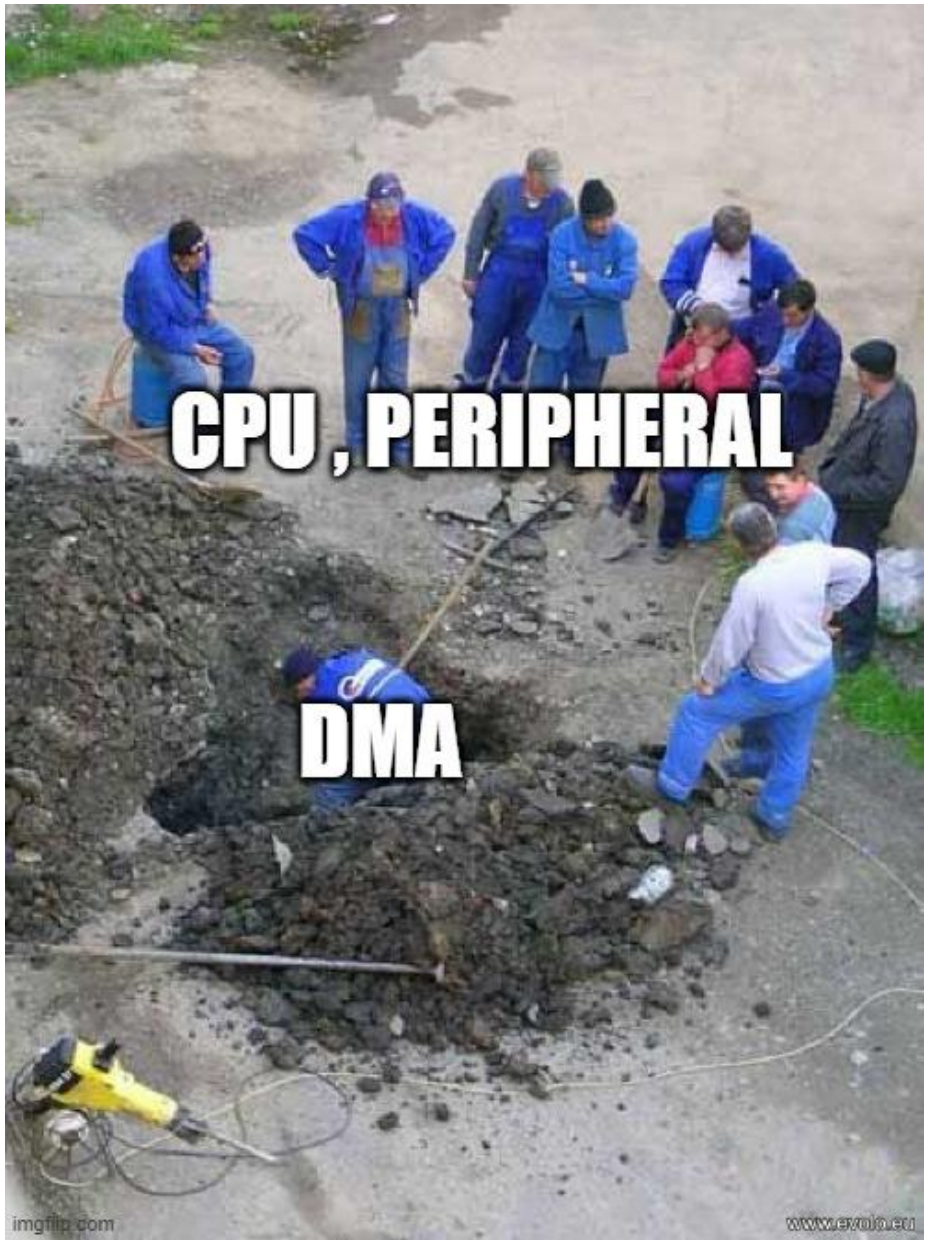
5.DMA (Direct Memory Access)

DR.SOMSIN THONGKRAIRAT


CPU , PERIPHERAL
DMA
imgflip.com
www.evolo.eu

DMA (Direct Memory Access)

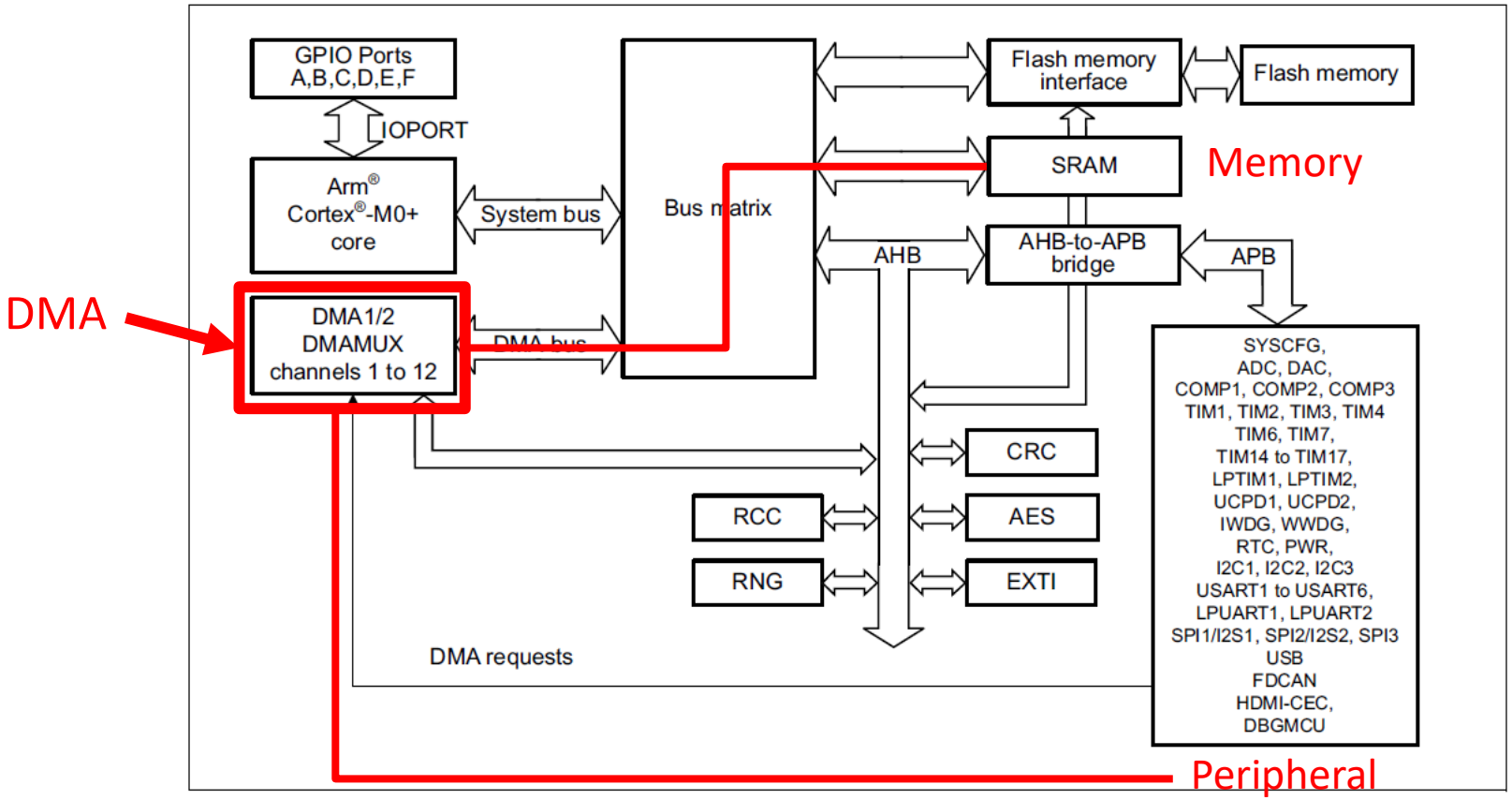
Transfer data directly without CPU

Transfer From Memory to Memory

Transfer From Peripheral to Memory

Transfer From Memory to Peripheral

DMA architecture



Purpose (จุดประสงค์)

การ copy ข้อมูลเป็นงานที่ไม่ซับซ้อน แต่ในระบบปกติเป็นการทำงานที่ขาดไม่ได้

Q: อะไรคือการ Copy ข้อมูล

A: การใช้เครื่องหมาย =

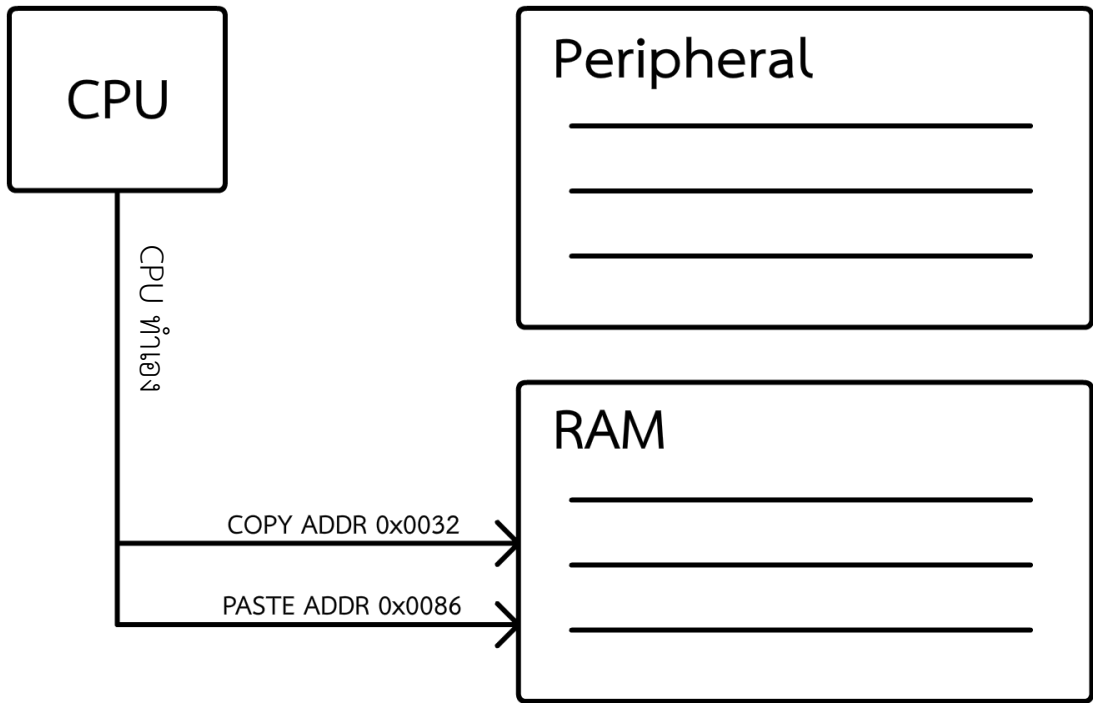
* มีโปรแกรมใหนไม่ใช้เครื่องหมาย = ในการทำงานได้บ้าง

