

Using ECC System Service in SmartFusion2 - Libero SoC v11.4

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Purpose

This application note explains how to access an elliptic curve cryptography (ECC) services in the SmartFusion[®]2 system-on-chip (SoC) field programmable gate array (FPGA) devices.

Introduction

ECC is a public key encryption technique based on the elliptic curve theory. ECC is a different mathematical approach used to encrypt and is based on a one-way property in which it is easy to perform a calculation, but not feasible to invert the results of the calculation to find the original numbers.

ECC is used:

- To implement faster, smaller size, and efficient cryptographic keys.
- In digital signatures through elliptic curve digital signature algorithm (ECDSA) and in key exchange through elliptic curve diffie-hellman (ECDH).

ECC feature is available in the larger SmartFusion2 devices such as: M2S090TS and M2S150TS.

ECC has two mathematical services such as: scalar point multiplication and point addition based on the NIST recommended P-384 elliptic curve domain parameters.

In SmartFusion2 SoC devices, ECC services is accessible through the system services. The system services are system controller actions initiated by asynchronous events from the ARM[®] Cortex[®]-M3 processor or a fabric master in the SmartFusion2. ECC is used for data and design security applications and can be disabled through factory or user security settings.

This application note provides a design example to implement and access the following ECC services:

- ECC Point Addition
- Scalar Point Multiplication
- Generate Public Key

References

The following are the references used:

- [SmartFusion2 Microcontroller Subsystem User Guide](#)
- [SmartFusion2 System Controller User Guide](#)
- [SmartFusion2 Security and Reliability User Guide](#)

System Controller Block in SmartFusion2 Device

The ECC services provide access to the System Controller's ECC core. ECC Core block is accessed through the communication block (COMM_BLK).

There are two COMM_BLK instances:

- One in the microcontroller subsystem (MSS) that the user interfaces with
- The other that communicates with the first block that is located in the system controller

The COMM_BLK consists of an APB interface, eight byte transmits FIFO, and eight byte receives FIFO. The COMM_BLK provides a bi-directional message passing facility between the MSS and the system controller.

The ECC system services are initiated using the COMM_BLK in the MSS, which can be read or written by any master on the AMBA high performance bus (AHB) matrix; typically either the Cortex-M3 processor or a design in the FPGA fabric (also known as a fabric master).

The system controller receives the command through the COMM_BLK in the system controller. On completion of the requested service, the system controller returns a status message through the COMM_BLK. The responses generated are based on the selected command.

Figure 1 shows the System Controller block in the SmartFusion2.

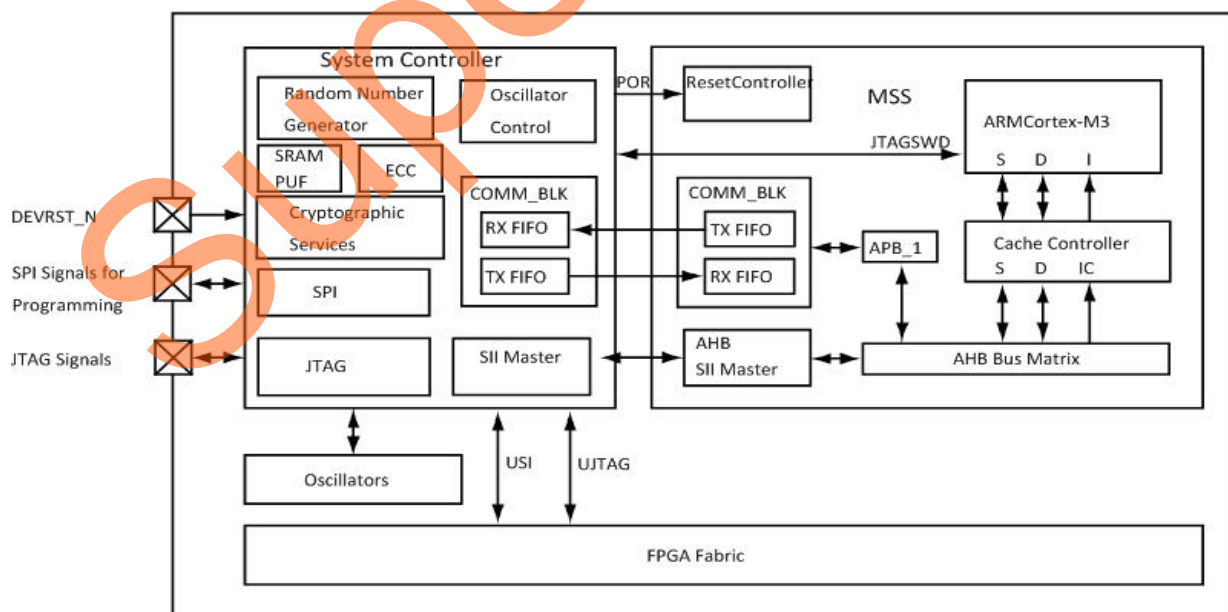


Figure 1 • System Controller Block in SmartFusion2 Device

For more information about "System Controller", refer to the [SmartFusion2 System Controller User Guide](#).

For more information about "COMM_BLK", refer to the "Communication Block" chapter in the [SmartFusion2 Microcontroller Subsystem User Guide](#).

ECC and Services

An elliptic curve defined as the set of points (X, Y), which satisfy an elliptic curve equation of the form:

$$Y^2 = X^3 + aX + b;$$

Where a and b are the elements of a finite field with p^n ($n=192, 224, 256, \text{ or } 384$) elements, where p is a prime number larger than 3. And an example of the Elliptical curve is as shown in [Figure 2](#).

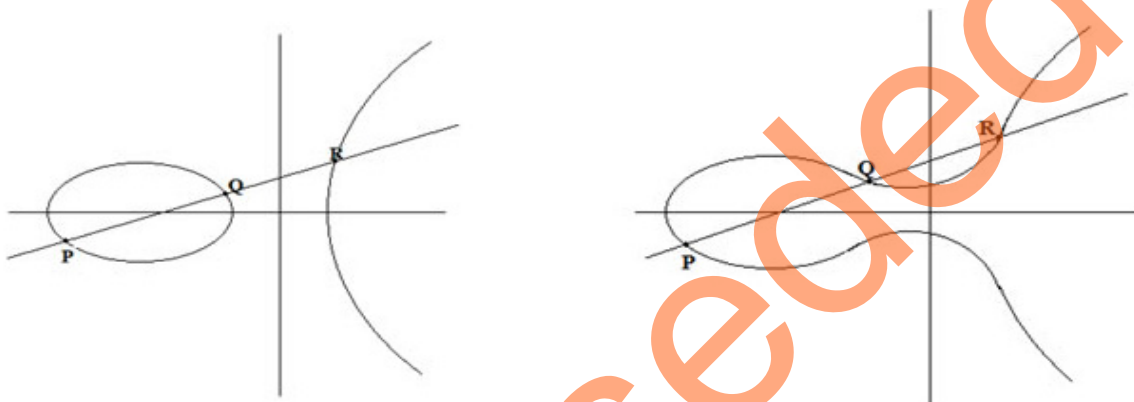


Figure 2 • Elliptical Curves

If $X^3 + aX + b$ contains no repeated factors, or equivalently if $4a^3 + 27b^2$ is not 0 (zero), then the elliptic curve $Y^2 = X^3 + aX + b$ can be used to form a group.

The elliptic curve groups are additive groups (that is, their basic function is addition).

