

TU0823
Tutorial
Secure Production Programming Solution using HSM





Power Matters.™

Microsemi Corporate Headquarters

One Enterprise, Aliso Viejo,
CA 92656 USA

Within the USA: +1 (800) 713-4113

Outside the USA: +1 (949) 380-6100

Fax: +1 (949) 215-4996

Email: sales.support@microsemi.com

www.microsemi.com

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Contents

1	Revision History	1
1.1	Revision 1.0	1
2	Secure Production Programming Solution using HSM	7
2.1	Overview	7
2.2	Terms and Definitions	7
2.3	References	7
2.4	Tutorial Requirements	8
2.4.1	Hardware Requirements	8
2.4.2	Software Requirements	8
2.4.3	Source Files	8
2.5	Prerequisites	8
3	SPPS Flow	9
3.1	Design and Firmware Data Hand-off	10
3.2	U-HSM and M-HSM Parameters Configuration	12
3.3	Keyset Generation	14
3.4	Programming Data Creation and Bitstream Initialization	15
3.4.1	Programming Data Creation via JDC Import	15
3.4.2	eNVM Client Modification	15
3.4.3	Initialization of Master Programming Bitstream	15
3.5	Programming Job Creation	16
3.5.1	Create HSM Task	16
3.6	Job Request-Reply Handshake Protocol	17
3.7	Export HSM Task	17
3.8	Production	18
3.9	HSM Job Completion or Termination	22
3.10	Post-Production	23

Tables

Table 1	Terms and Definitions	7
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Figures

Figure 1	SPPS Flowchart	10
Figure 2	Libero SoC Console Window	11
Figure 3	Exporting .jdc File	11
Figure 4	Libero Log displaying Finishing of Export of Job Manager Data	11
Figure 5	Script for U-HSM Parameter Setting	12
Figure 6	Executing a Script in Job Manager	13
Figure 7	Browsing the Script for Execution in Job Manager	13
Figure 8	Script for M-HSM Parameter Setting	14
Figure 9	Executing a Script in FlashPro Express	14
Figure 10	Browsing the Script for Execution in FlashPro Express	14
Figure 11	Keyset File Generation	15
Figure 12	Script for New Project Creation	15
Figure 13	Script for Loading Design Data in New Programming Data Entry	15
Figure 14	eNVM Client Modification	15
Figure 15	Script for Initialization of Bitstream Generation	16
Figure 16	Script for Programming Job Creation using Job Manager for FlashPro Express	16
Figure 17	Script for Task Creation and Job Tickets	17
Figure 18	Script for Exporting Job Request	17
Figure 19	Script to Process Job Request	17
Figure 20	Script for Importing Job Reply	17
Figure 21	Script for Exporting HSM Task	18
Figure 22	Script for Creating FlashPro Express Project from the Job File	18
Figure 23	Programming Job Folder (created on script execution)	18
Figure 24	Programming Window	19
Figure 25	Programming Window: PROGRAM option being RUN	19
Figure 26	Script for Exporting Job Status	20
Figure 27	Log - Before executing the Program	20
Figure 28	Log - After executing the Program	20
Figure 29	Log - After executing the Program in the new board	21
Figure 30	Log - After executing Verify and Erase	21
Figure 31	MyJobStatus File	21
Figure 32	Script for Job Status Check	22
Figure 33	Job Status in Message Window of Job Manager	22
Figure 34	Script for Terminating all Job Tickets	22
Figure 35	Job Competition - FlashPro Express Log	23
Figure 36	MyJobStatusEnd File	23
Figure 37	Script to Check Job End Status	23
Figure 38	Job End Status - Job Manager Log	24

1 Revision History

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

1.1 Revision 1.0

The first publication of this document.

2 Secure Production Programming Solution using HSM

2.1 Overview

Microsemi offers Secure Production Programming Solution (SPPS) to prevent overbuilding and cloning of the user designs. For implementing the SPPS, two Hardware Security Modules (HSM) are required. An HSM is a physical computing device connected to a PC via Interfaces like USB or PCIe. HSM protects and manages user key information and enables secured key injection at an untrusted manufacturing facility.

Using Thales e-Security FIPS140-2 level 3 certified HSMs, custom firmware and the state-of-the-art security protocols built into every Microsemi SmartFusion2 SoC FPGA and IGLOO2 FPGA, customers can automatically prevent overbuilding of their systems in any manufacturing facility anywhere in the world, saving millions of dollars in lost revenue.

This tutorial provides step-by-step instructions to use SPPS using tools provided by Microsemi and Thales nShield Edge module as HSM.

