UM1743
User manual

STM32CubeF4 demonstration platform

Introduction

The STM32Cube initiative was originated by STMicroelectronics to ease developers' life by reducing development efforts, time and cost. STM32Cube covers the STM32 portfolio.

The STM32CubeF4 demonstration platform comes on top of the STM32Cube as a firmware package that offers a full set of software components based on a modules architecture that makes it possible to re-use them separately in standalone applications.

All these modules are managed by the STM32CubeF4 demonstration kernel, with the possibility of dynamically add new modules and access the common resources (storage, graphical components and widgets, memory management, Real-Time operating system).

The STM32CubeF4 demonstration platform is built around the powerful graphical library STemWin and the FreeRTOS real time operating system. It uses almost the whole STM32 capability to offer a large scope of usage based on the STM32Cube HAL BSP and several middleware components.

The architecture is defined with the goal of making from the STM32CubeF4 demonstration core an independent central component that can be used with several RTOS and third party firmware libraries, through several abstraction layers inserted between the STM32CubeF4 demonstration core and the modules and libraries working around it.

The STM32CubeF4 demonstration supports STM32F4xx devices and runs on STM324x9I-EVAL,STM324xG-EVAL, STM32F429I-Discovery, STM32446E-EVAL, STM32F479I-EVAL, STM32F469IDISCO, STM32F412G-Discovery and STM32F413H-Discovery boards

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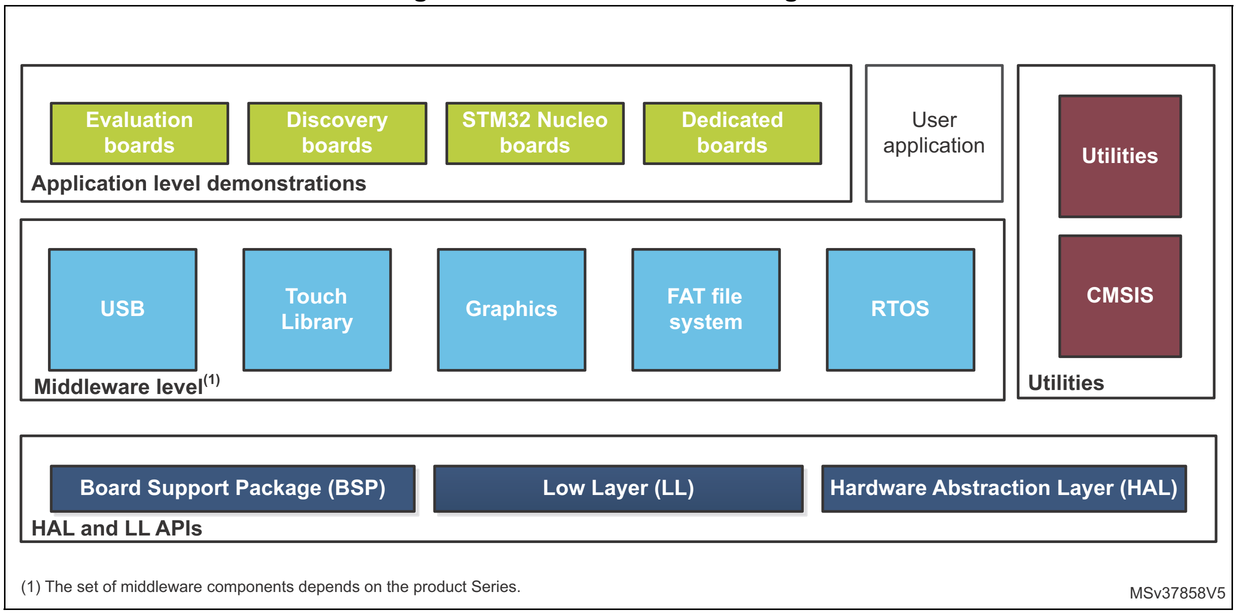
1 STM32Cube overview

The STM32Cube initiative was originated by STMicroelectronics to ease developers' life by reducing development efforts, time and cost. STM32Cube covers the STM32 portfolio.

STM32Cube Version 1.x includes:

- The STM32CubeMX, a graphical software configuration tool that allows to generate C initialization code using graphical wizards.
- A comprehensive embedded software platform, delivered per series (such as STM32CubeF4 for STM32F4 series)
  - The STM32CubeF4 HAL, an STM32 abstraction layer embedded software, ensuring maximized portability across STM32 portfolio
  - A consistent set of middleware components such as RTOS, USB, TCP/IP, Graphics
  - All embedded software utilities coming with a full set of examples.

Figure 1. STM32Cube block diagram



(1) The set of middleware components depends on the product Series.

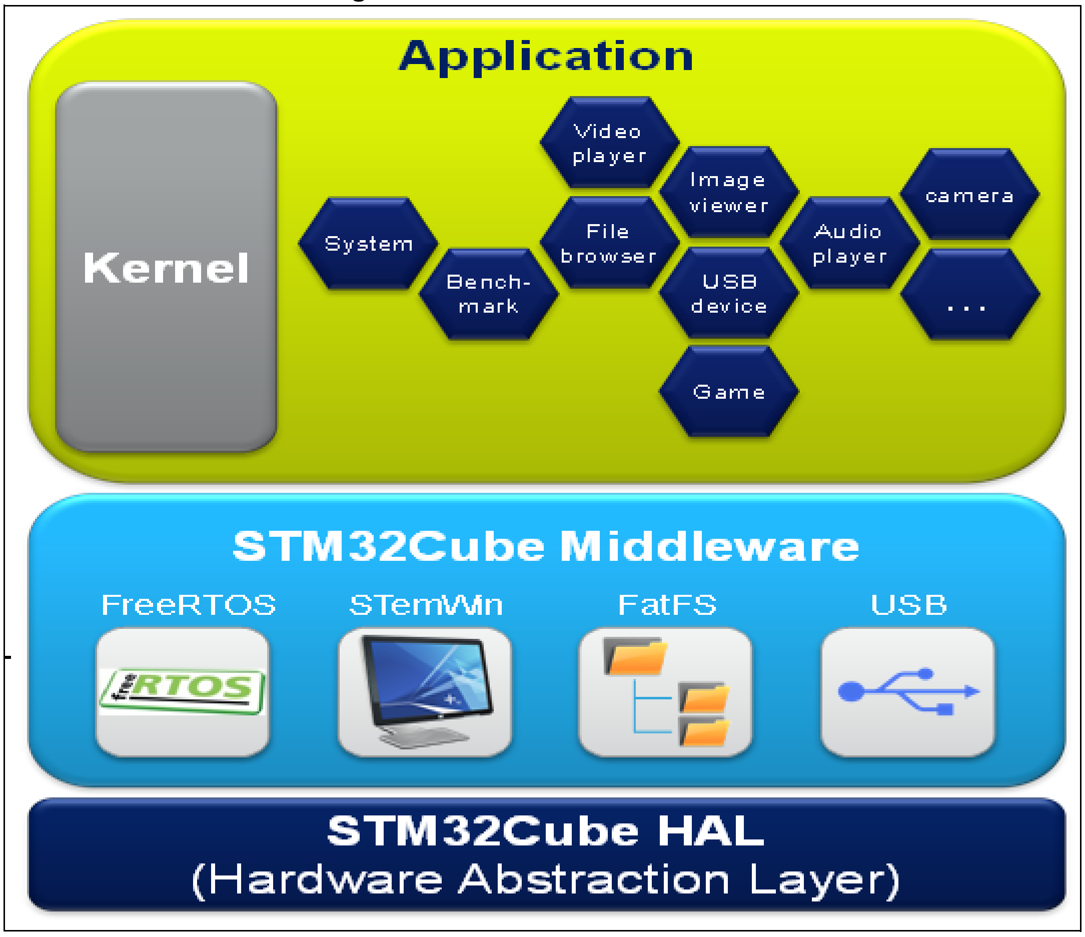
2 Global architecture

The STM32CubeF4 demonstration is composed of a central kernel based on a set of firmware and hardware services offered by the STM32Cube middleware and the several evaluation and discovery boards and a set of modules mounted on the kernel and built in a modular architecture. Each module can be reused separately in a standalone application. The full set of modules is managed by the Kernel which provides access to all common resources and facilitates the addition of new modules as shown in *Figure 2*.

Each module should provide the following functionalities and proprieties:

1. Icon and graphical aspect characteristics.
2. Method to startup the module.
3. Method to close down safety the module (example: Hot unplug for Unit Storage)
4. Method to manage low power mode
5. The module application core (main module process)
6. Specific configuration
7. Error management

Figure 2. STM32Cube architecture



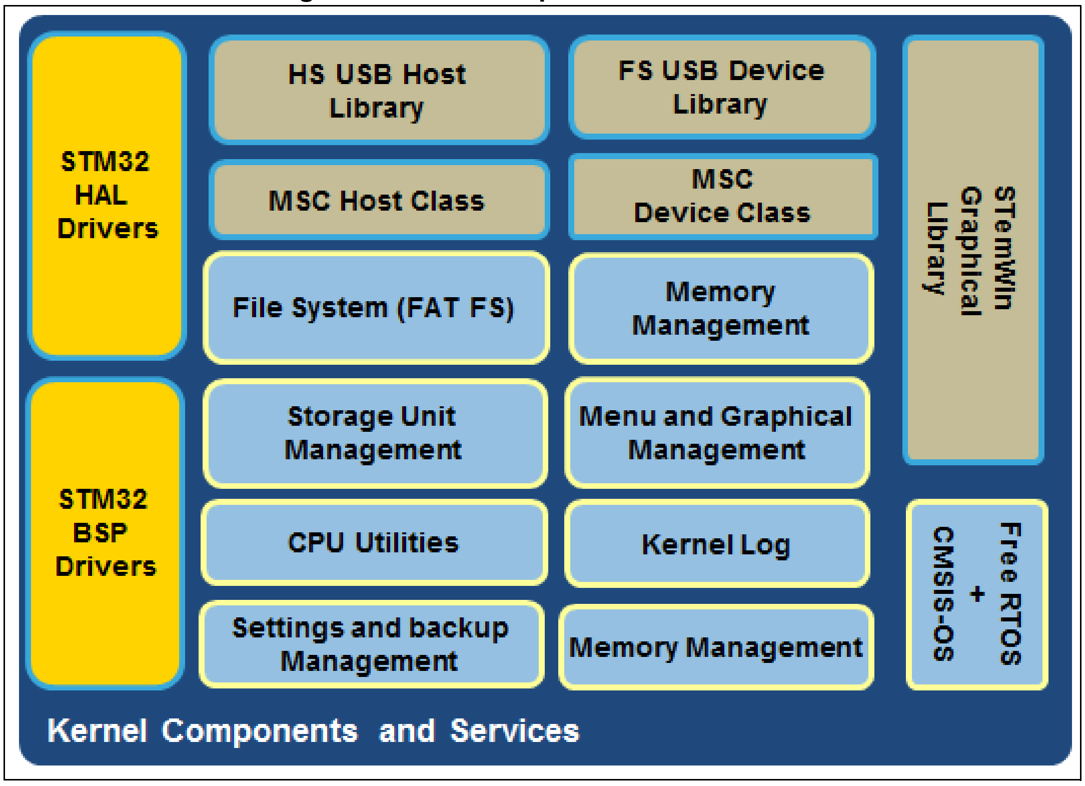
3 Kernel description

3.1 Overview

The role of the demonstration kernel is mainly to provide a generic platform that control and monitor all the application processes, the kernel provides a set of friendly user APIs and services that allow to the user modules to have access to all the hardware and firmware resources and provide the following tasks and services:

- Hardware and modules initialization:
  - BSP initialization (LEDs, SDRAM, Touch screen, CRC, SRAM, RTC, QSPI and audio)
  - GUI initialization and Touch screen calibration
- Memory management
- Kernel log
- Graphical resources and main menu management.
- Storage managements (USB Disk flash and microSD)
- System monitoring and settings
- Time and date resources management
- File browsing and contextual menu
- CPU utilities (CPU usage, running tasks)

Figure 3. Kernel components and services



3.2 Kernel initialization

The first task of the kernel is to initialize the hardware and firmware resources to make them available to its internal processes and the modules around it. The kernel starts by initializing the HAL, system clocks and then the hardware resources needed during the middleware components:

- LEDs and Touchscreen
- SDRAM/SRAM
- Backup SRAM
- RTC
- Quad-SPI Flash memory
- Audio Interface

Note: Not all the hardware resources can be used in all demonstration platforms, according to the availability and to the integrated modules.

Once the low level resources are initialized, the kernel performs the STemWin GUI library initialization and prepares the following common services:

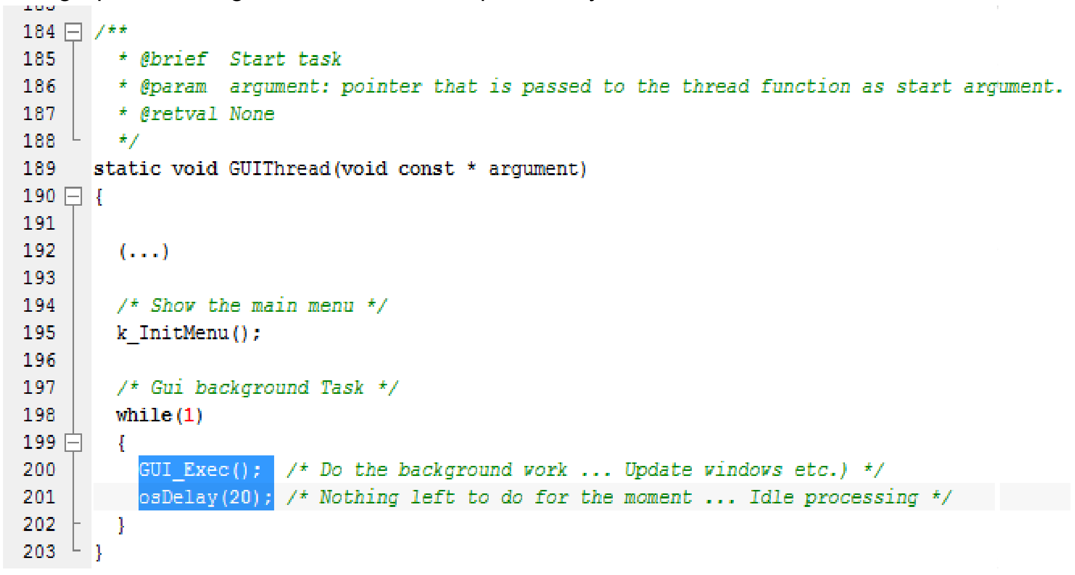
- Memory manager
- Storage units
- Modules manager
- Kernel Log

Upon full initialization phase, the kernel adds and links the system and user modules to the demonstration core.