Typical method (mem to mem)

ในกรณีปกติ CPU จะ Copy และ PASTE ข้อมูลทีละ Unit ในขณะที่ CPU กำลังทำงานดังกล่าวอยู่ CPU จะถือว่าอยู่ใน State Busy หรือกำลังทำงานอยู่ และไม่สามารถทำอย่างอื่นได้เลย เช่น

int a = 3,b = 5;

int c = a;

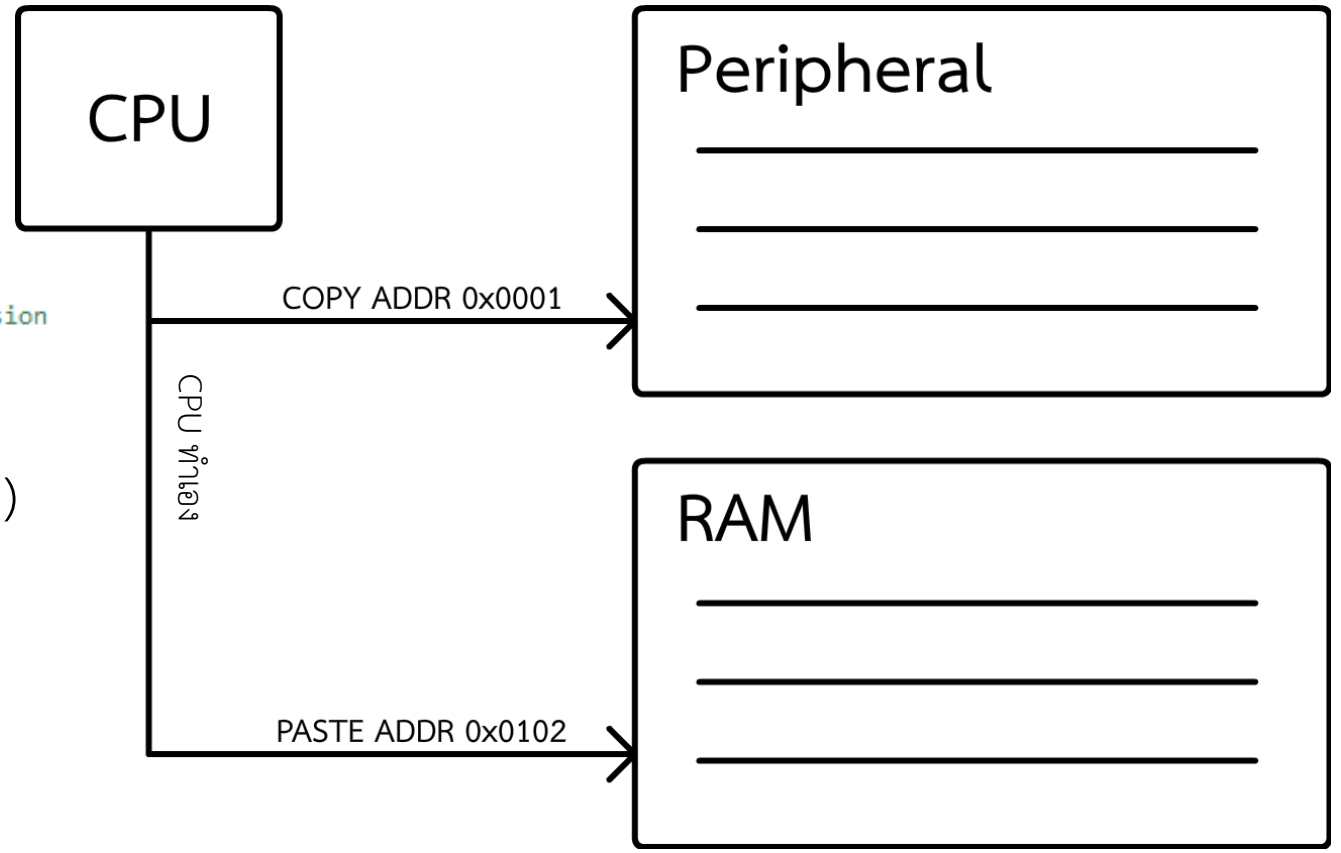


Peripheral to memory

เช่น ADC

```
HAL_ADC_Start(&hadc1); // start conversion
                       ; // wait until conversion
adc_value = HAL_ADC_GetValue(&hadc1);  / get ADC result value
                                        n
```

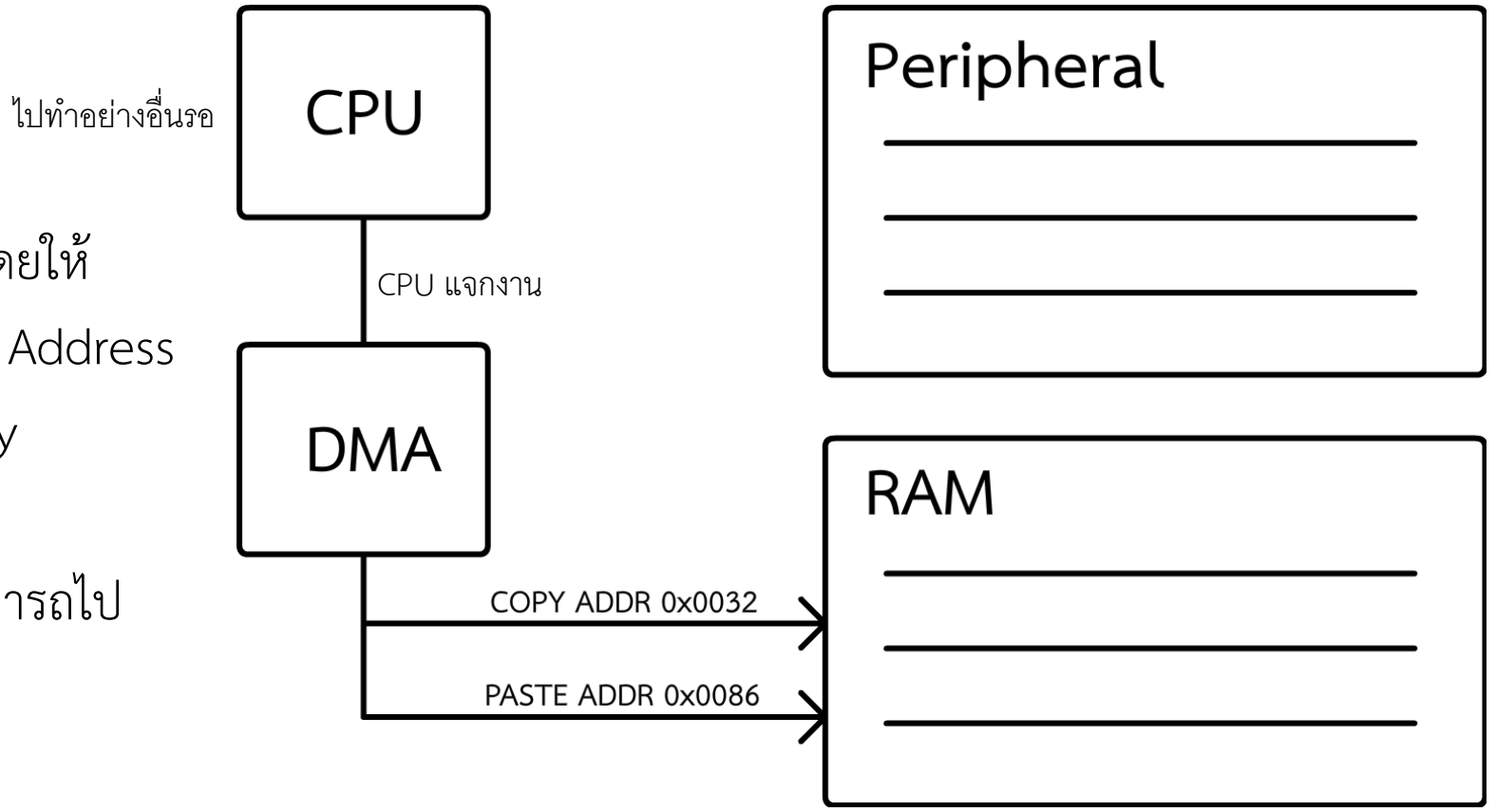
Copy ค่าที่อ่านมาจาก ADC ไปไว้ในตัวแปร(RAM)



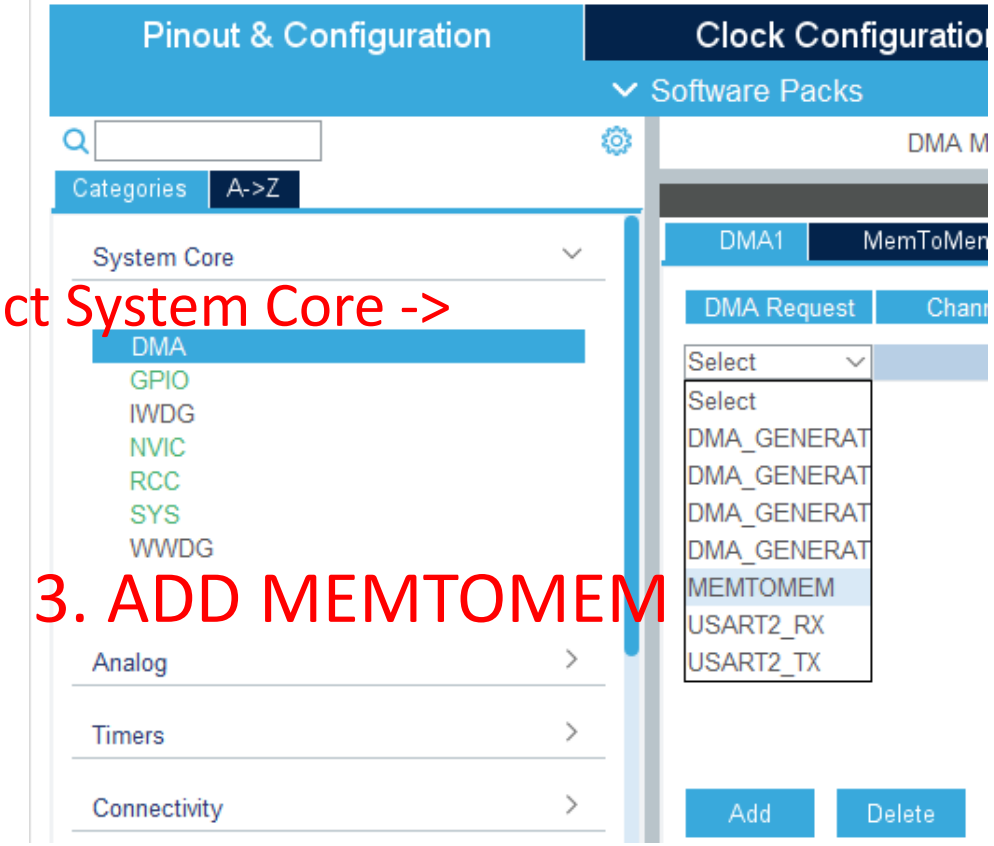
DMA Method

CPU แจกงานให้ DMA ทำแทน โดยให้ Source Address , Destination Address และ จำนวนข้อมูลที่ต้องการ copy

