嵌入式系統期末專題

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完整電路輸出

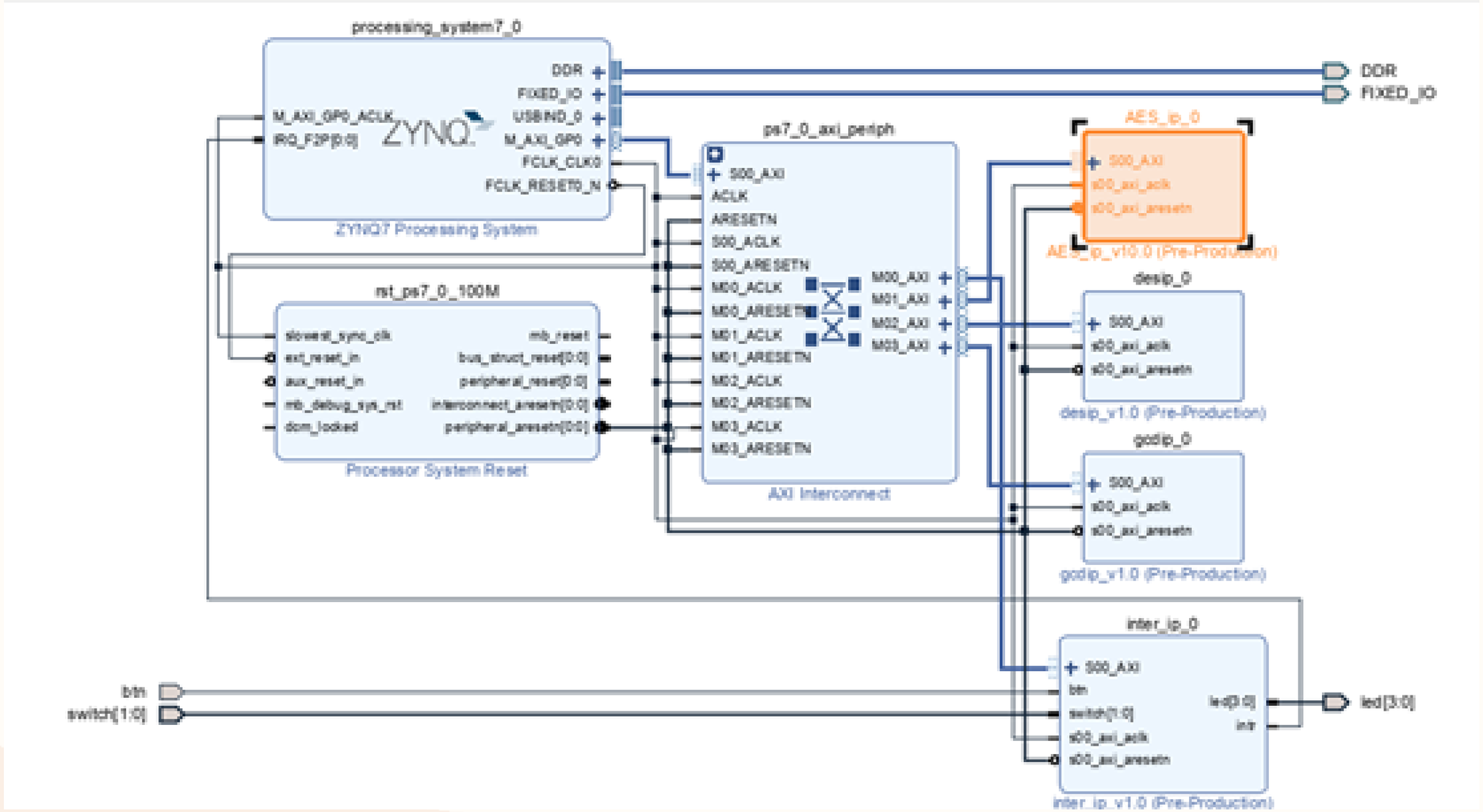


圖1 完整電路輸出

AES時序圖(加密成功)

