M4K Group (1)
Application Note
Trimming Circuit
(TRM-A)

Outlines

This application note is a reference material for developing products using the Trimming circuit (TRM) function of M4K Group (1).
This document helps the user check operation of the product and develop its program.

Target sample program: TRMOSC

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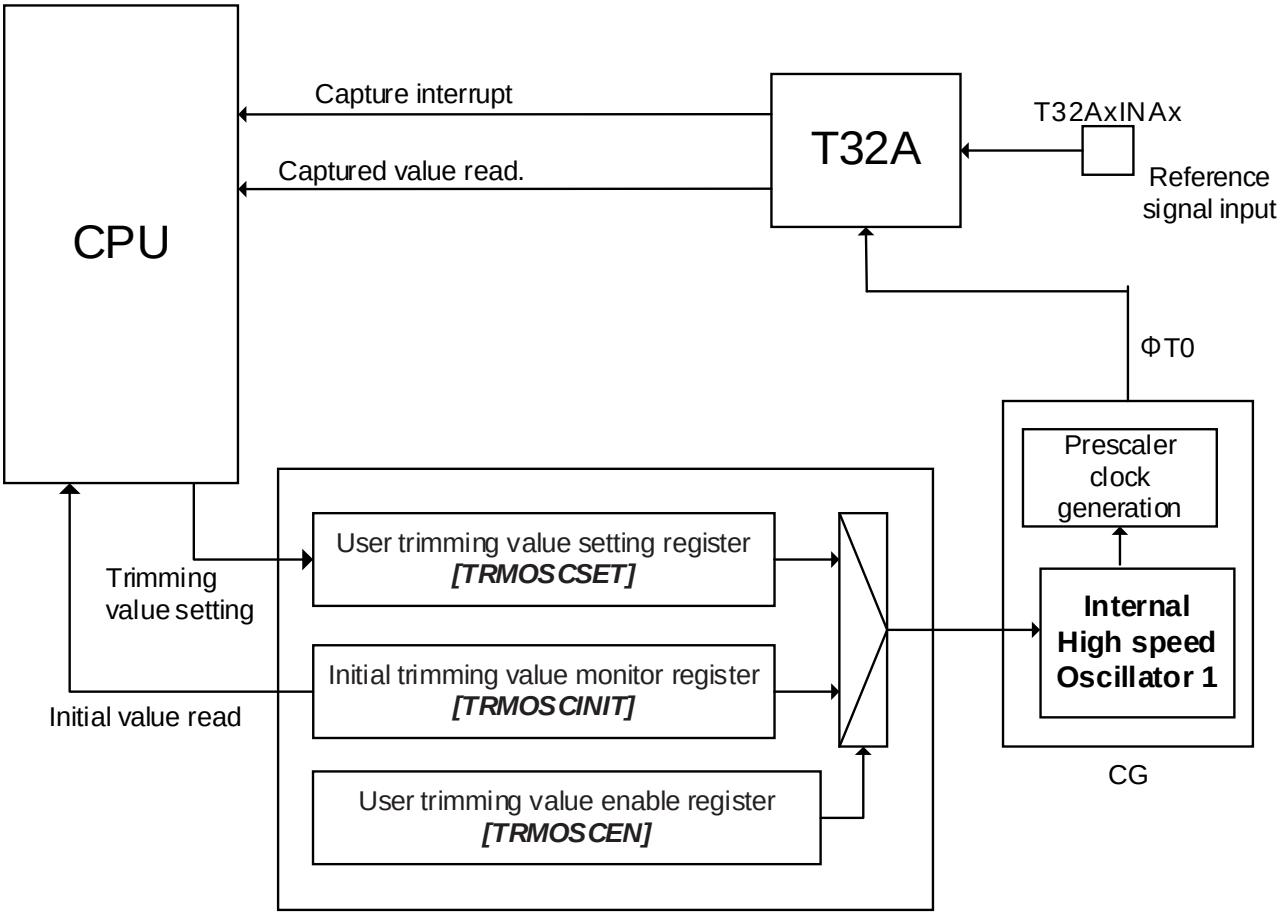
1. Preface

This sample program is used to adjust the internal oscillator using the Trimming circuit (TRM).
The frequency of the internal oscillator is corrected using the pulse measurement function of the Timer.
The correction of the frequency of the internal oscillator is done as follows;
A reference signal is input to T32AxINAx.