2.2 Terms and Definitions

Table 1 • Terms and Definitions

Term	Definition
HSM	Hardware Secure Module
U-HSM	User HSM
M-HSM	Manufacturer HSM
CM	Contract Manufacturer
OE	Operation Engineer
DSN	Device Serial Number
DFK-DB	Diversified Factory Key Database
IHP	In-House Programming
SPM	Security Policy Manager

2.3 References

1. SPPS User Guide: *Secure Production Programming Solution (SPPS) User Guide for Libero SoC v11.8 SP1*
2. User HSM Installation and Setup User Guide: *User HSM Installation and Setup User Guide for Libero SoC v11.8 SP1*
3. Manufacturer HSM Installation and Setup User Guide: *Manufacturer HSM Installation and Setup User Guide for Libero SoC v11.8 SP1*
4. Programming Job Manager User Guide: *Programming Job Manager User Guide for Libero SoC v11.8 SP1*
5. FlashPro Express User Guide: *FlashPro Express User Guide for Libero SoC v11.8 SP3*

2.4 Tutorial Requirements

2.4.1 Hardware Requirements

- Thales nShield Edge HSM (Part Number: **MSCNC4031U-10**) or Thales nShield Solo HSM (Part Number: **MSCNC4433E-500**) - 2 Modules
- Microsemi SmartFusion2 Security Evaluation Kits - 3 Kits
- FlashPro4/FlashPro5 Programmer

2.4.2 Software Requirements

- Libero SoC v11.8 SP2
- Programming & Debug v11.8 SP1¹
- SPPS HSM Servers
 - User HSM Server v11.8 SP1
 - Manufacturer HSM Server v11.8 SP1

2.4.3 Source Files

- Sample SPPS scripts

2.5 Prerequisites

Before you start:

1. Download the design files from the following link:
http://soc.microsemi.com/download/rsc/?f=m2s_tu0823_liberov11p8_df
2. Download and install Libero SoC v11.8 SP2 from the following location:
<https://www.microsemi.com/product-directory/soc-fpgas/1692-smartfusion2#documentation>

It is mandatory for all users to install the required software and setup the HSM modules. For more information, refer:

- *User HSM Installation and Setup User Guide for Libero SoC v11.8 SP1*
- *Manufacturer HSM Installation and Setup User Guide for Libero SoC v11.8 SP1*

¹.Programming & Debug Tools are installed automatically with Libero SoC. It is also available for standalone download for convenience (if needed for production programming and lab use). It includes FlashPro Express and Job Manager for secure production programming solution.

3 SPPS Flow

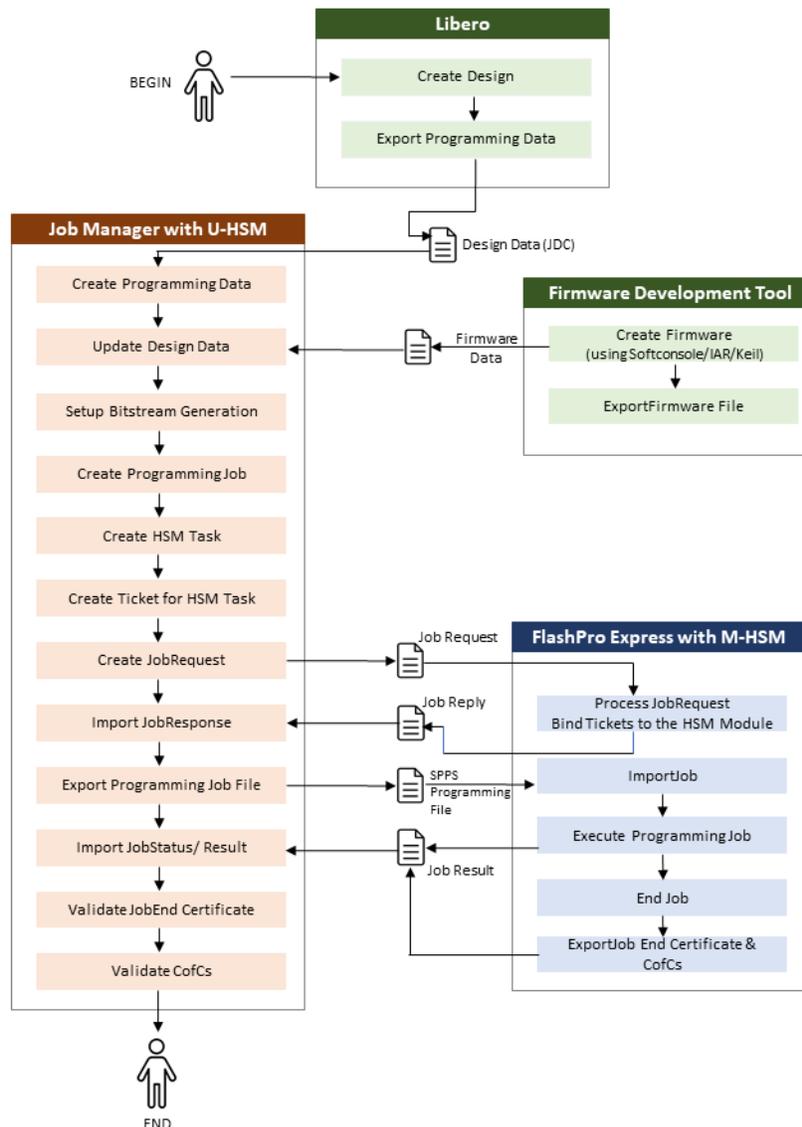
The Secured Production Programming Solution (SPPS) is designed to prevent overbuilding and cloning of the user design. In this solution, the User HSM (U-HSM) is used to generate and protect the user keys and a secured programming job file that can be safely sent to the Contract Manufacturer (CM). The job file contains the encrypted bitstream and job ticket. The job ticket contains the number of devices that the CM is authorized to program.