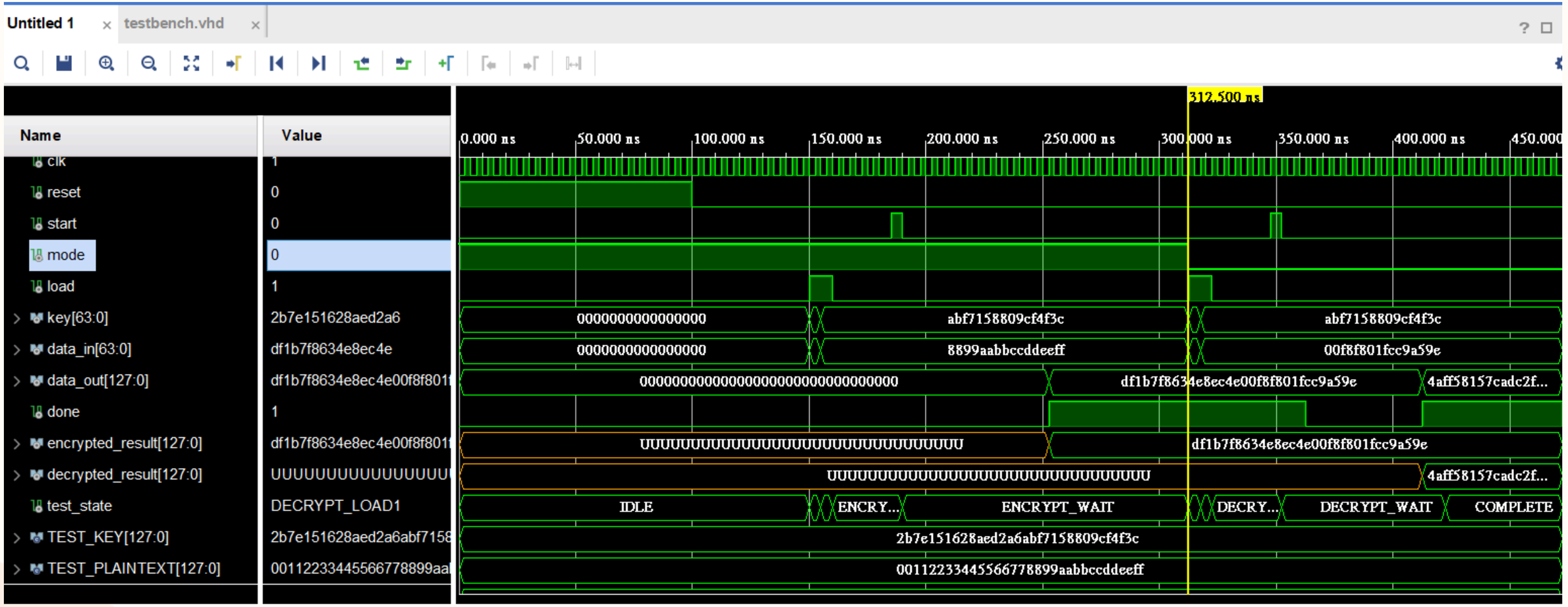
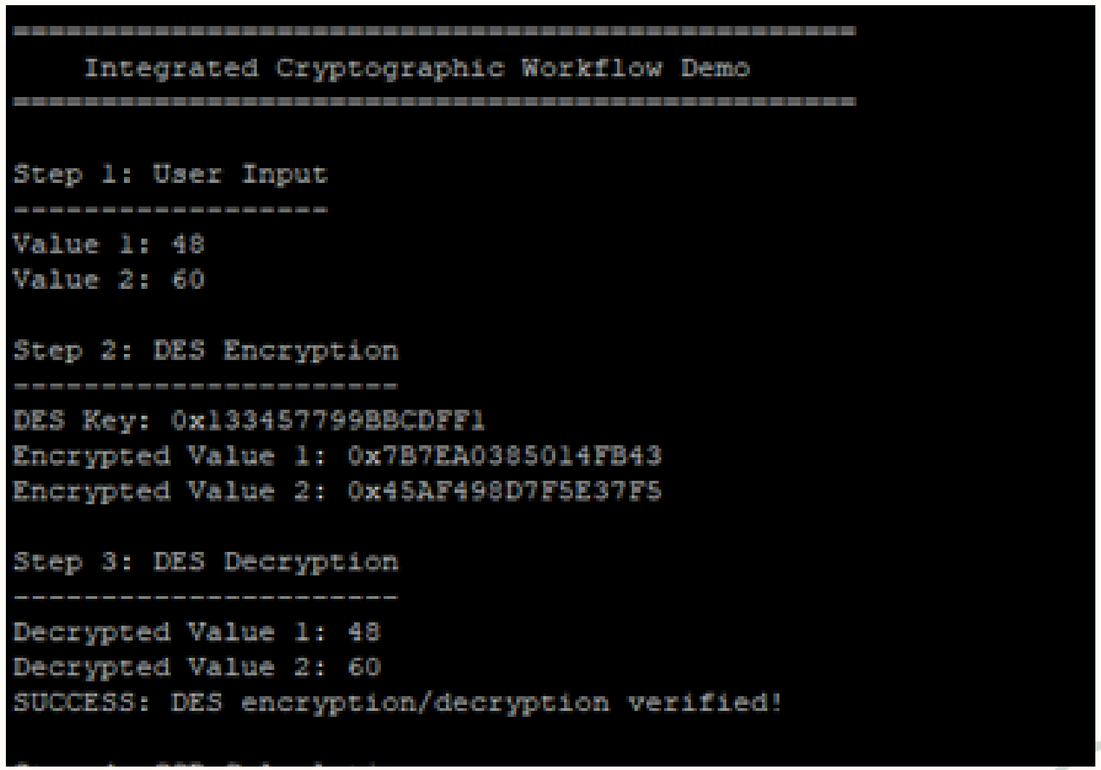


