

# RX Family

R20AN0036EJ0100

Rev.1.00

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

Oct.08.2010

### Introduction

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

### Target device

RX family

### Contents

1.	Library type definitions .....	3
2.	Generation.....	3
2.1	Library functions.....	3
2.1.1	DTMF Generation (R_DTMFGEN_Execute) .....	3
2.2	Sample program.....	4
2.2.1	Outline.....	4
2.2.2	Flow.....	5
2.2.3	Function list.....	6
2.2.4	Function chart .....	7
2.2.5	Folder composition in workspace .....	7
2.3	Sample software usage.....	8
2.3.1	Sample software execution procedure .....	8
(1)	Switch and LED operation during execution .....	8
(2)	PWM Output signal connection.....	8
(3)	PWM Operating Frequency.....	9
(4)	DTMF Tone Duration.....	9
2.4	Library characteristic .....	10
2.4.1	Occupied memory size .....	10
2.4.2	Generator processing speed (reference value) .....	10
3.	Detection .....	11
3.1	Library functions.....	11
3.1.1	DTMF Detection (R_DTMFDEC_Execute).....	11
3.2	Sample program.....	12
3.2.1	Outline.....	12
3.2.2	Flow.....	13
3.2.3	Function list.....	14
3.2.4	Function chart .....	15
3.2.5	Folder composition in workspace .....	15
3.3	Sample software usage.....	16
3.3.1	Sample software execution procedure .....	16
(1)	LED operation during execution.....	16
(2)	Input DTMF signal connection .....	16
(3)	Input Signal Sampling Frequency .....	16

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3.3.2	Avoiding Multiple Tone Detection .....	17
3.3.3	Configurable parameters .....	17
3.3.4	Non-configurable parameters .....	17
3.4	Library characteristics .....	18
3.4.1	Library Usage.....	18
3.4.2	Occupied memory size .....	18
3.4.3	Detection processing speed.....	18
	Website and Support.....	19
	Revision Record .....	19
	General Precautions in the Handling of MPU/MCU Products.....	20

## 1. Library type definitions

This section gives the details about the type definitions used in the library.

Datatype	Typedef
unsigned char	uint8_t
unsigned short	uint16_t
unsigned long	uint32_t
signed char	int8_t
signed short	int16_t
signed long	int32_t

## 2. Generation

### 2.1 Library functions

This section explains the specifications of the library functions.