When the terminal software is connected, the set trimming value can be displayed.
A Programmable Rectangular Wave (PPG) is output. So the trimming value can be also checked by observing the wave form.

1.1. Reference Signal Input to T32AxINAx

A reference signal should be input to T32AxINAx. The difference between the target frequency and the captured frequency is calculated. Then the trimming value is determined and set.



Connection example when a reference signal is input to T32AxINAx

The frequencies of the following clocks should be set. For the setting values, refer to “Clock”.
Target frequency (Frequency of internal high speed oscillator1): f_{IHOSC1}
Frequency of the count clock for capture: f_{CAPCLK}
Frequency of Reference signal : f_{BASE}

For an example of the correction of the frequency of the internal oscillator using the timer pulse measurement function, refer to “5.1.1. Input of Reference Clock to T32AxINAx Pin” in the Reference manual of “Trimming Circuit”.

2. Reference Document

1. Datasheet
   TMPM4K Group (1) datasheet Rev2.0 (Japanese edition)
2. Reference manual
   Trimming Circuit (TRM-A) Rev4.0 (Japanese edition)
   Asynchronous Serial Communication Circuit (UART-C) Rev3.0 (Japanese edition)
   32-bit Timer Event Counter (T32A-B) Rev3.0 (Japanese edition)
3. Application note
   M4K Group (1) Application Note Startup (CMSIS System & Clock Configuration) Rev1.0
4. Other reference document
   TMPM4KxA Group Peripheral Driver User Manual (Doxygen) V1.0.4.0

3. Function to Use

IP	Channel	Port	Function/Operation mode
Trimming Circuit	-	-	Built-in oscillator frequency correction
Asynchronous Serial Communication Circuit	ch0	PK0 (UT0RXD) PK1 (UT0TXDA)	UART mode
32-bit Timer Event Counter	ch3	PC0 (T32A03OUTA)	PPG output
	ch2	PG1 (T32A02INA0)	External clock input

4. Target Device

The target devices of this application note are as follows;

TMPM4K4FYAUG	TMPM4K4FWAUG	TMPM4K4FUAUG	TMPM4K4FSAUG
TMPM4K4FYAFG	TMPM4K4FWAFG	TMPM4K4FUAFG	TMPM4K4FSAFG
TMPM4K2FYADUG	TMPM4K2FWADUG	TMPM4K2FUADUG	TMPM4K2FSADUG
TMPM4K1FYAUG	TMPM4K1FWAUG	TMPM4K1FUAUG	TMPM4K1FSAUG
			TMPM4K0FSADUG

* This sample program operates on the evaluation board of TMPM4K4FYAUG.
If other function than the TMPM4K4 one is checked, it is necessary that CMSIS Core related files (the startup file and I/O header file) should be changed properly.
Additionally, the name of microcontroller which is set to the project should be changed.
The BSP related file is dedicated to the evaluation board (TMPM4K4FYAUG). If other function than the TMPM4K4 one is checked, the BSP related file should be changed properly.

5. Operation Confirmation Condition

Used microcontroller	TMPM4K4FYAUG
Used board	TMPM4K4 evaluation board (Product of ESP-kikaku Co. Ltd.)
Integrated development environment	IAR Embedded Workbench for ARM 8.22.2
Integrated development environment	Arm® Keil® MDK Version 5.24.2.0
Terminal software	Tera Term V4.96
Sample program	v1.0.0

6. Evaluation Board Operation

Board function	Microcontroller pin name
PPG waveform output	PC0
Reference signal input	PG1

1. A PC should be connected with the USB_UART connector to communicate with the terminal software.
2. A reference signal should be input to the PG1.
3. The terminal software should be started up, and the communication setting should be done.
4. The reset button on the evaluation board should be pushed down.

