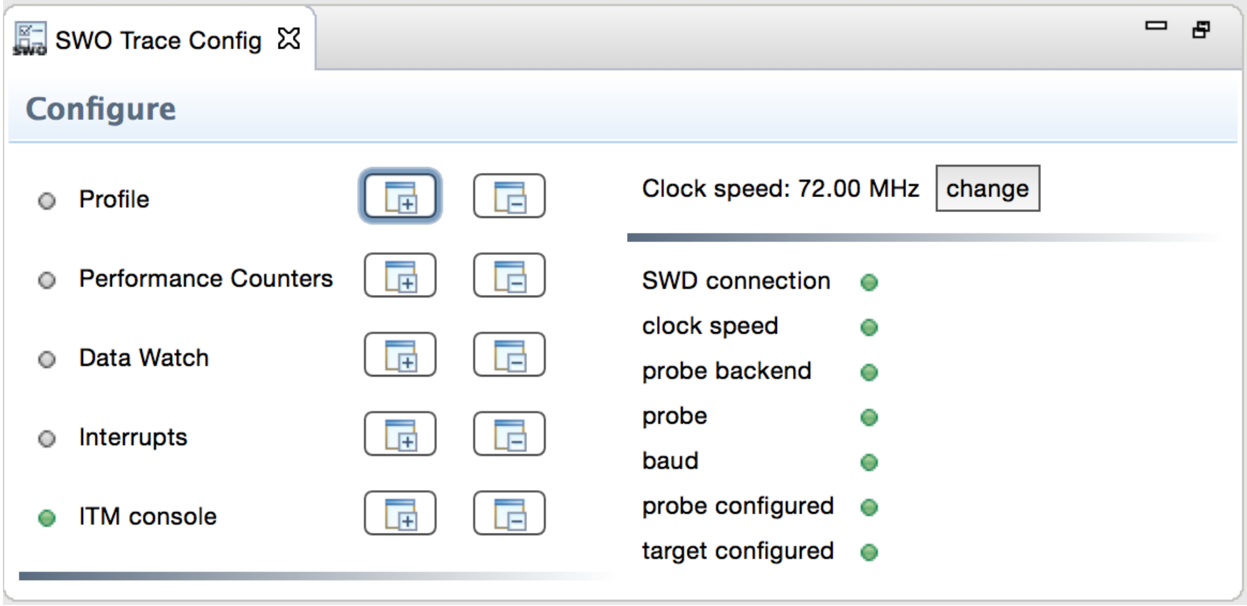


Figure 1.2. SWO Config View

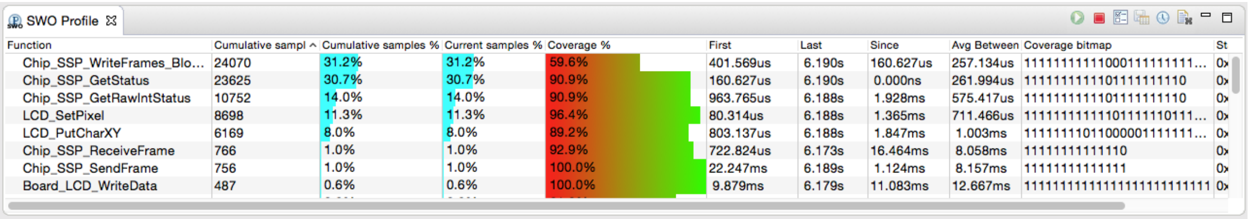
2. Profiling

2.1 Overview

Profile tracing provides a statistical profile of application activity. This works by sampling the program counter (PC) at the configured sample rate. It is completely nonintrusive to the application – it does not affect the performance in any way. As profile tracing provides a *statistical* profile of the application, more accurate results can be achieved by profiling for as long as possible. Profile tracing can be useful for identifying application behavior such as code hotspots.

2.2 SWO Profile View

The Profile View shows a profile of the code as it is running, providing a breakdown of time spent in different functions. An example screenshot is shown in Figure 2.1. Double-clicking on a row will jump to the corresponding function definition in the source code. Clicking on a column title will sort by that column. Clicking a second time will reverse the sorting order.



SWO Profile

Function	Cumulative sampl	Cumulative samples %	Current samples %	Coverage %	First	Last	Since	Avg Between	Coverage bitmap	St
Chip_SSP_WriteFrames_Blo...	24070	31.2%	31.2%	59.6%	401.569us	6.190s	160.627us	257.134us	11111111111000111111111...	0x
Chip_SSP_GetStatus	23625	30.7%	30.7%	90.9%	160.627us	6.190s	0.000ns	261.994us	11111111110111111110	0x
Chip_SSP_GetRawIntStatus	10752	14.0%	14.0%	90.9%	963.765us	6.188s	1.928ms	575.417us	11111111110111111110	0x
LCD_SetPixel	8698	11.3%	11.3%	96.4%	80.314us	6.188s	1.365ms	711.466us	1111111111101111110111...	0x
LCD_PutCharXY	6169	8.0%	8.0%	89.2%	803.137us	6.188s	1.847ms	1.003ms	1111111011000001111111...	0x
Chip_SSP_ReceiveFrame	766	1.0%	1.0%	92.9%	722.824us	6.173s	16.464ms	8.058ms	1111111111110	0x
Chip_SSP_SendFrame	756	1.0%	1.0%	100.0%	22.247ms	6.189s	1.124ms	8.157ms	1111111111111	0x
Board_LCD_WriteData	487	0.6%	0.6%	100.0%	9.879ms	6.179s	11.083ms	12.667ms	11111111111111111111111111	0x

Figure 2.1. SWO Profile View

- **Cumulative samples**: This is the total number of PC samples that have occurred while executing the particular function. A relatively high number of samples indicates a larger function or more frequently executed functions.
- **Cumulative samples (%)**: This is the same as above, but displayed as a percentage of total PC samples collected.
- **Current samples (%):** This column is a legacy item. In SWO Trace it is identical to the Cumulative samples(%).
- **Coverage (%)**: Percentage of instructions in the function that have been seen to have been executed.
- **Coverage Bitmap**: The coverage bitmap has one bit for each half-word in the function. The bit corresponding to the *address* of each sampled PC is set. Most Cortex-M instructions are 16 bits (one half-word) in length. However, there are some instructions that are 32 bits (two half-words). The bit corresponding to the second half-word of a 32-bit instruction will *never* be set.
- **First**: This is the first time (relative to the start time of tracing) that the function was sampled.
- **Last**: This is the last time (relative to the start time of tracing) that the function was sampled.
- **Since**: It is this long since you last saw this function (current – last).
- **Avg Between**: This is the average time between executions of this function.

The PC sampling rate is configured using the **Rate button** . The rate can be configured to be from one in every 64 instructions to one in every 16384 instructions. Note, however, that at the higher sample rates the SWO channel will be overwhelmed, resulting in data loss. See Figure 2.2.

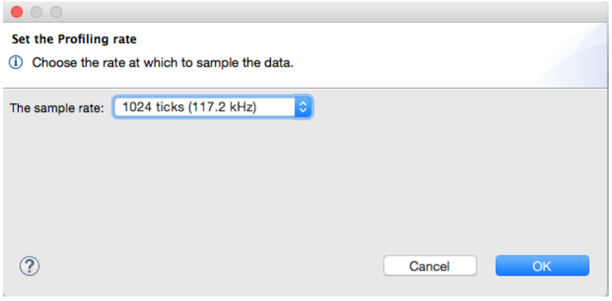


Figure 2.2. PC sample rate

The summary of the PC count by function depends on being able to map a PC sample to a function. The function name can only be determined if the source code is available (this may not be the case for library code or ROM code, for example). If code is dynamically loaded the profile will be inaccurate, as samples may get attributed to the wrong functions.

Note:

Coverage is calculated statistically – sampling the PC at the specified rate (e.g. 50Khz). It is possible for instructions to be executed but not observed. The longer Trace runs for, the more likely a repeatedly executed instruction is to be observed. As the length of the trace increases, the observed coverage will tend towards the true coverage of your code. However, this should not be confused with full code coverage.

3. ITM

3.1 Overview

The ITM block provides a mechanism for sending data from your target to the debugger via the SWO stream. This communication is achieved though a memory-mapped register interface. Data written to any of 32 stimulus registers is forwarded to the SWO stream. Unlike other SWO functionality, using the ITM stimulus ports requires changes to your code and so should not be considered nonintrusive.

3.2 Using the ITM to Handle `printf` and `scanf`

The ITM stimulus registers facilitate `printf` style debugging. MCUXpresso IDE uses the CMSIS standard scheme of treating any data written to stimulus port 0 (0xE0000000) as character data. A minor addition to your project can redirect the output of `printf` to this port.

