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# R8C Family, H8/300H Tiny Series, and M16C/Tiny Series

## M3S-DTMF-Tiny: DTMF Tone Generation/Detection Software for Tiny Microcontrollers

### Introduction

This document explains the usage of the DTMF Tone Generation/Detection software library along with a sample program.

### Target device

Tiny microcomputer (R8C Family, H8/300H Tiny Series, and M16C/Tiny Series)

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## 1. Generation

### 1.1 Library functions

This section explains the specifications of the library functions.

#### 1.1.1 DTMF Generation (ExecutedDTMFGen)

Prototype

```
unsigned int* ExecutedDTMFGen(unsigned char uc_DTMF_Key);
```

Explanation

This function returns the address of the Lookup Table containing PWM Duty Cycle values corresponding to the DTMF Key passed as the argument.

This function has to be executed only once for retrieving the pointer to the Lookup Table values for the required DTMF key. Thereafter the pointer can be incremented to retrieve successive look up table values for PWM waveform generation. There are a total of 512 lookup table values for the PWM duty cycle corresponding to each key.

The argument `uc_DTMF_Key` specifies the key for which DTMF tone is to be generated.

**Table 1: Arguments for the DTMF generation function**

Argument	Type	Explanation
<code>uc_DTMF_Key</code>	unsigned char	Key for which DTMF tone is to be generated

Return value

**Table 2: Return values from the DTMF generation function**

Type	Explanation
unsigned int*	Top address of lookup table containing the PWM duty cycle values for <code>uc_DTMF_Key</code>

## 1.2 Sample program

This section explains the sample program for DTMF Key Tone generation. The sample program is in the form of a HEW (High-Performance Embedded Workshop) workspace. Change the initialization of the microcomputer and its peripherals according to the system in use.

### 1.2.1 Outline

When the switch is pressed for the first time, the DTMF tone for the Key 0 is output. On successive key presses, the key value is incremented and the corresponding DTMF tone is outputted.

In the main function, the counter for the DTMF keys is initialized to zero at the start. When the switch is pressed, this DTMF key is passed to the library function. The library function returns the pointer to the Lookup Table containing the PWM Duty Cycle values corresponding to the key. These Duty Cycle values are passed to the timer which generates the PWM waveform as per the duty cycle values. This PWM waveform corresponding to the DTMF key is output on the PWM output pin. The DTMF tone can be heard by connecting the PWM output to an external speaker circuit (\*). On the next switch press, the DTMF key is incremented and the PWM waveform corresponding to the next tone is output. This continues till all the 16 DTMF key tones are output. Thereafter, the key is again reset to zero.

The DTMF Lookup Table values in the library are calculated for a frequency of 16 kHz. The PWM in the sample software is also operating at a frequency of 16 kHz. If the user wishes, the frequency can be increased to a suitable value by making appropriate modifications to the `init_pwm` function.

The size of the PWM Duty Cycle lookup table is determined by the following macro.

Size of Look Up Table

Macro name: ENCLUTSIZE

(\*) A typical external speaker circuit will consist of an analog filter, an amplifier and a speaker. Please note that this speaker circuit will have to be made by the user. The circuit will not come with the Renesas Solutions Kits that the user intends to buy and is not available from Renesas.

