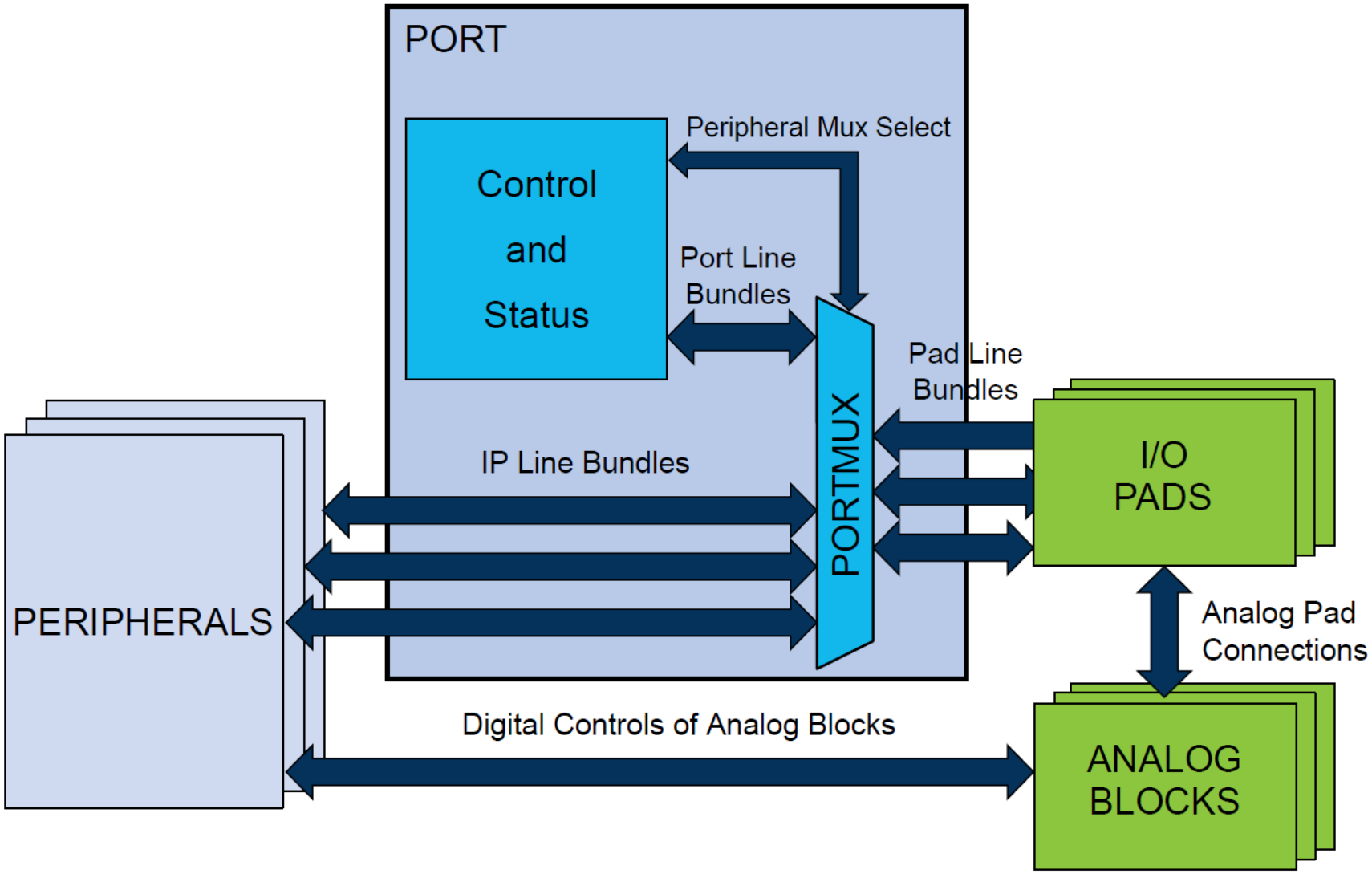
MICROCHIP

Regional Training Centers

Section 9
PINMUX &
SERCOM - UART Architecture

What's PINMUX ?



What's PINMUX ?

- Each pin is by default controlled by the PORT as a general purpose I/O and alternatively. It can be assigned to one of the peripheral functions group.

Function Groups (A ~ H)

PMUX					0	1					2	3	4	5	6	7
Pin(1)			I/O Pin	Supply	A	B(2)(3)					C	D	E	F	G	H
SAMD21E	SAMD21G	SAMD21J			EIC	REF	ADC	AC	PTC	DAC	SERCOM(2)(3)	SERCOM-ALT	TC(4)/TCC	TCC	COM	AC/ GCLK
15	23	31	PA14	VDDIO	EXTINT[14]						SERCOM2/ PAD[2]	SERCOM4/ PAD[2]	TC3/WO[0]	TCC0/ WO[4]		GCLK_IO[0]
16	24	32	PA15	VDDIO	EXTINT[15]						SERCOM2/ PAD[3]	SERCOM4/ PAD[3]	TC3/WO[1]	TCC0/ WO[5]		GCLK_IO[1]
19	27	37	PA18	VDDIO	EXTINT[2]				X[6]		SERCOM1/ PAD[2]	SERCOM3/ PAD[2]	TC3/WO[0]	TCC0/ WO[2]		AC/CMP[0]
20	28	38	PA19	VDDIO	EXTINT[3]				X[7]		SERCOM1/ PAD[3]	SERCOM3/ PAD[3]	TC3/WO[1]	TCC0/ WO[3]	I2S/SD[0]	AC/CMP[1]
21	31	43	PA22	VDDIO	EXTINT[6]				X[10]		SERCOM3/ PAD[0]	SERCOM5/ PAD[0]	TC4/WO[0]	TCC0/ WO[4]		GCLK_IO[6]
22	32	44	PA23	VDDIO	EXTINT[7]				X[11]		SERCOM3/ PAD[1]	SERCOM5/ PAD[1]	TC4/WO[1]	TCC0/ WO[5]	USB/SOF 1kHz	GCLK_IO[7]

Pin Name

PINMUX PLIB Analysis

main() @ main.c

```
SYS_Initialize ( NULL );
```

SYS_Initialize() @ initialization.c

```
PORT_Initialize();
```

Offset	Name	7	6	5	4	3	2	1	0
0x30	PMUX0	PMUXO[3:0]					PMUXE[3:0]		
0x3F	PMUX15	PMUXO[3:0]					PMUXE[3:0]		
0x40	PINCFG0		DRVSTR				PULLEN	INEN	PMUXEN
0x5F	PINCFG31		DRVSTR				PULLEN	INEN	PMUXEN

PMUX

PMUXO (ODD)

PMUXE (EVEN)

PINCFG

INEN

PMUXEN

PORT_Initialize() @ plib_port.c

```
PORT_REGS->GROUP[0].PORT_DIR = 0x120200;
PORT_REGS->GROUP[0].PORT_OUT = 0x200;
PORT_REGS->GROUP[0].PORT_PINCFG[14] = 0x3;
PORT_REGS->GROUP[0].PORT_PINCFG[15] = 0x3;
PORT_REGS->GROUP[0].PORT_PINCFG[18] = 0x1;
PORT_REGS->GROUP[0].PORT_PINCFG[19] = 0x1;
PORT_REGS->GROUP[0].PORT_PINCFG[22] = 0x1;
PORT_REGS->GROUP[0].PORT_PINCFG[23] = 0x1;

PORT_REGS->GROUP[0].PORT_PMUX[7] = 0x77;
PORT_REGS->GROUP[0].PORT_PMUX[9] = 0x44;
PORT_REGS->GROUP[0].PORT_PMUX[11] = 0x44;
```

PA14 (GCLK_IO0) — INEN = 1 (Button)

PA15 (GCLK_IO1) — INEN = 1 (Button)

PA18 (TC3_WO0)

PA19 (TC3_WO1)

PA22 (TC4_WO0)

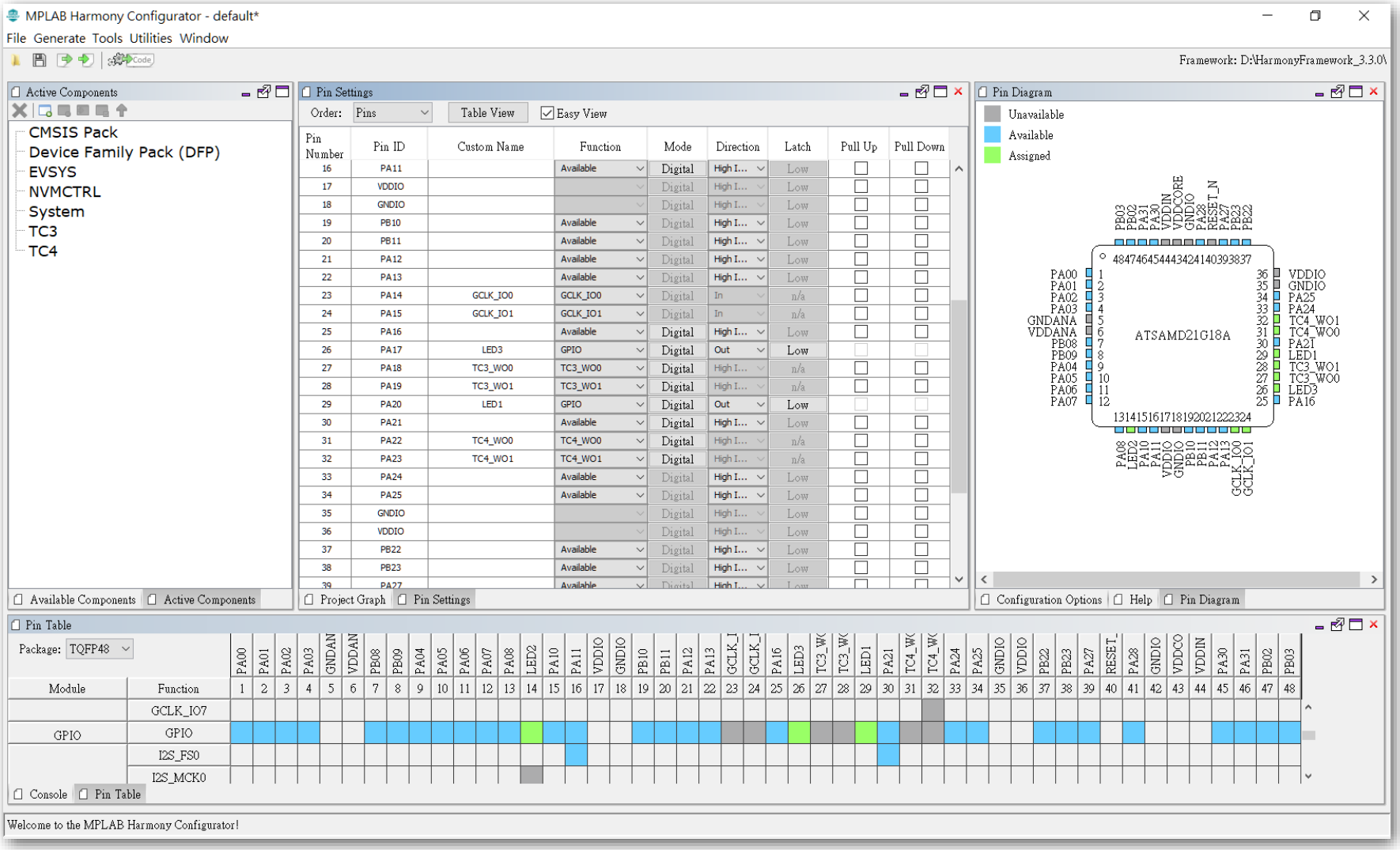
PA23 (TC4_WO1)