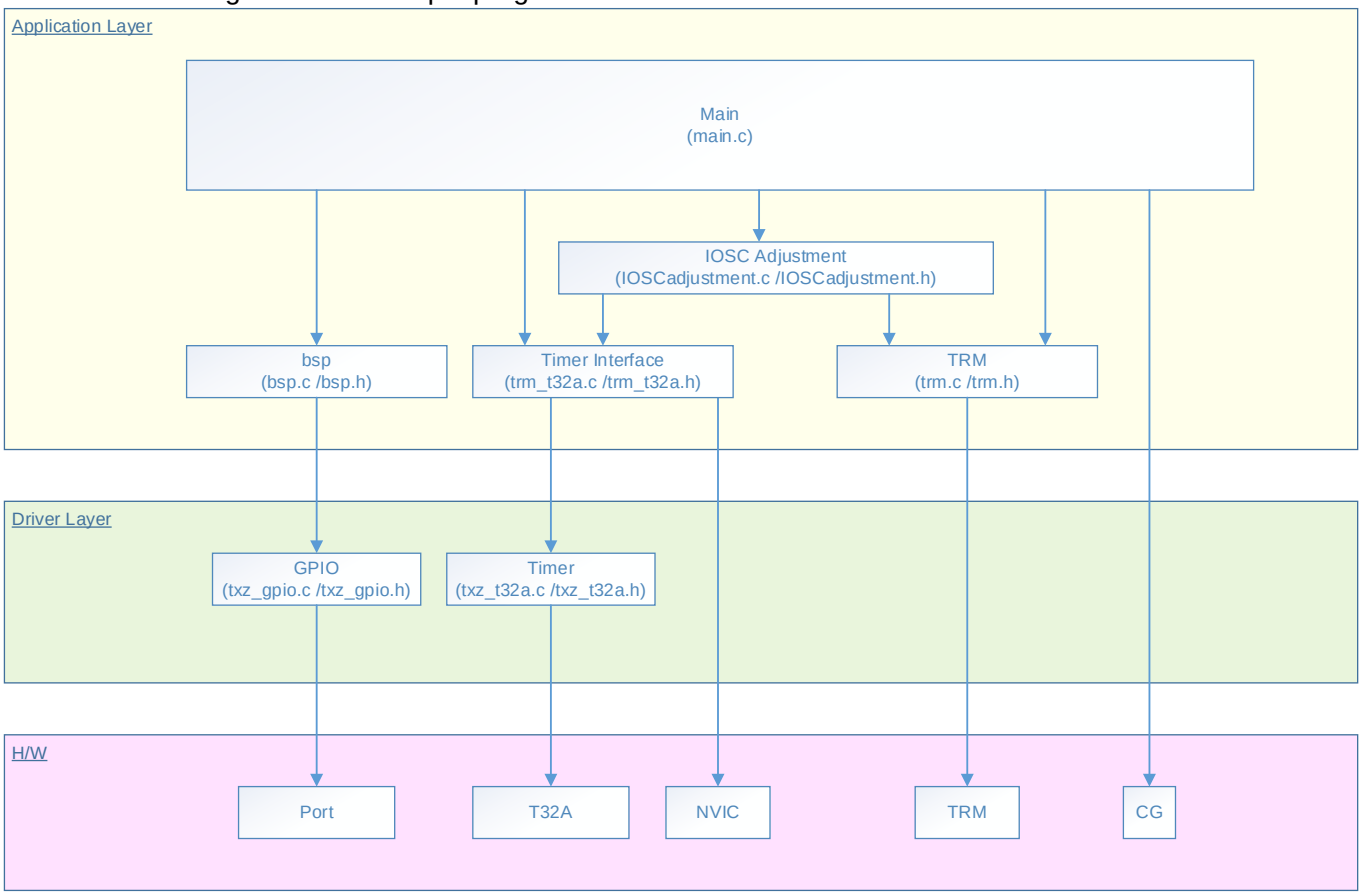
After the start-up, the following operations are enabled.

- The setting value of the trimming can be checked on the terminal software.
- The trimming value can be checked by a PPG waveform on the PC0.

7. Sample Program

7.1. Structure Diagram of Sample Software

The structure diagram of the sample program is shown below.



7.2. Each Setting

Each setting in the sample program is described in this section.