This application note uses NIST recommended P-384 curve to implement the ECC system services. The domain parameters for the curve P-384 are the prime, a, b and base point G. The recommended values for these parameters are:

The Prime $P^{384} = 2^{384} - 2^{128} - 2^{96} + 2^{32} - 1$:

In hexadecimal form:

```
p384 = ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff
00000000 00000000 ffffffff
```

The parameter a in hexadecimal form:

```
a = ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff ffffffff
00000000 00000000 ffffffff
```

The parameter b in hexadecimal form:

```
b = b3312fa7 e23ee7e4 988e056b e3f82d19 181d9c6e fe814112
0314088f 5013875a c656398d 8a2ed19d 2a85c8ed d3ec2aef
```

The base point G in hexadecimal form:

```
Gx = aa87ca22 be8b0537 8eb1c71e f320ad74 6e1d3b62 8ba79b98
59f741e0 82542a38 5502f25d bf55296c 3a545e38 72760ab7
Gy = 3617de4a 96262c6f 5d9e98bf 9292dc29 f8f41dbd 289a147c
e9da3113 b5f0b8c0 0a60b1ce 1d7e819d 7a431d7c 90ea0e5f
```

The following ECC services are implemented in this application note:

Point Addition

The Elliptic point addition service, adds two points according to the definition of elliptic curve point addition. The inputs are two points (x, y), each lying on the P-384 curve and the resulting point (x, y), which is guaranteed to be on the curve.

Point addition service computes the results as the following:

$$R(R_x, R_y) = P(P_x, P_y) + Q(Q_x, Q_y)$$

P and Q are two 384 bit input points (P_x, P_y) and (Q_x, Q_y) on the P-384 elliptic curve.

In order to add the points P and Q, a line is drawn through the two points. This line will intersect the elliptic curve in exactly one more point, call -R. The point -R is reflected in the x-axis to the point R. The law for addition in an elliptic curve group is $P + Q = R$, where R is the result of addition, as shown in Figure 3.

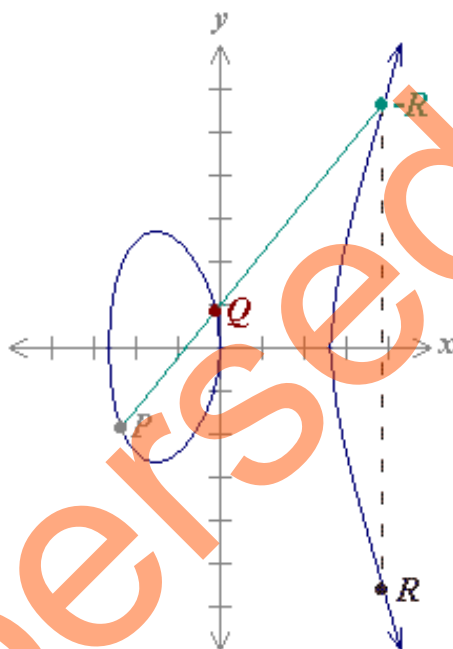


Figure 3 • Addition on an Elliptic Curve

The example input points P and Q are provided in this application note for P-384 elliptic curve, user can enter any P and Q points on the curve to perform the addition operation.

Note: Input points are not tested for validity by the ECC. If an input point is not a valid point on the P-384 curve (including the point at infinity), then the result will be undefined and no warning message are displayed. User can find NIST recommended input test vectors at the following location:

<http://csrc.nist.gov/groups/STM/cavp/documents/components/ecccdhtestvectors.zip>.

Table 1 shows the command value to perform the ECC Point Addition in the SmartFusion2 device.

Table 1 • ECC Point Addition

System Service Name	Command Value	Response Status
Point Addition	17	0:Success completion 127:HRESP error occurred during MSS transfer 253:License not available in device 254:Service disabled by factory security 255:Service disabled by user security

Scalar Point Multiplication

The scalar point multiplication service, multiplies the scalar point with the point on the P-384 curve.

The multiplication service computes the result as per the standard:

$$Q = d \times P$$

d is the scalar input (384 bit) and P is the 384bit point (P_x, P_y) on the curve.

Table 2 shows the command value to perform the ECC point multiplication.

Table 2 • ECC Point Multiplication

System Service Name	Command Value	Response Status
Point Multiplication	16	0:Success completion 127:HRESP error occurred during MSS transfer 253:License not available in device 254:Service disabled by factory security 255:Service disabled by user security

Generating a Public Key

The point multiplication is used for generating a public key given the private key (384 bit integer). The domain parameter G, specifies the base point on the curve P-384 to use. This domain base point is built into hardware accelerator, which has a special form of the scalar multiplication command that uses base point without the user having to enter.

The generated public key is used further to encrypt the data or an application. The data or the application can be decrypted using the private key.

Design Requirements

Table 3 shows the design requirements.

Table 3 • Design Requirements

Design Requirements	Description
Hardware Requirements	
SmartFusion2 Evaluation Kit:	Rev D or later
<ul style="list-style-type: none"> 12 V adapter FlashPro4 programmer USB A to Mini-B cable 	
Host PC or Laptop	Any 64-bit Windows Operating System
Software Requirements	
Libero® System-on-Chip (SoC)	v11.4 SP 1
FlashPro programming software	v11.4 SP 1
USB to UART drivers	-
One of the following serial terminal emulation programs:	-
<ul style="list-style-type: none"> HyperTerminal TeraTerm PuTTY 	

Design Description

The design is implemented on the SmartFusion2 Evaluation Kit Board using M2S090TS-1FGG484 device.

The design example consists of:

- RC oscillator
- Fabric CCC
- CORERESET
- MSS

The fabric PLL is used to provide the base clock for the MSS. The system services are run using various C routine in the MSS, as shown in the following sections. In addition, a universal asynchronous receiver/transmitter (UART1) in the MSS is used to display the operation of the ECC system service.

Hardware Implementation

Figure 4 shows a block diagram of the design example. The RC oscillator generates a 50 MHz input clock and the fabric PLL generates a 100 MHz clock from the RC oscillator. This 100 MHz clock is used as the base clock for the MSS.

The MMUART_1 signals are for communicating with the serial terminal program.

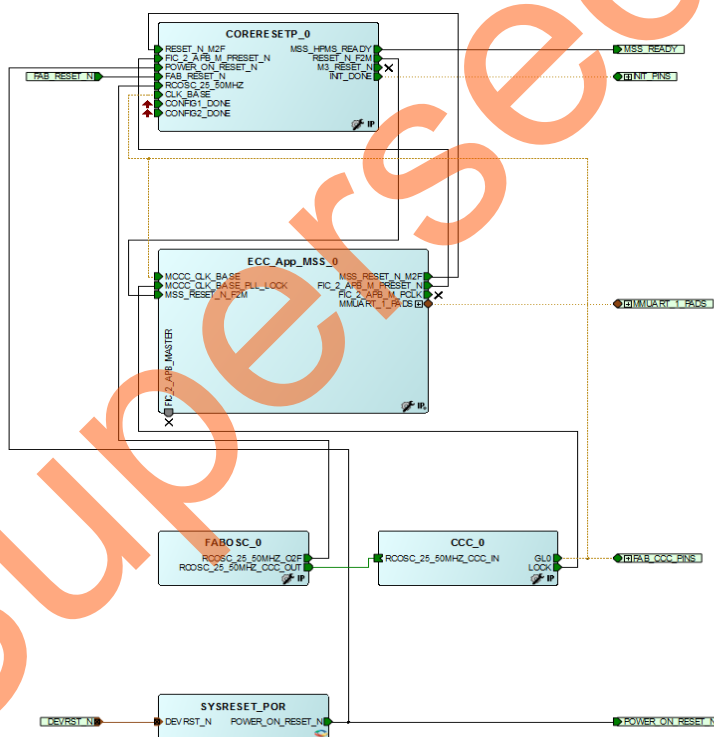


Figure 4 • Block Diagram of SmartFusion2 ECC Design Example

Software Implementation

The software design example performs the following operations:

- ECC point addition
- Scalar point multiplication
- Public key generation

Firmware Drivers

The following firmware drivers are used in this application:

- MSS MMUART driver: To communicate with the serial terminal program on the Host PC.
- MSS System Services driver: Provides access to the SmartFusion2 System Services.