PMUX[7] : PA15 , PA14

PMUX[9] : PA19 , PA18

PMUX[11] : PA23 , PA22

PINMUX Configuration Example



PINMUX PLIB Analysis

PMUX	0	1					2	3	4	5	6	7
Pin(1)		I/O Pin	Supply	A	B(2)(3)				C	D	E	F	G	H
SAMD21E	SAMD21G	SAMD21J			EIC	REF	ADC	AC	PTC	DAC	SERCOM(2)(3)	SERCOM-ALT	TC(4)/TCC	TCC	COM	AC/ GCLK
15	PA14 (7)	1	PA14	VDDIO	EXTINT[14]						SERCOM2/ PAD[2]	SERCOM4/ PAD[2]	TC3/WO[0]	GCLK_IO[0]		GCLK_IO[0]
16	PA15 (7)	2	PA15	VDDIO	EXTINT[15]						SERCOM2/ PAD[3]	SERCOM4/ PAD[3]	TC3/WO[1]	GCLK_IO[1]		GCLK_IO[1]
19	PA18 (4)	7	PA18	VDDIO	EXTINT[2]				X[6]		TC3/WO[0]		TC3/WO[0]	TCC0/ WO[2]		AC/CMP[0]
20	PA19 (4)	8	PA19	VDDIO	EXTINT[3]				X[7]		TC3/WO[1]		TC3/WO[1]	TCC0/ WO[3]	I2S/SD[0]	AC/CMP[1]
21	PA22 (4)	3	PA22	VDDIO	EXTINT[6]				X[10]		TC4/WO[0]		TC4/WO[0]	TCC0/ WO[4]		GCLK_IO[6]
22	PA23 (4)	4	PA23	VDDIO	EXTINT[7]				X[11]		TC4/WO[1]		TC4/WO[1]	TCC0/ WO[5]	USB/SOF 1kHz	GCLK_IO[7]

```
PORT_REGS->GROUP[0].PORT_PMUX[7] = 0x77;
PORT_REGS->GROUP[0].PORT_PMUX[9] = 0x44;
PORT_REGS->GROUP[0].PORT_PMUX[11] = 0x44;
```

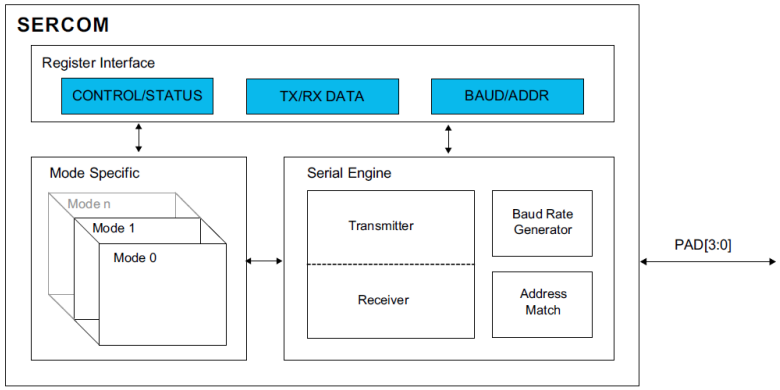
PA15 (7) , PA14 (7)

PA19 (4) , PA18 (4)

PA23 (4) , PA22 (4)

SERCOM Introduction

- Serial Communication Interface, SERCOM be configured to support a number of modes :
  - I2C
  - SPI
  - USART : RS232, RS485, IrDA
- There are up to six instances of the serial communication interface SERCOM peripheral.



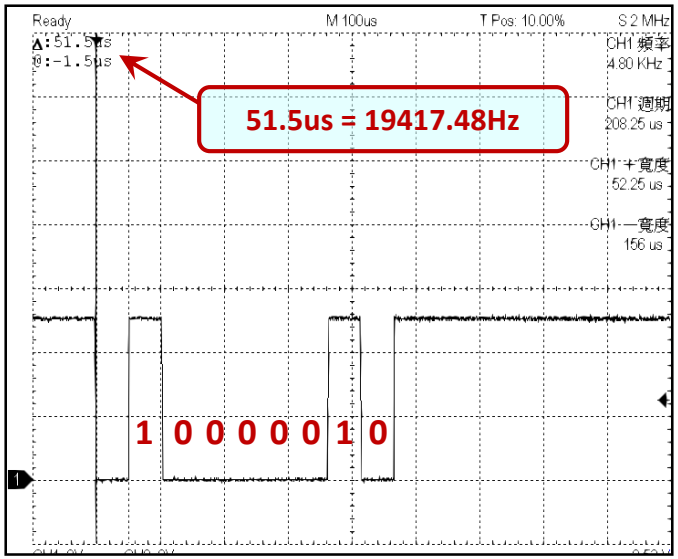
- The SERCOM serial engine consists of a transmitter and receiver, baud-rate generator and address matching functionality. It can use the internal generic clock or an external clock to operate in all sleep.

SERCOM Introduction

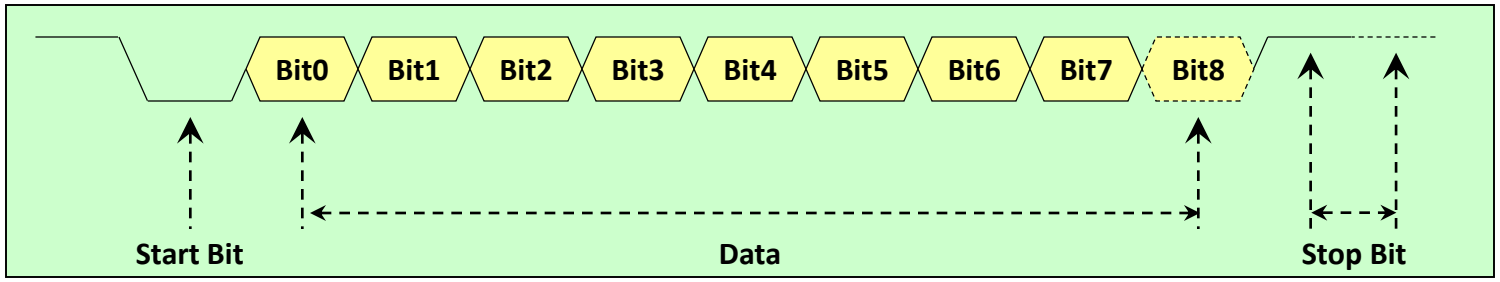
- **For I2C**
  - Fast Mode (400kHz)
  - Master or slave operation
  - SMBUS compatible
  - Wake on address match
- **For SPI**
  - Up to 24Mb/s
  - Supports all four SPI modes
  - Full-duplex operation
  - Single data direction mode frees unused MISO or MOSI pin
- **For USART**
  - Up to 24Mb/s
  - Half-/Full-duplex operation
  - Sync and Async operation

What's UART ?

- UART : Universal Asynchronous Receiver Transmitter.
- The module data exchange through serial communication.
- The data formatting include
  1 start bit,
  5 to 9 data bits and
  1 or 2 stop bits.

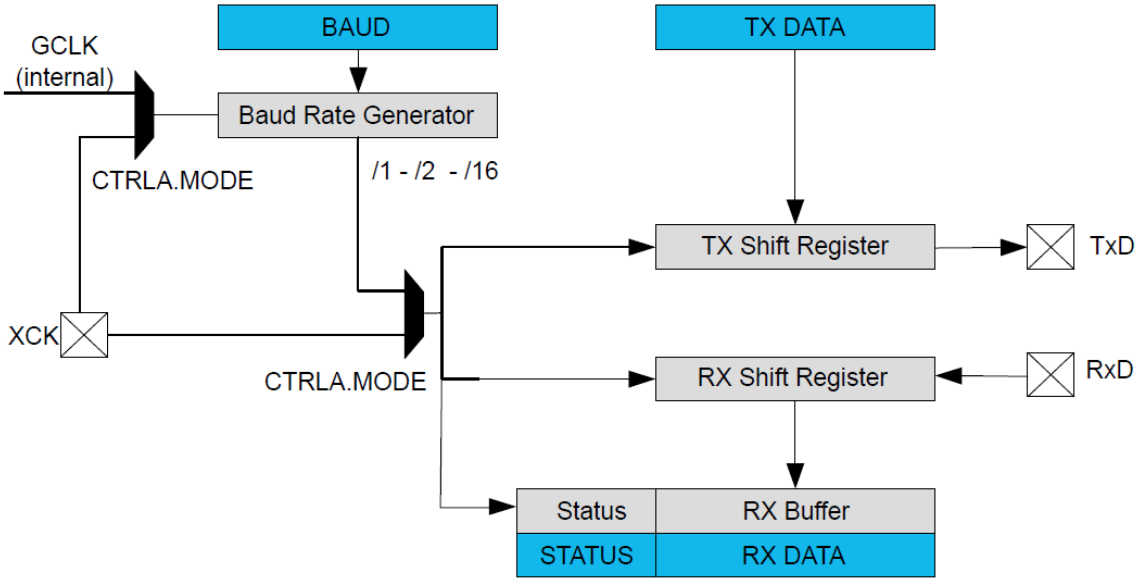


UART Transmit Example :
'A'(0x41), 19200 bps



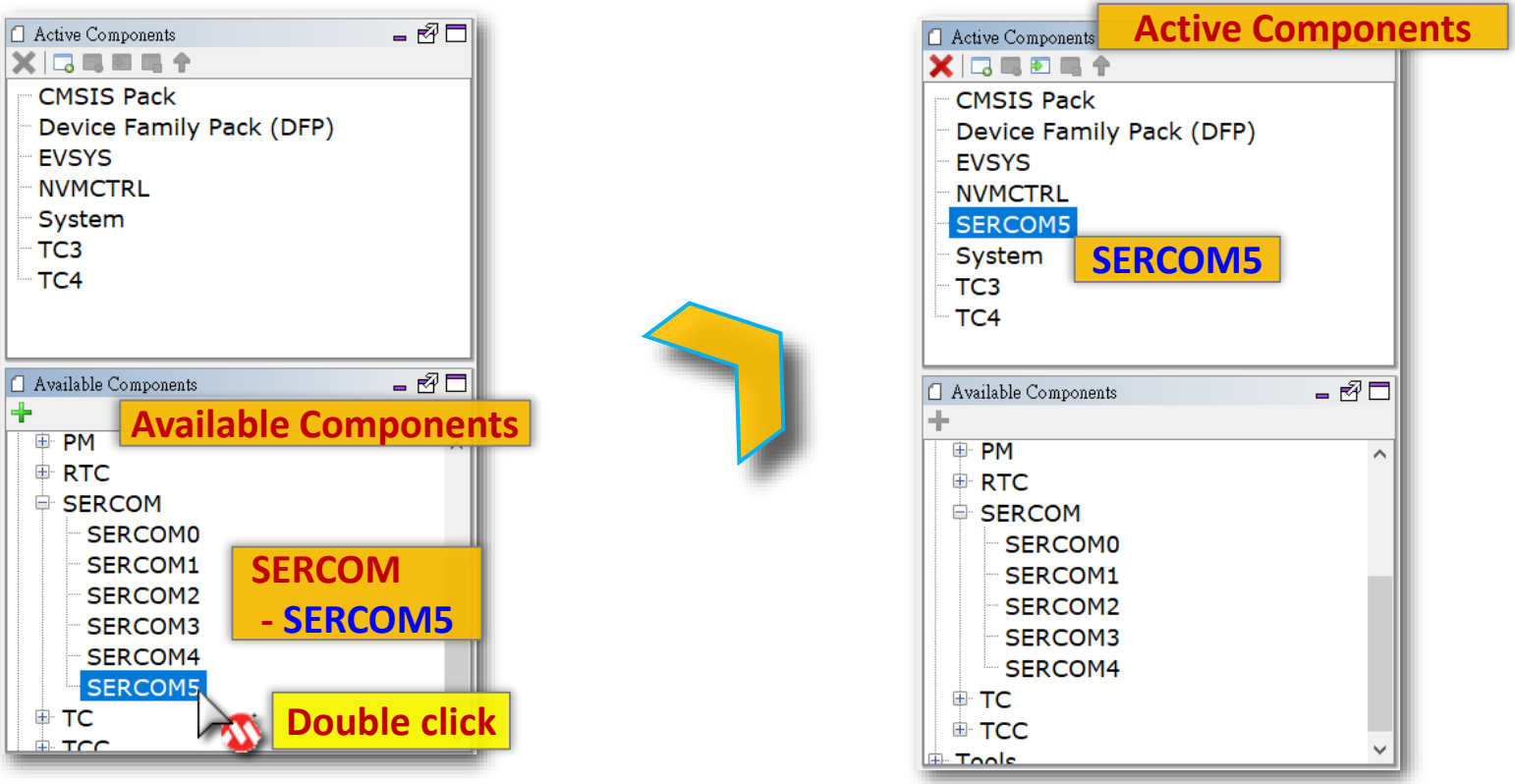
SERCOM - USART

- Supports serial frames with 5, 6, 7, 8 or 9 data bits and 1 or 2 stop bits, Parity Check, RTS and CTS flow control.
- Full-duplex operation, Support RS-232, RS-485 and IrDA.
- Buffer overflow and frame error detection.
- Internal or external clock source for asynchronous and synchronous operation.

