

**M4G Group (1)**  
**Application Note**  
**12-bit Analog to Digital Converter**  
**(ADC-C)**

**Outlines**

This application note is a reference material for developing products using 12-bit analog to digital converter (ADC) function of M4G group (1).

This document helps the user check operation of the product and develop its program.

Target sample program: ADC\_UART\_M4G9

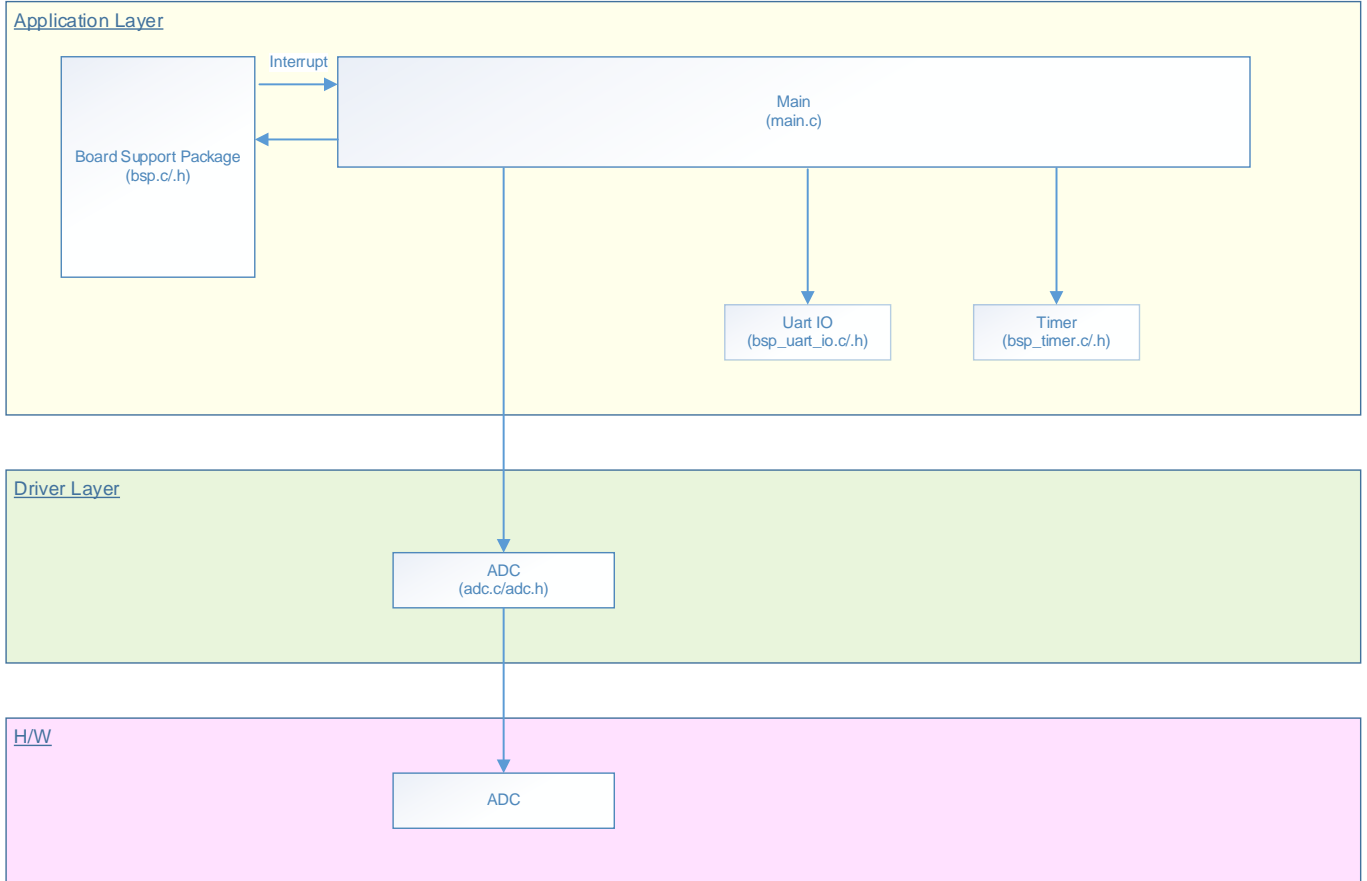
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# 1. Preface

The sample program measures the thermistor output voltage with ADC and displays it on the terminal software after temperature conversion by CPU. Additionally, it converts the analog input voltage with ADC and displays the digital values

Structure diagram of Sample program



### 2. Reference Document

- Datasheet  
TMPM4G Group (1) datasheet Rev1.0 (Japanese edition)
- Reference manual  
12-bit Analog to Digital Converter (ADC-C) Rev1.0 (Japanese edition)  
Asynchronous Serial Communication Circuit (UART-C) Rev3.0 (Japanese edition)  
Input/Output Ports (PORT-M4G(1)) Rev1.0 (Japanese edition)  
32-bit Timer Event Counter (T32A-B) Rev2.1 (Japanese edition)
- Application Note  
M4G Group (1) Application Note Startup (CMSIS System & Clock Configuration) Rev1.0
- Other reference document  
TMPM4G (1) Group Peripheral Driver User Manual (Doxygen)

### 3. Function to Use

| IP  | Channel    | Port                        | Function/Operation mode                         |
|---|------------|-----------------------------|---|
| Asynchronous Serial Communication Circuit | ch0        | PE2(UT0RXD)<br>PE3(UT0TXDA) | UART mode                                       |
| 12-bit Analog to Digital Converter        | ch1 (Note) | PP0(AINA08)                 | AD conversion (Continuous conversion operation) |
|   | ch0 (Note) | PR0(AINA16)                 |   |
| Input/Output ports                        | -          | PV1(Input)                  | Input   |
| 32-bit Timer Event Counter                | ch0        | -                           | Interval timer                                  |

(Note) The ADC channel is the channel defined in the sample program.

### 4. Target Device

The target devices of this application note are as follows;

|               |               |              |              |
|---------------|---------------|--------------|--------------|
| TMPM4G9F15FG  | TMPM4G9F10FG  | TMPM4G9FEFG  | TMPM4G9FDFG  |
| TMPM4G9F15XBG | TMPM4G9F10XBG | TMPM4G9FEXBG | TMPM4G9FDXBG |
| TMPM4G8F15FG  | TMPM4G8F10FG  | TMPM4G8FEFG  | TMPM4G8FDFG  |
| TMPM4G8F15XBG | TMPM4G8F10XBG | TMPM4G8FEXBG | TMPM4G8FDXBG |
|               | TMPM4G7F10FG  | TMPM4G7FEFG  | TMPM4G7FDFG  |
|               | TMPM4G6F10FG  | TMPM4G6FEFG  | TMPM4G6FDFG  |

\*This sample program operates on the evaluation board of TMPM4G9F15FG.

