Voice Intelligent Technology

Integration Guide

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Change History

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1.1	REL	Updated with Voice Commands information	Sebastien Chereau	2020-06-30
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1.5	REL	Updating RT600 information	Sebastien Chereau	2020-12-11

1 Reference & Abbreviations

References	
[1]	Release Notes

Table 1: Reference documents

Abbreviations	
VIT	Voice Intelligent Technology
WWE	Wake Word Engine
VCE	Voice Commands Engine

Table 2: Abbreviations

2 Introduction

Voice Intelligent Technology product is providing Voice services aiming to wake up and control IOT, Home devices.
Current version of VIT is supporting a Wake Word and a Voice Commands Text2Model functionalities.

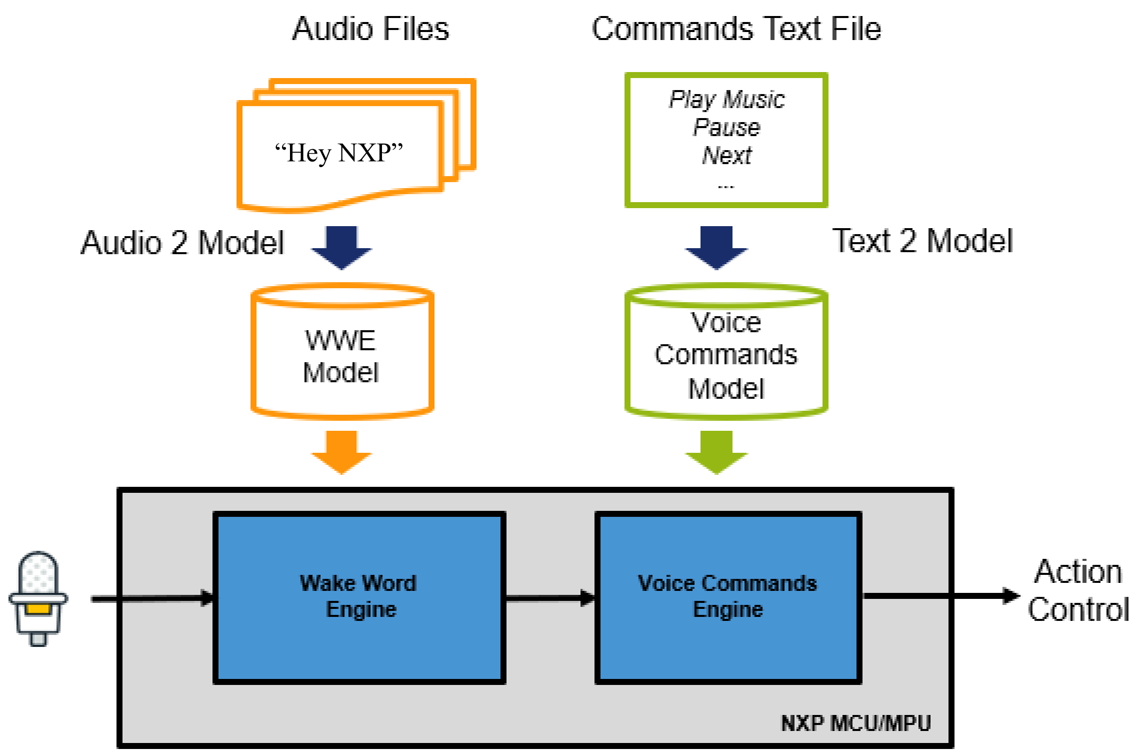


Figure 1 : VIT overview

The WakeWord model is built from a Database with recorded "keyword" files.
The Voice Commands Model is built from a text2Model approach which does not require any Command audio dataset.

The VIT lib is provided with a model allowing the detection of the "Hey NXP" key word and 12 Commands listed in VIT_Voice_Commands.h file.
Scenario supported by the VIT LIB :

- Wake Word detection only : "Hey NXP"

- WakeWord + Voice Commands detection
  Eg "Hey NXP – Play Music" - "Hey NXP – Next"

The Voice command should be pronounced in a 3 seconds time frame after the Wake word. See Appendix section for further details.
VIT will return an "UNKOWN" command if the audio captured after the WakeWord does not correspond to any targeted command.

The VIT lib is processing 10ms audio frame @16kHz - 16-bit data - mono

The VIT Lib has been ported on 2 cores :
- The VIT lib has been built for cortex-M7 core and validated on the IMXRT1060 platform.
- The VIT lib has been built for HIFI4 core and validated on the Xtensa simulator.