ในขณะที่ DMA ทำงาน CPU สามารถไปทำงานอย่างอื่นได้



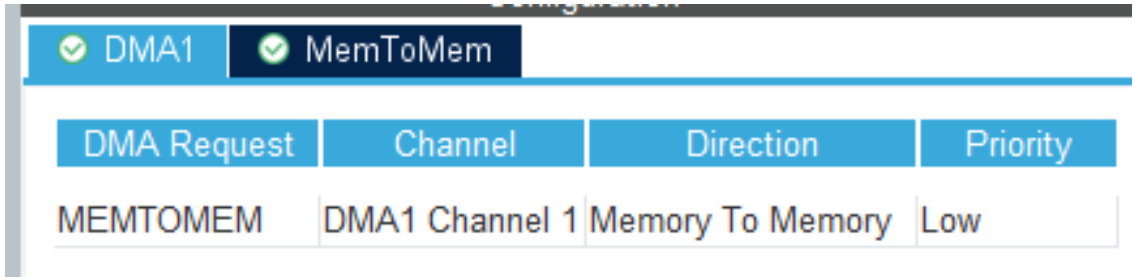
LAB 1 copy array



1. select System Core -> DMA

3. ADD MEMTOMEM

2. Click ADD



4. Check DMA

Coding

```
/* USER CODE BEGIN 2 */
HAL_UART_Transmit(&huart2, "haruhi DMA\r\n", 13, 1000);
/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{

    HAL_DMA_Start (&hdma_memtomem_dma1_channel1, string_source, string_destination, 22);
    while(HAL_DMA_PollForTransfer(&hdma_memtomem_dma1_channel1, HAL_DMA_FULL_TRANSFER, 100) != HAL_OK)
    {
      __NOP();
    }

    string_buffer_size = sprintf(string_buffer,"src = %sdest = %s\r\n",string_source,string_destination);
    HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
    HAL_Delay(2000);
  /* USER CODE END WHILE */

  /* USER CODE BEGIN 3 */
}
/* USER CODE END 3 */
```

```
/* USER CODE BEGIN 1 */
uint8_t string_source[128] = "Somsin Thongkrairat\r\n";
uint8_t string_destination[128] = "Thanavit Anuwongpinit\r\n ";


unsigned char string_buffer[256];
int string_buffer_size = -1;
/* USER CODE END 1 */



/* USER CODE BEGIN 2 */
HAL_UART_Transmit(&huart2, "haruhi DMA\r\n", 13, 1000);
/* USER CODE END 2 */


/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{


HAL_DMA_Start (&hdma_memtomem_dma1_channel1, string_source, string_destination, 22);
while(HAL_DMA_PollForTransfer(&hdma_memtomem_dma1_channel1, HAL_DMA_FULL_TRANSFER, 100) !=
HAL_OK)
{
__NOP();
}


string_buffer_size = sprintf(string_buffer,"src = %sdest =
%s\r\n",string_source,string_destination);
HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
HAL_Delay(2000);
/* USER CODE END WHILE */
```

Coding

```
/* USER CODE BEGIN 2 */
HAL_UART_Transmit(&huart2, "haruhi DMA\r\n", 13, 1000);
/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{

    HAL_DMA_Start (&hdma_memtomem_dma1_channel1, string_source, string_destination, 22);
    while(HAL_DMA_PollForTransfer(&hdma_memtomem_dma1_channel1, HAL_DMA_FULL_TRANSFER, 100) != HAL_OK)
    {
      __NOP();
    }

    string_buffer_size = sprintf(string_buffer,"src = %sdest = %s\r\n",string_source,string_destination);
    HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
    HAL_Delay(2000);
  /* USER CODE END WHILE */

  /* USER CODE BEGIN 3 */
}
/* USER CODE END 3 */
```

Assign Work to DMA

Wait until copy completed

Print Output

Coding

```
HAL_DMA_Start (&hdma_memtomem_dma1_channel1, string_source, string_destination, 22);
while(HAL_DMA_PollForTransfer(&hdma_memtomem_dma1_channel1, HAL_DMA_FULL_TRANSFER, 100) != HAL_OK)
{
  __NOP();
}

string_buffer_size = sprintf(string_buffer,"src = %sdest = %s\r\n",string_source,string_destination);
HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
HAL_Delay(2000);
* USER CODE END WHILE */
```

DMA Copy

```
src = Somsin Thongkrairat
dest = Somsin Thongkrairat
```

```
/*HAL_DMA_Start (&hdma_memtomem_dma1_channel1, string_source, string_destination, 22);
while(HAL_DMA_PollForTransfer(&hdma_memtomem_dma1_channel1, HAL_DMA_FULL_TRANSFER, 100) != HAL_OK)
{
  __NOP();
}*/

string_buffer_size = sprintf(string_buffer,"src = %sdest = %s\r\n",string_source,string_destination);
HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
HAL_Delay(2000);
/* USER CODE END WHILE */
```

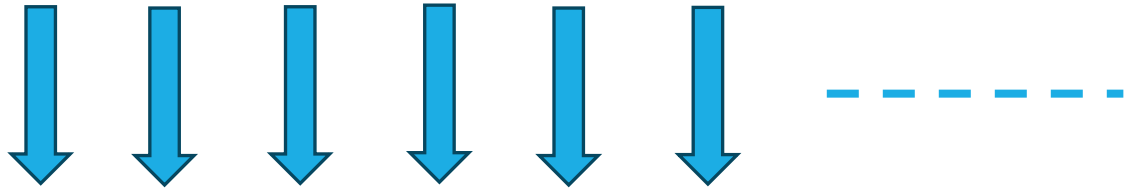
Comment!

DMA not Copy

```
src = Somsin Thongkrairat
dest = Thanavit Anuwongpinit
```

DMA Transferring data

string_ source



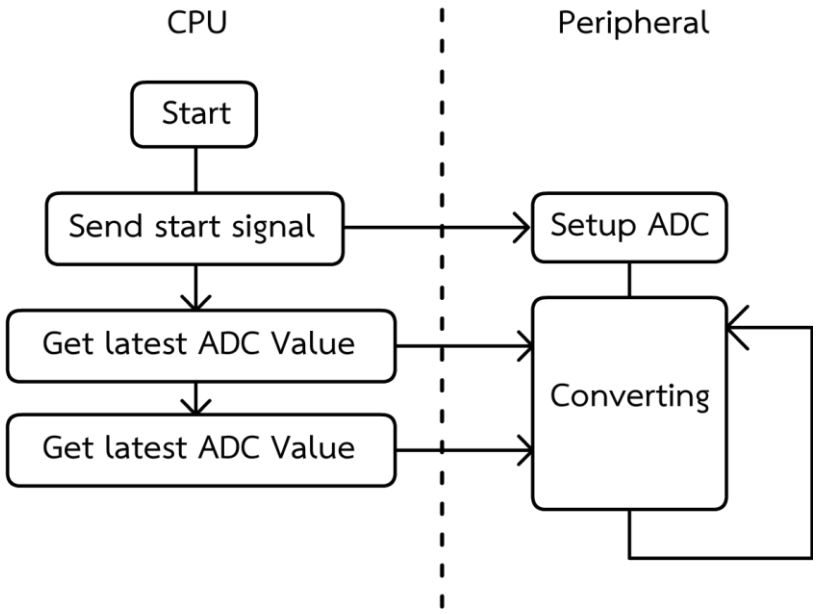
string_ destination


```
for(int i=0;i<22;i++){ // using CPU
   string_destination[i] = string_source[i];
}
```

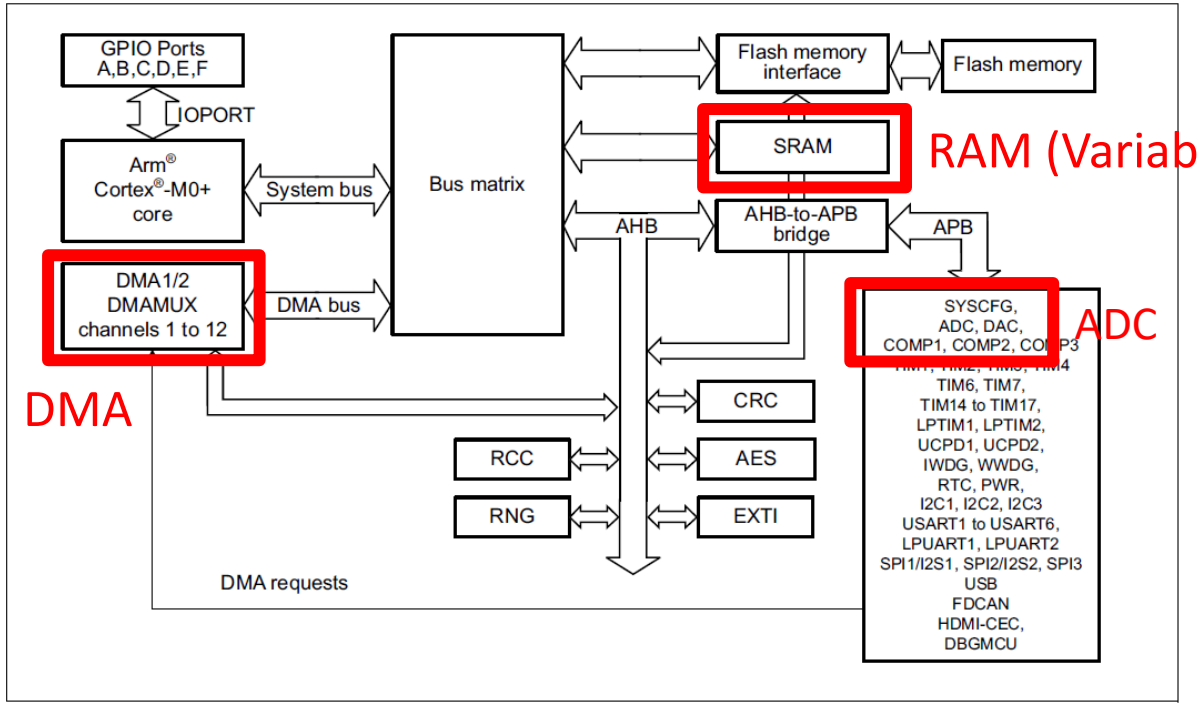
Same Result! But using CPU

Peripheral to memory (ADC to RAM)

