To our customers,

Old Company Name in Catalogs and Other Documents

On April 1\textsuperscript{st}, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: \url{http://www.renesas.com}

April 1\textsuperscript{st}, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (\url{http://www.renesas.com})
Send any inquiries to \url{http://www.renesas.com/inquiry}. 

"Renesas"
Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.

2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.

3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.

4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.

5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.

6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.

7. Renesas Electronics products are classified according to the following three quality grades: “Standard”, “High Quality”, and “Specific”. The recommended applications for each Renesas Electronics product depend on the product’s quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as “Specific” without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as “Specific” or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is “Standard” unless otherwise expressly specified in a Renesas Electronics data sheets or data books, etc.

“Standard”: Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.

“High Quality”: Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.

“Specific”: Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.

8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.

9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.

10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.

11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.

12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) “Renesas Electronics” as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) “Renesas Electronics product(s)” means any product developed or manufactured by or for Renesas Electronics.
H8/38099 Group
Using the TPU for Audio Output by PWM

Introduction
This application note describes an example of voice output by the 16-bit timer pulse unit (TPU) of an H8/38099F product in PWM operation.

Non-compressed 8-bit audio data, sampled at 8 kHz, are stored in the on-chip flash memory of the H8/38099F product.

Target Device
H8/38099F

Contents
1. Specification .................................................................................................................. 2
2. Applicable Conditions .................................................................................................. 3
3. Description of Hardware ............................................................................................. 4
4. Principles of Operation ............................................................................................... 6
5. Description of Software ............................................................................................. 10
1. Specification

(1) The 16-bit timer pulse unit (TPU) of the H8/38099F is used for output of a voice sound in PWM mode.
(2) Non-compressed 8-bit-length audio data (PCM data), sampled at 8 kHz, are stored in on-chip flash memory of the H8/38099F product.
(3) A low-pass filter and amplifier are externally connected to a PWM output pin (TIOCA1) to drive output of the voice sound from a speaker.
(4) Pressing the IRQ0 pin interrupt switch starts output of the voice sound. The LED connected to the I/O port (P90 pin) lights up during audio output.
(5) A block diagram of the hardware for this sample task is shown in figure 1. In this sample task, audio output is realized by externally connecting an audio-output circuit (low-pass filter, amplifier, speaker, etc.) to the starter kit (RSKH838099-1) manufactured by Renesas Technology.

(6) When the switch connected to the IRQ0 interrupt pin is pressed, the sound of a voice saying "Irasshaimase" is output. The specification of the audio data (PCM data) is shown in table 1.

Table 1 Specification of Audio Data (PCM)

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>8 bits</td>
</tr>
<tr>
<td>Sampling frequency</td>
<td>8 kHz</td>
</tr>
<tr>
<td>Number of channels</td>
<td>1 (monaural)</td>
</tr>
<tr>
<td>Total playback time</td>
<td>0.97 sec</td>
</tr>
<tr>
<td>Total number of samples</td>
<td>7,769</td>
</tr>
<tr>
<td>Data size</td>
<td>7,769 bytes</td>
</tr>
</tbody>
</table>
(7) In this sample application, all modules are initialized after release from the reset state; the chip is then placed in watch mode. Pressing the switch connected to the IRQ0 pin initiates a transition from watch mode to active mode (high-speed mode) in which audio output is performed. Once the audio output is completed, the chip reenters watch mode and again waits until the switch connected to the IRQ0 pin is pressed. A state transition diagram for this sample task is given as figure 2.

**Figure 2  State Transition Diagram**

### 2. Applicable Conditions

The applicable conditions for the H8/38099F product in this sample task are listed in table 2.

**Table 2  Applicable Conditions**

<table>
<thead>
<tr>
<th>Item</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>System clock frequency</td>
<td>Crystal oscillator frequency: 10 MHz</td>
</tr>
<tr>
<td></td>
<td>System clock (φ): 10 MHz</td>
</tr>
<tr>
<td>Sub clock frequency</td>
<td>Crystal oscillator frequency: 32.768 kHz</td>
</tr>
<tr>
<td></td>
<td>Watch clock (φW): 32.768 kHz</td>
</tr>
<tr>
<td>Power supply voltage</td>
<td>Vcc = AVcc = 3.3 V</td>
</tr>
</tbody>
</table>
3. Description of Hardware

3.1 Audio Output Block

PWM waveforms generated by the 16-bit timer pulse unit (TPU) of the H8/38099F product are input to the operational amplifier via the low-pass filter. A speaker is connected to the output of the operational amplifier to handle audio output. Figure 3 is a diagram of the audio output circuit.