1.2.2 Flow

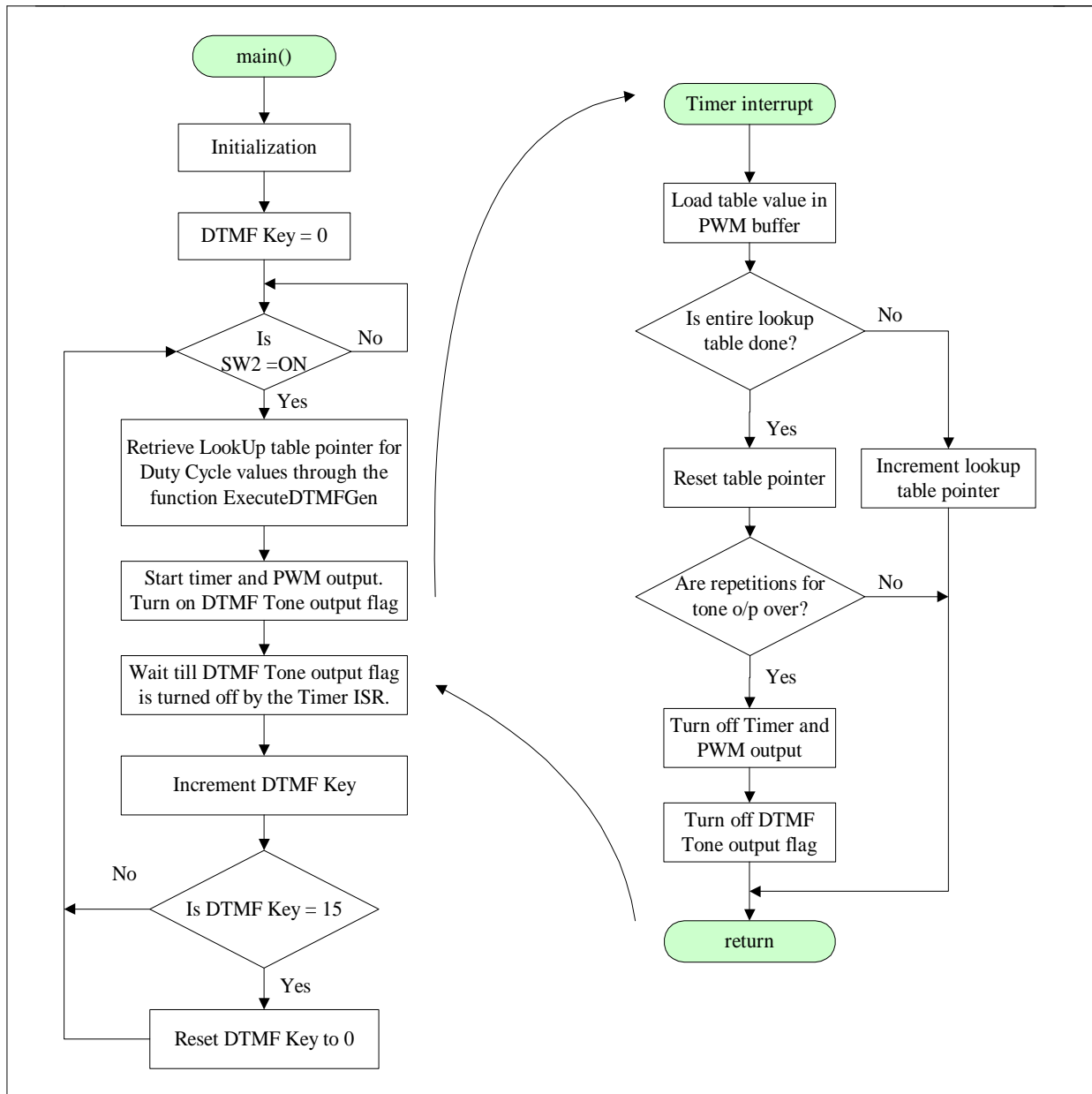


Figure 1: Flow of sample program

### 1.2.3 Function list

**Table 3: List of functions in the sample program**

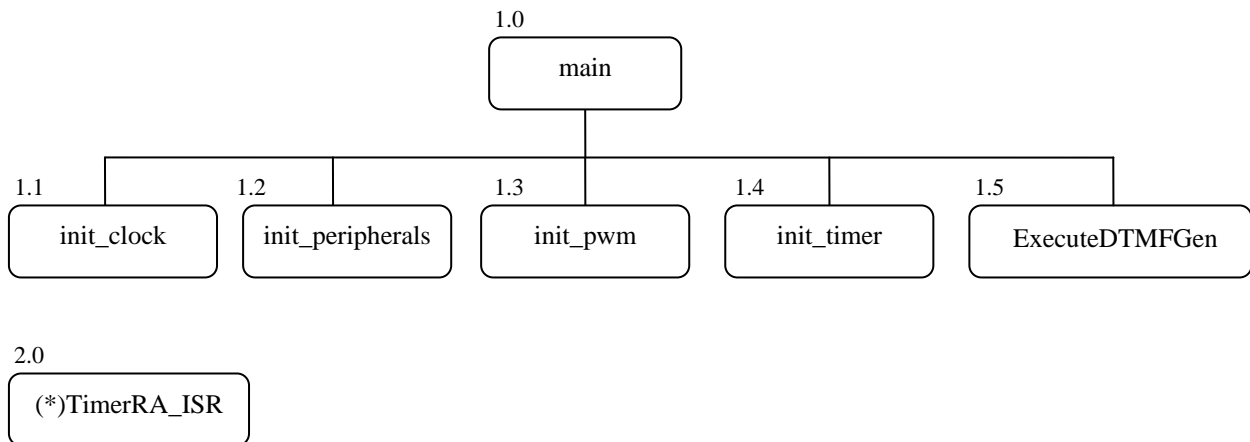
No.	Function name	Outline
1.0	main	DTMF Tones corresponding to the different DTMF keys are generated using PWM output.
1.1	init_clock	The clock of the microcomputer and other clock related registers are initialized.
1.2	init_peripherals	The peripherals such as the LED and switches are initialized
1.3	init_timer	The timer for interrupt processing is set.
1.4	init_pwm	Timer is initialized for PWM output.
1.5	ExecuteDTMFGen	A pointer to the PWM values corresponding to the DTMF Key are returned - This is a library function.
2.0	(*)TimerRA_ISR	Interrupt Service Routine for Timer. Loads the PWM data buffer with the look up table value.

