RL78/G23
Timer Array Unit (Interval timer)

Introduction

This application note describes the interval timer function of the timer array unit (TAU). This unit inverts the LED indication each time a timer interrupt occurs. Also, it changes the timer interrupt cycle time based on the number of times the switch is pressed.

Target Device

RL78/G23

When applying the sample program covered in this application note to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.
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1. Specifications

1.1 Overview of Specifications

This application note describes an example setting for using timer interrupts (INTTM00) from the interval timer and interrupts (INTP0) generated on pin input edge detection.

The TAU inverts the LED indication each time a timer interrupt (INTTM00) occurs. Also, this unit changes the timer interrupt (INTTM00) cycle time based on the number of times the switch (SW) is pressed.

Table 1-1 lists the peripheral functions to be used and their uses. Figure 1-1 shows the timer and its interrupt operation.

Table 1-1 Peripheral Functions and Uses

<table>
<thead>
<tr>
<th>Peripheral Function</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timer array unit 0 (TAU0) channel 0</td>
<td>The 16-bits interval timer interrupt (INTTM00)</td>
</tr>
<tr>
<td></td>
<td>Controls the time interval for inversion of LED indication</td>
</tr>
<tr>
<td>P53</td>
<td>The output port for the LED indications</td>
</tr>
<tr>
<td>External interrupt</td>
<td>The pin input edge detection (INTP0) by switch input</td>
</tr>
<tr>
<td></td>
<td>Controls the interval between each generation of the timer interrupt (INTTM00)</td>
</tr>
</tbody>
</table>
Clock input supplied to TAU0

Count operation enabled

INTTM00 × 250

250

10 ms

INTTM00
1.2 Outline of Operation

This application note describes how to set up the interval timer function of TAU0.

This setup is followed by operation for counting the number of timer interrupts (INTTM00) generated by the interval timer. Each time the count reaches 250, the LED indication is inverted. The timer interrupt (INTTM00) cycle time is changed by changing the value of timer data register 00 (TDR00) according to the number of times the switch is pressed. The LED on/off cycle time is changed as follows.

500 ms -> 250 ms -> 125 ms -> 62.5 ms -> 500 ms

(1) Initialize the TAU.
   - Use the interval timer mode as the timer operation mode.
   - Initialize timer data register 00 (TDR00) to F9FFH (2 ms).
   - Set the timer output enable register to disable operation.
   - Use timer interrupts (INTTM00) from timer channel 0.

(2) Initialize the I/O port.
   - P53 pin: Set as an output port.

(3) Initialize the external interrupt.
   - Select a falling edge as the valid edge for INTP0.
   - Use INTP0 interrupts.

(4) Execute a HALT instruction and wait for a timer interrupt (INTTM00).

(5) After the HALT mode is cancelled by a timer interrupt (INTTM00), the number of INTTM00 interrupts generated is counted.

(6) When the timer interrupt count reaches 250, the LED indication is inverted. The value (g_tdr00_work) in RAM for the timer data register is set in the timer data register (TDR00).

(7) INTP0 interrupt processing changes the switch input count (INTP0 interrupt count) and g_tdr00_work value.
2. Operation Confirmation Conditions

The operation of the sample code provided with this application note has been tested under the following conditions.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MCU used</td>
<td>RL78/G23 (R7F100GLG)</td>
</tr>
<tr>
<td>Board used</td>
<td>RL78/G23 Fast Prototyping Board (RTK7RLG230CLG000BJ)</td>
</tr>
<tr>
<td>Operating frequency</td>
<td>High-speed on-chip oscillator clock: 32 MHz</td>
</tr>
<tr>
<td></td>
<td>CPU/peripheral hardware clock: 32 MHz</td>
</tr>
<tr>
<td>Operating voltage</td>
<td>3.3 V (can be operated at 1.8 V to 5.5 V)</td>
</tr>
<tr>
<td></td>
<td>LVD0 detection voltage: Reset mode</td>
</tr>
<tr>
<td></td>
<td>At rising edge TYP. 1.90 V (1.84 V to 1.95 V)</td>
</tr>
<tr>
<td></td>
<td>At falling edge TYP. 1.86 V (1.80 V to 1.91 V)</td>
</tr>
<tr>
<td>Integrated development</td>
<td>CS+ V8.05.00 from Renesas Electronics Corp.</td>
</tr>
<tr>
<td>environment (CS+)</td>
<td></td>
</tr>
<tr>
<td>C compiler (CS+)</td>
<td>CC-RL V1.10.00 from Renesas Electronics Corp.</td>
</tr>
<tr>
<td>Integrated development</td>
<td>e2 studio V2021-04 (21.4.0) from Renesas Electronics Corp.</td>
</tr>
<tr>
<td>environment (e2studio)</td>
<td></td>
</tr>
<tr>
<td>C compiler (e2studio)</td>
<td>CC-RL V1.10.00 from Renesas Electronics Corp.</td>
</tr>
<tr>
<td>Integrated development</td>
<td>IAR Embedded Workbench for Renesas RL78 V4.21.1 from IAR Systems Corp.</td>
</tr>
<tr>
<td>environment (IAR)</td>
<td></td>
</tr>
<tr>
<td>C compiler (IAR)</td>
<td>IAR C/C++ Compiler for Renesas RL78 V4.21.1 from IAR Systems Corp.</td>
</tr>
<tr>
<td>Smart configurator (SC)</td>
<td>V1.0.1 from Renesas Electronics Corp.</td>
</tr>
<tr>
<td>Board support package (BSP)</td>
<td>V1.00 from Renesas Electronics Corp.</td>
</tr>
</tbody>
</table>
3. Hardware Descriptions