List of APIs

The following APIs in [Table 4](#) are used in software design to access the ECC Services.

Table 4 • APIs to access the ECC System Services

API	Description
MSS_SYS_ecc_point_addition()	Point addition
MSS_SYS_ecc_point_multiplication ()	Scalar point multiplication
MSS_SYS_ecc_get_base_point()	To get base point

Setting up the Design

Plug the FlashPro4 ribbon cable into the connector J5 (JTAG Programming Header) on the SmartFusion2 Evaluation Kit Board.

1. Connect the mini USB cable between the FlashPro4 and the USB port of the PC.
2. Connect the power supply to the J6 connector.
3. Connect one end of the USB mini cable to the J18 connector provided on the SmartFusion2 Evaluation Kit. Connect the other end of the USB cable to the host PC.
4. Ensure that the USB to UART bridge drivers are automatically detected. This can be verified in the Device Manager.

[Figure 5](#) shows example device manager window. If USB to UART bridge drivers are not installed, download and install the drivers from:

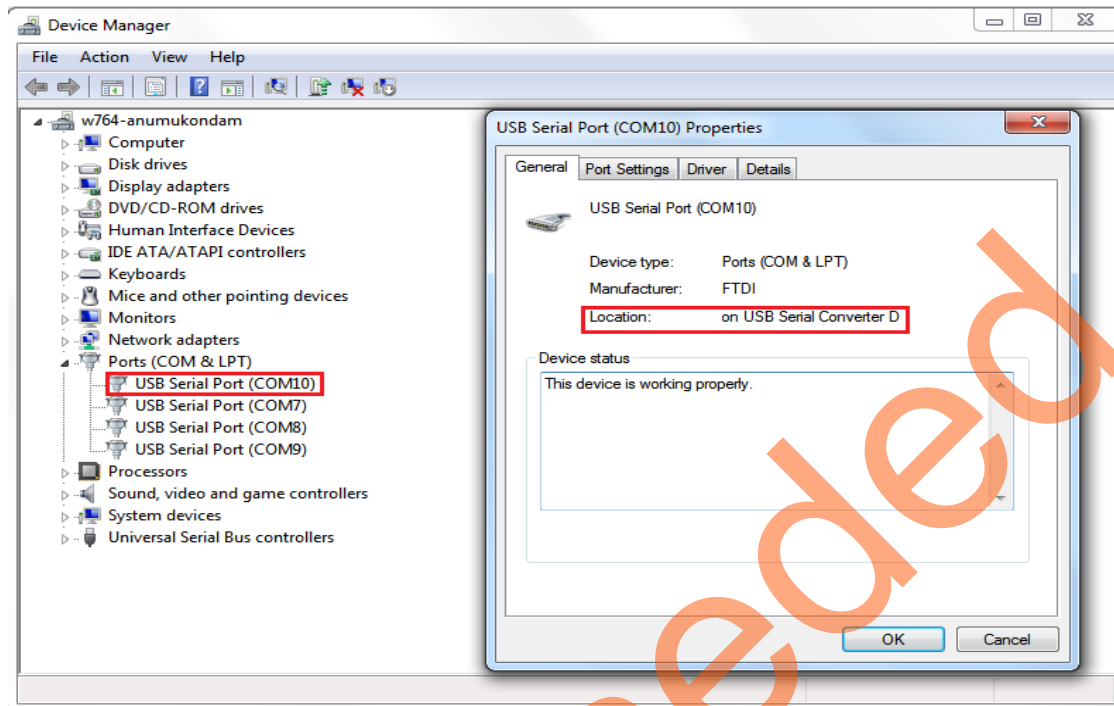


Figure 5 • Device Manager Window

5. Connect the jumpers on the SmartFusion2 Evaluation Kit as shown in [Table 5](#).

Note: Ensure that power supply switch **SW7** is switched off while connecting the jumpers on the SF2 Kit.

Table 5 • SmartFusion2 SoC FPGA Evaluation Kit Jumper Settings

Jumper	Pin (from)	Pin (to)	Comments
J22	1	2	default
J23	1	2	default
J24	1	2	default
J8	1	2	default
J3	1	2	default

Figure 6 shows the board setup for running the ECC services design on the SmartFusion2 Evaluation Kit.



Figure 6 • SmartFusion2 Evaluation Kit

Running the Design

The following steps describes how to run the design on the SmartFusion2 Evaluation Kit Board using the M2S090TS-1FGG484 device:

1. Switch ON the power supply switch, **SW7**.
2. Start a PUTTY or HyperTerminal session with 115200 baud rate, 8 data bits, 1 stop bit, no parity, and no flow control. Use any free serial terminal emulation program such as: HyperTerminal or Tera Term, if the computer does not have the PUTTY program. For more information about configuring HyperTerminal, Tera Term, or PuTTY, refer to [Configuring Serial Terminal Emulation Programs Tutorial](#).
3. Program the SmartFusion2 Evaluation Kit Board with the provided STAPL file using FlashPro4. Refer to "Appendix A - Design and Programming Files" on page 19" for more information.

4. After programming, HyperTerminal displays a message to run the ECC Services as shown in Figure 7.

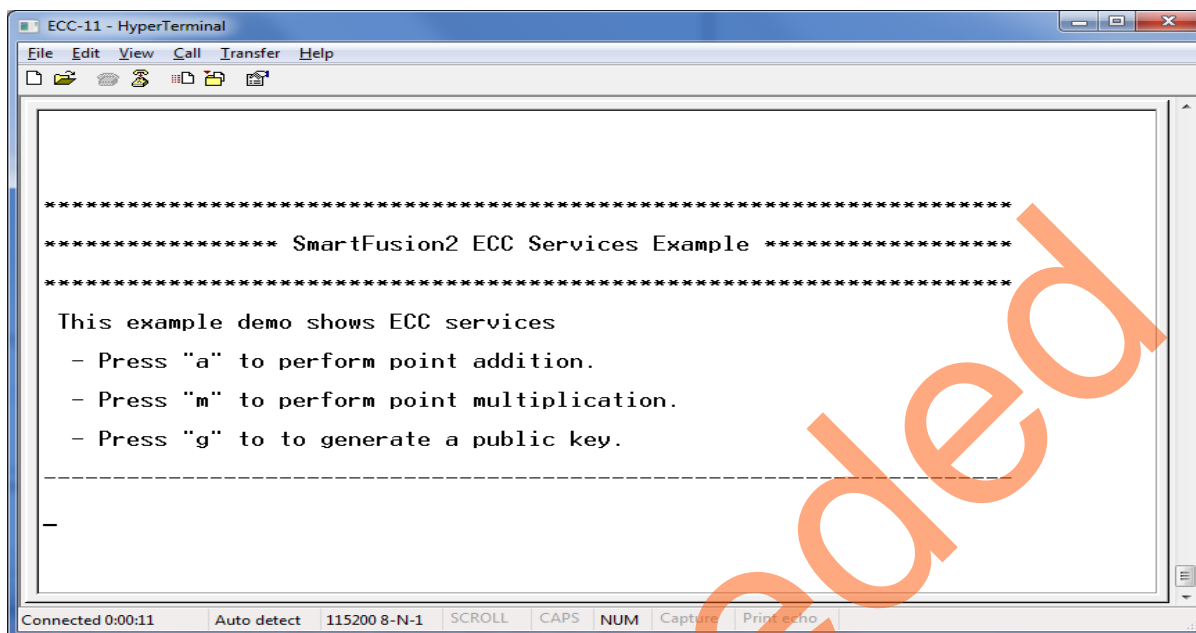


Figure 7 • Welcome Message

1. Enter "a" to perform point addition, HyperTerminal displays "Enter the X Coordinate of input point P". Enter the following X coordinate of P in Hyper terminal (or) copy each line, right click in the HyperTerminal and click **paste to host** to paste the coordinate as shown in Figure 8.

```
a7c76b970c3b5fe8
b05d2838ae04ab47
697b9eaf52e76459
2efda27fe7513272
734466b400091adb
f2d68c58e0c50066
```