7.2.1. Clock

f_{BASE} : 240 Hz
f_{IHOSC1}: 10 MHz
Prescaler value (ΦT0): 1/1
f_{CAPCLK}: 5 MHz

7.2.2. Timer for Capture

- ***[T32AxCRA]*** (Counter control register A)

Bit symbol	Function	Setting
PRSCLA[2:0]	Prescaler division rate selection	001: 1/2
CLKA[2:0]	Count clock selection	000: Prescaler output
WBFA	Double buffer control	0: Disable
UPDNA[1:0]	Counter operation	00: Up-count
RELDA[2:0]	Counter reload condition	000: No reload (Free-run)
STOPA[2:0]	Counter stop condition	010: External trigger (T32AxINA0) rise edge
STARTA[2:0]	Counter start condition	011: External trigger (T32AxINA0) fall edge

- ***[T32AxCAPCRA]*** (Capture control register A)

Bit symbol	Function	Setting
CAPMA1[2:0]	[T32AxCAPA1] capture timing	010: External trigger (T32AxINA0) rise edge
CAPMA0[2:0]	[T32AxCAPA0] capture timing	011: External trigger (T32AxINA0) fall edge

7.2.3. Timer for PPG

- ***[T32AxCRA]*** (Counter control register A)

Bit symbol	Function	Setting
PRSCLA[2:0]	Prescaler division rate selection	000: 1/1
CLKA[2:0]	Count clock selection	000: Prescaler output
WBFA	Double buffer control	0: Disable
UPDNA[1:0]	Counter operation	00: Up-count
RELDA[2:0]	Counter reload condition	111: Match with the Timer register A1
STOPA[2:0]	Counter stop condition	000: A trigger is not used.
STARTA[2:0]	Counter start condition	000: A trigger is not used.

- ***[T32AxOUTCRA0]*** (Output control register A0)

Bit symbol	Function	Setting
OCRA[1:0]	T32AxOUTA control	00: No change

- ***[T32AxOUTCRA1]*** (Output control register A1)

Bit symbol	Function	Setting
OCRCAPA1[1:0]	T32AxOUTA control by the Capture register A1	00: Invalid.
OCRCAPA0[1:0]	T32AxOUTA control by the Capture register A0	00: Invalid.
OCRCMPA1[1:0]	T32AxOUTA control by the Comparator A1	11: Reversal
OCRCMPA0[1:0]	T32AxOUTA control by the Comparator A0	11: Reversal

- ***[T32AxRGA0]*** (Timer register A0)

Bit symbol	Function	Setting
RGA0[15:0]	A value is set to compare with the counter value.	0

- ***[T32AxRGA1]*** (Timer register A1)

Bit symbol	Function	Setting
RGA1[15:0]	A value is set to compare with the counter value.	1

- ***[T32AxRELDA]*** (Counter reload register A)

Bit symbol	Function	Setting
RELDA[15:0]	A value is set to reload the counter.	0

7.3. Outlines of Operation

The outlines of the operation of the sample program are described in this section.

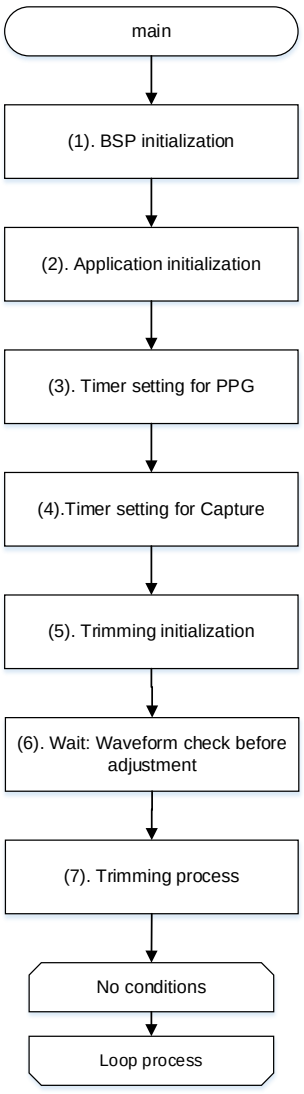
7.3.1. Startup Routine

The following initialization is done after power is supplied.