After receiving secured programming job file, the job must be loaded into the targeted Manufacturing HSM (M-HSM), through FlashPro Express. To program a device, an authorization code specific to the device must be obtained from the M-HSM and sent to the device, before sending in the bitstream. This process enables the M-HSM to track the device being programmed, as well as the number of devices which are programmed. M-HSM will stop issuing authorization codes, once the allowed device number has been reached.

Figure 1, page 10 shows the overall SPPS flowchart. For more detailed information on SPPS flow, refer [Secure Production Programming Solution \(SPPS\) User Guide for Libero SoC v11.8 SP1](#). To understand the flow, this tutorial is split into following steps:

1. [Design and Firmware Data Hand-off](#), page 10
2. [U-HSM and M-HSM Parameters Configuration](#), page 12
3. [Keyset Generation](#), page 14
4. [Programming Data Creation and Bitstream Initialization](#), page 15
5. [Programming Job Creation](#), page 16
6. [Job Request-Reply Handshake Protocol](#), page 17
7. [Export HSM Task](#), page 17
8. [Production](#), page 18
9. [HSM Job Completion or Termination](#), page 22
10. [Post-Production](#), page 23

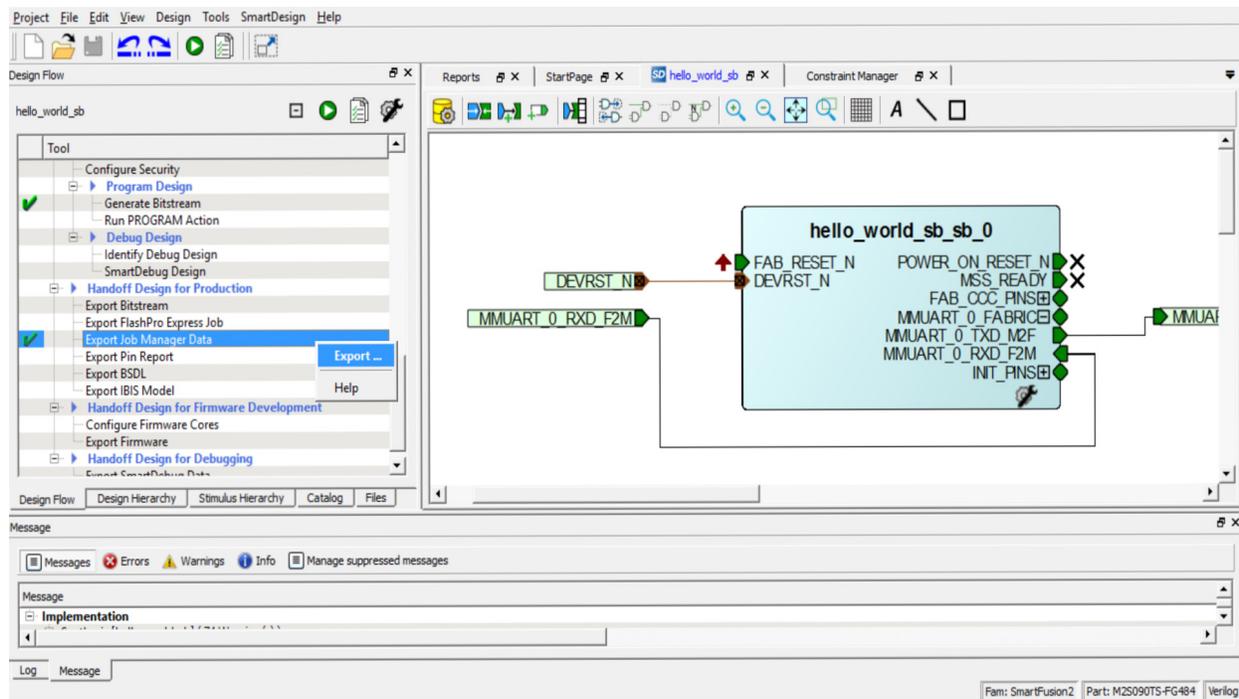
Figure 1 • SPPS Flowchart



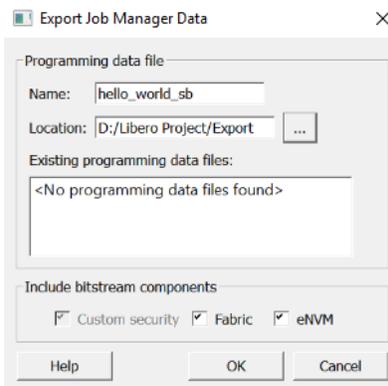
3.1 Design and Firmware Data Hand-off

A design is converted into Bitstream Data and is exported as JDC file to create secure production programming jobs using SPPS flow. The following steps explain design and firmware data hand-off:

1. Using Libero SoC v11.8 SP2 software, open the Libero design for which the secure programming job needs to be created.
2. Configure design security features using Security Policy Manager. Open the Security Policy Manager by double-clicking on Configure Security in Libero Design Flow window. For more information on Configuration of Security features, refer [Libero SoC User Guide](#).
3. In Libero Design Flow console, Right-click on Export Job Manager Data (under Hand-off Design for Production) and select Export option.

Figure 2 • Libero SoC Console Window


4. Enter the **.jdc** (Job Data Container) file name as shown in Figure 3, page 11 and select the Location by browsing for exporting the file. Bitstream components: Fabric, and eNVM; are given as options. Choose the required option while Exporting the Job Manager Data.

