M4G Group (1)
Application Note
32-bit Timer Event Counter
(T32A-B)
Rectangular Wave Output Function

Outlines

This application note is a reference material for developing products using rectangular wave output (PPG) function in the 32-bit timer event counter (T32A) functions of M4G Group (1).

This document helps the user check operation of the products and develop its programs.

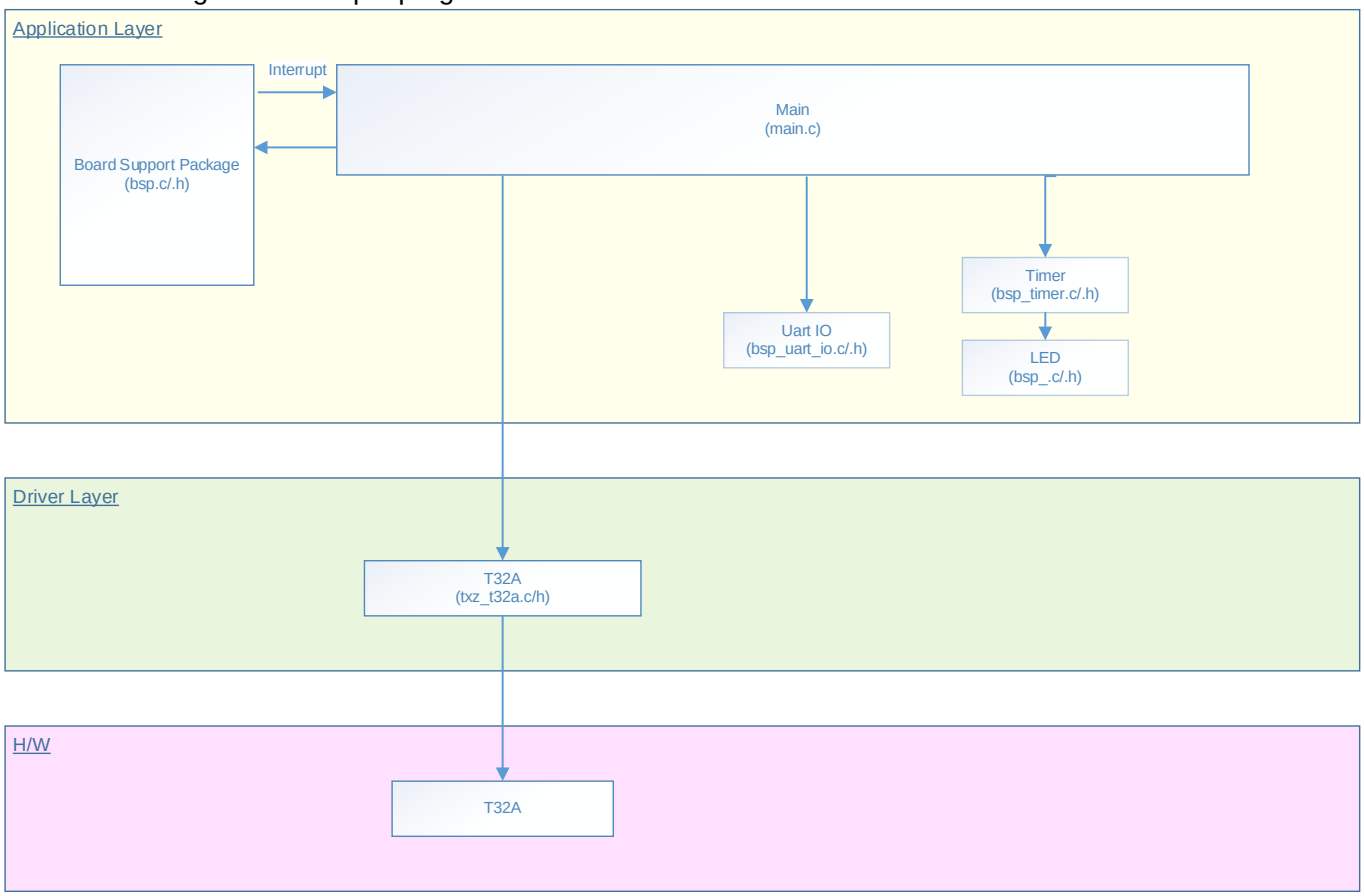
Target sample program: Timer_PPG

Table of Contents

1. Preface

This sample program executes to start the PPG output of the timer function when the PL4 push SW (S4) is pushed down.
When the PL5 Push SW (S5) is pushed down, the PPG output stops. And the duty ratio is changed to 10 %, 25 %, 50 %, 75%, or 90%, one after the other, by the push-down.

Structure diagram of Sample program



2. Reference Document

- Datasheet
  TMPM4G Group (1) datasheet Rev1.0 (Japanese edition)
- Reference manual
  32-bit Timer Event Counter (T32A-B) Rev.2.1 (Japanese edition)
  Asynchronous Serial Communication Circuit (UART-C) Rev3.0 (Japanese edition)
  Input/Output Ports (PORT-M4G(1)) Rev.1.0 (Japanese edition)
  Exception (EXCEPT-M4G(1)) Rev1.0 (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) PE3(UT0TXDA)	UART mode
Input/Output ports	-	PL4(INT12b)	External interrupt
	-	PL5(INT13b)	
32-bit Timer Event Counter	ch0	-	Interval timer
	ch3	PB4(T32A03OUTA)	PPG operation

4. Target Device

The target devices of this application note are as follows;