- Clock setting for the system core
- Setting of disable of the watchdog timer

7.3.2. Main Operation

After the initialization completes, the “main” function is executed. The following flow is done.



“main” flow

(1) BSP initialization
Clocks are supplied to peripheral functions and the ports are initialized.

(2) Application initialization
The following operation is done as the initialization of the application module.

- UART input and output control module (for communication with the terminal software)

(3) Timer setting for PPG
The setting of the Timer for the PPG is done.
For the setting value, refer to “Timer for PPG”

(4) Timer setting for Capture
The setting of the Timer for capture is done.

For the setting value, refer to “Timer for Capture”.

(5) Trimming initialization
Refer to “Trimming Initialization”.

(6) Wait: Waveform check before adjustment
A wait of any interval is prepared to check the PPG waveform before trimming.

(7) Trimming process
Refer to “Trimming Process”.

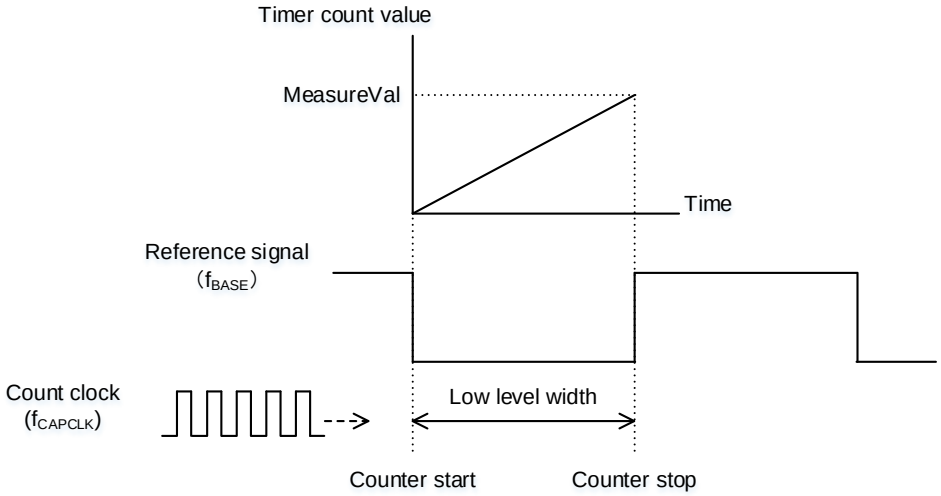
7.3.3. Trimming Initialization

The TRM register is normally initialized only by Power ON Reset.
In this sample program, however, the TRM register is initialized by the software because the trimming has not been adjusted yet at the startup.

7.3.4. Trimming Process

The Low level width is measured by the pulse width measurement. The measured width is compared with the target width of Low level. Then the frequency difference is calculated. The trimming value is determined by the frequency difference.

- Measured Low level width (MeasureVal)



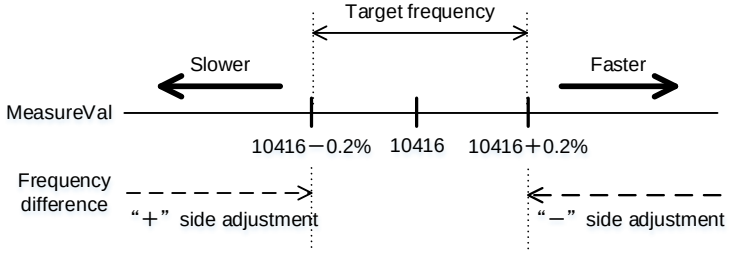
Pulse width measurement

For the measurement of the pulse width using the capture function, refer to “5.8. Pulse Width Measurement Using Capture Function” in the Reference manual of “32-bit Timer Event Counter”.

