

AC492
Application Note
Running BareMetal User Applications on PolarFire SoC
FPGA



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1 Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Revision 2.0

Updated for Libero SoC v12.6.

1.2 Revision 1.0

The first publication of this document.

2 Running BareMetal User Applications on PolarFire SoC FPGA

Microchip's PolarFire® SoC FPGAs include industry's first RISC-V based Microprocessor Subsystem (MSS) and a fabric that inherits all the features of the PolarFire family. The PolarFire SoC MSS includes 5x 64-bit RISC-V processor cores, AXI Switch, DDR Controller, fabric Interface Controllers (FIC), and a rich set of peripherals. For more information about the PolarFire SoC MSS and its components, see [UG0880: PolarFire SoC FPGA MSS User Guide](#). PolarFire SoC FPGAs are ideal for running BareMetal applications.

PolarFire SoC standalone MSS Configurator (no separate license required) facilitates independent configuration of MSS for use in Libero® SoC and SoftConsole. The standalone MSS configurator provides a seamless interface and can be used by Embedded Software developers and FPGA designers. For more information, see [PolarFire SoC Standalone MSS Configurator User Guide](#). FPGA designers can add fabric components by using Libero SoC SmartDesign and IP Library.

Microchip's MPFS-ICICLE-KIT features the MPFS250T_ES SoC FPGA, a rich set of peripherals, ROM, and RAM options. For ROM requirement, the kit includes an 8 GB eMMC Flash memory. For external RAM requirement, the kit includes a 2 GB LPDDR4 device. The kit also features an SD Card slot. For more information, see [UG0882: PolarFire SoC FPGA ICICLE Kit User Guide](#).

This application note describes how to run BareMetal user applications on MPFS-ICICLE-KIT.

2.1 Prerequisites

Before running the BareMetal user applications, the ICICLE kit must be programmed with the ICICLE reference design. Ensure to follow the documentation provided on [GitHub](#) and program the ICICLE kit reference design with one of the FlashPro Express programming files.

3 Running the BareMetal User Applications

Before you start, ensure to program the ICICLE KIT as described in [Prerequisites](#). After successful programming, the following user applications can be run:

- System Services
- Single-Bit Error Detection and Correction for L2 LIM
- MicroPython

This document describes the steps to run the System Services application.

Note: For information about running other BareMetal user applications, see the [baremetal_applications GitHub](#) web page.

3.1 System Services

System Services [SoftConsole](#) project includes the following source files for running System Services:

- BareMetal MSS System Services driver which is available at the following location:
https://github.com/polarfire-soc/polarfire-soc-bare-metal-library/tree/master/src/platform/drivers/mss_sys_services
- PolarFire SoC hardware abstraction layer source code (`mpfs_hal`). Using the `mpfs_hal` code, the user can access all of the PolarFire SoC MSS registers like E51 and U54 local interrupt registers, L2 cache, MPU, segmentation blocks, and others registers. This folder also includes the MSS peripherals base address file.

Note: Hardware parameters like MSS clocks, memory, and peripheral source files are generated in SoftConsole using the MSS XML configuration file. The MSS XML configuration file is available at <https://github.com/polarfire-soc/icicle-kit-reference-design/tree/master/XML>.

3.1.1 Running the System Service Application

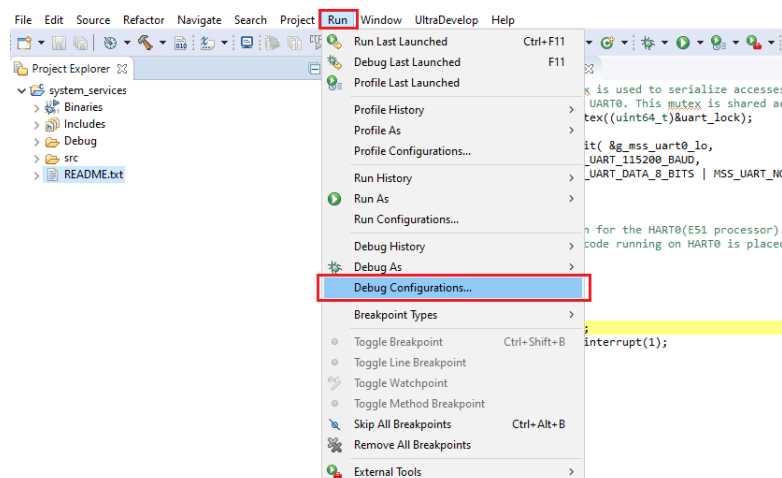
This section describes how to launch the System Services application in debug mode using SoftConsole and run the PolarFire SoC System Services via serial interface.