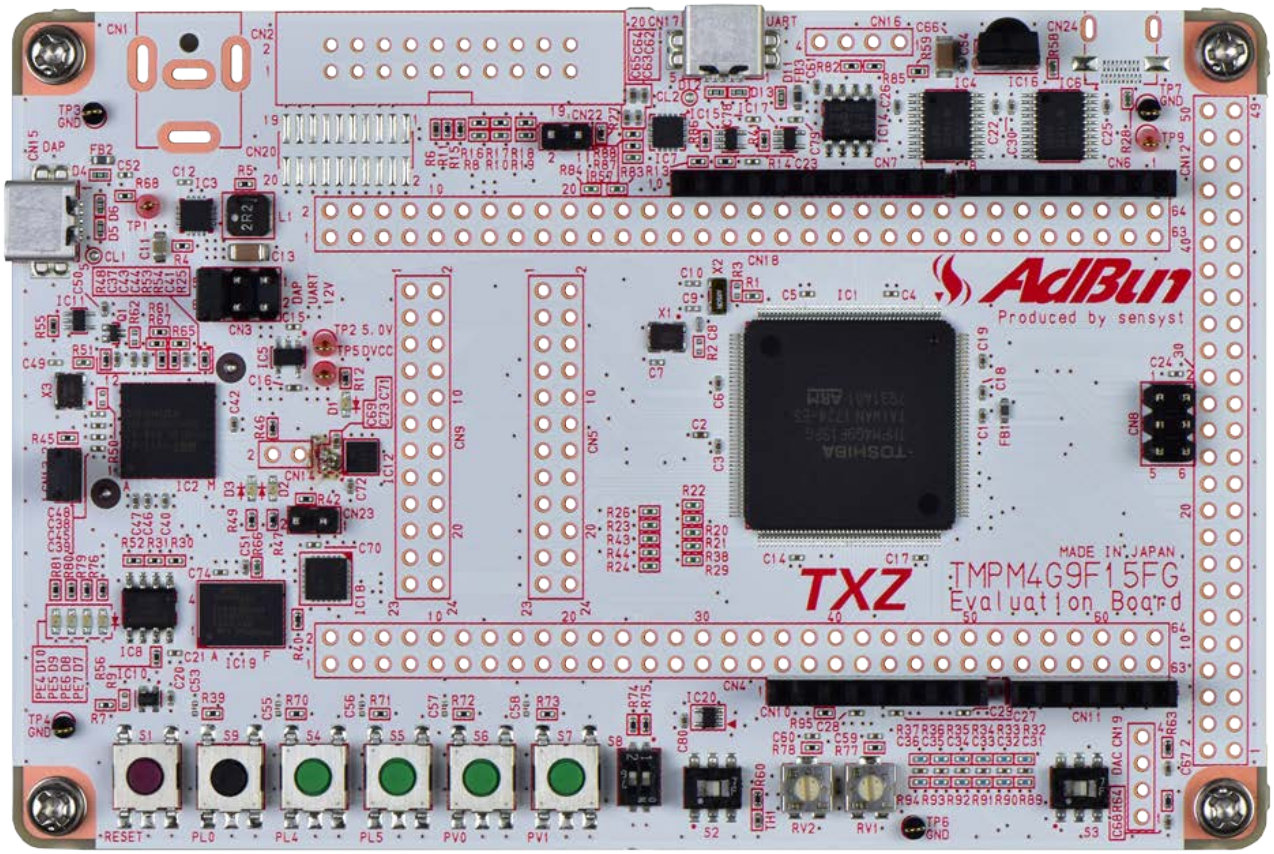
TMPM4G9F15FG	TMPM4G9F10FG	TMPM4G9FEFG	TMPM4G9FDFG
TMPM4G9F15XBG	TMPM4G9F10XBG	TMPM4G9FEXBG	TMPM4G9FDXBG
TMPM4G8F15FG	TMPM4G8F10FG	TMPM4G8FEFG	TMPM4G8FDFG
TMPM4G8F15XBG	TMPM4G8F10XBG	TMPM4G8FEXBG	TMPM4G8FDXBG
	TMPM4G7F10FG	TMPM4G7FEFG	TMPM4G7FDFG
	TMPM4G6F10FG	TMPM4G6FEFG	TMPM4G6FDFG

*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 Sensyst
Unified development environment	IAR Embedded Workbench for ARM 8.11.2.13606
Unified development environment	µVision MDK Version 5.24.2.0
Terminal software	TeraTerm V4.96
Sample program	V1000

Evaluation board (TMPM4G9F15FG Evaluation Board) Top view

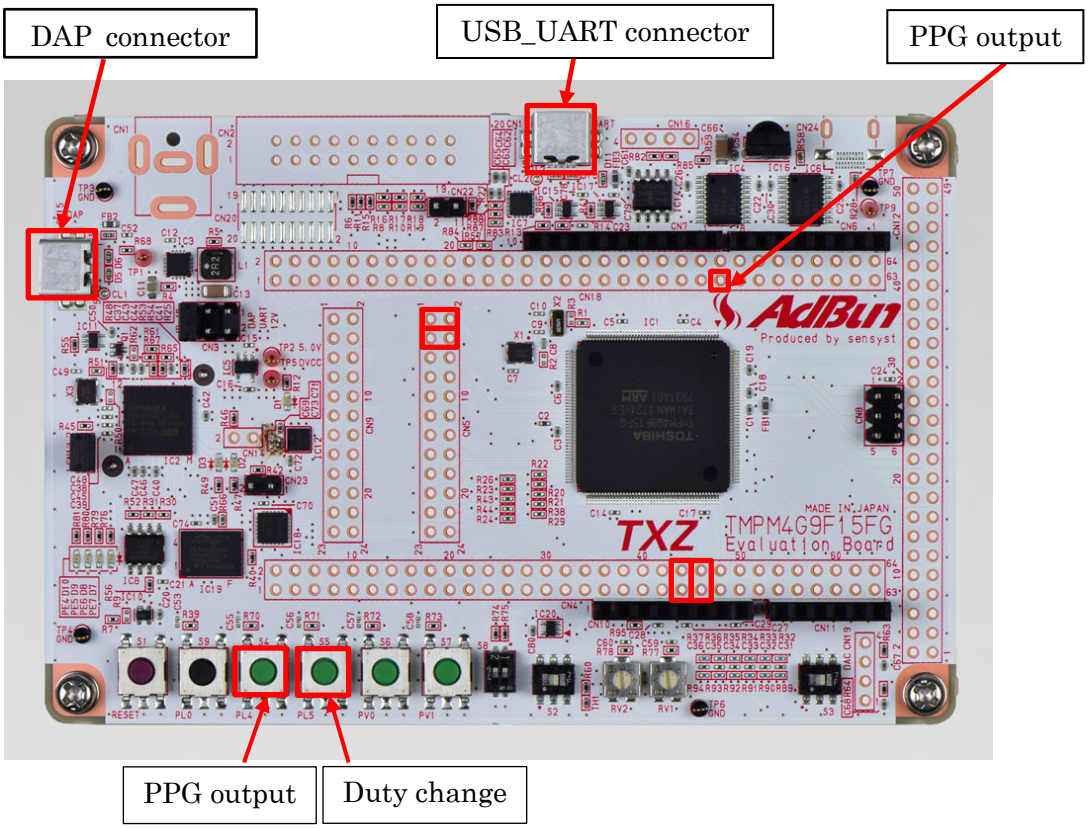


6. Evaluation Board Setting

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

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

CN4		
Board function	Through-hole No.	Through-hole No.
Push switch (S5)	43: SW_INT1	44: PL5
Push switch (S4)	45: SW_INT0	46: PL4



7. Operation of Evaluation Board

The PPG output and the duty ratio can be set using the push switches.

Key	Function
Push switch (S4): PL4	PPG output: start
Push switch (S5): PL5	Duty ratio change/PPG output stop

The duty ratios preset in this sample program are 10 %, 25 %, 50 %, 75 %, and 90 %.
The PPG output can be monitored at PB4 (T32A03OUTA). (It can be monitored at CN18: 47 pin.)

8. Outline of T32A Function

T32A can work as a 16-bit timer (timer A, timer B) of 2ch or a 32-bit timer (timer C) of 1ch by 1UNIT circuit unit. The following table shows the list of the functions of the T32A.