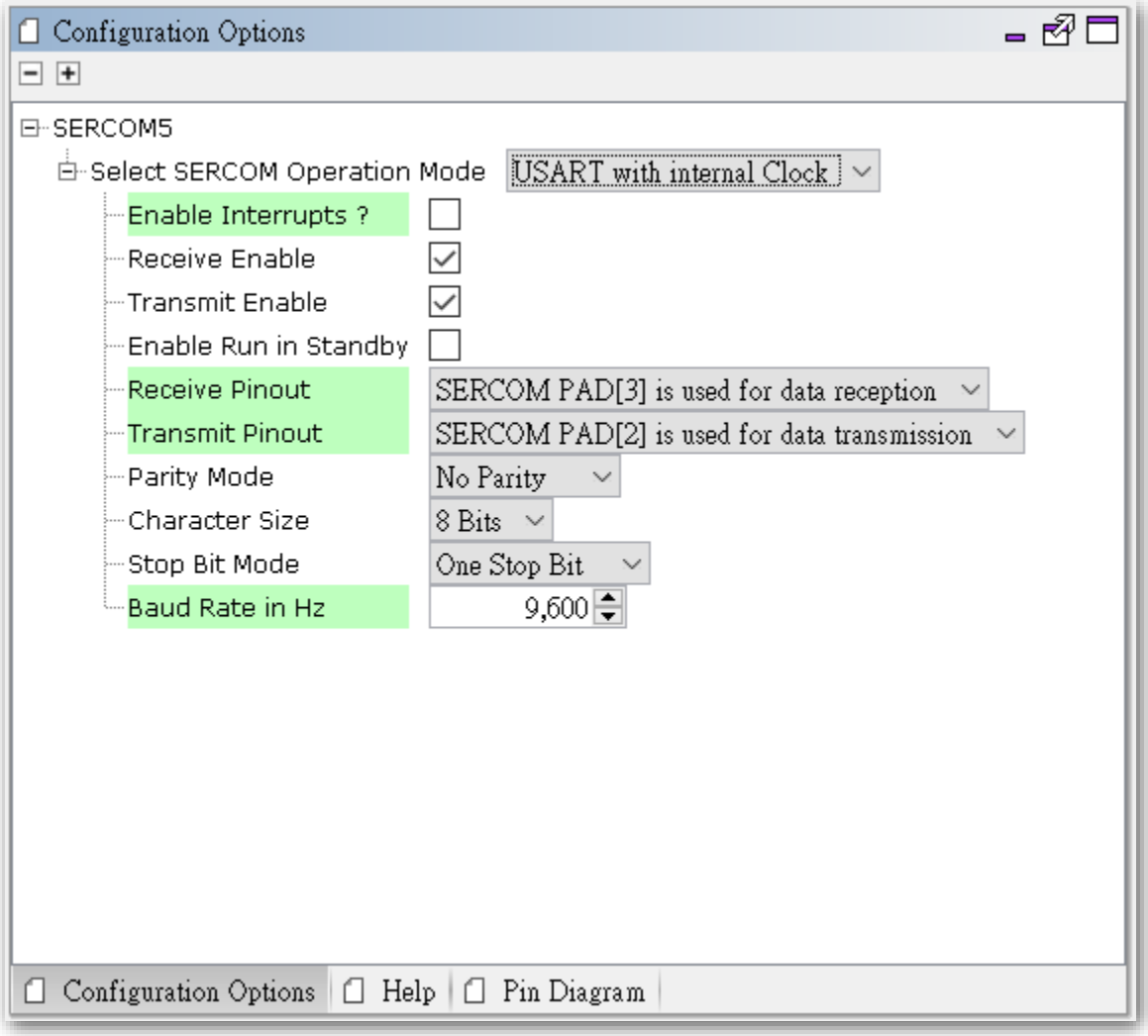


Add SERCOM Function using MHC

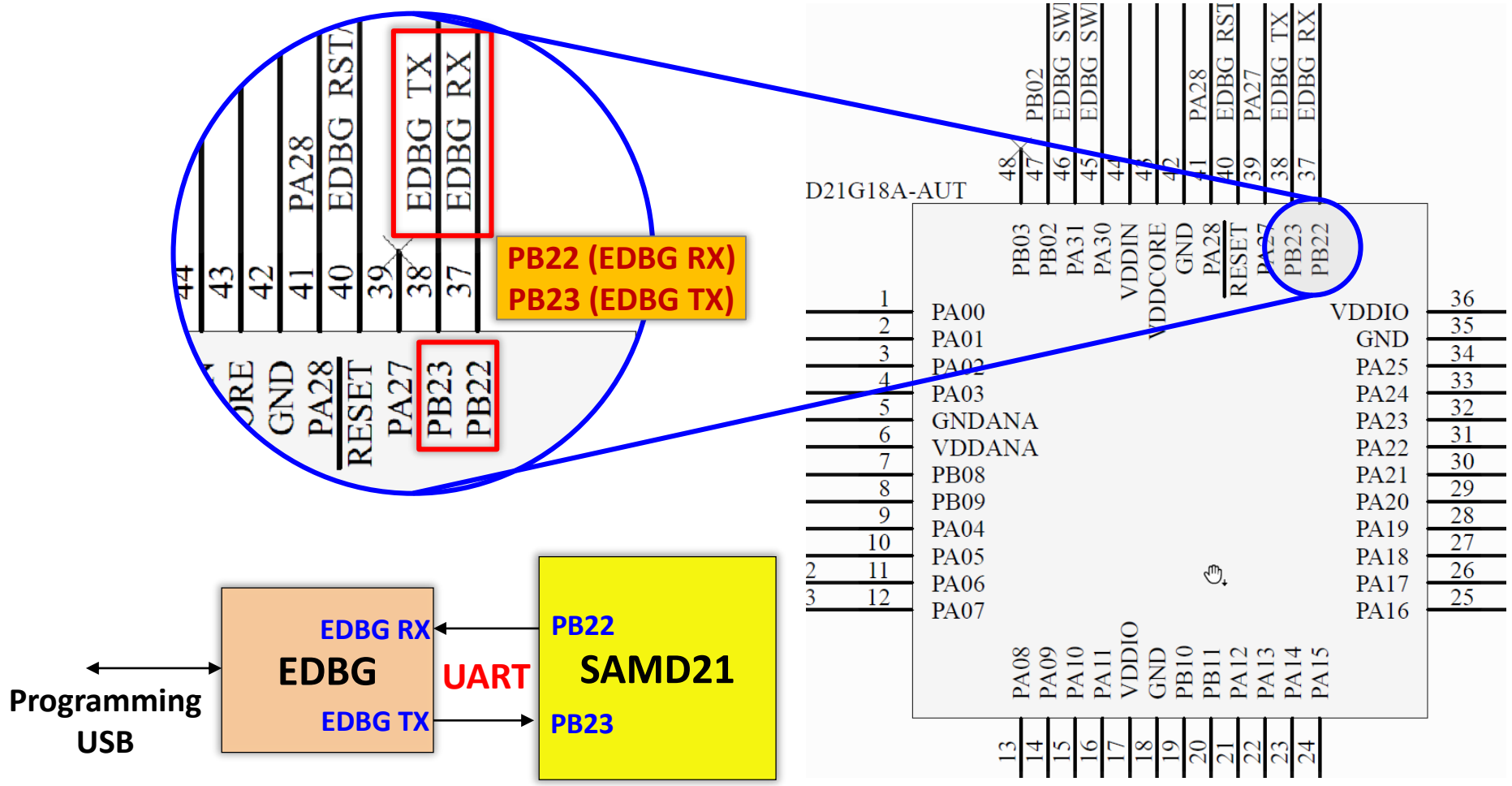
- Find SERCOM component in Available Components window.
- Double click SERCOM5 to add to Active Components window.



SERCOM USART Polling Configuration Options Example



APP045 SERCOM USART Schematic



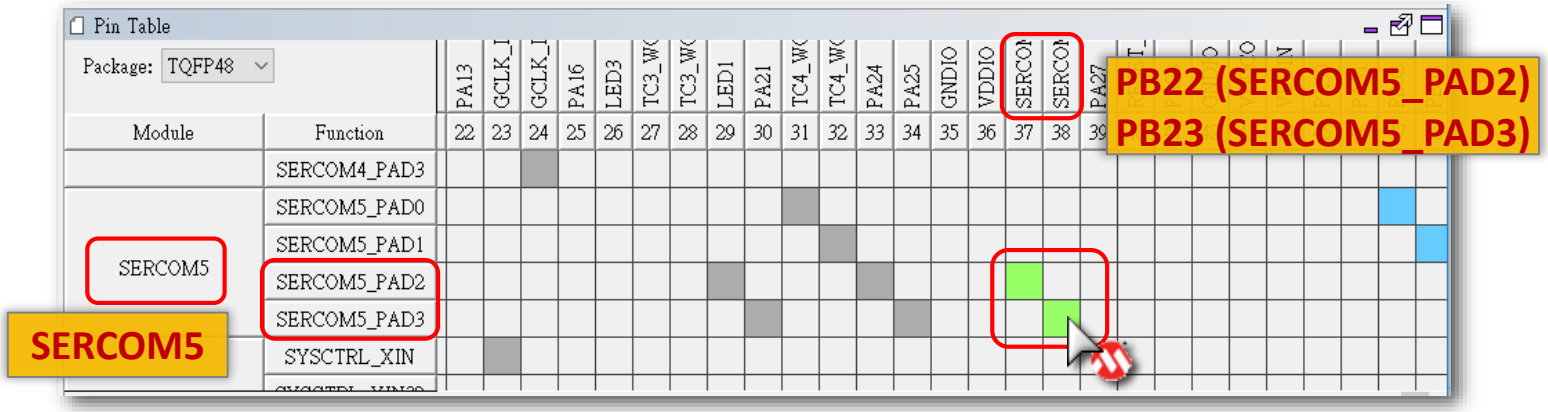
SERCOM USART PINMUX Configuration Example

- SERCOM allow limited alternate pad index assignment.
- For example : PB22 as SERCOM5_PAD2
  PB23 as SERCOM5_PAD3

Pin(1)			I/O Pin	Supply	A	B(2)(3)					C	D	E	F	G	H
SAMD21E	SAMD21G	SAMD21J			EIC	REF	ADC	AC	PTC	DAC	SERCOM(2)(3)	SERCOM-ALT	TC(4)/TCC	TCC	COM	AC/ GCLK
	37	49	PB22	VDDIO	EXTINT[6]							SERCOM5/ PAD[2]				GCLK_IO[0]
	38		PB23	VDDIO	EXTINT[7]							SERCOM5/ PAD[3]		WO[1]		GCLK_IO[1]

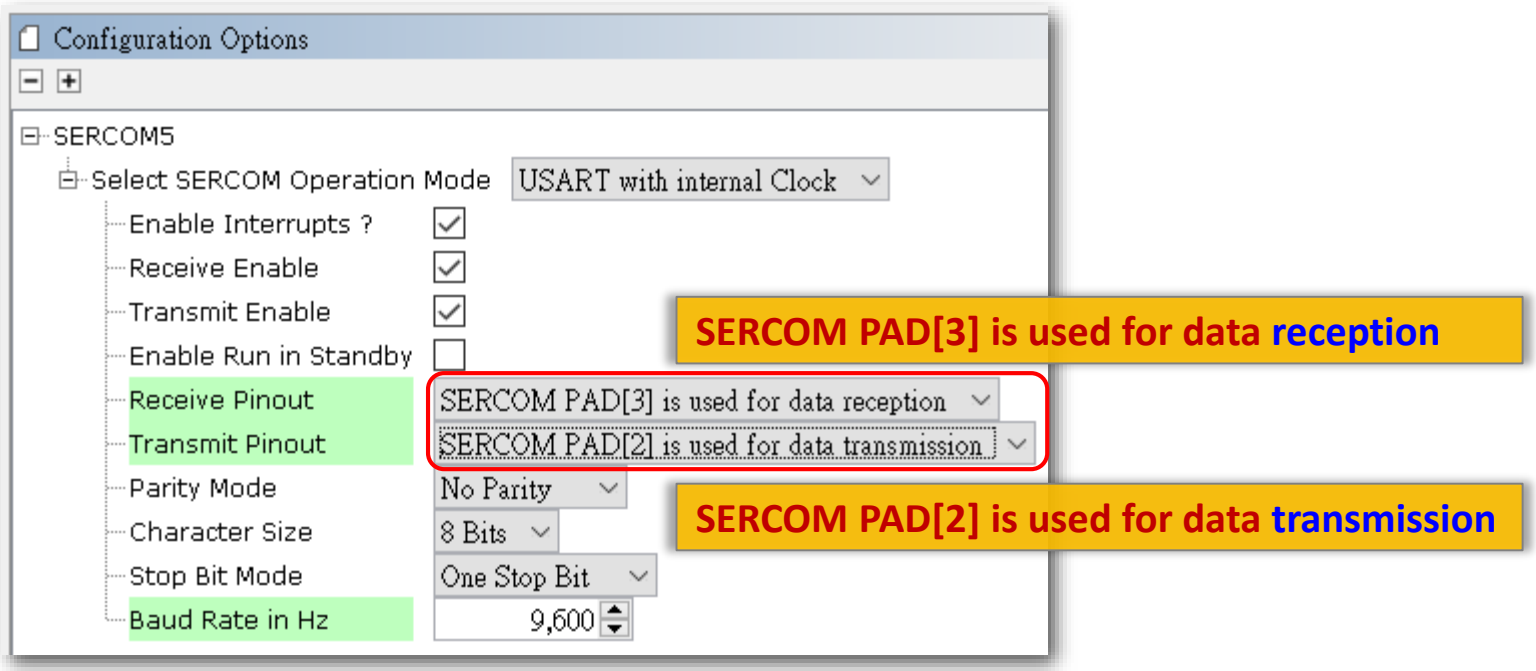
PB22
PB23

SERCOM5/PAD[2]
SERCOM5/PAD[3]