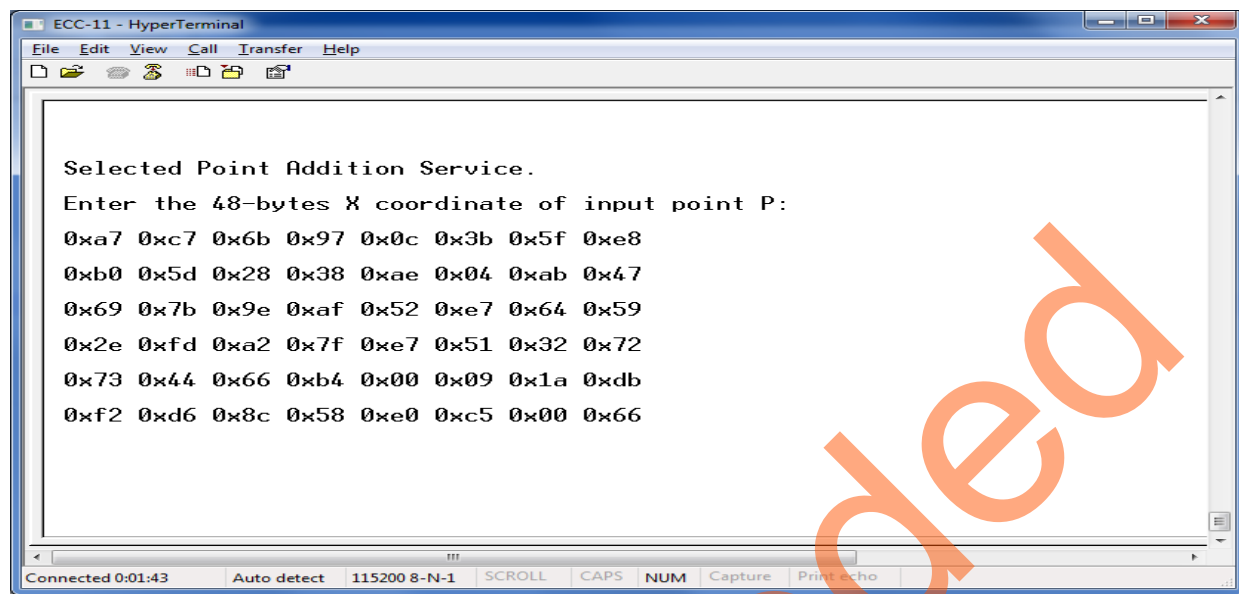


Figure 8 • Point Addition Input

2. Enter the Y Coordinate of P (Py), X and Y coordinates of Q (Qx, Qy) as shown in: [Figure 9](#), [Figure 10](#), and [Figure 11](#).

Y Coordinate of P:

ac68f19f2e1cb879
aed43a9969b91a08
39c4c38a49749b66
1efedf243451915e
d0905a32b060992b
468c64766fc8437a

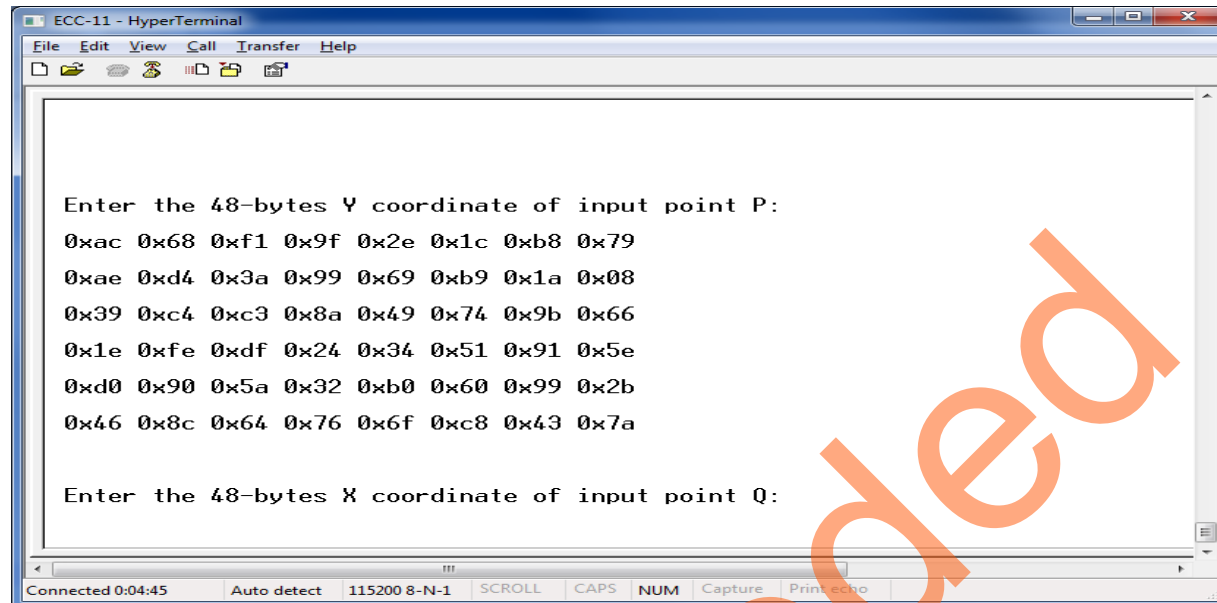


Figure 9 • Point Addition Input P

X Coordinate of Q:

9803807f2f6d2fd9
66cdd0290bd410c0
190352fbec7ff624
7de1302df86f25d3
4fe4a97bef60cff5
48355c015dbb3e5f

Y Coordinate of Q:

ba26ca69ec2f5b5d
9dad20cc9da71138
3a9dbe34ea3fa5a2
af75b46502629ad5
4dd8b7d73a8abb06
a3a3be47d650cc99