![Figure 3 Circuit Diagram of Audio Output](image-url)
3.2 **IRQ0 Pin Interrupt Switch**

Figure 4 is a circuit diagram for the IRQ0 interrupt switch connected to the IRQ0 pin of the H8/38099F product. Pressing the switch releases the chip from watch mode, and initiates a transition to active mode (high-speed mode). Audio output is then performed in active mode.

![Figure 4 Circuit Diagram for the IRQ0 Pin Interrupt Switch](image)

3.3 **LED Block**

Figure 5 is a circuit diagram for the LED connected to the P90 pin of the H38099F product. When the output signal from the P90 pin switches to the high level, the LED light goes out. When the signal switches to the low level, the LED lights up.

![Figure 5 Circuit Diagram for the LED](image)
4. Principles of Operation

4.1 Description of Audio-Output Operation

Figure 6 illustrates audio-output operation. On-chip peripheral modules are initialized in active mode (high-speed mode) after release from the reset state; the H8/38099F chip then enters watch mode. Pressing the IRQ0-pin interrupt switch releases the chip from watch mode to perform audio output. The LED connected to the P90 pin lights up during audio output. Once the audio output is completed, the chip returns to watch mode and again waits until the IRQ0-pin interrupt switch is pressed.

<table>
<thead>
<tr>
<th>Operating mode</th>
<th>Active-H</th>
<th>Watch</th>
<th>Active-H</th>
<th>Watch</th>
<th>Active-H</th>
<th>Watch</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRQ0 pin input</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P90 pin output</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial setting</td>
<td>LED lights up</td>
<td>Audio output</td>
<td>LED lights up</td>
<td>Audio output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exit from reset</td>
<td>SLEEP instruction</td>
<td>IRQ0 interrupt</td>
<td>SLEEP instruction</td>
<td>IRQ0 interrupt</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SLEEP instruction</td>
<td></td>
<td>SLEEP instruction</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend
- Active-H: Active (high-speed) mode
- Watch: Watch mode

**Figure 6  Audio-Output Operation**
4.2 Description of PWM Output Operation by Using TPU

Figure 7 illustrates PWM output operation by the timer pulse unit (TPU) of the H8/38099F. In this sample application, channels 1 and 2 of the TPU are used to output PWM waveforms from the TIOCA1 pin. Channel 1 outputs a 40-kHz (39.0625-kHz) PWM waveform and channel 2 is used as an 8-kHz (7.8125-kHz) PWM timer.

Although the audio data in use were sampled at 8 kHz, setting the frequency of the PWM output waveform within the range of audible frequencies (20 Hz to 20 kHz) at 8 kHz will result in superposed noise (a tone) at 8 kHz. Therefore, channel 1 of the TPU is used to output a PWM waveform at 40-kHz (8 kHz x 5), i.e. out of the range of audible frequencies and at a multiple of the 8-kHz sampling frequency, from the TIOCA1 pin.

In the normal mode, the period of the signal on channel 2 is five times that of the signal on channel 1. Channel 2 is used to overwrite the audio data (duty cycle) of the PWM waveform for output from the TIOCA1 pin.
(1) Setting of TGRA_1 (Timer General Register A1)

Timer general register A1 (TGRA_1) is used as the cycle register for the PWM waveform output from the TIOCA1 pin. The input clock for the timer counter 1 (TCNT_1) is set to $\phi$. Since the sample size for the audio data is 8 bits, the TGRA_1 setting $\text{H'}\text{FF}$:

\[ \text{TGRA}_1 = \text{H'}\text{FF} \text{ (8-bit size (256) - 1)} \]

produces the following period for the PWM waveform output from the TIOCA1 pin.

\[ (1/(\phi)) \times 256 = 25.6 \mu s \]

(2) Setting of TGRB_1 (Timer General Register B1)

Timer general register B1 (TGRB_1) is used as the duty-cycle register for the PWM waveform output from the TIOCA1 pin. Settings for output of a PWM waveform from the TIOCA1 pin are initial output = 1, output on compare match with TGRA_1 = 1, and output on compare match with TGRB_1 = 0.