A special global variable is used to achieve `scanf` functionality, which allows the debugger to send characters from the console to the target. The debugger writes data to the global variable named `ITM_RxBuffer` to be picked up by `scanf`.

Inside the `Examples/Misc` subdirectory of your MCUXpresso IDE installation, you will find the file `retarget_itm.c`, which can be used to provide the above functionality for the C library `printf` and `scanf` functions. This provides better performance than the standard semihosting mechanism, as the MCU does not have to temporarily drop into debug state and hence stop execution to transfer the data. This code can also be automatically included in projects by selecting the appropriate option on the *Advanced project settings* page of the SDK project wizards.

3.3 SWO ITM Console View

Data written to the ITM stimulus port 0 is presented in this View. An example screenshot is shown in Figure 3.1. The View shows the ITM console for the active debug session. Once the target is terminated, the View is cleared.

Text entered into this console is sent to the target if a suitable receiving buffer exists (specifically the global `int32_t ITM_RxBuffer`).

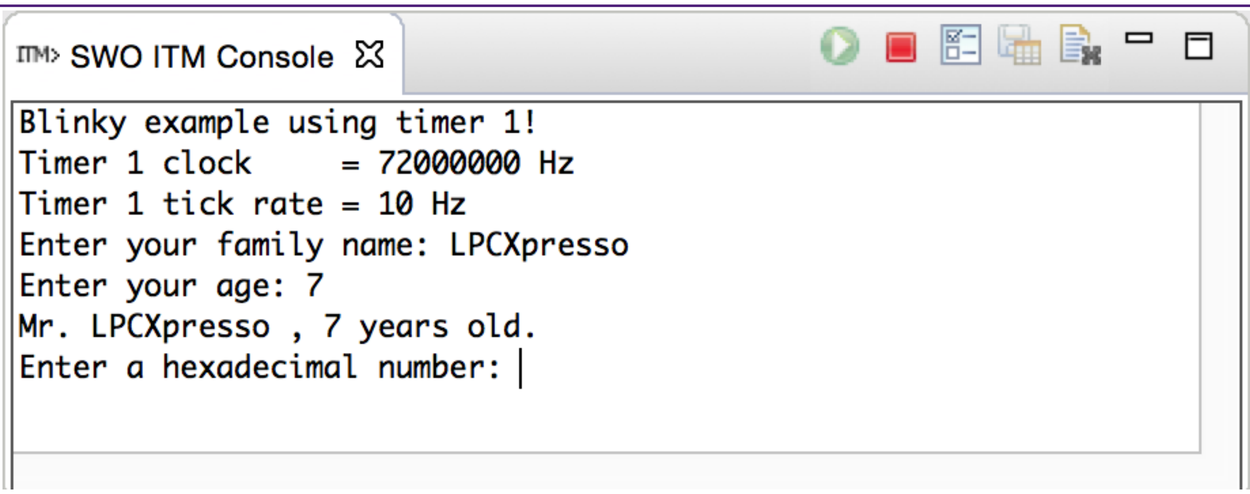


Figure 3.1. SWO ITM Console View

In addition to the standalone ITM Console View, the ITM console is also displayed as part of the standard console viewer: see Figure 3.2. It can be displayed by selecting the “Display Selected

Console” button and choosing the console named "<your project> **ITM Console**". This View persists after the target is terminated, unlike the standalone ITM Console View. Note that the standard console viewer switches automatically between consoles to show consoles that are being written to. This switching can be disorienting, as the ITM console is easily lost among the other consoles displayed there. It is easier to keep track of the standalone ITM console.

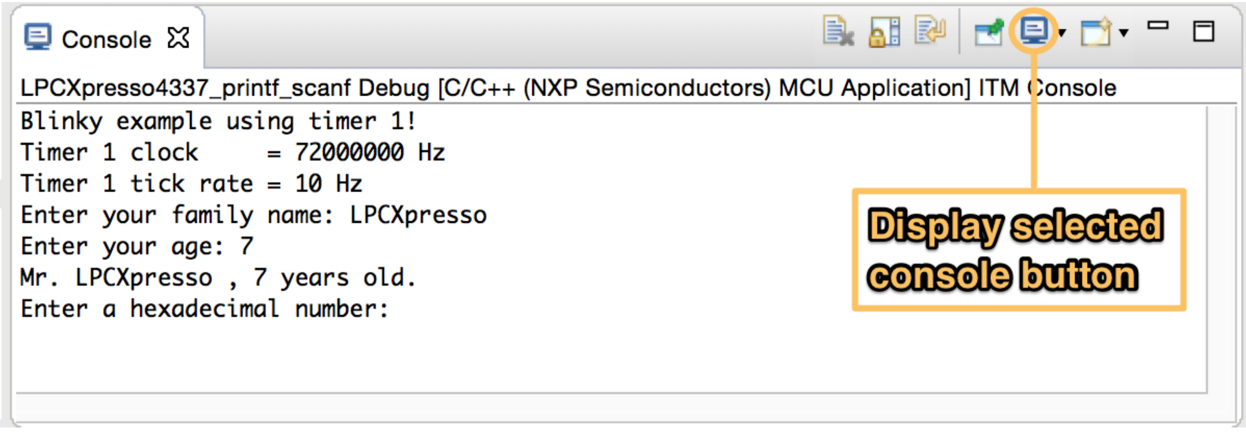


Figure 3.2. SWO ITM Console shown in the standard Console View

3.3.1 Toolbar

- Enable stimulus port 0 and start collecting data.
- Disable stimulus port 0.
- Switch to the SWO config View.
- Clear the ITM data and console.

The start and stop buttons in the ITM Console View enable and disable stimulus port 0.

4. Interrupt Tracing

4.1 Overview

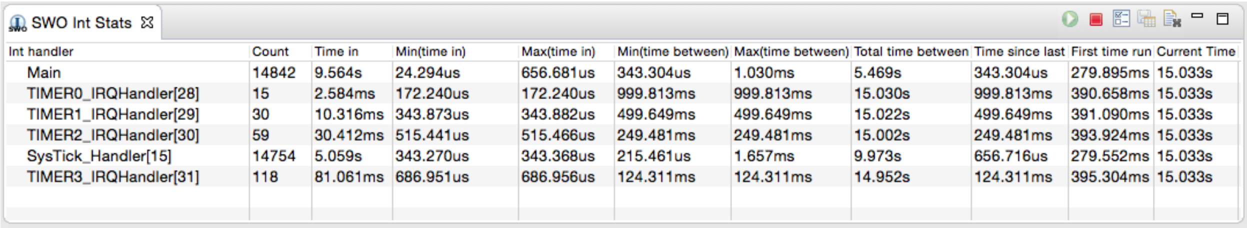
Interrupt tracing provides information on the interrupt performance of your application. This can be used to determine time spent in interrupt handlers and to help optimize their performance.

SWO interrupt tracing provides precise timing for entry and exits of interrupt handlers without any code instrumentation or processor overhead. The SWO stream reports three different events and the times at which they occurred:

- Entry to *i* - when the handler for interrupt *i* is initially executed
- Exit from *i* - when the handler *i* finishes or is preempted by an interrupt of higher priority
- Return to *i* - when the handler for interrupt *i* is returned to after being preempted

4.2 SWO Interrupt Statistics View

The Interrupt Statistics View displays counts and aggregated timing information for interrupt handlers. An example screenshot is shown in Figure 4.1.


SWO Int Stats

Int handler	Count	Time in	Min(time in)	Max(time in)	Min(time between)	Max(time between)	Total time between	Time since last	First time run	Current Time
Main	14842	9.564s	24.294us	656.681us	343.304us	1.030ms	5.469s	343.304us	279.895ms	15.033s
TIMER0_IRQHandler[28]	15	2.584ms	172.240us	172.240us	999.813ms	999.813ms	15.030s	999.813ms	390.658ms	15.033s
TIMER1_IRQHandler[29]	30	10.316ms	343.873us	343.882us	499.649ms	499.649ms	15.022s	499.649ms	391.090ms	15.033s
TIMER2_IRQHandler[30]	59	30.412ms	515.441us	515.466us	249.481ms	249.481ms	15.002s	249.481ms	393.924ms	15.033s
SysTick_Handler[15]	14754	5.059s	343.270us	343.368us	215.461us	1.657ms	9.973s	656.716us	279.552ms	15.033s
TIMER3_IRQHandler[31]	118	81.061ms	686.951us	686.956us	124.311ms	124.311ms	14.952s	124.311ms	395.304ms	15.033s

Figure 4.1. SWO Interrupt Statistics View

Information displayed includes:

- **Count**: The number of times the interrupt routine has been entered so far
- **Time In**: The total time spent in the interrupt routine so far
- **Min (time in)**: Minimum time spent in the interrupt routine for a single invocation
- **Max (time in)**: The Maximum time spent in a single invocation of the routine
- **Min (time between)**: The minimum time between invocations of the interrupt
- **Max (time between)**: The maximum time between invocations of the interrupt
- **Total time between**: The total time spent outside this interrupt routine
- **Time since last**: The time elapsed since the last time in this interrupt routine
- **First time run**: The time (relative to the start of Trace) that this interrupt routine was first run
- **Current time**: The elapsed time since Trace start

Also see the **Overhead** and **Sleep** performance counters.