圖2 AES時序圖

Standalone

1。使用者輸入慾處理數據
2。DES 加解密
3。GCD 找出最大公因數
4。將最大公因數使用 AES 加密
5。LED 閃縮表示程序結束



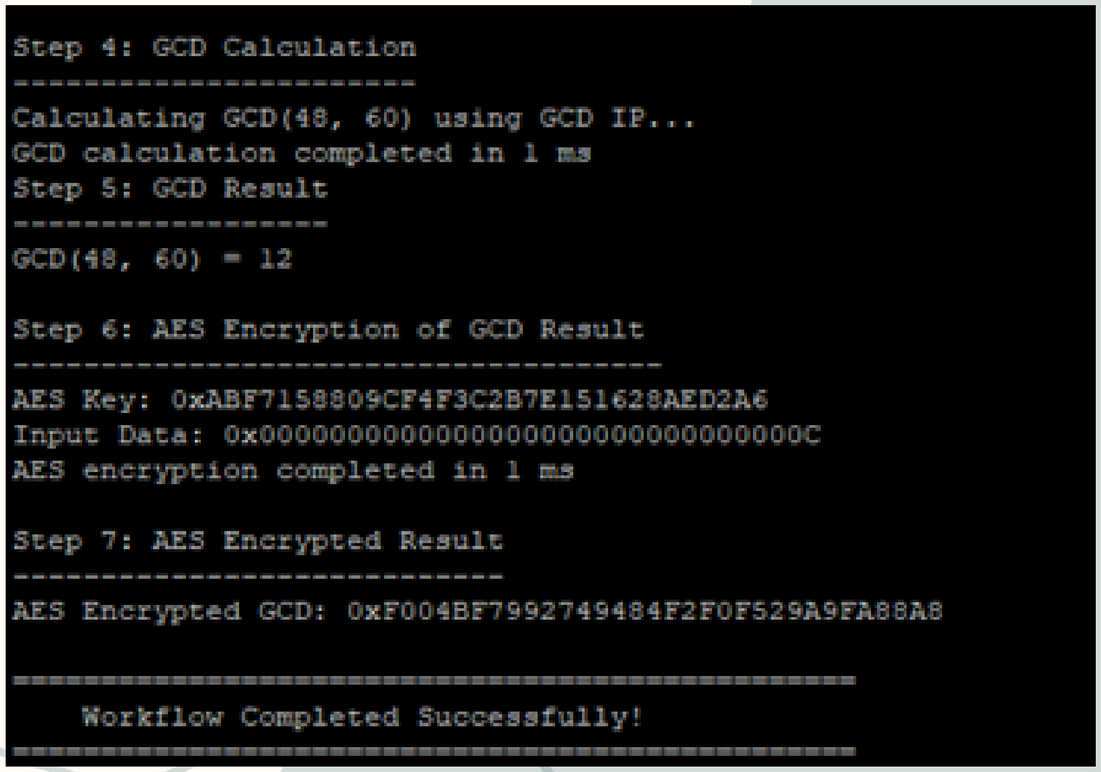


圖3 Putty 輸出端

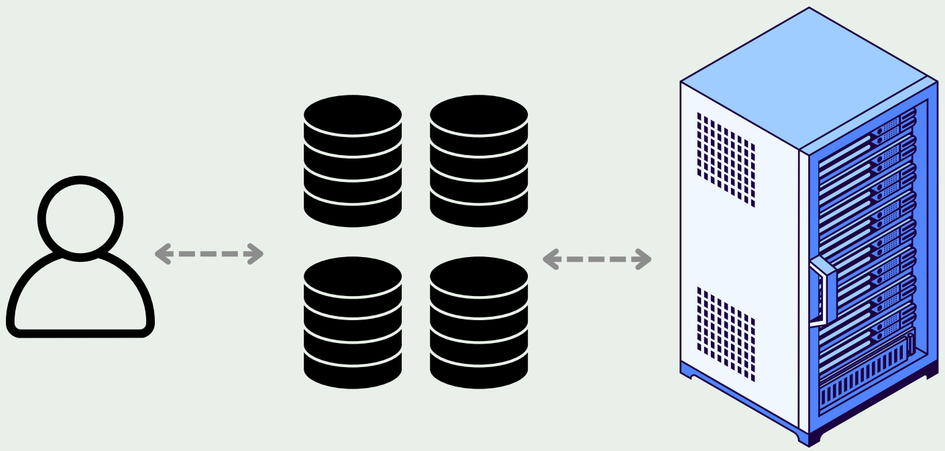
FreeRTOS

增加測試功能：

1。每四秒會多一個使用者輸入

2。輸入但尚未被處理的值，會在佇列等待

3。預設系統每次執行計算需要間格10秒



```
Encrypted value1: 0x2D95CA36844116B4
Encrypted value2: 0xCFDB52B7B81268DD
Data queued for processing

>>> USER INPUT <<<
User entered values: 84, 126
Encrypted value1: 0xD99E074773C8FBF3
Encrypted value2: 0x9D38F45C072E1069
Queue full! Data lost.

[STATUS] Queue items waiting: 2

>>> USER INPUT <<<
User entered values: 84, 126
Encrypted value1: 0xD99E074773C8FBF3
Encrypted value2: 0x9D38F45C072E1069
Queue full! Data lost.

=== SYSTEM PROCESSING CYCLE ===
Processing values: 100, 150

[STATUS] Queue items waiting: 1
Decrypted values: 100, 150
GCD(100, 150) = 50
AES encrypted GCD result: 0x2D35E8CF292107C9
Processing completed successfully!
```

```
>>> USER INPUT <<<
User entered values: 84, 126
Encrypted value1: 0xD99E074773C8FBF3
Encrypted value2: 0x9D38F45C072E1069
Data queued for processing

[STATUS] Queue items waiting: 2
>>> ALL TEST INPUTS COMPLETED <<<

=== SYSTEM PROCESSING CYCLE ===
Processing values: 17, 19

[STATUS] Queue items waiting: 1
Decrypted values: 17, 19
GCD(17, 19) = 1
AES encrypted GCD result: 0x1523A8FF47B1D916
Processing completed successfully!

[STATUS] Queue items waiting: 1

=== SYSTEM PROCESSING CYCLE ===
Processing values: 84, 126

[STATUS] Queue items waiting: 0
Decrypted values: 84, 126
GCD(84, 126) = 42
AES encrypted GCD result: 0xDBB365614C27ED6F
Processing completed successfully!

[STATUS] Queue items waiting: 0

=== SYSTEM PROCESSING CYCLE ===
No data in queue to process
All inputs processed. System processing will continue monitoring.
```