Function category		Function		Description
16-bit timer Timer A	Time control	Interval timer		This function generates interrupt to CPU at set interval time.
	Measurement control	Event counter		Up counting or down counting or up/down counting can be selected as count operation. And when the count value matches the timer register, you can generate timer interrupt.
		Capture	Frequency measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate frequency from difference of capture data.
			Pulse width measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate Pulse Width from difference of capture data.
			Time difference measurement	Capture count value on rising edge or falling edge of input pulse. You can calculate Time difference from difference of capture data.
	Rectangular wave output	PPG		Can output rectangular wave of arbitrary frequency or arbitrary duty.
	Synchronous Operation	Counter start		Timer counter start the count in synch with count start of master timer counter.
		Counter stop		Timer counter stop the count in synch with count stop of master timer counter.
		Counter reload		Timer counter is reloaded in synch with reload of master timer counter.
16-bit timer Timer B	Time control	Interval timer		This function generates interrupt to CPU at set interval time.
	Measurement control	Event counter		Up counting or down counting or up/down counting can be selected as count operation. And when the count value matches the timer register, you can generate timer interrupt.
		Capture	Frequency measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate frequency from difference of capture data.
			Pulse width measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate Pulse Width from difference of capture data.
			Time difference measurement	Capture count value on rising edge or falling edge of input pulse. You can calculate Time difference from difference of capture data.
	Rectangular wave output	PPG		Can output rectangular wave of arbitrary frequency or arbitrary duty.
	Synchronous Operation	Counter start		Timer counter start the count in synch with count start of master timer counter.
		Counter stop		Timer counter stop the count in synch with count stop of master timer counter.
		Counter reload		Timer counter is reloaded in synch with reload of master timer counter.

Function category		Function		Description
32-bit timer Timer C	Time control	Interval timer		This function generates interrupt to CPU at set interval time.
	Measurement control	Event counter		Up counting or down counting or up/down counting can be selected as count operation. And when the count value matches the timer register, you can generate timer interrupt.
		Pulse count	1-phase pulse count	The change of the T32AxINC0 input signal or the T32AxINC1 input signal is counted. The counter can select a count increment or decrement.
			2-phase pulse count	The change of the combination of the T32AxINC0 input signal and the T32AxINC1 input signal increments or decrements the counter value.
		Capture	Frequency measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate frequency from difference of capture data.
			Pulse width measurement	Capture count value on rising edge and falling edge of input pulse. You can calculate Pulse Width from difference of capture data.
			Time difference measurement	Capture count value on rising edge or falling edge of input pulse. You can calculate Time difference from difference of capture data.
	Rectangular wave output	PPG		Can output rectangular wave of arbitrary frequency or arbitrary duty.
	Synchronous Operation	Counter start		Timer counter start the count in synch with count start of master timer counter.
		Counter stop		Timer counter stop the count in synch with count stop of master timer counter.
		Counter reload		Timer counter is reloaded in synch with reload of master timer counter.

9. Sample Program

When Low input is detected at PL4, the PPG output starts.
When Low input is detected at PL5, the PPG output stops. And the duty ratio is changed.
The terminal software displays the duty ratio value.

The pulse width has been set to 500 µs in this sample program.
5 values are defined for the duty ratio of the PPG output (50 µs, 125 µs, 250 µs, 375 µs, and 450 µs)
Those values generate 5 duty ratios, 10 %, 25 %, 50 %, 75 %, and 90 %, respectively.

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 definition is set for the duty ratio of the PPG output signal.
The BSP (Board Support Package) is initialized.
The timer is initialized.
The setting of the pulse output is initialized.
The application is initialized.
The timer starts after the USB-UART interface and the switches are initialized.

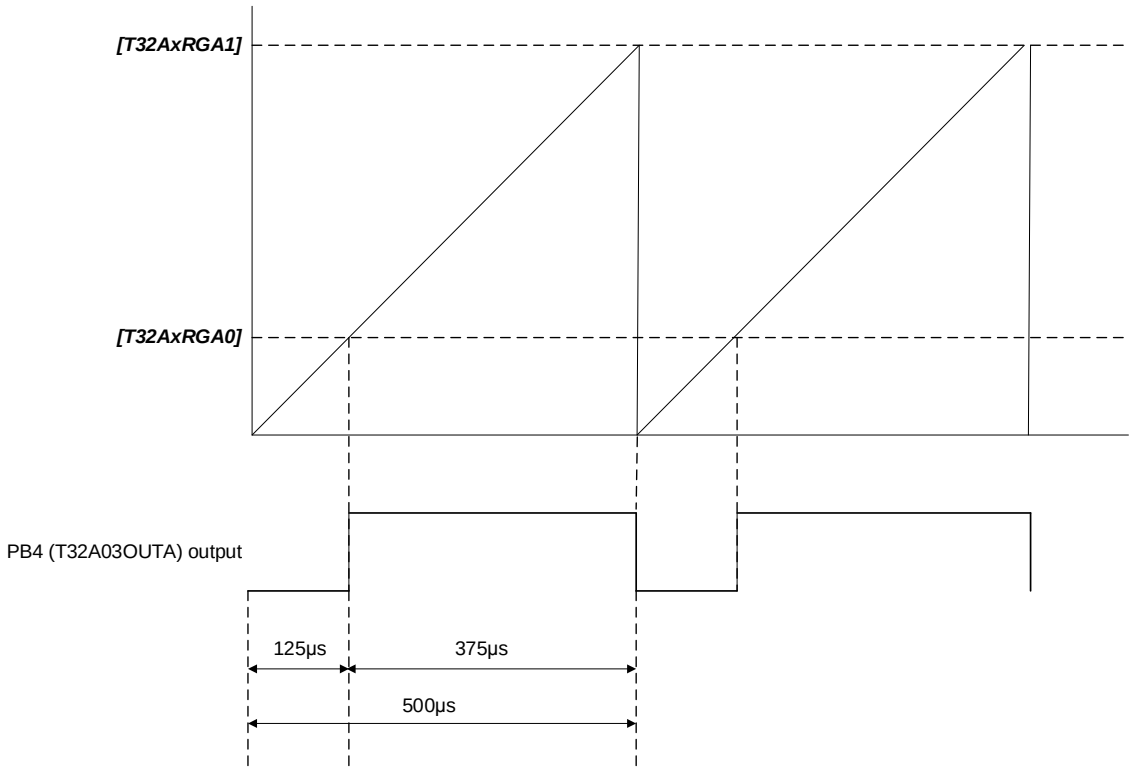
The status of the switches is polled. A push-down of a switch starts its corresponding operation.
The polling is done using the ch0 of the Timer A.
The pulse with the width of 500 µs and the duty ratio of 10 % is output initially.
The pulse is generated using the ch3 of the Timer A.

When the SW4 push-down is detected, the pulse is output.
When the SW5 push-down is detected, the duty ratio changes from 10 %, 25 %, 50 %, 75 %, 90 %, and 10% again, in the order.

The terminal software displays the operation status.

When the value of the Timer A counter matches the values of the timer registers (***[T32AxRGA0]*** and ***[T32AxRGA1]***), the output signal from T32A03OUTA pin is changed High or Low, respectively, which a pulse with a predetermined width can be generated.

The following example is an output wave with a duty ratio of 25 % (Low active).