#### 2.1.1 DTMF Generation (R\_DTMFGEN\_Execute)

Prototype

```
uint16_t* R_DTMFGEN_Execute(uint8_t 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 720 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>	<code>uint8_t</code>	Key for which DTMF tone is to be generated

Return value

Table 2: Return values from the DTMF generation function

Type	Explanation
<code>uint16_t*</code>	Top address of lookup table containing the PWM duty cycle values for <code>uc_DTMF_Key</code>

## 2.2 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.

### 2.2.1 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.

The counter for the DTMF keys is initialized to zero at the start of the main function. 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 R\_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: DTMF\_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.

2.2.2 Flow

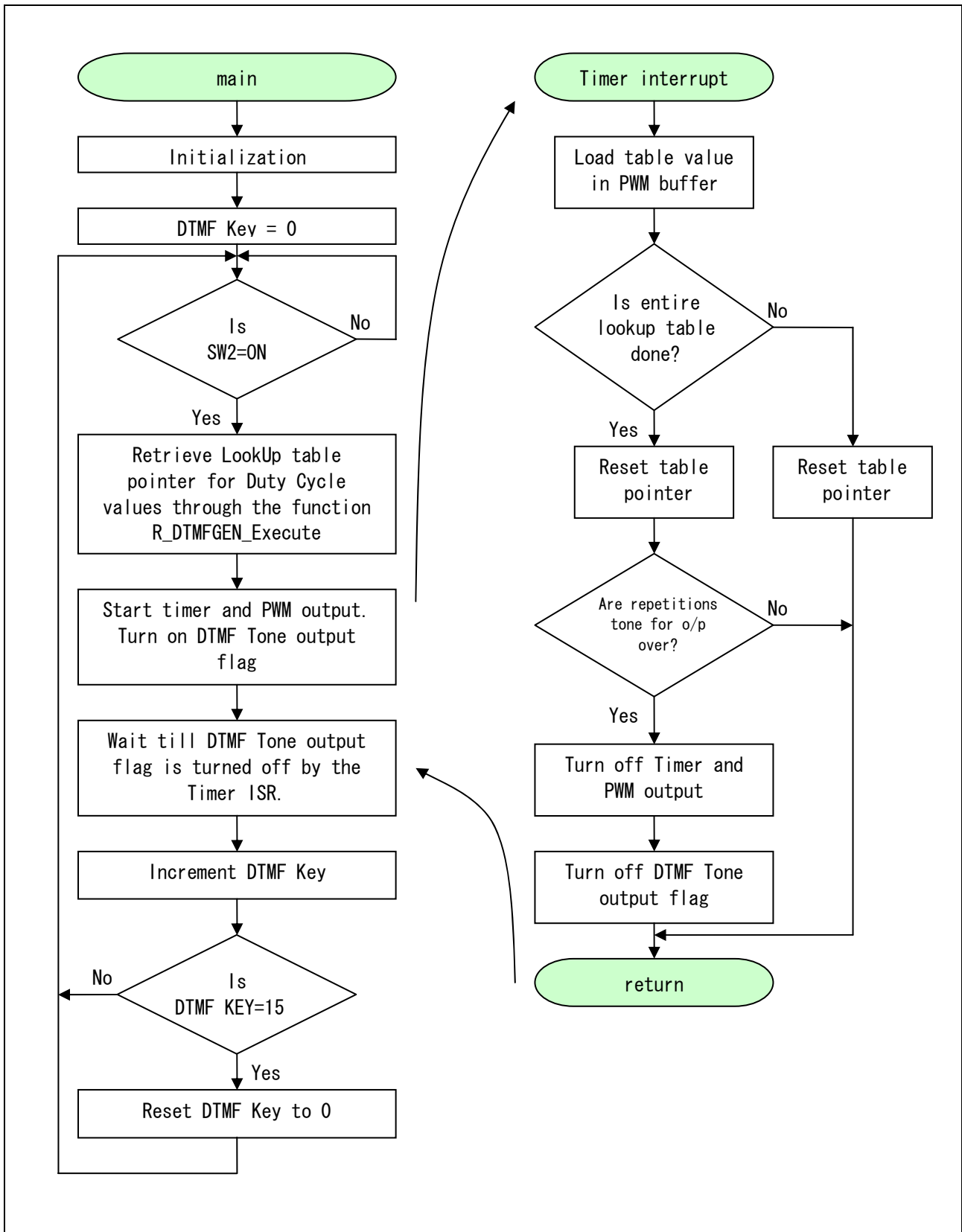


Figure 1: Flow of sample program

### 2.2.3 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	R_init_clock	The clock of the microcomputer and other clock related registers are initialized.
1.2	R_init_peripherals	The peripherals such as the LED and switches are initialized