SERCOM USART PINMUX Configuration Example

- Remember arrange pads function in SERCOM module.
- For example : SERCOM5 PAD[2] as USART TXD (PB22)
  SERCOM5 PAD[3] as USART RXD (PB23)



SERCOM USART Polling Interface Routines

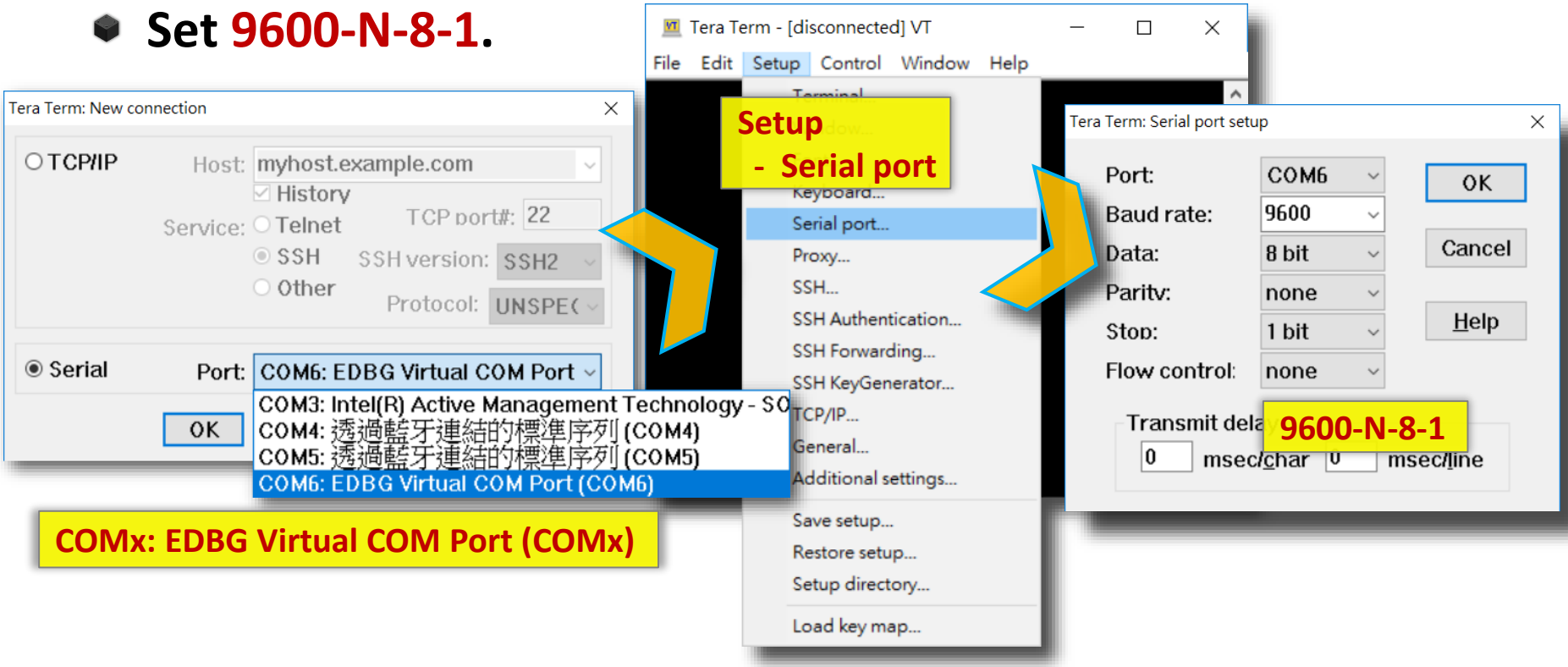
```
/*** SERCOM USART Interface Routines***/

void SERCOM5_USART_Initialize( void );

bool SERCOM5_USART_SerialSetup( USART_SERIAL_SETUP * serialSetup,
                                uint32_t clkFrequency );

bool SERCOM5_USART_Write( void *buffer, const size_t size );

bool SERCOM5_USART_TransmitterIsReady( void );

bool SERCOM5_USART_TransmitComplete( void );

void SERCOM5_USART_WriteByte( int data );

bool SERCOM5_USART_Read( void *buffer, const size_t size );

bool SERCOM5_USART_ReceiverIsReady( void );

int SERCOM5_USART_ReadByte( void );

USART_ERROR SERCOM5_USART_ErrorGet( void );

uint32_t SERCOM5_USART_FrequencyGet( void );
```

SERCOM USART Tx Polling Code Example

```
 …

int main (void)
{
   SYS_Initialize ( NULL );
   …

   while(1)
   {
      …
      SERCOM5_USART_Write( "Hello world!\r\n", 14 );
   }
}
```

Terminal Console Software

- Tera Term is a terminal console software. (http://ttssh2.sourceforge.jp/index.html.en)
- Select COMx EDBG Virtual COM Port
- Set 9600-N-8-1.



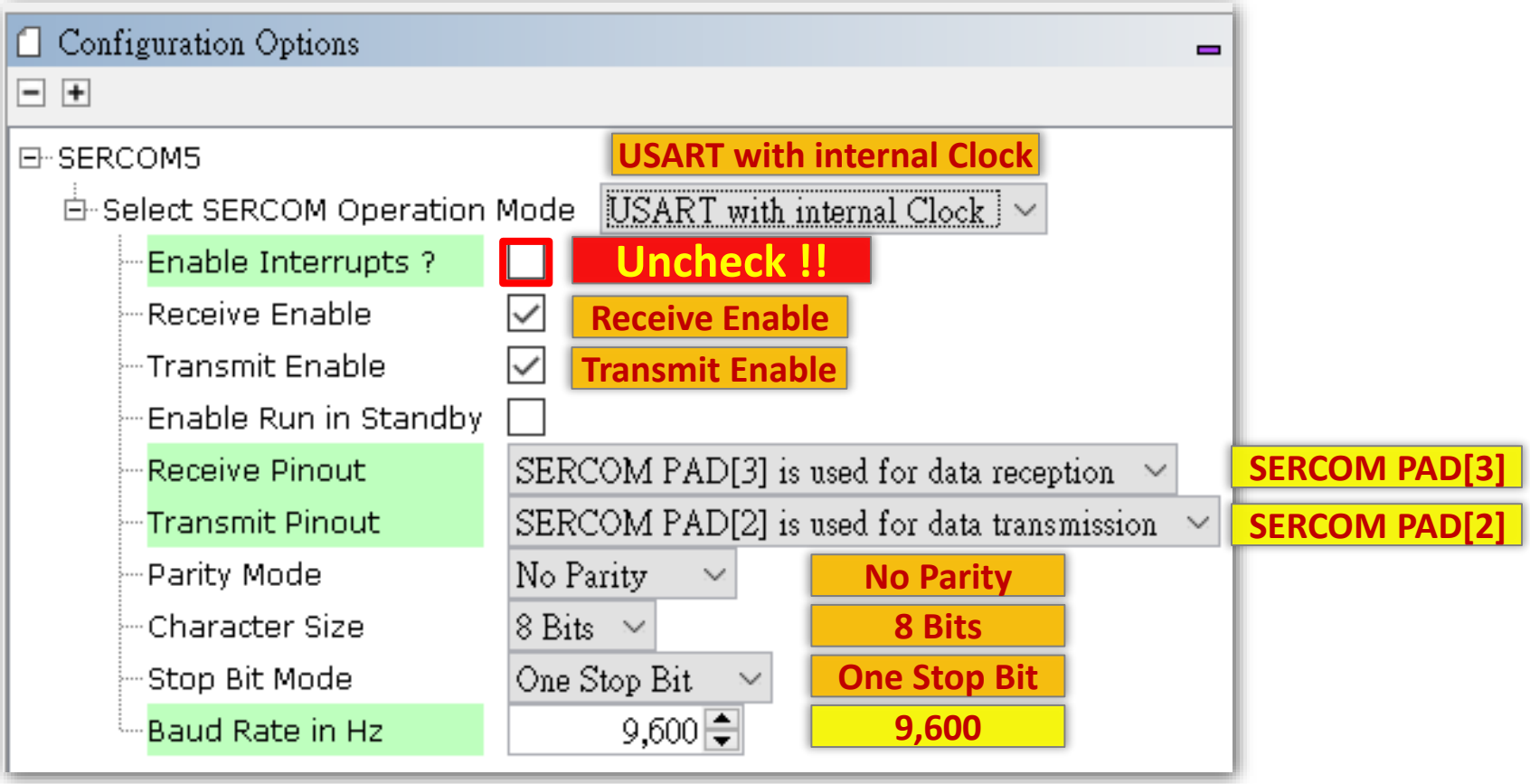
Lab9 SERCOM - UART Tx Polling

- Try to add SERCOM-USART function to project.
- UART set to 9600-N-8-1, No flow control.
- Send string from UART to PC of one second interval repeated. (Hello World!)
- Character \r for carriage Return (0x0D)
- Character \n for New line (0x0A)

- How to start ?