Figure 3 • Exporting .jdc File


5. Click OK.
6. Job Manager Data is exported. In the 'Export' folder of the Libero Project Location, a **.jdc** file is created.

Figure 4, page 11 display the Log Window with export job manager data finish message.

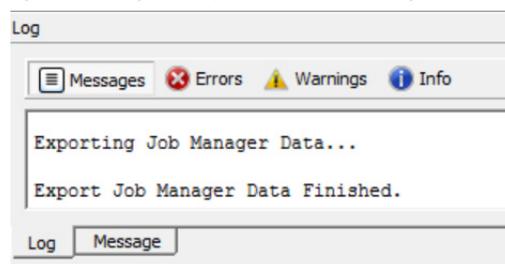
Figure 4 • Libero Log displaying Finishing of Export of Job Manager Data


Figure 6 • Executing a Script in Job Manager

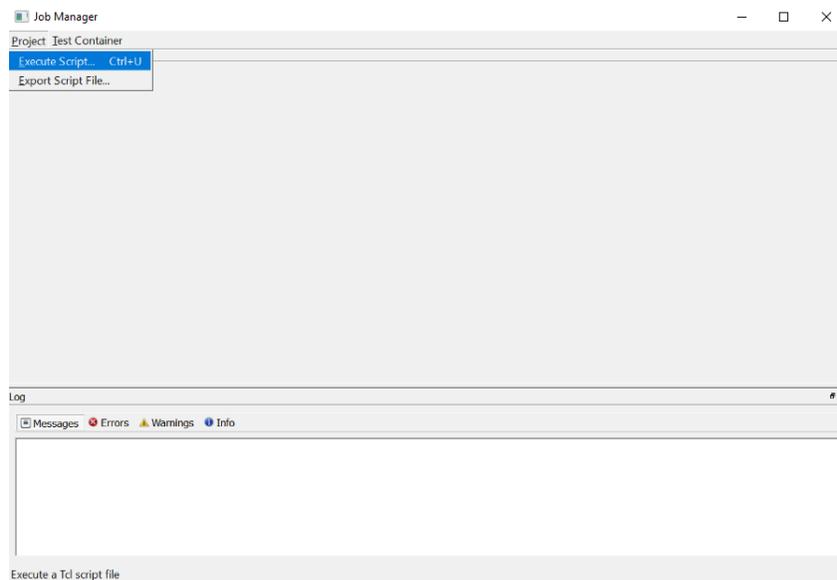
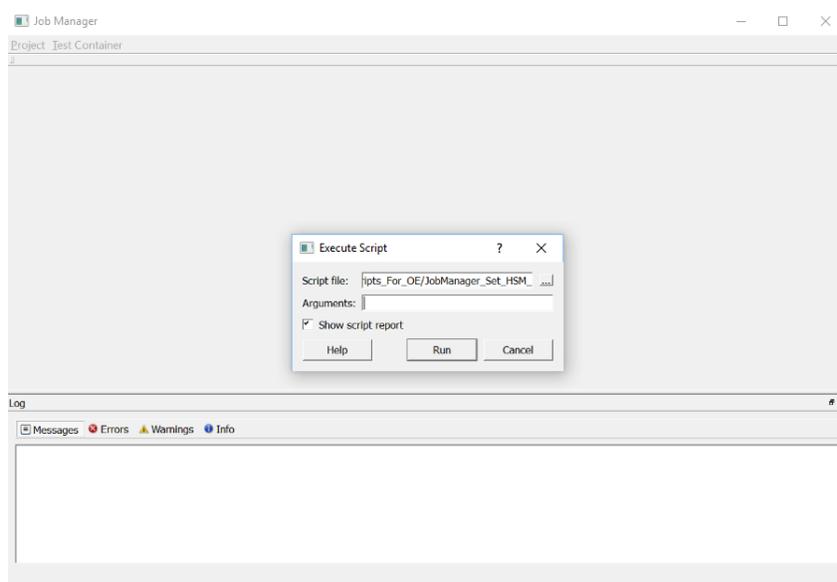


Figure 7 • Browsing the Script for Execution in Job Manager



11. To use FlashPro Express in the HSM flow, M-HSM parameters must be set. M-HSM configuration data specifies:

- Name or IP address of the M-HSM server
- M-HSM UUID assigned by Microsemi
- HSM type
 - TRUE - FlashPro Express will use the Manufacturer features of the User HSM
 - FALSE - FlashPro Express will use a Manufacturer HSM
- Username to access the HSM files via FTP server.
- Password to access the HSM files via FTP server.

The `set_hsm_params` TCL command is used to configure HSM. This command saves the HSM parameters for the FlashPro Express application. This remains in effect until it is overridden using this same command.

Use the ***FlashProExpress_Set_HSM_Parameters.tcl*** script as shown in [Figure 8](#), page 14, to set the M-HSM parameters. Edit this script to set your M-HSM configuration.

Figure 15 • Script for Initialization of Bitstream Generation

```
# Init master bitstream that uses Auth code protocol to program initial security, eNVM and FABRIC. Generate CoC.
# Note: that this bitstream will program all eNVM clients available in design.
# If you need to program only specific client(s), use "-envm_clients" option
init_bitstream -data_name {MyProgData0} -bitstream_name {MyBistream} -bitstream_type {MASTER} \
  -features {SECURITY} -use_protocol {AUTH_CODE} -generate_coc -auth_keymode {KFPE}
```

13. Edit the **JobManager_Create_Project.tcl** script as per the application requirements and run it using Job Manager to create programming job entry and initialize bitstream.