3.3 Kernel processes and tasks

The kernel is composed of two main tasks managed by FreeRTOS through the CMSIS-OS wrapping layer:

- GUI Thread: this task Initializes the demonstration main menu and then handles the graphical background task when requested by the STemWin;



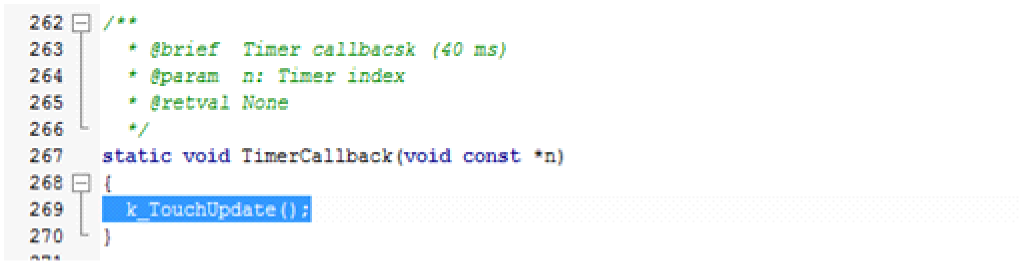
```
/**
  * @brief  Start task
  * @param  argument: pointer that is passed to the thread function as start argument.
  * @retval None
  */
static void GUIThread(void const * argument)
{

  (...)

  /* Show the main menu */
  k_InitMenu();

  /* Gui background Task */
  while(1)
  {
    GUI_Exec(); /* Do the background work ... Update windows etc.) */
    osDelay(20); /* Nothing left to do for the moment ... Idle processing */
  }
}
```

- Timer Callback: this is the callback of the Timer managing periodically the touch screen state, the Timer callback is called periodically each 40 milliseconds.



```
/**
  * @brief  Timer callbacsk (40 ms)
  * @param  n: Timer index
  * @retval None
  */
static void TimerCallback(void const *n)
{
  k_TouchUpdate();
}
```

3.4 Kernel graphical aspect

The STM32CubeF4 demonstration is built around the STemWin Graphical Library, based on SEGGER emWin one. STemWin is a professional graphical stack library, enabling Graphical User Interfaces (GUI) building up with any STM32, any LCD and any LCD controller, taking benefit from STM32 hardware accelerations, whenever possible.

The graphical aspect of the STM32CubeF4 demonstration is divided into two main graphical components:

- the startup window (*Figure 4* and *Figure 5*), showing the progress of the hardware and software initialization;
- the main desktop (shown in figures *6*, *7*, *8* and *9*), that handles the main demonstration menu and the many kernel and module controls.

Figure 4. Startup window

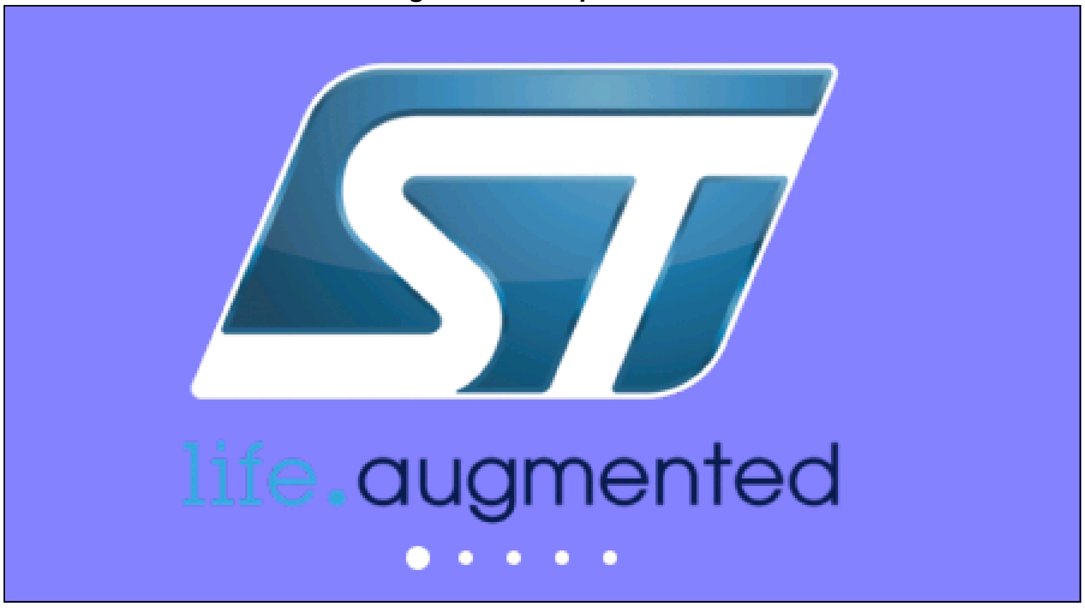
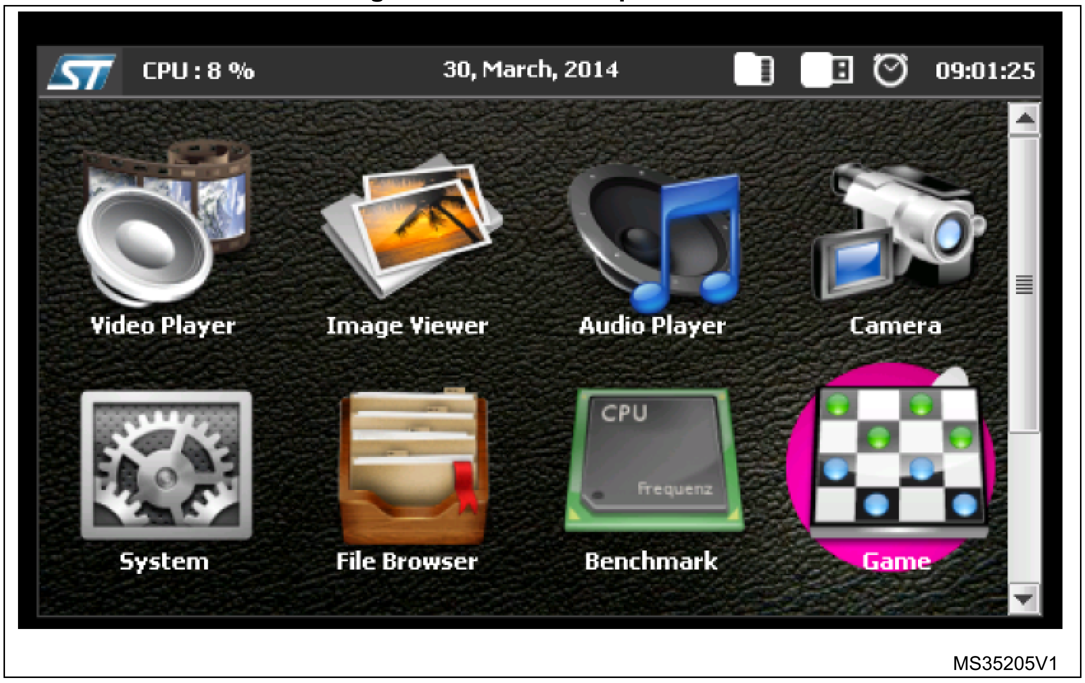


Figure 5. Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations

Figure 6. Main desktop window



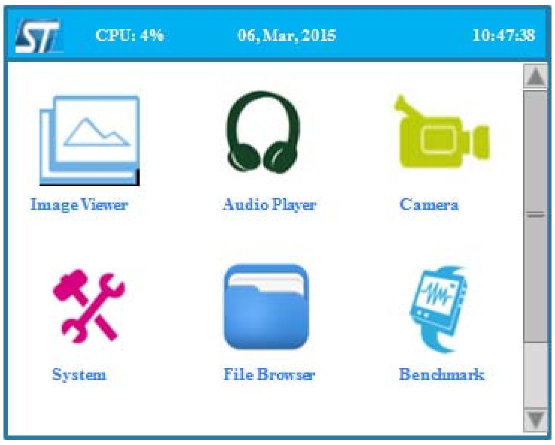


Figure 7. Main desktop window for STM32446E-EVAL demonstration

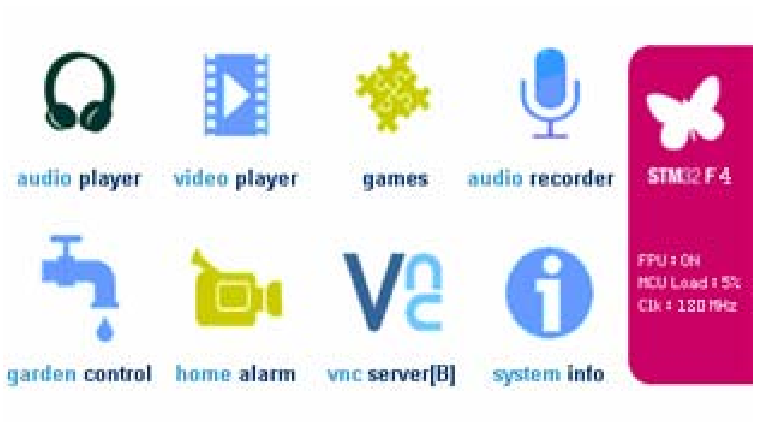


Figure 8. Main desktop window for STM32479I-EVAL demonstration

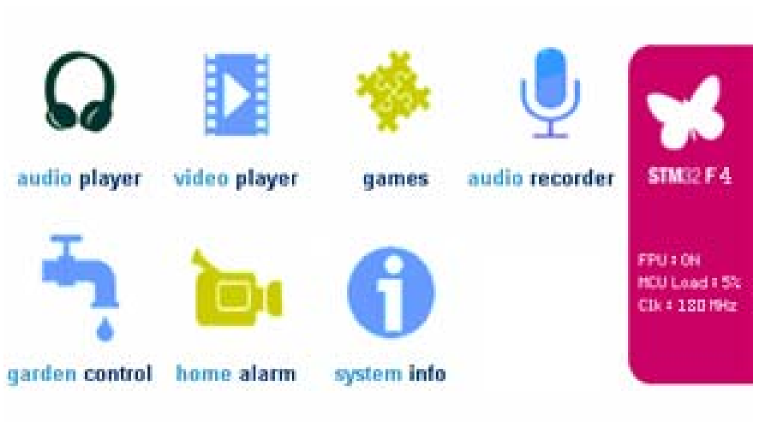
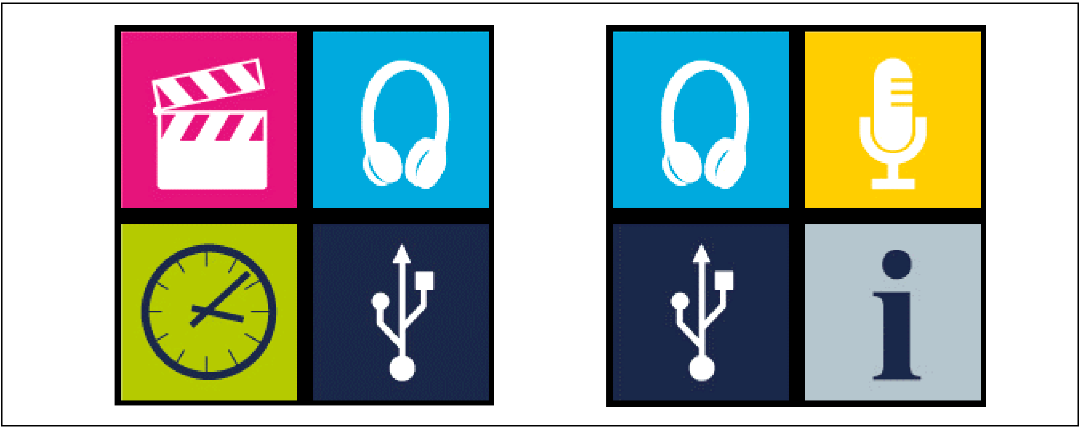


Figure 9. Main desktop window for STM32469I-DISCO demonstration

Figure 10. Main desktop window for STM32412G-DISCO and STM32413H-DISCO demonstrations



3.5 ST widget add-ons

Note: This section is applicable only for STM32F479I-EVAL and STM32F469I-DISCO demonstrations.

The ST_addons binary file provided with STM32F4 demonstration contains new widgets based on STemWin graphical library:

- ST animated icon view
- ST slider skin

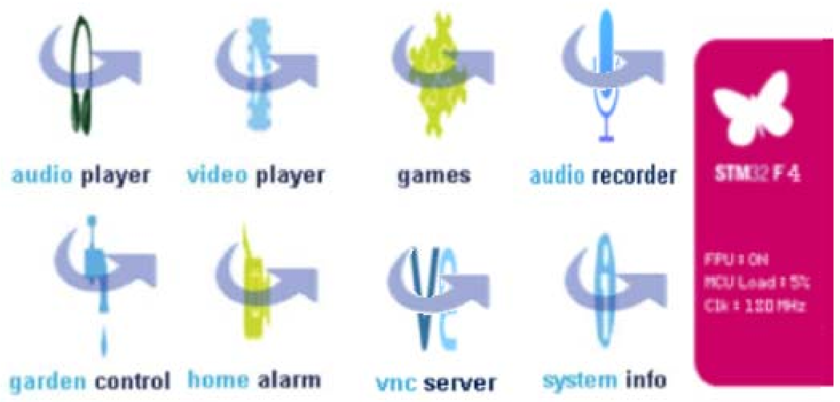
3.5.1 ST animated icon view

A new icon view widget is delivered with STM32F4 demonstration based on STemWin graphical library.

The new widget offers the possibility to turn all the modules icons in the menu after startup with a configured number of frames and configured a delay between each frame.

The new icon view (see *Figure 11*) offers also the possibility to configure the module name with two different colors and fonts.

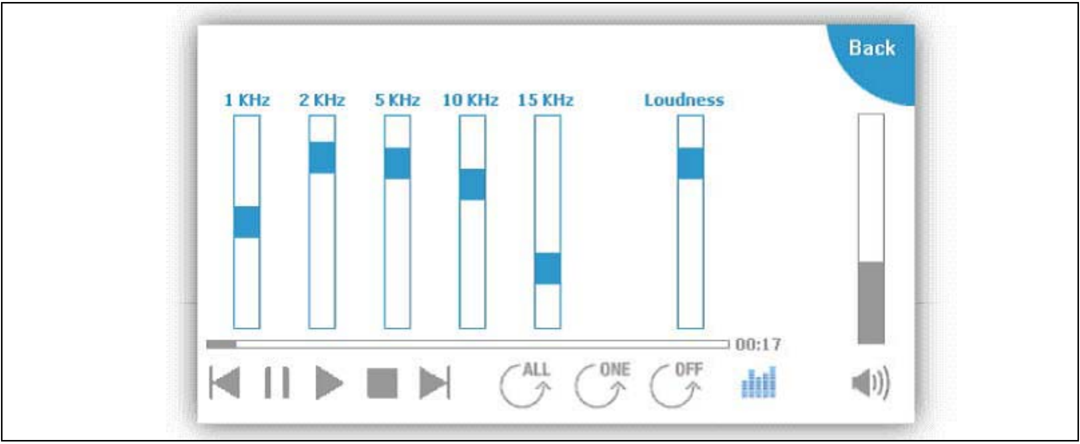
Figure 11. Icon view widget



3.5.2 ST slider skin

A new slider skin is delivered with STM32F4 demonstration based on STemWin graphical library. The new skin offers the possibility to change the slider color and the behavior as shown in *Figure 12*.

Figure 12. Slider skin



3.6 Kernel menu management

The main demonstration menu is initialized and launched by the GUI thread. Before the initialization of the menu the following actions are performed:

- Draw the background image.
- Create the status bar (not applicable for STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and and STM32F413H-DISCO demonstrations).
- Restore general settings from backup memory.
- Setup the main desktop callback to manage main window messages.

The main desktop is built around two main graphical components:

- The status bar (*Figure 13* and *Figure 14*): indicates the storage units connection status, current time and date and a system button to allow to get system information like (running task, CPU load, and kernel log).
- The icon view widget (*Figure 15* and *Figure 16*): contains the icons associated to added modules. User can launch a module by a simple click on the module icon.