(\*) Function name for the sample software for R8C Family.

"TimerB1\_ISR" in the sample program for H8/Tiny. "TimerB\_ISR" in the sample program for M16C/Tiny



### 1.2.4 Function chart

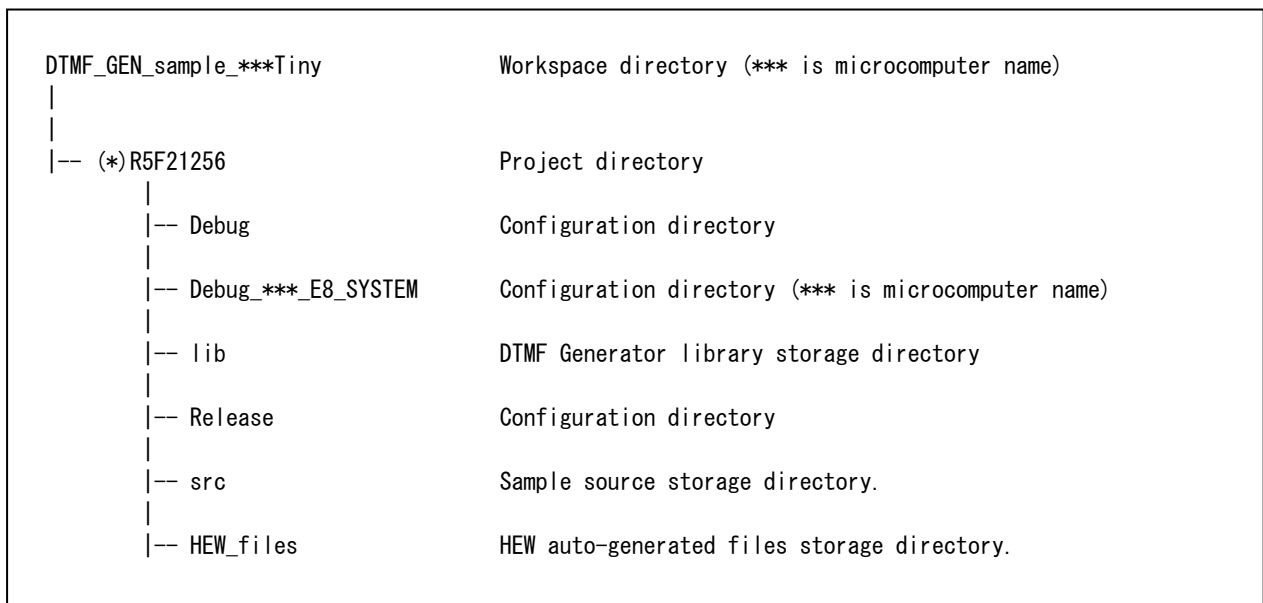


**Figure 2: Function chart**

(\*) Function name for the sample software for R8C Family.

"TimerB1\_ISR" in the sample program for H8/Tiny. " TimerB\_ISR" in the sample program for M16C/Tiny

### 1.2.5 Folder composition in workspace



(\*) Project directory name for R8C project. Following are the Project directory names for the other MCUs

R5F21258 – R8CE

36077GF – H8N

36079GF – H8A

M30260F8AGP – M16C

## 1.3 Sample software usage

This section explains the details related to sample software execution.

### 1.3.1 Sample software execution procedure

#### (1) Switch and LED operation during execution

- Build the sample software workspace and download the x30 file to the RSK\*.
- After the “Reset Go” button is clicked the program starts running. The program waits for the switch press by user.
- When the switch SW2 on the RSK is pressed for the first time after “Reset Go”, the DTMF tone for Key 0 is output.
- The program again loops back waiting for subsequent switch press by the user. On each successive switch press, the DTMF Key count is incremented and the corresponding DTMF tone is output. This DTMF can be heard through the external speaker circuit (not present on the RSK).
- When the DTMF Key count reaches 15 (DTMF tone for Key #), the Key count is reset to 0 and the count starts all over again.
- When the switch is pressed, along with the DTMF tone, the LEDs also display the key pressed in binary. The four LEDs on the RSK represent the current key press in binary. LED0 is the Least Significant Bit (LSB) while LED3 is the Most Significant Bit (MSB). OFF LED indicates 0 while ON LED indicates 1.
- Following table gives examples of representation of some of the numbers on the LEDs