3.5 Programming Job Creation

A Programming Job is a set of data used by programming systems for device programming in HSM flow. The Programming Jobs created by the Job Manager can be programmed into the device using FlashPro Express or In House Programming (IHP). A Programming Job contains the following data:

- Job type (FlashPro Express or IHP)
- Job origin
- Bitstream(s) for various programming actions (PROGRAM, ERASE, and VERIFY)
- Hardware setup information – for FlashPro Express job type
 - Type of hardware interface (JTAG in this version of the Job Manager)
 - Configuration
- Job device(s) – includes basic device information
- Encrypted Job Tickets authorizing programming actions and overbuild protection under control of the HSM
- Encrypted keys and security protocol data required by HSM protocols

A programming job is created in the Job Manager project using the `new_prog_job` TCL command. After creating a FlashPro Express Programming Job, the user specifies type of the hardware setup. Microsemi devices can be programmed using a bitstream generated by a Programming Data entry using `add_microsemi_prog_device` TCL command. A sample command to create JTAG chain with a single device is shown in the following figure.

Figure 16 • Script for Programming Job Creation using Job Manager for FlashPro Express

```
# Create Prog Job for FlashProExpress tool. These steps create JTAG chain with single device and sets MyBistream to program it.
new_prog_job -job_name {MyProgJob} -job_type {FPExpress}
add_microsemi_prog_device -job_name {MyProgJob} -device_name {MyDevice} -device_hw_location {1} \
  -data_name {MyProgData0} -bitstream_name {MyBistream}
```

Refer *Programming Job Manager User Guide for Libero SoC v11.8 SP1* for more information on `add_microsemi_prog_device` TCL command.

3.5.1 Create HSM Task

The OE can prevent overbuilding by allowing the only specific amount of devices to be programmed. The OE manages this by adding HSM task to a Job.

For each HSM Task, the OE can specify programming actions which the CM is authorized to run and the number of devices the actions can be executed on.

This is accomplished by adding the Job Ticket to every authorized programming action (PROGRAM, ERASE, VERIFY) for the target device.

The Job Ticket is created as per the user-selected programming action. This allows the user to separately manage those actions. A new Job Ticket is created with the `new_hsmtask_ticket` TCL command. The `max_device` parameter is used to limit the number of devices a programming action can be executed on. If the `max_device` parameter is set to 'unlimited', overbuild protection is disabled.

Figure 17, page 17 shows the sample commands for HSM task creation and Job Tickets for programming actions for the target device.

Figure 17 • Script for Task Creation and Job Tickets

```
# Create HSM task with tickets to execute programming job. Same job can be executed by multiple CMs,
# if needed via separate HSM Tasks.
#add_hsmtask_to_job -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -cm_request_type {INTERNAL}
add_hsmtask_to_job -job_name {MyProgJob} -hsmtask_name {MyHSMTask}

# Create ticket for each bitstream action: tickets contain encrypted keys and protocol data including optional overbuild protection.
new_hsmtask_ticket -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -ticket_name {MyTicket1} -device_name {MyDevice} -actions {PROGRAM}\
-max_device {2}
new_hsmtask_ticket -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -ticket_name {MyTicket2} -device_name {MyDevice} -actions {VERIFY}\
-max_device {2}
new_hsmtask_ticket -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -ticket_name {MyTicket3} -device_name {MyDevice} -actions {ERASE}\
-max_device {2}
```

14. Edit the **JobManager_Create_HSM_Task.tcl** script per application requirements and run it using the Job Manager to create HSM task with tickets.

3.6 Job Request-Reply Handshake Protocol

The OE executes the Job Request-Reply handshake protocol between the U-HSM and the M-HSM to bind Job Tickets of the HSM Task to the specific physical M-HSM. This process ensures that the Job can only be executed by one HSM only, to ensure effective overbuild protection.

15. The OE exports the file with the Job Request from the Job Manager.
Run the **JobManager_Create_HSM_Job_Request.tcl** script as shown in [Figure 18](#), page 17 using the Job Manager to export the Job Request.

Figure 18 • Script for Exporting Job Request

```
# Export job request file and sent it to CM.
hsmtask_m_request -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -request_file {./MyProgJobRequest.req}

# Close project
close_project -save {TRUE}

# END OF SCRIPT: load created request file in FlashProExpress and bring back generated job response
```

16. The OE passes this Job Request to the Contract Manufacturer (CM). The OE and CM agree on the transport type for delivering the Job Request, depending on their specific case and security policies.
17. The CM loads the received Job Request with FlashPro Express & M-HSM, and exports a Job Reply with ticket IDs and HSM binding information for Job Manager.
Run the **FlashProExpress_Process_Job_Request.tcl** script as shown in [Figure 19](#), page 17 using the FlashPro Express to export Job Reply.