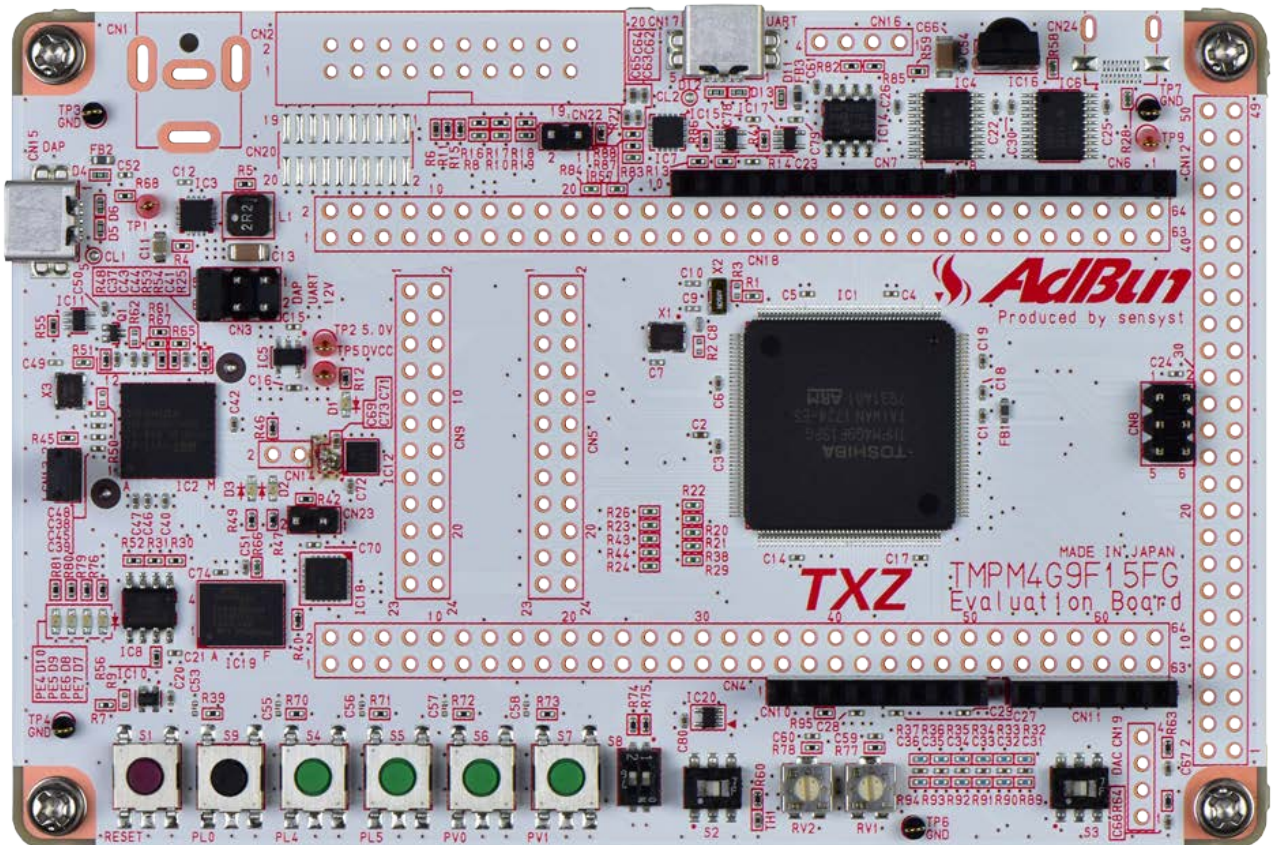
If other function than the TMPM4G9F15 one is checked, it is necessary that CMSIS Core related files (C startup file and I/O header file) should be changed properly.

The BSP related file is dedicated to the evaluation board (TMPM4G9F15). If other function than the TMPM4G9F15 one is checked, the BSP related file should be changed properly.

**5. Operation Confirmation Condition**

|                                 |   |
|---------------------------------|---|
| Used microcontroller            | TMPM4G9F15FG                                |
| Used board                      | TMPM4G9F15FG Evaluation Board by Sensystr   |
| Unified development environment | IAR Embedded Workbench for ARM 8.11.2.13606 |
| Unified development environment | µVision MDK Version 5.24.2.0                |
| Terminal software               | Tera Term V4.96                             |
| Sample program                  | V1000                                       |

Evaluation board (TMPM4G9F15FG Evaluation Board) Top view





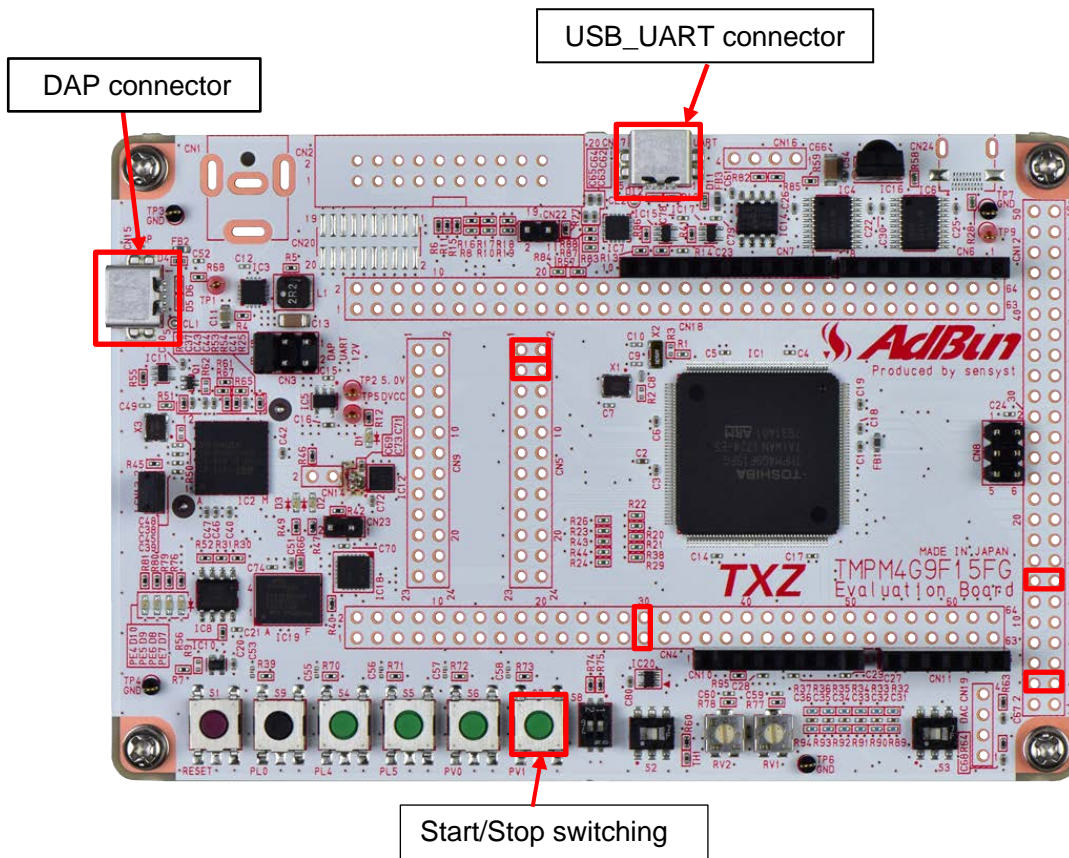
## 6. Evaluation Board Setting

The following pin connections should be done on the evaluation board.