The VIT release is aimed to be distributed only for demo or evaluation purpose.

3 Release description

The VIT release is including following files :
- Lib/libVIT_*PLATFORM_VERSION*.a : PLATFORM can be either HIFI4 or Cortex-M7
- Lib/VIT.h : file describing VIT public API
- Lib/VIT_Model.h : file containing VIT model description for the WakeWord and Voice Commands Engines
- VIT_Voice_Commands.h : file listing the commands supported by the VIT library
- Lib/Inc : folder integrating additional VIT public interface definitions
- ExApp/VIT_ExApp.c : VIT Integration example

4 Public interfaces description

4.1 Header files

4.1.1 VIT.h

VIT.h describes all the definitions required for VIT configuration and usage:
- Detection status enumerator

- Neural Network Model strategy enumerator
- Instance parameters structure
- Control parameters structure
- Status parameters structure
- All Vit public functions

4.1.2 VIT_Model.h

VIT_Model.h contains the Model array.
The VIT_Model array can be stored in ROM (Flash) or in RAM.

- If the Model is stored in flash, VIT will make the necessary memory reservation to copy part of the Model in RAM before using it : current Cortex-M7 case.
- If the Model is stored in RAM, VIT will use directly the model from its original memory location. : HIFI4 case.

4.1.3 PL_platformTypes_CortexM7.h

PL_platformTypes_CortexM7.h describes the dedicated platform definition for VIT library.

4.1.4 PL_platformTypes_HIFI4.h

PL_platformTypes_HIFI4.h describes the dedicated platform definition for VIT library.

4.1.5 PL_memoryRegion.h

PL_memoryRegion.h describes all the memories definition dedicated to the VIT handle allocation.

4.2 Public APIs

The VIT library present different public functions to control and exercise the library:

- VIT_SetModel
- VIT_GetMemoryTable
- VIT_GetInstanceHandle
- VIT_SetControlParameters
- VIT_Process
- VIT_GetVoiceCommandFound
- VIT_GetModelInfo (subsidiary interface)
- VIT_ResetInstance (subsidiary interface)

- VIT_GetControlParameters (subsidiary interface)
- VIT_GetStatusParameters (subsidiary interface)

For detailed description of the different APIs (Parameters, return values, usage…) – Please refer to the VIT.h file.

4.2.1 Main APIs

The Main VIT APIs has to be called (in the right sequence) in order to instantiate, control and exercise VIT algorithms.

4.2.1.1 VIT_SetModel

VIT_ReturnStatus_en VIT_SetModel (PL_UINT8* pVITModelGroup)

4.2.1.1.1 Goal:

Save the address of the VIT Model and check whether the Model provided is supported by the VIT library.

4.2.1.1.2 Input parameters:

The address of the VIT Model in ROM.

4.2.1.1.3 Output parameters:

None

4.2.1.1.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS is returned, then:

- VIT Model ROM address is saved
- VIT Model is supported by the VIT library

4.2.1.2 VIT_GetMemoryTable

```
VIT_ReturnStatus_en VIT_GetMemoryTable(VIT_Handle_t              phInstance,
                                       PL_MemoryTable_st        *pMemoryTable,
                                       VIT_InstanceParams_st    *pInstanceParams);
```

4.2.1.2.1 Goal:

Goal is to inform the SW application about the required memory needed by the VIT library.
4 kinds of memory are identified:

- Fast data
- Slow data

- Fast coefficient
- Temporary or scratch

4.2.1.2.2 Input parameters:

1- A pointer to an instance of VIT. It must be a Null pointer as instance is not reserved yet.
2- A pointer to a memory table structure.
3- The instance parameter of the VIT library.

4.2.1.2.2.1 Output parameters:

The memory table structure is filled. It informs about the memory size required for each memory type.

4.2.1.2.3 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS is returned, then VIT is succeeding to get memory requirement of

- Each sub module
- The VIT Model

4.2.1.3 VIT_GetInstanceHandle

```
VIT_ReturnStatus_en VIT_GetInstanceHandle(VIT_Handle_t          *phInstance,
                                          PL_MemoryTable_st     *pMemoryTable,
                                          VIT_InstanceParams_st *pInstanceParams );
```

4.2.1.3.1 Goal:

Goal is to set and initialize the instance of VIT before processing call.
All memory is mapped to the required buffer of each sub module.

4.2.1.3.2 Input parameters:

1- Pointer to the future instance of VIT.
2- A pointer to the memory table structure. Memory allocation must be done and memory address per memory type has been saved in the table.
3- The instance parameter of the VIT library.
Depending the value of the instance parameter, sub module initialization is different.