The duty-cycle setting in TGRB_1 is overwritten on a compare match with the TGRB_2 register of TPU_2.

\[ \text{TGRB}_1 = (\text{audio data} - 1) \]

(3) Setting of TGRA_2 (Timer General Register A2)

Timer general register A2 (TGRA_2) is used as the cycle register for the PWM timer to drive overwriting of the audio data (duty-cycle) setting in TGRB_1. The setting is for a period five times that for a compare match with TGRA_1. Although the audio data in use were sampled at 8 kHz, setting the frequency of the PWM output waveform within the range of audible frequencies at 8 kHz will result in an audible sound at 8 kHz. Therefore, the period of the PWM waveform output from the TIOCA1 pin is set to 40 kHz (39.0625 kHz), i.e. five times the sampling frequency of 8 kHz, with updating of the audio data at 8 kHz.

\[ \text{TGRA}_2 = ((8 \text{ bits (256)}) \times 5) - 1 = \text{H'}4\text{FF} \]

(4) Setting of TGRB_2 (Timer General Register B2)

Timer general register B2 (TGRB_2) is used as the duty-cycle register for the PWM timer to drive overwriting of the audio data (duty-cycle) setting in TGRB_1. The duty-cycle setting is for four cycles plus the duty cycle (4 cycles + duty cycle) of the 40-kHz (3.90625-kHz) PWM waveform output from the TIOCA1 pin.

\[ \text{TGRB}_2 = ((8 \text{ bits (256)} \times 4) + (\text{audio data})) - 1 \]
(5) Timing for Overwriting of Audio Data

Figure 8 shows the timing for overwriting of the audio data (duty cycle).

![Diagram showing timing for overwriting of audio data]

H'00FF = TGRA_1
(audio data\(\text{\textregistered} - 1\)) = TGRB_1
H'0000

H'04FF = TGRA_2
TGRB_2 = (H'0400 + audio data\(\text{\textregistered}\)) – 1
H'0000

The next audio datum (audio data\(\text{\textregistered}\)) is written to TGRB_1 and TGRB_2 by TG2B interrupt processing.

Figure 8  Timing for Overwriting of Audio Data
5. Description of Software

5.1 Operating Environment

Table 3 Operating Environment

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development tool</td>
<td>High-performance Embedded Workshop Ver.4.02.00.02</td>
</tr>
<tr>
<td>C/C++ complier</td>
<td>H8S, H8/300 SERIES C/C++ Compiler Ver.6.01.02</td>
</tr>
<tr>
<td>Compiler options</td>
<td>-cpu = 300HA:24 -object = &quot;$(CONFIGDIR)$(FILELEAF).obj&quot; -debug -nolist -chginincpath -nologo</td>
</tr>
</tbody>
</table>

Table 4 Section Settings

<table>
<thead>
<tr>
<th>Address</th>
<th>Section Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H'000000</td>
<td>CVECT</td>
<td>Vector table area</td>
</tr>
<tr>
<td>H'000100</td>
<td>P, C</td>
<td>Program area, constant area</td>
</tr>
<tr>
<td>H'FFFF380</td>
<td>B</td>
<td>On-chip RAM area (non-initialized data area)</td>
</tr>
</tbody>
</table>