| CN4            |                  |                  |
|----------------|------------------|------------------|
| Board function | Through-hole No. | Through-hole No. |
| Mode switching | 29: ISD_SW1      | 30: PV1          |

| CN5                 |                  |                  |
|---------------------|------------------|------------------|
| Board function      | Through-hole No. | Through-hole No. |
| USB UART conversion | 1: USB_UT_RX     | 2: PE2           |
| USB UART conversion | 3: USB_UT_TX     | 4: PE3           |

| CN12              |                  |                  |
|-------------------|------------------|------------------|
| Board function    | Through-hole No. | Through-hole No. |
| Variable resistor | 3: AIN_VR0       | 4: PP0           |
| Thermistor        | 13: AIN_NTC      | 14: PR0          |



## 7. Operation of Evaluation Board

PC and the USB\_UART are connected for communication with the terminal software. A message indicating the suspension of ADC is displayed with the set interval on the terminal software. When the Push switch S7 is pushed down, ADC starts the operation and displays the output by AD conversion on the terminal software. When the Push switch S7 is pushed down again, ADC stops the operation and displays a message indicating the suspension of ADC with the set interval on the terminal software.

## 8. Outline of 12-bit Analog to Digital Converter Function

The 12-bit analog to digital converter (ADC) can convert multiple analog inputs(AINx0 to AINxn) to digital in each unit. The function list is shown as follows.

| Function classification   | Function                        | Operation explanation   |
|---------------------------|---------------------------------|---|
| AD conversion             | Conversion resolution           | 12bits  |
|                           | Conversion time                 | AVDD3 =2.7 to 3.6[V]: 1.0[μs] at ADCLK=60[MHz]  |
|                           | Store conversion result         | 24 conversion result storage registers.   |
| Start conversion          | Highest start-up factor         | - Highest priority trigger<br>- Highest priority conversion operation (software)<br>Start-up factor program (Note1) can perform up to 24 AD conversions at each start-up.   |
|                           | General purpose start-up factor | - General purpose trigger conversion<br>- Software (Continuous conversion operation, Single conversion operation)<br>Start-up factor program (Note1) can perform up to 24 AD conversions at each start-up.  |
| Conversion status         | Status flags                    | - Flag showing that the AD conversion is executing.<br>- Flag showing that the program is executing (for each trigger).<br>- Conversion result storage flag (for each conversion result storage register).<br>- Conversion result overrun flag (for each conversion result storage register).   |
| Interrupt                 | -                               | - Highest priority program AD conversion completion (INTADxHP)<br>- General purpose trigger program completion (INTADxTRG)<br>- Software single conversion program completion (INTADxSGL)<br>- Software continuous conversion program completion (INTADxCNT)<br>- Monitor function interrupt (INTADxCP0, INTADxCP1, INTADxCP2, INTADxCP3) (Note2) |
| Monitor conversion result | AD monitor function             | - Each ADC unit has 4 channels of monitor function.<br>- Selectable conversion result storage register to be monitored.<br>- Selectable detection method:<br>Whether the target register value is larger or smaller than the comparison register.<br>- Selectable number of detections.<br>- Selectable continuous count and accumulated count.   |

Note1: Conversion program can specify conversion channel (analog input) and presence / absence of interrupt. There are multiple programs. Each is started with the start-up factor / trigger.

Note2: For the channel of the AD monitor function, refer to “Product Information” in the reference manual.

## 9. Sample Program

The thermistor output is AD converted and output to the terminal software with every setup interval. The ADC stop status and AD conversion status are switched by pressing the button. While ADC is stopped, the stop status is output to the terminal software.

### 9.1. Initialization

The following initialization is done after power is supplied.  
The initialization of each clock setting and the setting of the watchdog timer are done.

### 9.2. Sample Program Main Operation

The initialization of BSP is executed.  
The initialization of variables is executed.  
The initialization of driver is executed.  
As the initialization of an application, the initialization of timer, push switch, USB\_UART and thermistor are executed.  
The timer starts.  
The initial state is the ADC stop status, and the ADC stop is output to the terminal software with a set interval.

When the pushing down of switch S7 is detected, the status is changed from ADC stop to AD conversion. While in AD conversion status, the conversion results by ADC is output to the terminal software with a set interval.

The input voltage from the thermistor (TH1) is converted into temperature and displayed.  
For variable resistance (RV1) input, input voltage is indicated by Hex.

After that, when the pushing down of switch S7 is detected, the status is switched between ADC stop and AD conversion.

### 9.3. AIN Channel Setting of ADC

The AIN channel sets the channel to be used in the application initialization of main.c.  
If you would like to change the channel, change the ain of the ADC setting structure (adc\_channel\_setting\_t) and the argument of the channel setting function adc\_channel\_setting.  
The numbers 0 to 23 are selected for the channel setting.

### 9.4. Interval Time and Polling Time Settings

The output display interval time while in conversion output status can be changed by setting the "CFG\_OUTPUT\_INTERVAL" of "main.c"  
The switch polling time is changed by setting "CFG\_SW\_POLLING\_TIME"