4.3 SWO Interrupt Trace View

The Interrupt Trace View plots a time line showing the entry, exit, and return events of interrupt handlers. It is useful for debugging exception priorities and seeing how interrupts may be interacting in your running code.

> **Note**
> To see the chart in Linux you may need to install addition dependencies to enable the SWT Browser widget. See here for more information. For example, in Ubuntu run `sudo apt-get install -y libwebkitgtk-1.0-0`

An example screenshot is shown in Figure 4.2.

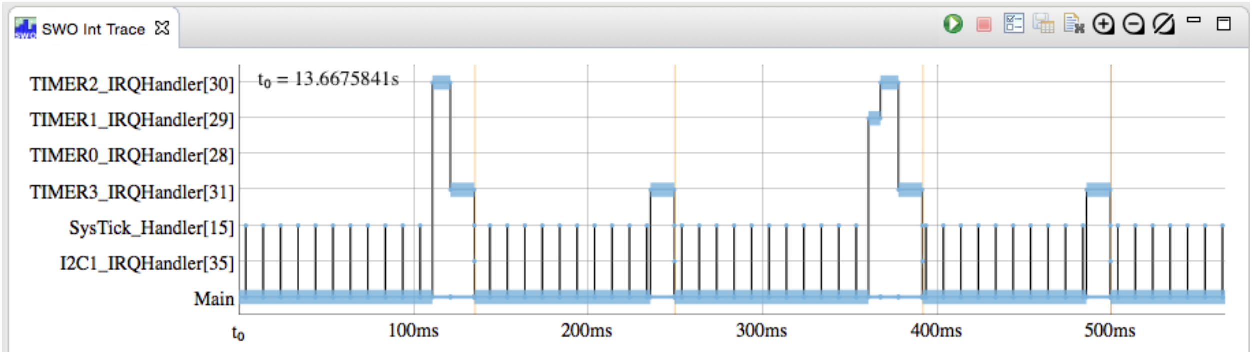


Figure 4.2. SWO Interrupt Statistics View

4.3.1 Zooming and Panning

You can interact with the chart using the mouse by clicking and dragging inside the chart:

- Zoom in on time axis: click and drag horizontally to highlight the region to zoom into
- Zoom out to see all data: double-click in graph
- Pan left and right: hold down **shift** as you click and drag on the graph

Additionally, there are the buttons in the toolbar to change the time scale:

- 2x zoom in
- 2x zoom out
- reset time scale to show all data

4.3.2 Time Axis

Time is plotted along the x-axis at the bottom of the graph. It is labeled relative to the origin of the chart `t0`. The value of `t0` is plotted in the top left of the chart.

When the chart is panned, by pressing shift and dragging the chart using the mouse, the grid lines may not appear to move but you should see `t0` changing as the plot moves along.

4.3.3 Interrupt Axis

Each observed interrupt is listed on the vertical axis. The labels consist of the name of the handler with the number of the interrupt prepended to it. For example `SysTick_Handler[15]` refers to interrupt 15, which is handled by the function `SysTick_Handler`. The special entry `Main` represents all code executed outside of the Handler mode.

4.3.4 Interpretation

Each row in the chart represents the execution state of the labeled interrupt handler. No horizontal line indicates that the interrupt handler is not being executed.

Executing an Interrupt from Outside Handler Mode

Figure 4.3 shows an example of a SysTick handler that increments an integer and returns. The figure has been labeled to show how the SWO events are represented.

- Initial state
  - Initially the processor is executing user code, as indicated by the thick line in the far left of the `Main` row.
- Entry into 15 (`SysTick_Handler`)
  - The Systick interrupt handler is entered at time 2s+50ns and an ENTRY event is sent over the SWO with the corresponding time stamp. This entry is represented in the chart by a vertical black line connecting the previously executing code's row (the `Main` row in this case) to the newly entered handler's row (the `SysTick_Handler` row).
  - The execution of `SysTick_Handler` is represented by the thick blue line.
  - The thin blue line in the `Main` row represents that `Main`'s execution is suspended, but not completed.
- Exit from 15 (`SysTick_Handler`)
  - When `SysTick_Handler` completes at 2s+125ns an EXIT event is generated with a corresponding time stamp.
  - The EXIT event is represented by the end of the thick blue line.
  - After exiting there is an overhead before the execution of `Main` can resume; this is represented by a thick gray line in the row of the handler which has just exited.
  - ***Note:*** *This example was chosen to show the overhead clearly. The small code size of the handler makes the overhead seem relatively large, but the overhead is only seven cycles here.*
- Return to `Main`
  - When execution of code in `Main` begins at 2s + 160ns a RETURN event is generated with a corresponding time stamp.
  - A thin black vertical line connects the handler that is being returned from to the one now executing.
  - A thick horizontal line in the `Main` row shows that it is being executed.

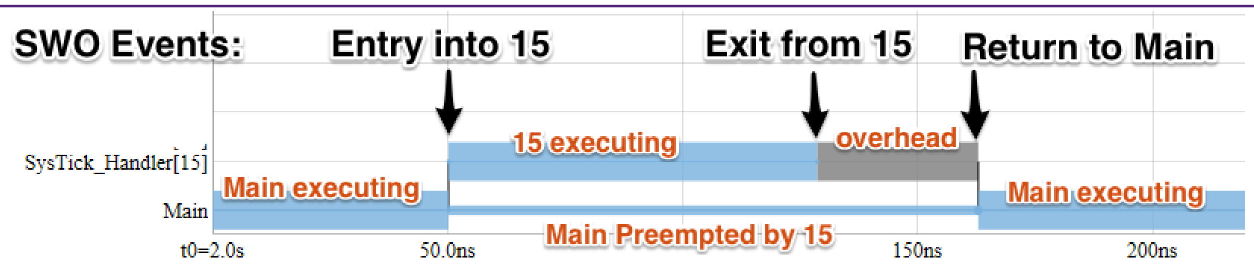


Figure 4.3. An Example exit entry and return

Tail Chaining

Figure 4.4(a) shows an example of tail chaining, where one interrupt is exited and another entered without returning to `Main`. Figure 4.4(b) shows a zoomed-in view of the first tail chaining, allowing the overhead to be visible. The figure has been labeled to show how the SWO events are represented.

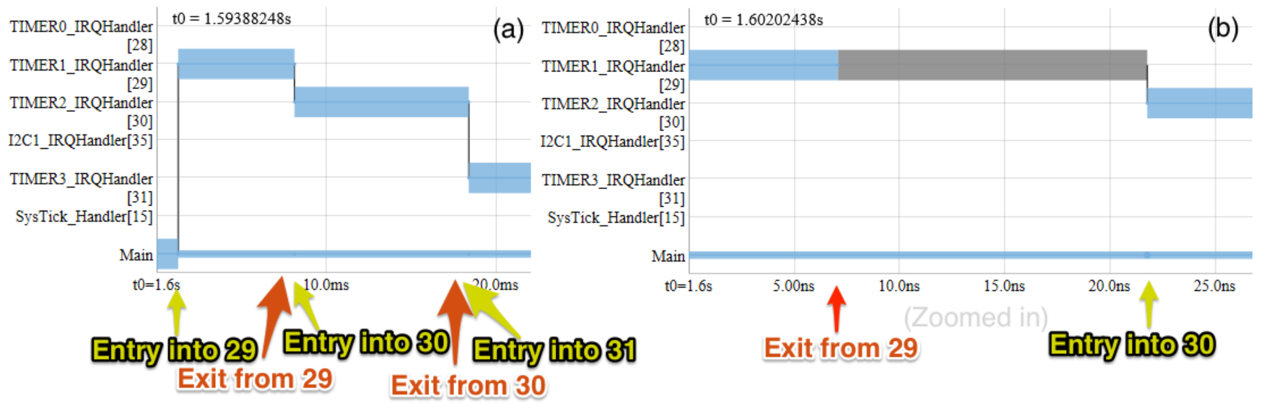


Figure 4.4. Tail chaining

Buffer Breaks

When data is not collected from the debug probe by the IDE as quickly as it is being generated, some data is lost. Typically this would happen if data collection were paused for a while and then resumed, or when there is an unusually high amount of processing being performed by the IDE. Lost buffers are represented in the chart by an orange block – see Figure 4.5(a).