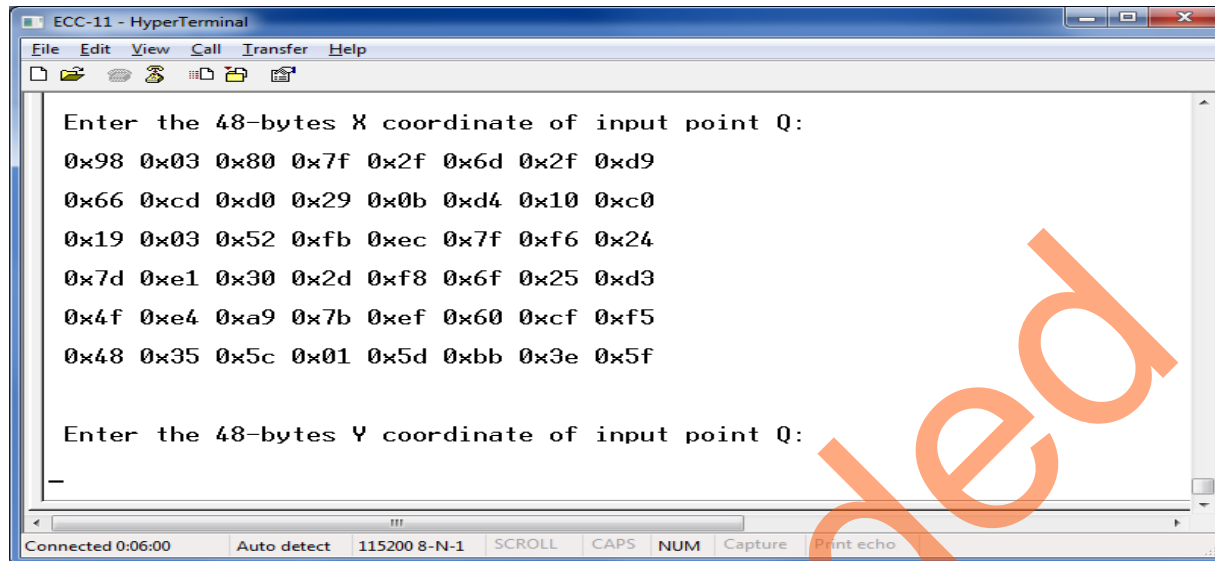


Figure 10 • Point Addition Input

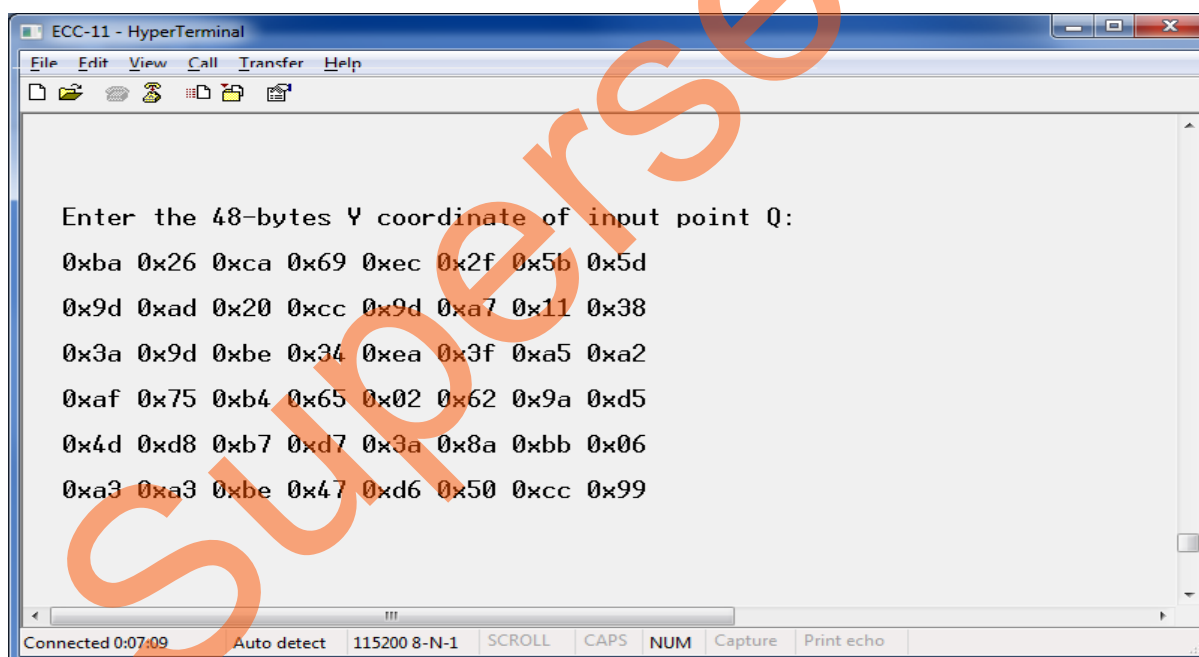
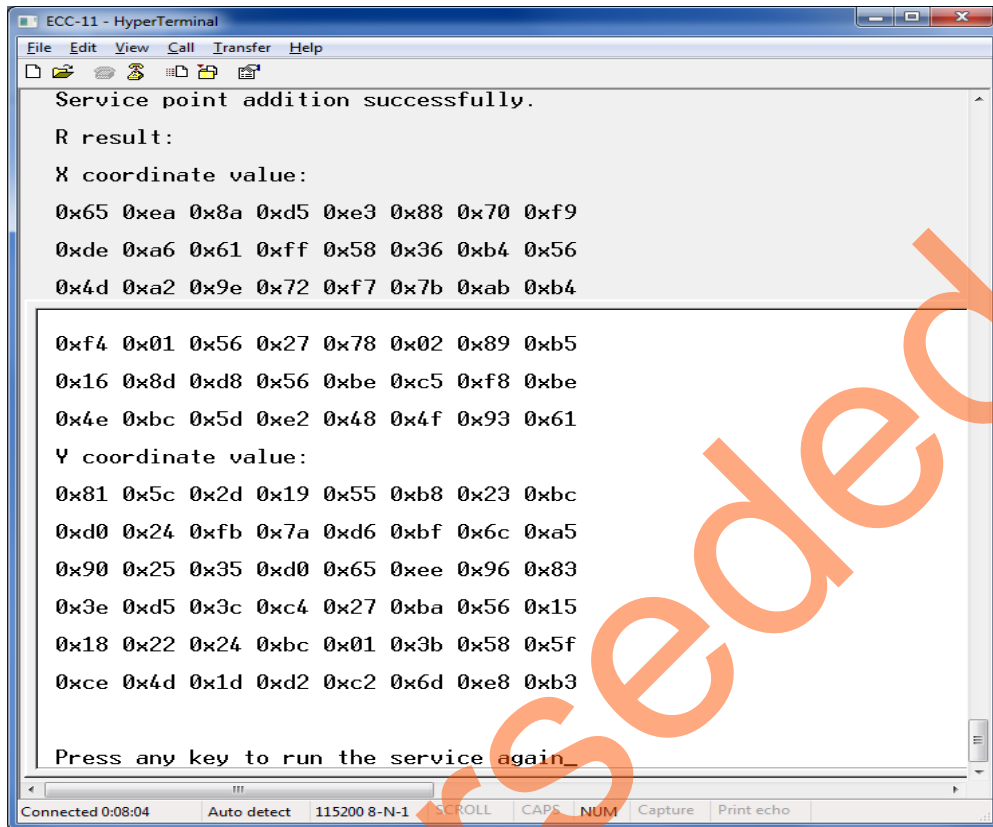


Figure 11 • Point Addition Input

3. Point addition result is displayed on HyperTerminal as shown in [Figure 12](#).



```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help
Service point addition successfully.
R result:
X coordinate value:
0x65 0xea 0x8a 0xd5 0xe3 0x88 0x70 0xf9
0xde 0xa6 0x61 0xff 0x58 0x36 0xb4 0x56
0x4d 0xa2 0x9e 0x72 0xf7 0x7b 0xab 0xb4

0xf4 0x01 0x56 0x27 0x78 0x02 0x89 0xb5
0x16 0x8d 0xd8 0x56 0xbe 0xc5 0xf8 0xbe
0x4e 0xbc 0x5d 0xe2 0x48 0x4f 0x93 0x61
Y coordinate value:
0x81 0x5c 0x2d 0x19 0x55 0xb8 0x23 0xbc
0xd0 0x24 0xfb 0x7a 0xd6 0xbf 0x6c 0xa5
0x90 0x25 0x35 0xd0 0x65 0xee 0x96 0x83
0x3e 0xd5 0x3c 0xc4 0x27 0xba 0x56 0x15
0x18 0x22 0x24 0xbc 0x01 0x3b 0x58 0x5f
0xce 0x4d 0x1d 0xd2 0xc2 0x6d 0xe8 0xb3

Press any key to run the service again_
Connected 0:08:04 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo

```

Figure 12 • Point Addition Result

4. Enter "m" to perform point multiplication and enter the 384 bit input scalar D as shown in [Figure 13](#)

Input Scalar D:

D =

```

b7847b54eb40d602
dbe18b5386ac9a99
e0a584e3d01e2ef5
a5700be26e7076ca
c390d423a0033b07
e4ecbe709001fc39

```

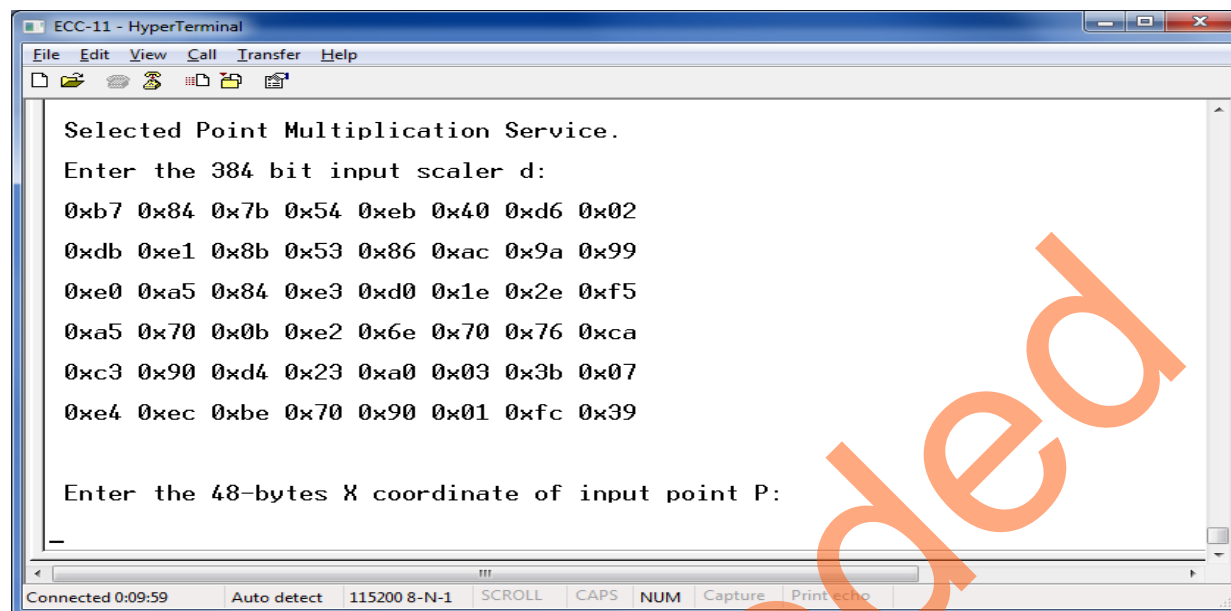


Figure 13 • Point Multiplication

5. Enter 48 byte X, Y coordinates of Input point P (Px, Py) as shown in [Figure 14](#), [Figure 15](#).

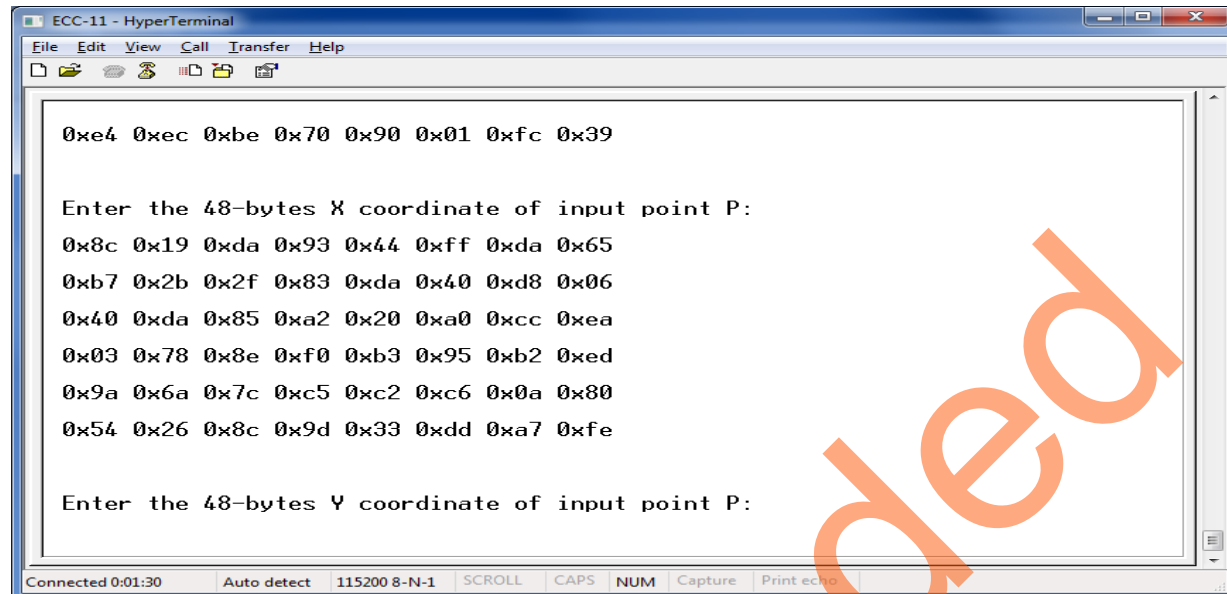
X, Y coordinates of the point P on the elliptic curve are:

X Coordinate of P:

8c19da9344ffda65
b72b2f83da40d806
40da85a220a0ccea
03788ef0b395b2ed
9a6a7cc5c2c60a80
54268c9d33dda7fe

Y Coordinate of P:

a86d11a4ab265d8d
c4aa0d86e16bdbdb
8c78914f4ef6aef0
9c382b689460eacb
363fc795ec1914c0
276a7b75b562fe6b



```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help
0xe4 0xec 0xbe 0x70 0x90 0x01 0xfc 0x39

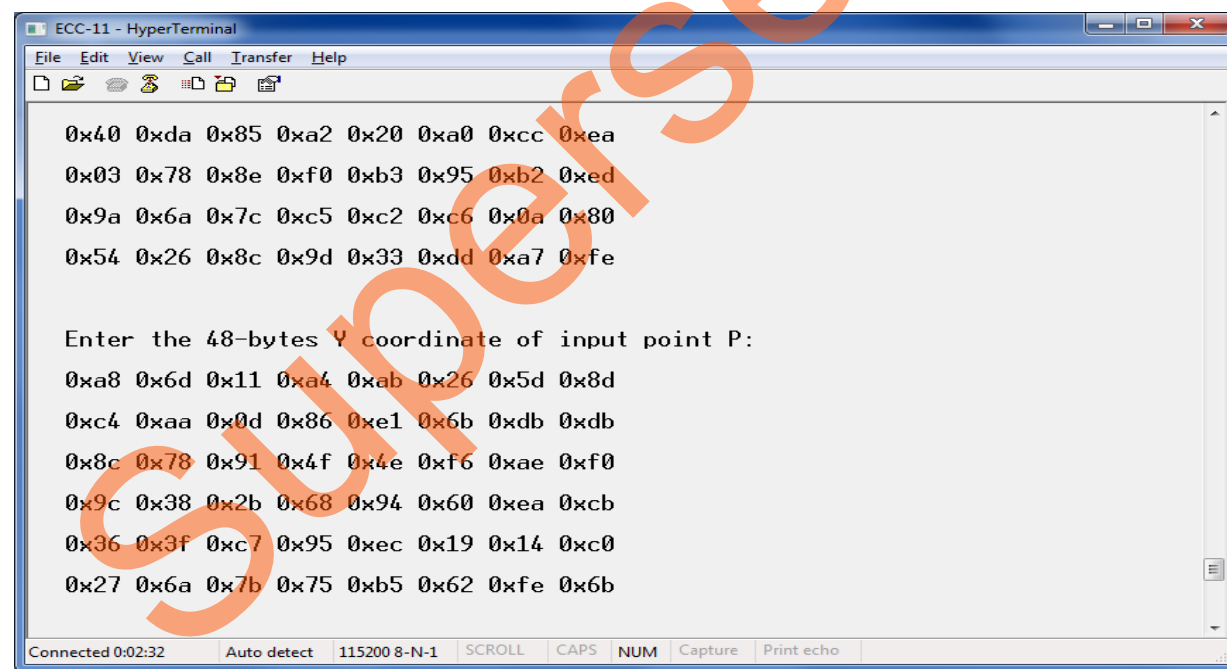
Enter the 48-bytes X coordinate of input point P:
0x8c 0x19 0xda 0x93 0x44 0xff 0xda 0x65
0xb7 0x2b 0x2f 0x83 0xda 0x40 0xd8 0x06
0x40 0xda 0x85 0xa2 0x20 0xa0 0xcc 0xea
0x03 0x78 0x8e 0xf0 0xb3 0x95 0xb2 0xed
0x9a 0x6a 0x7c 0xc5 0xc2 0xc6 0x0a 0x80
0x54 0x26 0x8c 0x9d 0x33 0xdd 0xa7 0xfe

Enter the 48-bytes Y coordinate of input point P:

Connected 0:01:30 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo

```

Figure 14 • X Input of Point P



```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help
0x40 0xda 0x85 0xa2 0x20 0xa0 0xcc 0xea
0x03 0x78 0x8e 0xf0 0xb3 0x95 0xb2 0xed
0x9a 0x6a 0x7c 0xc5 0xc2 0xc6 0x0a 0x80
0x54 0x26 0x8c 0x9d 0x33 0xdd 0xa7 0xfe

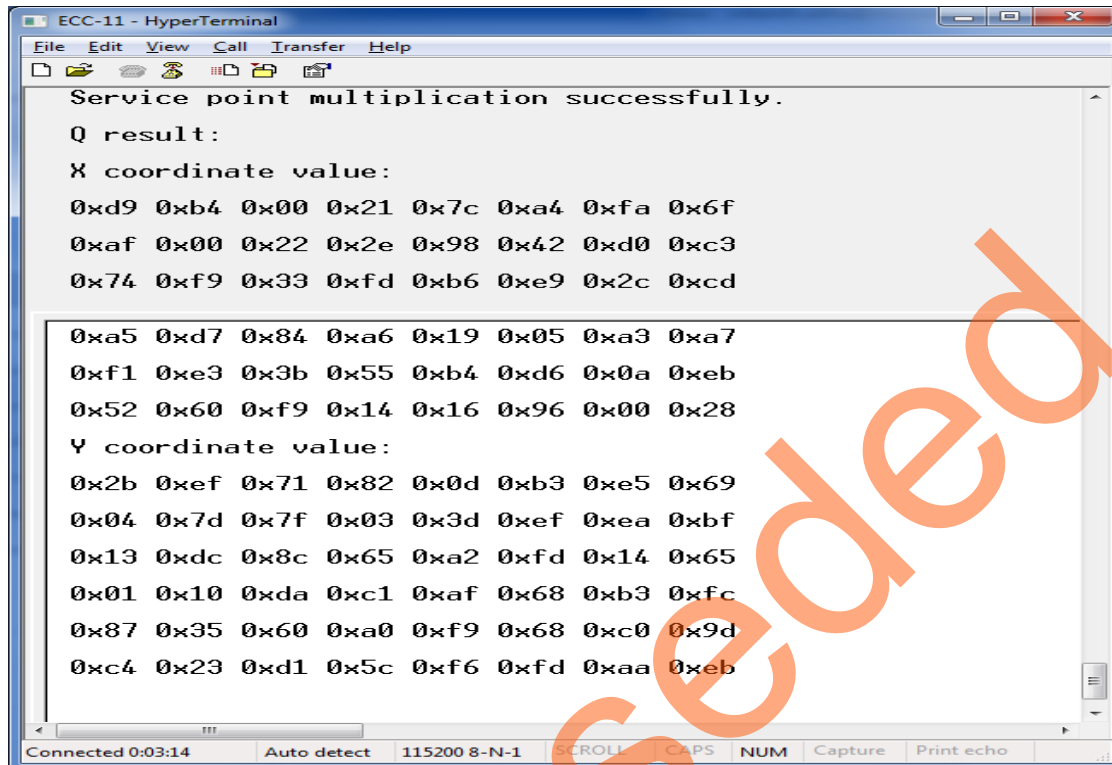
Enter the 48-bytes Y coordinate of input point P:
0xa8 0x6d 0x11 0xa4 0xab 0x26 0x5d 0x8d
0xc4 0xaa 0x0d 0x86 0xe1 0x6b 0xdb 0xdb
0x8c 0x78 0x91 0x4f 0x4e 0xf6 0xae 0xf0
0x9c 0x38 0x2b 0x68 0x94 0x60 0xea 0xcb
0x36 0x3f 0xc7 0x95 0xec 0x19 0x14 0xc0
0x27 0x6a 0x7b 0x75 0xb5 0x62 0xfe 0x6b

Connected 0:02:32 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo

```

Figure 15 • Y Input of Point P

6. Point Multiplication result is displayed on the HyperTerminal as shown in Figure 16.



```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help
Service point multiplication successfully.
Q result:
X coordinate value:
0xd9 0xb4 0x00 0x21 0x7c 0xa4 0xfa 0x6f
0xaf 0x00 0x22 0x2e 0x98 0x42 0xd0 0xc3
0x74 0xf9 0x33 0xfd 0xb6 0xe9 0x2c 0xcd

0xa5 0xd7 0x84 0xa6 0x19 0x05 0xa3 0xa7
0xf1 0xe3 0x3b 0x55 0xb4 0xd6 0x0a 0xeb
0x52 0x60 0xf9 0x14 0x16 0x96 0x00 0x28
Y coordinate value:
0x2b 0xef 0x71 0x82 0x0d 0xb3 0xe5 0x69
0x04 0x7d 0x7f 0x03 0x3d 0xef 0xea 0xbf
0x13 0xdc 0x8c 0x65 0xa2 0xfd 0x14 0x65
0x01 0x10 0xda 0xc1 0xaf 0x68 0xb3 0xfc
0x87 0x35 0x60 0xa0 0xf9 0x68 0xc0 0x9d
0xc4 0x23 0xd1 0x5c 0xf6 0xfd 0xaa 0xeb

Connected 0:03:14 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo

```

Figure 16 • Point Multiplication Result

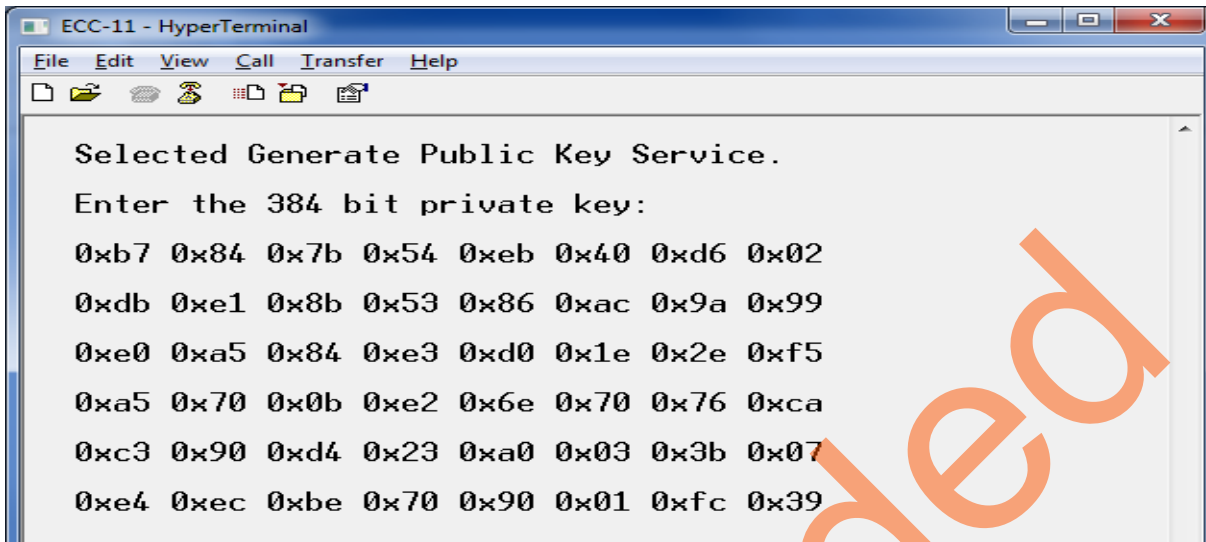
7. Enter g to generate a public key and enter 384bit private key as shown in Figure 17.

Private Key:

```

b7847b54eb40d602
dbe18b5386ac9a99
e0a584e3d01e2ef5
a5700be26e7076ca
c390d423a0033b07
e4ecbe709001fc39

```



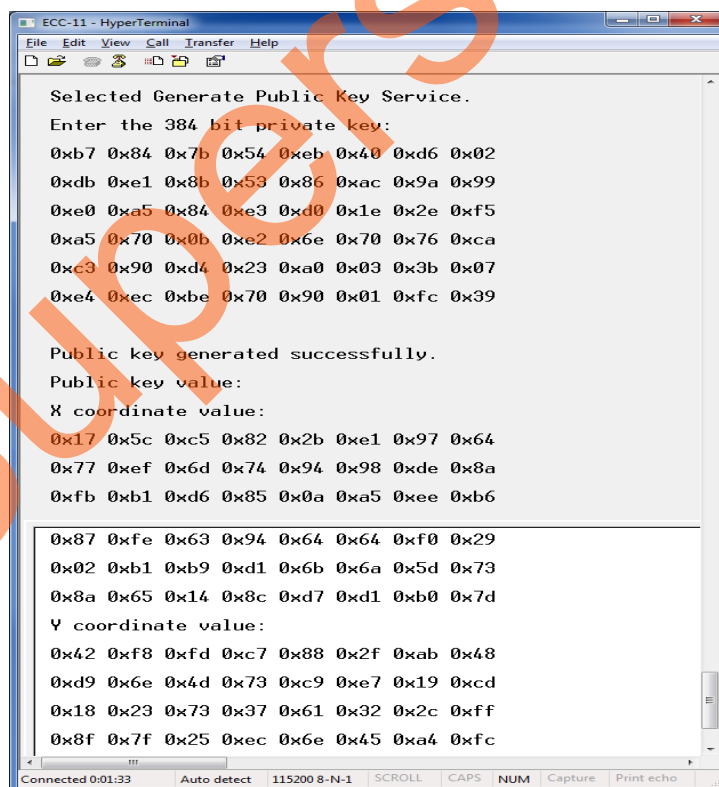
```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help

Selected Generate Public Key Service.
Enter the 384 bit private key:
0xb7 0x84 0x7b 0x54 0xeb 0x40 0xd6 0x02
0xdb 0xe1 0x8b 0x53 0x86 0xac 0x9a 0x99
0xe0 0xa5 0x84 0xe3 0xd0 0x1e 0x2e 0xf5
0xa5 0x70 0x0b 0xe2 0x6e 0x70 0x76 0xca
0xc3 0x90 0xd4 0x23 0xa0 0x03 0x3b 0x07
0xe4 0xec 0xbe 0x70 0x90 0x01 0xfc 0x39
  
```

Figure 17 • Input Private Key

This service uses the internal 384 bit base point and performs the point multiplication with a private key to generate the public key. Generated public key X, Y coordinates are displayed on the HyperTerminal as shown in [Figure 18](#).



```

ECC-11 - HyperTerminal
File Edit View Call Transfer Help

Selected Generate Public Key Service.
Enter the 384 bit private key:
0xb7 0x84 0x7b 0x54 0xeb 0x40 0xd6 0x02
0xdb 0xe1 0x8b 0x53 0x86 0xac 0x9a 0x99
0xe0 0xa5 0x84 0xe3 0xd0 0x1e 0x2e 0xf5
0xa5 0x70 0x0b 0xe2 0x6e 0x70 0x76 0xca
0xc3 0x90 0xd4 0x23 0xa0 0x03 0x3b 0x07
0xe4 0xec 0xbe 0x70 0x90 0x01 0xfc 0x39

Public key generated successfully.
Public key value:
X coordinate value:
0x17 0x5c 0xc5 0x82 0x2b 0xe1 0x97 0x64
0x77 0xef 0x6d 0x74 0x94 0x98 0xde 0x8a
0xfb 0xb1 0xd6 0x85 0x0a 0xa5 0xee 0xb6

0x87 0xfe 0x63 0x94 0x64 0x64 0xf0 0x29
0x02 0xb1 0xb9 0xd1 0x6b 0x6a 0x5d 0x73
0x8a 0x65 0x14 0x8c 0xd7 0xd1 0xb0 0x7d
Y coordinate value:
0x42 0xf8 0xfd 0xc7 0x88 0x2f 0xab 0x48
0xd9 0x6e 0x4d 0x73 0xc9 0xe7 0x19 0xcd
0x18 0x23 0x73 0x37 0x61 0x32 0x2c 0xff
0x8f 0x7f 0x25 0xec 0x6e 0x45 0xa4 0xfc

Connected 0:01:33 Auto detect 115200 8-N-1 SCROLL CAPS NUM Capture Print echo
  
```

Figure 18 • X, Y Coordinates of Public Key

Conclusion

This application note explains how to access the ECC services in the SmartFusion2 SoC FPGAs. It implements how to perform the ECC point addition, scalar point multiplication, and public key generation.

Appendix A - Design and Programming Files

Download the design files from the Microsemi SoCProducts Group website:

http://soc.microsemi.com/download/rsc/?f=SF2_AC435_11p4_DF

The design files consist of a Libero Verilog project and programming files (*.stp) for the SmartFusion2 Evaluation Kit.

Refer to the readme.txt file included in the design files for the directory structure and description.

Download the programming files (*.stp) in release mode from the Microsemi SoC Products Group website:

www.microsemi.com/soc/download/rsc/?f=SF2_AC435_11p4_PF

The programming zip file consists of the STAPL programming file (*.stp) for the SmartFusion2 Evaluation Kit.

Superseded

List of Changes

The following table lists critical changes that were made in each revision of the chapter in the application note.

Date*	Changes	Page
Revision 1 (October, 2014)	Initial release.	N/A

Note: *The revision number is located in the part number after the hyphen. The part number is displayed at the bottom of the last page of the document. The digits following the slash indicate the month and year of publication.

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