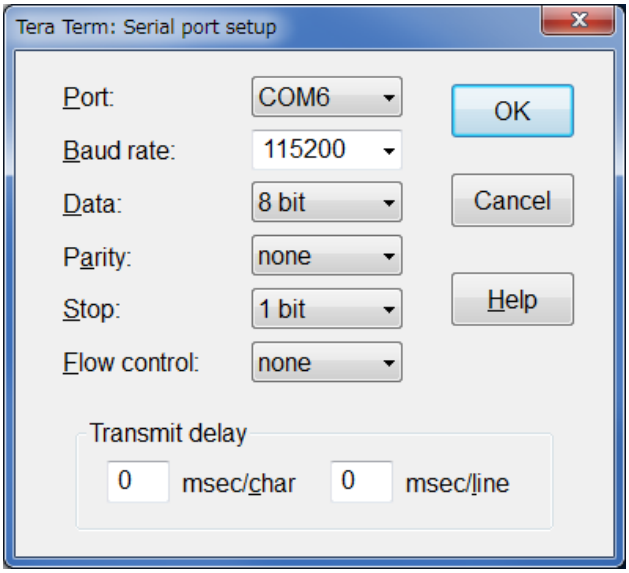
9.3. Output Example of Sample Program

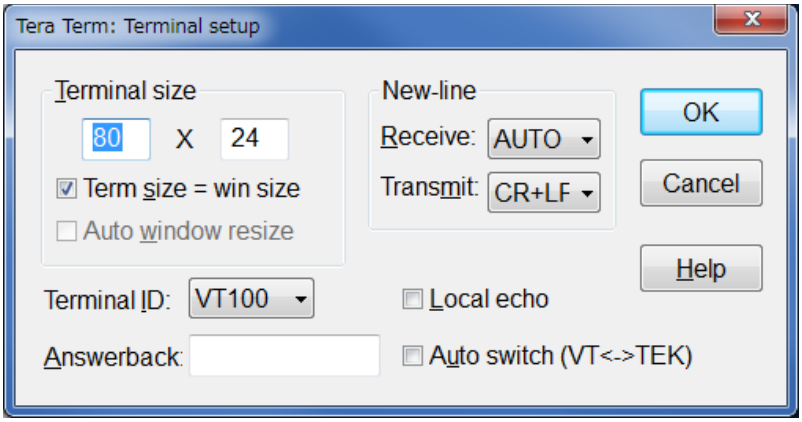
After the sample program starts to operate, the command results are displayed as shown in the following.

```
PPG Output
Duty: 10%
Change to Duty: 25%
Change to Duty: 50%
Change to Duty: 75%
Change to Duty: 90%
Change to Duty: 10%
Change to Duty: 25%
PPG Output
Duty: 25%
```

9.3.1. Setting Example of Terminal Software

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





9.4. Duty Setting Change

When the duty is changed, the following setting should be modified.

```
static uint32_t tgtRisingTiming[5U] = { 10U, 25U, 50U, 75U, 90U };
```

5 values are available from 10 % to 90 % in the above setting.

The following equations are used in this sample program.
Pulse width setting

```
p_pulse->init.pulse_trailing = 500U;
```

500-µs pulse width is defined above.
Duty setting

```
RisingTimingus[i] = tgtRisingTiming[i] * 5U;
```

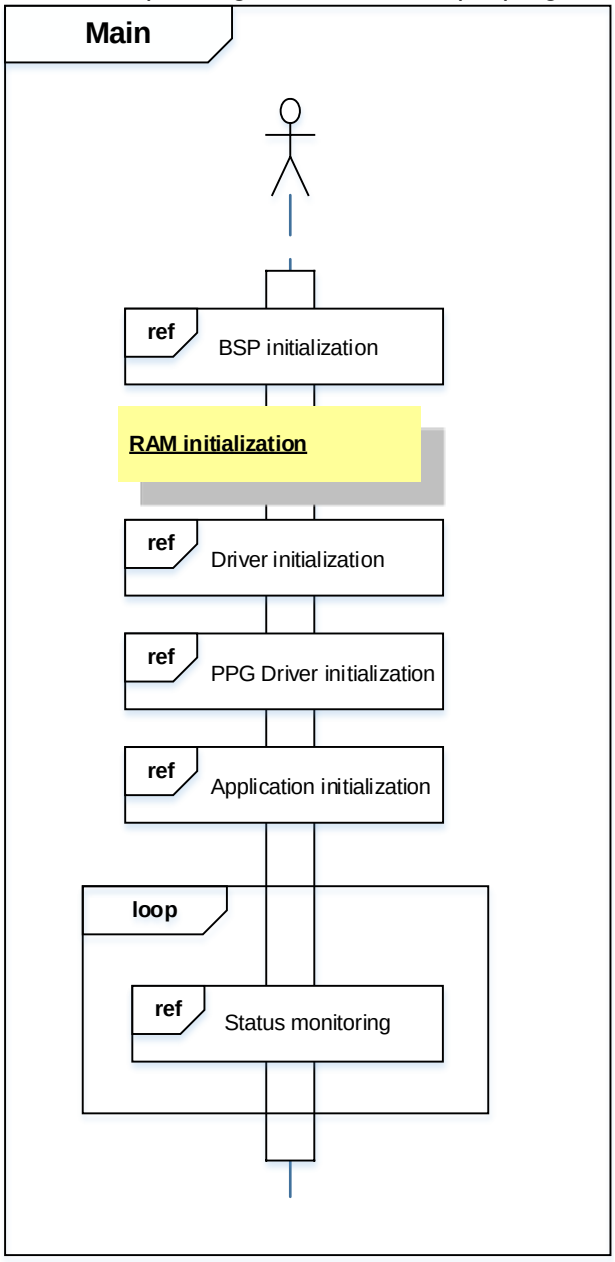
The Low time is set by the equation above.
The duty ratios of 10 %, 25 %, 50 %, 75 %, and 90 % are defined in tgtRisingTiming[i].
The rising times are calculated to 50, 125, 250, 375, and 450 µs, respectively.
The pulse width is supposed to be 500µs to calculate the duty ratios.

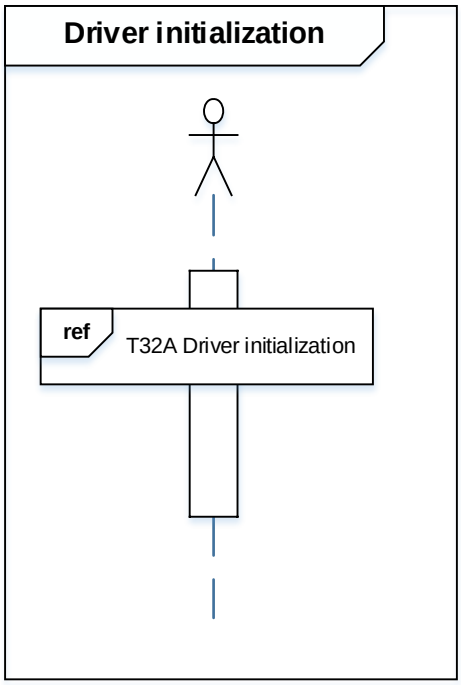
If the duty ratio is changed, the corresponding set value should be changed in the following.