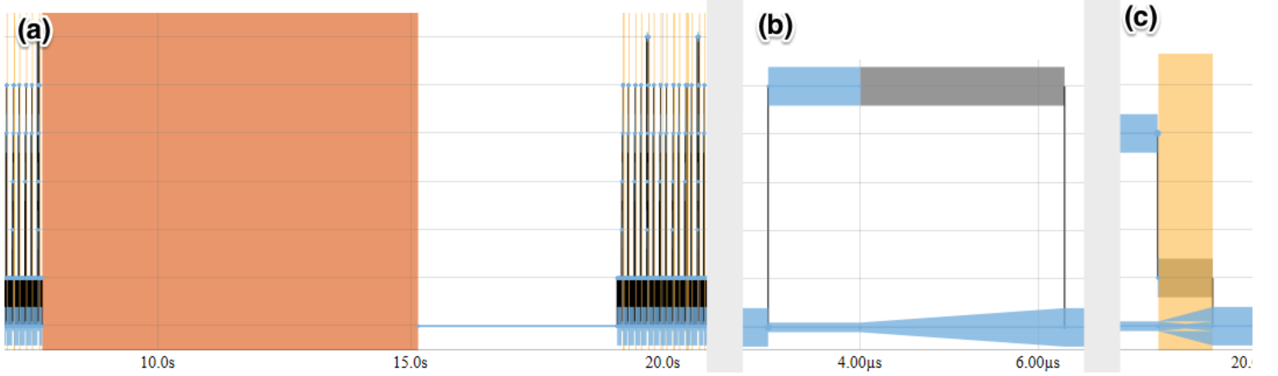


Figure 4.5. Overflows and "late" time stamps

Time Ranges

Usually an event has a precise time stamp associated with it. In some cases the debug circuit may be unable to generate a matching time stamp. In these cases it may generate a "late" time stamp corresponding to a time after the last event occurs. This "late" time stamp tells us that the event occurred between the previous time stamp and the "late" time stamp. This is represented in the chart as a tapered line.

Figure 4.5(b) shows a representation of a "late" time stamp. The ENTRY event into and EXIT event from the handler have precise time stamps. The return event has a "late" time stamp. Since the EXIT's time stamp is at 4us and the "late" time stamp is just after 6us, the chart shows `Main`'s execution state, as represented by the thickness of the line in the bottom row, increasing from the preempted-state thickness to the executing-state thickness between 4us and 6us.

FIFO Overflows

The debug circuit on the target formats events into packets that drain via a FIFO over the SWO line. If too many events happen close together, this FIFO can overflow, resulting in data loss. When this occurs, the overflow is represented as a yellow block on the chart – see Figure 4.5(c).

In addition to the overflow in Figure 4.5(c) we see the effect of two “late” time-stamped events. Two handlers are tail chained (the second handler is much shorter than the others and looks just like a dot). Both the EXIT of the second handler and the RETURN into `Main` at the bottom are associated with “late” packets. This means that the preemption of `Main` ends within the range and so tapers, becoming smaller. Similarly, the re-entry into `Main` is represented by an increasing tapering from the preemption width to the executing width.

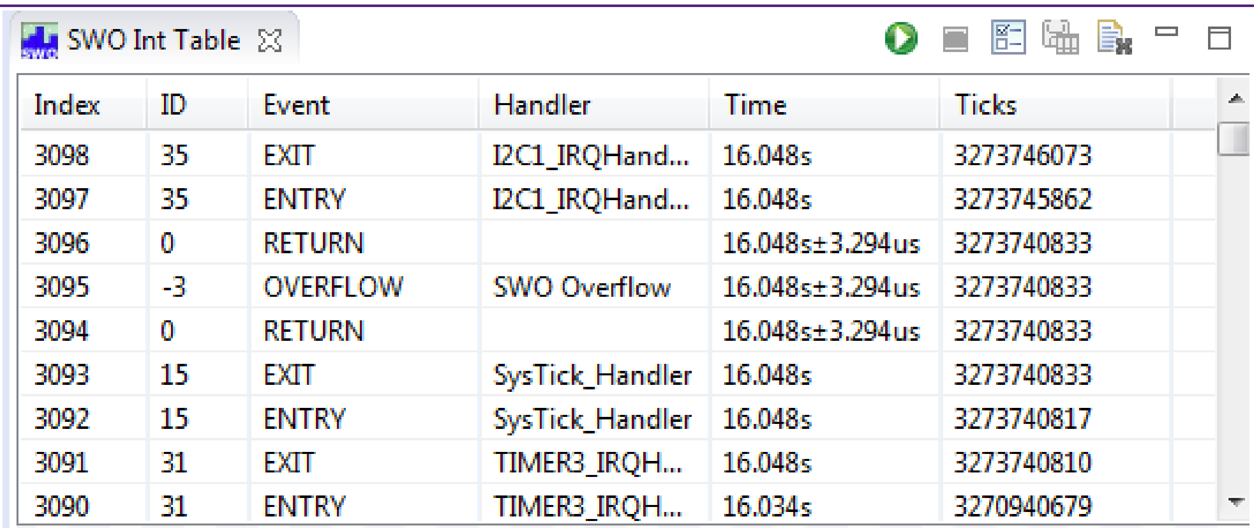
4.3.5 Graph Buffer Depth

The buffer depth can be configured via the **Interrupt Trace Graph Buffer depth** option in Preferences -> MCUXpresso IDE -> LPC-Link2 SWO Trace. The default depth is 5000 and corresponds to the number of starts and ends for each handler. Note that one handler’s buffer may fill up before another.

Note: Large buffer depths may result in the UI becoming very slow when plotting all points. This limitation may be addressed in later releases.

4.4 SWO Interrupt Trace Table

The SWO Interrupt Trace Table View shows the collected interrupt events and their corresponding time stamps – see Figure 4.6.



Index	ID	Event	Handler	Time	Ticks
3098	35	EXIT	I2C1_IRQHand...	16.048s	3273746073
3097	35	ENTRY	I2C1_IRQHand...	16.048s	3273745862
3096	0	RETURN		16.048s±3.294us	3273740833
3095	-3	OVERFLOW	SWO Overflow	16.048s±3.294us	3273740833
3094	0	RETURN		16.048s±3.294us	3273740833
3093	15	EXIT	SysTick_Handler	16.048s	3273740833
3092	15	ENTRY	SysTick_Handler	16.048s	3273740817
3091	31	EXIT	TIMER3_IRQH...	16.048s	3273740810
3090	31	ENTRY	TIMER3_IRQH...	16.034s	3270940679

Figure 4.6. SWO Interrupt Trace Table View

4.4.1 Columns

- Index
  - Sequential ID for each event
- ID
  - Interrupt handler ID if greater than zero; or:
  - **0** - Out of Handler mode (i.e. normal execution)
  - **-1** - Unknown ID
  - **-2** - Inconsistent state (data corruption)
  - **-3** - SWO packet formatter FIFO overflow
  - **-4** - Break in data stream (dropped buffer(s))
- Event
  - **ENTRY** - execution of the associated interrupt handler begins
  - **EXIT** - execution of the associated interrupt handler ends

    - **RETURN** - re-entry into executing handler after preemption
    - **OVERFLOW** - data lost (see ID code for more info)
- Handler
    - The assigned interrupt handler, or the interrupt handler ID if no source for the handler can be located
- Time
    - The time stamp associated with the event, expressed in seconds
    - May be a range – if so, it will have a +/- term
- Ticks
    - The time stamp expressed as a number of CPU clock ticks
    - For time stamps representing a range, this is the start of the range

5. Data Watch Trace

5.1 Overview

This View provides the ability to monitor (and update) any memory location in real time, without stopping the processor. Up to four memory locations can be traced simultaneously allowing all accesses to the traced locations to be captured. Information that can be collected includes whether data is read or written, the value that is accessed, and the PC of the instruction causing the access.

This information can be used to help identify “rogue” memory accesses, to monitor and analyze memory accesses, or to profile data accesses.