Table 5 Vector Table for Interrupt Exception Handling

<table>
<thead>
<tr>
<th>Exception Handling Source</th>
<th>Vector No.</th>
<th>Address in Vector Table</th>
<th>Destination Interrupt Processing Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>RES</td>
<td>0</td>
<td>H'000000 to H'000003</td>
<td>main</td>
</tr>
<tr>
<td>Watchdog timer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>System reserved</td>
<td>1</td>
<td>H'000004 to H'000007</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>2</td>
<td>H'000008 to H'00000B</td>
<td>main</td>
</tr>
<tr>
<td>NMI</td>
<td>3</td>
<td>H'00000C to H'00000F</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>4</td>
<td>H'000010 to H'000013</td>
<td>main</td>
</tr>
<tr>
<td>Address break</td>
<td>5</td>
<td>H'000014 to H'000017</td>
<td>main</td>
</tr>
<tr>
<td>IRQ0</td>
<td>6</td>
<td>H'000018 to H'00001B</td>
<td>int_irq0</td>
</tr>
<tr>
<td>IRQ1</td>
<td>7</td>
<td>H'00001C to H'00001F</td>
<td>main</td>
</tr>
<tr>
<td>IRQAEC</td>
<td>8</td>
<td>H'000020 to H'000023</td>
<td>main</td>
</tr>
<tr>
<td>IRQ3</td>
<td>9</td>
<td>H'000024 to H'000027</td>
<td>main</td>
</tr>
<tr>
<td>IRQ4</td>
<td>10</td>
<td>H'000028 to H'00002B</td>
<td>main</td>
</tr>
<tr>
<td>WKP0</td>
<td>11</td>
<td>H'00002C to H'00002F</td>
<td>main</td>
</tr>
<tr>
<td>WKP1</td>
<td>12</td>
<td>H'000030 to H'000033</td>
<td>main</td>
</tr>
<tr>
<td>WKP2</td>
<td>13</td>
<td>H'000034 to H'000037</td>
<td>main</td>
</tr>
<tr>
<td>WKP3</td>
<td>14</td>
<td>H'000038 to H'00003B</td>
<td>main</td>
</tr>
<tr>
<td>WKP4</td>
<td>15</td>
<td>H'00003C to H'00003F</td>
<td>main</td>
</tr>
<tr>
<td>WKP5</td>
<td>16</td>
<td>H'000040 to H'000043</td>
<td>main</td>
</tr>
<tr>
<td>WKP6</td>
<td>17</td>
<td>H'000044 to H'000047</td>
<td>main</td>
</tr>
<tr>
<td>WKP7</td>
<td>18</td>
<td>H'000048 to H'00004B</td>
<td>main</td>
</tr>
<tr>
<td>RTC 0.25-second overflow</td>
<td>19</td>
<td>H'00004C to H'00004F</td>
<td>main</td>
</tr>
<tr>
<td>RTC 0.5-second overflow</td>
<td>20</td>
<td>H'000050 to H'000053</td>
<td>main</td>
</tr>
<tr>
<td>RTC second periodic overflow</td>
<td>21</td>
<td>H'000054 to H'000057</td>
<td>main</td>
</tr>
<tr>
<td>RTC minute periodic overflow</td>
<td>22</td>
<td>H'000058 to H'00005B</td>
<td>main</td>
</tr>
</tbody>
</table>
## Exception Handling Source Vector No. Address in Vector Table Destination Interrupt Processing Function