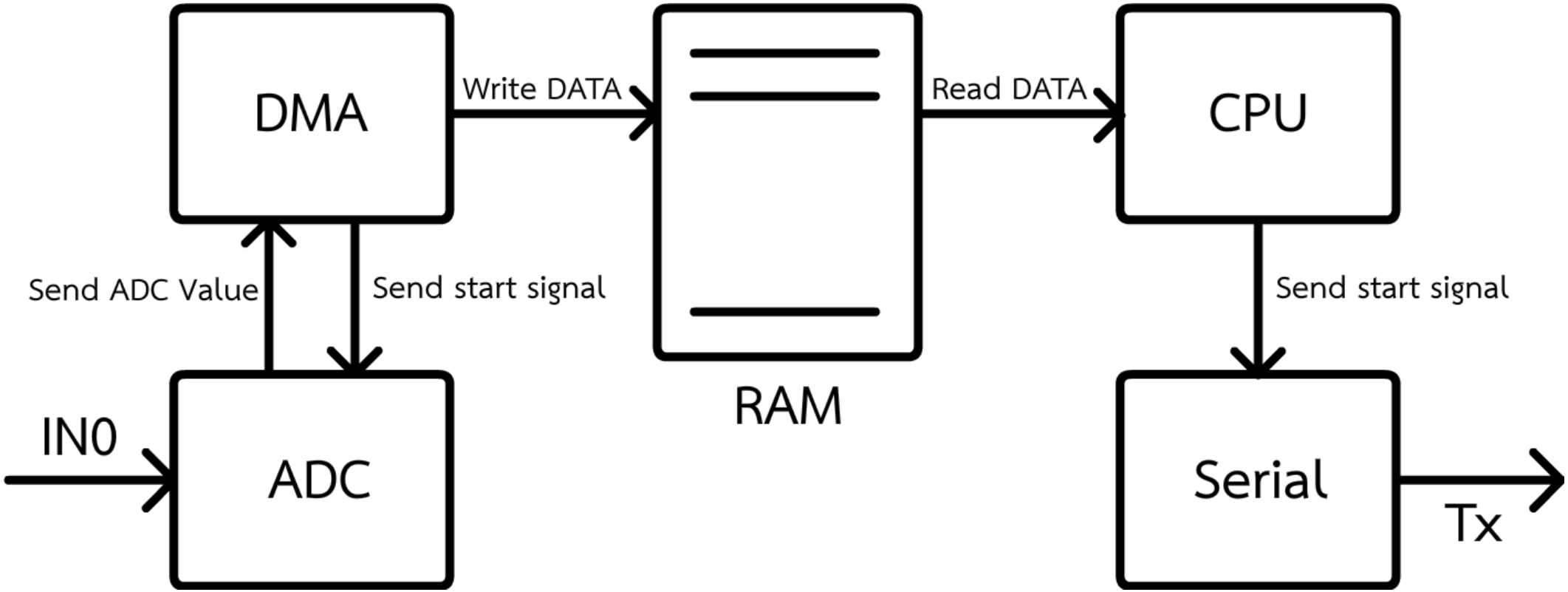
ยังจำ ADC กันได้ใช้ไหมครับ?