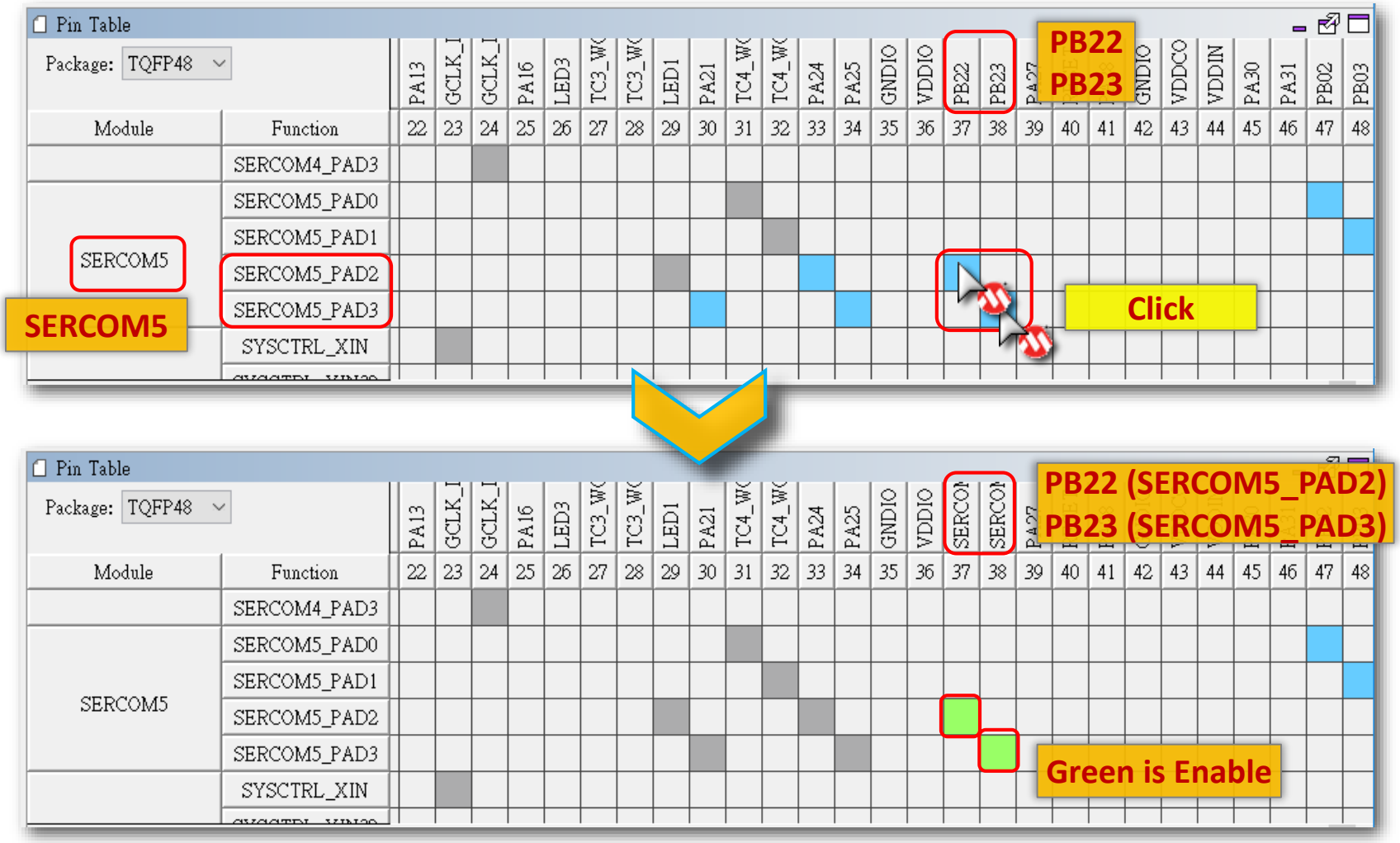
Lab9 SERCOM - UART Tx Polling

Step 1



Lab9 SERCOM - UART Tx Polling

Step 2

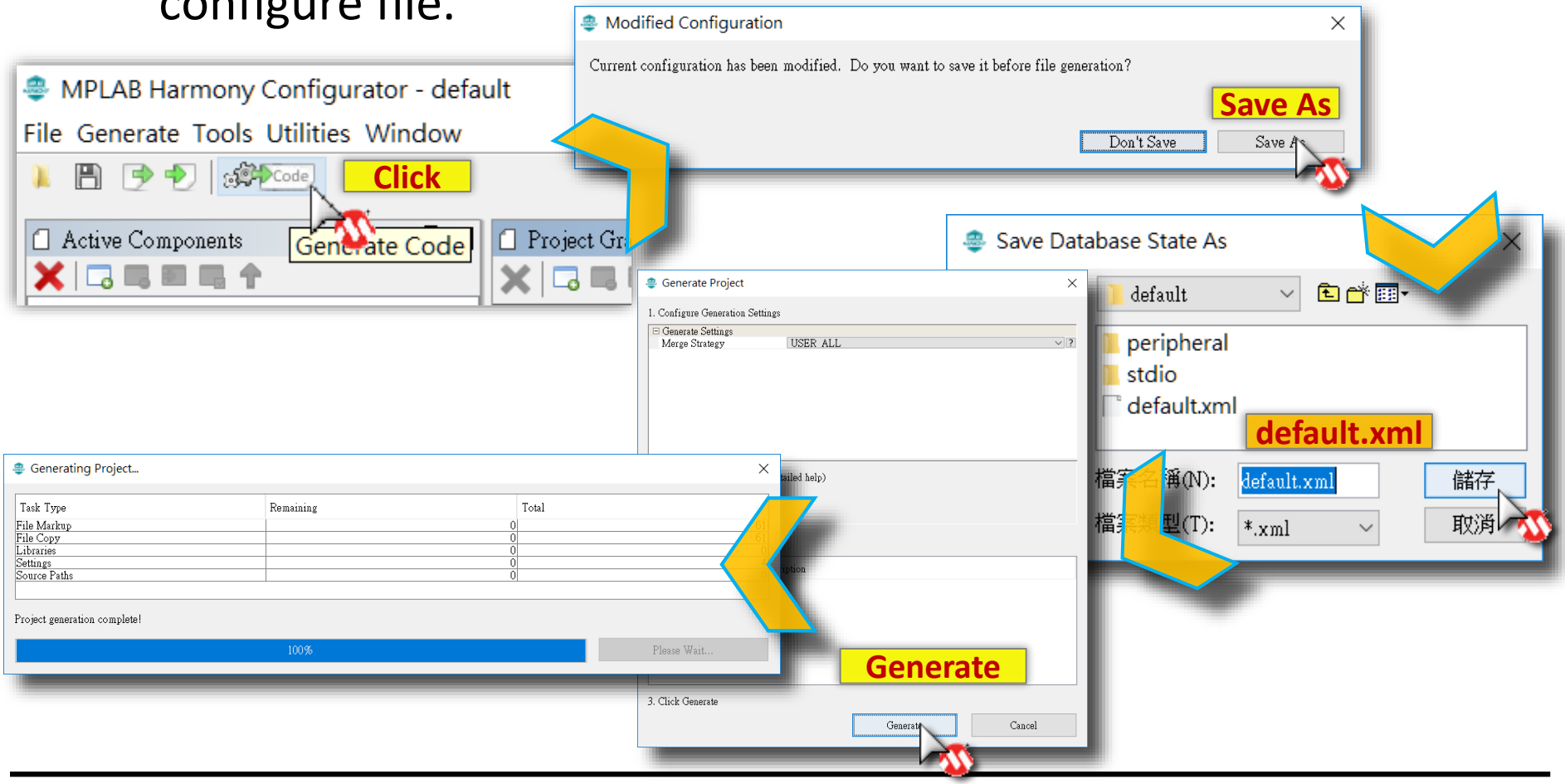


Lab9 SERCOM - UART Tx Polling

Step 3

- Click 

to Generate Code and save changes to MHC configure file.

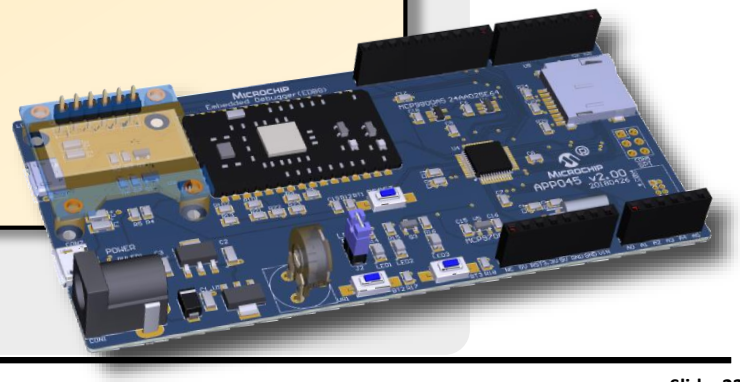


Lab9 SERCOM - UART Tx Polling

Step 4

a. **Add code segment to your main loop**

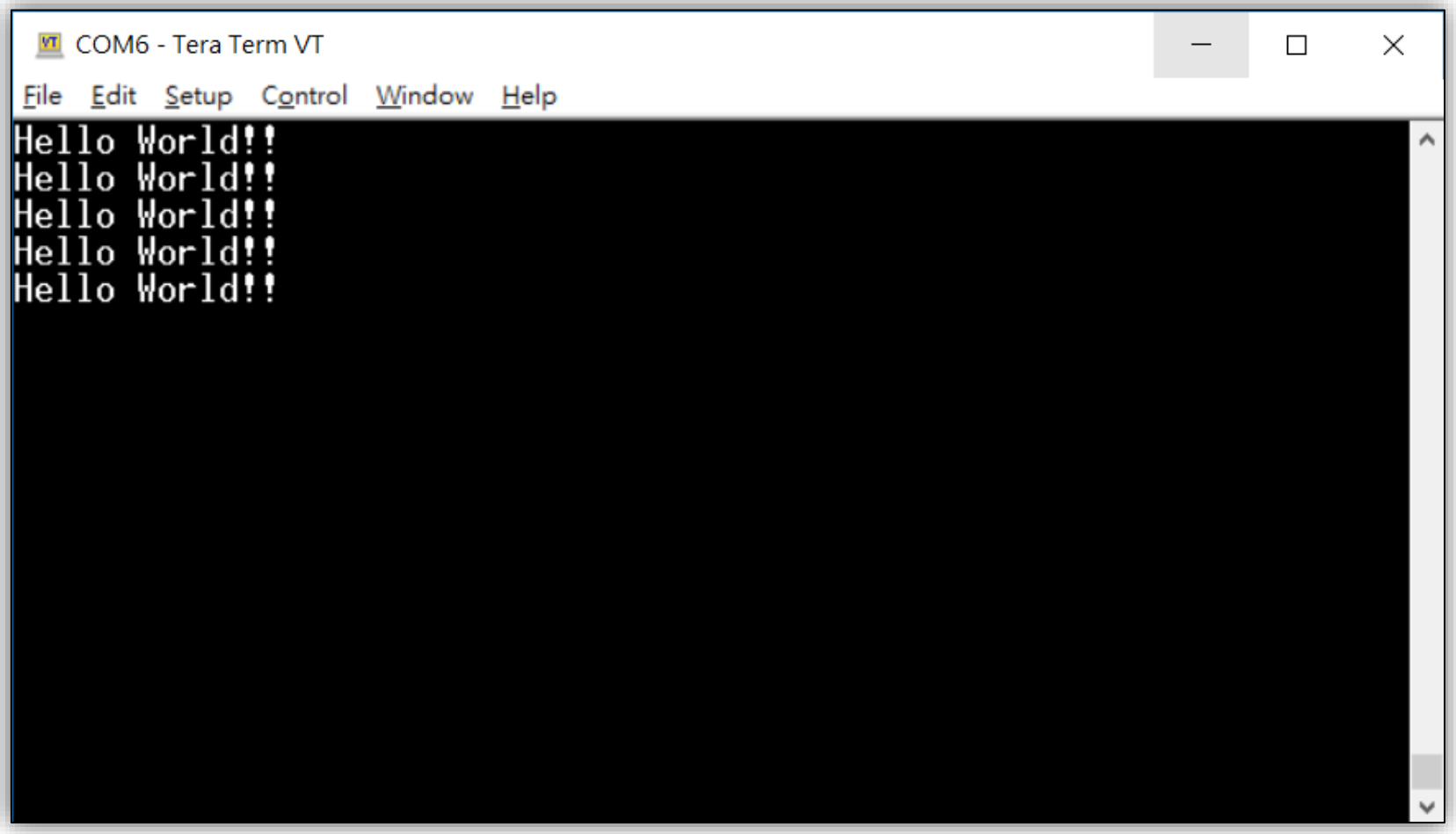
```
void TC3_Overflow(TC_COMPARE_STATUS status, uintptr_t context)
{
      if( status & TC_INTFLAG_OVF_Msk )
      {
         LED1_Toggle();

         // TODO 9.01
         SERCOM5_USART_Write( "Hello world!\r\n", 14 );
      }
}

int main (void)
{
   SYS_Initialize ( NULL );

   …

}
```