<table>
<thead>
<tr>
<th>Exception Handling Source</th>
<th>Vector No.</th>
<th>Address in Vector Table</th>
<th>Destination Interrupt Processing Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTC hour periodic overflow</td>
<td>23</td>
<td>H'000005C to H'000005F</td>
<td>main</td>
</tr>
<tr>
<td>RTC day periodic overflow</td>
<td>24</td>
<td>H'0000060 to H'0000063</td>
<td>main</td>
</tr>
<tr>
<td>RTC week periodic overflow</td>
<td>25</td>
<td>H'0000064 to H'0000067</td>
<td>main</td>
</tr>
<tr>
<td>RTC free-running overflow</td>
<td>26</td>
<td>H'0000068 to H'000006B</td>
<td>main</td>
</tr>
<tr>
<td>WDT overflow</td>
<td>27</td>
<td>H'000006C to H'000006F</td>
<td>main</td>
</tr>
<tr>
<td>AEC</td>
<td>28</td>
<td>H'0000070 to H'0000073</td>
<td>main</td>
</tr>
<tr>
<td>TPU TG1A</td>
<td>29</td>
<td>H'0000074 to H'0000077</td>
<td>main</td>
</tr>
<tr>
<td>TPU TG1B</td>
<td>30</td>
<td>H'0000078 to H'000007B</td>
<td>main</td>
</tr>
<tr>
<td>TPU TC11V</td>
<td>31</td>
<td>H'000007C to H'000007F</td>
<td>main</td>
</tr>
<tr>
<td>TPU TG2A</td>
<td>32</td>
<td>H'0000080 to H'0000083</td>
<td>main</td>
</tr>
<tr>
<td>TPU TG2B</td>
<td>33</td>
<td>H'0000084 to H'0000087</td>
<td>int_tg2b</td>
</tr>
<tr>
<td>TPU TC12V</td>
<td>34</td>
<td>H'0000088 to H'000008B</td>
<td>main</td>
</tr>
<tr>
<td>Timer FL</td>
<td>35</td>
<td>H'000008C to H'000008F</td>
<td>main</td>
</tr>
<tr>
<td>Timer FH</td>
<td>36</td>
<td>H'0000090 to H'0000093</td>
<td>main</td>
</tr>
<tr>
<td>SCI4</td>
<td>37</td>
<td>H'0000094 to H'0000097</td>
<td>main</td>
</tr>
<tr>
<td>SCI3_1</td>
<td>38</td>
<td>H'0000098 to H'000009B</td>
<td>main</td>
</tr>
<tr>
<td>SCI3_2</td>
<td>39</td>
<td>H'000009C to H'000009F</td>
<td>main</td>
</tr>
<tr>
<td>IIC2</td>
<td>40</td>
<td>H'00000A0 to H'00000A3</td>
<td>main</td>
</tr>
<tr>
<td>10-bit A/D</td>
<td>41</td>
<td>H'00000A4 to H'00000A7</td>
<td>main</td>
</tr>
<tr>
<td>Direct transition</td>
<td>42</td>
<td>H'00000A8 to H'00000AB</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>43</td>
<td>H'00000AC to H'00000AF</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>44</td>
<td>H'00000B0 to H'00000B3</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>45</td>
<td>H'00000B4 to H'00000B7</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>46</td>
<td>H'00000B8 to H'00000BB</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>47</td>
<td>H'00000BC to H'00000BF</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>48</td>
<td>H'00000C0 to H'00000C3</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>49</td>
<td>H'00000C4 to H'00000C7</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>50</td>
<td>H'00000C8 to H'00000CB</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>51</td>
<td>H'00000CC to H'00000CF</td>
<td>main</td>
</tr>
<tr>
<td>System reserved</td>
<td>52</td>
<td>H'00000D0 to H'00000D3</td>
<td>main</td>
</tr>
<tr>
<td>Timer C</td>
<td>53</td>
<td>H'00000D4 to H'00000D7</td>
<td>main</td>
</tr>
<tr>
<td>Timer G</td>
<td>54</td>
<td>H'00000D8 to H'00000DB</td>
<td>main</td>
</tr>
<tr>
<td>SCI_3</td>
<td>55</td>
<td>H'00000DC to H'00000DF</td>
<td>main</td>
</tr>
</tbody>
</table>
5.2 List of Functions

Table 6 List of Functions

<table>
<thead>
<tr>
<th>Function Name</th>
<th>Description</th>
</tr>
</thead>
</table>
| main          | Main routine  
                 Specifies stack pointers, initializes on-chip peripheral modules, controls interrupts, the transition to watch mode, and the LED. |
| int_irq0      | IRQ0 interrupt handling routine  
                 Clears interrupt request flags. |
| int_tg2b      | TG2B interrupt handling routine  
                 Clears interrupt request flags and makes the duty-cycle settings in TGRB_1 and TGRB_2. |
| initialize    | Initialization subroutine  
                 Initializes the watchdog timer, module standby mode, and I/O pins. |
| init_tpu      | TPU initialization subroutine  
                 Initializes the TPU. |

5.3 List of On-Chip RAM Areas in Use (Non-Initialized Data Area)

Table 7 List of On-Chip RAM Areas in Use

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Variable Name</th>
<th>Description</th>
<th>Address</th>
<th>Used in</th>
</tr>
</thead>
<tbody>
<tr>
<td>unsigned short</td>
<td>voice_cnt</td>
<td>Counter for audio data</td>
<td>H’FFF380</td>
<td>main, int_tg2b, init_tpu</td>
</tr>
</tbody>
</table>