Note: This SoftConsole project can also be built in release mode and run from eNVM. Select Run > External Tools > PolarFire SoC program non secure boot mode 1 option to program the eNVM with the application and execute it.

To run the System Services:

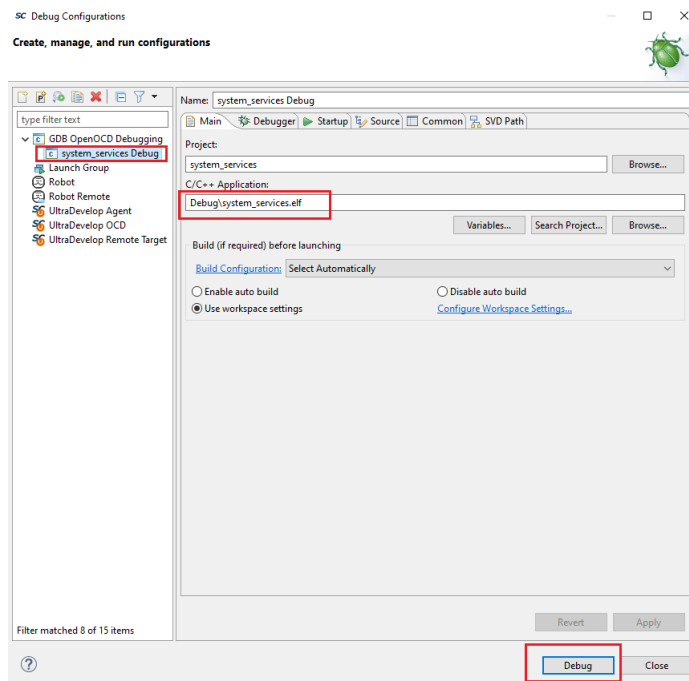
1. Launch SoftConsole with the provided System Services project.
2. Click **Run->Debug Configurations**.

Figure 1 • Debug Configurations



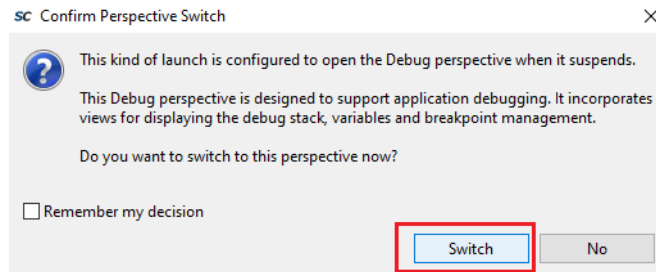
3. In the Debug Configurations window, select the debug project highlighted in Figure 2.
4. Select the **Debug** option in the dialog box for launching the application in debug mode.

Figure 2 • Launching the Debugger



5. In the **Confirm Perspective Switch** window, click **Switch** to go to the debug view.

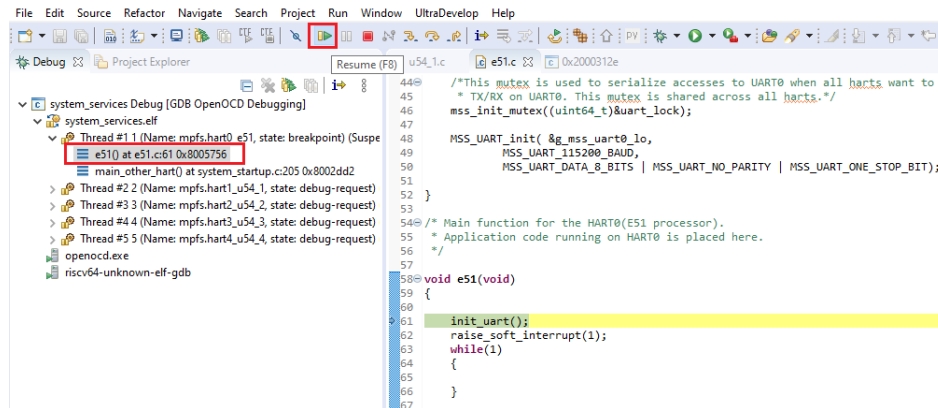
Figure 3 • Confirm Perspective Switch Message



The debugger stops at the `void e51 (void) startup` function in the `e51.c` file. This function initializes the UART interface and sends a software interrupt to the U54_1 processor core and releases it from the wait for interrupt mode (WFI). The u54_1 hart starts executing the System Services functions.