3.1 Example of Hardware Configuration

Figure 3-1 shows an example of the hardware configuration used in the application note.

![Hardware Configuration Diagram]

**Note 1.** This simplified circuit diagram was created to show an overview of connections only. When actually designing your circuit, make sure the design includes appropriate pin handling and meets electrical characteristic requirements (connect each input-only port to VDD or VSS through a resistor).

**Note 2.** Connect any pins whose name begins with EVSS to VSS, and any pins whose name begins with EVDD to VDD, respectively.

**Note 3.** VDD must not be lower than the reset release voltage (VLVD0) that is specified for the LVD0.

3.2 List of Pins to be Used

Table 3-1 lists the pins to be used and their functions.

<table>
<thead>
<tr>
<th>Pin name</th>
<th>I/O</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>P53</td>
<td>Output</td>
<td>Output port for LED indications</td>
</tr>
<tr>
<td>P137 / INTP0</td>
<td>Input</td>
<td>Input pin for the switch (SW) (external interrupt request input pin)</td>
</tr>
</tbody>
</table>

**Caution** In this application note, only the used pins are processed. When actually designing your circuit, make sure the design includes sufficient pin processing and meets electrical characteristic requirements.
4. Software Explanation

4.1 Setting of Option Byte

Table 4-1 shows the option byte settings. Set the values that are most suited to your system as necessary.

<table>
<thead>
<tr>
<th>Address</th>
<th>Setting Value</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>000C0H / 040C0H</td>
<td>11101111B</td>
<td>Disables the watchdog timer. (Counting stopped after reset)</td>
</tr>
<tr>
<td>000C1H / 040C1H</td>
<td>11111110B</td>
<td>LVD0 detection voltage: reset mode</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At rising edge TYP. 1.90 V (1.84 V to 1.95 V)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>At falling edge TYP. 1.86 V (1.80 V to 1.91 V)</td>
</tr>
<tr>
<td>000C2H / 040C2H</td>
<td>11101000B</td>
<td>HS mode, High-speed on-chip oscillator clock (fIH): 32 MHz</td>
</tr>
<tr>
<td>000C3H / 040C3H</td>
<td>10000101B</td>
<td>Enables on-chip debugging</td>
</tr>
</tbody>
</table>

4.2 List of Constants

Table 4-2 shows the constants that are used in this sample program.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Setting</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>g_tdr00_data[]</td>
<td>(64000-1)</td>
<td>TDR00 settings by number of times the switch is pressed</td>
</tr>
<tr>
<td></td>
<td>(32000-1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(16000-1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(8000-1)</td>
<td></td>
</tr>
<tr>
<td>g_10ms_count[]</td>
<td>(5+1)</td>
<td>10 ms timer count values by number of times the switch is pressed</td>
</tr>
<tr>
<td></td>
<td>(10+1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(20+1)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(40+1)</td>
<td></td>
</tr>
</tbody>
</table>

4.3 List of Variables

Table 4-3 lists global variables.

<table>
<thead>
<tr>
<th>Type</th>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>__saddr uint8_t</td>
<td>g_sw_counter</td>
<td>Switch press count</td>
</tr>
<tr>
<td></td>
<td></td>
<td>main r_Config_INTC_intp0_interrupt</td>
</tr>
<tr>
<td>__saddr uint16_t</td>
<td>g_tdr00_work</td>
<td>Value which is set in TDR00 each time the timer interrupt count reaches 250.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>main r_invert_led r_Config_INTC_intp0_interrupt</td>
</tr>
<tr>
<td>__saddr uint8_t</td>
<td>g_inttm00_counter</td>
<td>The number of timer interrupt generation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>main r_invert_led</td>
</tr>
</tbody>
</table>
### 4.4 List of Functions

Table 4-4 shows a list of functions.