1.3	R_init_timer	The timer for interrupt processing is initialized.set.
1.4	R_init_pwm	Timer is initialized for PWM output.
1.5	R_DTMFGEN_Execute	A pointer to the PWM values corresponding to the DTMF Key are returned - This is a library function.
2.0	R_int_timer_TGI1A	Interrupt Service Routine for Timer. Loads the PWM data buffer with the look up table value.

2.2.4 Function chart

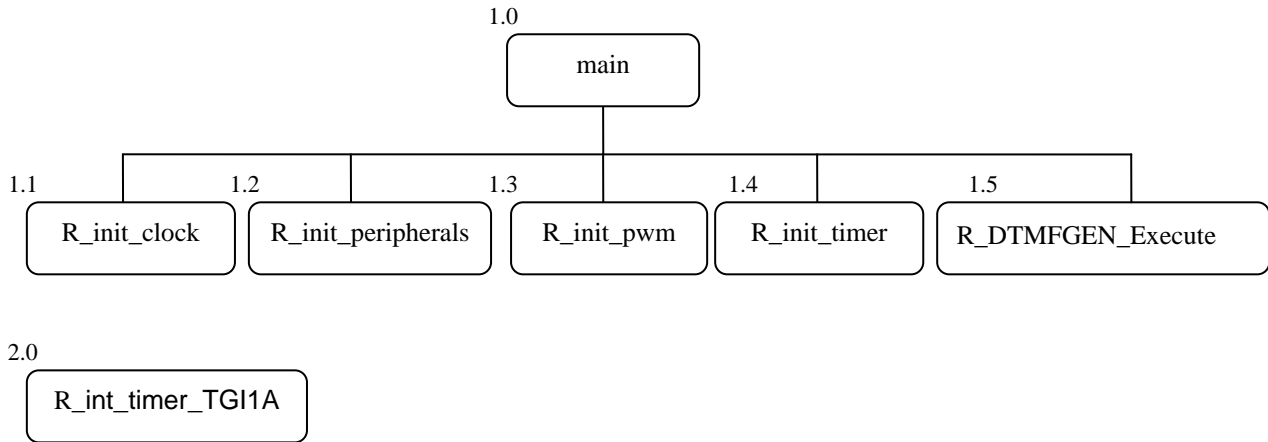
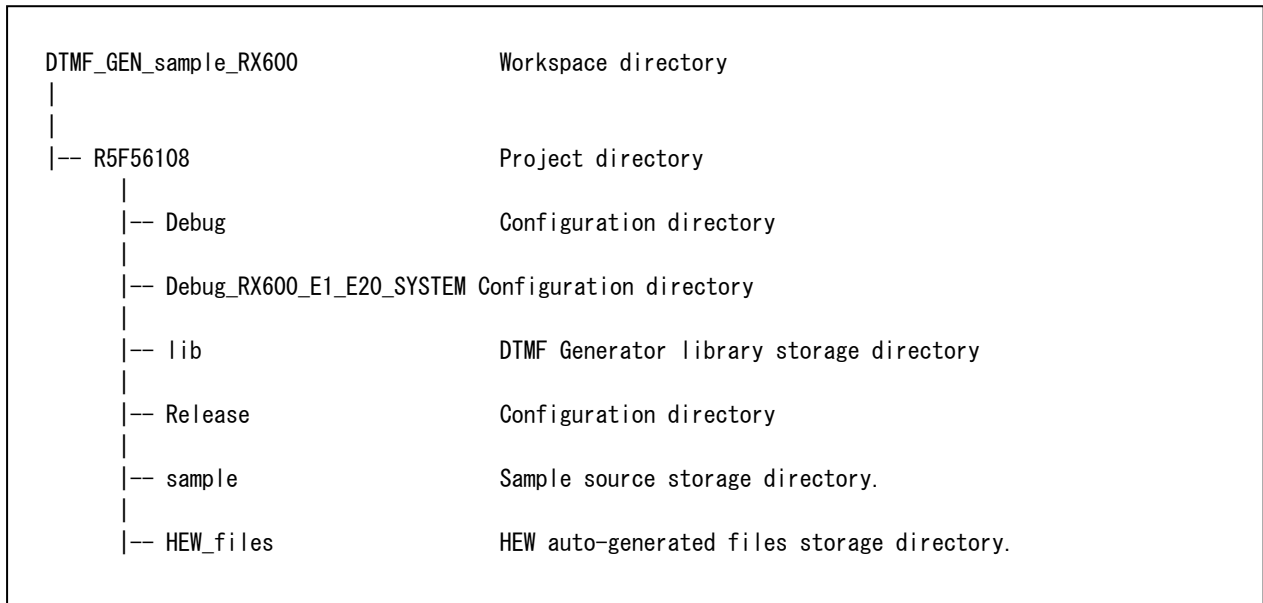


Figure 2: Function chart

2.2.5 Folder composition in workspace



## 2.3 Sample software usage

This section explains the details related to sample software execution.

### 2.3.1 Sample software execution procedure

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

- Build the sample software workspace and download the abs 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, the four LEDs on the RSK display the DTMF key in binary notation. 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 Starter Kit for RSKRX610 – R0K556108C000BR

#### (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 pin of the JA2 Application Header. The mapping of the pins is as follows:

JA2 Pin	JA2 Header Pin Name	RSK Signal Name	Microcontroller	Microcontroller Pin