**9.5. Output Example of Sample Program**

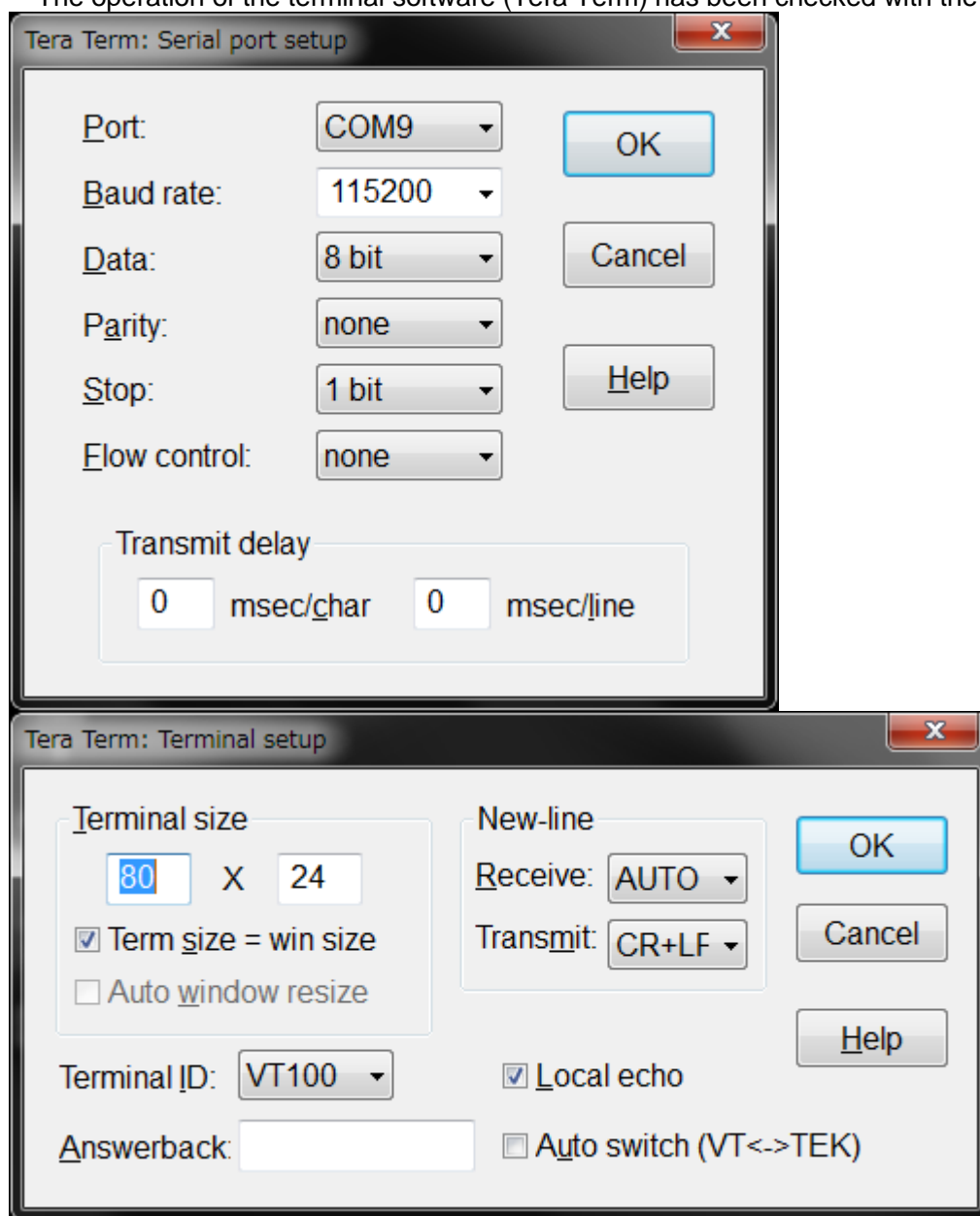
While in the running condition of sample program, the ADC output result or the stop status is displayed. The output is periodically (default 5 seconds) displayed.

```

ADC Stop
ADC Stop
Temp:24degrees
Convert Result Value[VR1]:0x77d
Temp:24degrees
Convert Result Value[VR1]:0x77d
Temp:24degrees
Convert Result Value[VR1]:0x77d
ADC Stop
ADC Stop
ADC Stop
    
```

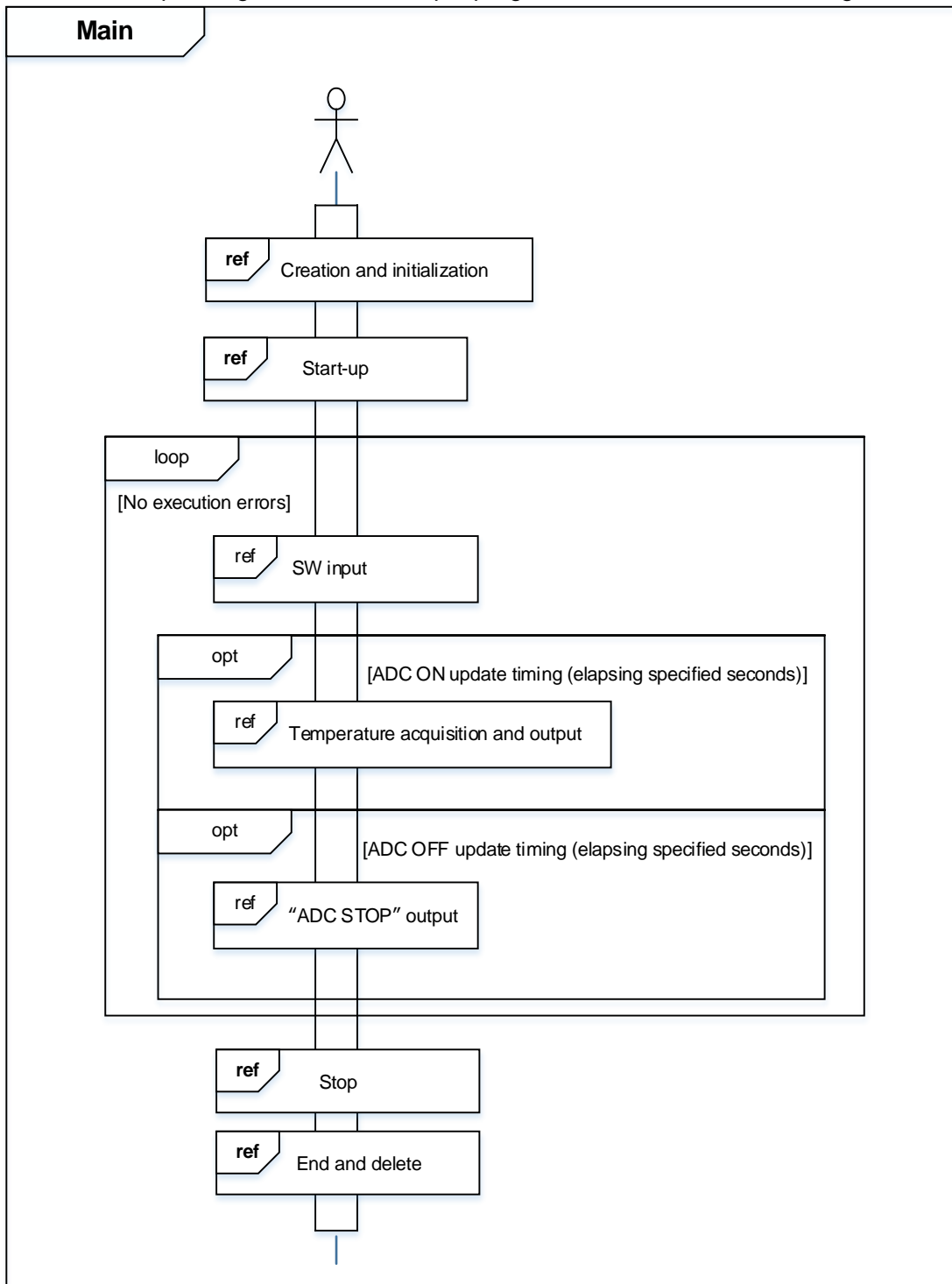
**9.5.1. Setting Example of Terminal Software**