Figure 13. Status bar

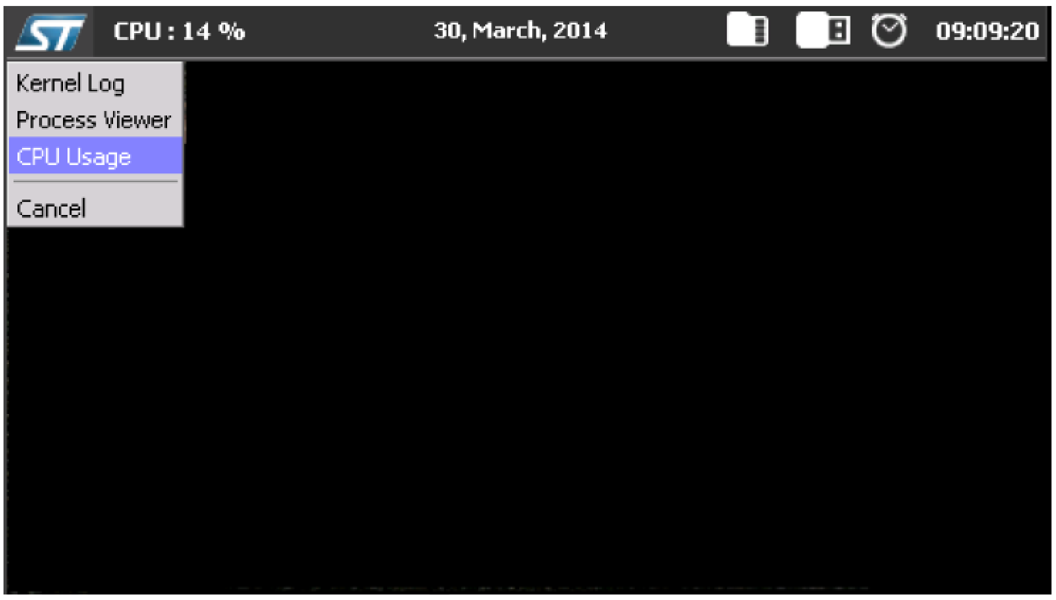


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Figure 14. Status bar for STM32446E-EVAL demonstration

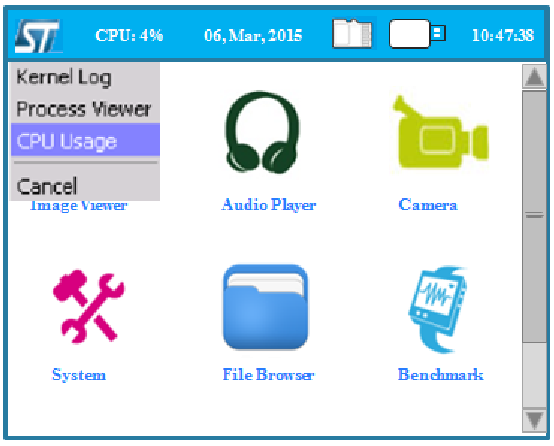


Figure 15. Icon view widget

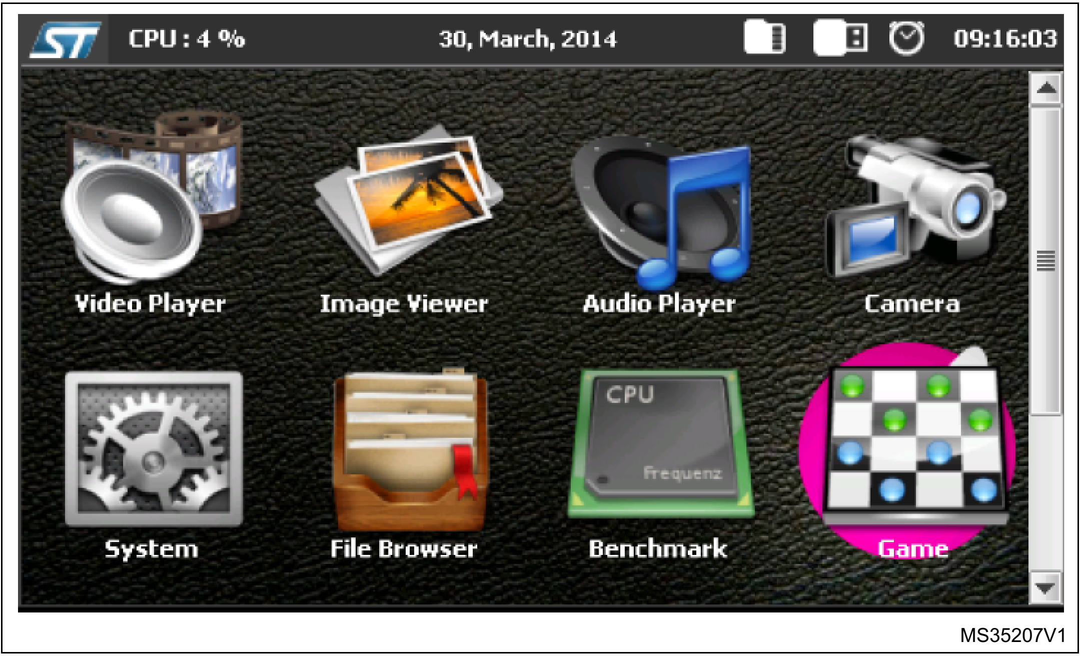
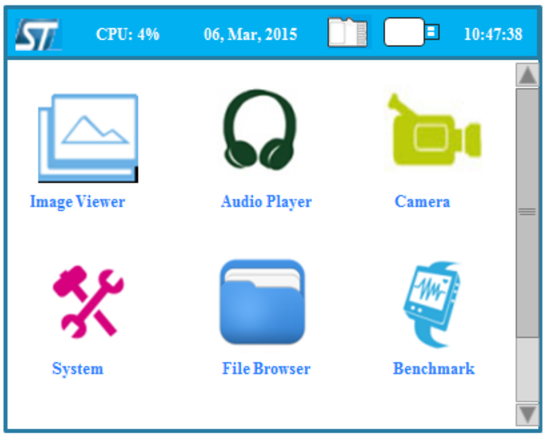
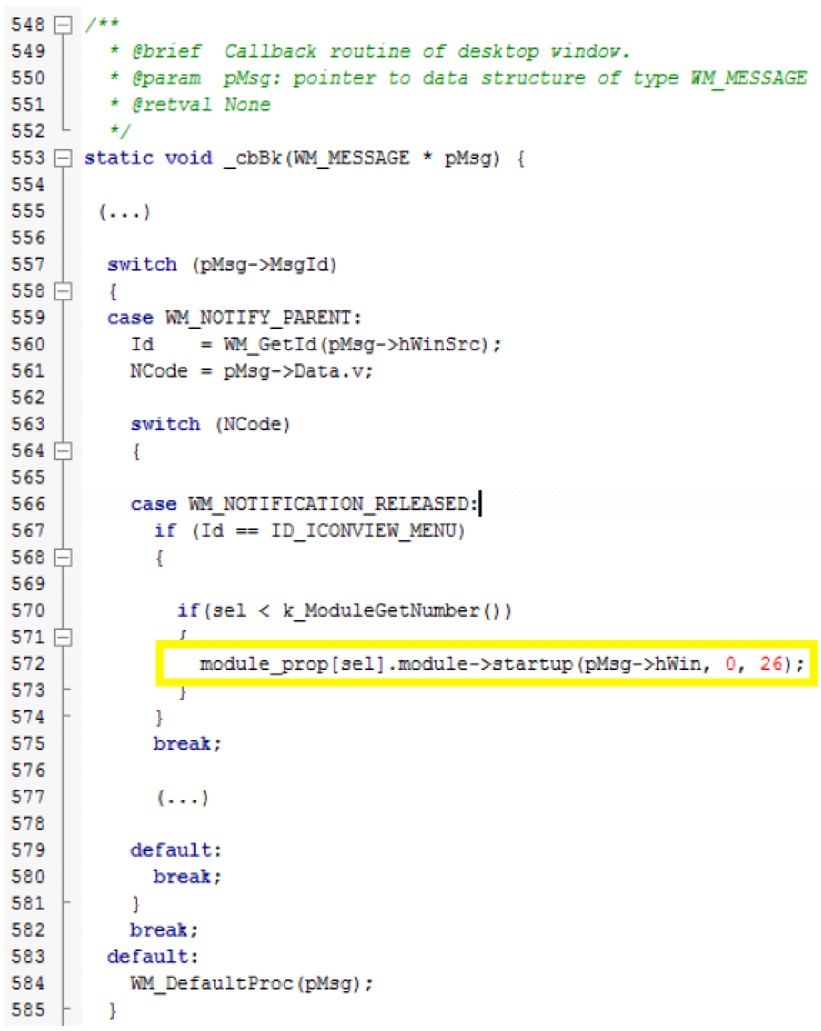


Figure 16. Icon view widget for STM32446E-EVAL demonstration



A module is launched on simple click on the associated icon by calling to the startup function in the module structure; this is done when a WM_NOTIFICATION_RELEASED message arrives to the desktop callback with ID_ICONVIEW_MENU:



```
/**
  * @brief  Callback routine of desktop window.
  * @param  pMsg: pointer to data structure of type WM_MESSAGE
  * @retval None
  */
static void _cbBk(WM_MESSAGE * pMsg) {

 (...)

  switch (pMsg->MsgId)
  {
  case WM_NOTIFY_PARENT:
    Id    = WM_GetId(pMsg->hWinSrc);
    NCode = pMsg->Data.v;

    switch (NCode)
    {

    case WM_NOTIFICATION_RELEASED:
      if (Id == ID_ICONVIEW_MENU)
      {

        if(sel < k_ModuleGetNumber())
        {
          module_prop[sel].module->startup(pMsg->hWin, 0, 26);
        }
      }
      break;

      (...)

    default:
      break;
    }
    break;
  default:
    WM_DefaultProc(pMsg);
  }
```

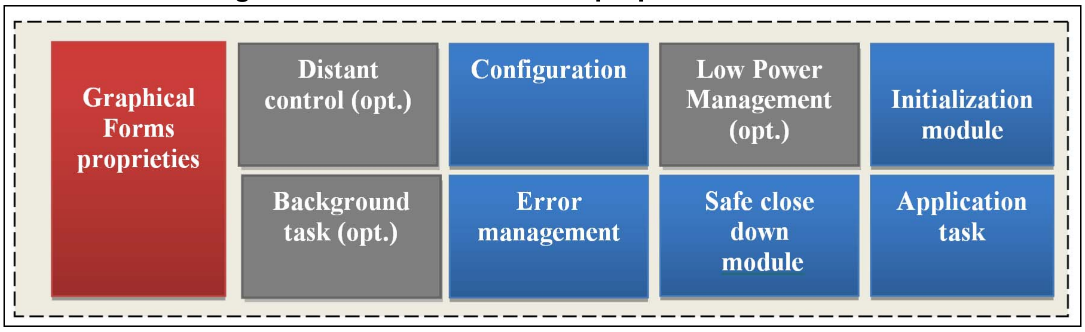
3.7 Modules manager

The modules are managed by the kernel; the latter is responsible of initializing the modules, initializing hardware and GUI resources relative to the modules and initializing the common resources such as the storage Unit, the graphical widgets and the system menu.

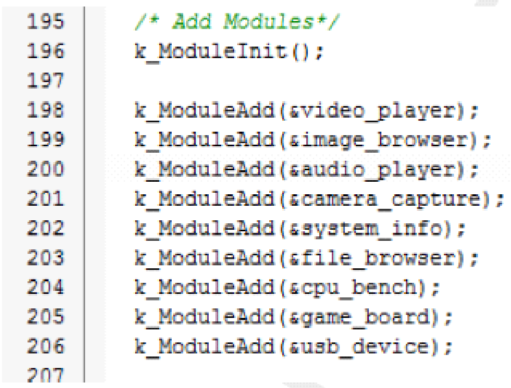
Each module should provide the following functionalities and proprieties:

1. Icon and graphical component structure.
2. Method to startup the module.
3. Method to close down safety the module (example: Hot unplug for MS flash disk)
4. Method to manage low power mode (optional)
5. The Application task
6. The module background process (optional)
7. Remote control method (optional)
8. Specific configuration
9. Error management

Figure 17. Functionalities and properties of modules



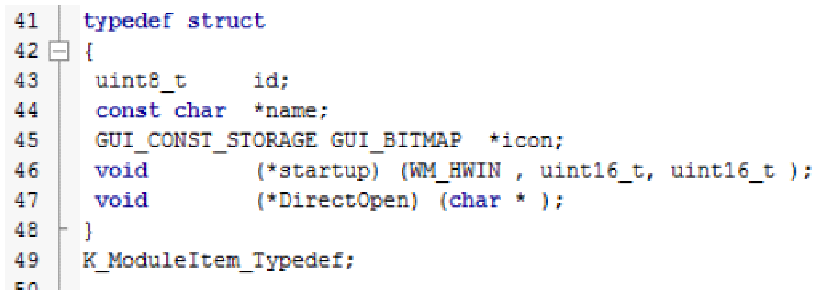
The modules could be added in run time to the demonstration and can use the common kernel resources. The following code shows how to add a module to the demonstration:



```
/* Add Modules*/
k_ModuleInit();

k_ModuleAdd(&video_player);
k_ModuleAdd(&image_browser);
k_ModuleAdd(&audio_player);
k_ModuleAdd(&camera_capture);
k_ModuleAdd(&system_info);
k_ModuleAdd(&file_browser);
k_ModuleAdd(&cpu_bench);
k_ModuleAdd(&game_board);
k_ModuleAdd(&usb_device);
```

A module is a set of function and data structures that are defined in a data structure that provides all the information and pointers to specific methods and functions to the kernel. This later checks the integrity and the validity of the module and inserts its structure into a module table.

Each module is identified by a unique ID. When two modules have the same UID, the Kernel rejects the second one. The module structure is defined as follows:



```
typedef struct
{
 uint8_t      id;
 const char   *name;
 GUI_CONST_STORAGE GUI_BITMAP   *icon;
 void         (*startup) (WM_HWIN , uint16_t, uint16_t );
 void         (*DirectOpen) (char * );
}
K_ModuleItem_Typedef;
```

In this definition:

- Id: unique module identifier.
- Name: pointer to module name
- Icon: pointer to module icon (bitmap format)
- Startup: the function that create the module frame and control buttons
- DirectOpen: the function that creates the module frame and launch the media associated to the file name selected in the file browser linked to a specific file extension (note that this functionality is not used in STM32F479I-EVAL; STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations).