4.2.1.3.3 Output parameters:

Address of the VIT instance is set.

4.2.1.3.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS is returned, then:

- VIT instance has been set and initialize correctly
- VIT Model layers are copied in dedicated memory.

4.2.1.4 VIT_SetControlParameters

```
VIT_ReturnStatus_en VIT_SetControlParameters(VIT_Handle_t                     phInstance,
                                             const VIT_ControlParams_st   *const pNewParams);
```

4.2.1.4.1 Goal:

Set or modify the control parameter of VIT instance. The New parameters won't be set immediately. Indeed, to avoid processing artifact due to the new parameters themselves the update sequence is under internal processing condition and will occur as soon as possible.

4.2.1.4.2 Input parameters:

1- VIT Handle
2- Pointer to a control parameter structure

Operating mode supported : `VIT_ALL_MODULE_ENABLE ou VIT_WAKEWORD_MODULE_ENABLE`

4.2.1.4.3 Output parameters:

None

4.2.1.4.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS then control parameter structure has been considered and will be effective as soon as possible.

4.2.1.5 VIT_Process

```
VIT_ReturnStatus_en VIT_Process (  VIT_Handle_t              phInstance,
                                   VIT_DataIn_st             *pVIT_InputBuffers,
                                   VIT_DetectionStatus_en  *pVIT_DetectionResults
                                 );
```

4.2.1.5.1 Goal:

Analyse the audio flow to detect a “Hot Word” or a Voice command.

4.2.1.5.2 Input parameters:

1- VIT Handle
2- Temporal audio samples (160 samples @16kHz – 16-bit data)

4.2.1.5.3 Output parameters:

Detection status can have 3 different states:

- `VIT_NO_DETECTION` : No detection
- `VIT_WW_DETECTED` : WakeWord has been detected
- `VIT_VC_DETECTED`: a Voice Command has been detected

When `VIT_WW_DETECTED` is returned – VIT will switch in a Voice commands detection phase for ~3s.
When `VIT_VC_DETECTED` is returned – `VIT_GetVoiceCommandFound`() shall be called to know which command has been detected.
`VIT_VC_DETECTED` is also indicating the end of the Voice command research period and the switch to a WakeWord detection phase until the WakeWord is detected again. See Appendix section for further details.

4.2.1.5.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS then the process of the new audio frame has successfully been done.

4.2.1.6 VIT_GetVoiceCommandFound

VIT_ReturnStatus_en VIT_GetVoiceCommandFound (VIT_Handle_t pVIT_Instance,
VIT_VoiceCommands_t *pVoiceCommand);

4.2.1.6.1 Goal:

Retrieve the command ID and name (when present) detected by VIT.
The function shall be called only when VIT_Process() is informing that a Voice Command has been detected (*pVIT_DetectionResults==VIT_VC_DETECTED)

4.2.1.6.2 Input parameters:

1- VIT Handle
2- Pointer to a Voice Commands struct type

4.2.1.6.3 Output parameters:

pVoiceCommand will be filled with the ID and name of the command detected.

A "UNKNOWN" command is returned if VIT does not identify any targeted command during the voice command detection phase.

4.2.1.6.4 Return value:

A value of type PL_ReturnStatus_en. If PL_SUCCESS then pVoiceCommand can be considered.

4.2.2 Secondary APIs

The secondary VIT APIs are not mandatory for good usage of VIT algorithms. They can be used in order to reset VIT in case of discontinuity in the audio recording flow (see VIT_ResetInstance description), get information on the VIT Model and get information on the internal state of VIT.

4.2.2.1 VIT_GetModelInfo

VIT_ReturnStatus_en VIT_GetModelInfo (VIT_Model_Info_t *pModel_Info)

4.2.2.1.1 Goal:

This function returns different information of the VIT model registered within VIT lib. The function shall be called only when VIT_SetModel() is informing that the model is correct. (ReturnStatus == VIT_SUCCESS).

4.2.2.1.2 Input parameters:

1- Pointer to a VIT_Model_Info structure

4.2.2.1.3 Output parameters:

VIT_Model_Info will be filled with the details on VIT_Model.
See VIT.h for further information.

4.2.2.1.4 Return value:

A value of type PL_ReturnStatus_en. If PL_SUCCESS then *pModel_Info can be considered.