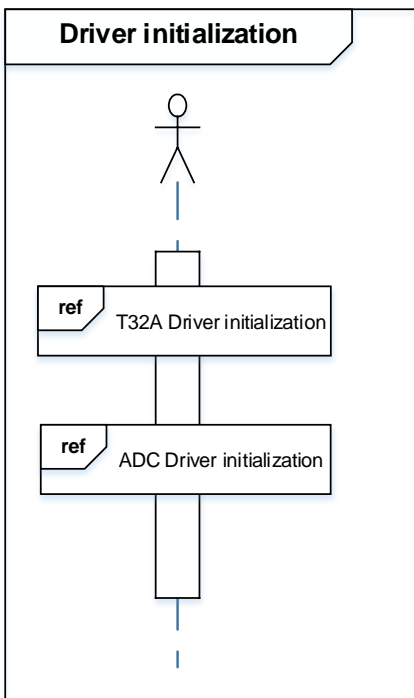
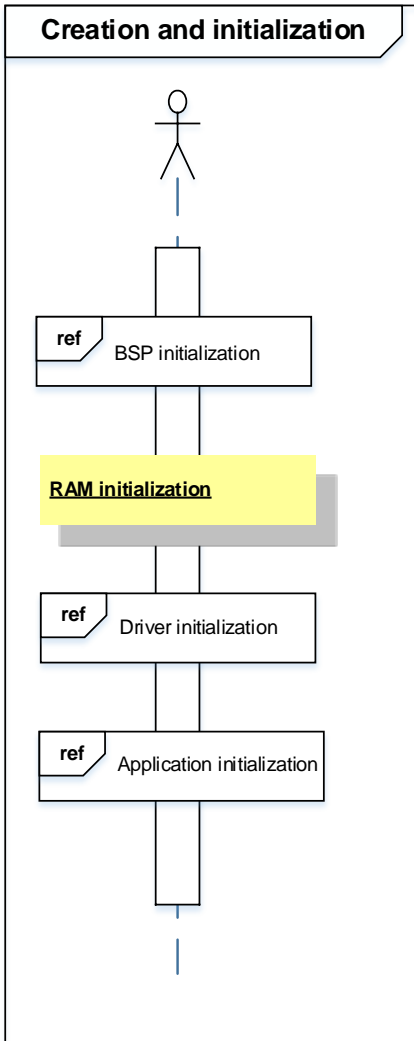
The operation of the terminal software (Tera Term) has been checked with the following settings.

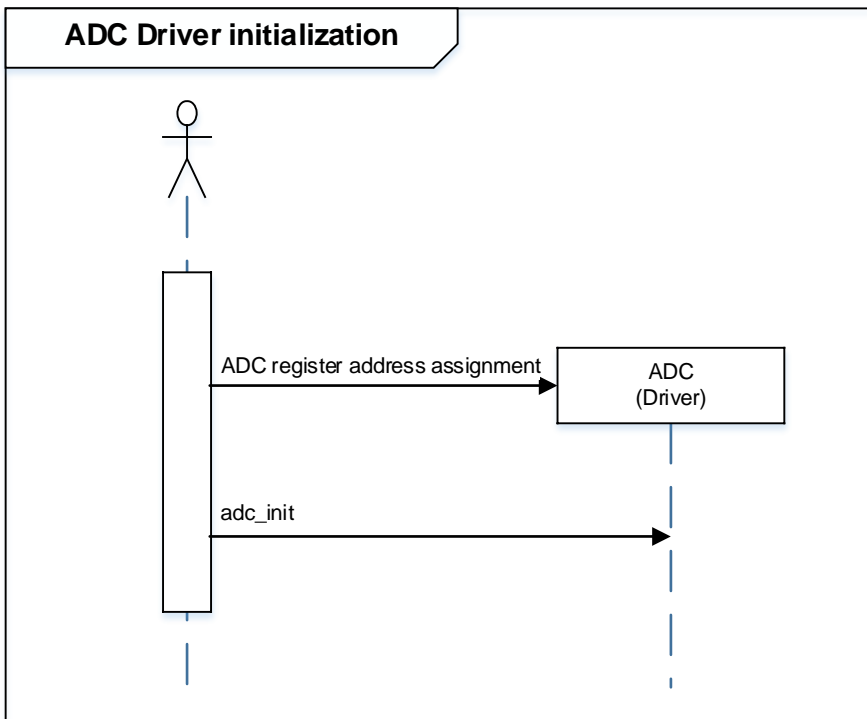
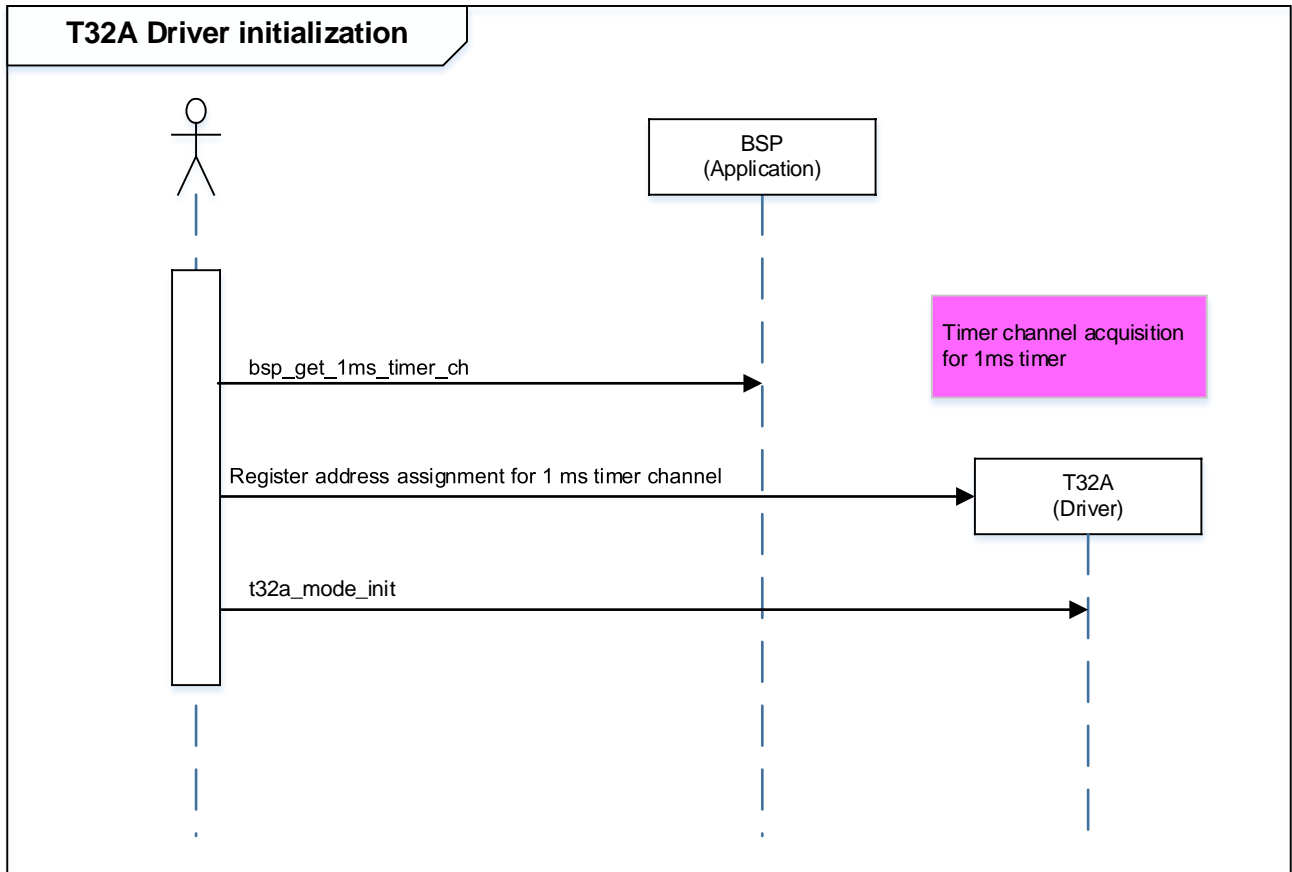