CPU Method



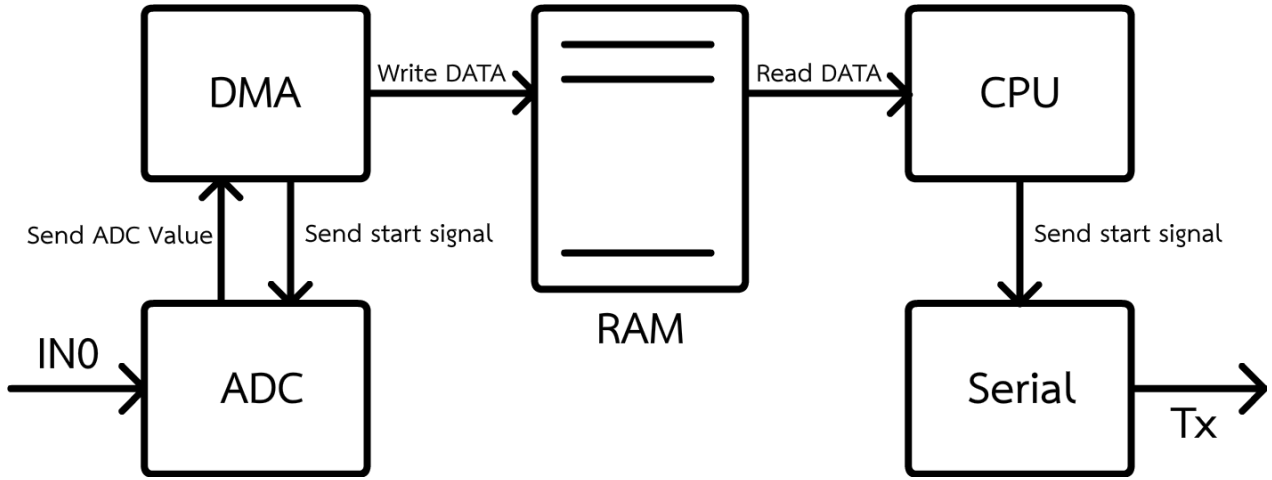
ADC using DMA

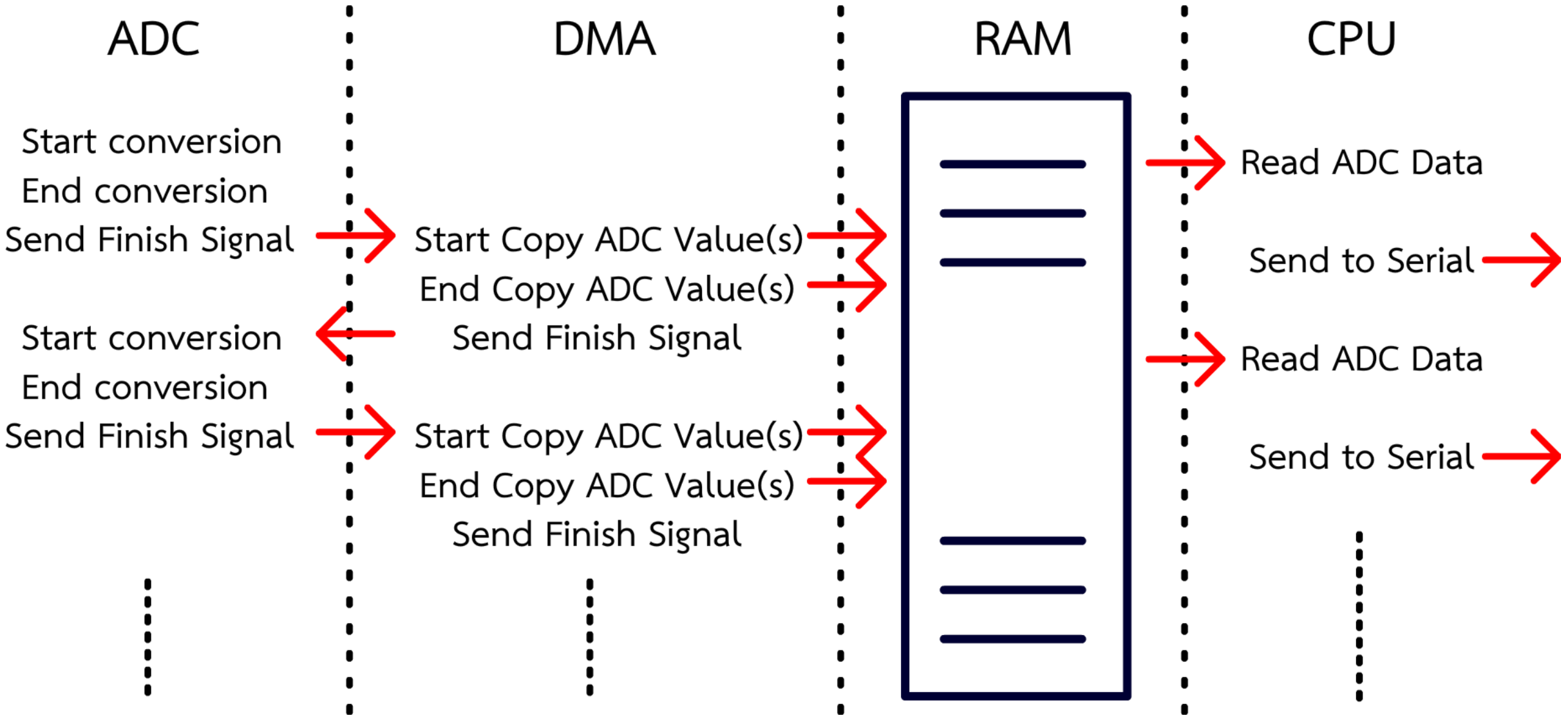


ADC using DMA

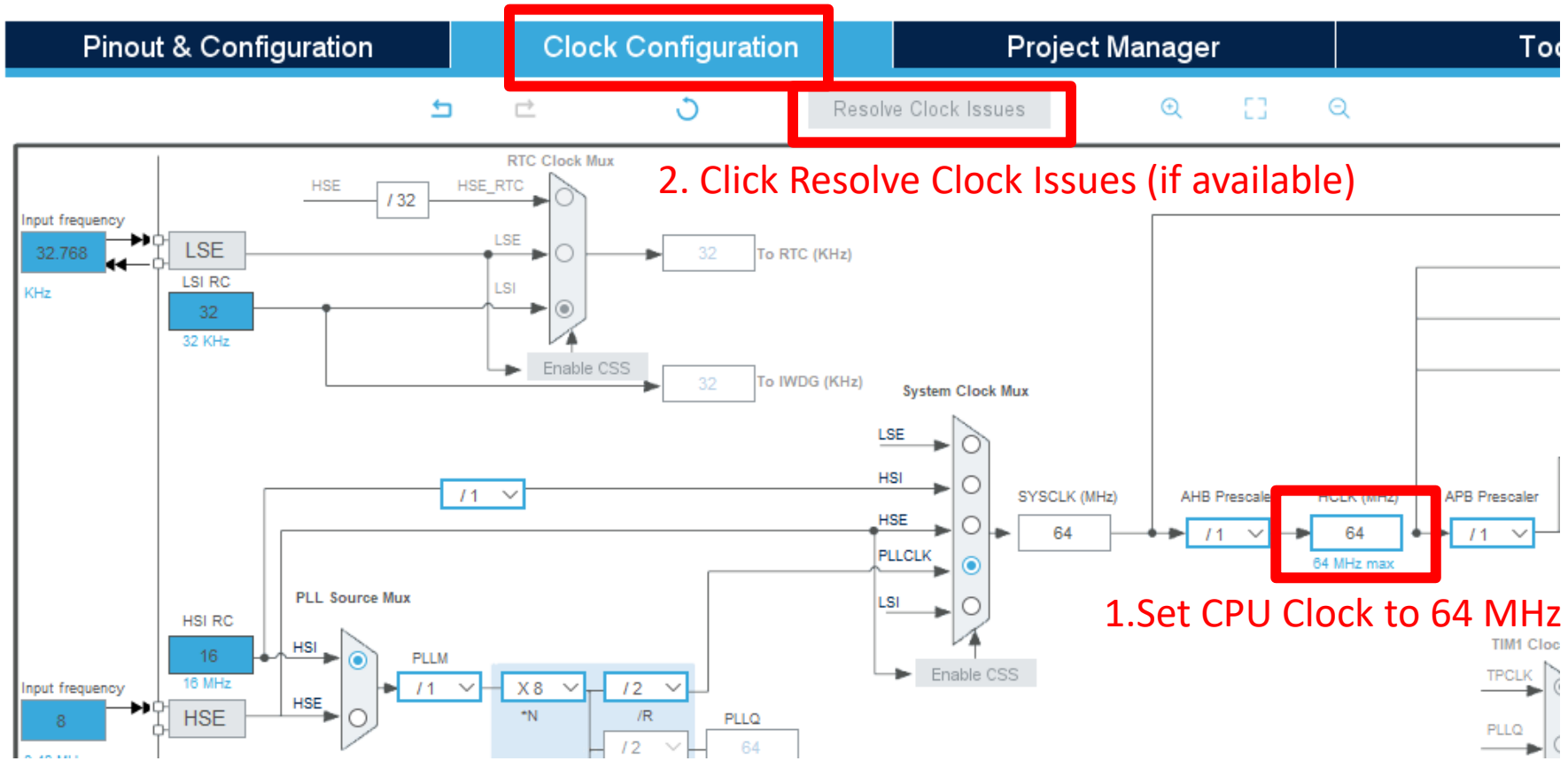
CPU ไม่ต้อง Polling ข้อมูลจาก DMA เหมือน Polling method และสามารถไปทำอย่างอื่นระหว่างที่ DMA และ ADC ทำงานได้

*จะสังเกตว่า CPU ไม่ได้ ติดต่อกับ ADC เลย มีเพียงขั้นตอน Setup (Set resolution , Set sequence การเชื่อมต่อ) เท่านั้น ที่ CPU ติดต่อกับ ADC

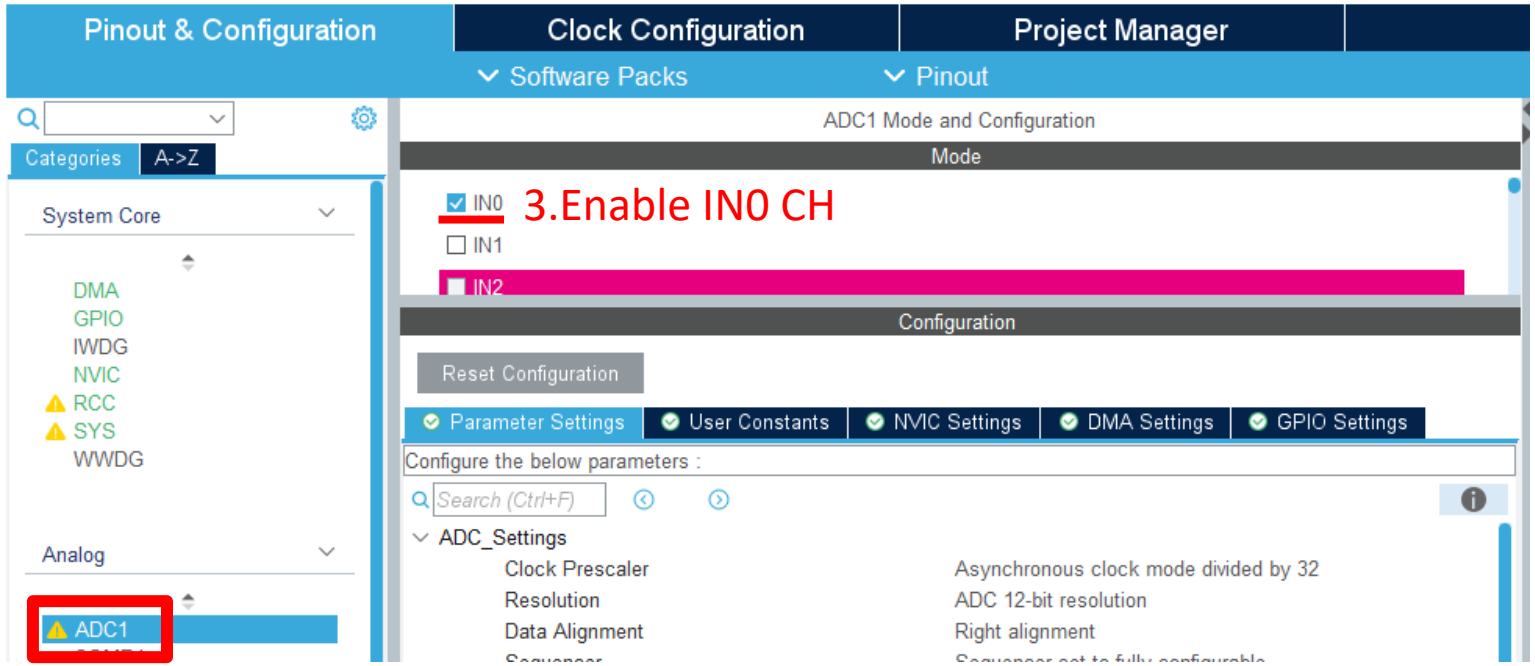



ADC
DMA
RAM
CPU
Start conversion
End conversion
Send Finish Signal
Start Copy ADC Value(s)
End Copy ADC Value(s)
Send Finish Signal
Read ADC Data
Send to Serial
Start conversion
End conversion
Send Finish Signal
Start Copy ADC Value(s)
End Copy ADC Value(s)
Send Finish Signal
Read ADC Data
Send to Serial

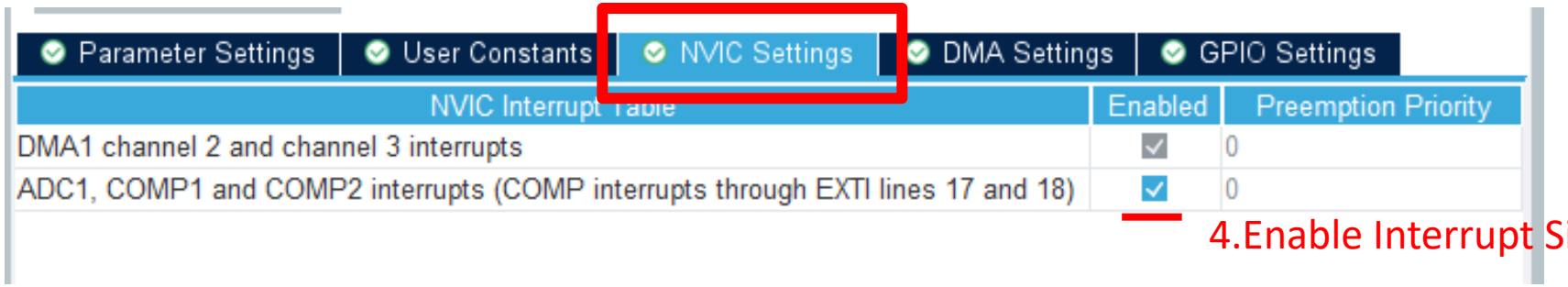
LAB 2 DMA ADC (ยากมากกกก)



LAB 2 DMA ADC (ยากมากกกก)