Figure 19 • Script to Process Job Request

```
# FlashProExpress serves job request: generates ticket IDs and HSM binding information for JobManager
process_job_request -request_file {./MyProgJobRequest.req} -reply_file {./MyProgJobReply.rep} -overwrite_reply {TRUE}
save_log -file {./MyProgJobRequestResponse.log}
```

18. The CM sends the Job Reply file back to the OE.
19. The OE imports the received Job Reply into the HSM Task on the Job Manager side.
Run the **JobManager_Import_Job_Reply.tcl** script as shown in [Figure 20](#), page 17 using the Job Manager. After performing this handshake protocol, the HSM Job can be exported from this HSM Task.

Figure 20 • Script for Importing Job Reply

```
open_project -project {./MyProject/MyProject.jprj}

# Import Job Replay with ticket IDs and HSM binding data
hsmtask_m_reply -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -reply_file {./MyProgJobReply.rep}

close_project -save {TRUE}
```

3.7 Export HSM Task

An HSM Task (SPPS programming job) can be exported with the `export_hsmtask` TCL command. The HSM job can only be exported after importing the Job Reply. The HSM job can only be executed on the physical M-HSM that was used to generate the Job Reply.

- Run the **JobManager_Export_HSM_Task.tcl** script as shown in [Figure 21](#), page 18 using the Job Manager to export the HSM task.

Figure 21 • Script for Exporting HSM Task

```
open_project -project {./MyProject/MyProject.jprj}

# Exporting HSM Task
export_hsmtask -job_name {MyProgJob} -hsmtask_name {MyHSMTask} -location {./} -name {MyProgJob}

close_project -save {TRUE}
```

- The OE passes the exported Job to the CM.

3.8 Production

The CM receives the SPPS Programming Job file from the OE and creates a FlashPro Express project with the HSM Job in the SPPS Programming Job file. For the HSM job, some ticket information, such as ticket IDs and overbuild protection data, gets loaded into the specific M-HSM module that participated in the Job Request-Reply handshake protocol.

- Connect the **SmartFusion 2** evaluation board to a FlashPro device before the programming actions are executed.
- Run the script **FlashProExpress_Create_Job_Project.tcl** script as shown in [Figure 22](#), page 18 to create a FlashPro Express project from the Job file received from OE.

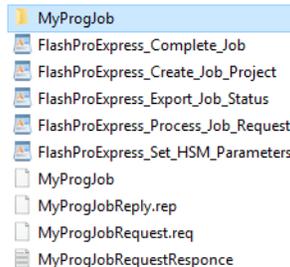
Figure 22 • Script for Creating FlashPro Express Project from the Job File

```
# Create FlashProExpress project from the JOB file.
# This will create a folder with same name as job_file name at the specified location.
# This will import tickets into the CM HSM
create_job_project \
    -job_project_location {./} \
    -job_file {./MyProgJob.job} \
    -overwrite 0

# Run Program/Verify/Erase, etc..
# ...
```

On successful execution of the script, a Programming Job folder is created as shown in [Figure 23](#), page 18 and Programming Window is displayed in the FlashPro Express as shown in [Figure 24](#), page 19.

Figure 23 • Programming Job Folder (created on script execution)



Run *FlashProExpress_Export_Job_Status.tcl* script as shown in [Figure 26](#), page 20 in FlashPro Express to know the number of remaining authorization codes for various programming actions.

Figure 26 • Script for Exporting Job Status

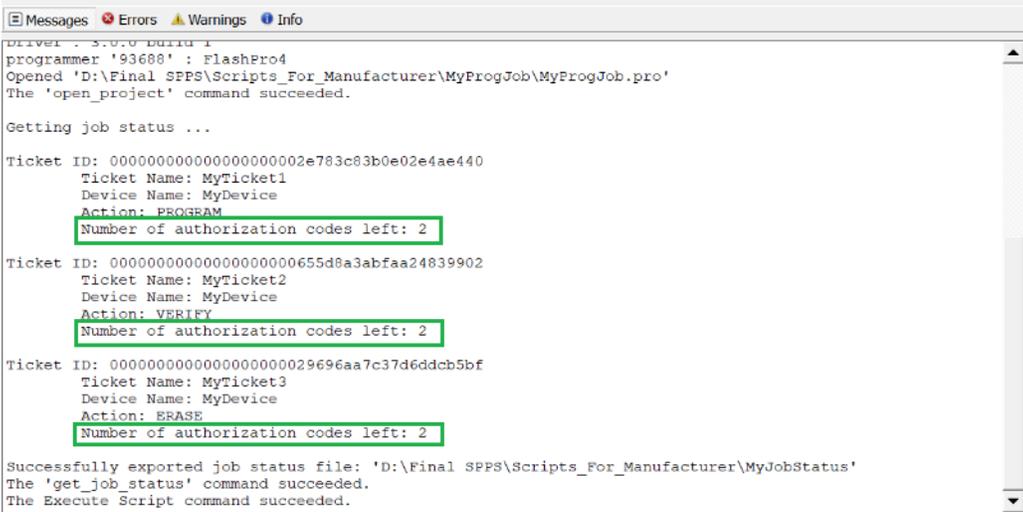
```
# *optional step*: obtain intermediate job status to be sent to JobManger
# FlashProExpress project must be loaded first...
open_project -project {./MyProgJob/MyProgJob.pro}
get_job_status -job_status_file {./MyJobStatus}

# Load exported status file into JobManager to see job status..
```

26. On successful execution of the script, the Job Status is displayed in the Message Box of FlashPro Express and exported as Job Status file.