Real-time memory access is also available, allowing any memory location to be read or written without stopping the processor. This can be useful in real-time applications where stopping the processor is not possible, but you wish to view or modify in-memory parameters. Any number of memory locations may be accessed in this way, and modified by simply typing a new value into a cell in the Data Watch Trace View.

Note: MCUXpresso IDE’s Global Variable View also offers Live Variables functionality when used via a LinkServer non-stop debug connection. This provides similar functionality to SWO data watch, in that a recent value for a variable is displayed, and can be modified. Live Variables cannot provide a full trace of updates and accesses. However, the Live Variables functionality can also be used with Cortex-M0/M0+ based MCUs – which SWO Data Watch Trace cannot.

5.2 SWO Data Watch View

The View is split into two sections, with the **item display** on the left and the **Trace display** on the right, as shown in Figure 5.1.

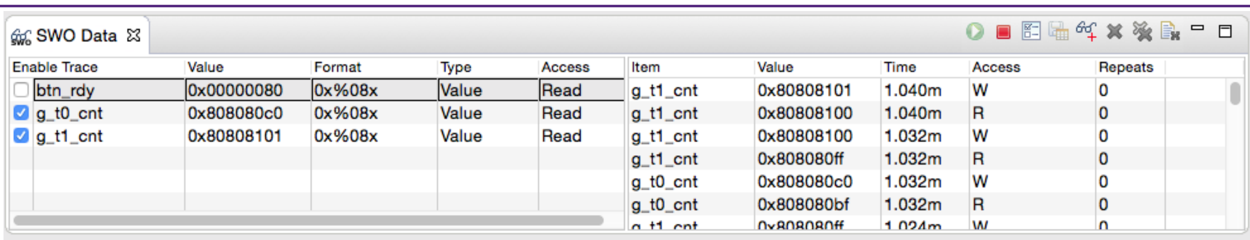


Figure 5.1. SWO Data Watch View

Use the **Add Datawatch items** button to display a dialog to allow the memory locations that will be presented to be chosen, as per Figure 5.2.

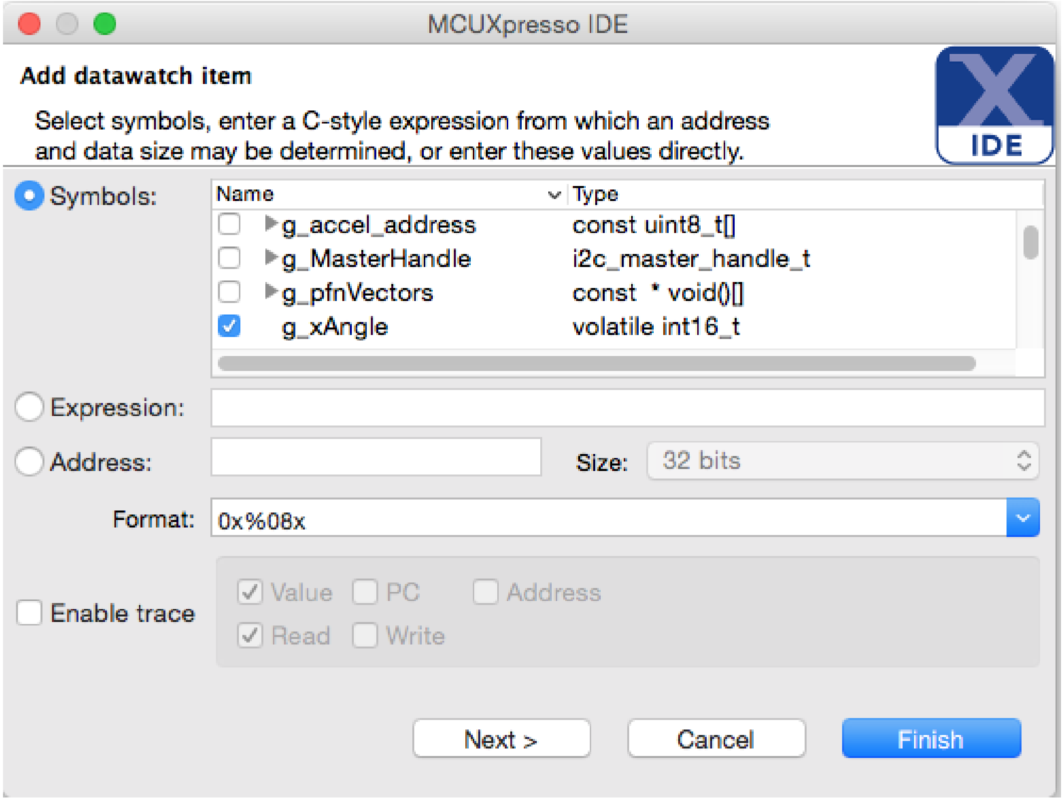


Figure 5.2. Add datawatch items

These locations may be specified by selecting global variables from a list; by entering a C expression; or by entering an address and data size directly. Trace may be enabled for each new item. If Trace is not enabled, the value of the data item will be read from memory.

Data Watch Trace works by setting an address into a register on the target chip. This address is calculated at the time that you choose an item to watch in the **Add datawatch items** dialog. Thus, while you can use an expression, such as `buffer[bufIndex+4]`, the watched address will not be changed should `bufIndex` subsequently change. This behavior is a limitation of the hardware.

The format dropdown box provides several format strings to choose from for displaying an item's value. The format string can be customized in this box, as well as in the item display.

With Trace enabled, the options for tracing the item's value, the PC of the instruction accessing the variable, or its address can be set. Additionally, the option to trace reads, writes, or both can be set when adding a variable. These settings can be subsequently updated in the item display.

Note:
It is not possible to add some kinds of variables when the target is running. Suspending the execution of the target with the button before adding these variables will overcome this limitation.

Pressing **Finish** adds the current data watch item to the item display and returns to the Data Watch View. Pressing **Next** adds the current data watch item, and displays the dialog to allow another item to be added.

5.2.1 Item Display

As shown in Figure 5.1, the item display lists the data watch items that have been added. The following information is presented:

- **Enable Trace** - Tracing of this item may be enabled or disabled using the checkbox. A maximum of four items may be traced at one time. Each traced item is given a color code, so that it may be picked out easily on the Trace display.
- **Value** - shows the current value of the item and may be edited to write a new value to the target. If the current value has changed since the last update, then it will be shown highlighted in yellow.
- **Format** - shows the `printf`-style expression used to format the value, and may be edited.
- **Type** - shows the trace type, which may be edited while Trace is disabled:
  - **Value** - just trace the value transferred to/from memory
  - **PC only** - just trace the PC of the instruction making the memory access
  - **PC and value** - trace the value and the PC
  - **Address** - trace the address of memory accessed
  - **Address and value** - trace the address and value
- **Access** - shows the access type, which may be edited while Trace is disabled:
  - **Write** - just trace writes to the memory location
  - **Read** - just trace reads to the memory location
  - **Read & Write** - trace both reads and writes

5.2.2 Trace Display

The Trace display shows the traced values of the memory locations.

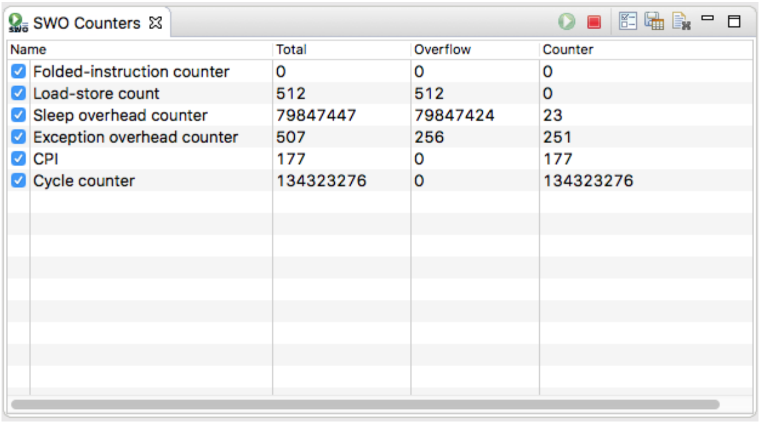
6. Performance Counters

6.1 Overview

There are several counters available in the Cortex-M3 and Cortex-M4 processors to help analyze the performance of the target application.