3.8 Direct open feature

The direct open feature allows the user to launch a media module directly from file browser when the extension file match with supported media type. The file extension should be previously associated to a module by using the following code:

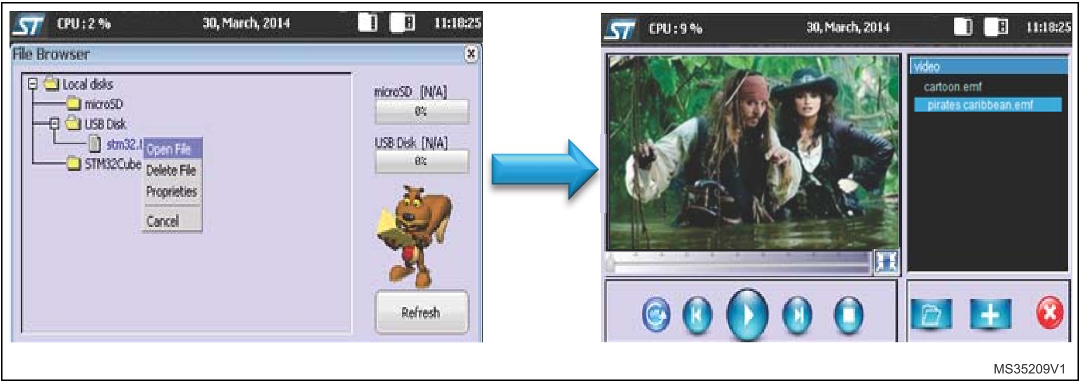
```
/* Add Modules*/
k_ModuleInit();

k_ModuleAdd(&video_player);
k_ModuleOpenLink(&video_player, "emf");
```

For STM32446E-EVAL we have:

```
/* Add Modules*/
k_ModuleInit();

k_ModuleAdd(&image_browser);
k_ModuleOpenLink(&image_browser, "jpg");
k_ModuleOpenLink(&image_browser, "JPG");
k_ModuleOpenLink(&image_browser, "bmp");
k_ModuleOpenLink(&image_browser, "BMP");
```

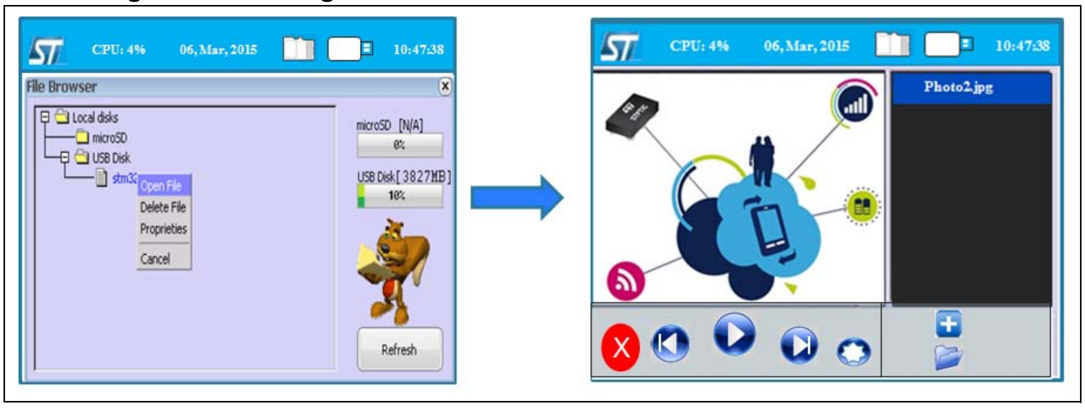
When the file browser is opened, a simple click on a file will open a contextual menu, that direct file open can be executed, as shown in *Figure 18* and in *Figure 19*.

Figure 18. Starting file execution



Note: The video player module is not supported in STM32446E-EVAL demonstration.

Figure 19. Starting file execution for STM32446E-EVAL demonstration



3.9 Backup and settings configuration

The STM32CubeF4 demonstration saves the kernel and modules settings in two different methods:

1. Using the RTC backup register (32 bits data width) , in this method the data to be saved should be a 32 bits data and could be defined as a bitfield structure, example:

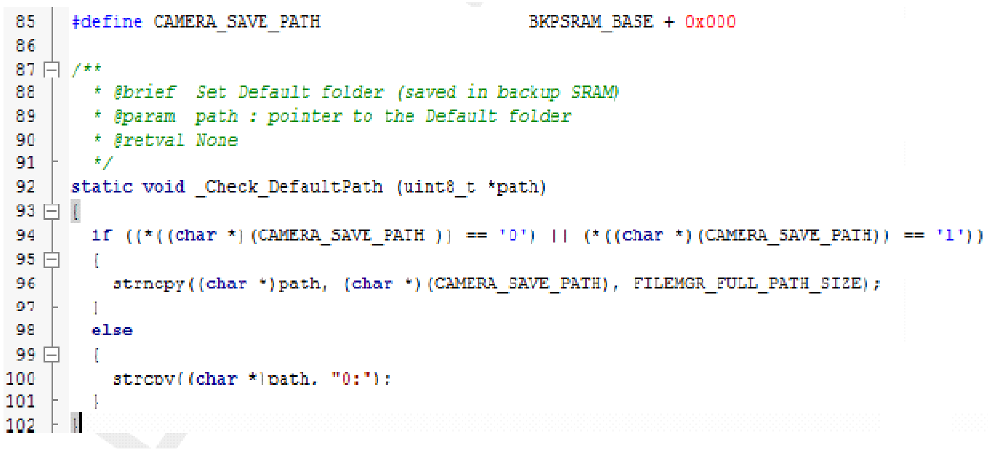
```
typedef union
{
  uint32_t d32;
  struct
  {
    uint32_t repeat          : 2;
    uint32_t pause           : 2;
    uint32_t mute            : 1;
    uint32_t volume          : 8;
    uint32_t reserved        : 21;
  }b;
}
AudioSettingsTypeDef;
```

   The structure could be handled than, by using the two following kernel APIs to save or restore it from the RTC backup registers.

```
void     k_BkupSaveParameter(uint32_t address, uint32_t data);
uint32_t k_BkupRestoreParameter(uint32_t address);
```

2. Using the backup SRAM: the backup SRAM is a memory that the content is not lost when the board is powered down. When available, the backup SRAM is 4 Kbytes size

and located at address: BKPSRAM_BASE (0x40024000). The backup SRAM could be used as normal RAM to save file paths or big structure example:

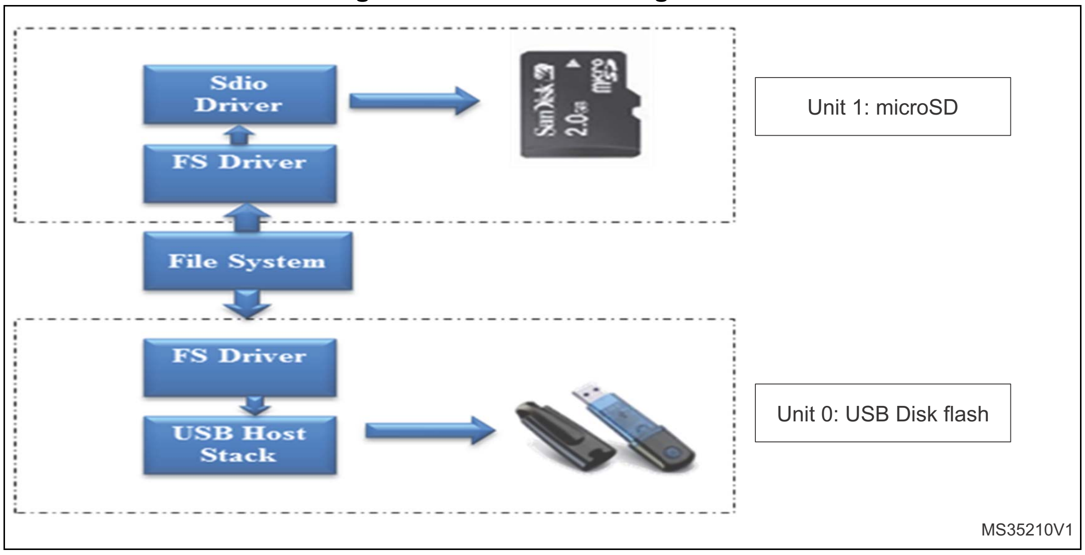


```
#define CAMERA_SAVE_PATH                    BKPSRAM_BASE + 0x000

/**
  * @brief  Set Default folder (saved in backup SRAM)
  * @param  path : pointer to the Default folder
  * @retval None
  */
static void _Check_DefaultPath (uint8_t *path)
{
  if ((*((char *)(CAMERA_SAVE_PATH )) == '0') || (*((char *)(CAMERA_SAVE_PATH)) == '1'))
  {
    strncpy((char *)path, (char *)(CAMERA_SAVE_PATH), FILEMGR_FULL_PATH_SIZE);
  }
  else
  {
    strcpy((char *)path, "0:");
  }
}
```

3.10 Storage units

The STM32CubeF4 demonstration kernel offers two storage units that can be used to retrieve audio, Image and Video media or to save captured images from the camera (*Figure 20*).

Figure 20. Available storage units



The two units are initialized during the platform startup and thus they are available to all the modules during the STM32CubeF4 demonstration run time. These two units are accessible through the standard I/O operations offered by the FatFS used in the development platform. The USB Disk flash unit is identified as the Unit 0 and available only if a USB disk flash is connected on the USB FS connector, while the microSD flash is identified as the Unit1 and available only if the microSD card is connected. The units are mounted automatically when the physical media are connected to the connector on the board.

The implemented functions in the file system interface to deal with the physical storage units are summarized in *Table 1*.

Table 1. File system interface: physical storage control functions

Function	Description
disk_initialize	Initialize disk drive
disk_read	Interface function for a logical page read
disk_write	Interface function for a logical page write
disk_status	Interface function for testing if unit is ready
disk_ioct	Control device dependent features

The full APIs functions set given by the file system interface are listed in *Table 2*:

Table 2. File system interface APIs

Function	Description
f_mount	Register/Unregister a work area
f_open	Open/Create a file
f_close	Close a file
f_read	Read file
f_write	Write file
f_lseek	Move read/write pointer, Expand file size
f_truncate	Truncate file size
f_sync	Flush cached data
f_opendir	Open a directory
f_readdir	Read a directory item
f_getfree	Get free clusters
f_stat	Get file status
f_mkdir	Create a directory
f_unlink	Remove a file or directory
f_chmod	Change attribute
f_utime	Change timestamp
f_rename	Rename/Move a file or directory
f_mkfs	Create a file system on the drive
f_forward	Forward file data to the stream directly
f_chdir	Change current directory
f_chdrive	Change current drive
f_getcwd	Retrieve the current directory
f_gets	Read a string

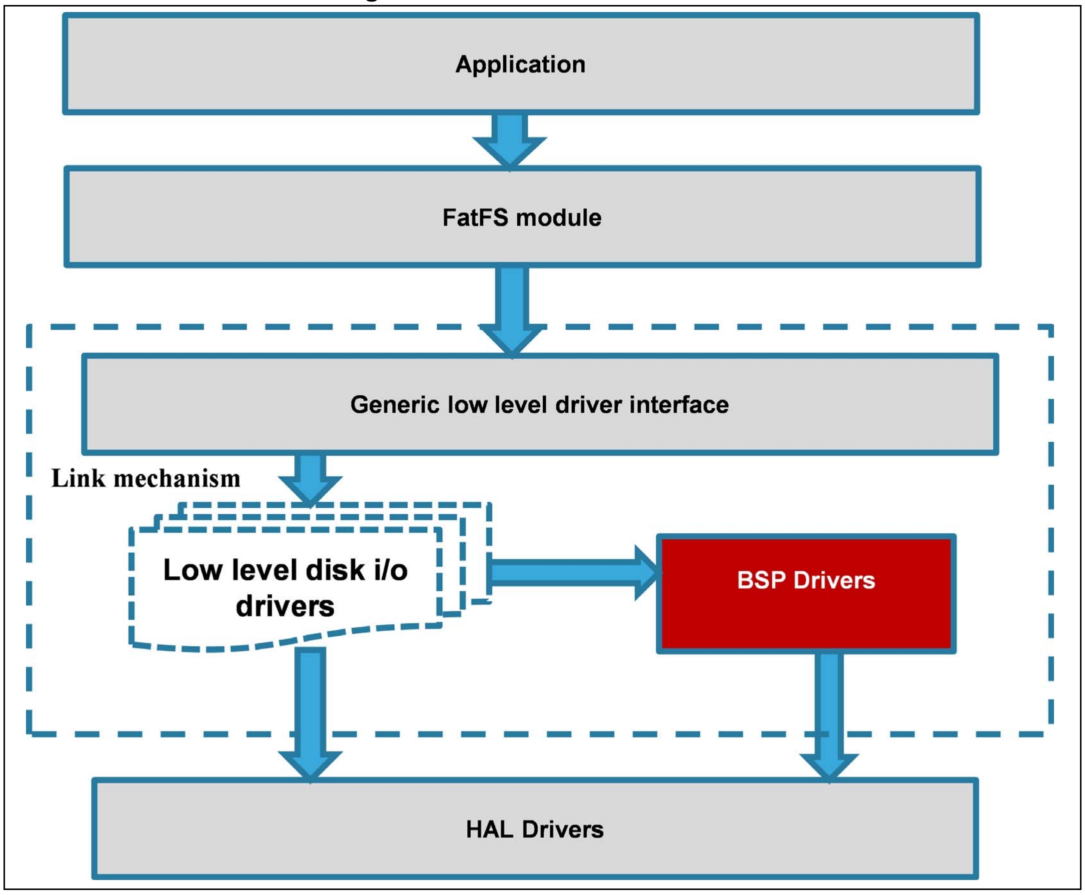
Table 2. File system interface APIs (continued)

Function	Description
f_putc	Write a character
f_puts	Write a string
f_printf	Write a formatted string

For the FAT FS file system, the page size is fixed to 512 bytes. USB Flash disks with higher page size are not supported.

The Storage units are built around the USB host library in high speed and the microSD BSP drivers; the software architecture is shown in *Figure 21*.

Figure 21. Software architecture


Application
FatFS module
Generic low level driver interface
Link mechanism
Low level disk i/o drivers
BSP Drivers
HAL Drivers

The FatFS is mounted upon the USB Host mass storage class and the SD BSP driver to allow an abstract access to the physical media through standard I/O methods.

The storage units' presence detection is handled internally by the kernel and the status bar shows the icons of the available media, as shown in *Figure 22* and in *Figure 23*.