- Job Status before executing the Program (as shown in [Figure 27](#), page 20):

Figure 27 • Log - Before executing the Program



```
Messages Errors Warnings Info
Driver: 3.0.0 build 1
programmer '93688' : FlashPro4
Opened 'D:\Final SPPS\Scripts_For_Manufacturer\MyProgJob\MyProgJob.pro'
The 'open_project' command succeeded.

Getting job status ...

Ticket ID: 000000000000000000000002e783c83b0e02e4ae440
Ticket Name: MyTicket1
Device Name: MyDevice
Action: PROGRAM
Number of authorization codes left: 2

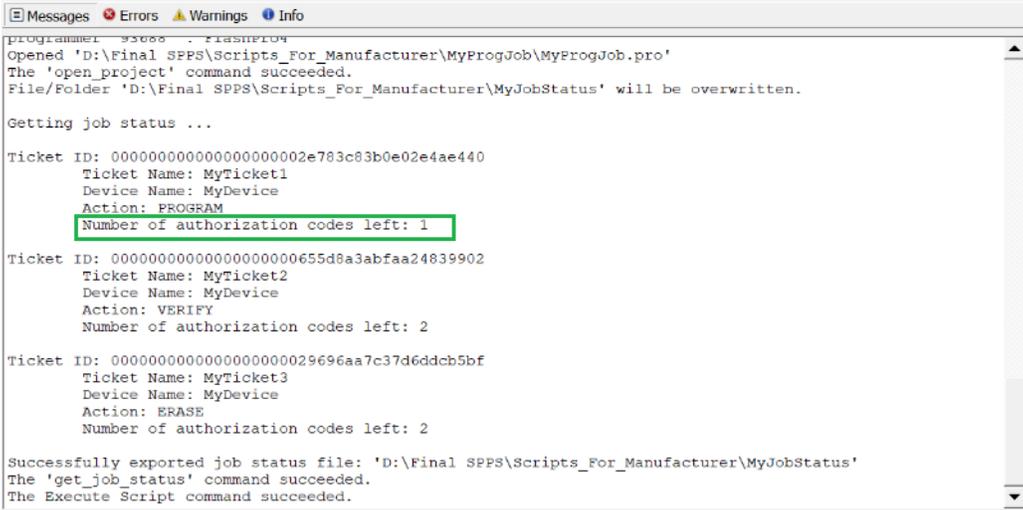
Ticket ID: 0000000000000000000000655d8a3abfaa24839902
Ticket Name: MyTicket2
Device Name: MyDevice
Action: VERIFY
Number of authorization codes left: 2

Ticket ID: 000000000000000000000029696aa7c37d6ddcb5bf
Ticket Name: MyTicket3
Device Name: MyDevice
Action: ERASE
Number of authorization codes left: 2

Successfully exported job status file: 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus'
The 'get_job_status' command succeeded.
The Execute Script command succeeded.
```

- Job Status after executing the Program (as shown in [Figure 28](#), page 20):

Figure 28 • Log - After executing the Program



```
Messages Errors Warnings Info
programmer '93688' : FlashPro4
Opened 'D:\Final SPPS\Scripts_For_Manufacturer\MyProgJob\MyProgJob.pro'
The 'open_project' command succeeded.
File/Folder 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus' will be overwritten.

Getting job status ...

Ticket ID: 000000000000000000000002e783c83b0e02e4ae440
Ticket Name: MyTicket1
Device Name: MyDevice
Action: PROGRAM
Number of authorization codes left: 1

Ticket ID: 0000000000000000000000655d8a3abfaa24839902
Ticket Name: MyTicket2
Device Name: MyDevice
Action: VERIFY
Number of authorization codes left: 2

Ticket ID: 000000000000000000000029696aa7c37d6ddcb5bf
Ticket Name: MyTicket3
Device Name: MyDevice
Action: ERASE
Number of authorization codes left: 2

Successfully exported job status file: 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus'
The 'get_job_status' command succeeded.
The Execute Script command succeeded.
```

- Connect another **SmartFusion 2** evaluation board and Program it. [Figure 29](#), page 21 shows the Job Status after executing the Program in the new board.

Figure 29 • Log - After executing the Program in the new board

```

Messages Errors Warnings Info
FDB File 'D:\Final SPPS\Scripts_For_Manufacturer\MyProgJob\MyBistream.pdb' has been loaded successfully.
DESIGN : hello world sb; CHECKSUM : 0000; PDB_VERSION : 1.9
Driver : 3.0.0 build 1
programmer '93688' : FlashPro4
Opened 'D:\Final SPPS\Scripts_For_Manufacturer\MyProgJob\MyProgJob.pro'
The 'open_project' command succeeded.
File/Folder 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus' will be overwritten.

Getting job status ...

Ticket ID: 000000000000000000000002e783c83b0e02e4ae440
Ticket Name: MyTicket1
Device Name: MyDevice
Action: PROGRAM
Number of authorization codes left: 0

Ticket ID: 00000000000000000000000655d8a3abfaa24839902
Ticket Name: MyTicket2
Device Name: MyDevice
Action: VERIFY
Number of authorization codes left: 2

Ticket ID: 0000000000000000000000029696aa7c37d6ddcb5bf
Ticket Name: MyTicket3
Device Name: MyDevice
Action: ERASE
Number of authorization codes left: 2