22	Timer_In	TMCIO	RX610	36



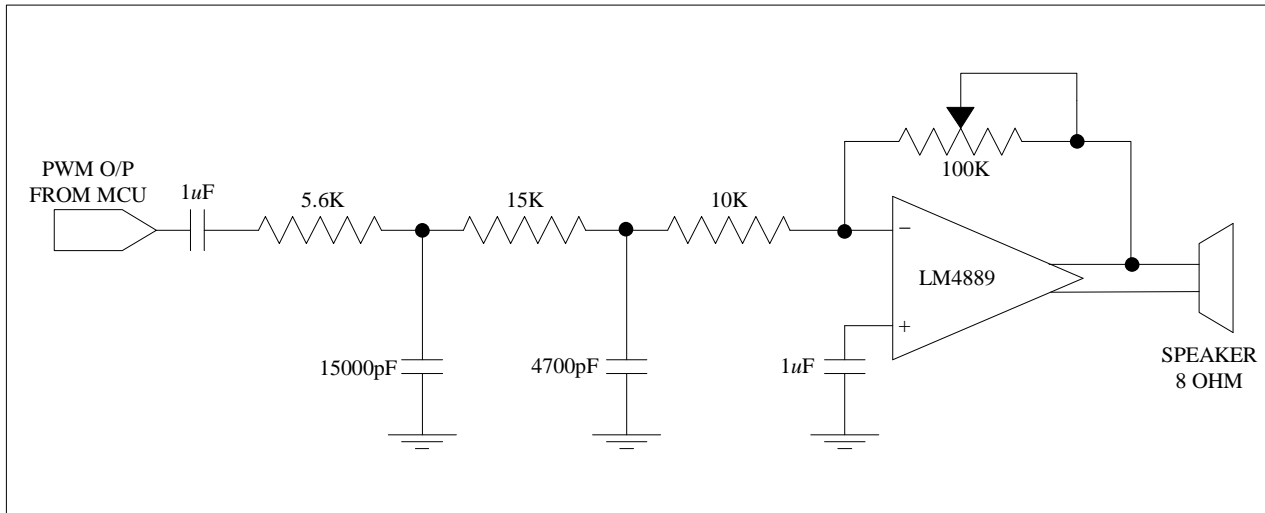


Figure 3: Sample external speaker circuit

**(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 45 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

$$\begin{aligned} \text{DTMF Tone duration} &= \text{Minimum Tone Duration} \times \text{TONE\_TIME\_FACTOR} \\ &= 45 \text{ msec} \times 10 \\ &= 450 \text{ msec} \end{aligned}$$

## 2.4 Library characteristic

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

### 2.4.1 Occupied memory size

Table 4 Occupied memory

Micro-computer	ROM	RAM	Stack
			R_DTMFGEN_Execute
RX600	23172	0	4

Unit: Byte

### 2.4.2 Generator processing speed (reference value)

Table 5 Generator processing speed (reference value)

Microcomputer	Generator processing speed ( $\mu$ sec)*
RX600	0.3

\* The above values are reference values at an operating frequency of 100 MHz for the given microcomputers.

### 3. Detection

#### 3.1 Library functions

This section explains the specifications of the library functions.

##### 3.1.1 DTMF Detection (R\_DTMFDEC\_Execute)

Prototype