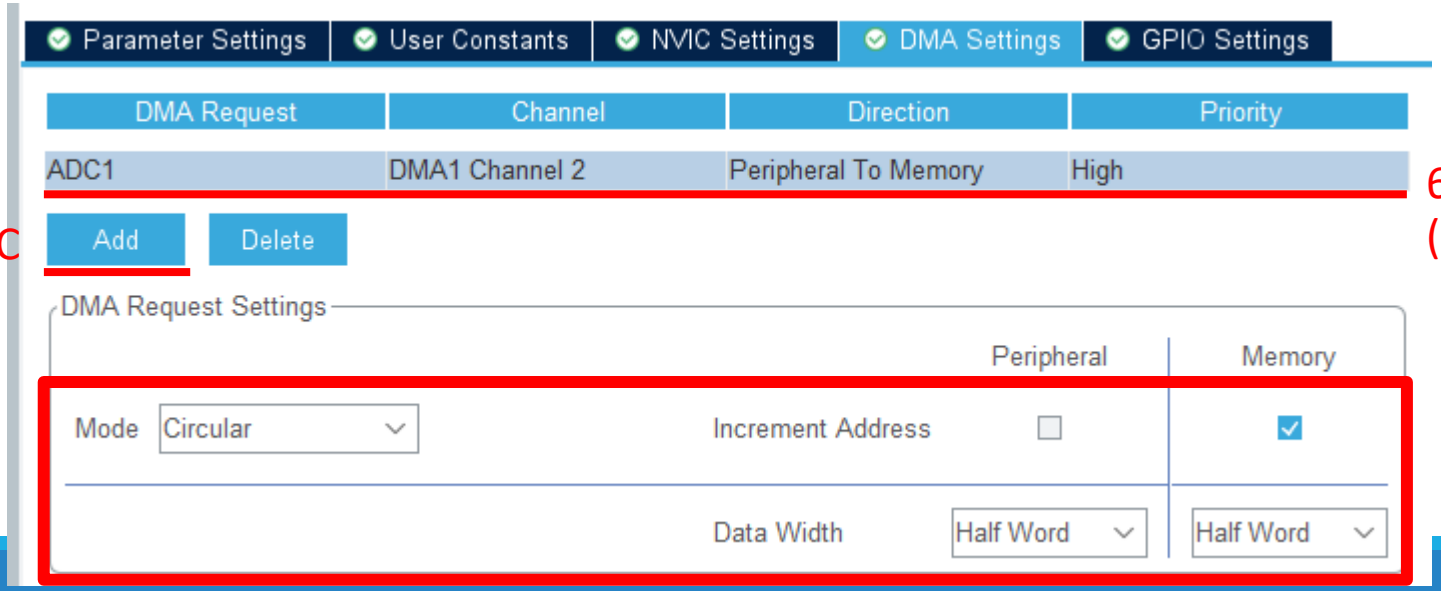


LAB 2 DMA ADC Setup



4.Enable Interrupt Signal

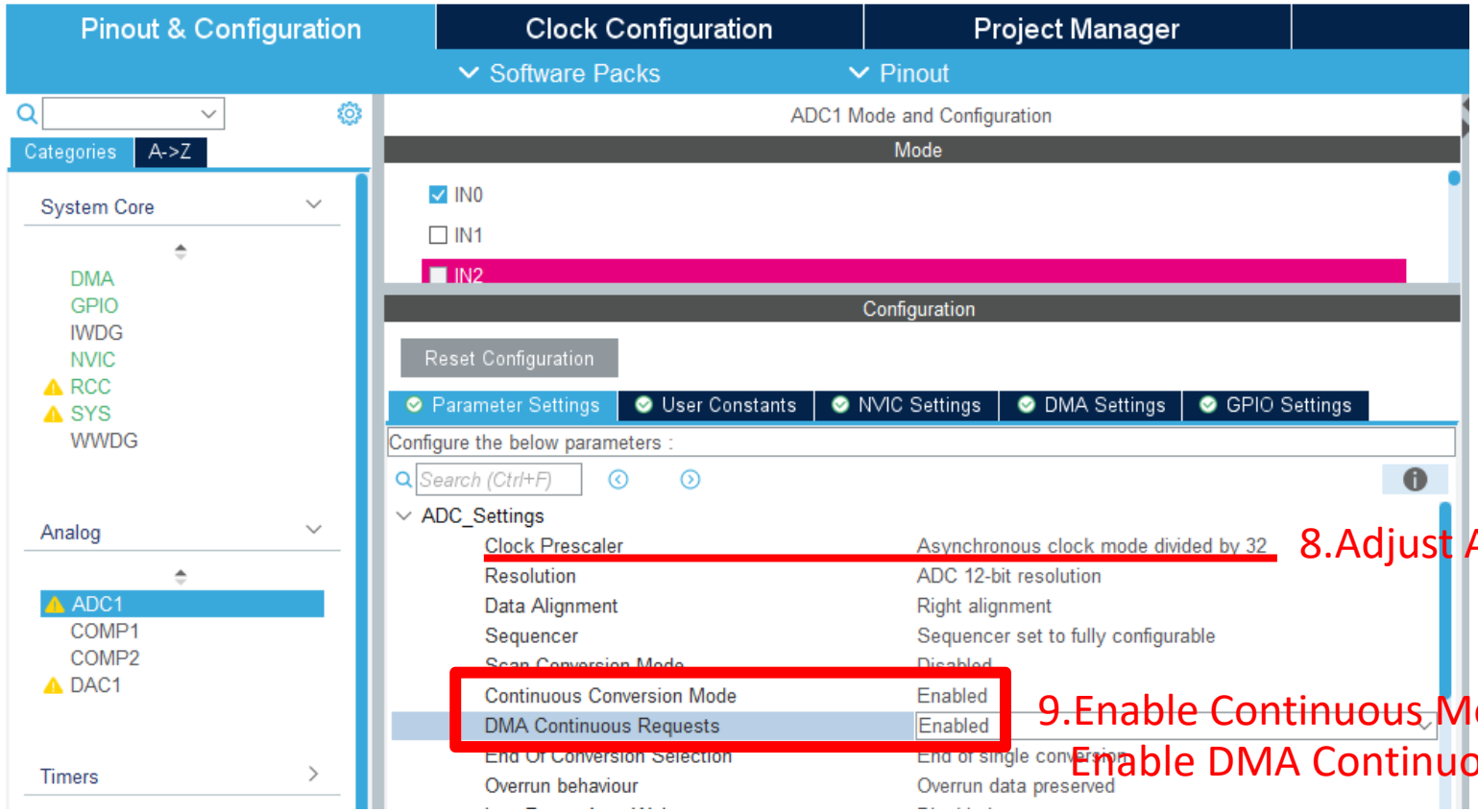
5.Add DMA to ADC



6.Config DMA Channel (can be any channel)

7.Config data transfer
- Circular mode
- Incremen Address
- Half word or word should fine

LAB 2 DMA ADC (ยากมากกกก)



8.Adjust ADC Clock Speed

9.Enable Continuous Mode &
Enable DMA Continuous Mode

Coding

```
 98  MX_ADC1_Init();
 99  /* USER CODE BEGIN 2 */
100  HAL_ADCEx_Calibration_Start(&hadc1); // Calibrate ADC
101
102  unsigned char string_buffer[256];
103  int string_buffer_size = -1;
104
105  volatile unsigned int ADC_value = 0;
106
107  HAL_ADC_Start_DMA(&hadc1, &ADC_value, 1);
108  /* USER CODE END 2 */
109
110  /* Infinite loop */
111  /* USER CODE BEGIN WHILE */
112  while (1)
113  {
114      string_buffer_size = sprintf(string_buffer,"ADC = %d\r\n",ADC_value);
115      HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
116      HAL_Delay(1000);
117    /* USER CODE END WHILE */
```

Setup ADC in DMA Mode

```
/* USER CODE BEGIN 2 */
HAL_ADCEx_Calibration_Start(&hadc1); // Calibrate ADC
unsigned char string_buffer[256];
int string_buffer_size = -1;
volatile unsigned int ADC_value = 0;


HAL_ADC_Start_DMA(&hadc1, &ADC_value, 1);
/* USER CODE END 2 */


/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
string_buffer_size = sprintf(string_buffer,"ADC = %d\r\n",ADC_value);
HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
HAL_Delay(1000);
/* USER CODE END WHILE */
```

Coding

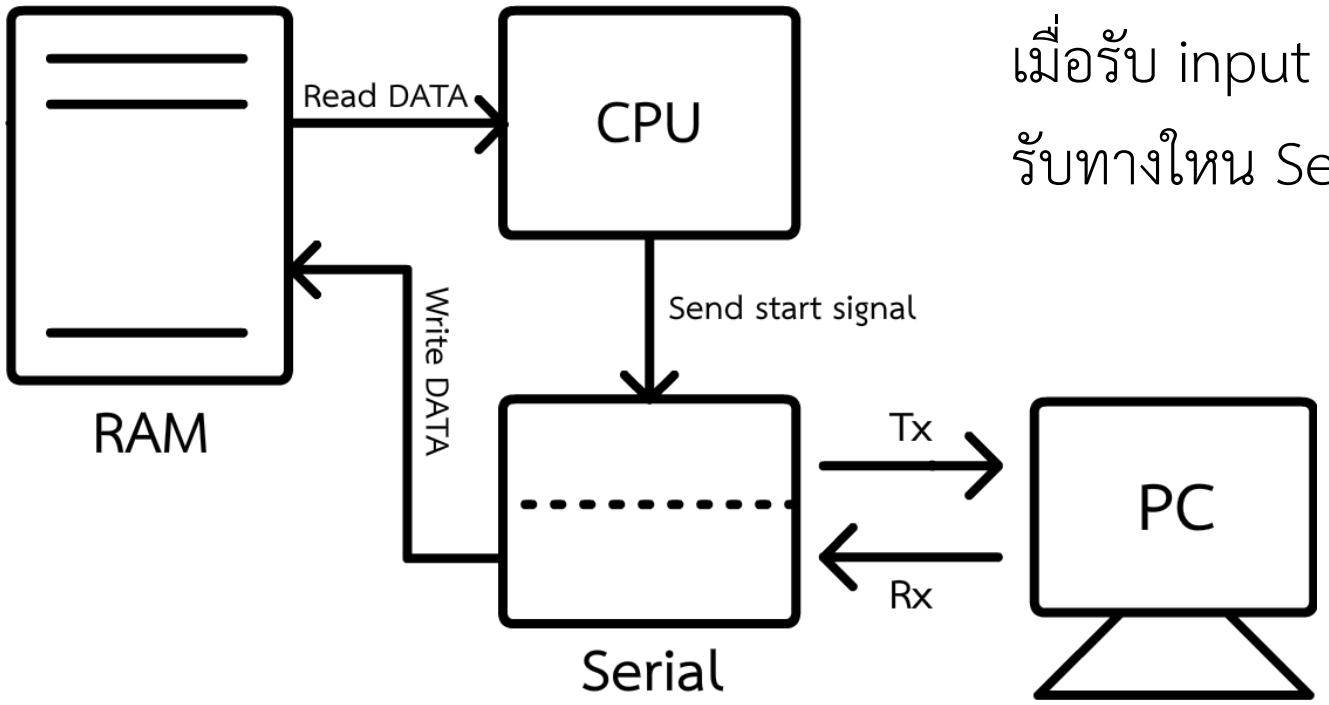
จะสังเกตว่า CPU ทำเพียงแค่การอ่านค่าและนำเข้า function sprint การเปลี่ยนแปลงค่าของตัวแปร *ADC_value* ถูกเปลี่ยนจากที่อื่น ไม่ใช่ด้วย CPU และ main function

DMA Keep change *ADC_value* Value

```
 98  MX_ADC1_Init();
 99  /* USER CODE BEGIN 2 */
100  HAL_ADCEx_Calibration_Start(&hadc1); // Calibrate ADC
101
102  unsigned char string_buffer[256];
103  int string_buffer_size = -1;
104
105  volatile unsigned int ADC_value = 0;
106
107  HAL_ADC_Start_DMA(&hadc1, &ADC_value, 1);
108  /* USER CODE END 2 */
109
110  /* Infinite loop */
111  /* USER CODE BEGIN WHILE */
112  while (1)
113  {
114      string_buffer_size = sprintf(string_buffer,"ADC = %d\r\n",ADC_value);
115      HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
116      HAL_Delay(1000);
117    /* USER CODE END WHILE */
```

```
ADC = 1246
ADC = 1232
ADC = 1238
ADC = 1220
ADC = 1244
ADC = 1222
ADC = 1238
ADC = 1246
ADC = 1240
ADC = 1233
ADC = 1216
ADC = 1247
ADC = 1233
ADC = 1232
ADC = 1234
ADC = 1254
ADC = 1235
ADC = 1211
```