```

- Job Status after Verifying and Erasing actions (as shown in [Figure 30](#), page 21):

Figure 30 • Log - After executing Verify and Erase

```

Messages Errors Warnings Info
programmer '93688' : FlashPro4
Opened 'D:\Final SPPS\Scripts_For_Manufacturer\MyProgJob\MyProgJob.pro'
The 'open_project' command succeeded.
File/Folder 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus' will be overwritten.

Getting job status ...

Ticket ID: 000000000000000000000002e783c83b0e02e4ae440
Ticket Name: MyTicket1
Device Name: MyDevice
Action: PROGRAM
Number of authorization codes left: 0

Ticket ID: 00000000000000000000000655d8a3abfaa24839902
Ticket Name: MyTicket2
Device Name: MyDevice
Action: VERIFY
Number of authorization codes left: 1

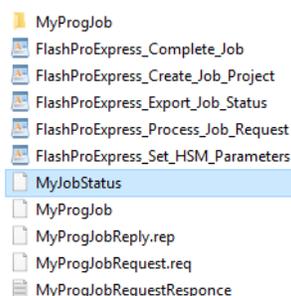
Ticket ID: 0000000000000000000000029696aa7c37d6ddcb5bf
Ticket Name: MyTicket3
Device Name: MyDevice
Action: ERASE
Number of authorization codes left: 1

Successfully exported job status file: 'D:\Final SPPS\Scripts_For_Manufacturer\MyJobStatus'
The 'get_job_status' command succeeded.
The Execute Script command succeeded.

```

- The Job Status file (as shown in [Figure 31](#), page 21) can be transferred to OE for Intermediate Job Status check.

Figure 31 • MyJobStatus File



- The OE can import the Job Status File and check the status of programming job. Run **JobManager_Check_Job_Status.tcl** script as shown in [Figure 32](#), page 22 in Job Manager to check the Intermediate Job Status.

Figure 32 • Script for Job Status Check

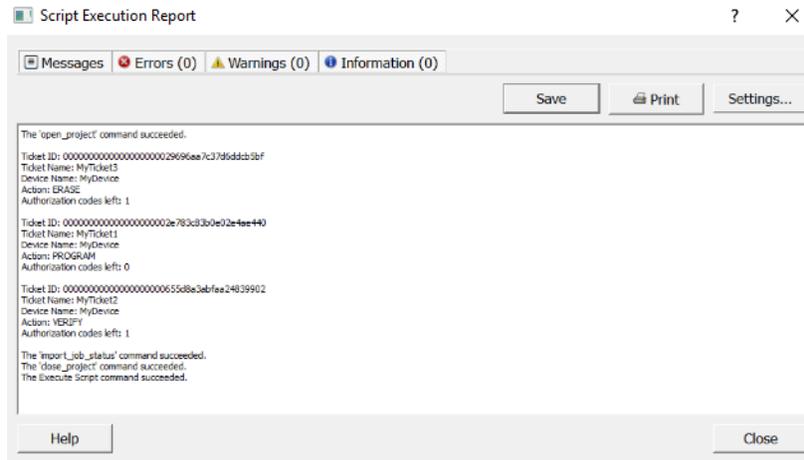
```
# *Optional Step* View job status recieved from FlashProExpress

# Open JobManager project
open_project -project {./MyProject/MyProject.jprj}

# read job status recieved from FlashProExpress..
import_job_status -job_status_file {./MyJobStatus}

close_project -save {TRUE}
```

On successful execution of the script, the Intermediate Job Status is displayed in the Message Box of the Job Manager as shown in [Figure 33](#), page 22.

Figure 33 • Job Status in Message Window of Job Manager

3.9 HSM Job Completion or Termination

Job execution can be stopped in two ways:

- Normal job ending upon finishing programming of the target number of devices. For example, all job ticket overbuild protection counters are exhausted
- Job termination - If some job ticket overbuild protection counters still have devices to program.

Both types of job termination will do the following:

- Remove job tickets from the M-HSM and archive them in a dedicated folder on the M-HSM.
- Generate Job Status with the following data:
 - Device Certificates of Conformance (CofC) generated by devices. The OE can validate the CofC using U-HSM to ensure that only intended contents are programmed into the device.
 - Ticket End certifiers. This is a cryptographically validated proof of removing ticket data from the M-HSM module. Validation of this data can be done by the Job Manager using the U-HSM. Once the Job ticket is removed, the job ticket can no longer be used by the M-HSM.

29. The job can be terminated using `complete_prog_job` command. It exports ticket information to a `JobStatusEnd` file. Use `-terminate` option to terminate the incomplete job.

Run **FlashProExpress_Complete_Job.tcl** script as shown in [Figure 35](#), page 23 in FlashPro Express to terminate all the job tickets.

Figure 34 • Script for Terminating all Job Tickets

```
# This will terminate all the job tickets and export ticket information into the export file
# NOTE that the "-terminate" option must be specified if the job is incomplete (i.e. overbuild
# protection counters not reached).
open_project -project {./MyProgJob/MyProgJob.pro}
complete_prog_job -terminate -job_status_file {./MyJobStatusEnd}

# Load the exported file into JobManager to read job end/termination status..
```


Figure 38 • Job End Status - Job Manager Log