```
uint8_t R_DTMFDEC_Execute(uint16_t* 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 6: Arguments for the DTMF detection function

Argument	Type	Explanation
uiADCSample	uint16_t*	Pointer to ADC samples corresponding to the input DTMF tone to be detected

Return value

Table 7: Return value from the DTMF detection function

Type	Explanation
uint8_t	Detected DTMF Key value

Range of Return values

The R\_DTMFDEC\_Execute 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 8: 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

## 3.2 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.

### 3.2.1 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  $125 \mu\text{sec}$  (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: DTMF\_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.

3.2.2 Flow

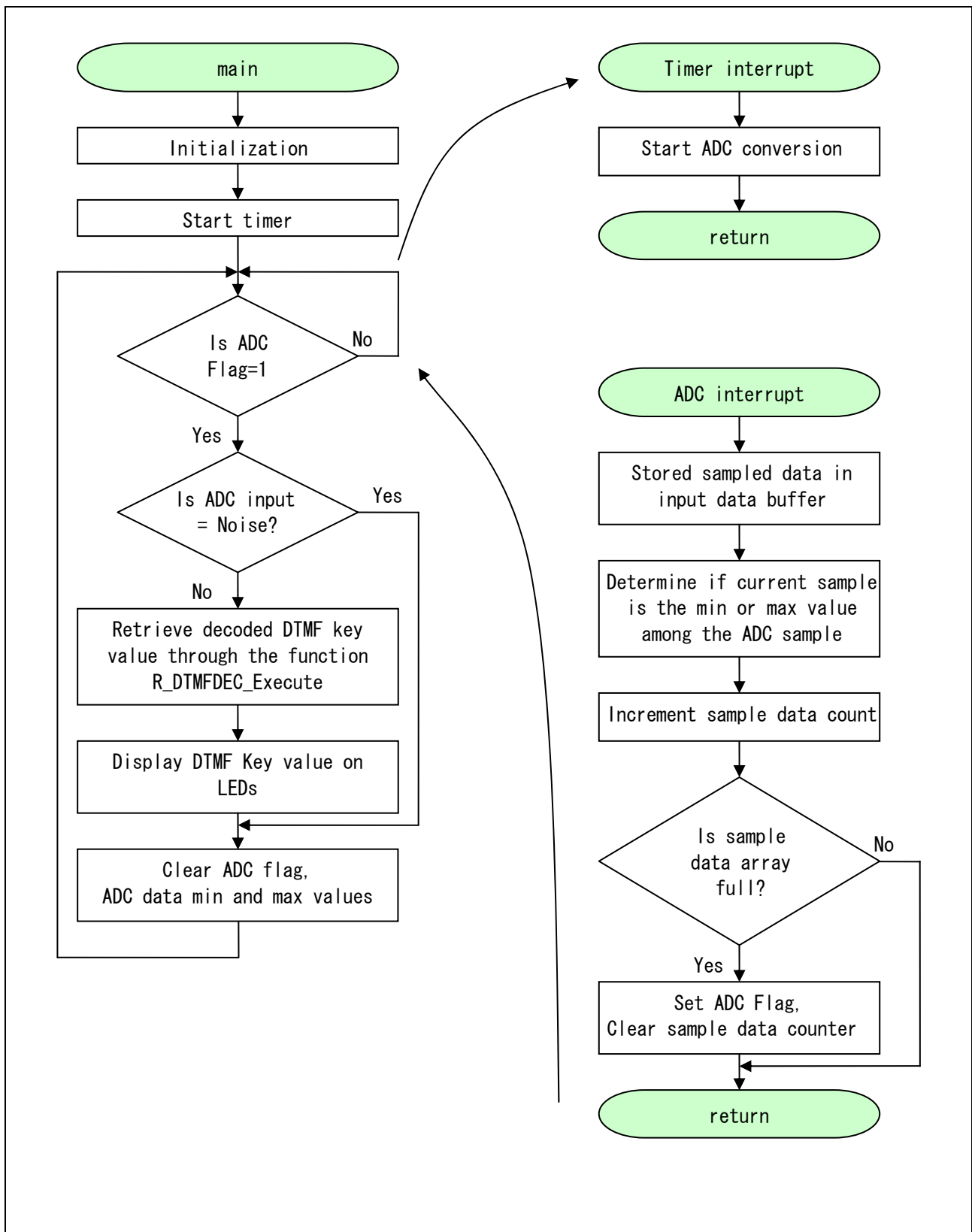


Figure 4: Flow of sample program

## 3.2.3 Function list

Table 9: 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	R_init_clock	The clock of the microcomputer and other clock related registers are initialized.
1.2	R_init_peripherals	The LEDs are initialized
1.3	R_init_timer	The timer for interrupt processing is set. The timer is used for triggering the ADC.
1.4	R_init_adc	Initializes the ADC for conversion of input analog signal.
1.5	R_DTMFDEC_Execute	Detects the DTMF Key from the DTMF tone analog data at the input - This is a library function.
2.0	R_int_timer_TGI1A	Triggers the ADC converter.
3.0	R_ADCISR	Converts the input analog signal into digital data

3.2.4 Function chart

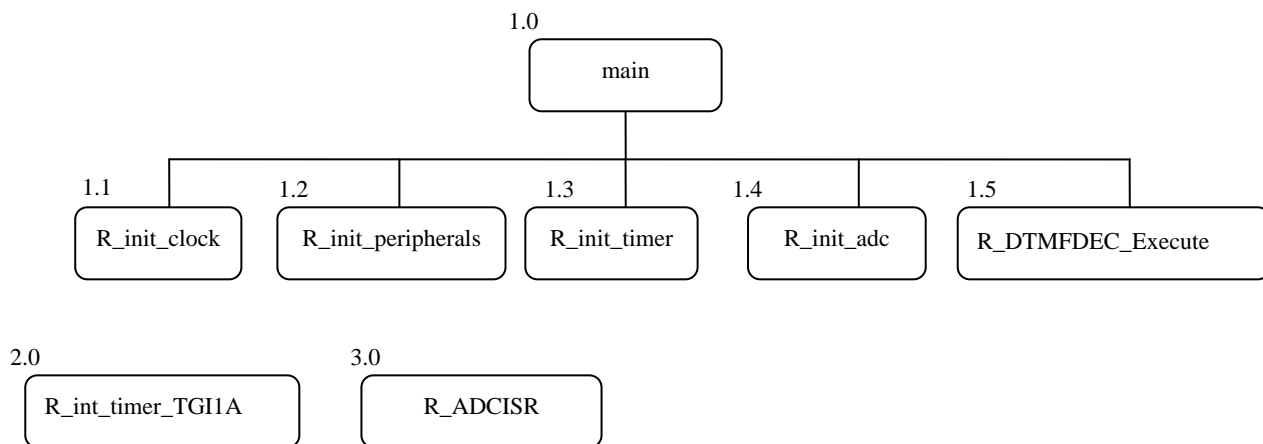
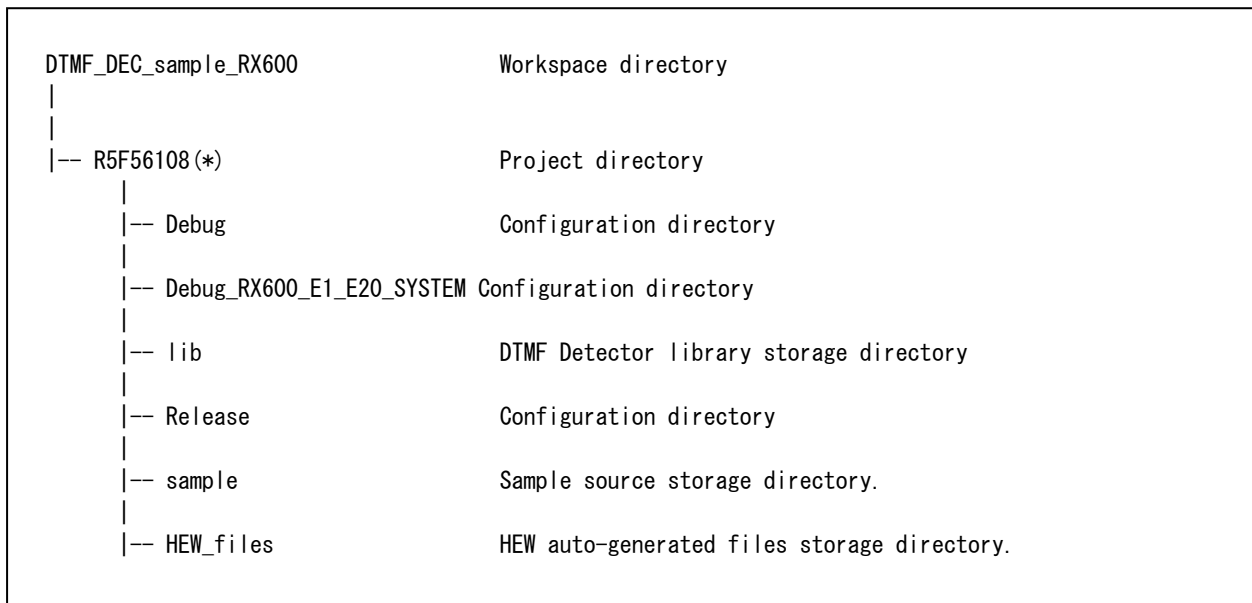