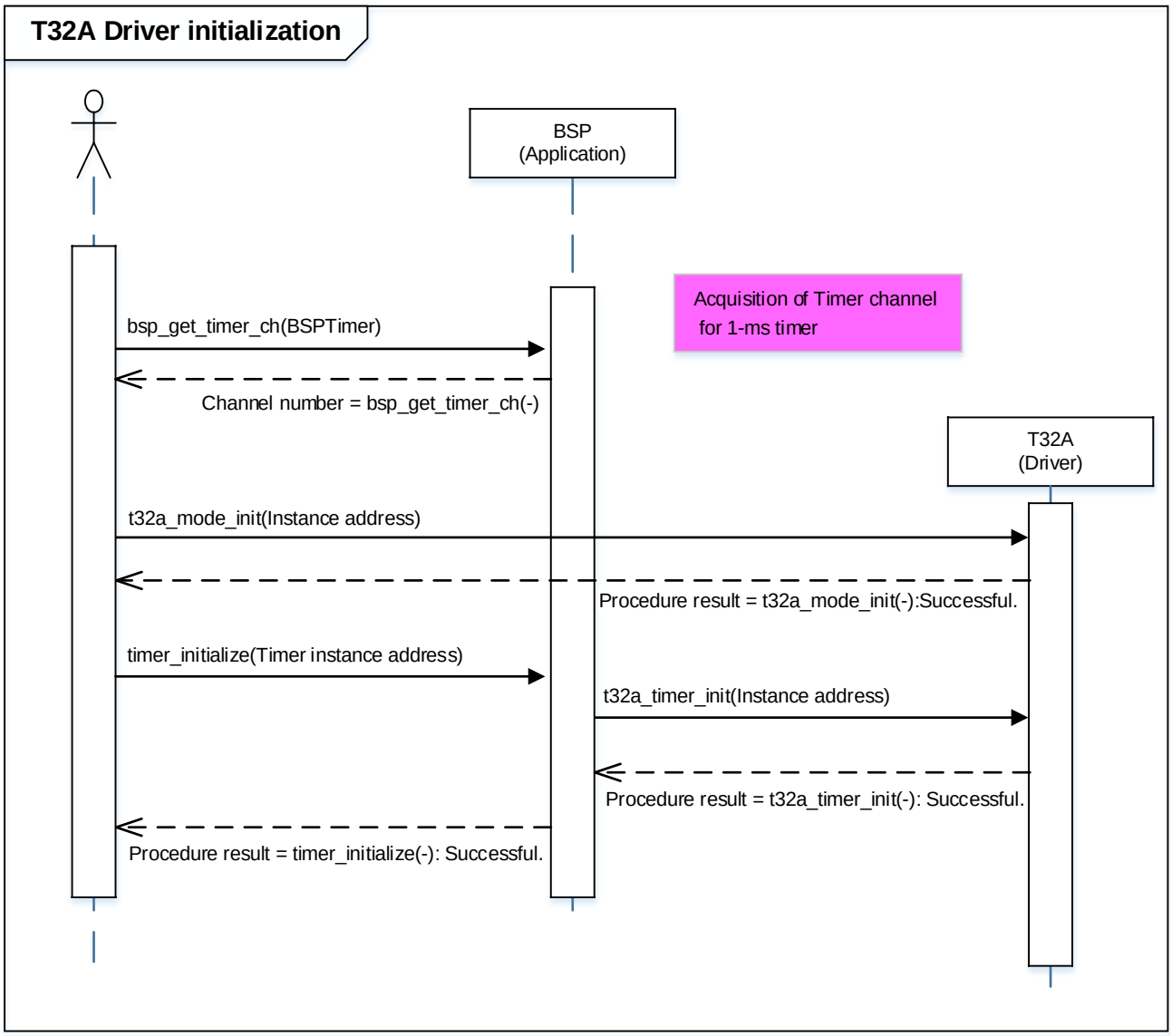
```
static uint32_t tgtRisingTiming[5U] = { 10U, 25U, 50U, 75U, 90U };
```