6.2 SWO Performance Counters View

The Performance Counter View displays the target's Performance Counters as shown below:



Name	Total	Overflow	Counter
Folded-instruction counter	0	0	0
Load-store count	512	512	0
Sleep overhead counter	79847447	79847424	23
Exception overhead counter	507	256	251
CPI	177	0	177
Cycle counter	134323276	0	134323276

Figure 6.1. SWO Performance Counters View

The performance counters are described here as follows:

- **Cycle counter** (CYCCNT)
  - Increments on each clock cycle when the processor is not halted in debug state.
- **Folded Instruction Counter** (FOLDCNT)
  - Cycles saved by instructions which execute in zero cycles.
- **Load-Store Counter** (LSUCNT)
  - increments on each additional cycle required to execute a multi-cycle load-store instruction. It does not count the first cycle required to execute any instruction.
- **Sleep Overhead Counter** (SLEEPCNT)
  - increments on each cycle associated with power saving, whether initiated by a WFI or WFE instruction, or by the sleep-on-exit functionality.
- **Exception Overhead Counter** (EXCCNT)
  - increments on each cycle associated with exception entry or return. That is, it counts the cycles associated with entry stacking, return unstacking, preemption, and other exception-related processes.
- **CPI** (CPICNT)
  - increments on each additional cycle required to execute a multi-cycle instruction, except for those instructions recorded by Load-store count. It does not count the first cycle required to execute any instruction. The counter also increments on each cycle of any instruction fetch stall.

The number of instructions can be calculated as:

number of instructions = CYCCNT – CPICNT – EXCCNT – SLEEPCNT – LSUCNT + FOLDCNT

Various other calculations and inferences can be made using these counters. For example, the time spent spent executing instructions vs the time sleeping will give an indication of the how hard the CPU is working.

% time awake = ((CYCCNT – SLEEPCNT)/CYCCNT) x 100

6.2.1 Display features

Whenever the CPU is running, the performance counters will be continously updated internally. However, with trace enabled within the Performance Counters view, an individual counter will only be sampled when it check box is ticked. When this is done the initial value of all counters held within the debugger will be set to count up from zero.

The total value for any displayed counter is calculated by adding two components: - the current value of the counter within the CPU plus any accumulated overflow value

These counters change very rapidly so all counters apart from the Cycle counter will only display their total values when the target is paused.

7. Bandwidth Considerations

7.1 Overview

SWO Trace allows you to use multiple SWO Views at the same time. For example, the Interrupt Trace and Profile Trace can be running at the same time. The SWO pipeline is composed of five parts that get the trace data from the target into MCUXpresso:

1. The trace hardware on the target generates the data.
2. The probe reads this data from the target via the SWO pin.
3. The probe caches the data read to be sent to MCUXpresso IDE.
4. MCUXpresso IDE requests data from the probe over USB.
5. MCUXpresso IDE decodes the SWO stream and displays it to users.

Data loss can occur at any of these steps when they become overloaded. This can happen if the target is configured to generate more Trace data than can be handled. When the SWO channel becomes overloaded it is recommended that Trace be reconfigured to reduce the load. You could stop using a component altogether, or reduce the sample rate in profile, for example.

Data loss can result in inaccurate timing information and the introduction of corrupted data. It is therefore generally a good idea to adjust your SWO settings to minimize data loss.

7.2 SWO Stats View

The **SWO Stats** View provides a low-level display of the utilization of the different parts of the SWO pipeline. This View allows you to identify any bottlenecks in the SWO pipeline, which may indicate that they are overloading the SWO channel. SWO data is collected into buffers and sent, a buffer at a time, to the MCUXpresso IDE.

For metric two numbers are presented: the total for the entire SWO session in the “Total” column and the data for the last 2000 collected buffers (corresponding to the last 2s) in the “Windowed” column.

This list will help you interpret the presented statistics:

- Good bytes and Bad bytes
  - Shows how much of the data is being detected as valid, expected, SWO packets.
  - A few bad bytes can be expected in normal operation.
  - If the number of bad bytes is greater than or the same order of magnitude as good bytes it suggests that the SWO stream is corrupted.
    - This can often be caused when SWO Trace is configured with the wrong target clock speed.
- Full buffers and Empty buffers
  - This presents the USB utilization. The windowed statistics are most useful here.
  - The more full buffers there are, relative to the empty buffers, the heavier the USB load is.
  - The windowed statistics for the full and empty buffers add up to 2000.
    - If full = 700 and empty = 1300 you have a lot of head room in the USB channel and should not be losing data there
    - If full = 1978 and empty = 22 the USB channel is nearly fully utilized, and bursts of data may saturate the USB channel, resulting in lost data.
  - Seeing the number of empty buffers increase but no full buffers, when you are expecting to see data, implies that the target may not be configured correctly – your target may require additional configuration. See “Overview of Trace support in MCUXpresso IDE” at https://community.nxp.com/message/630730 for more information.
- Lost buffers

  - This shows the number of buffers of SWO data that were collected by the probe from the target, but were not sent over USB before being overwritten with new data.
  - It is possible to lose buffers even if the USB channel is not fully saturated.
  - A high number of lost buffers relative to full buffers indicates that the SWO channel is overloaded.
  - A small number of lost buffers is likely to occur in normal operation.
- Overflow packets
  - When the trace hardware on the target generates more data than it can send out of the SWO pin, it generates an Overflow packet.
  - This indicates that the SWO channel is overloaded.
  - Some Overflow packets can be expected, but most of the time you should aim to have 0 overflow packets in the windowed statistics.

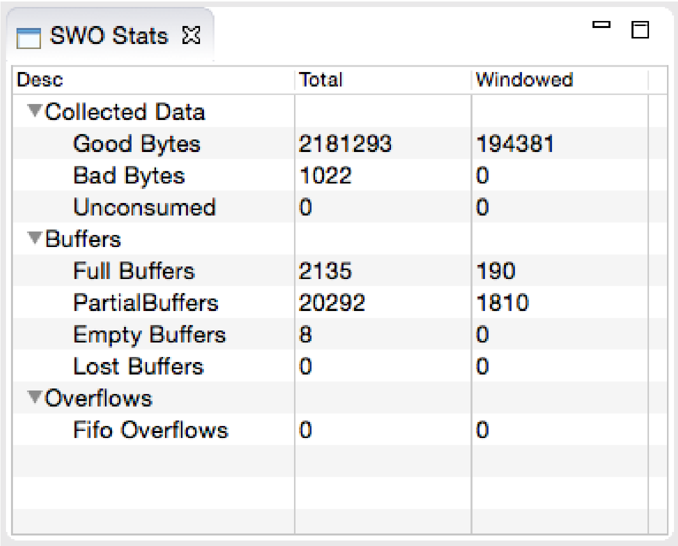


Figure 7.1. SWO Stats View

8. Preferences

There are several user-configurable options for SWO Trace that can be accessed via the Preferences menu item at: Preferences -> MCUXpresso IDE -> LPC-Link2 SWO Trace.

8.1 Options

These options apply to the entire workspace, and persist between IDE restarts.

- **Data watch buffer depth**
  - The depth of the data watch ring buffer
  - This is the number of data points that will be kept in the history.
  - The data watch ring buffer acts like a FIFO containing the most recent events.
- **Interrupts capture size**
  - The depth of the interrupt event ring buffer
  - These events are viewable in the **SWO Interrupt Table** View.
- **Interrupt Trace Graph Buffer depth**
  - The depth of the ring buffers for the **SWO Interrupt Trace** View
  - If the user interface slows down too much when plotting the entire collected dataset, try reducing this value.