Figure 5: Function chart

3.2.5 Folder composition in workspace



### 3.3 Sample software usage

This section explains the details related to sample software execution.

#### 3.3.1 Sample software execution procedure

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

- Build the sample software workspace and download the abs 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 in HEW.

(\*)RSK refers to

Renesas Starter Kit for RSKRX610 – R0K556108C000BR

##### (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 pin12 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 pin12 of JA1. The mapping of the pins is as follows:

JA1 Pin	JA1 Header Pin Name	RSK Signal Name	Microcontroller	Microcontroller Pin
9	AD0	AN0	RX610	141

##### (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.



### 3.3.2 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.

### 3.3.3 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 `300h` 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 1023 since the 8-bit ADC data is used. The noise threshold level increases from 0 to 1023. 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 1023, the data will never be passed for detection as the maximum possible difference between any two ADC data values is 1023.

### 3.3.4 Non-configurable parameters

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

- **DTMF\_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.

### 3.4 Library characteristics

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

#### 3.4.1 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).

#### 3.4.2 Occupied memory size

Table 10: Occupied memory

Micro-computer	ROM	RAM	Stack
			R_DTMFDEC_Execute
RX600	1020	81	44

Unit: Byte

#### 3.4.3 Detection processing speed

Table 11: Detection processing speed (reference value)

Microcomputer	Detection processing time( $\mu$ s)*
RX600	250

\* The above values are reference values at an operating frequency of 100 MHz for the given microcomputers

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Rev.	Date	Description	
		Page	Summary
1.00	Oct.08.10	—	First edition issued

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Handle unused pins in accord 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

### 2. Processing at Power-on

The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

### 3. Prohibition of Access to Reserved Addresses

Access to reserved addresses is prohibited.

- The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

### 4. Clock Signals

After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

### 5. Differences between Products

Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

- The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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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