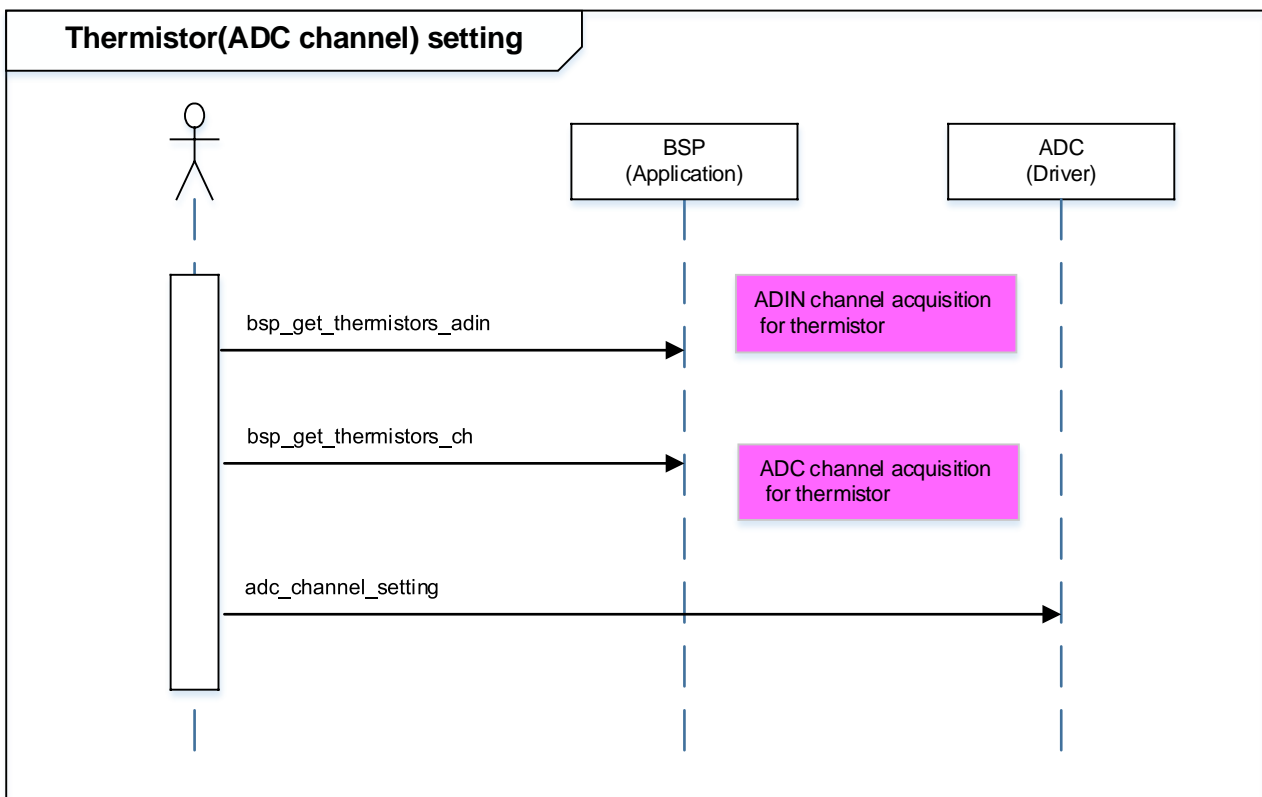
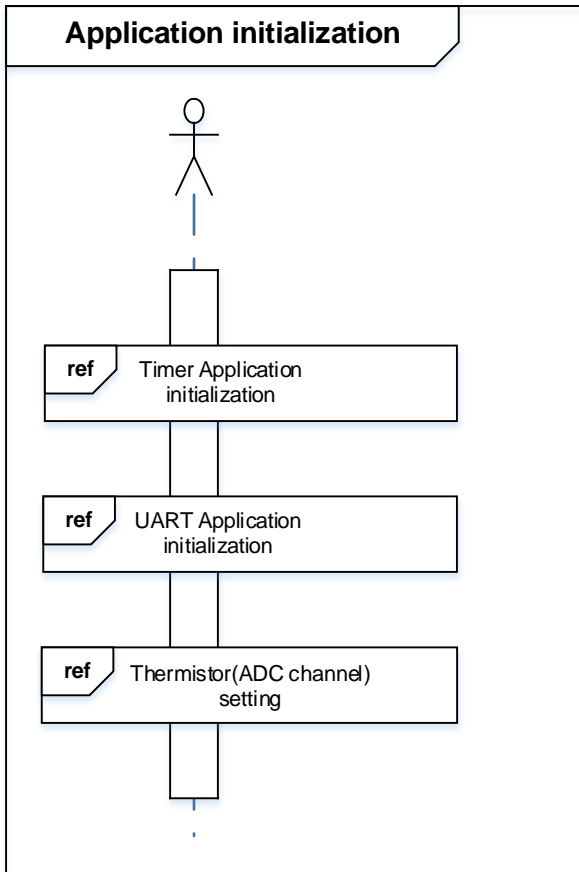
### 9.6. Operating Flow of Sample Program