b. **Program firmware to target board then observe result.**

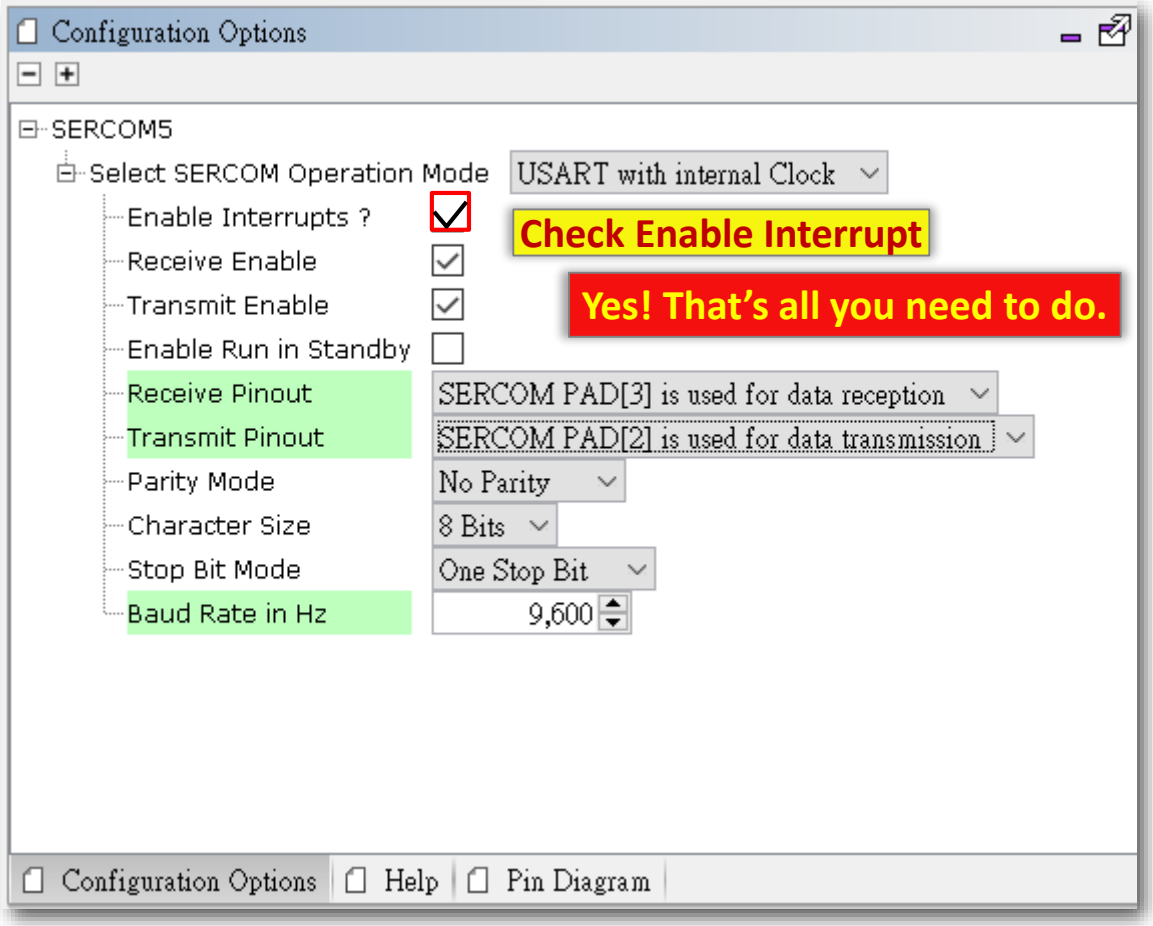
Lab9 SERCOM - UART Tx Polling

Result



SERCOM USART Interrupt Configuration Options Example

- SERCOM provide callback(interrupt) mode, also.



SERCOM USART Interrupt Callback Interface Routines

```
/*** SERCOM USART Interface Routines***/

void SERCOM5_USART_Initialize( void );

bool SERCOM5_USART_SerialSetup( USART_SERIAL_SETUP * serialSetup,
                                uint32_t clkFrequency );

bool SERCOM5_USART_Write( void *buffer, const size_t size );

bool SERCOM5_USART_WriteIsBusy( void );

size_t SERCOM5_USART_WriteCountGet( void );

void SERCOM5_USART_WriteCallbackRegister( SERCOM_USART_CALLBACK callback,
                                          uintptr_t context );

bool SERCOM5_USART_Read( void *buffer, const size_t size );

bool SERCOM5_USART_ReadIsBusy( void );

size_t SERCOM5_USART_ReadCountGet( void );

void SERCOM5_USART_ReadCallbackRegister( SERCOM_USART_CALLBACK callback,
                                         uintptr_t context );

USART_ERROR SERCOM5_USART_ErrorGet( void );

uint32_t SERCOM5_USART_FrequencyGet( void );
```

USART TxRx Interupt Code Example

```
uint8_t USART5_ReceiveData[1];
void USART5_Receive( uintptr_t context )
{
  SERCOM5_USART_Write( USART5_ReceiveData, 1 );
  SERCOM5_USART_Read( USART5_ReceiveData, 1 );
}

void USART5_ Transmit( uintptr_t context ) { }

int main (void)
{
   SYS_Initialize ( NULL );
   …
   SERCOM5_USART_ReadCallbackRegister( USART5_Receive, (uintptr_t )NULL );
   SERCOM5_USART_WriteCallbackRegister( USART5_Transmit, (uintptr_t )NULL );
   SERCOM5_USART_Read( USART5_ReceiveData, 1 );
   while(1)
   { …
     SERCOM5_USART_Write( "Hello world!\r\n", 14 );
   }
}
```

One-Shot Event

Callback Register

About String Functions

- UART 所處理的資料大多是字串或文字資料, 使用C所提供的字串處理函式將能更方便的進行“資料” <-> “字串”的轉換。常用的轉換函式有sprintf( ), strlen( )。
- int sprintf(char *s, const char *format, ...);
  將資料依據指定格式轉換後存入指定的buffer字串中。
  * 必需 include <stdio.h>
  size_t strlen(const char *s);
  計算字串(string)的長度(不包含字串結尾的Null(‘\0’))。
  * 必需 include <string.h>
- For Example

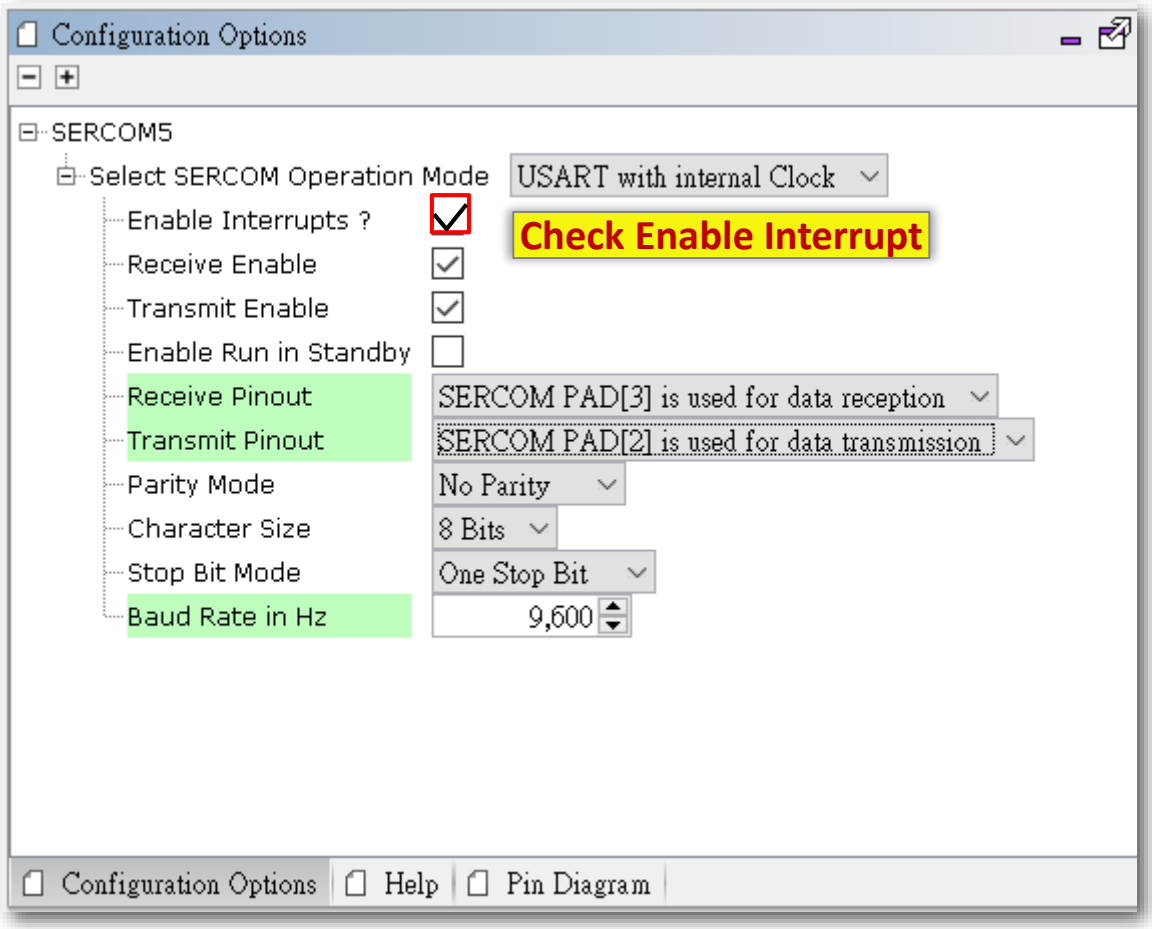
```
uint8_t USARTRTxBuffer[100];
uint16_t USART5_ReceiveData;
sprintf((char *) USARTRTxBuffer, "Received Data : %1c\r\n", USART5_ReceiveData);
SERCOM5_USART_Write( USARTRTxBuffer, strlen((char *)USARTRTxBuffer));
```

Lab10 SERCOM - UART TxRx Interrupt Callback

- Try to enable SERCOM-USART Interrupt Callback driver.
- Modify polling transmit function to asynchronous function.
- Add new USART receive function base on interrupt callback function.
- Try to receive character from PC and loopback to TeraTerm as string format “Received Data : x” .
- SERCOM - UART setting same as Lab9

- Let’s go!

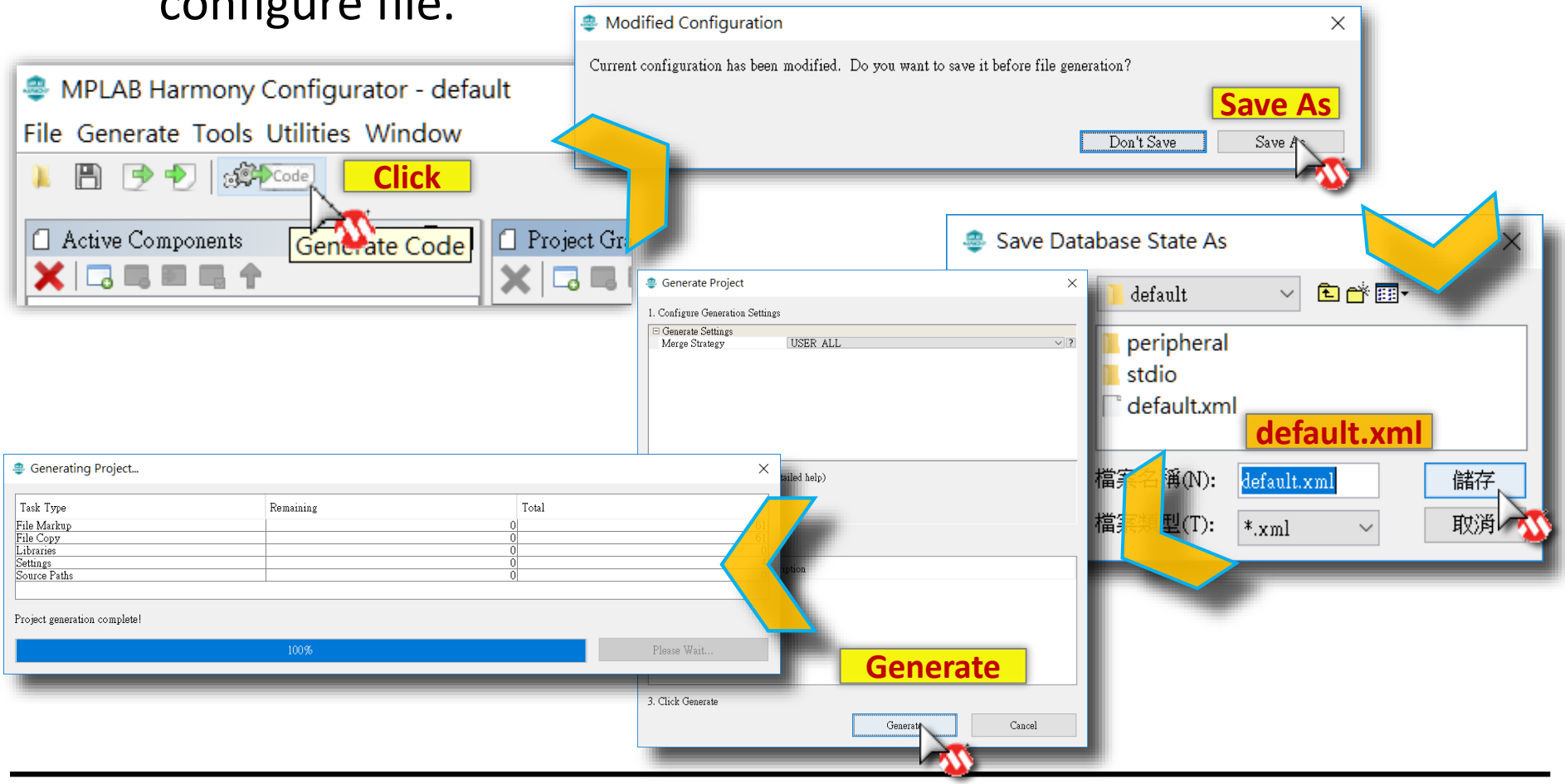
Lab10 SERCOM - UART TxRx Interrupt Callback Step 1



Lab10 SERCOM - UART TxRx Interrupt Callback Step 2

- Click 

to Generate Code and save changes to MHC configure file.