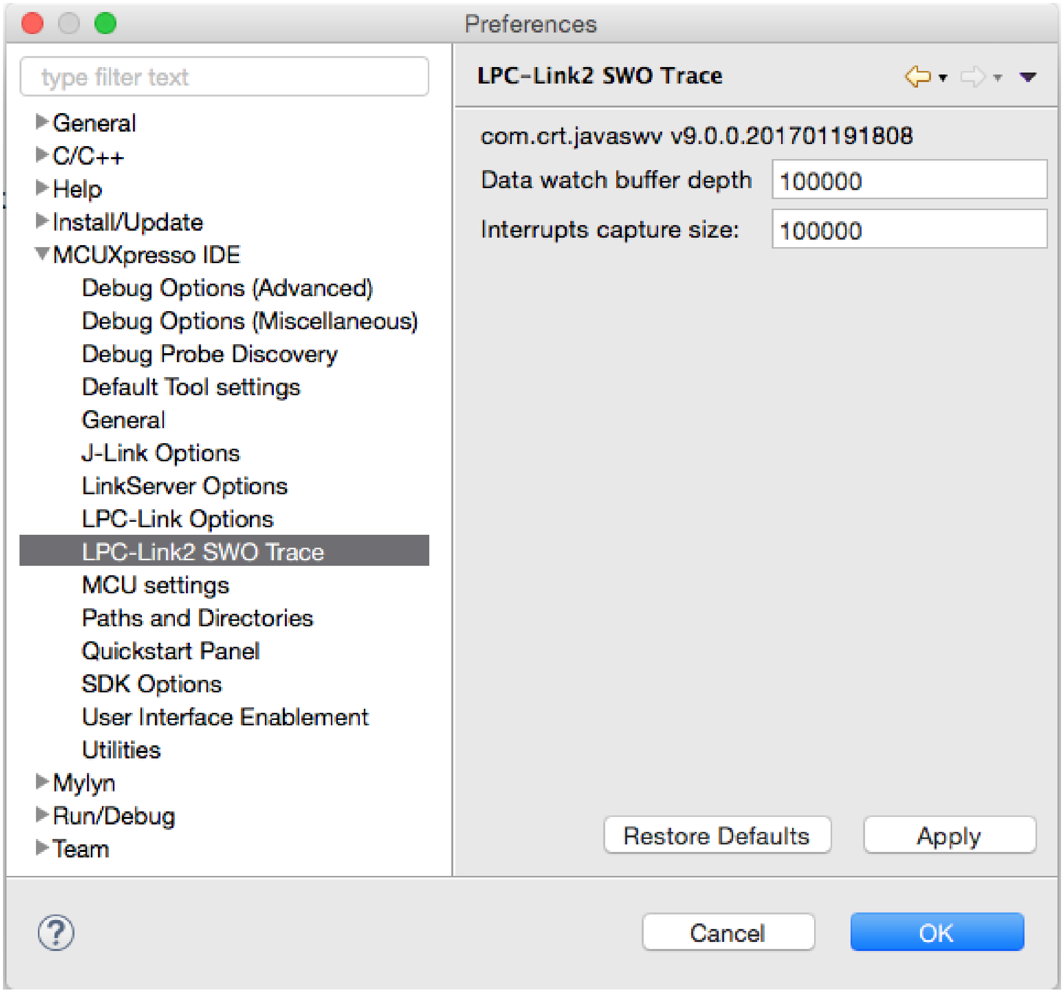


Figure 8.1. SWO Preferences

9. Appendix A – SWO Trace Setup for LPC13xx

9.1 To Carry Out SWO Trace on LPC13xx

1. Ensure that your board has SWO pinned out to the debug connector.
2. Turn on the trace clock within the MCU, as this is not enabled by default.
3. Configure the MCU pinmuxing, so that the SWO signal is accesible on the appropriate pin of the MCU.

This should typically be done within each of your application projects (or library projects that your projects link against).

9.1.1 SWO Pin and Debug Connector

On LPC13xx parts, the SWO signal is accessible via pin P0_9 of the MCU. Thus, you will need to check the schematic for your board to ensure that SWO is connected to the debug connector.

9.1.2 Enabling the Trace Clock

The startup code generated by the new project wizards for LPC13xx parts in MCUXpresso IDE (and later versions of LPCXpresso IDE) contains codes to turn on the trace clock. By default this code will be enabled by the new project wizard, but if not required it can be removed by defining the compiler symbol `DONT_ENABLE_SWVTRACECLK`.

9.1.3 SWO Pinmux Configuration

On LPC13xx parts, the SWO signal is accessible via pin P0_9 of the MCU.

Thus, the pinmux settings for your project need to ensure that this pin is configured to use the SWO function. In particular, this means that this pin is no longer available for use as the MOSI0 for the SSP0 peripheral. Example code to do this is given below.

Note that the default LPCOpen packages for LPC1343 and LPC1347 set up P0_9 as MOSI0 in `board_sysinit.c` of their board library project.

9.1.4 Example Setup Code for LPC1315/16/46/47 MCUs

Adding the following code to your `main()` function, after the call to `Board_Init()` if using LPCOpen, should allow SWO trace to function:

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x400480AC;
volatile unsigned int *IOCON_PIO_0_9 = (unsigned int *) 0x40044024;
// Write 1 to TRACECLKDIV  – Trace divider
*TRACECLKDIV = 1;
// Write 0x93 to I/O configuration for pin PIO0_9 to select ARM_TRACE_SWV
*IOCON_PIO_0_9 = 0x93;
```

9.1.5 Example Setup Code for LPC1311/13/42/43 MCUs

Adding the following code to your `main()` function, after the call to `Board_Init()` if using LPCOpen, should allow SWO trace to function:

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x400480AC;
volatile unsigned int *IOCON_PIO_0_9 = (unsigned int *)  0x40044064;
// Write 1 to TRACECLKDIV  – Trace divider
```

```
*TRACECLKDIV = 1;
// Write 0x93 to I/O configuration for pin PIO0_9 to select ARM_TRACE_SWV
*IOCON_PIO_0_9 = 0x93;
```

10. Appendix B – SWO Trace Setup for LPC15xx

10.1 To Carry Out SWO Trace on LPC15xx

1. Ensure that your board has SWO pinned out to the debug connector.
2. Turn on the trace clock within the MCU, as this is not enabled by default.
3. Configure the switch matrix, so that the SWO signal is accesible on an appropriate pin of the MCU.

This should typically be done within each of your application projects (or library projects that your projects link against).

10.1.1 SWO Pin and Debug Connector

The first revisions of the LPCXpresso1549 board did not provide for connecting the SWO pin on the debug connector. You will need a revision C (or later) of this board to carry out SWO Trace.

To identify which revision of board you have, look in the top right of the back of the board which should be marked:

```
LPCXpresso1549
OM13056   v2 Rev C
```

If you are using a different board, you will need to check the schematics to identify if SWO is connected to the debug connector.

10.1.2 Enabling the Trace Clock

The startup code generated by the new project wizards for LPC15xx in MCUXpresso IDE (and later versions of LPCXpresso IDE) contains code to optionally turn on the trace clock. By default this code will be enabled by the new project wizard, but if it is not required it can be removed by defining the compiler symbol `DONT_ENABLE_SWVTRACECLK`.

If you are using different startup code (for instance, as provided in the projects in the LPCOpen v2.08c package for the LPCXpresso1549 board), then you can add the following code to your project to turn on the trace clock (for example, right at the start of `main()` or in the startup file before the call to `main()`):

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x400740D8;
*TRACECLKDIV = 1;
```

Note that later versions of the LPCOpen package for LPC15xx should contain appropriate trace clock setup code within the startup file.

10.1.3 SWO Switch Matrix Configuration

The SWO signal from the Cortex CPU is not assigned to a fixed pin on the LPC15xx MCU. You therefore need to configure the switch matrix correctly.

For example, if you are using LPCOpen v2.08c package for the LPCXpresso1549 board (and have a revision C or later board), then you will need to modify `board_sysinit.c` in the lpc_board_nxp_lpcxpresso_1549 project to add SWO to the switch matrix setup, thus:

```
STATIC const SWM_GRP_T swmSetup[] = {
/* USB related */
```

```
{(uint16_t) SWM_USB_VBUS_I, 1, 11}, /* PIO1_11-ISP_1-AIN_CTRL */
/* UART */
{(uint16_t) SWM_UART0_RXD_I, 0, 13}, /* PIO0_13-ISP_RX */
{(uint16_t) SWM_UART0_TXD_O, 0, 18}, /* PIO0_18-ISP_TX */
// == ADD THE BELOW PINMUX ==
/* SWO signal */
{(uint16_t) SWM_SWO_O, 1, 2}, /* PIO01_2-SWO */
};
```

Note that later versions of the LPCOpen package for LPC15xx should contain appropriate SWO switch matrix setup code for the LPCXpresso1549 board in the board library.

11. Appendix C – SWO Trace Setup for LPC5410x

11.1 To Carry Out SWO Trace on LPC5410x

1. Ensure that your board has SWO pinned out to the debug connector.
2. If using the built-in LPC-Link2 debug probe of an LPCXpresso54102 board, ensure that the probe is configured for DFU booting.
3. Turn on the trace clock within the MCU, as this is not enabled by default.
4. Configure the MCU pinmuxing, so that the SWO signal is accessible on the appropriate pin of the MCU.

This should typically be done within each of your application projects (or library projects that your projects link against).

Note that SWO Trace on LPC5410x MCUs can only be carried out for debug sessions connected to the Cortex-M4 CPU, not to the Cortex-M0+.

11.1.1 SWO Pin and Debug Connector

On LPCXpresso54102 boards, pin P0_15 is connected to SWO of the debug connector.

If you are using a different board, you will need to check the schematics to identify if SWO is connected to the debug connector (and on which pin from the MCU).

11.1.2 Debug Probe

The LPCXpresso54102 board is typically shipped with an old version of CMSIS-DAP firmware installed into the built-in LPC-Link2 debug probe, which does not provide the necessary channels for SWO Trace data transfer back to the host debugger. You need to configure your board so that the MCUXpresso IDE can softload the latest version of firmware. This is done by fitting a jumper on JP5, and then repowering the board. For more details, please see http://www.nxp.com/lpcxpresso-boards

11.1.3 Enabling the Trace Clock

The startup code generated by the new project wizards for LPC5410x in MCUXpresso IDE (and later versions of LPCXpresso IDE) contain code to optionally turn on the trace clock. By default this code will be enabled by the new project wizard, but if it is not required it can be removed by defining the compiler symbol `DONT_ENABLE_SWVTRACECLK`.

If you are using different startup code (for instance, as provided in the projects in the LPCOpen v2.14.1 package for the LPCXpresso5410x board), then you can add the following code to your project to turn on the trace clock (for example, right at the start of `main()` or in the startup file before the call to `main()`) :

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x400000E4;
volatile unsigned int *SYSAHBCLKCTRLSET = (unsigned int *) 0x400000C8;
// Write 0x00000001 to TRACECLKDIV (0x400000E4) – Trace divider
*TRACECLKDIV = 1;
// Enable IOCON peripheral clock (for SWO on PIO0-15 or PIO1_1)
// by setting bit13 via SYSAHBCLKCTRLSET[0] (0x400000C8)
*SYSAHBCLKCTRLSET = 1 << 13; // 0x2000
```