4.2.2.2 VIT_ResetInstance

VIT_ReturnStatus_en VIT_ResetInstance(VIT_Handle_t phInstance);

4.2.2.2.1 Goal:

Reset the instance of VIT with instance parameters saved while VIT_GetInstanceHandle called. The reset doesn't take effect immediately. Indeed, to avoid processing artifact due to the reset itself the reset sequence is under internal processing condition and will occur as soon as possible.
The VIT_ResetInstance function should be called whenever there is a discontinuity in the input audio stream. A discontinuity means that the current block of samples is not contiguous with the previous block of samples.
Examples are

- Calling the VIT process function after a period of inactivity
- Buffer underrun or overflow in the audio driver

After resetting VIT Instance, VIT shall be reconfigured (call to VIT_SetControlParameters()) before continuing the VIT detection process (i.e VIT_Process()).

4.2.2.2.2 Input parameters:

VIT Handle

4.2.2.2.3 Output parameters:

None

4.2.2.2.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS then the reset has been considered and will be effective as soon as possible.

4.2.2.3 VIT_GetControlParameters

```
VIT_ReturnStatus_en VIT_GetControlParameters(VIT_Handle_t           *phInstance,
                                             VIT_ControlParams_st   *pControlParams);
```

4.2.2.3.1 Goal:

Get the current control parameter of VIT instance.

4.2.2.3.2 Input parameters:

1- VIT Handle
2- Pointer to a control parameter structure

4.2.2.3.3 Output parameters:

Parameter structure is updated

4.2.2.3.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS then parameter structure has been updated correctly

4.2.2.4 GET_StatusParameters

```
VIT_ReturnStatus_en VIT_GetStatusParameters( VIT_Handle_t          phInstance,
                                             VIT_StatusParams_st   *pStatusParams);
```

4.2.2.4.1 Goal:

Get the status parameters of the VIT library.

4.2.2.4.2 Input parameters:

1- VIT Handle
2- Pointer to a status parameter buffer

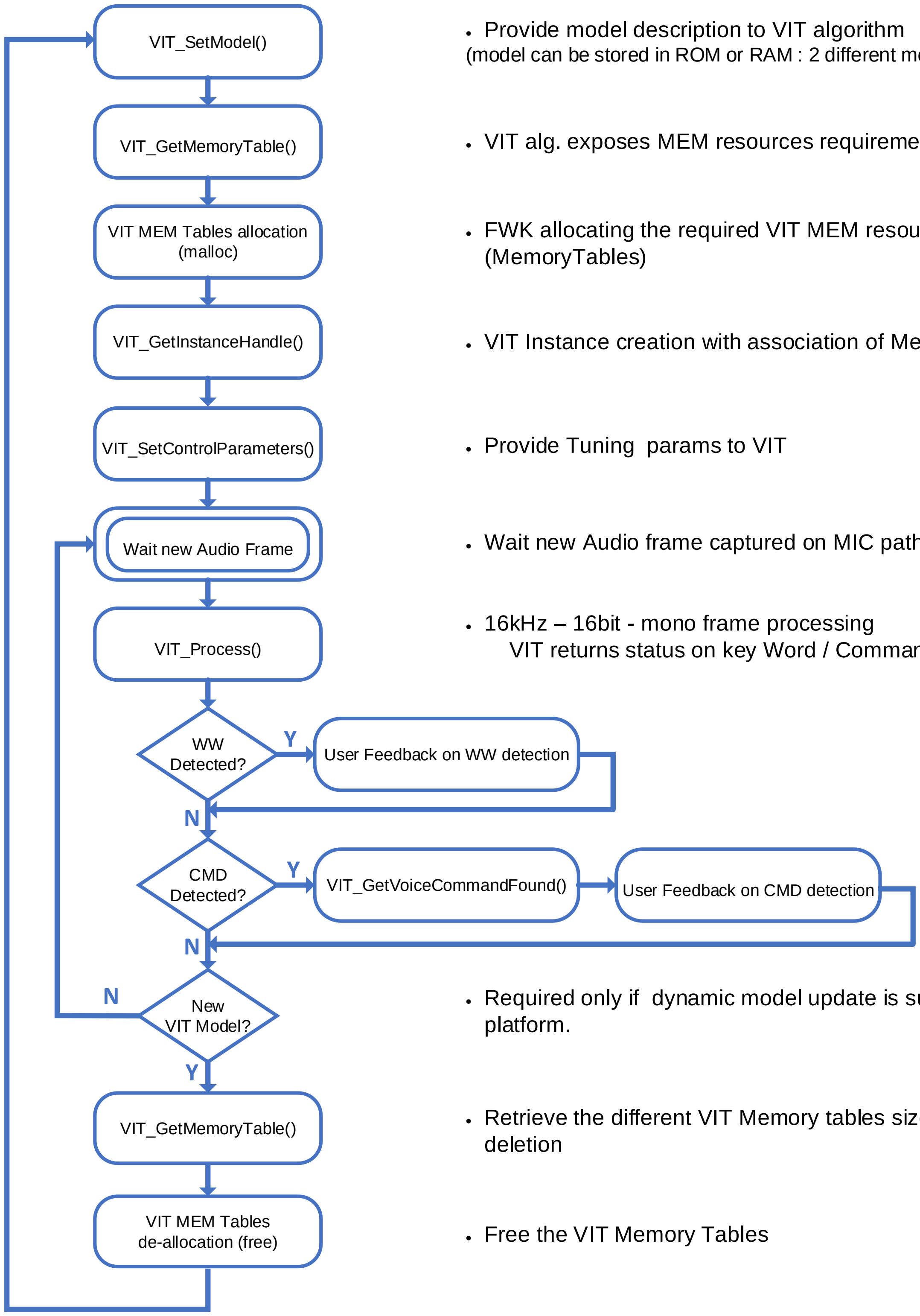
4.2.2.4.3 Output parameters:

Fill the status parameter structure.

4.2.2.4.4 Return value:

A value of type PL_ReturnStatus_en.
If PL_SUCCESS then the status parameters are valid and can be considered.

4.3 Programming sequence



VIT_SetModel()
VIT_GetMemoryTable()
VIT MEM Tables allocation (malloc)
VIT_GetInstanceHandle()
VIT_SetControlParameters()
Wait new Audio Frame
VIT_Process()
WW Detected?
Y
User Feedback on WW detection
N
CMD Detected?
Y
VIT_GetVoiceCommandFound()
User Feedback on CMD detection
N
N
New VIT Model?
Y
VIT_GetMemoryTable()
VIT MEM Tables de-allocation (free)

- Provide model description to VIT algorithm
  (model can be stored in ROM or RAM : 2 different models)
- VIT alg. exposes MEM resources requirement to FWK
- FWK allocating the required VIT MEM resources (MemoryTables)
- VIT Instance creation with association of MemoryTables
- Provide Tuning params to VIT
- Wait new Audio frame captured on MIC path
- 16kHz – 16bit - mono frame processing
  VIT returns status on key Word / Commands detection
- Required only if dynamic model update is supported by the platform.
- Retrieve the different VIT Memory tables size for deletion
- Free the VIT Memory Tables

4.4 Code Sample

The code sample below aimed to explain the configuration and usage of the main VIT interfaces.
See ExApp.c for further details.

4.4.1 Initialization phase

Initialization sequence permit to set an instance of VIT. After initialization sequence, VIT is ready to process audio data. Initialization sequence is in the application code and must respect the following order:

1- Local variable declaration:

```
VIT_Handle_t            VITHandle;             // VIT handle pointer
VIT_InstanceParams_st   VITInstParams;         // VIT instance parameters structure
VIT_ControlParams_st    VITControlParams;      // VIT control parameters structure
PL_MemoryTable_st       VITMemoryTable;        // VIT memory table descriptor
PL_ReturnStatus_en      Status;                // status of the function
VIT_VoiceCommands_t    VoiceCommand;
VIT_DetectionStatus_en  VIT_DetectionResults = VIT_NO_DETECTION; // VIT detection result
VIT_DataIn_st           VIT_InputBuffers  = { PL_NULL, PL_NULL, PL_NULL };
```

2- Set the instance parameters:

Software application code set the instance parameters of VIT function
As an example:

```
VITInstParams.SampleRate_Hz    = VIT_SAMPLE_RATE;
VITInstParams.SamplesPerFrame = VIT_SAMPLES_PER_FRAME;
VITInstParams.NumberOfChannel = _1CHAN;
```

3- Set model address:

```
Status = VIT_SetModel(VIT_Model);  // Pass the address of the VIT Model
```

4- Get memory size and location requirement:

```
Status = VIT_GetMemoryTable(PL_NULL,
                            &VITMemoryTable,
                            &VITInstParams);
```

5- Reserve memory space:

Based on the VITMemoryTable informations, the software application reserve memory space in the required memory type. The start address of each memory type is saved in VITMemoryTable structure.

```
#define MEMORY_ALIGNMENT   4
```

```
//Following pseudo code applied to MemType =
//PL_MEMREGION_PERSISTENT_SLOW_DATA, PL_MEMREGION_PERSISTENT_COEF and
//PL_MEMREGION_TEMPORARY
if (VITMemoryTable.Region[MemType].Size != 0)
  {
    pMemory = malloc_in_SLOW_MEMORY (VITMemoryTable.Region[MemType].Size +
              MEMORY_ALIGNMENT);
      VITMemoryTable.Region[MemType].pBaseAddress = (void *) pMemory;
  }
}

//Following pseudo code applied to MemType = PL_MEMREGION_PERSISTENT_FAST_DATA
if (VITMemoryTable.Region[MemType].Size != 0)
  {
    pMemory = malloc_in_FAST_MEMORY (VITMemoryTable.Region[MemType].Size +
              MEMORY_ALIGNMENT);
      VITMemoryTable.Region[MemType].pBaseAddress = (void *) pMemory;
  }
}
```

6- **Get instance of VIT:**

```
VITHandle = PL_NULL;  // force to null address for correct initialization
Status = VIT_GetInstanceHandle(    &VITHandle,
                                   &VITMemoryTable,
                                   &VITInstParams);
```

7- **Set control parameters:**

SW application code set the new control parameters and call VIT_SetControlParameters:

```
VITControlParams.OperatingMode = VIT_ALL_MODULE_ENABLE;
Status = VIT_SetControlParameters( VITHandle,
                                   &VITControlParams);
```

4.4.2 Process phase

For each new input audio frame, VIT_Process is called by the application code.

```
VIT_InputBuffers.pBuffer_Chan1 = Audio_Buffer;  //temporal data(10ms @16khz mono 16-bit)
VIT_InputBuffers.pBuffer_Chan2 = PL_NULL;
VIT_InputBuffers.pBuffer_Chan3 = PL_NULL;

Status = VIT_Process( VITHandle,
                      &VIT_InputBuffers,
                      &VIT_DetectionResults );       // VIT detection results
```

Check status of the detection:

```
        if (VIT_DetectionResults == VIT_WW_DETECTED)
        {
            // WakeWord detected - possible action :
            printf("WakeWord detected \n");
        }
        else if (VIT_DetectionResults == VIT_VC_DETECTED)
        {
            // a Voice Command detected - Retrieve command information :
            Status = VIT_GetVoiceCommandFound(VITHandle, &VoiceCommand);
            printf("Voice Command : %d detected \n", VoiceCommand.Cmd_Id);

           // Retrieve CMD name : OPTIONAL
            // Check first if CMD string is present
           if (VoiceCommand.Cmd_Name != PL_NULL)
           {
               printf(" %s\n", VoiceCommand.Cmd_Name);
           }
        }
        else
        {
            // No specific action since VIT did not detect anything for this frame
        }
```

4.4.3 Delete phase

The framework can delete the environment process/task of VIT with stopping calling VIT_Process. There is no specific VIT APIs in order to free VIT internal memory since the memory allocation is owned by the framework itself (no internal memory allocation).

The framework will have to free the memory associated with the different VIT memoryTables.
If the framework did not save the MemoryTables properties, `VIT_GetMemoryTable` can be called with `VITHandle` in order to retrieve base addresses and size of the different MemoryTables.

```
Status = VIT_GetMemoryTable(VITHandle,
                            &VITMemoryTable,
                            &VITInstParams);
// Free memory
for (i = 0; i<PL_NR_MEMORY_REGIONS; i++)
{
    if (VITMemoryTable.Region[i].Size != 0)
    {
         free((PL_INT8 *)VITMemoryTable.Region[i].pBaseAddress);
    }
```

}

4.4.4 Additional code snippet (secondary APIs)

- VIT_GetSatusParameters

```
VIT_StatusParams_st  VIT_StatusParams_Buffer;
VIT_StatusParams_st* pVIT_StatusParam_Buffer = (VIT_StatusParams_st*)&VIT_StatusParams_Buffer;

VIT_GetStatusParameters(VITHandle, pVIT_StatusParam_Buffer, sizeof(VIT_StatusParams_Buffer));
printf("\nVIT Status Params\n");
printf(" VIT LIB Release = 0x%04x\n", pVIT_StatusParam_Buffer->VIT_LIB_Release);
printf(" VIT Model Release = 0x%04x\n", pVIT_StatusParam_Buffer->VIT_MODEL_Release);
```

5 VIT Profiling

Cortex-M7 :