- Target Low level width

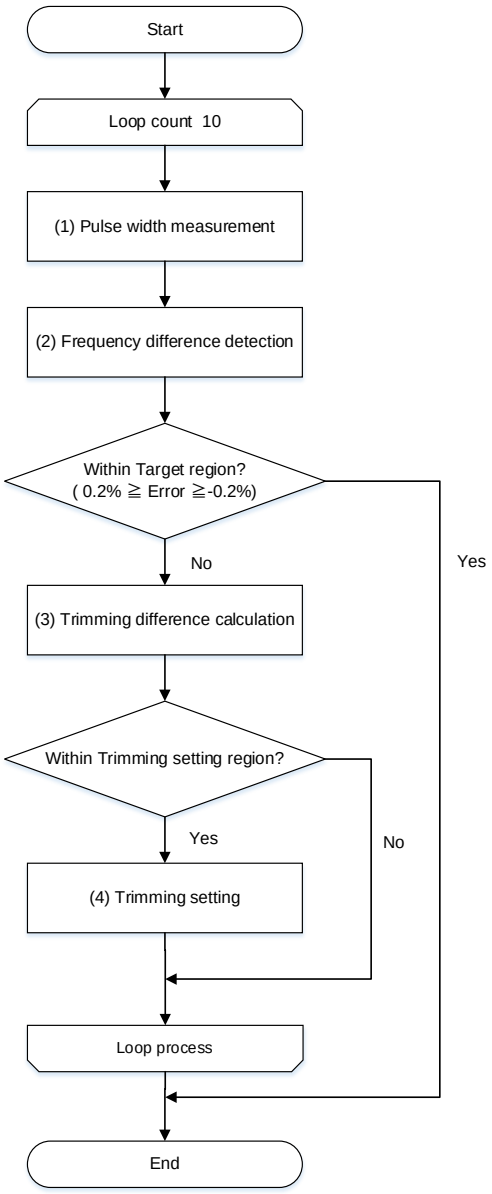
f_{CAPCLK}	Timer count value of Low width (Target value)
5 MHz	10416

The timer count of the target frequency should be in the target region of the MeasureVal (10416 ± 0.2%).
The trimming process should be done to realize the target frequency.



Target region of MeasureVal

The following flow shows the trimming process.



Trimming process flow

(1) Pulse width measurement
The Low level width of the reference signal is measured.
Refer to “Pulse Width Measurement”.

(2) Frequency difference calculation
The frequency difference is calculated using the pulse width measured in Step (1).
Refer to “Frequency Difference CalculationPulse Width Measurement”.

(3) Trimming value calculation
The trimming value is calculated using the frequency difference acquired in Step (2).
Refer to “Trimming Value Calculation”.

(4) Trimming setting
The trimming value acquired in Step (3) is set to the user trimming value.
Refer to “Trimming Setting”.

The trimming repeats predetermined times (the initial value is 10). Then the process completes.

7.3.4.1. Pulse Width Measurement

- Measured value of Low level width
  MeasureVal = ***[T32AxCAPA1]***<CAPA1[15:0]>

The following function executes the process in the source code.

File: IOSCadjustment.c
Function name: MeasureWave

7.3.4.2. Frequency Difference Calculation

The frequency difference is calculated using the measured value of the Low level width and the target value of the Low level width.

The target value of the Low level width has been calculated and defined as a constant value.

- Target value of Low level width
  #define CAPTUREVAL10MHZ (10416) /* Reference signal frequency 240 (Hz) */

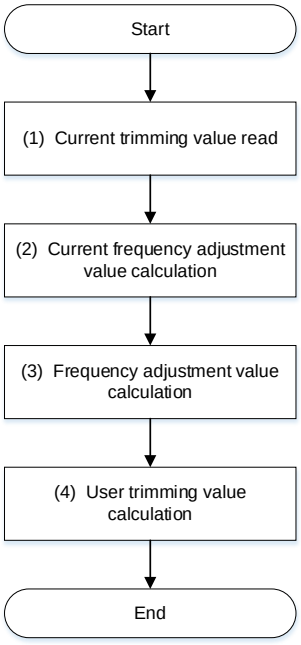
- Frequency difference (%)
  The difference value is calculated for adjustment.
  MeasureDiff = (1 - (MeasureVal ÷CAPTUREVAL10MHZ)) × 100

The following function executes the process in the source code.