Figure 22. Detection of storage units

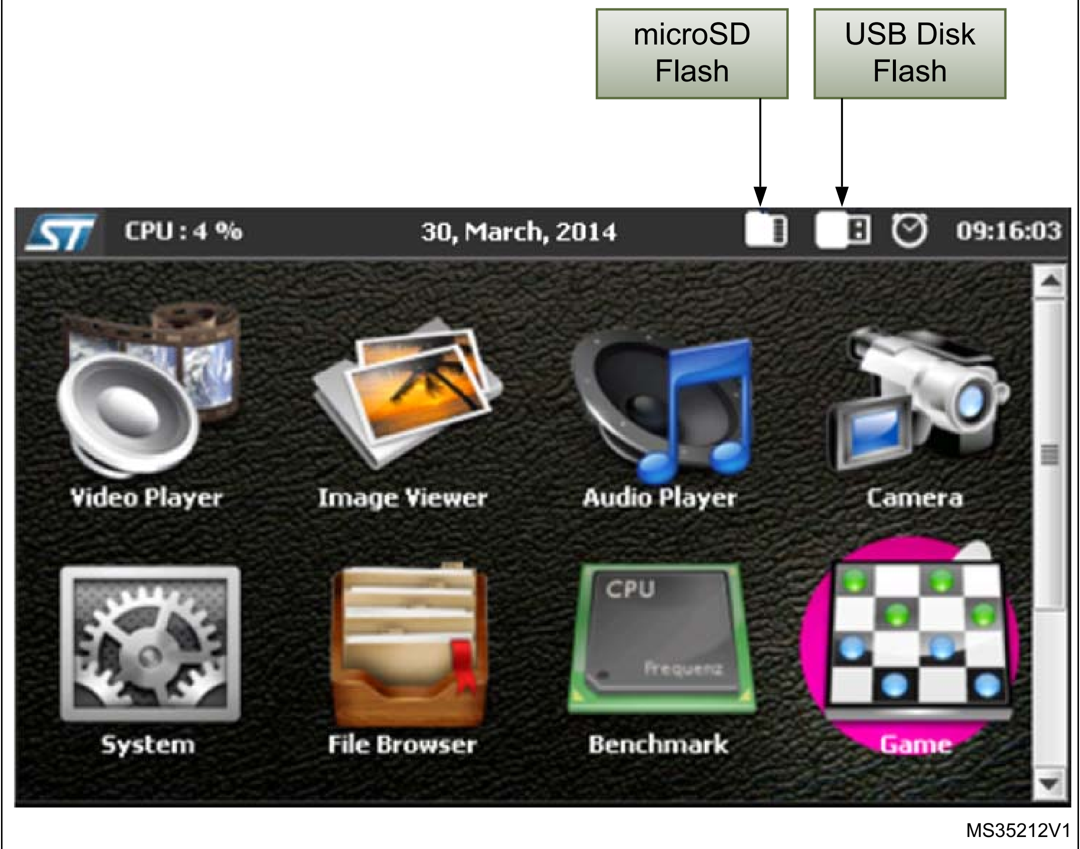
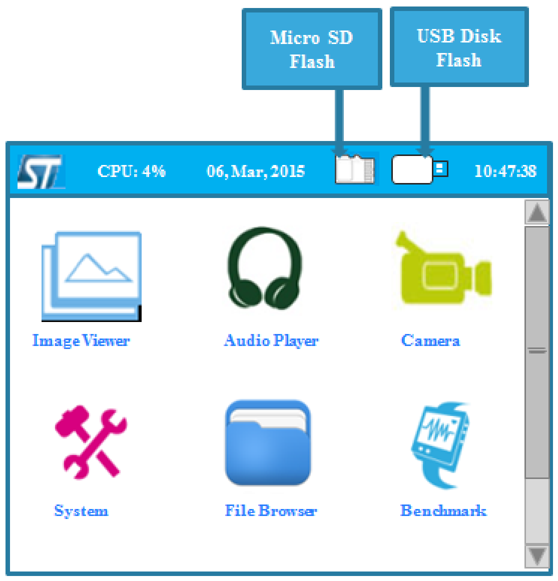


Figure 23. Detection of storage units for STM32446E-EVAL demonstration



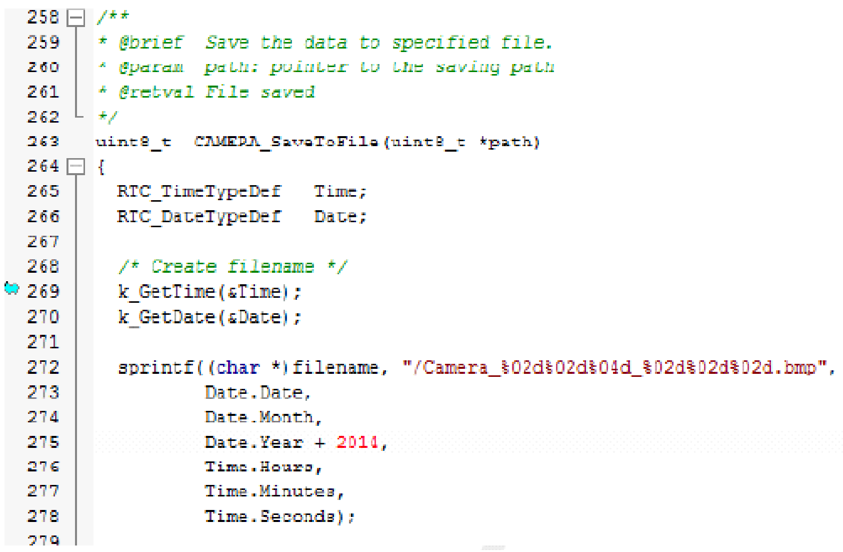
3.11 Clock and date

The clock and date are managed by the RTC HAL driver, the RTC module initializes the LSE source clock and provides a set of methods to retrieve date and clock in addition to backup save and restore ones. *Table 3* shows the different APIs offered by the RTC module:

Table 3. APIs from the RTC module

Function	Description
k_calendarBkupInit	Initialize RTC peripheral (clock and backup registers)
k_BkupSaveParameter	Save a 32bits word into backup registers
k_BkupRestoreParameter	Retrieve a saved 32bits word from backup registers
k_SetTime	Change system time through the RTC_TimeTypeDef
k_GetTime	Get system time into the RTC_TimeTypeDef structure
k_SetDate	Change system date through the RTC_DateTypeDef
k_GetDate	Get system date into the RTC_DateTypeDef structure

The following code shows an example of how to retrieve the system data:



```
/**
* @brief  Save the data to specified file.
* @param  path: pointer to the saving path
* @retval File saved
*/
uint8_t  CAMERA_SaveToFile(uint8_t *path)
{
  RTC_TimeTypeDef   Time;
  RTC_DateTypeDef   Date;

  /* Create filename */
  k_GetTime(&Time);
  k_GetDate(&Date);

  sprintf((char *)filename, "/Camera_%02d%02d%04d_%02d%02d%02d.bmp",
          Date.Date,
          Date.Month,
          Date.Year + 2014,
          Time.Hours,
          Time.Minutes,
          Time.Seconds);

```

The kernel uses the RTC for modules settings saving and getting the time and date, displayed in the status bar of the main desktop. Time and date could be changed through the system module, as shown in *Figure 24* and in *Figure 25*.

Figure 24. Setting the time and the date

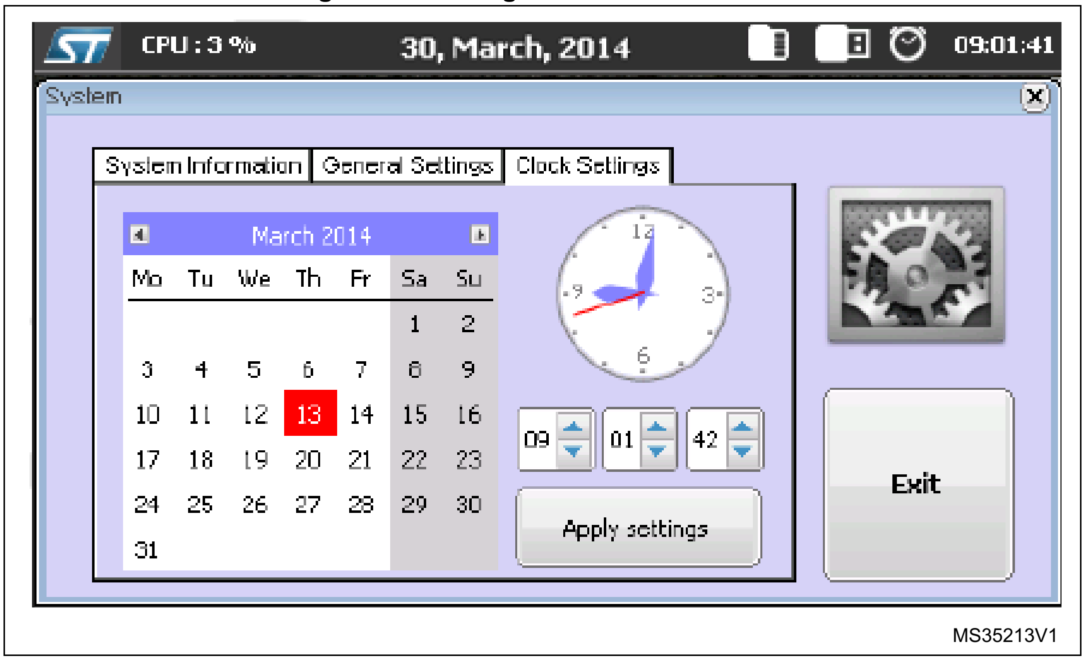
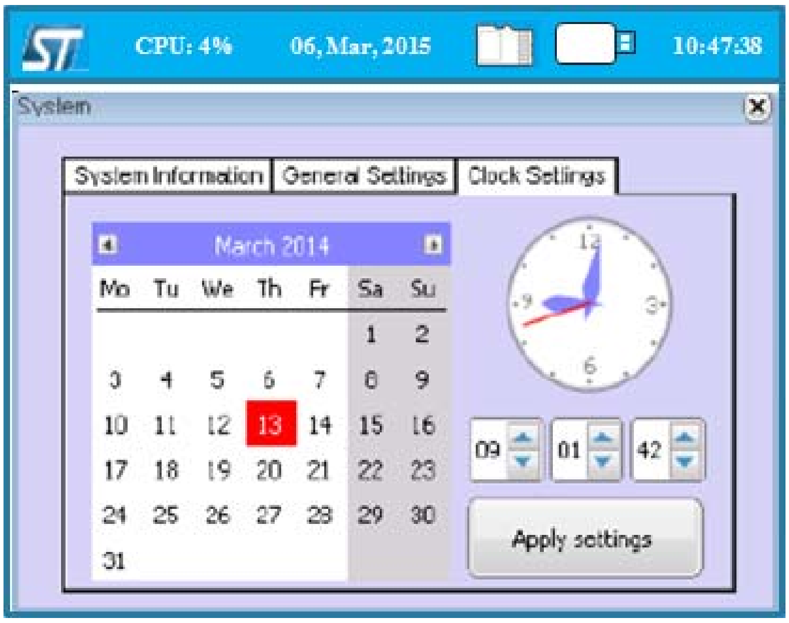


Figure 25. Setting the time and the date for STM32446E-EVAL demonstration



Note: The clock and the date are not shown in STM32F479I-EVAL, STM32F469I-DISCO and STM32F413H-DISCO demonstrations.

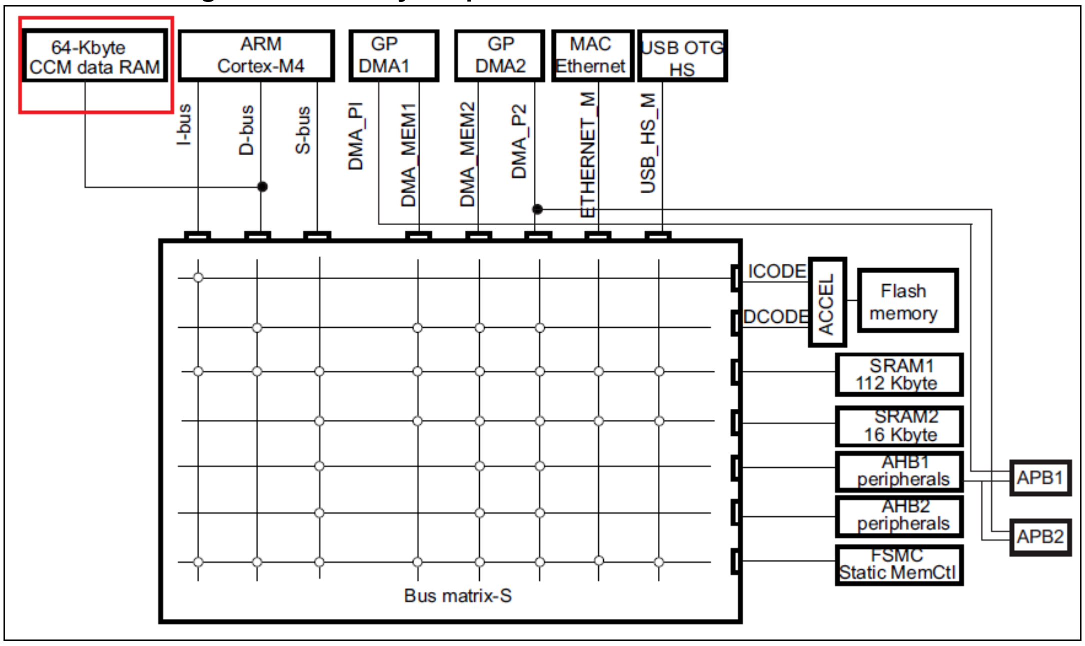
3.12 Memory management

A huge amount of system RAM is allocated to the GUI internal heap, the kernel memory manager is used as a standalone memory allocator for some specific data blocks, like file lists and kernel log buffer.

The kernel memory manager is based on a single memory pool that could be placed anywhere in the additional internal or external memory resources. The memory heap is built on a contiguous memory blocks managed by the mem_Typedef structure through a pages table that gather the block status after each memory allocation or deallocation operations.

For the STM32CubeF4 demonstration, the memory heap is located in the CCM data RAM.

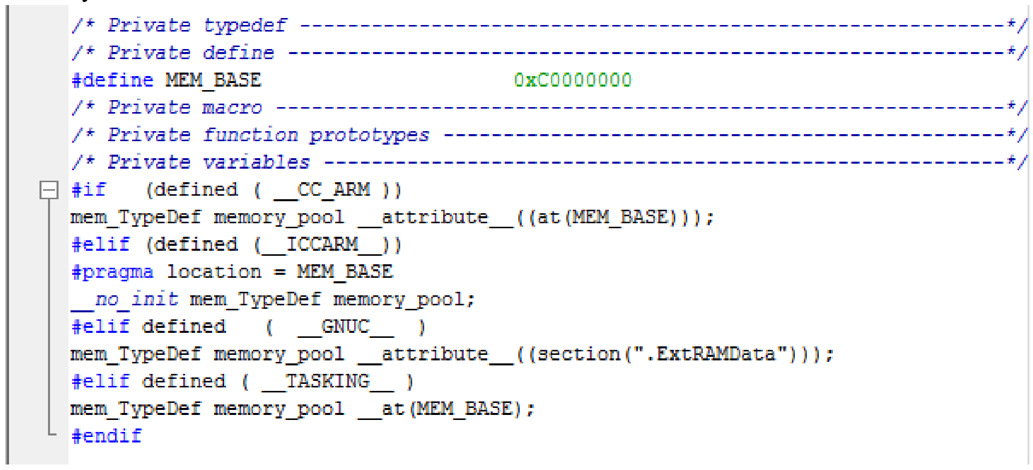
Figure 26. Memory heap for STM32CubeF4 demonstration



The memory manager offers a set of standard high level APIs to allocate and free memory block from the predefined pool. The granularity of the memory allocation is defined by the SIZE_OF_PAGE define, set to 1024 bytes by default and the total number of available blocks depending on the heap size, in the k_mem.h file as shown in the code below.

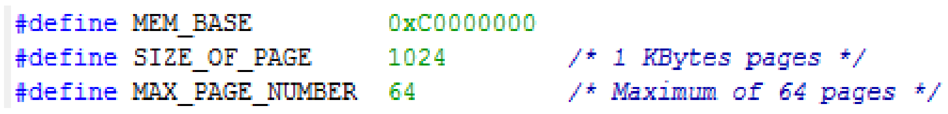
```
#define MEM_BASE                  0x10000000
#define SIZE_OF_PAGE              1024    /* 1 KBytes pages */
#define MAX_PAGE_NUMBER           64     /* Maximum of 64 pages */

```

For STM32446E-EVAL demonstration, the memory heap is located in the external SDRAM memory.



```
/* Private typedef -----------------------------------------------------------*/
/* Private define ------------------------------------------------------------*/
#define MEM_BASE                    0xC0000000
/* Private macro -------------------------------------------------------------*/
/* Private function prototypes -----------------------------------------------*/
/* Private variables ---------------------------------------------------------*/
#if   (defined ( __CC_ARM ))
mem_TypeDef memory_pool __attribute__((at(MEM_BASE)));
#elif (defined (__ICCARM__))
#pragma location = MEM_BASE
__no_init mem_TypeDef memory_pool;
#elif defined   (  __GNUC__  )
mem_TypeDef memory_pool __attribute__((section(".ExtRAMData")));
#elif defined ( __TASKING__ )
mem_TypeDef memory_pool __at(MEM_BASE);
#endif
```

Note: For STM32F479I-EVAL, STM32F469I-DISCO and STM32F412G-DISCO demonstrations the memory manager is not applicable.



```
#define MEM_BASE          0xC0000000
#define SIZE_OF_PAGE      1024          /* 1 KBytes pages */
#define MAX_PAGE_NUMBER   64            /* Maximum of 64 pages */
```

Table 4 shows the different APIs offered by the memory manager module.