DTMF Key	LED3	LED2	LED1	LED0
0	OFF	OFF	OFF	OFF
3	OFF	OFF	ON	ON
9	ON	OFF	OFF	ON
15	ON	ON	ON	ON

(\*)RSK refers to

Renesas Solutions Kit RSKR8C25 – ROK521256C000BR / ROK521258C000BR (for R8C)

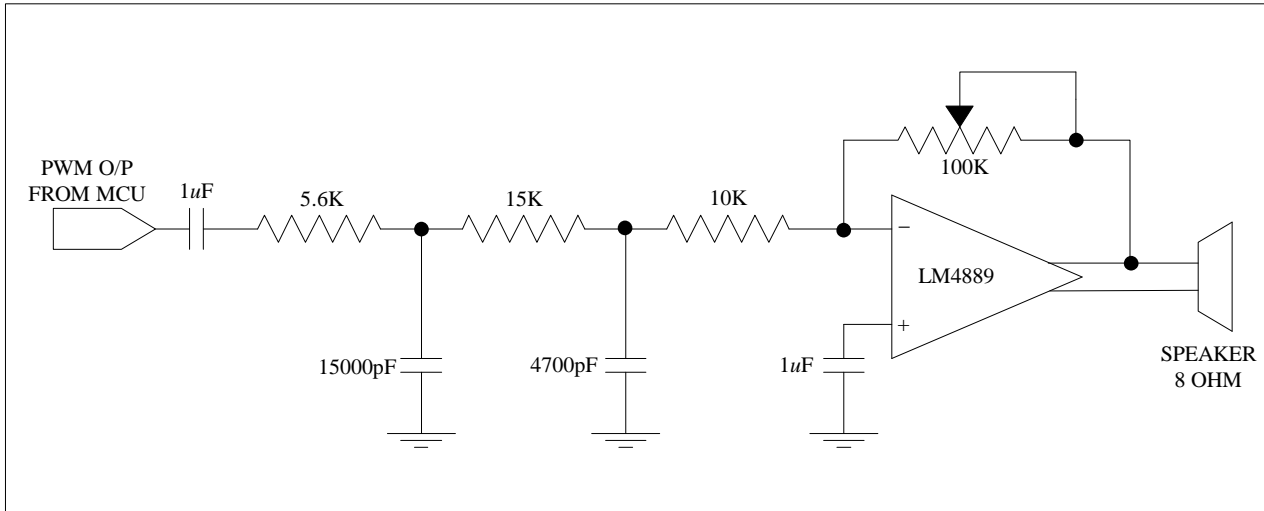
Renesas Solutions Kit RSKH836077– ROK436079S000BE (for H8)

Renesas Solutions Kit RSKM16C26A – ROK33026AC001BR (for M16C)

#### (2) PWM Output signal connection

The sample software outputs the PWM waveform corresponding to each DTMF Tone. This PWM needs to be converted into analog signal with the help of external speaker board (not provided with the RSK). The PWM output is received on one of pins of the JA2 Application Header as mentioned below. The external speaker board should be connected such that the input signal to the board comes from the appropriate of JA2 Application Header. The mapping of the pins is as follows:

JA2 Pin	JA2 Header Pin Name	RSK Signal Name	Microcontroller	Microcontroller Pin
13	Motor Control	MO_Up	R8C / R8CE	19
19	TMR0	TMR0	H8N / H8A Tiny	30
15	Motor Control	MO_Vp	M16C Tiny	23



**Figure 3: Sample external speaker circuit**

**(3) PWM Operating Frequency**

The PWM is operating at a frequency of 16 kHz.

**(4) DTMF Tone Duration**

The DTMF Tone duration can be modified as per requirement using the macro `TONE_TIME_FACTOR`. The Minimum Duration of the DTMF tone is 32 msec. This can be increased by modifying the macro `TONE_TIME_FACTOR` in the sample software. The duration of the DTMF tone is `TONE_TIME_FACTOR` times the minimum tone duration.

E.g. If the `TONE_TIME_FACTOR` is 10, then the duration of the DTMF tone will be

$$\begin{aligned}
 \text{DTMF Tone duration} &= \text{Minimum Tone Duration} \times \text{TONE\_TIME\_FACTOR} \\
 &= 32 \text{ msec} \times 10 \\
 &= 320 \text{ msec}
 \end{aligned}$$

## 1.4 Library characteristic

This section explains the memory occupation and the speed performance (reference values) of the library functions.