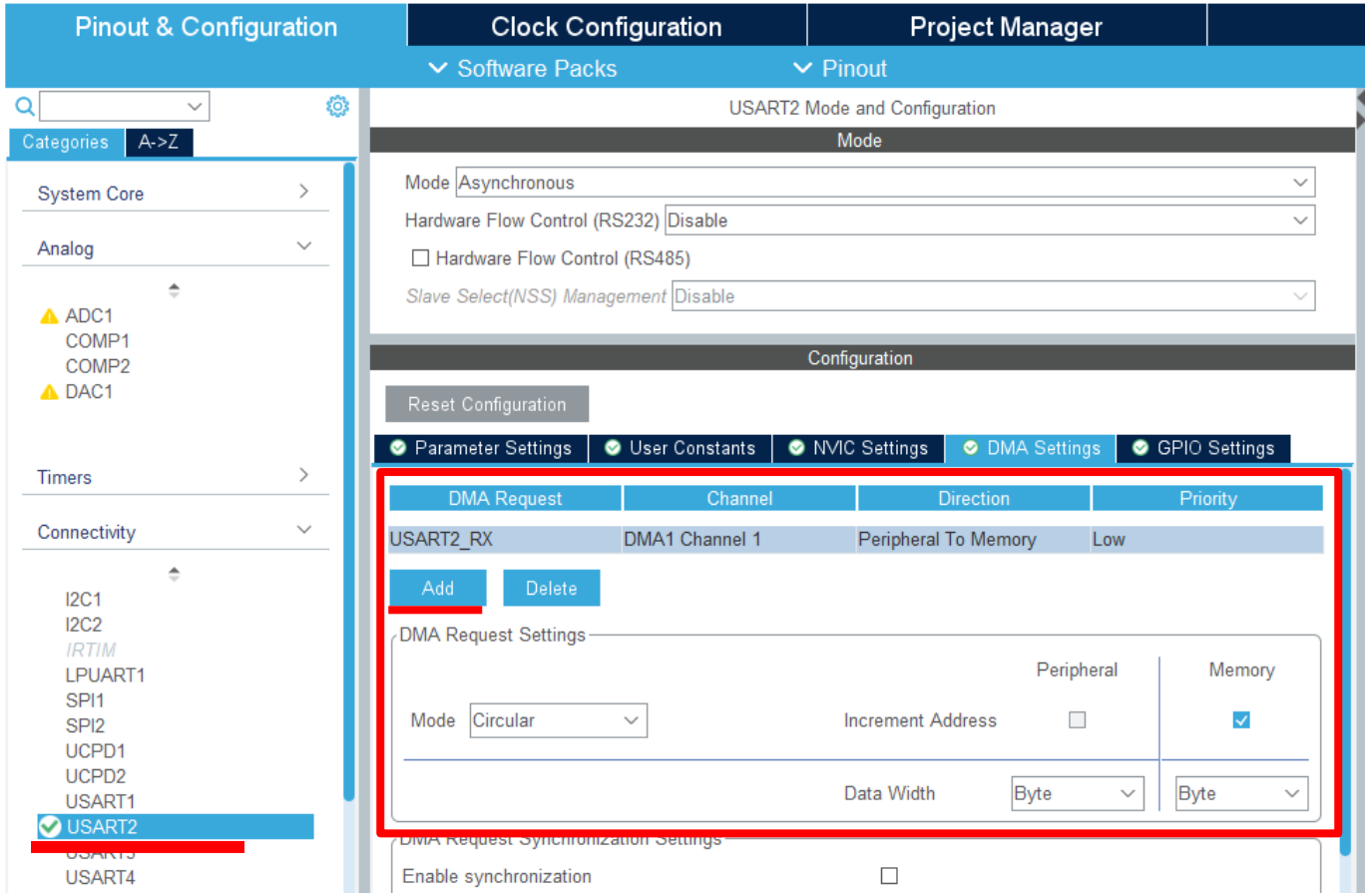
Serial DMA



เมื่อรับ input จาก PC ให้เขียนข้อมูลลงในตัวแปร

รับทางใหน Serial ผ่านทาง Keyboard

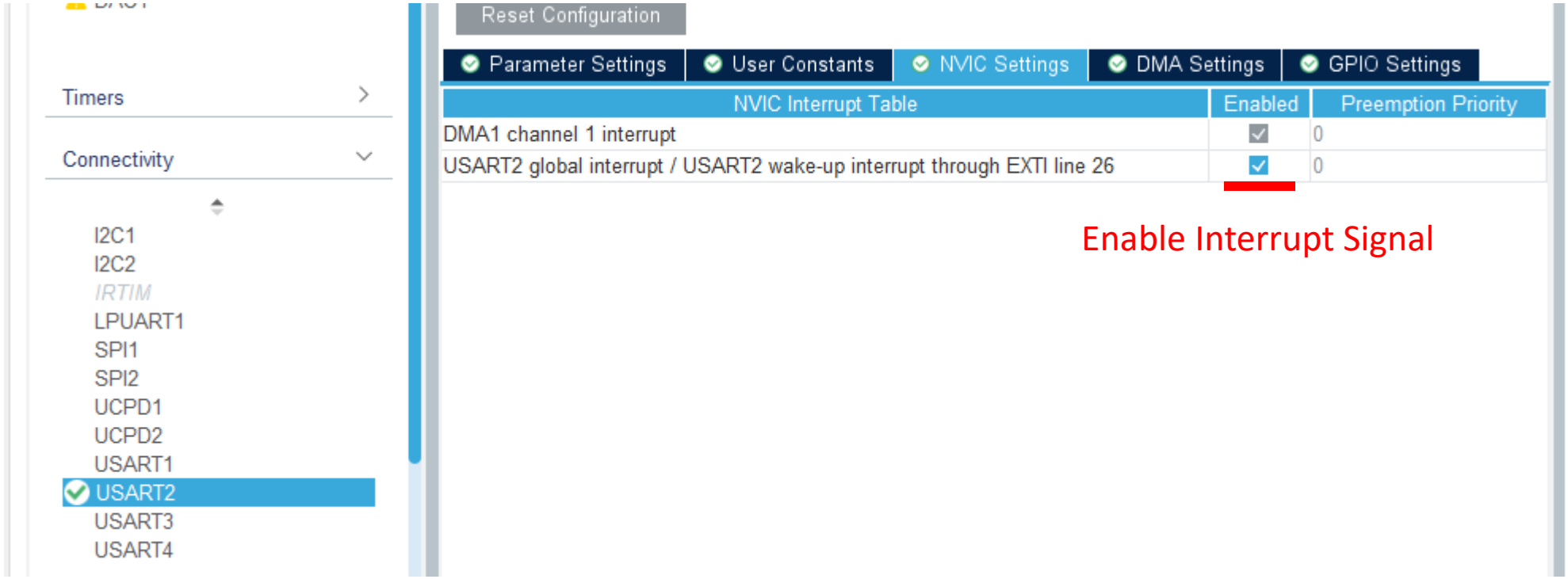
LAB3 DMA Serial



Add ADC

- USART2_RX (ตัวรับ , Receiver)
- Circular Mode
- Byte data (ASCII code)

LAB3 DMA Serial



Coding

```
94  MX_USART2_UART_Init();
95  /* USER CODE BEGIN 2 */
96  unsigned char string_buffer[256];
97  int string_buffer_size = -1;
98  volatile unsigned char Rx_value = 'H';
99
100 HAL_UART_Receive_DMA(&huart2, &Rx_value, 1);
101 /* USER CODE END 2 */
102
103 /* Infinite loop */
104 /* USER CODE BEGIN WHILE */
105 while (1)
106 {
107   string_buffer_size = sprintf(string_buffer,"Rx = %c\r\n",Rx_value);
108   HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
109   HAL_Delay(1000);
110   /* USER CODE END WHILE */
```

```
/* USER CODE BEGIN 2 */
unsigned char string_buffer[256];
int string_buffer_size = -1;
volatile unsigned char Rx_value = 'H';


HAL_UART_Receive_DMA(&huart2, &Rx_value, 1);
/* USER CODE END 2 */


/* Infinite loop */
/* USER CODE BEGIN WHILE */
while (1)
{
string_buffer_size = sprintf(string_buffer,"Rx = %c\r\n",Rx_value);
HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
HAL_Delay(1000);
/* USER CODE END WHILE */
```

Coding

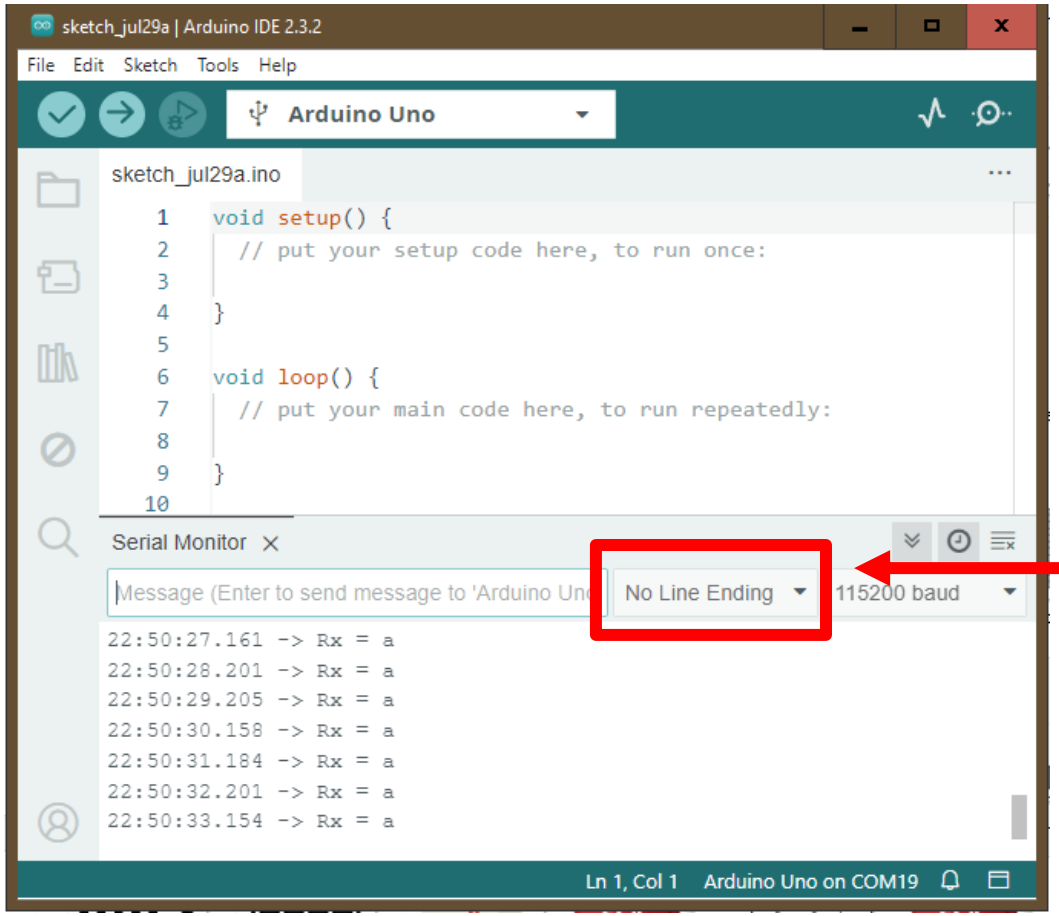
ลองพิมสักอย่างที่ console ลองดู

```
Rx = H
aRx = a
rRx = r
uRx = u
hRx = h
iRx = i
Rx = i
```