MHz	Memory (kB)					
	ROM		RAM			
	Data	Code	FAST	SLOW	SCRATCH	Total
260*	637	45	411	177	12.7	600.7

*with FAST memory buffer (PL_MEMREGION_PERSISTENT_FAST_DATA) allocated in DTC

Figure 2 - VIT profiling figures on RT1060 platform

VIT Stack usage < 1kB

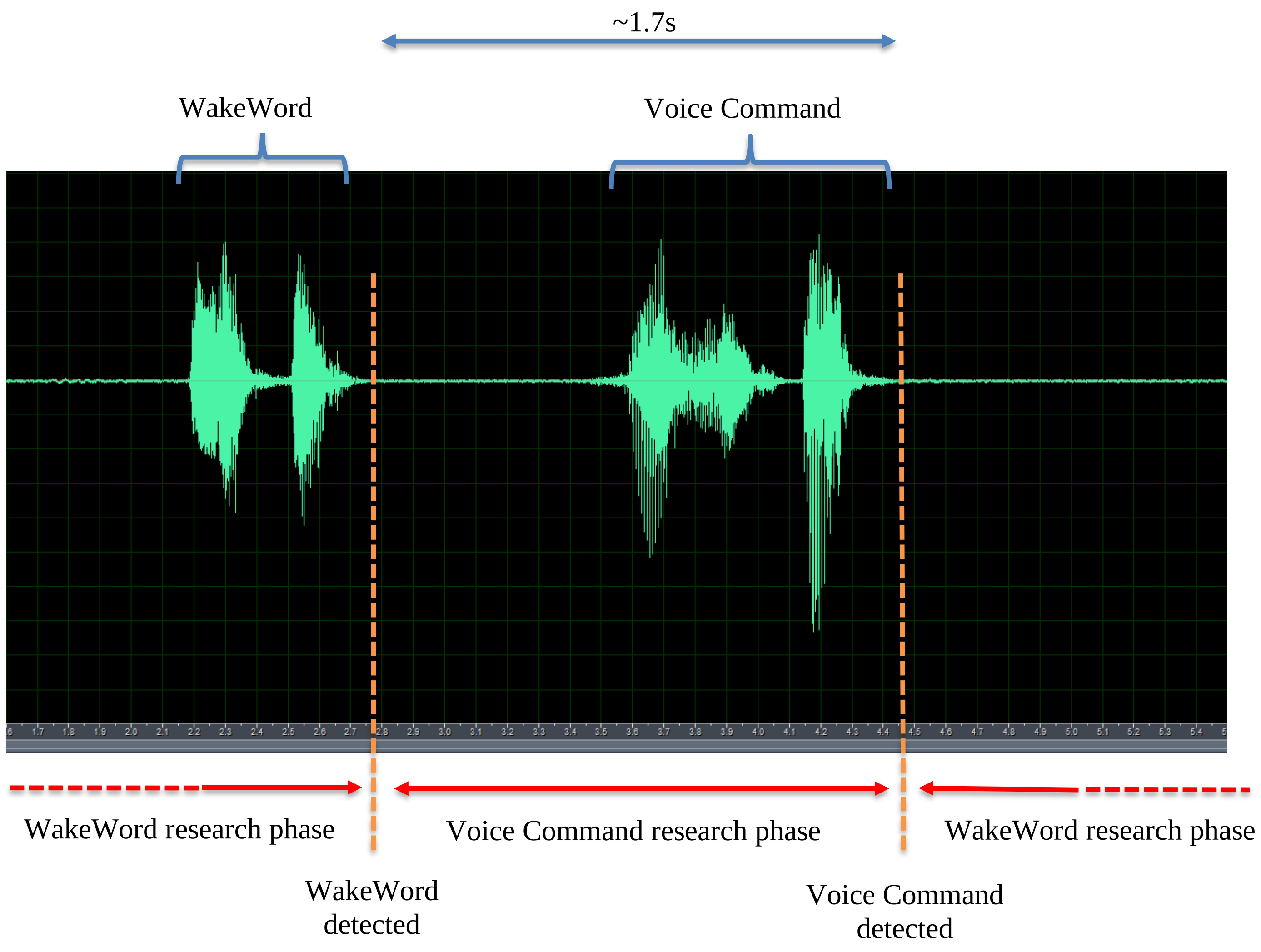
6 Appendix

The example below is illustrating the voice command research window : end of Voice Command utterance shall occur in a ~3s window from the wake word.