6. Click Resume to start running System Services application as shown in Figure 4.

Figure 4 • Resume Debugging



7. System Services options are displayed on the terminal, as shown in Figure 5. For information about each System Service and output bit fields, see *UG0905: PolarFire SoC FPGA System Services User Guide*.

Figure 5 • System Services Options

```

**** PolarFireSoC system services Example ****
Notes: Return data from System controller is displayed byte-wise with LSB first
       Input data is provided LSB first. Each ASCII character is one Nibble of d
       ata
Select Service:
Device and Design Information Services:
1. Read Device Serial Number
2. Read Device User-code
3. Read Device Design-info
4. Read Device Certificate
5. Read Digest
6. Query Security
7. Read Debug Information
Data Security Services:
8. Digital Signature
9. PUF Emulation
a. Nonce
  
```

8. Enter 1 to select **Read Device Serial Number**.
The 128-bit Read Device Serial Number (DSN) is displayed, as shown in Figure 6.

Figure 6 • Read Device Serial Number

```

-----
Device serial number:  E24B8BFEB7CA08B639F6FDB7D0E9EB45
-----
  
```

Each PolarFire SoC FPGA device has a unique, publicly readable, 128-bit DSN. The DSN can be used in cryptographic protocols to uniquely identify the device. For more information, see *UG0918: PolarFire SoC FPGA Security User Guide*.

9. Enter 2 to select **Read Device User-code**.
This can be configured in the Libero SoC project from Design flow->Program Design->Configure Programming Options.
The 32-bit device USERCODE/Silicon signature is displayed, as shown in Figure 7.

Figure 7 • Read Device User-code

```

-----
32bit USERCODE/Silicon signature <MSB first>:  ABCDEF01
-----
  
```

Note: In the Libero project, this USERCODE/silicon signature can be configured from Design flow->Program Design->Configure Programming Options. If the values are not entered, you can see zero.

10. Enter 3 to select **Read Device Design-info**.

Figure 8 • Read Device Design-info

```

-----
Design ID:
F6B0746F700000000000000000000000
00000000000000000000000000000000
Design Version: 0100
Design Back-Level: 0000
-----
  
```

The device design information consists of:

- 256-bit user-defined Design ID.
- 16-bit design version: This can be configured from Design flow->Program Design->Configure Programming Options. In auto update programming, the current design version is compared with the available images in external SPI flash to initiate the auto update on power up.
- 16-bit design back-level: This can be configured from Design flow->Program Design->Configure Security. When back level protection is enabled, the device can only be programmed if the target design version is more than the back-level value.

11. Enter 4 to select **Read Device certificate.**

The device supply chain assurance certificate is displayed, as shown in [Figure 9](#).

Figure 9 • Read Device Certificate

[illegible]

The Device Certificate is a 1024 bytes Microsemi-signed X-509 certificate programmed during manufacturing. The certificate is used to guarantee the authenticity of a device and its characteristics.

12. Enter 5 to select **Read Digest**.

The 576 bytes Digest contains the fabric digest, sNVM digest, and user key digests. The digest protects data integrity. Figure 10 shows the 576 bytes digest.