圖4 Free RTOS 執行結果

Interrupt

增加功能：

1。Switch 可提供功能模式切換

2。Push Button 提供模式確認及系統進程推進功能

模式選擇：

Auto Mode　　:自動運行

Manual Mode :手動選擇輸入且自行點擊Push Button 確認

Debug Mode　:顯示詳細資訊

Simple Mode　:使用最簡單的輸入進行測試

Input		Output		
SW0	SW1	Mode	Case	
			Value 1	Value 2
0	0	Auto Mode	12	8
0	1	Manual Mode	49	18
1	0	Debug Mode	144	96
1	1	Simple Mode	255	85

表一 Switch 輸入對應模式與 Input Case

Interrupt

```
================================================
Restarting system...
================================================

=== Stage 1: Mode Selection ===
Use 2 Switch combination to select operation mode:
SW1 SW0 = Mode
0   0   = Auto Mode (fully automatic execution)
0   1   = Manual Mode (pushbutton confirmation for each step)
1   0   = Debug Mode (show detailed intermediate results)
1   1   = Simple Mode (minimal output for quick testing)
Press pushbutton to confirm selection

Current selection: SW1=0 SW0=0 = Mode 0 - Auto Mode
Current selection: SW1=0 SW0=1 = Mode 1 - Manual Mode
Mode confirmed: 1

=== Stage 2: Test Case Selection ===
=== Value Input Instructions ===
Use 2 Switch combination to select test case:
SW1 SW0 = Test Case
0   0   = Case 0: Values 12, 8   (simple case)
0   1   = Case 1: Values 48, 18  (medium case)
1   0   = Case 2: Values 144, 96 (complex case)
1   1   = Case 3: Values 255, 85 (max complexity)

Press pushbutton when ready
Test case confirmed: 1
```

```
Test case 1 selected: Value1=48, Value2=18

=== Starting Cryptographic Workflow ===
Processing values: 48 and 18

=== Stage 3: DES Encryption ===
DES encryption completed
Encrypted Value 1: 0x7B7EA0385014FB43
Encrypted Value 2: 0x81a47DF4D287CF53
Press pushbutton to continue...

=== Stage 4: DES Decryption Verification ===
DES verification SUCCESS: decrypted values 48, 18
Decrypted Value 1: 0x0000000000000030
Decrypted Value 2: 0x0000000000000012
Press pushbutton to continue...

=== Stage 5: GCD Calculation ===
GCD(48, 18) = 6
Press pushbutton to continue...

=== Stage 6: AES Encryption of GCD Result ===
AES Encrypted Result: 0xE4FB886BC8F045C37D72F5E55BAF4B9C

=== Stage 7: Workflow Complete ===
All cryptographic operations completed!

Press pushbutton to restart...
Press pushbutton to continue...

================================================
Restarting system...
================================================
```