Table 4. APIs from the memory manager module

Function	Description
void k_MemInit(void)	Initialize the memory heap (base address)
void * k_malloc (size_t s)	Allocate an amount of contiguous memory blocks
void k_free (void * p)	Free an already allocated amount of RAM blocks

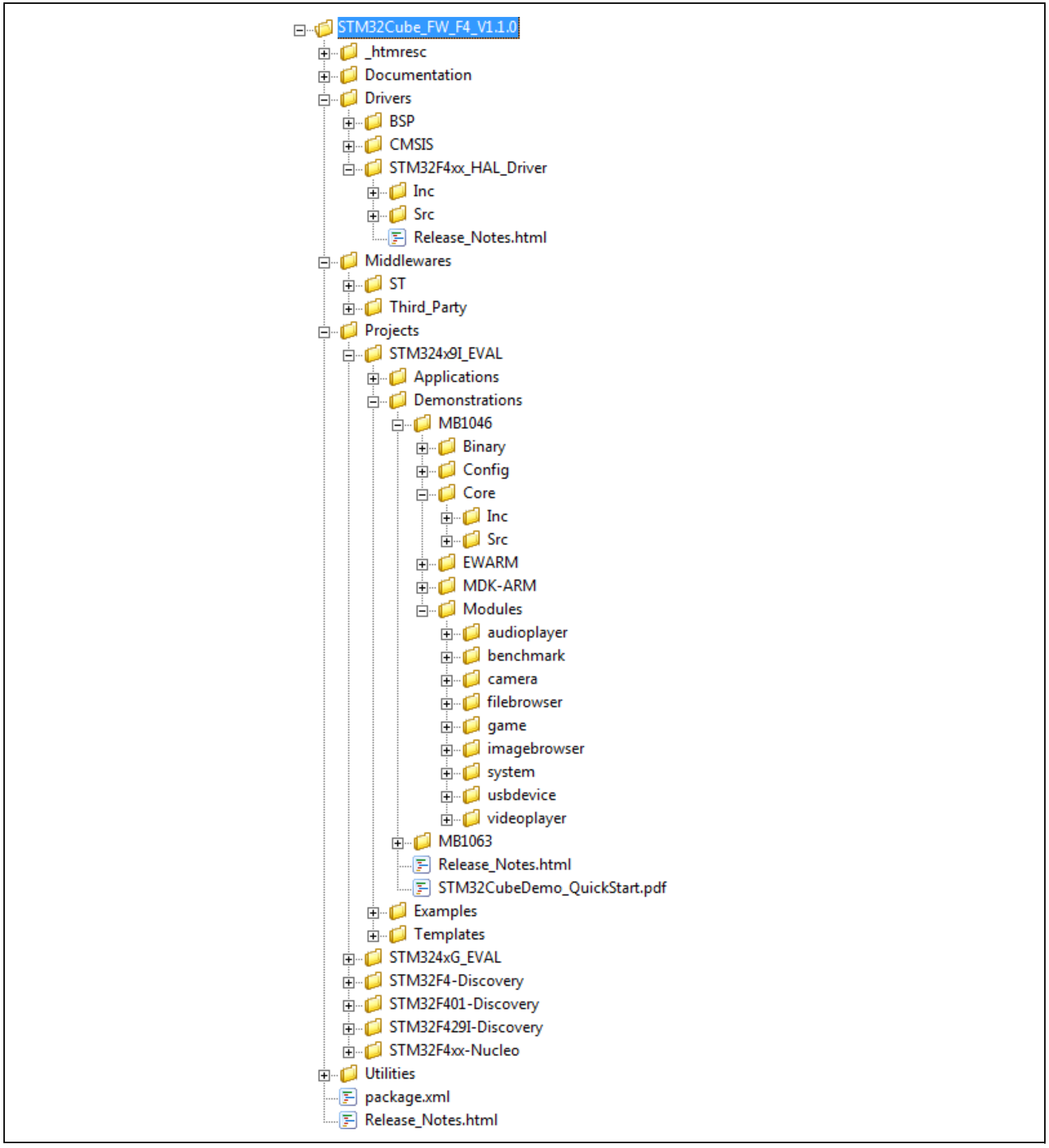
For STM32446E-EVAL demonstration, the different icons of the applications are stored in the external memory QSPI, configured in memory-mapped mode to the STM32 address space, and seen by the system as if it were an internal memory.

This mode provides a direct interface to access data from external SPI memory and thus simplify Software requirements.

3.13 Demonstration repository

The STM32Cube is a component in the STM32Cube package. *Figure 27* shows the demonstration folder organization:

Figure 27. Folder structure



```
STM32Cube_FW_F4_V1.1.0
  _htmresc
  Documentation
  Drivers
    BSP
    CMSIS
    STM32F4xx_HAL_Driver
      Inc
      Src
      Release_Notes.html
  Middlewares
    ST
    Third_Party
  Projects
    STM324x9I_EVAL
      Applications
      Demonstrations
        MB1046
          Binary
          Config
          Core
            Inc
            Src
          EWARM
          MDK-ARM
          Modules
            audioplayer
            benchmark
            camera
            filebrowser
            game
            imagebrowser
            system
            usbdevice
            videoplayer
        MB1063
        Release_Notes.html
        STM32CubeDemo_QuickStart.pdf
      Examples
      Templates
    STM324xG_EVAL
    STM32F4-Discovery
    STM32F401-Discovery
    STM32F429I-Discovery
    STM32F4xx-Nucleo
  Utilities
  package.xml
  Release_Notes.html
```

The demonstration sources are located in the projects folder of the STM32Cube package for each supported board. The sources are divided into five groups described as follows:

1. Core: contains the kernel files
2. Modules: contains the system and user modules including the graphical aspect and the modules functionalities.
3. Binary: demonstration binary file in Hex format
4. Config: all middleware's components and HAL configuration files
5. Project settings: a folder per tool chain containing the project settings and the linker files.

3.14 Kernel components

Table 5. Kernel components list

Function	Description
Kernel core	Kernel core and utilities
Modules	User and system modules
STM32 HAL Drivers	STM32Cube HAL driver relative to the STM32 device under use
BSP Drivers	Evaluation board (or discovery kit) BSP drivers
CMSIS	CMSIS Cortex®-M3/4 Device Peripheral Access Layer System
FatFS	FATFS File system
FreeRTOS	FreeRTOS Real Time Operating System
STemWin	STemWin Graphical Library
USBD_Library	USB Device Library (Mass Storage Class)
USBH_Library	USB Host Library (Mass Storage Class)

Note: Components may not exist in one or more demonstrations following the integrated modules.

3.15 Kernel core files

Table 6. Kernel core files list

Function	Description
main.c	Main program file
stm32fxxx_it.c	Interrupt handlers for the application
k_bsp.c	Provides the kernel BSP functions
k_calibration.c	Touch screen calibration processes
k_log.c	Kernel Log manager
k_mem.c	Kernel memory heap manager
k_menu.c	Kernel menu and desktop manager
k_module.c	Modules manager
k_modules_res.c	Common modules resources
k_rtc.c	RTC and backup manager
k_startup.c	Demonstration startup windowing process
k_storage	Storage units manager
startup_stm32fyyyxx.s	Startup file
cpu_utils.c	CPU load calculation utility

Note: Files may not exist in one or more demonstrations following the integrated modules.

3.16 Hardware settings

The STM32CubeF4 demonstration supports STM32F4xx devices and runs on the following demonstration boards from STMicroelectronics:

- STM324x9I-EVAL
- STM324xG-EVAL
- STM32F429I-Discovery
- STM32446E-EVAL
- STM32F479I-EVAL
- STM32F469I-DISCO
- STM32F412G-DISCO
- STM32F413H-DISCO

Figure 28. STM32Cube demonstration boards

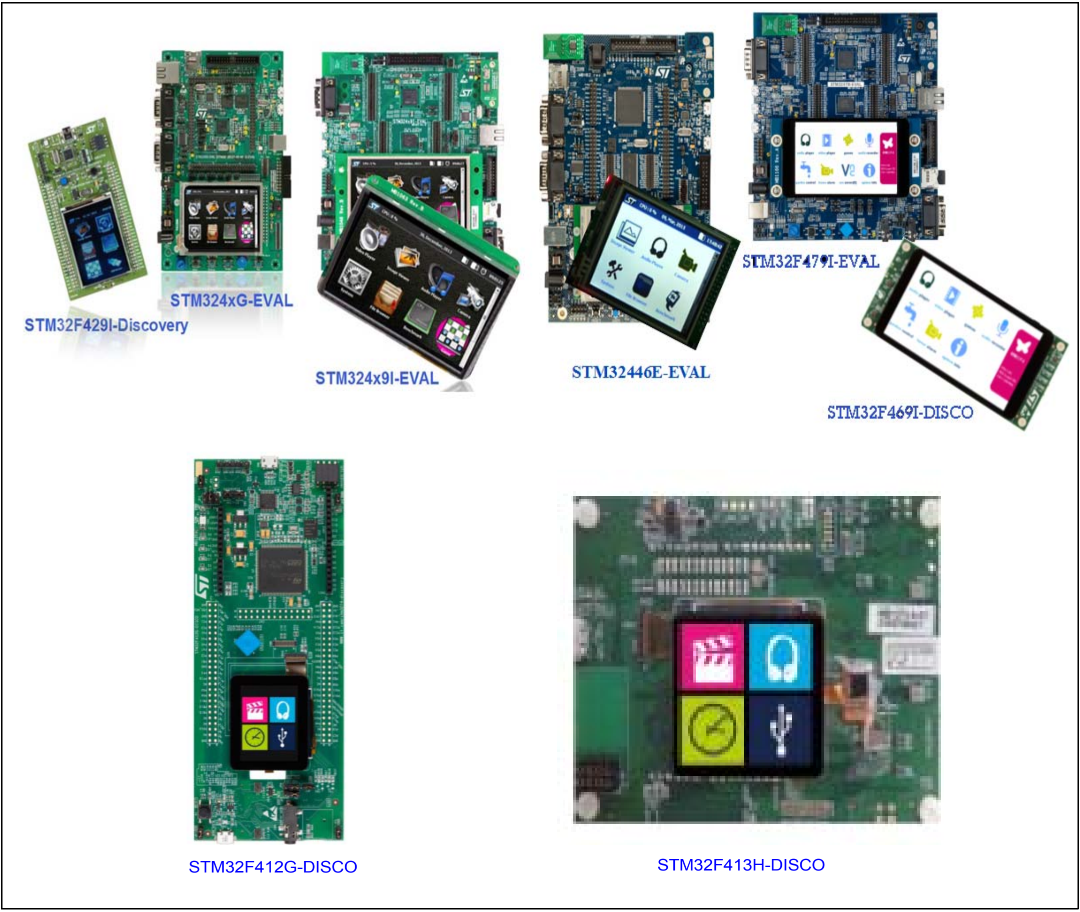


Table 7. Jumpers for different demonstration boards

Board	Jumper	Position description
STM324x9I-EVAL	JP16	Not fitted (used for USB device module)
	JP4/JP5	<2-3> (used for Audio demonstration)
	JP8	<2-3> (used for backup domain on battery)
STM324xG-EVAL	JP16	<2-3> (used for Audio demonstration)
	JP19	<2-3> (used for backup domain on battery)
	JP31	<2-3> (used for USB device module)
STM32F429I-Discovery	JP3	ON (Power on MCU)
	CN4	ON (Discovery mode)
STM324446E-EVAL	JP4	<2-3> (used for USB device module)
	JP19	<1-2> (used for audio player module)
STM32F479I-EVAL	JP5/JP6	<2-3> (used for Audio demonstration)
	JP7	<1-2> (used for VNC server demonstration)
	JP2	Fitted (Power on MCU)
	JP17/JP18	<2-3> (used for Audio recorder demonstration)
	JP11	Fitted (disables the NOR Flash write protection)
STM32F469I-DISCO	JP5	Fitted (Power on MCU)
STM32F412G-DISCO	JP5	<1-2> VDD MCU: 3V3
STM32F413H-DISCO	JP3	Fitted (Power on MCU)

4 How to create a new module

A module is composed of two main parts:

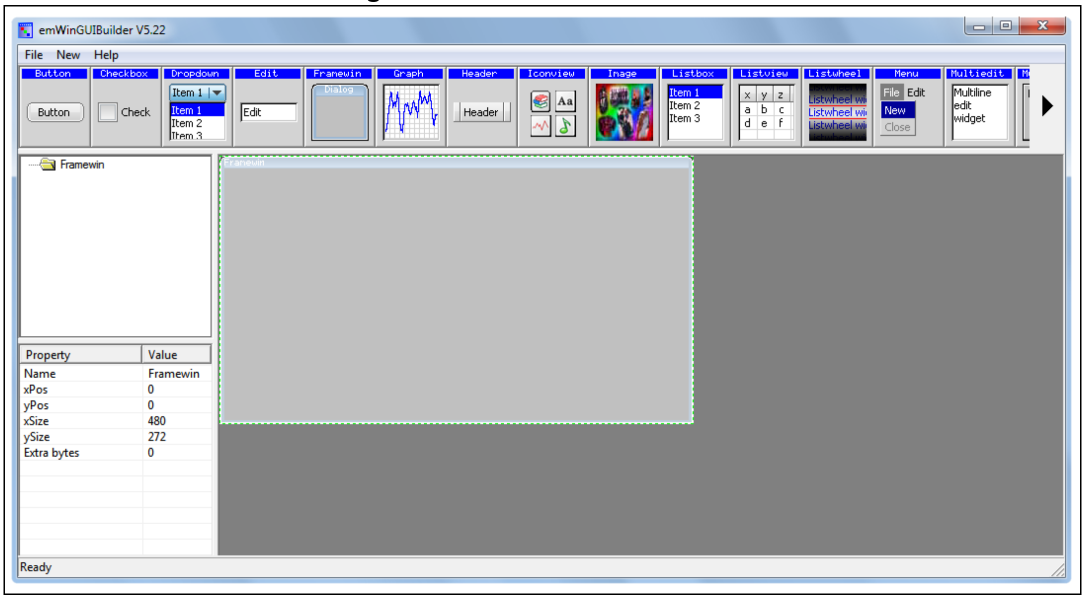
- Graphical aspect: the main window frame and module's controls
- Functionalities: module functions and internal processes

4.1 Creating the graphical aspect

The graphical aspect consists of the main frame window in addition to the set of the visual elements and controls (buttons, check boxes, progress bars…) used to control and monitor the module's functionalities.

The STM32CubeF4 demonstration package provides a PC tool; the *GUIBuilder* (*Figure 29*) that allows easily and quickly creating the module frame window and all its components in few steps. For more information about the GUI Builder, refer to the emwin User and reference guide (UM03001).

Figure 29. GUI Builder overview



Property	Value
Name	Framewin
xPos	0
yPos	0
xSize	480
ySize	272
Extra bytes	0

The GUI Builder needs only a few minutes to totally design the module appearances using "drag and drop" commands and then generate the source code file to be included into the application.