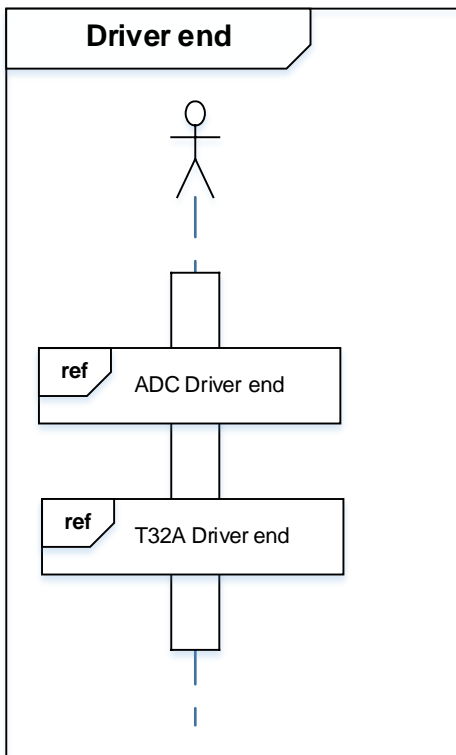
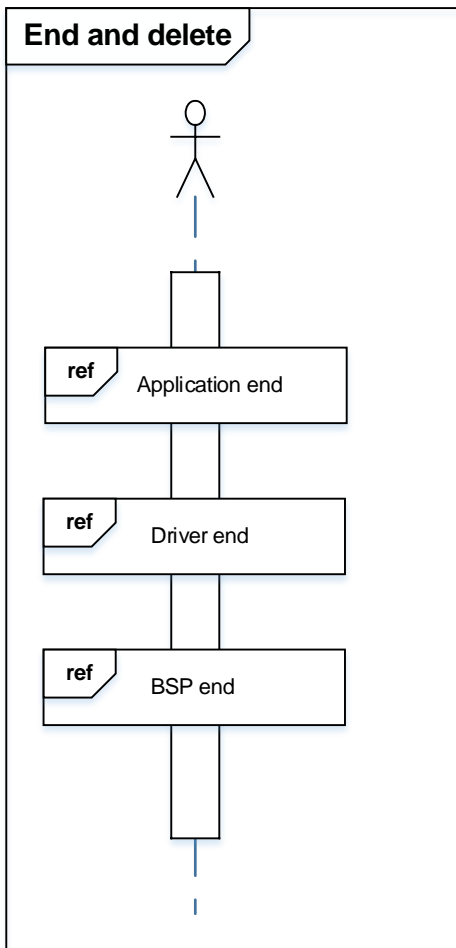
The basic operating flows of the sample program are shown in the following.



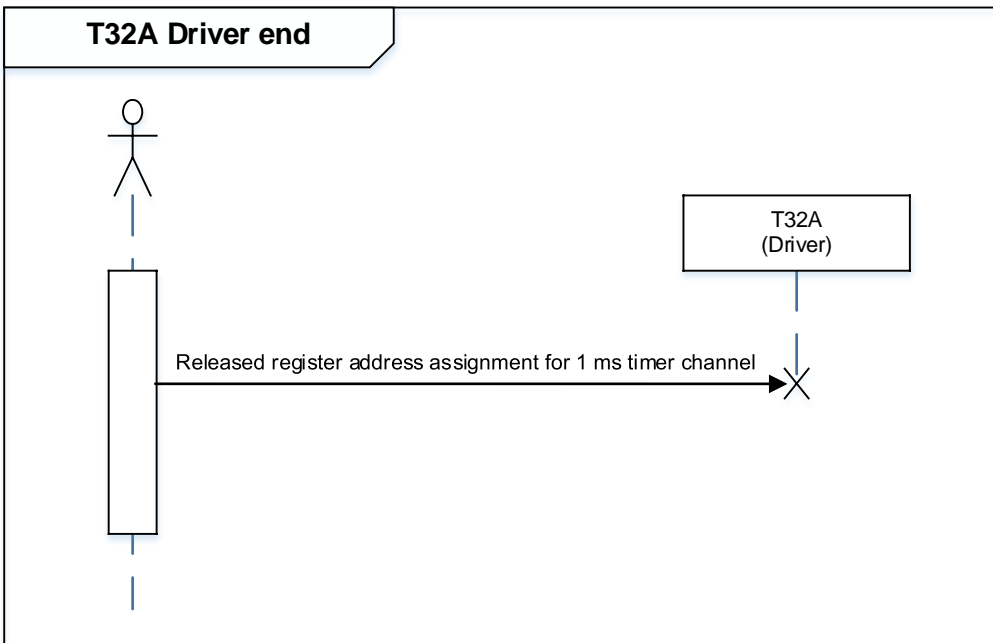
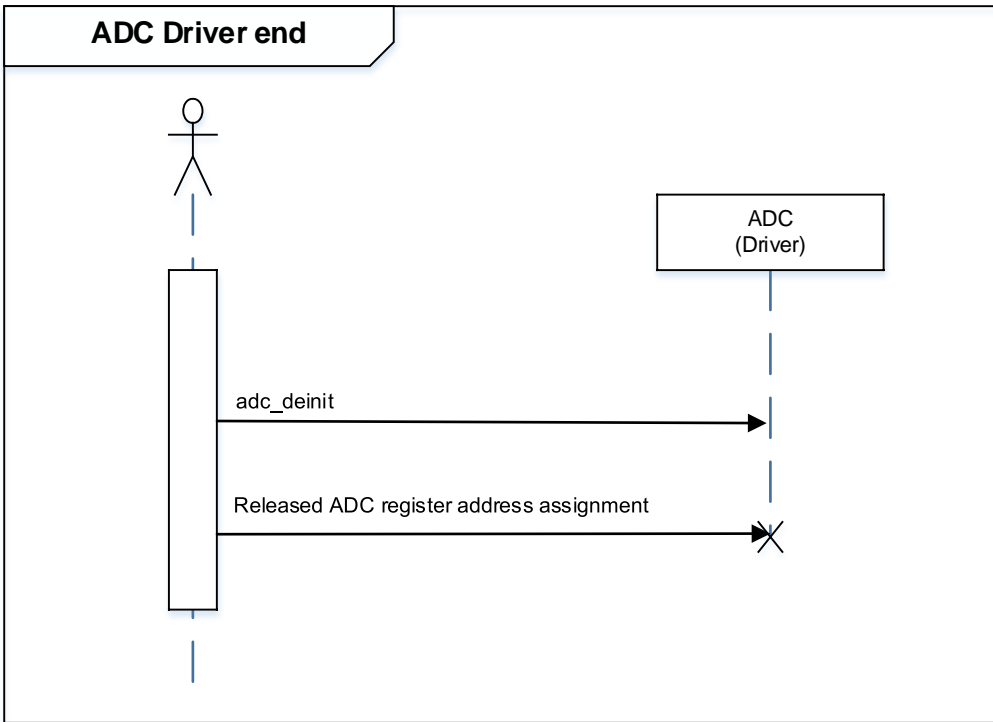