圖5 Manual Mode

Linux Driver

增加功能：

1。顯示模組載入資訊及硬體輸入資訊

2。腳位及功能自動測試

IP名稱	Device Tree節點
inter_ip_0	inter_ip@43c00000
AES_ip_0	aes_ip@43c10000
desip_0	des_ip@43c20000
gcdip_0	gcd_ip@43c30000

表二 IP對應Device Tree節點

Linux Driver

```
root@pynqz2:~# insmod crypto_ips.ko
major: 243
virtual irq: 48
Crypto IPs module loaded successfully
INTER: 0x43c00000 => 71aaf2f8
AES: 0x43c10000 => d3c4bb24
DES: 0x43c20000 => 5e5bd9e6
GCD: 0x43c30000 => e1a4e547
root@pynqz2:~# lsmod
Module                  Size  Used by
crypto_ips             16384  0
char2platform          16384  0
uio_pdrv_genirq        16384  0
root@pynqz2:~# ./switch_read
```

```
root@pynqz2:~# ./switch_read
SWITCH data (read): 0
SWITCH data (ioctl): 0
root@pynqz2:~# ./led_control ll
LED pattern set to: ll (0xB)
root@pynqz2:~# ./crypto_test
```

圖6 模組載入資訊、switch按鈕值、寫入led燈值

Linux Driver

```
root@pynqz2:~# ./crypto_test
================================================
    Crypto IPs Individual Test Program
================================================

=== Switch/LED Test ===
Current switch value: 0
Testing LED patterns...
Setting LED pattern: 0x1
Setting LED pattern: 0x3
Setting LED pattern: 0x6
Setting LED pattern: 0x9
Setting LED pattern: 0xC
Setting LED pattern: 0xF
Setting LED pattern: 0xA
Switch/LED Test: COMPLETED

=== DES Test ===
Key: 0x0000000000418C1C
Plaintext: 0x0000000000418C2C
Encrypted: 0x0000000000418C5C
Decrypted: 0x0000000000418C8C
DES Test: PASSED
```

```
=== GCD Test ===
GCD(48, 18) = 6
GCD(144, 96) = 48
GCD Test: COMPLETED

=== AES Test ===
Key: 0x09CF4F3CABF7158828AED2A62B7E1516
Input: 0x7393172AE93D7E112E409F966BC1BEE2
Output: 0xDF761F6541A3422FDD4D6791B8D37244
AES Test: COMPLETED

All tests completed!
root@pynqz2:~#
```

圖7 腳位以及功能測試

Linux Driver

```
/include/ "system-conf.dtsi"
/ {

        amba {
                /* AES IP  */
                aes_ip: aes_ip@43c10000 {
                        compatible = "xlnx,aes-ip-1.00";
                        reg = <0x43c10000 0x1000>;
                        xlnx,s00-axi-data-width = <32>;
                        xlnx,s00-axi-addr-width = <6>;
                };

                /* DES IP  */
                des_ip: des_ip@43c20000 {
                        compatible = "xlnx,des-ip-1.00";
                        reg = <0x43c20000 0x1000>;
                        xlnx,s00-axi-data-width = <32>;
                        xlnx,s00-axi-addr-width = <6>;
                };
```

```
                /* GCD IP  */
                gcd_ip: gcd_ip@43c30000 {
                        compatible = "xlnx,gcd-ip-1.00";
                        reg = <0x43c30000 0x1000>;
                        xlnx,s00-axi-data-width = <32>;
                        xlnx,s00-axi-addr-width = <6>;
                };

                /* INTER IP */
                inter_ip: inter_ip@43c00000 {
                        compatible = "xlnx,myhwip-1.00";
                        interrupt-parent = <&intc>;
                        interrupts = <0 29 1>;
                        reg = <0x43c00000 0x1000>;
                        xlnx,s00-axi-data-width = <32>;
                        xlnx,s00-axi-addr-width = <6>;
                };
        };

        usb_phy0: phy0 {
                compatible = "ulpi-phy";
                #phy-cells = <0>;
```

圖8 system-conf.dtsi編譯前修改