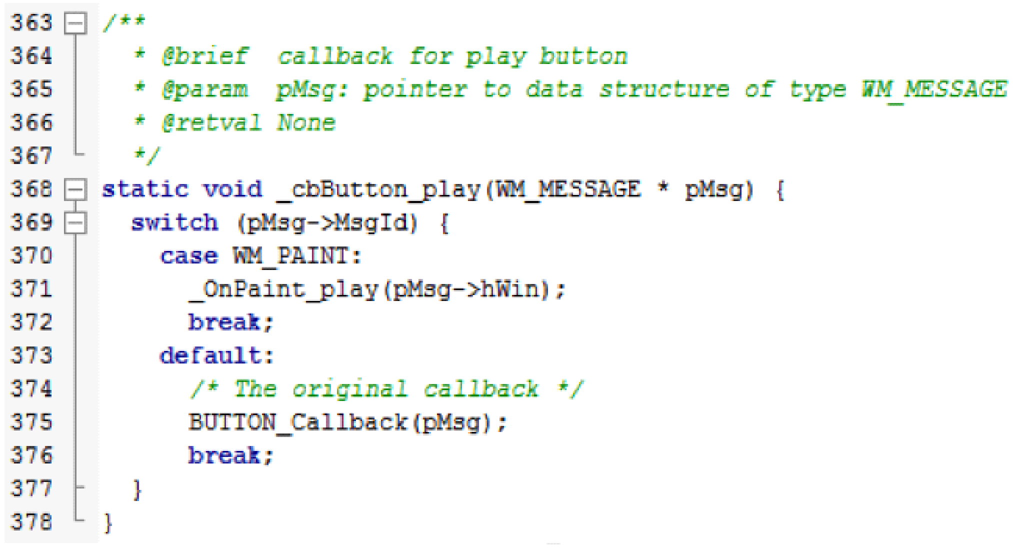
The file generated is composed of the following main parts:

- A resource table: it's a table of type GUI_WIDGET_CREATE_INFO, which specifies all the widgets to be included in the dialog and also their respective positions and sizes.
- A dialog callback routine: described more in detail in section 4.3 (it is referred to as “main module callback routine”).

4.2 Graphics customization

After the basic module graphical appearance is created, it is then possible to customize some graphical elements, such as the buttons, by replacing the standard aspect by the user defined image. To do this, a new element drawing callback should be created and used instead of the original one.

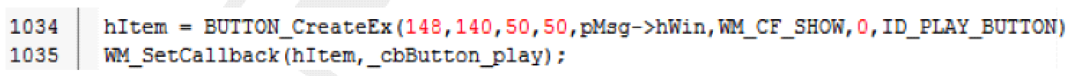
Below an example of a custom callback for the Play button:



```
/**
  * @brief  callback for play button
  * @param  pMsg: pointer to data structure of type WM_MESSAGE
  * @retval None
  */
static void _cbButton_play(WM_MESSAGE * pMsg) {
  switch (pMsg->MsgId) {
    case WM_PAINT:
      _OnPaint_play(pMsg->hWin);
      break;
    default:
      /* The original callback */
      BUTTON_Callback(pMsg);
      break;
  }
}
```

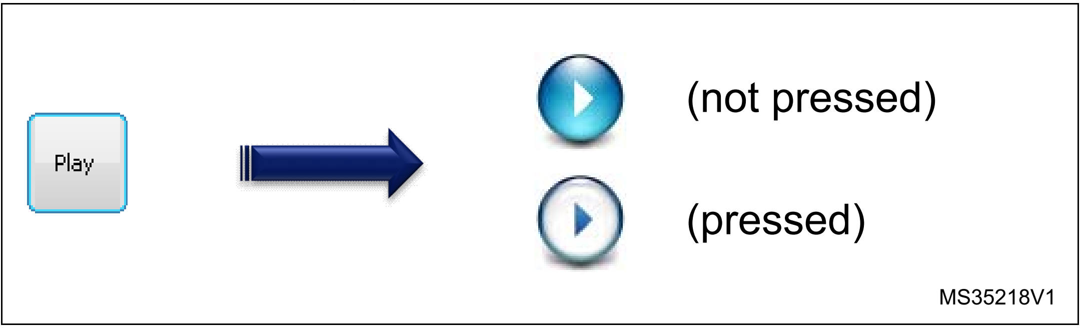
On the code portion above, the _OnPaint_play routine contains just the new button drawing command.

Note that the new callback should be associated to the graphical element at the moment of its creation, as shown below:



```
hItem = BUTTON_CreateEx(148,140,50,50,pMsg->hWin,WM_CF_SHOW,0,ID_PLAY_BUTTON)
WM_SetCallback(hItem,_cbButton_play);
```

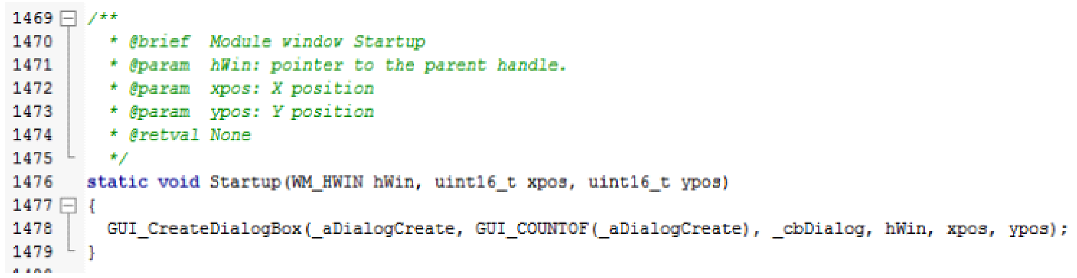
Figure 30. Graphics customization



4.3 Module implementation

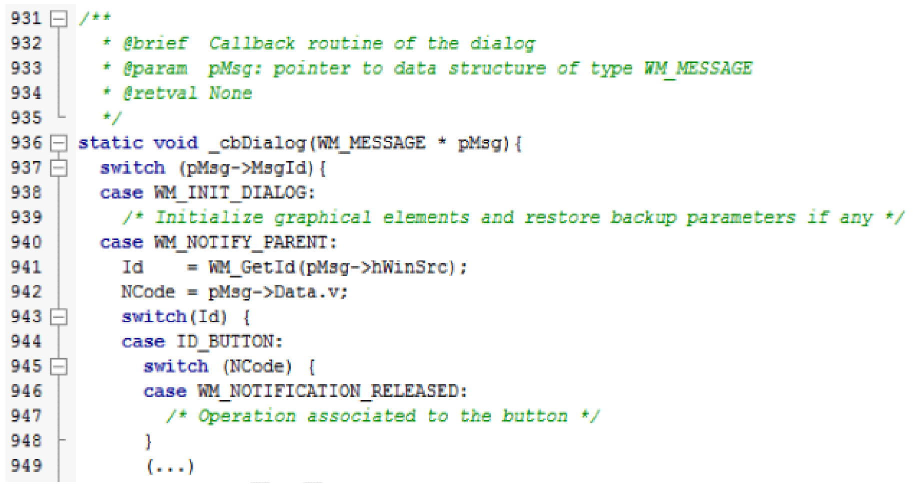
Once the graphical part of the module is finalized, the module functionalities and processes could be added then. It begins with the creation of the main module structure as defined in *Section 3.7: Modules manager*.

Then, each module has its own Startup function which simply consists of the graphical module creation, initialization and link to the main callback:



```
/**
  * @brief  Module window Startup
  * @param  hWin: pointer to the parent handle.
  * @param  xpos: X position
  * @param  ypos: Y position
  * @retval None
  */
static void Startup(WM_HWIN hWin, uint16_t xpos, uint16_t ypos)
{
  GUI_CreateDialogBox(_aDialogCreate, GUI_COUNTOF(_aDialogCreate), _cbDialog, hWin, xpos, ypos);
}
```

In the example above cbDialog refers to the main module callback routine. Its general skeleton is structured like the following:



```
/**
  * @brief  Callback routine of the dialog
  * @param  pMsg: pointer to data structure of type WM_MESSAGE
  * @retval None
  */
static void _cbDialog(WM_MESSAGE * pMsg){
  switch (pMsg->MsgId){
  case WM_INIT_DIALOG:
    /* Initialize graphical elements and restore backup parameters if any */
  case WM_NOTIFY_PARENT:
    Id     = WM_GetId(pMsg->hWinSrc);
    NCode = pMsg->Data.v;
    switch(Id) {
    case ID_BUTTON:
      switch (NCode) {
      case WM_NOTIFICATION_RELEASED:
        /* Operation associated to the button */
      }
      (...)
```

The list of windows messages presented in the code portion above (WM_INIT_DIALOG and WM_NOTIFY_PARENT) is not exhaustive, but represents the essential message IDs used:

- "WM_INIT_DIALOG: allows initializing the graphical elements with their respective initial values. It is also possible here to restore the backup parameters (if any) that will be used during the dialog procedure.
- "WM_NOTIFY_PARENT: describes the dialog procedure, for example: define the behavior of each button.

The full list of window messages can be found in the WM.h file.

4.4 Adding a module to the main desktop

Once the module appearance and functionality are defined and created, it still only to add the module to the main desktop view, this is done by adding it to the list (structure) of menu items: module_prop[ ], defined into k_module.h.

To do this, k_ModuleAdd() function should be called just after the module initialization into the main.c file.

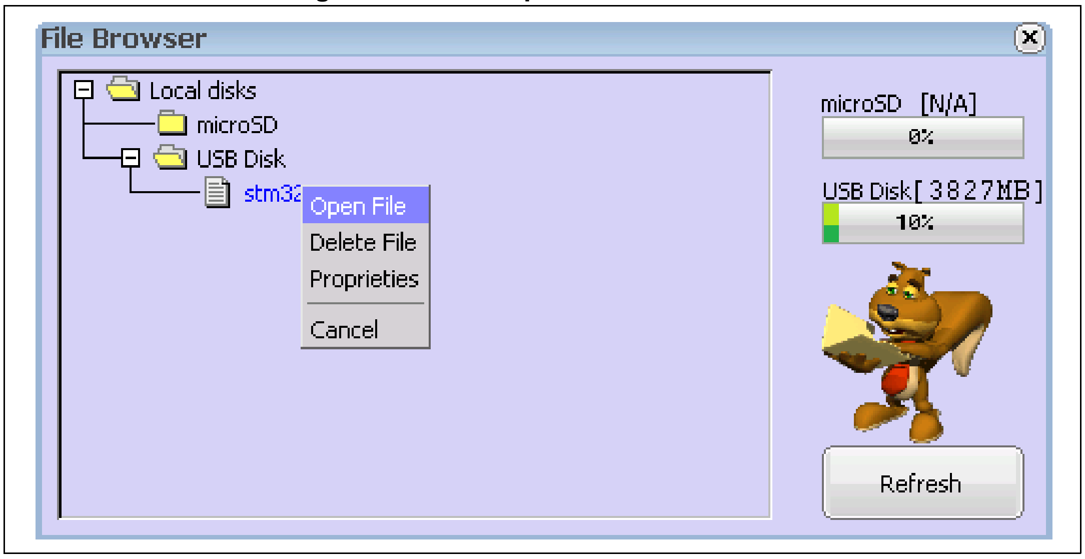
Note that the maximum modules number in the demonstration package is limited to 15; this value can be changed by updating MAX_MODULES_NUM defined into k_module.c.

4.5 Module's direct open

If there is a need to launch the module directly from the file browser contextual menu, an additional method should be added in the module structure for the direct open feature. This callback is often named _ModuleName_DirectOpen.

Figure 31 is an example of how to open a file using the adequate module from the file browser.

Figure 31. Direct open from file browser



In the STM32CubeF4 demonstration, there are three modules linked to the file browser contextual menu:

- The **video player**[(1)], supporting the format:
  - emf
- The **image browser**, supporting the formats:
  - jpg
  - bmp
- The **audio player**, supporting the format:
  - wav.

Then, to link the module to the file browser open menu, the command k_ModuleOpenLink() is called after the module is added.

1. The video player is not supported by STM32446E-EVAL demonstration.

5 Demonstration customization and configuration

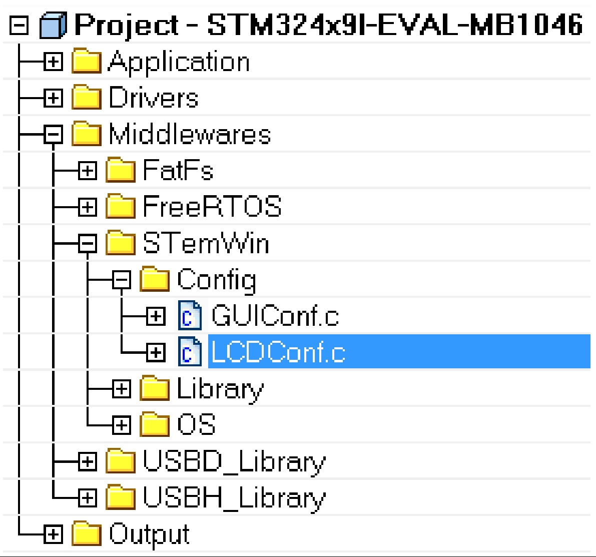
5.1 LCD configuration

The LCD is configured through the LCDConf.c file, see *Figure 32*. The main configuration items are listed below:

- Multiple layers:
  - The number of layers to be used defined using GUI_NUM_LAYERS.
- Multiple buffering:
  - If NUM_BUFFERS is set to a value "n" greater than 1, it means that "n" frame buffers will be used for drawing operation (see section 7.1 for impact of multiple buffering on performance).
- Virtual screens:
  - If the display area is greater than the physical size of the LCD, NUM_VSCREENS should be set to a value greater than 1. Note that virtual screens and multi buffers are not allowed together.
- Frame buffers locations:

The physical location of frame buffer is defined through LCD_LAYERX_FRAME_BUFFER.

Figure 32. LCDConf location



```
Project - STM324x9I-EVAL-MB1046
├─ Application
├─ Drivers
├─ Middlewares
│  ├─ FatFs
│  ├─ FreeRTOS
│  ├─ STemWin
│  │  ├─ Config
│  │  │  ├─ GUIConf.c
│  │  │  └─ LCDConf.c
│  │  ├─ Library
│  │  └─ OS
│  ├─ USBD_Library
│  └─ USBH_Library
└─ Output
```

5.2 Layers management

In the STM32CubeF4 demonstration package with the STM324x9I-EVAL, Discovery Kit, STM32F479I-EVAL and STM32F469I-DISCO, GUI_NUM_LAYERS is set to 2 (both layers are used):

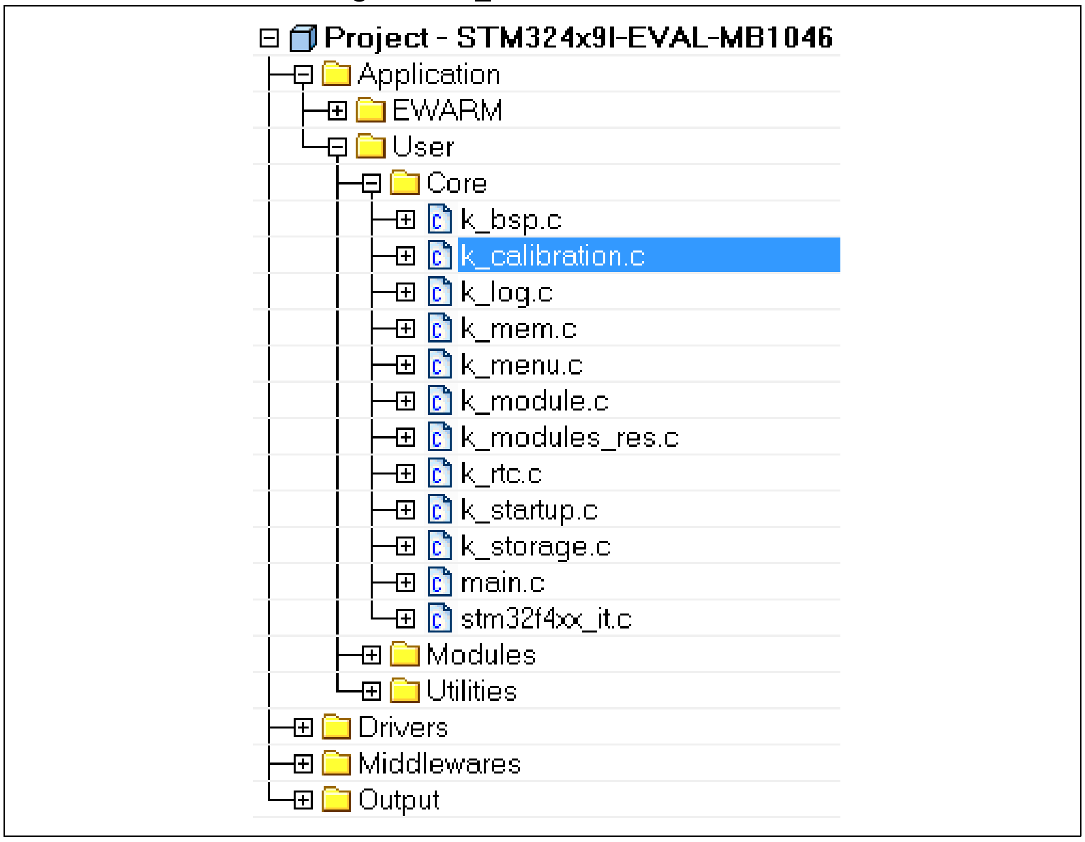
- "Layer 0 is dedicated to background display
- "Layer 1 is used for the main desktop display

Dedicated layers usage will lighten the CPU load during the refresh tasks.