Figure 10 • Read Digest

```

Read Digest:
98DDC8BD2892E8427A5A2FC92DE86C14
BE721C795FCBE6F80B9A4BBFE165169F
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
3880781015D4B19CC8CBA0EDD682120
C6BB7851335F7C410312397F01C88F50
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
00000000000000000000000000000000
2EA9AB9198D1638007400CD2C3BEF1CC
745B864B76011A0E1BC52180AC6452D4
F5A5FD42D16A20302798EF6ED309979B
43003D2320D9F0E8EA9831A92759FB4B
00000000000000000000000000000000
00000000000000000000000000000000
2EA9AB9198D1638007400CD2C3BEF1CC
745B864B76011A0E1BC52180AC6452D4
F5A5FD42D16A20302798EF6ED309979B
43003D2320D9F0E8EA9831A92759FB4B
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
00243D7630DD1E1CA4C5B93988B4B1D2A
4F7676103B9D88F34DCF228E044F4B00
F5A5FD42D16A20302798EF6ED309979B
43003D2320D9F0E8EA9831A92759FB4B
00000000000000000000000000000000
00000000000000000000000000000000
EC5E6321EA8D054484CD9F6F98DCC28
9F3C58913D36EDE2ED95174E15EB1204
B5F0B8CB89DAD4031B7B8B57ED90F2AE
CC5AF9197C26BE8387F4C0C73A8D5348
  
```

13. Enter 6 to select **Query Security**.

The non-volatile states of user security lock is displayed, as shown in Figure 11.

The design does not include any user security settings for device security. Security locks can be configured from Design flow->Program and Debug Design->Configure Security.

Figure 11 • Security Locks

```

-----
Security locks: 00000000000000000000357AB801000000
FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF
00
-----
  
```

14. Enter 7 to select **Read Debug Information**.

The debug information is displayed, as shown in Figure 12. In Figure 12, the highlighted 4 bytes E1000000 (LSB first) indicates the number of times the device was programmed (programming cycles).

Figure 12 • Read Debug Information

```

Debug info:
000000CE280021002300CF09C409CB09
0A07B902CC190000000000000000000
C101C44C0171198AFF00FFFF00000000
0003FFFFCA00000044040000E1000000
0080781015D4B19C0000000000010010
FF3E00007E00030003000000000000
  
```

15. Enter 8 to select **Digital Signature**.

The digital signature in both Raw and DER formats is displayed, as shown in Figure 13.

Figure 13 • Digital Signature

```

Digital Signature service:
48 byte hash value:
1B50C211898959574808084B47DD499D
1CD656DC4C18A187F4CE58A6265F689D
1B50C211898959574808084B47DD499D
Raw format:
Digital Signature service successful.
Output Digital Signature - Raw format:
FCFACE438477C71DC46E37A95C996FD4
223BD44547B1C914B5800647FFFC1D13
865DB760968604BC61975E8936725A45
3287F42FEDDAC4F6452F14151BD0C754
BF18EA57D677578D1F6EF4D73E9E40BA
7EEF45F2D33F562A99D5243B2ECA61A8
DER format:
Digital Signature service successful.
Output Digital Signature - DER format:
3066023100A83885070B274618CAF277
33B889CD6A8B870D4B0D51966BB9B2DC
EE5A86AB58EFBB580A4EC51EE1D22CE1
540251979A023100B9DD245769CE911E
00C2125DFC2E777A0352BB5AE5E77959
6418BB7005F2B287963A2E862643ACEA
EA6BB2DB9863DB76
  
```

The digital signature service takes a user supplied SHA384 hash and signs it with the devices private key. The application randomly generates the SHA384 hash value. The Digital Signature service sends the hash value to the System Controller. The System Controller Cryptoprocessor runs the Elliptic Curve Digital Signature Algorithm (ECDSA) using the hash and the device private key to generate the signature.

16. Enter 9 to select PUF Emulation service.

The PUF emulation service provides a mechanism for authenticating a device, or for generating a pseudo-random bit strings that can be used for different purposes. When this service is selected, the service by default accepts a 128-bit challenge and an 8-bit optype, and returns a 256-bit response unique to the challenge and the optype as shown in Figure 14.

Figure 14 • PUF Emulation Service

```

The challenge OPTYPE range(0x0 to 0xFF): C8
16 byte challenge:
C8B02F4FB7F702B1A08AD1FECBACCC63
PUF emulation service successful.Generated Response:
23C8C11D424C6837C1DFCCBFAFE60D05
59C96927D179026E187E1B1FDE996DB6
  
```

17. Enter "a" to select **Nonce service**.

The 32 bytes nonce value is generated by the device as shown in Figure 15.

Figure 15 • Nonce Value

```

Generated Nonce:
897DF0D3A3A6F64963A616995A7602FA
D8441714A2AFE3964897F6BD524E7C71
  
```

This concludes the running System Services application and the SoftConsole debug session can be terminated.