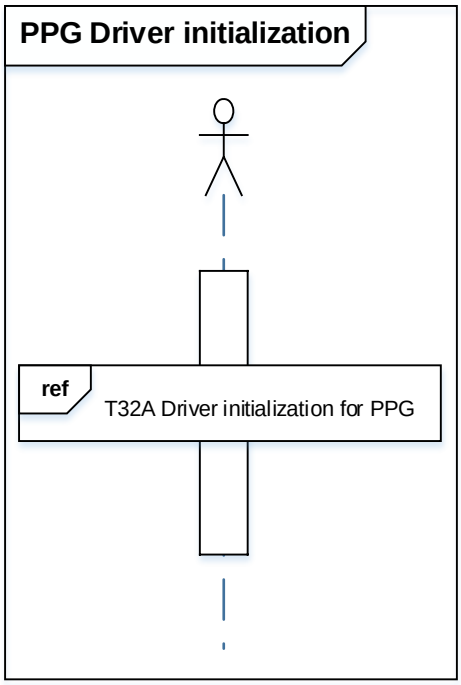
9.5. Operating Flow of Sample Program

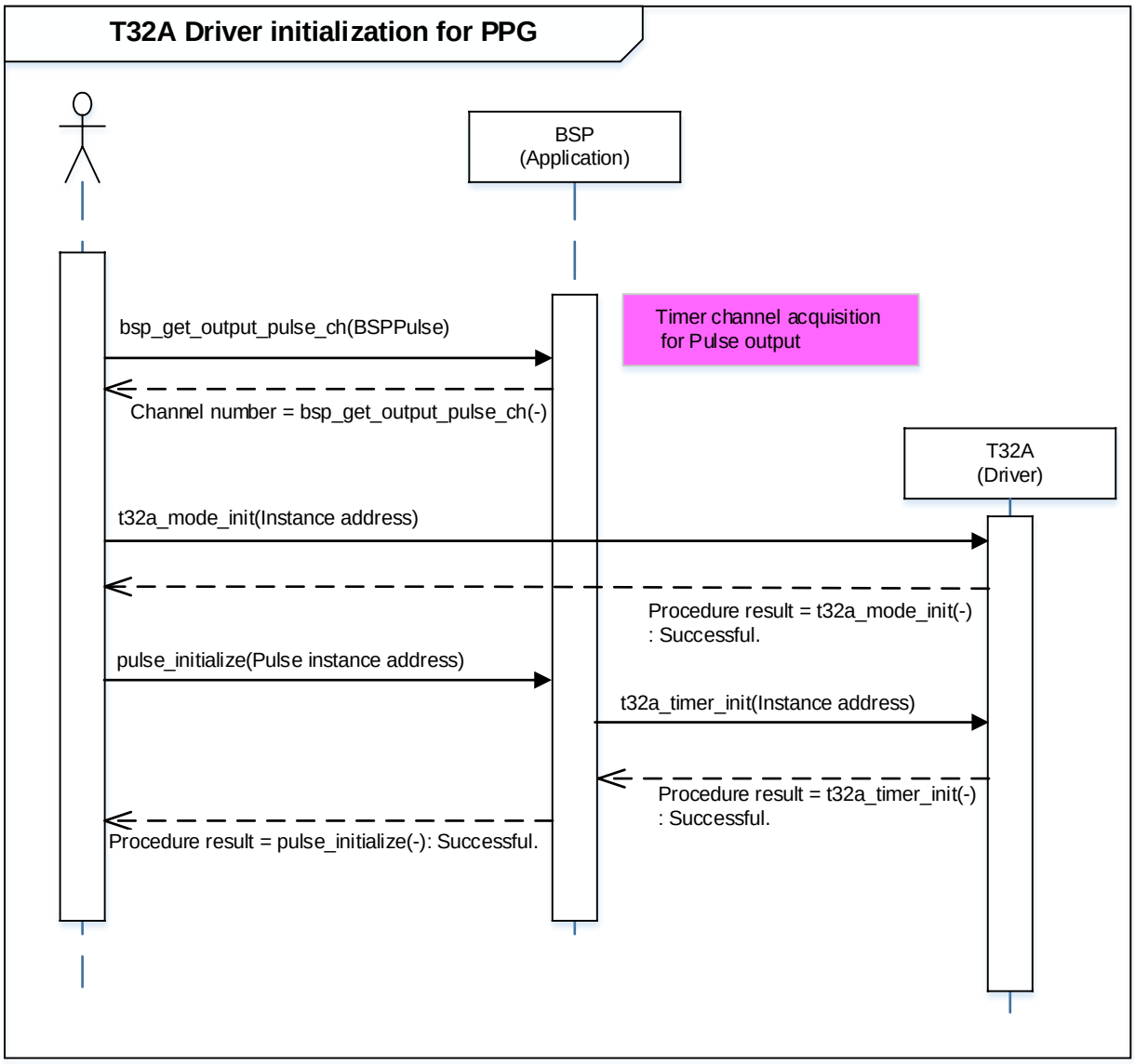
The basic operating flows of the sample program are shown in the following;