Lab10 SERCOM - UART TxRx Interrupt Callback Step 3

a. Create UART TxRx Callback function, related buffer and

```
// TODO 10.01
#include <stdio.h>
#include <string.h>

// TODO 10.02
uint8_t USARTRTxBuffer[100];
uint8_t USART5_ReceiveData[1];
volatile uint8_t USART5_IsReceived = 0;
volatile uint8_t USART5_IsTransmitted = 1;

void USART5_Transmit( uintptr_t context )
{
  USART5_IsTransmitted = 1;
}

void USART5_Receive( uintptr_t context )
{
  USART5_IsReceived = 1;
}

int main (void)
{   ...   }
```

Lab10 SERCOM - UART TxRx Interrupt Callback Step 4

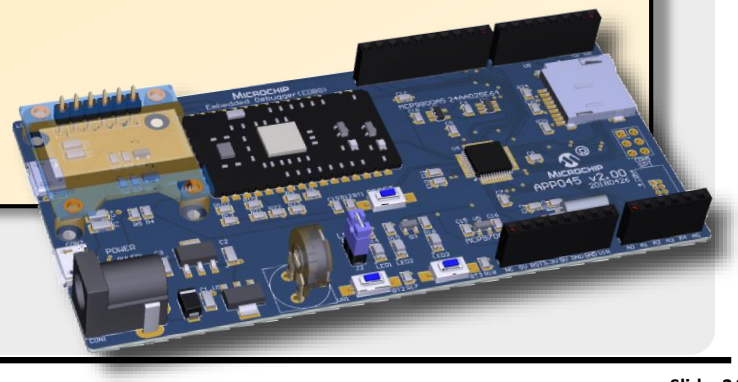
a. **Add code segment to your main loop**

```
int main (void)
{  …
   // TODO 10.03
   SERCOM5_USART_ReadCallbackRegister( USART5_Receive, (uintptr_t )NULL );
   SERCOM5_USART_WriteCallbackRegister( USART5_Transmit, (uintptr_t )NULL );
   SERCOM5_USART_Read( USART5_ReceiveData, 1 );

   while(1)
   {  …
      // TODO 10.04
      if( USART5_IsReceived )
      {
        USART5_IsReceived = 0;
        sprintf((char *) USARTRTxBuffer,
                        "\r\nReceived Data : %1c\r\n", USART5_ReceiveData[0] );
        SERCOM5_USART_Write( USARTRTxBuffer, strlen((char*)USARTRTxBuffer) );
        while( SERCOM5_USART_WriteIsBusy() );
        SERCOM5_USART_Read( USART5_ReceiveData, 1 );
      }
   }
}
```

Lab10 SERCOM - UART TxRx Interrupt Callback Step 5

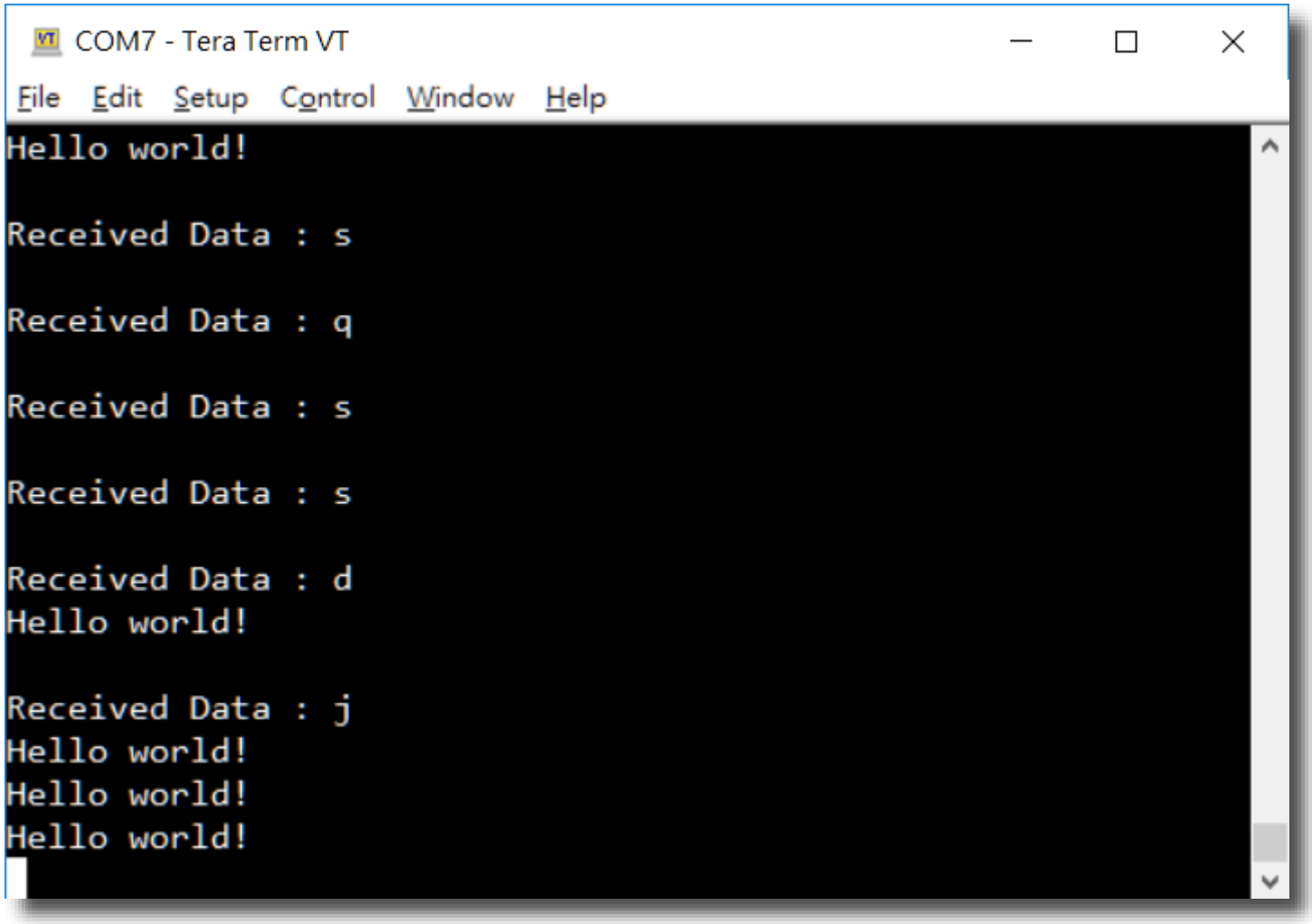
a **Modify TC3 Callback for UART Tx**

```
void TC3_Overflow(TC_COMPARE_STATUS status, uintptr_t context)
{
      if( status & TC_INTFLAG_OVF_Msk )
      {
         LED1_Toggle();

         // TODO 10.05
         sprintf((char *) USARTRTxBuffer, "Hello world!\r\n" );
         SERCOM5_USART_Write( USARTRTxBuffer, strlen((char*)USARTRTxBuffer) );
      }
}

int main (void)
{
   SYS_Initialize ( NULL );

   …

}
```



b **Program firmware to target board then observe result.**

Lab10 SERCOM - UART TxRx Interrupt Callback Result



Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO

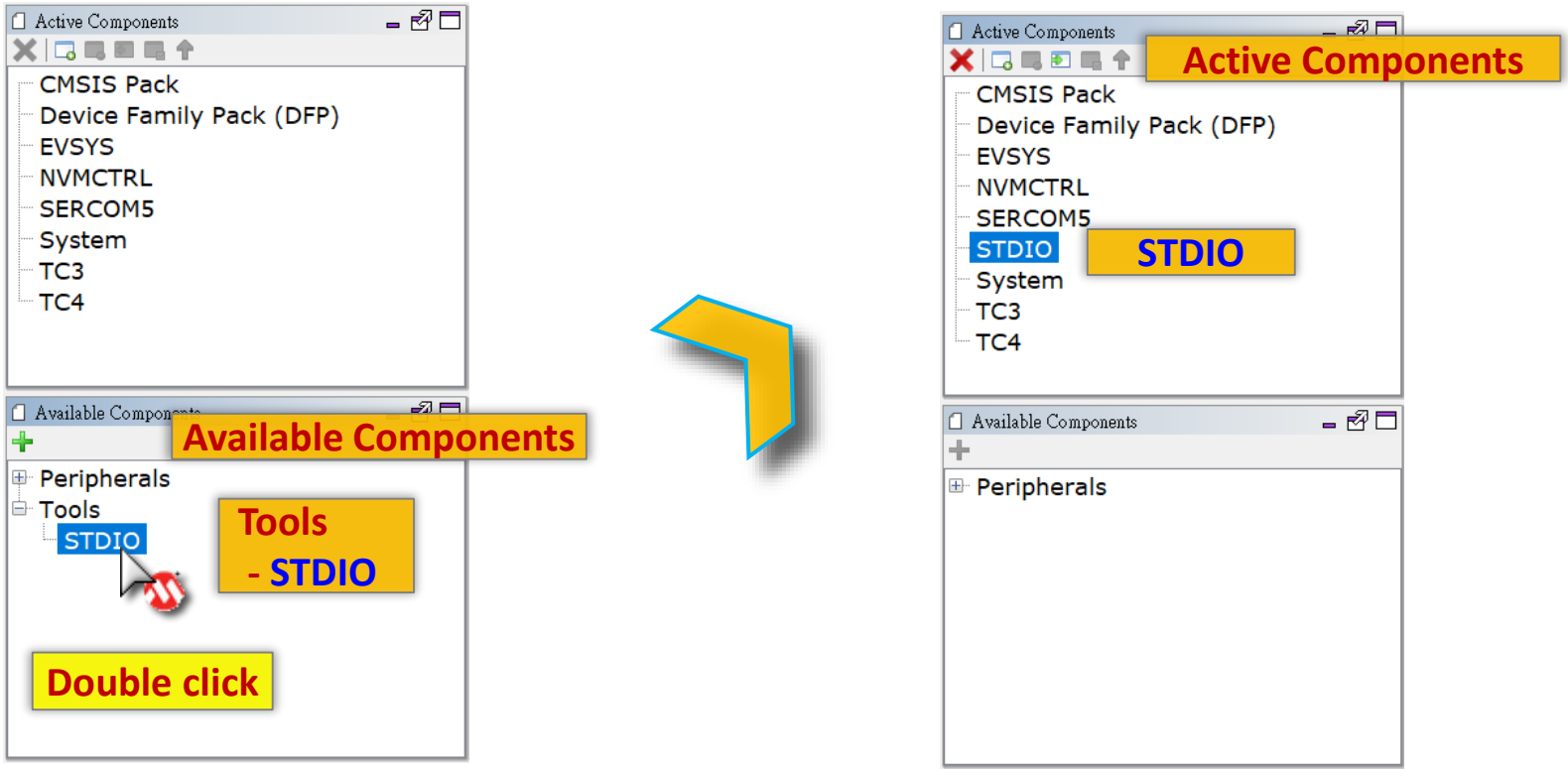
- Try add STDIO interface for SERCOM-USART
- After done this, you could use printf() function to instead of USART interface routines.

- Let's go!

Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Step 1

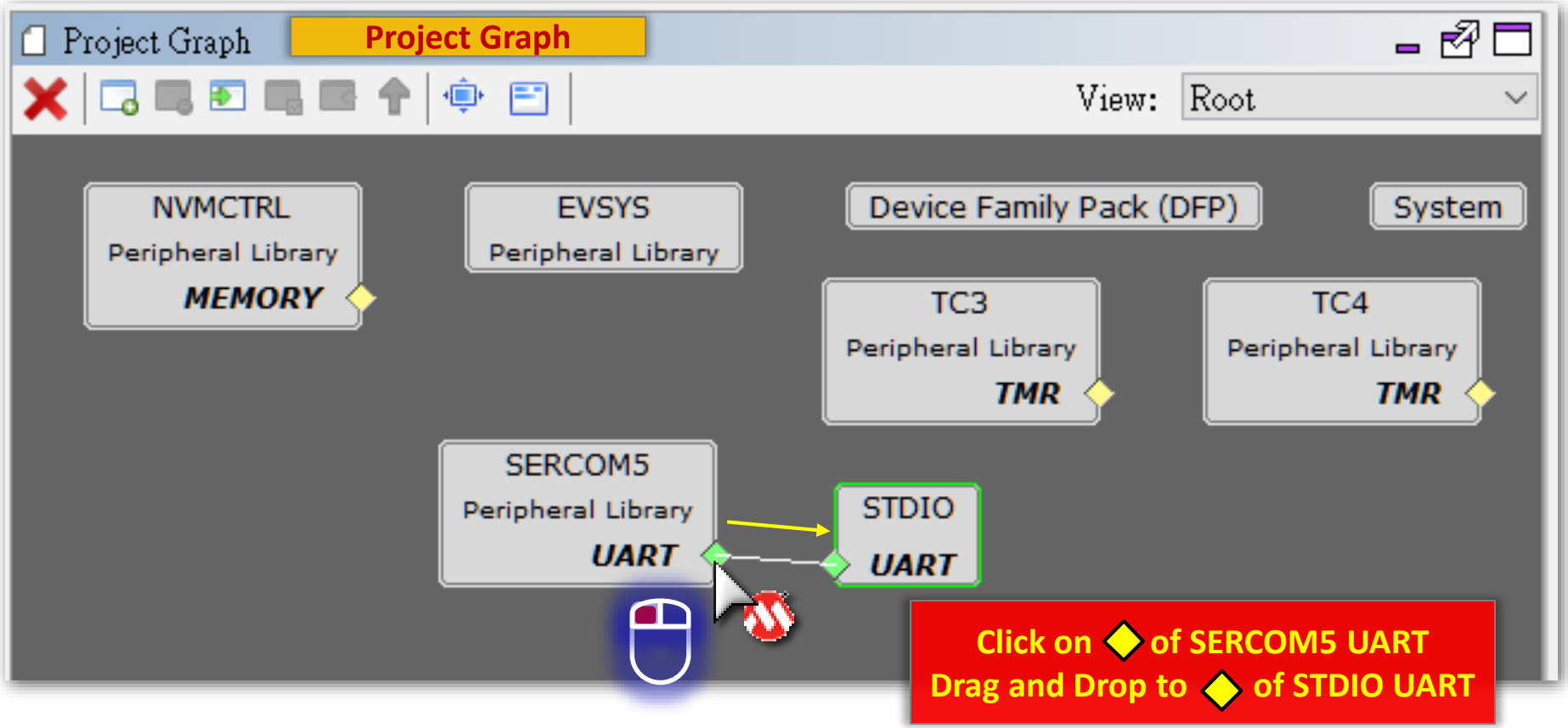
Add STDIO Function using MHC

- Find Tools ▸ STDIO component in Available Components window.
- Double click STDIO to add to Active Components window.



Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Step 2

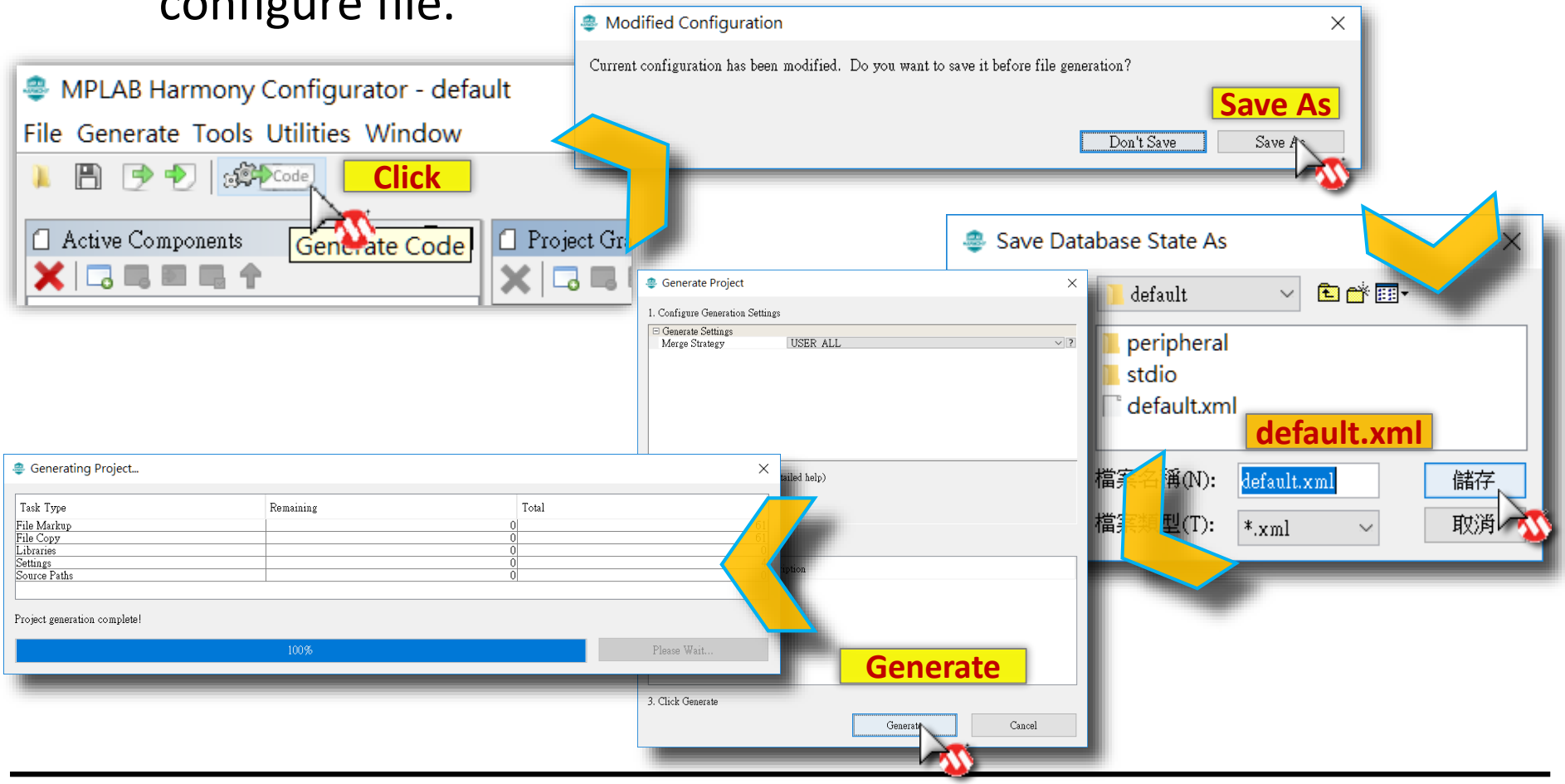
Project Graph Connection



Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Step 3

- Click 

to Generate Code and save changes to MHC configure file.



Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Step 4

a **Add software flag control of TC3 and TC4.**

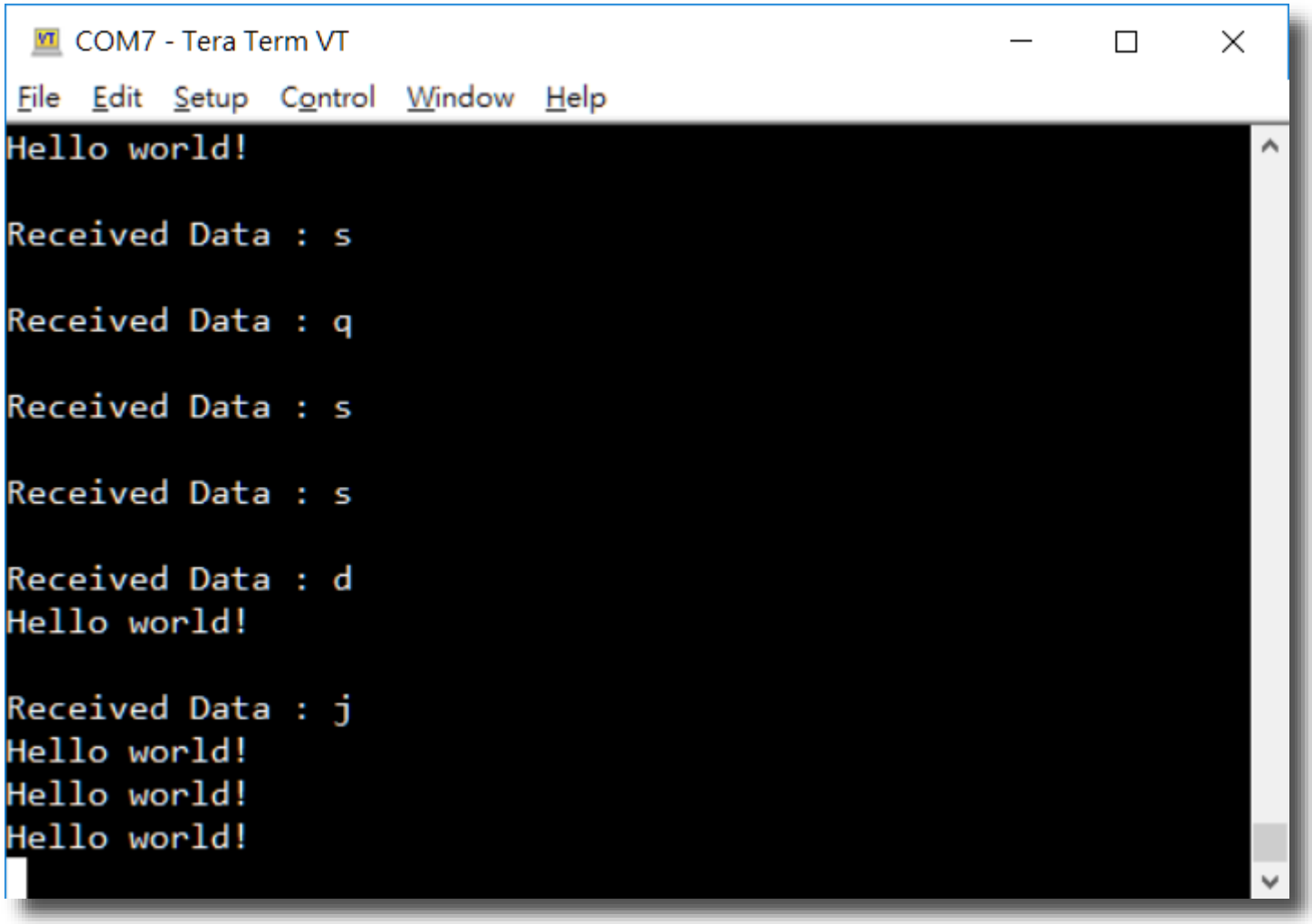
```
// TODO 11.01
volatile uint8_t TC3_IsOverflow = 0;
volatile uint8_t TC4_IsOverflow = 0;
…
void TC3_Overflow(TC_COMPARE_STATUS status, uintptr_t context) /* CallBack */
{
   if( status & TC_INTFLAG_OVF_Msk )
   {
      // TODO 11.02
      TC3_IsOverflow = 1;
   }
}

void TC4_Overflow(TC_COMPARE_STATUS status, uintptr_t context) /* CallBack */
{
   if( status & TC_INTFLAG_OVF_Msk )
   {
      // TODO 11.03
      TC4_IsOverflow = 1;
   }
}
```

Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Step 5

a. **Add code segment to your main while loop.**

```
while(1)
{
  // TODO 11.04
  if (TC3_IsOverflow)
  {
    TC3_IsOverflow = 0;
    LED1_Toggle();
    printf( "Hello World!!\r\n" );
  }

  if (TC4_IsOverflow)
  {
    TC4_IsOverflow = 0;
    LED2_Toggle();
  }

  if( USART5_IsReceived )
  {
     // TODO 11.05
    printf( "\r\nReceived Data : %1c\r\n", USART5_ReceiveData[0] );
    …
  }
```

Lab11 SERCOM - UART TxRx Interrupt Callback with STDIO Result



Bonus Lab

- Input “LED1” in TeraTerm will toggle LED1
- Input “LED2” in TeraTerm will toggle LED2
- Input “LED3” in TeraTerm will toggle LED3

- Let’s go!