### 1.4.1 Occupied memory size

Table 4 Occupied memory

Micro-computer	Mode/Option	ROM	RAM	Stack	
				Executed	DTMFGen
R8C Family	R8C	16543	0	6	
	R8CE	16543	0	6	
H8/Tiny	Normal	16516	0	2	
	Advanced	16558	0	4	
M16C/Tiny	-	16584	0	3	

Unit: Byte

### 1.4.2 Generator processing speed (reference value)

Table 5 Generator processing speed (reference value)

Microcomputer	Mode/Option	Generator processing speed (μsec)*
R8C Family	R8C	4.5
	R8CE	4.5
H8/Tiny	Normal	3
	Advanced	4
M16C/Tiny	-	3

\* The above values are reference values at an operating frequency of 20 MHz for the given microcomputers.

## 2. Detection

### 2.1 Library functions

This section explains the specifications of the library functions.

#### 2.1.1 DTMF Detection (ExecuteDTMFDec)

Prototype

```
unsigned char ExecuteDTMFDec(unsigned char* uiADCSample);
```

Explanation

This function returns the DTMF key corresponding to the ADC samples data passed as the argument.

After all the ADC samples are collected, they can be passed to this function for DTMF Key Detection. The function determines the DTMF Key Tone from which the ADC samples are generated. This detection is done by comparing the energy content of all the DTMF frequencies in the given ADC data.

Arguments

**Table 1: Arguments for the DTMF detection function**

Argument	Type	Explanation
uiADCSample	unsigned char*	Pointer to ADC samples corresponding to the input DTMF tone to be detected

Return value

**Table 2: Return value from the DTMF detection function**

Type	Explanation
unsigned char	Detected DTMF Key value

Range of Return values

The ExecuteDTMFDec function will return one of the following values given in the table. The table gives the significance of the return values received from the function.

**Table 3: Return value from the DTMF detection function**

Value	Significance
0x00 to 0xd	Corresponding detected DTMF Key value
0xe	Detected DTMF Key "*"
0xf	Detected DTMF Key "#"
0x10	Insufficient number of ADC converted input data samples (less than 128)
0x11	No DTMF key corresponding to input sample data

## 2.2 Sample program

This section explains the sample program for DTMF Key Tone detection. The sample program is in the form of a HEW (High-Performance Embedded Workshop) workspace. Change the initialization of the microcomputer and its peripherals according to the system in use.

### 2.2.1 Outline

The DTMF tone is detected from ADC samples of the input data. The detected DTMF tone is displayed on the LEDs.

When program is run, the timer starts and keeps running continuously. The timer triggers the ADC after every 125  $\mu$  sec (frequency 8 kHz). The ADC converts the analog signal at the input into digital data samples. After all the samples are collected, they are passed to the detection function. The detection function returns the DTMF Key value corresponding to these samples. The detected key value is displayed on the LEDs. To pass the input sound signal to the ADC, an external microphone circuit\* is necessary. The input sound signal (DTMF Tone) is converted into analog signal by the microphone circuit and then passed to the ADC.

The number of samples of the input analog signal used for detection is determined by the following macro

Number of ADC Samples	Macro name: ADCSAMPLES
-----------------------	------------------------

**N.B.** The value of this macro is 128 i.e. 128 samples of the input signal will be used for detection. **Please do not change** this macro as the library is designed for operation on 128 samples of input data.

(\*) A typical external microphone circuit will consist of a microphone and an analog filter. Please note that this microphone circuit will have to be made by the user. The circuit will not come with the Renesas Solutions Kits that the user intends to buy and is not available from Renesas.