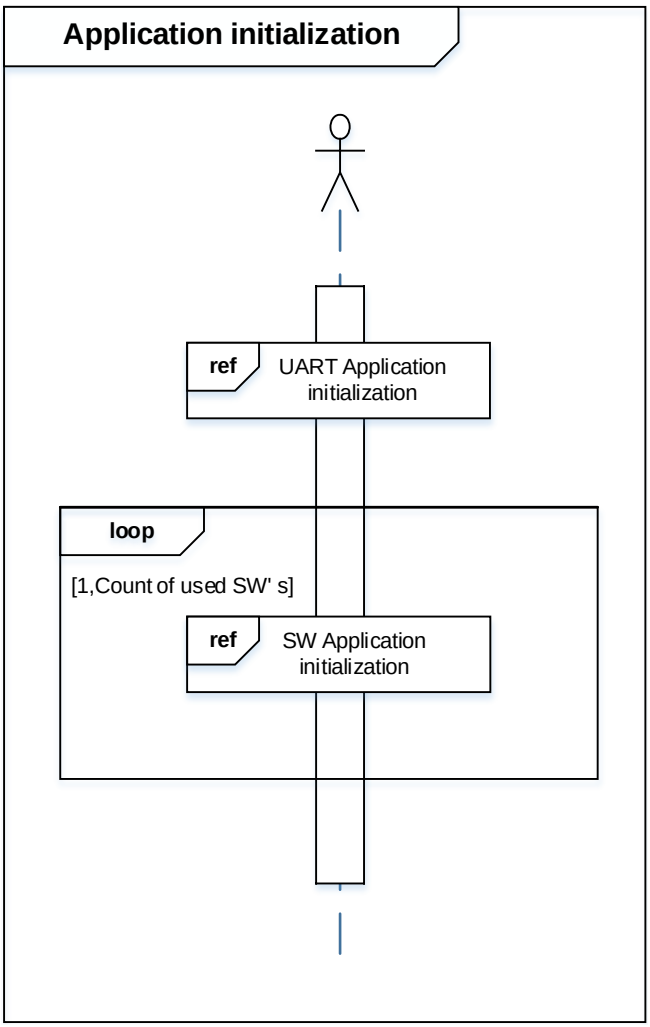


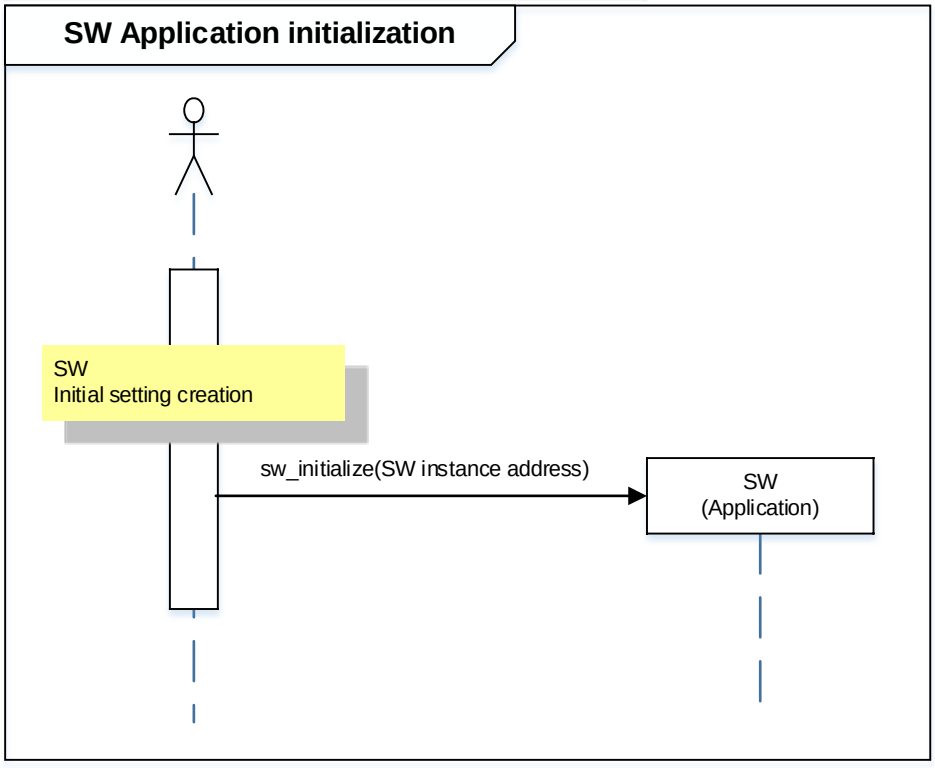

Driver initialization
ref
T32A Driver initialization

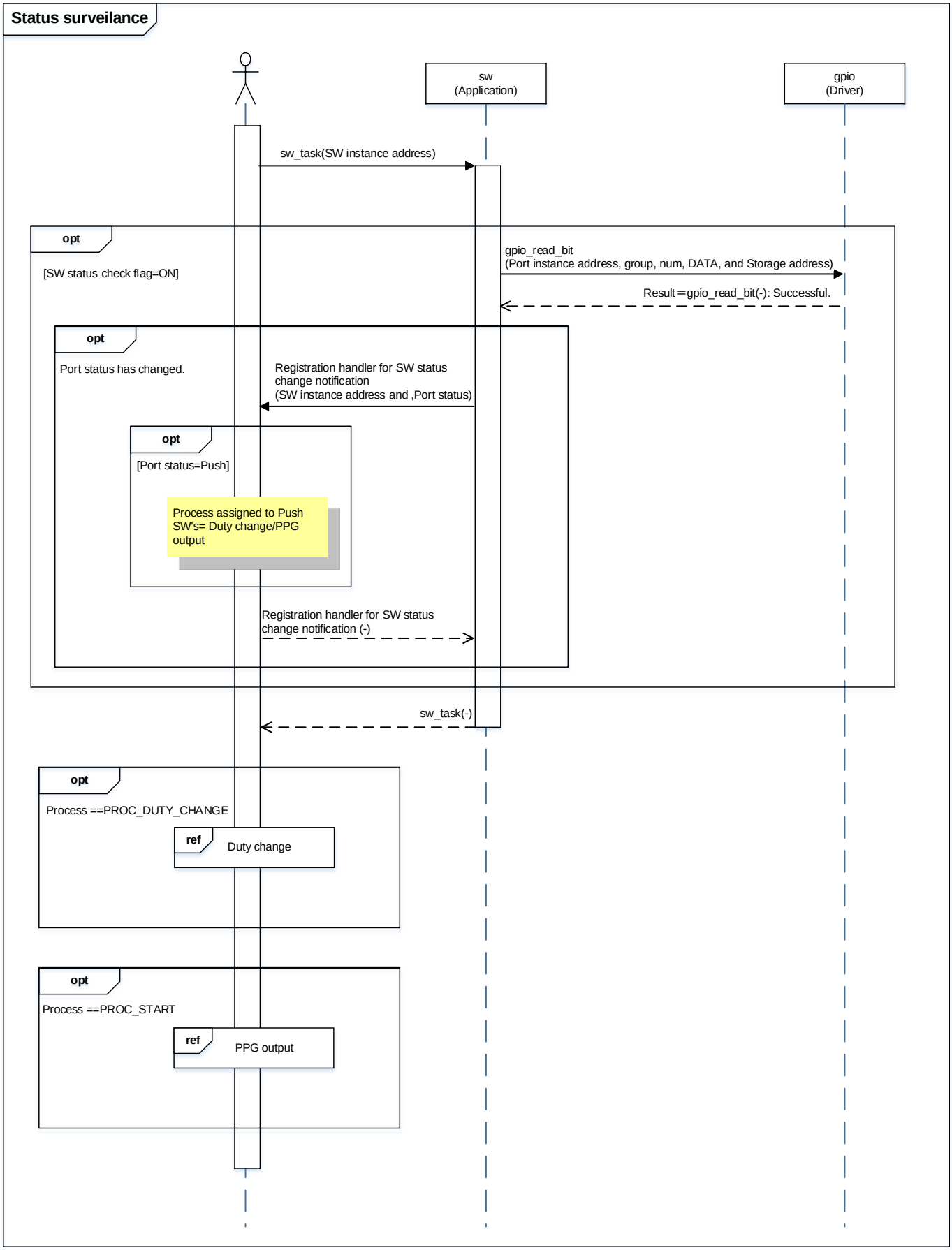

T32A Driver initialization
BSP
(Application)
Acquisition of Timer channel
for 1-ms timer
bsp_get_timer_ch(BSPTimer)
Channel number = bsp_get_timer_ch(-)
T32A
(Driver)
t32a_mode_init(Instance address)
Procedure result = t32a_mode_init(-):Successful.
timer_initialize(Timer instance address)
t32a_timer_init(Instance address)
Procedure result = t32a_timer_init(-): Successful.
Procedure result = timer_initialize(-): Successful.