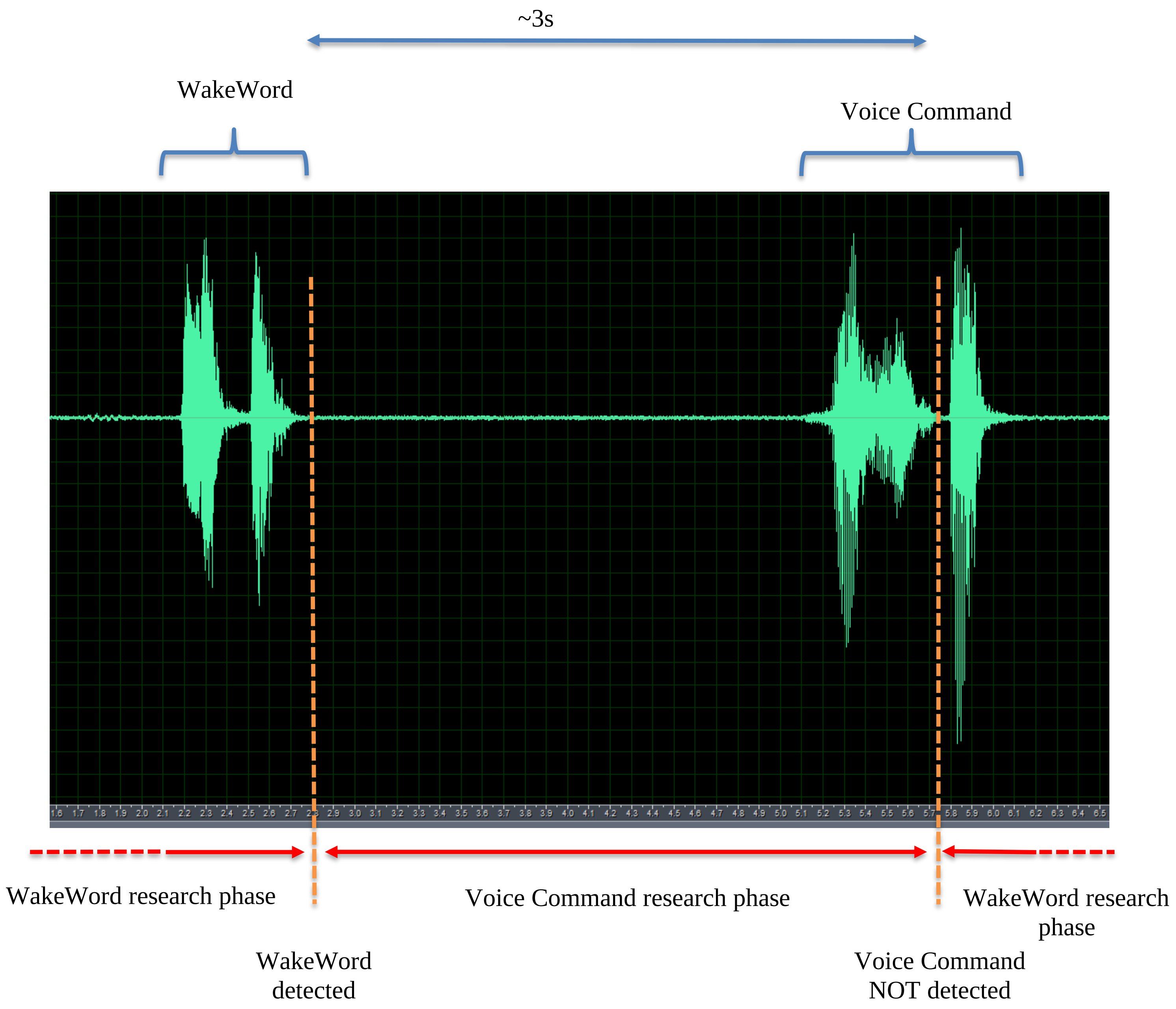
Example 1 :

The voice command utterance is ending 1.7s after the WakeWord :

After having detected the WakeWord, VIT will switch to the Voice Command research mode. VIT will detect the Voice command, and switch back to the Wake word detection mode.



Example 2:
The voice command utterance is ending 3s after the WakeWord :
After having detected the WakeWord, VIT will switch to the Voice Command research mode. VIT will not be able to detect the Voice command, since the Command is not fitting in the 3s window.
At the end of the 3s research window, VIT will return an “UNKNOWN” command and switch back to the WakeWord detection mode.



~3s
WakeWord
Voice Command
WakeWord research phase
Voice Command research phase
WakeWord research phase
WakeWord detected
Voice Command NOT detected