2.2.2 Flow

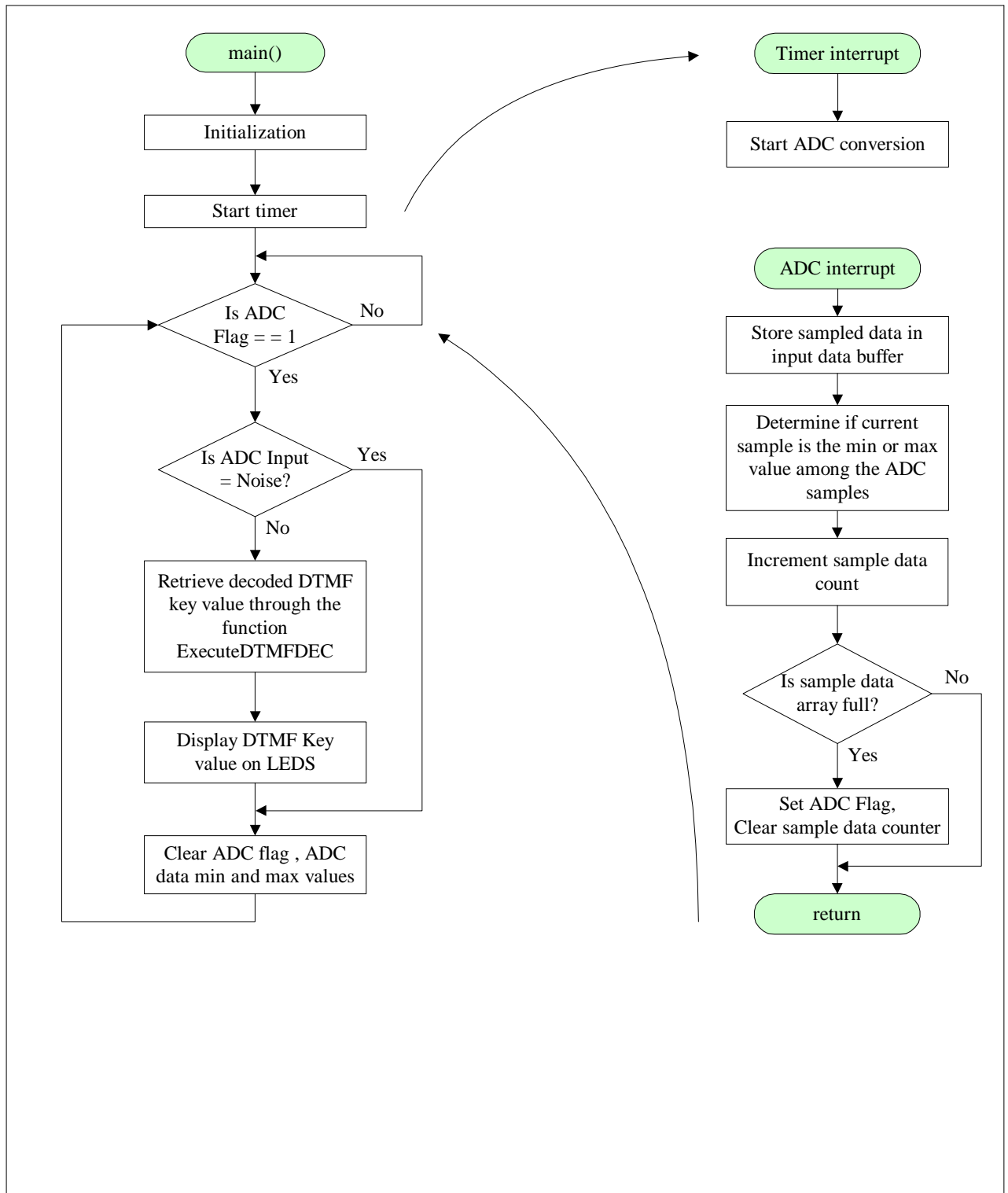


Figure 1: Flow of sample program

### 2.2.3 Function list

**Table 4: List of functions in the sample program**

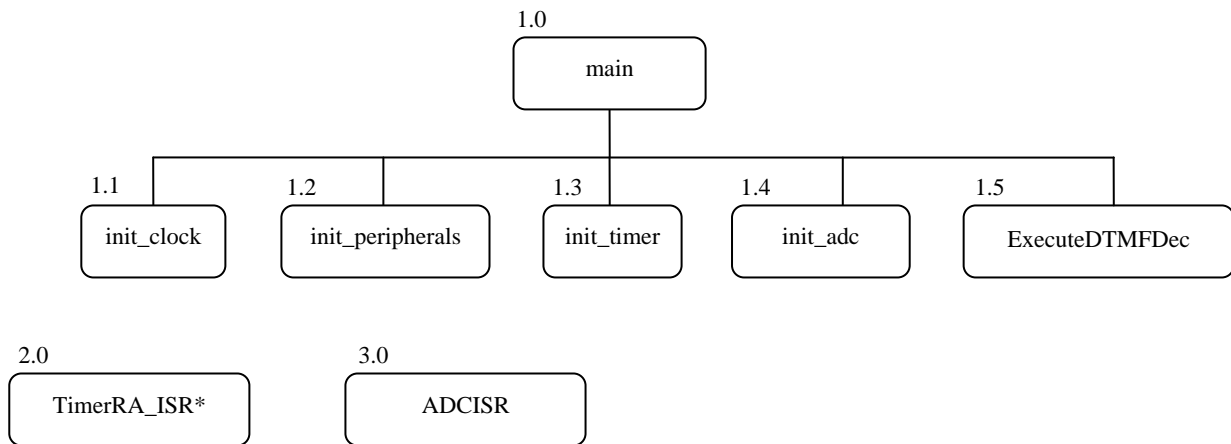
No.	Function name	Outline
1.0	main	Detects the DTMF tone from the analog signal at the input.
1.1	init_clock	The clock of the microcomputer and other clock related registers are initialized.
1.2	init_peripherals	The LEDs are initialized
1.3	init_timer	The timer for interrupt processing is set. The timer is used for triggering the ADC.
1.4	init_adc	Initializes the ADC for conversion of input analog signal.
1.5	ExecuteDTMFDec	Detects the DTMF Key from the DTMF tone analog data at the input - This is a library function.
2.0	TimerRA_ISR*	Triggers the ADC converter.
3.0	ADCISR	Converts the input analog signal into digital data

(\*) Function name for the sample software for R8C Family.