File: IOSCadjustment.c
Function name: CalcDiff

7.3.4.3. Trimming Value Calculation

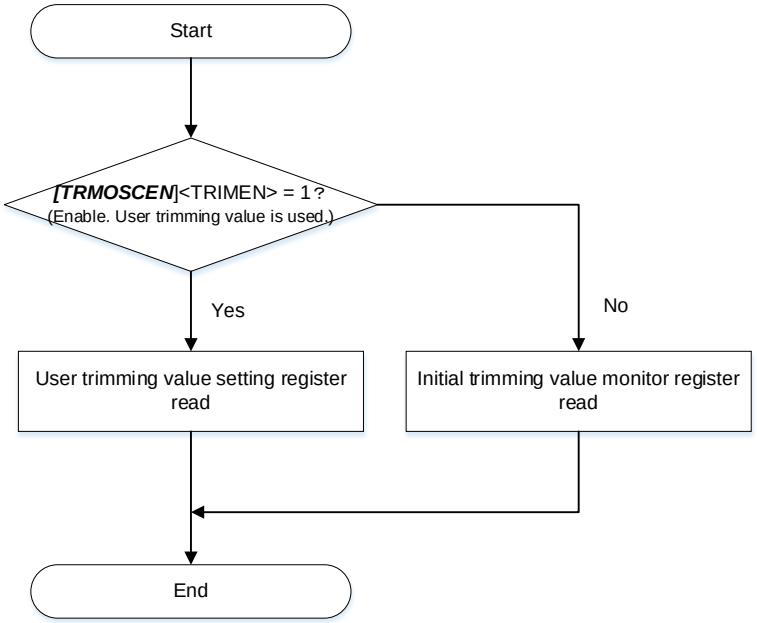
The trimming value is calculated by the following flow.



Trimming value calculation flow

(1) Current trimming value read

The current trimming value is read.
The read target register is selected by the value in the User trimming value enable control (***[TRMSCEN]***<TRIMEN>).



Current trimming value read flow

The trimming values can be read from the following registers.

- User trimming value setting register read
  Coarse trimming value:
  trimvalueC = ***[TRMOSCSET]***<TRIMSETC[5:0]>
  Fine trimming value:
  trimvalueF = ***[TRMOSCSET]***<TRIMSETF[3:0]>

- Initial trimming value setting register read
  Coarse trimming value:
  trimvalueC = ***[TRMOSCINIT]***<TRIMINITC[5:0]>
  Fine trimming value:
  trimvalueF = ***[TRMOSCINIT]***<TRIMINITF[3:0]>

The following function executes the process in the source code.

File:	IOSCadjustment.c
Function name:	GetAdjustmentValue

(2) Current Frequency Adjustment Value Calculation

The current frequency adjustment value is calculated using the read trimming value.
Each frequency adjustment value is calculated by multiplying the trimming value by an adjustment step value.

- Adjustment step

The following values in “1. Outlines” in the Reference manual should be used.

Coarse trimming mean step: 0.8%
Fine trimming step: 0.1%

- Coarse frequency adjustment value (%)

adjvalueC

- Fine frequency adjustment value (%)

adjvalueF

- Current frequency adjustment value (%)

adjvalue = adjvalueC + adjvalueF

The following function executes the process in the source code.

File: IOSCadjustment.c
Function name: GetAdjustmentValue

(3) Frequency adjustment value calculation

The frequency adjustment value is calculated.

- Frequency adjustment value (%)

difference = MeasureDiff + adjvalue

The following function executes the process in the source code.

File: IOSCadjustment.c
Function name: CalcAdjVal

(4) User trimming value calculation

The user trimming value is calculated using the frequency adjustment value.

The user trimming value is calculated by dividing each frequency adjustment value by an adjustment step value.

- Adjustment step

The following values in “1. Outlines” in the Reference manual should be used.

Coarse trimming mean step: 0.8%
Fine trimming step: 0.1%

- Coarse trimming value (Absolute value)

This value is a quotient of the frequency adjustment value divided by the coarse trimming mean step value.
coarse = (|difference| / 0.8)

- Fine trimming value (Absolute value)

This value is a quotient of the frequency adjustment value divided by the fine trimming step value.
fine = ((|difference|－(coarse × 0.8)) / 0.1)

The user trimming values are as follows;
In the case of (difference ≥ 0):

- Coarse trimming value

CoarseTrim = coarse

- Fine trimming value

FineTrim = fine

In the case of (difference < 0):

- Coarse trimming value

CoarseTrim = －coarse

- Fine trimming value
  FineTrim = －fine

The following function executes the process in the source code.
File: IOSCadjustment.c
Function name: CalcAdjVal

7.3.4.4. Trimming Setting

The user trimming value is stored in the User trimming value setting register ***[TRMOSCSET]***.