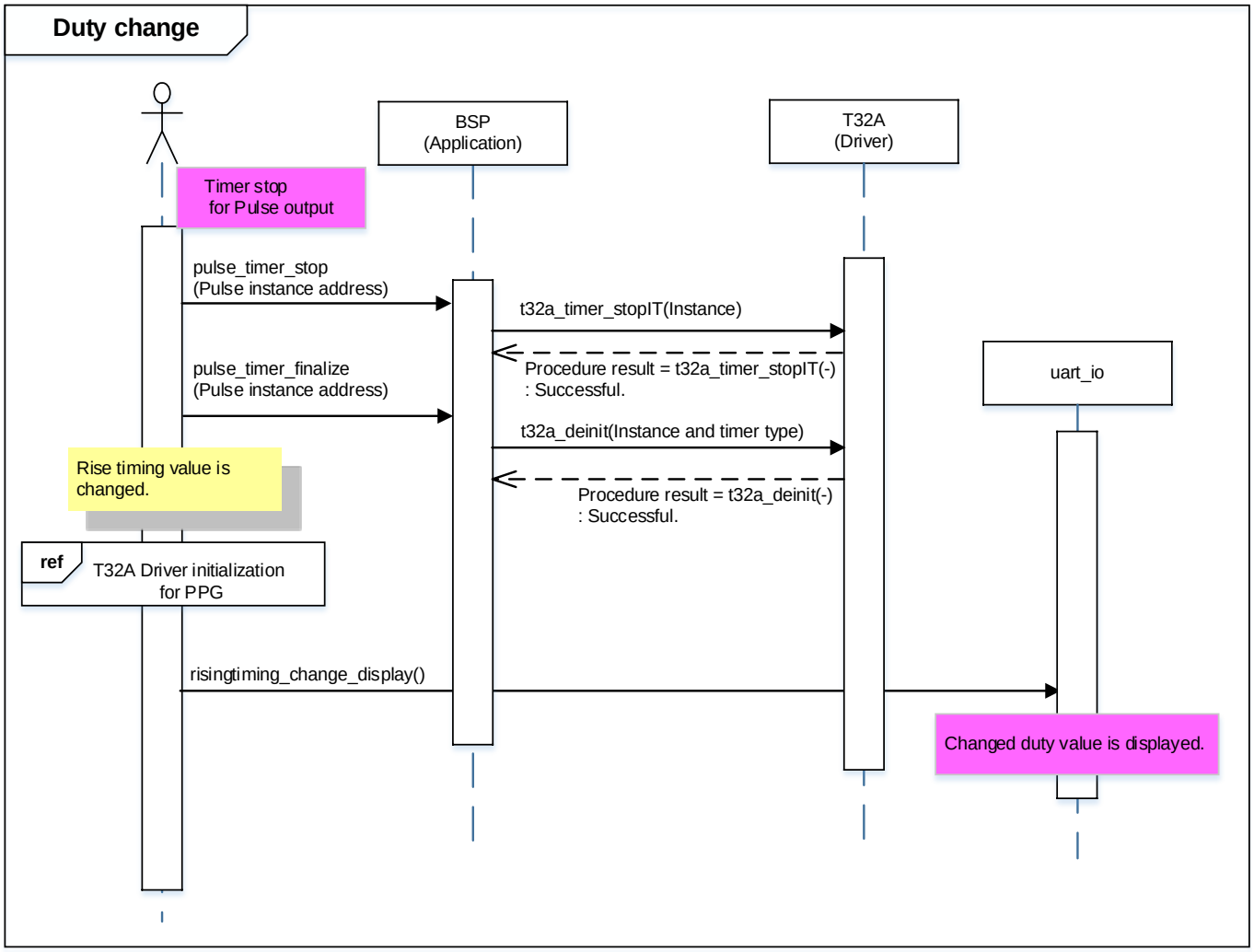

PPG Driver initialization
ref
T32A Driver initialization for PPG

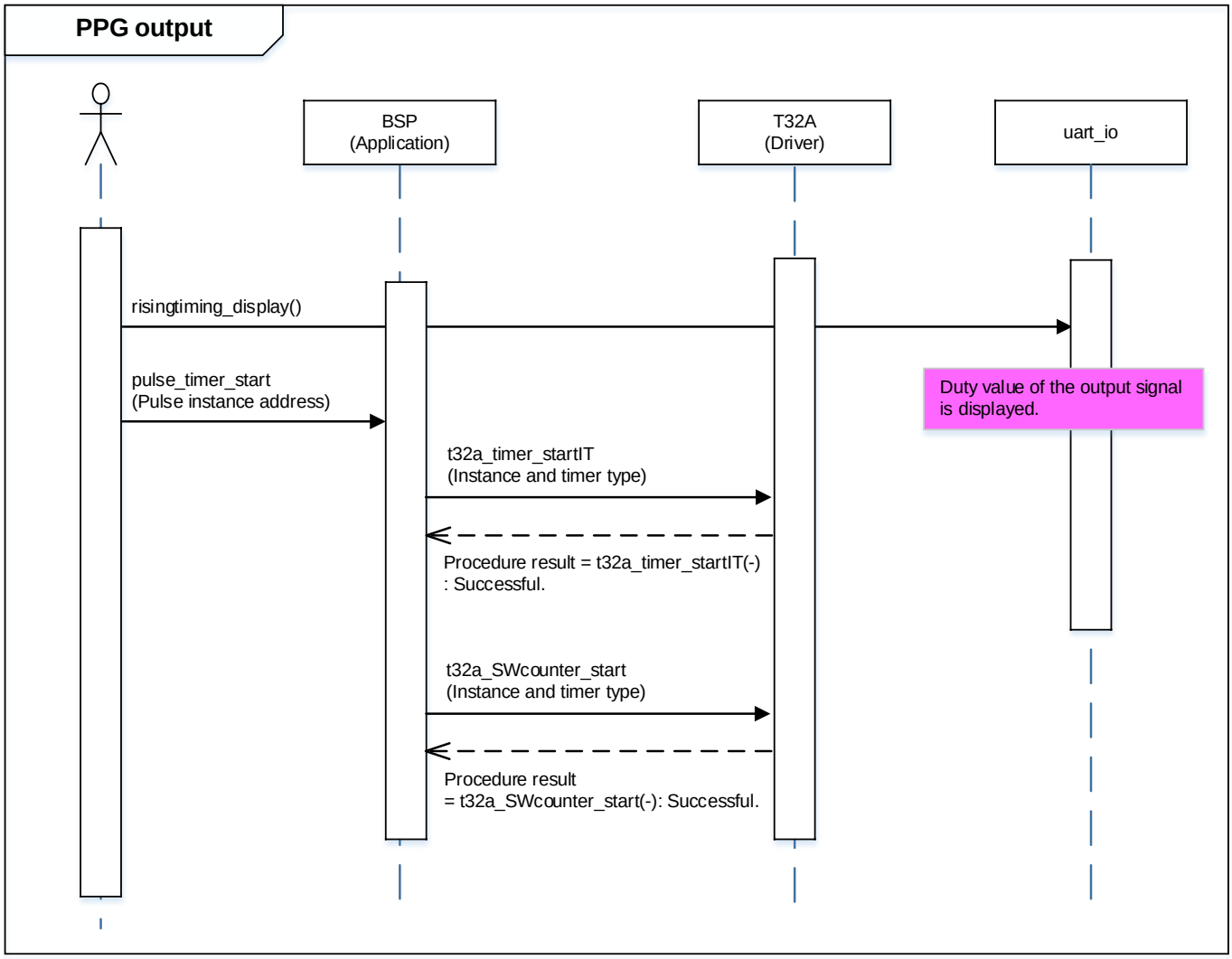

T32A Driver initialization for PPG
BSP
(Application)
Timer channel acquisition
for Pulse output
bsp_get_output_pulse_ch(BSPPulse)
Channel number = bsp_get_output_pulse_ch(-)
T32A
(Driver)
t32a_mode_init(Instance address)
Procedure result = t32a_mode_init(-)
: Successful.
pulse_initialize(Pulse instance address)
t32a_timer_init(Instance address)
Procedure result = t32a_timer_init(-)
: Successful.
Procedure result = pulse_initialize(-): Successful.


Application initialization
ref
UART Application initialization
loop
[1,Count of used SW' s]
ref
SW Application initialization


SW Application initialization
SW
Initial setting creation
sw_initialize(SW instance address)
SW
(Application)


Status surveilance
sw
(Application)
gpio
(Driver)
sw_task(SW instance address)
opt
[SW status check flag=ON]
gpio_read_bit
(Port instance address, group, num, DATA, and Storage address)
Result=gpio_read_bit(-): Successful.
opt
Port status has changed.
Registration handler for SW status
change notification
(SW instance address and ,Port status)
opt
[Port status=Push]
Process assigned to Push
SW's= Duty change/PPG
output
Registration handler for SW status
change notification (-)
sw_task(-)
opt
Process ==PROC_DUTY_CHANGE
ref
Duty change
opt
Process ==PROC_START
ref
PPG output


Duty change
BSP
(Application)
T32A
(Driver)
uart_io
Timer stop
for Pulse output
pulse_timer_stop
(Pulse instance address)
t32a_timer_stopIT(Instance)
Procedure result = t32a_timer_stopIT(-)
: Successful.
pulse_timer_finalize
(Pulse instance address)
t32a_deinit(Instance and timer type)
Procedure result = t32a_deinit(-)
: Successful.
Rise timing value is
changed.
ref
T32A Driver initialization
for PPG
risingtiming_change_display()
Changed duty value is displayed.


PPG output
BSP
(Application)
T32A
(Driver)
uart_io
risingtiming_display()
pulse_timer_start
(Pulse instance address)
Duty value of the output signal
is displayed.
t32a_timer_startIT
(Instance and timer type)
Procedure result = t32a_timer_startIT(-)
: Successful.
t32a_SWcounter_start
(Instance and timer type)
Procedure result
= t32a_SWcounter_start(-): Successful.

10. Precaution

When using the sample program with CPU other than TMPM4G9F15, please check operation sufficiently.

11. Revision History

Rev	Date	Page	Description
1.0	2018-12-12	-	First release

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