"INT\_TimerB1" in the sample program for H8/Tiny. "TimerB0\_ISR" in the sample program for M16C/Tiny



### 2.2.4 Function chart

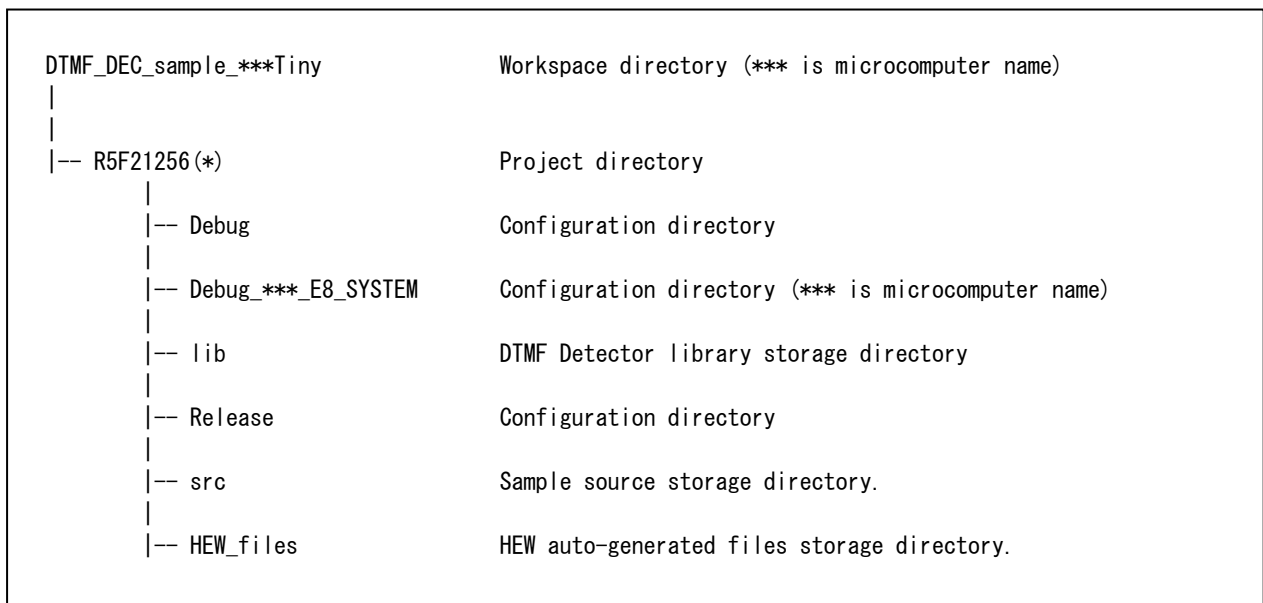


**Figure 2: Function chart**

(\*) Function name for the sample software for R8C Family.

"INT\_TimerB1" in the sample program for H8/Tiny. "TimerB0\_ISR" in the sample program for M16C/Tiny

### 2.2.5 Folder composition in workspace



(\*) Project directory name for R8C project. Following are the Project directory names for the other MCUs

R5F21258 – R8CE

36077GF – H8N

36079GF – H8A

M30260F8AGP – M16C

## 2.3 Sample software usage

This section explains the details related to sample software execution.

### 2.3.1 Sample software execution procedure

#### (1) LED operation during execution

- Build the sample software workspace and download the x30 file to the RSK\*.
- After the “Reset Go” button is clicked the program starts running.
- The timer is running continuously. The timer triggers the ADC which samples the input analog signal and converts it into the digital data. This sampling is going on continuously even if a DTMF tone is present at the input or not.
- If the sampled data is above the noise level, it is passed to the library function for DTMF Tone detection. The library function uses the sampled data to determine the DTMF tone.
- The DTMF Detection function returns the DTMF Key value or any one of the other two return values.
- The detected DTMF key is displayed on the LEDs present on the RSK. The four LEDs on the RSK represent the detected key press in binary. LED0 is the Least Significant Bit (LSB) while LED3 is the Most Significant Bit (MSB). OFF LED indicates 0 while ON LED indicates 1.
- Following table gives example representations of some of the numbers on the LEDs

DTMF Key	LED3	LED2	LED1	LED0
0	OFF	OFF	OFF	OFF
3	OFF	OFF	ON	ON
9	ON	OFF	OFF	ON
15	ON	ON	ON	ON

- The DTMF Tone detection process goes on continuously till the time the program is reset or stopped.