Note that later versions of the LPCOpen package for LPC5410x should contain appropriate trace clock setup code in the startup file.

11.1.4 SWO Pinmux Configuration

On LPCXpresso54102 boards, pin P0_15 is connected to SWO of the debug connector. This needs configuring in the pinmux settings for your project.

If you are using the examples from the LPCOpen v2.14.1 package for the LPCXpresso5410x board, then you need to modify the pinmux settings in `board_sysinit.c` of the lpc_board_lpcxpresso_54102 library project, so that the SWO settings are not commented out by the `#if 0 ... #endif` clause (as they are by default). Thus, after modifying the code, it should look like:

```
      {0, 15, (IOCON_FUNC2 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWO */
#if 0  /* Debugger signals, do not touch */
      {0, 16, (IOCON_FUNC5 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWCLK_TCK */
      {0, 17, (IOCON_FUNC5 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWDIO */
#endif
```

Note that later versions of the LPCOpen package for LPC5410x should contain appropriate SWO pinmux setup code for the LPCXpresso54102 board in the board library.

12. Appendix D – SWO Trace Setup for LPC5411x

12.1 To Carry Out SWO Trace on LPC5411x

1. Ensure that your board has SWO pinned out to the debug connector.
2. If using the built-in LPC-Link2 debug probe of a LPCXpresso54114 board, ensure that the probe is configured for DFU booting.
3. Turn on the trace clock within the MCU, as this is not enabled by default.
4. Configure the MCU pinmuxing, so that the SWO signal is accessible on the appropriate pin of the MCU.

This should typically be done within each of your application projects (or library projects that your projects link against).

Note that SWO Trace on LPC5411x MCUs can only be carried out for debug sessions connected to the Cortex-M4 CPU, not to the Cortex-M0+.

12.1.1 SWO Pin and Debug Connector

On LPCXpresso54102 boards, pin P0_15 is connected to SWO of the debug connector.

If you are using a different board, you will need to check the schematics to identify if SWO is connected to the debug connector (and on which pin from the MCU).

12.1.2 Debug Probe

The LPCXpresso54114 board is often shipped with an old version of CMSIS-DAP firmware installed into the built-in LPC-Link2 debug probe, which does not provide the necessary channels for SWO Trace data transfer back to the host debugger. You need to configure your board so that the MCUXpresso IDE can softload the latest version of firmware. This is done by fitting a jumper on JP5, and then repowering the board. For more details, please see http://www.nxp.com/lpcxpresso-boards

12.1.3 Enabling the Trace Clock

Preinstalled Part Support for LPC5411x

The startup code generated by the new project wizards for LPC5411x in MCUXpresso IDE (and LPCXpresso IDE) contains code to optionally turn on the trace clock. By default this code will be enabled by the new project wizard, but if it is not required it can be removed by defining the compiler symbol `DONT_ENABLE_SWVTRACECLK`.

This should also be included in the startup code provided as part of LPCOpen packages for LPC5411x.

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x40000304;
volatile unsigned int *SYSAHBCLKCTRLSET = (unsigned int *) 0x40000220;
// Write 0x00000000 to TRACECLKDIV – Trace divider
*TRACECLKDIV = 0;
// Enable IOCON peripheral clock (for SWO on PIO0-15 or PIO1_1)
// by setting bit13 via SYSAHBCLKCTRLSET[0]
*SYSAHBCLKCTRLSET = 1 << 13; // 0x2000
```

SDK Installed Part Support for LPC5411x

The startup code for LPC5411x from the SDK for these parts contains similar clock code setup to the preinstalled part support given above.

12.1.4 SWO Pinmux Configuration

On LPCXpresso54114 boards, pin P0_15 is connected to SWO of the debug connector. This needs configuring in the pinmux settings for your project.

Preinstalled Part Support for LPC5411x

If you are using LPCOpen, this will normally have already been done in the pinmux settings in `board_sysinit.c` of the lpc_board_lpcxpresso_54114 library project, so that the SWO settings are not commented out by the `#if 0 ... #endif` clause, thus:

```
      {0, 15, (IOCON_FUNC2 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWO */
#if 0  /* Debugger signals, do not touch */
      {0, 16, (IOCON_FUNC5 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWCLK_TCK */
      {0, 17, (IOCON_FUNC5 | IOCON_MODE_INACT | IOCON_DIGITAL_EN)}, /* SWDIO */
#endif
```

SDK Installed Part Support for LPC5411x

The file `/board/pin_mux.c` needs modifying to configure the pinmux settings for SWO. The can be done by adding the following code to the end of `BOARD_InitPins()`:

```
/* PORT0 PIN15 (coords: 50) is configured as SWO */
IOCON_PinMuxSet(IOCON, PORT0_IDX, PIN15_IDX, port0_pin15_config);
```

Note that this change may have been already made in some of the SDK supplied examples (for example the *demo_apps*), but not for all of them. So do check before attempting to carry out SWO Trace whether the pinmux for your project has been configured for SWO or not.

13. Appendix E – SWO Trace Setup for LPC546xx

13.1 To Carry Out SWO Trace on LPC546xx

1. Ensure that your board has SWO pinned out to the debug connector.
2. Turn on the trace clock within the MCU, as this is not enabled by default.
3. Configure the MCU pinmuxing, so that the SWO signal is accessible on the appropriate pin of the MCU.

13.1.1 SWO Pin and Debug Connector

On LPCXpresso54608 boards, pin P0_10 is connected to SWO of the debug connector. The pinmuxing needs to set this pin up for FUNC6 to connect SWO.

If you are using a different board, you will need to check the schematics to identify if SWO is connected to the debug connector (and on which pin from the MCU).

13.1.2 Enabling the Trace Clock

This should typically be done within each of your application projects. For instance, the following code could be added to your startup code:

```
volatile unsigned int *TRACECLKDIV = (unsigned int *) 0x40000304;
volatile unsigned int *SYSAHBCLKCTRLSET = (unsigned int *) 0x40000220;
// Write 0x00000000 to TRACECLKDIV / Trace divider
*TRACECLKDIV = 0;
// Enable IOCON peripheral clock
// by setting bit13 via SYSAHBCLKCTRLSET[0]
*SYSAHBCLKCTRLSET = 1 << 13; // 0x2000
```

When using the SDK, this is generally implemented in the function `SystemInit()` in `CMSIS/system_LPC54608.c`, which will normally be called by the startup code.

```
SYSCON->ARMTRCLKDIV   = 0;
```

13.1.3 SWO Pinmux Configuration

The file `/board/pin_mux.c` needs modifying to configure the pinmux settings for SWO. The can be done by adding the following code to the end of `BOARD_InitPins()`:

```
IOCON_PinMuxSet(IOCON, 0, 10, IOCON_MODE_INACT | IOCON_FUNC6 |
                          IOCON_DIGITAL_EN | IOCON_INPFILT_OFF);
```

Note that some of the SDK supplied examples may already have the pinmuxing set up for SWO (for example, the *demo_apps*). But typically not all do. So do check before attempting to carry out SWO Trace whether the pinmuxing for your project has been configured for SWO or not.