<table>
<thead>
<tr>
<th>Function name</th>
<th>Outline</th>
</tr>
</thead>
<tbody>
<tr>
<td>r_Config_TAU0_0_interrupt()</td>
<td>TAU0 channel 0 timer interrupt processing</td>
</tr>
<tr>
<td>r_Config_INTC_intp0_interrupt()</td>
<td>External interrupt processing.</td>
</tr>
<tr>
<td>r_invert_led()</td>
<td>Counts the number of INTTM00 interrupts generated. Inverts the LED indication each time the interrupt count reaches 250.</td>
</tr>
</tbody>
</table>

### 4.5 Specification of Functions

The function specifications of the sample code are shown below.

**r_Config_TAU0_0_interrupt()**

- **Outline**: TAU0 channel 0 timer interrupt processing
- **Header**: r_cg_macrodriver.h, r_cg_userdefine.h, Config_TAU0_0.h
- **Declaration**: static void __near r_Config_TAU0_0_interrupt(void)
- **Description**: This function calls the function which will invert the LED indication.
- **Argument**: None
- **Return Value**: None

**r_Config_INTC_intp0_interrupt()**

- **Outline**: External interrupt processing
- **Header**: r_cg_macrodriver.h, r_cg_userdefine.h, Config_INTC.h
- **Declaration**: static void __near r_Config_INTC_intp0_interrupt(void)
- **Description**: External interrupt (INTP0) processing by SW input. It waits 10 ms or longer and then scans P13.7 (SW input pin). When the switch is pressed, this function changes the g_tdr00_work value.
- **Argument**: None
- **Return Value**: None

**r_invert_led()**

- **Outline**: External interrupt processing
- **Header**: r_cg_macrodriver.h, r_cg_userdefine.h
- **Declaration**: void r_invert_led( void )
- **Description**: This function counts 250 timer interrupts (INTTM00) and then inverts the LED indication (for port latch inversion). It also changes the TDR00 setting to the value specified with g_tdr00_work.
- **Argument**: None
- **Return Value**: None
4.6 Flowcharts
4.6.1 Main Processing

Figure 4-1 shows the flowchart of the main processing.

Figure 4-1  Main Processing

```
main

Clear g_inttm00_counter
Clear g_sw_counter

Initialize interval value of TAU0 channel0

Enable external interrupt
R_Config_INTC_INTP0_Start()

Start operation of TAU0 channel0
R_Config_TAU0_0_Start()

Enable interrupts

IE←1

: while(1) loop

HALT

TAU0 channel0 timer interrupt (INTTM00)
External interrupt (INTP0)
```

![Flowchart Diagram](image-url)
4.6.2 TAU0 Channel 0 Timer Interrupt Processing

Figure 4-2 shows the flowchart of TAU0 channel 0 timer interrupt processing.

![Flowchart of TAU0 Channel 0 Timer Interrupt Processing]

1. \texttt{r_Config\_TAU0\_0\_interrupt}
2. Turn LED on / off
   - \texttt{r_invert\_led()}
3. return

---

**Figure 4-2** TAU0 Channel 0 Timer Interrupt Processing
4.6.3 External Interrupt Processing

Figure 4-3 and Figure 4-4 show the flowchart of external interrupt processing.

Figure 4-3  External Interrupt Processing (1/2)
Figure 4-4  External Interrupt Processing (2/2)

1

NO

SW pressed state?

YES

Update SW input count

g_sw_counter = 0\rightarrow 1\rightarrow 2\rightarrow 3\rightarrow 0

Update interval timer cycle time setting

Inject external interrupt request flag

return

g_sw_counter?

0

Interval timer cycle time
500 ms

1

Interval timer cycle time
250 ms

2

Interval timer cycle time
125 ms

3

Interval timer cycle time
62.5 ms

Update interval timer cycle time

PIF0 bit\rightarrow 0 : Clear INTP0 interrupt request flag

g_tdr00_work\rightarrow Table data reference
4.6.4 LED Turn-On/Off Processing

Figure 4-5 shows the flowchart of LED turn-on/off processing.
5. **Sample Code**

Sample code can be downloaded from the Renesas Electronics website.

6. **Reference Documents**

RL78/G23 User’s Manual: Hardware (R01UH0896J)
RL78 family user's manual software (R01US0015J)
The latest versions can be downloaded from the Renesas Electronics website.

Technical update
The latest versions can be downloaded from the Renesas Electronics website.

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## Revision History

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Page</th>
<th>Description</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Jun. 09, 2021</td>
<td>-</td>
<td></td>
<td>First Edition</td>
</tr>
</tbody>
</table>
1. Precaution against Electrostatic Discharge (ESD)

A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. Handling of unused pins

Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.

5. Clock signals

After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.

6. Voltage application waveform at input pin

Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between $V_{IL}$ (Max.) and $V_{IH}$ (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between $V_{IL}$ (Max.) and $V_{IH}$ (Min.).

7. Prohibition of access to reserved addresses

Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.
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