**Note:** All possible return values from the function cannot be displayed on the RSK because of the limitation of the number of LEDs on the RSK. The return values 0x10 and 011 are displayed in the same LED format as that for 0x00 and 0x01 respectively. The user should re-confirm the return value through some other method in the code or by using the Watch window.

(\*RSK refers to

Renesas Solutions Kit RSKR8C25 – ROK521256C000BR / ROK521258C000BR (for R8C)

Renesas Solutions Kit RSKH836077– ROK436079S000BE (for H8)

Renesas Solutions Kit RSKM16C26A – ROK33026AC001BR (for M16C)

#### (2) Input DTMF signal connection

The sample software processes analog signal for DTMF Tone detection. The input DTMF sound signal needs to be received with the help of external microphone board (not provided with the RSK) before it can be passed to the ADC. The pin9 of the JA1 Application Header corresponds to the different ADC input pins of different microcontrollers as mentioned in the table below. The external microphone board should be connected such that the output of the microphone is connected to this pin9 of JA1. The mapping of the pins is as follows:

JA1 Pin	JA1 Header Pin Name	RSK Signal Name	Microcontroller	Microcontroller Pin
9	ADC0	AD0	R8C/R8CE	38
9	AD0	AN0	H8N/H8A Tiny	62
9	ADC0	AD0	M16C Tiny	45

### (3) Input Signal Sampling Frequency

The Timer is operating at a frequency of 8 kHz. Sample of the input signal is taken every 125  $\mu$  sec

#### 2.3.2 Avoiding Multiple Tone Detection

Multiple Tone Detection means detection of the same DTMF tone multiple times which happens in case the DTMF tone duration is very long. The sample software uses the flag “chk\_repeat\_tone” to prevent multiple tone detection. Once a tone is detected, this flag is set to TRUE. This flag remains TRUE till the time the pause between two DTMF tones is detected. Once this pause is detected, the flag is set to FALSE enabling DTMF detection for the next set of ADC data. If the pause is not present, that means the ADC data represents the same DTMF tone sampled again because of the long tone duration. A pause indicates that the next set of ADC data is definitely from the successive DTMF tone.

#### 2.3.3 Configurable parameters

There is one configurable macro in the sample software:

- **NOISE\_LEVEL** – During execution, the program is running continuously waiting for a DTMF tone. Thus, the environmental noise is also picked up and passed through the ADC. In the sample software, for each set of ADC sampled data, the difference between the minimum and the maximum value of the data is compared with the macro NOISE\_LEVEL. The data is processed only if the difference is greater than the value of NOISE\_LEVEL. Else it is considered as noise and is ignored. This macro is configured to the value 230 in the sample software. The user can modify this macro depending upon the usage environment. The range of this macro value can be from 0 to 255 since the 8-bit ADC data is used. The noise threshold level increases from 0 to 255. At the value 0, the data will always be passed for detection as the noise threshold level will be reduced to 0. At the value 255, the data will never be passed for detection as the maximum possible difference between any two ADC data values is 255.

#### 2.3.4 Non-configurable parameters

There is one non-configurable macro in the sample software:

- **ADCSAMPLES** – This macro denotes the number of samples of the input signal that will be used for detection. This macro is configured to the value 128 in the sample software. Please do not modify this macro as the library is designed to operate on 128 samples of data.

## 2.4 Library characteristics

This section explains the memory occupation and the speed performance (reference values) of the library functions.

### 2.4.1 Library Usage

As mentioned earlier, the library is designed to operate on a fixed number of 128 samples and return the corresponding DTMF Key value. The user should ensure that insufficient number of valid input data samples (less than 128) are not passed to the library as then there will be no DTMF Key detection (return value 0x10).

While using the ADC, the user should be careful about the synchronization of the ADC sampling and the input DTMF Key tone data. ADC sampling should take place exactly when the input data is available. Even if a small number of samples are from the non-DTMF key input, then this may lead to non-detection of the key (return value 0x11).

### 2.4.2 Occupied memory size

Table 5: Occupied memory

Micro-computer	Mode/Option	ROM	RAM	Stack	
				Execute	DTMFDec
R8C Family	R8C	1875	81	19	
	R8CE	1892	81	19	
H8/Tiny	Normal	2538	81	22	
	Advanced	2906	81	28	
M16C/Tiny	-	1892	81	19	

Unit: Byte

### 2.4.3 Detection processing speed

Table 6: Detection processing speed (reference value)

Microcomputer	Mode/Option	Detection processing time(ms)*
R8C Family	R8C	6.7
	R8CE	7.2
H8/Tiny	Normal	7.8
	Advanced	8.8
M16C/Tiny	-	4.5

\* The above values are reference values at an operating frequency of 20 MHz for the given microcomputers

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