5.4 List of Constant Areas

Table 8 List of Constant Areas

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Constant Name</th>
<th>Description</th>
<th>Address</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Const unsigned short</td>
<td>DATA_SIZE</td>
<td>Audio data size</td>
<td>H’000276</td>
<td>H’1E59</td>
</tr>
<tr>
<td>Const unsigned char</td>
<td>VOICE_DATA [0]</td>
<td>Audio data (0)</td>
<td>H’000278</td>
<td>H’80</td>
</tr>
<tr>
<td>Const unsigned char</td>
<td>VOICE_DATA [1]</td>
<td>Audio data (1)</td>
<td>H’000279</td>
<td>H’80</td>
</tr>
<tr>
<td>Const unsigned char</td>
<td>VOICE_DATA [7767]</td>
<td>Audio data (7767)</td>
<td>H’0020CF</td>
<td>H’80</td>
</tr>
<tr>
<td>Const unsigned char</td>
<td>VOICE_DATA [7768]</td>
<td>Audio data (7768)</td>
<td>H’0020D0</td>
<td>H’80</td>
</tr>
</tbody>
</table>
5.5 Description of Functions

5.5.1 main Function (main routine)

1. Functional Overview
   This function specifies stack pointers, initializes on-chip peripheral modules, and controls interrupts, the transition to watch mode, starting of the TPU counters, and the LED.

2. Arguments
   None

3. Return value
   None
4. Flowchart

```
main
  SP = H'FFFF80
  initialize
    IRR10 = 0
    IEN0 = 1
  CCR I-bit = 0
  SLEEP
    IEN0 = 0
    TGFB_2 = 0
    TGIEB_2 = 1
    TSTR = H'06
    P90 = 0

voice_cnt < DATA_SIZE

Yes
  Audio output in progress

No
  P90 = 1
  TGIEB_2 = 0
  init_tpu
    IRR10 = 0
    IEN0 = 1

Figure 9  Flowchart of main Function
```
5.5.2 int_irq0 Function

1. Functional Overview
   IRQ0 interrupt handling routine; performs wait processing to eliminate chattering signal from the IRQ0-pin interrupt switch, and clears the IRQ0 interrupt request flag.

2. Arguments
   None

3. Return value
   None

4. Flowchart

![Flowchart of int_irq0 Function](image)

**Figure 10 Flowchart of int_irq0 Function**
5.5.3 int_tg2b Function

1. Functional Overview
   TG2B interrupt handling routine of TPU_2; clears the TG2B interrupt flag and makes audio-data (duty-cycle) settings in TGRB_1 and TGRB_2.

2. Arguments
   None

3. Return value
   None

4. Flowchart

   int_tg2b
   --------------- Clearing of TG2B interrupt request flag
   TGFB_2 = 0
   --------------- Setting of audio data (duty cycle) in TGRB_1
   Set the duty cycle in TGRB_1
   • TGRB_1 = audio data – 1
   --------------- Setting of audio data (duty cycle) in TGRB_2
   Set the duty cycle in TGRB_2
   • TGRB_2 = (H'400 + audio data) – 1
   Return

Figure 11 Flowchart of int_tg2b Function
5.5.4 initialize Function

1. Functional Overview
   This function halts the watchdog timer, makes settings for module standby mode and for initialization of the I/O pin (pin P90 connected to the LED), TPU, IRQ0 pin, and the system control register for the transition to watch mode.

2. Arguments
   None

3. Return value
   None

4. Flowchart

Figure 12 Flowchart of initialize Function
5.5.5 init_tpu Function

1. Functional Overview
   This function initializes the TPU.

2. Arguments
   None

3. Return value
   None

4. Flowchart

   ![Flowchart of init_tpu Function]

   - **voice_cnt = H'0000**
     - Initialization of on-chip RAM areas
   - **TSTR = H'00**
     - Stops the timer counters (TCNT_1 and TCNT_2)
   - **TCR_1 = H'20**
     - TCNT_1 starts counting on a rising edge from the internal clock (φ) and is cleared by a compare match with TGRA_1.
   - **TIOR_1 = H'16**
     - Initial output from the TIOCA1 pin is 1. The TIOCA1 outputs 0 on compare matches with TGRB_1 and 1 on compare matches with TGRA_1.
   - **TCNT_1 = H'0000**
     - Initialization of TCNT_1
   - **TGRA_1 = H'00FF**
     - Setting of the cycle period (25.6 µs) in TGRA_1
   - **TMDR_1 = H'C2**
     - Setting of the duty cycle (audio data) in TGRB_1
       - TGRB_1 = audio data - 1
   - **TCR_2 = H'20**
     - TPU_1 operates in PWM mode 1.
   - **TIOCA2 and TIOCB2 is disabled.**
   - **TCNT_2 = H'0000**
     - Initialization of TCNT_2
   - **TGRA_2 = H'04FF**
     - Setting of the cycle period (128 µs) in TGRA_2
   - **TMDR_2 = H'C0**
     - Setting of the duty cycle (audio data) in TGRB_2
       - TGRB_2 = (H'0400 + audio data) - 1
   - **voice_cnt = H'0000**
     - Output from TIOCA2 and TIOCB2 is disabled.
   - **Return**