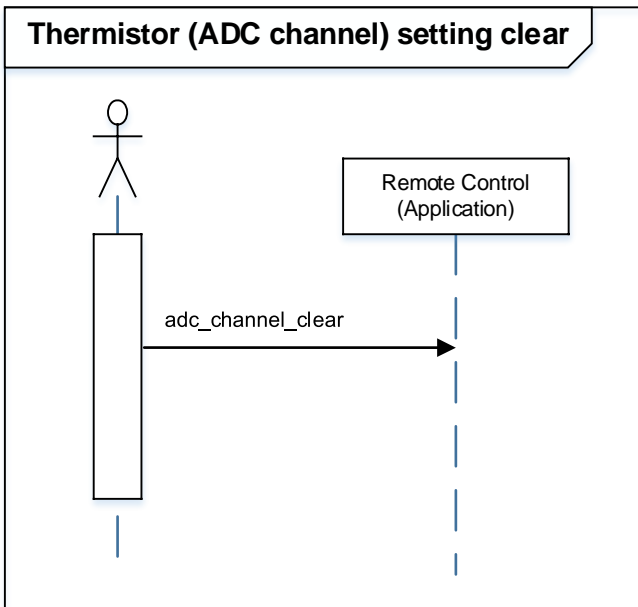
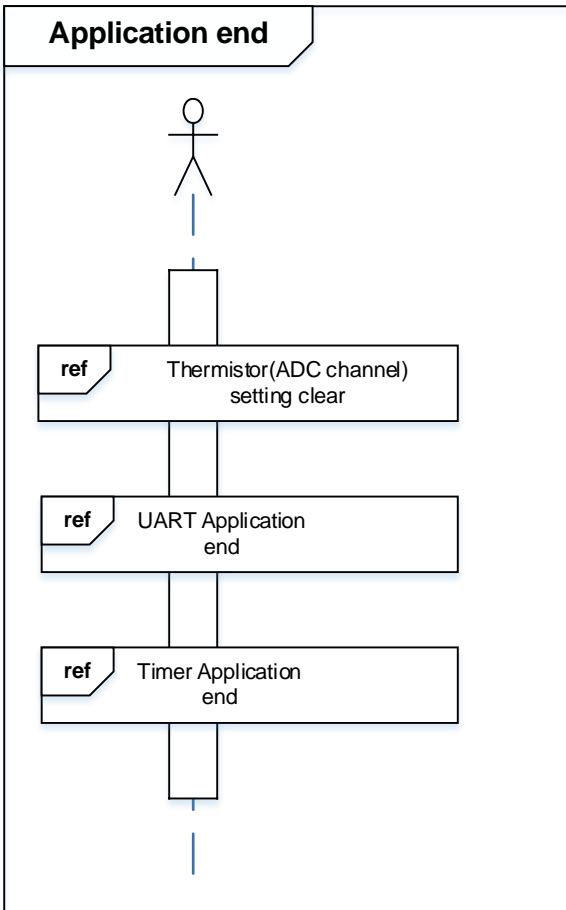


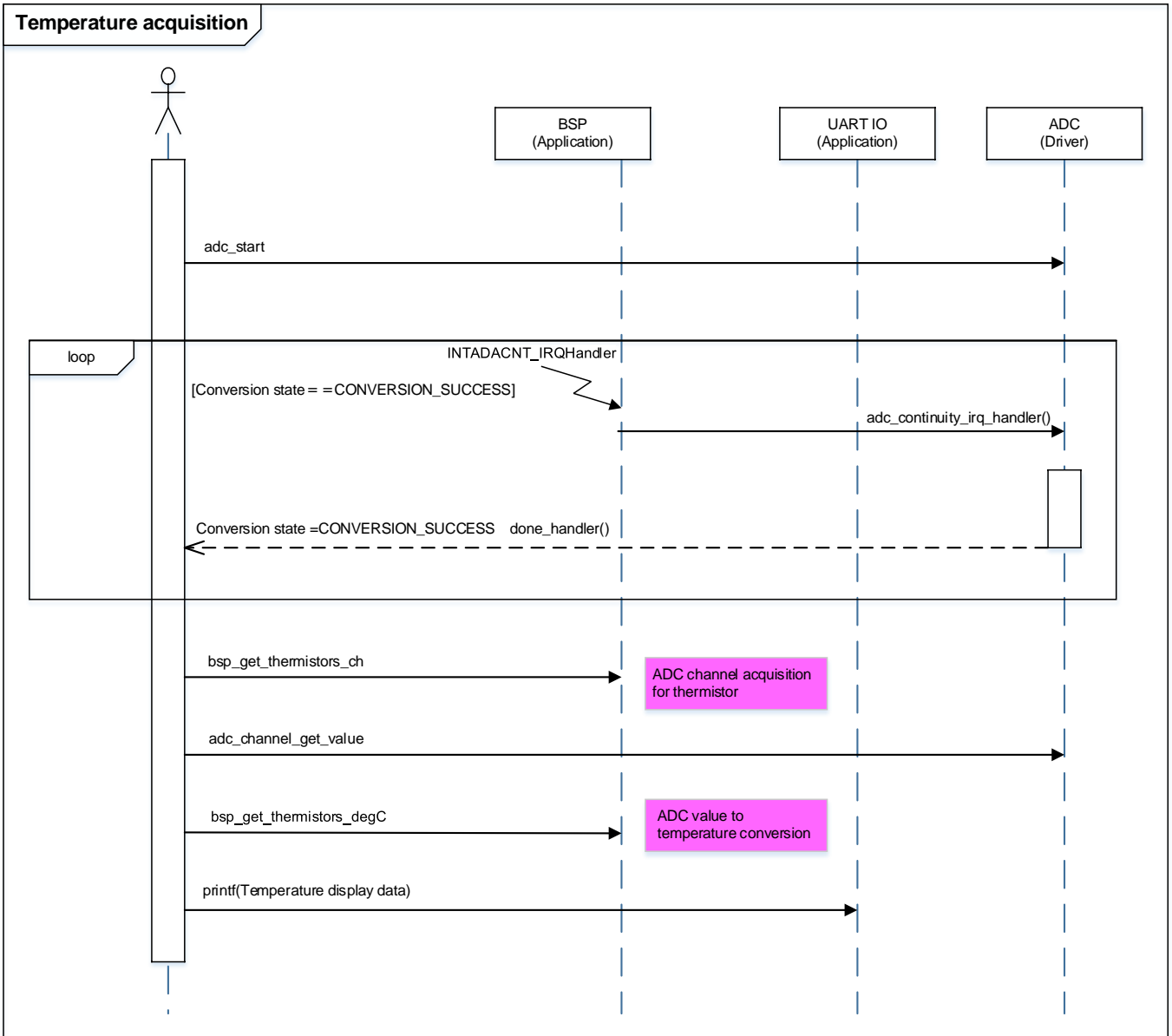












**10. Precaution**

When using the sample program with CPU other than TPM4G9F15, please check operation sufficiently.

**11. Revision History**

| Rev | Date       | Description   |
|-----|------------|---------------|
| 1.0 | 2018-11-26 | First release |

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