DMA Keep change *Rx_value* Value

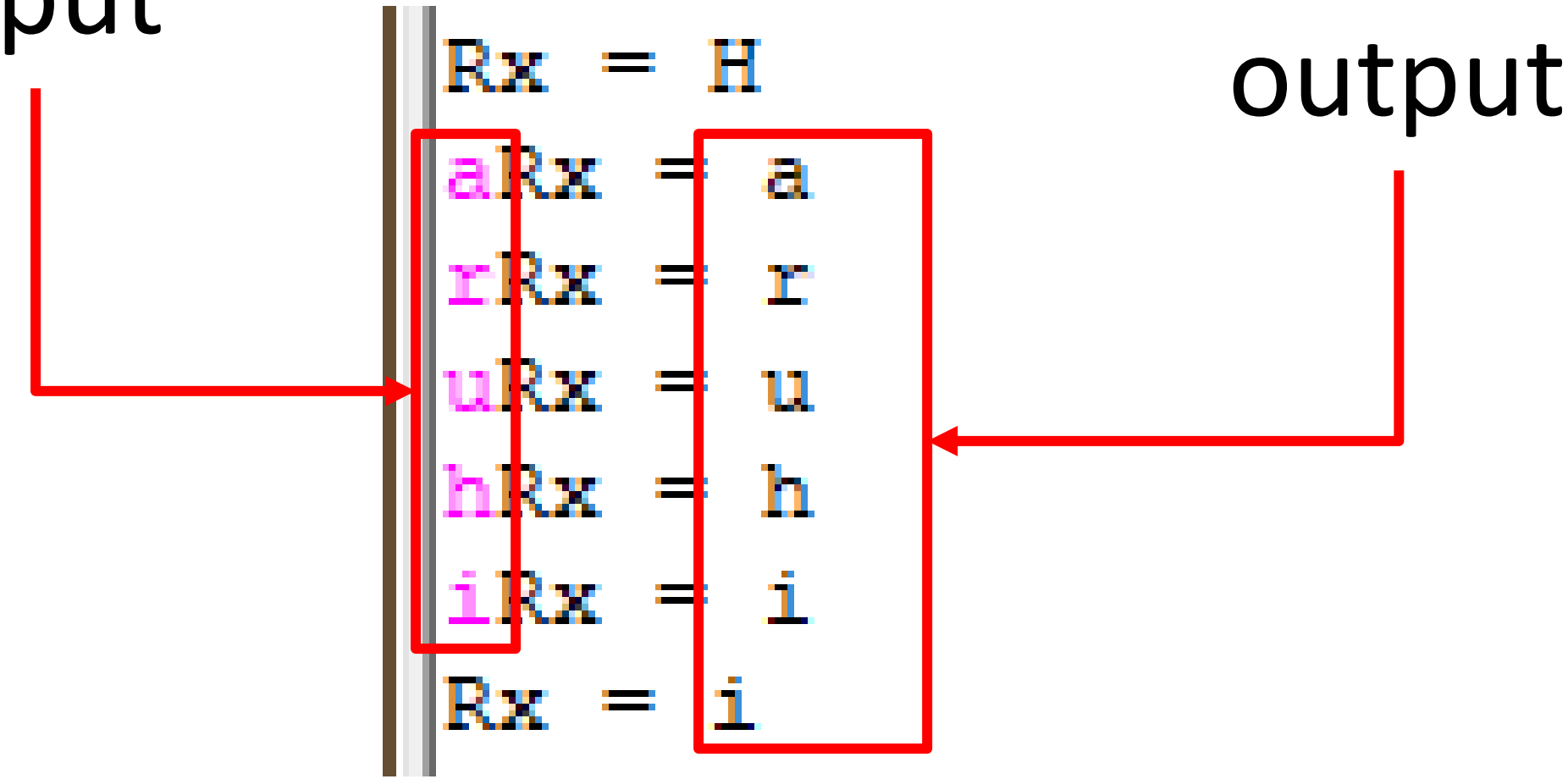
```
94  MX_USART2_UART_Init();
95  /* USER CODE BEGIN 2 */
96  unsigned char string_buffer[256];
97  int string_buffer_size = -1;
98  volatile unsigned char Rx_value = 'H';
99
100 HAL_UART_Receive_DMA(&huart2, &Rx_value, 1);
101 /* USER CODE END 2 */
102
103 /* Infinite loop */
104 /* USER CODE BEGIN WHILE */
105 while (1)
106 {
107   string_buffer_size = sprintf(string_buffer,"Rx = %c\r\n",Rx_value);
108   HAL_UART_Transmit(&huart2, string_buffer, string_buffer_size, 1000);
109   HAL_Delay(1000);
110   /* USER CODE END WHILE */
```

*สำหรับคนที่ใช้ Arduino

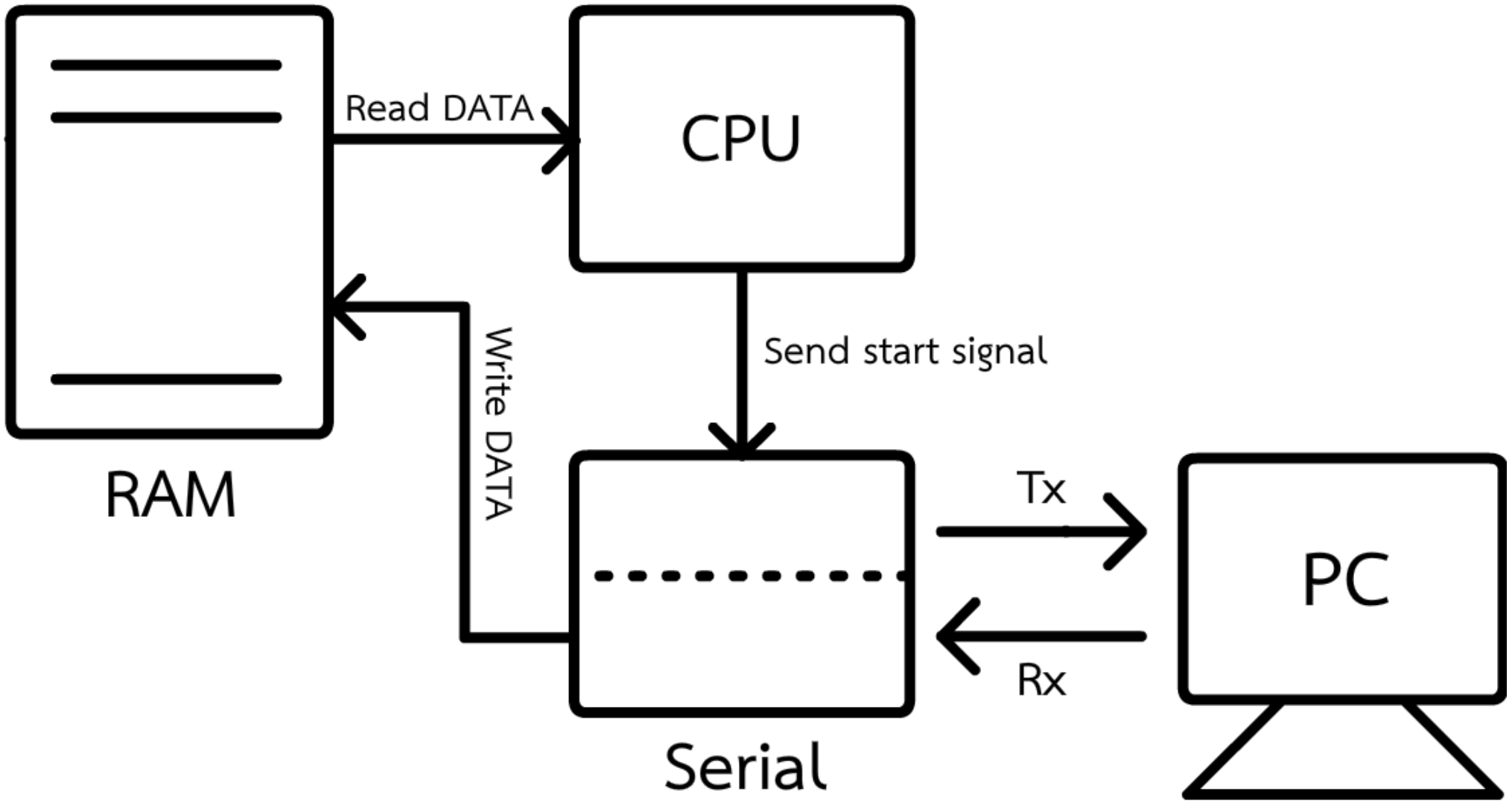


ให้เลือก ending word เป็น No Line Ending

input



output


Read DATA
CPU
Send start signal
Write DATA
RAM
Tx
PC
Rx
Serial

LAB ให้เลือก 2 อย่าง ทำแบบไหนก็ได้

1. ถ้ากด A-Z ที่ keyboard ให้ไฟ LD4 ติด แต่ถ้า กดเลข 1-9 ให้ LD4 ดับ
2. ถ้าจ่าย 0-2 V เข้าที่ขา A0 ให้ LD4 ติด แต่ถ้า จ่าย 2-3.3V ให้ LD4 ดับ

ทำอะไรก็ได้ เลือกมา 1 อย่าง

กันลืม (Reminder)

สั่งให้ไฟติด

```
HAL_GPIO_WritePin(LED_GREEN_GPIO_Port,LED_GREEN_Pin, 1);
```

สั่งให้ไฟดับ

```
HAL_GPIO_WritePin(LED_GREEN_GPIO_Port,LED_GREEN_Pin, 0);
```