   **Figure 13 Flowchart of init_tpu Function**
Website and Support

Renesas Technology Website
http://www.renesas.com/

Inquiries
http://www.renesas.com/inquiry
csc@renesas.com

Revision Record

<table>
<thead>
<tr>
<th>Rev.</th>
<th>Date</th>
<th>Description</th>
<th>Page</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>Apr.17.08</td>
<td></td>
<td></td>
<td>First edition issued</td>
</tr>
</tbody>
</table>
Notes regarding these materials

1. This document is provided for reference purposes only so that Renesas customers may select the appropriate Renesas products for their use. Renesas neither makes warranties or representations with respect to the accuracy or completeness of the information contained in this document nor grants any license to any intellectual property rights or any other rights of Renesas or any third party with respect to the information in this document.

2. Renesas shall have no liability for damages or infringement of any intellectual property or other rights arising out of the use of any information in this document, including, but not limited to, product data, diagrams, charts, programs, algorithms, and application circuit examples.

3. You should not use the products or the technology described in this document for the purpose of military applications such as the development of weapons of mass destruction or for the purpose of any other military use. When exporting the products or technology described herein, you should follow the applicable export control laws and regulations, and procedures required by such laws and regulations.

4. All information included in this document such as product data, diagrams, charts, programs, algorithms, and application circuit examples, is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas products listed in this document, please confirm the latest product information with a Renesas sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas such as that disclosed through our website. (http://www.renesas.com)

5. Renesas has used reasonable care in compiling the information included in this document, but Renesas assumes no liability whatsoever for any damages incurred as a result of errors or omissions in the information included in this document.

6. When using or otherwise relying on the information in this document, you should evaluate the information in light of the total system before deciding about the applicability of such information to the intended application. Renesas makes no representations, warranties or guaranties regarding the suitability of its products for any particular application and specifically disclaims any liability arising out of the application and use of the information in this document or Renesas products.

7. With the exception of products specified by Renesas as suitable for automobile applications, Renesas products are not designed, manufactured or tested for applications or otherwise in systems the failure or malfunction of which may cause a direct threat to human life or create a risk of human injury or which require especially high quality and reliability such as safety systems, or equipment or systems for transportation and traffic, healthcare, combustion control, aerospace and aeronautics, nuclear power, or undersea communication transmission. If you are considering the use of our products for such purposes, please contact a Renesas sales office beforehand. Renesas shall have no liability for damages arising out of the uses set forth above.

8. Notwithstanding the preceding paragraph, you should not use Renesas products for the purposes listed below:
   (1) artificial life support devices or systems
   (2) surgical implantations
   (3) healthcare intervention (e.g., excision, administration of medication, etc.)
   (4) any other purposes that pose a direct threat to human life

Renesas shall have no liability for damages arising out of the uses set forth in the above and purchasers who elect to use Renesas products in any of the foregoing applications shall indemnify and hold harmless Renesas Technology Corp., its affiliated companies and their officers, directors, and employees against any and all damages arising out of such applications.

9. You should use the products described herein within the range specified by Renesas, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas shall have no liability for malfunctions or damages arising out of the use of Renesas products beyond such specified ranges.

10. Although Renesas endeavors to improve the quality and reliability of its products, IC products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Please be sure to implement safety measures to guard against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other applicable measures. Among others, since the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.

11. In case Renesas products listed in this document are detached from the products to which the Renesas products are attached or affixed, the risk of accident such as swallowing by infants and small children is very high. You should implement safety measures so that Renesas products may not be easily detached from your products. Renesas shall have no liability for damages arising out of such detachment.

12. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written approval from Renesas.

13. Please contact a Renesas sales office if you have any questions regarding the information contained in this document, Renesas semiconductor products, or if you have any other inquiries.