7.4. Change of Setting

7.4.1. Reference Signal Frequency

When the reference signal frequency is changed, the following should be modified in “IOSCadjustment.c”.

- Target value of Low level width
  #define CAPTUREVAL10MHZ (10416)

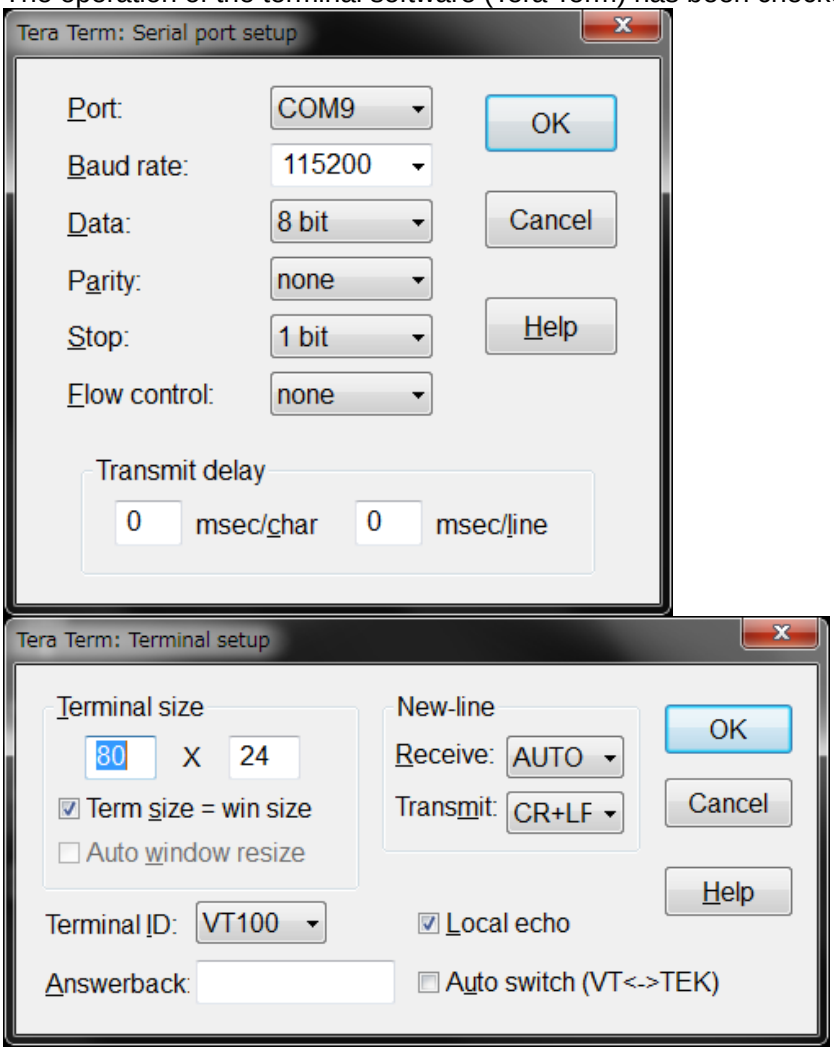
7.5. Output Example of Terminal Software

An output example of the terminal software is shown as follows;

```
--------------
| TRMOSC_demo |
--------------
please wait...
--------------
|    start    |
--------------
TRMOSC_RUN
<TRIMSETC>:0
<TRIMSETF>:B
TRMOSC_RUN
<TRIMSETC>:0
<TRIMSETF>:A
TRMOSC_DONE
<TRIMSETC>:0
<TRIMSETF>:A
```

7.5.1. Setting Example of Terminal Software

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



8. Points to Remember on Handling of Sample Programs

When using the sample program with other than “Operation Confirmation Condition” please check the operation sufficiently.

9. Revision History

Revision	Date	Description
1.0	2019-10-21	First release

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