5.3 Touchscreen calibration

When the demonstration is launched for the first time, the touchscreen needs to be calibrated. A full set of dedicated routines is included in the demonstration package and regrouped into k_calibration.c file (*Figure 33*).

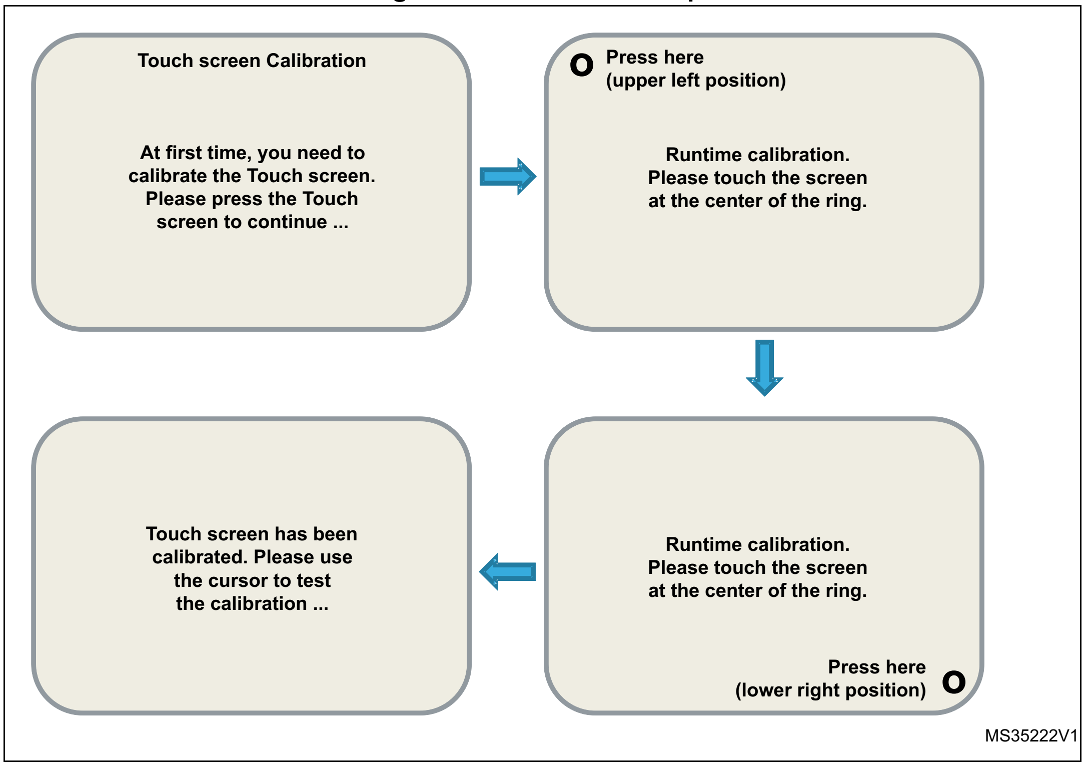
Figure 33. k_calibration.c location



```
⊟ Project - STM324x9I-EVAL-MB1046
├⊟ Application
│ ├⊞ EWARM
│ └⊟ User
│   ├⊟ Core
│   │ ├⊞ k_bsp.c
│   │ ├⊞ k_calibration.c
│   │ ├⊞ k_log.c
│   │ ├⊞ k_mem.c
│   │ ├⊞ k_menu.c
│   │ ├⊞ k_module.c
│   │ ├⊞ k_modules_res.c
│   │ ├⊞ k_rtc.c
│   │ ├⊞ k_startup.c
│   │ ├⊞ k_storage.c
│   │ ├⊞ main.c
│   │ └⊞ stm32f4xx_it.c
│   ├⊞ Modules
│   └⊞ Utilities
├⊞ Drivers
├⊞ Middlewares
└⊞ Output
```

To do this, after the startup screen is displayed, the user has to follow the displayed calibration instructions by touching the screen at the indicated positions (*Figure 34*). This will allow getting the physical Touch screen values that will be used to calibrate the screen.

Figure 34. Calibration steps


Touch screen Calibration
At first time, you need to calibrate the Touch screen. Please press the Touch screen to continue ...
O Press here (upper left position)
Runtime calibration. Please touch the screen at the center of the ring.
Touch screen has been calibrated. Please use the cursor to test the calibration ...
Runtime calibration. Please touch the screen at the center of the ring.
Press here (lower right position) O
MS35222V1

Once this runtime calibration is done, the touch screen calibration parameters are saved to the RTC Backup data registers: RTC_BKP_DR0 and RTC_BKP_DR1, so the next time the application is restarted, these parameters are automatically restored and there is no need to re-calibrate the touchscreen.

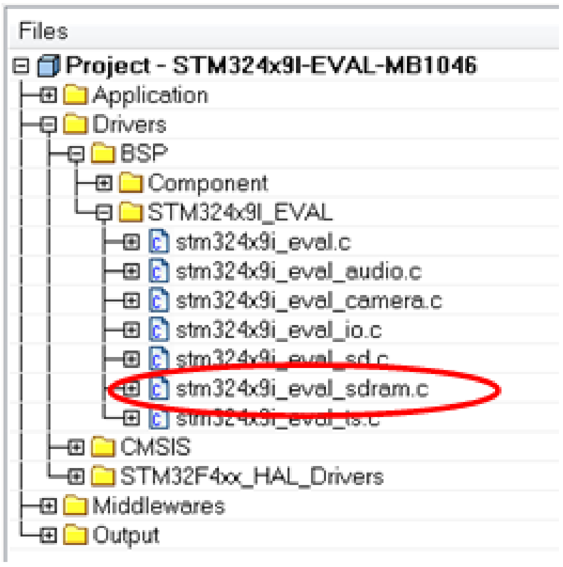
Note: The touch screen calibration step is not needed for STM32F479I-EVAL and STM32F469-DISCO demonstrations.

5.4 BSP customization

5.4.1 SDRAM configuration

The SDRAM capacity is 1 Mbyte x 32 bits x 4 banks. The BSP SDRAM driver offers a set of functions to initialize, read/write in polling or DMA mode.

Figure 35. SDRAM initialization



The SDRAM external memory must be initialized before the GUI initialization to allow its use as LCD layers frame buffer.

Table 8. LCD frame buffer locations

Layer	Address
LCD Layer0	0xC0200000 0xC0000000 (for STM32F479I-EVAL and STM32F469-DISCO)
LCD Layer1	0xC0400000

The SDRAM is used also as DCMI output for camera module. The camera output is stored in camera frame buffer address as 16 bpp (RGB565) and converted to 24 bpp in the Camera converted frame before its stocking in the selected storage unit.

Table 9. Camera frame buffer locations

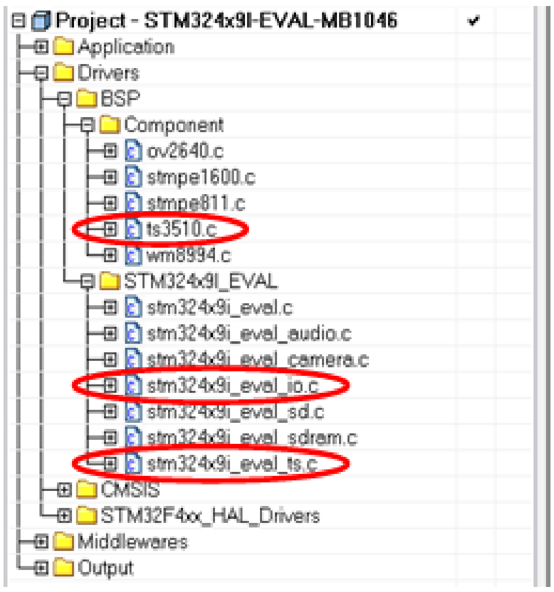
Camera	Address
Camera frame buffer	0xC0000000
Camera converted frame	0xC0025800

5.4.2 Touch screen configuration

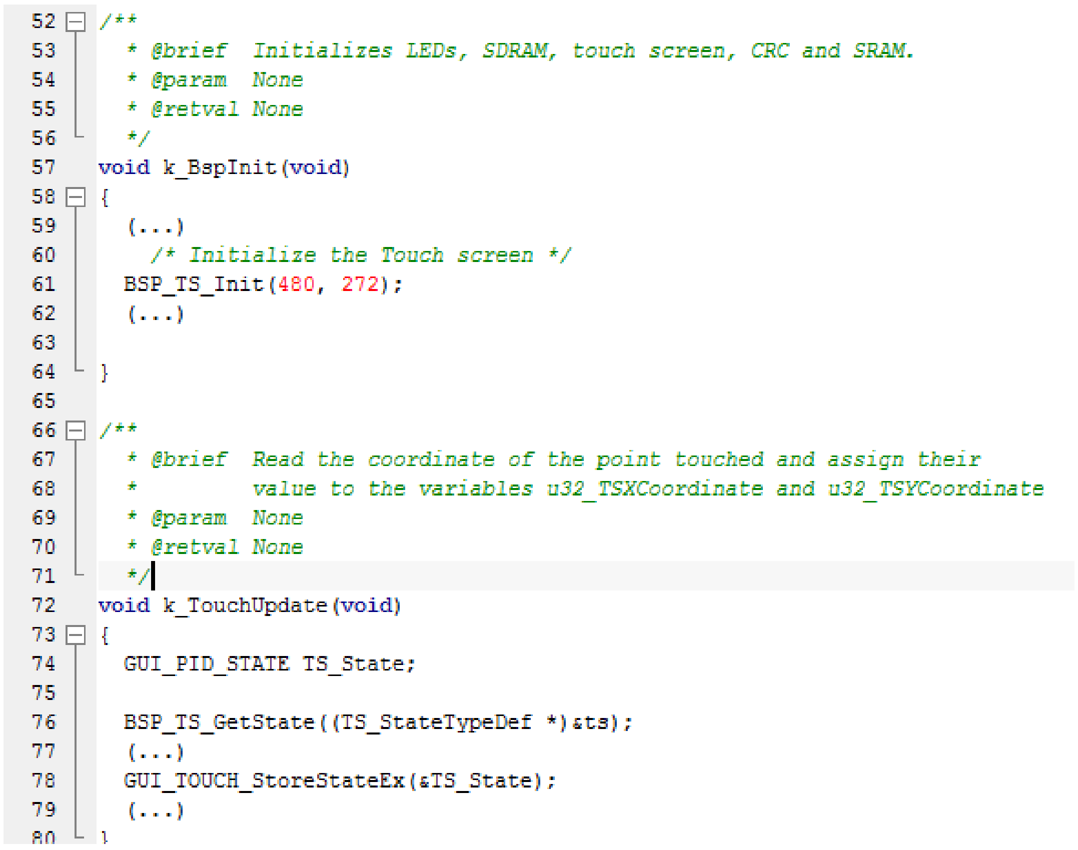
The touch screen is controlled by:

- the BSP TS driver, which uses the BSP IO driver for STM32429-EVAL, STM32446E-EVAL, STM32F479I-EVAL and STM32F469I-DISCO boards
- the TS3510 component for the STM32439-EVAL board
- the ft6x06 component for the STM32412G-DISCO and STM32413H-DISCO boards.

Figure 36. Touch screen initialization



The touch screen is initialized in 'k_BspInit' following the used screen resolution as shown in the code below.



```
/**
  * @brief  Initializes LEDs, SDRAM, touch screen, CRC and SRAM.
  * @param  None
  * @retval None
  */
void k_BspInit(void)
{
  (...)
    /* Initialize the Touch screen */
  BSP_TS_Init(480, 272);
  (...)

}

/**
  * @brief  Read the coordinate of the point touched and assign their
  *         value to the variables u32_TSXCoordinate and u32_TSYCoordinate
  * @param  None
  * @retval None
  */
void k_TouchUpdate(void)
{
  GUI_PID_STATE TS_State;

  BSP_TS_GetState((TS_StateTypeDef *)&ts);
  (...)
  GUI_TOUCH_StoreStateEx(&TS_State);
  (...)
}
```

6 Performance

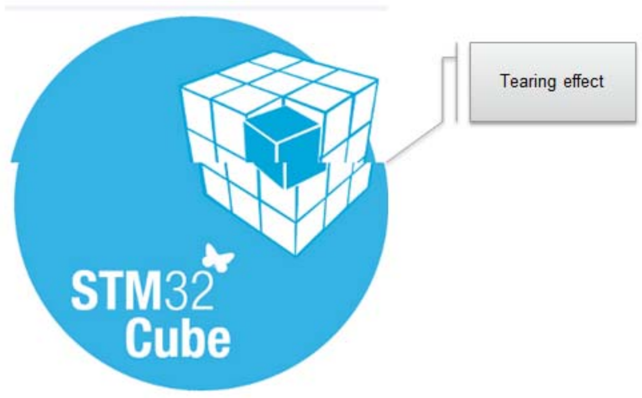
Note: This section is only available for STM329I-EVAL, STM32F479I-EVAL and STM32F469I-DISCO demonstrations.

6.1 Multi buffering features

Multiple buffering is the use of more than one frame buffer, so that the display ever shows a screen which is already completely rendered, even if a drawing operation is in process. When starting the process of drawing the current content of the front buffer is copied into a back buffer. After that all drawing operations take effect only on this back buffer. After the drawing operation has been completed the back buffer becomes the front buffer. Making the back buffer the visible front buffer normally only requires the modification of the frame buffer start address register of the display controller.

Now it should be considered that a display is refreshed by the display controller approximately 60 times per second. After each period there is a vertical synchronization signal, known as VSYNC signal. The best moment to make the back buffer the new front buffer is this signal. If not considering the VSYNC signal tearing effects can occur, as shown in *Figure 37*.

Figure 37. Example of tearing effect

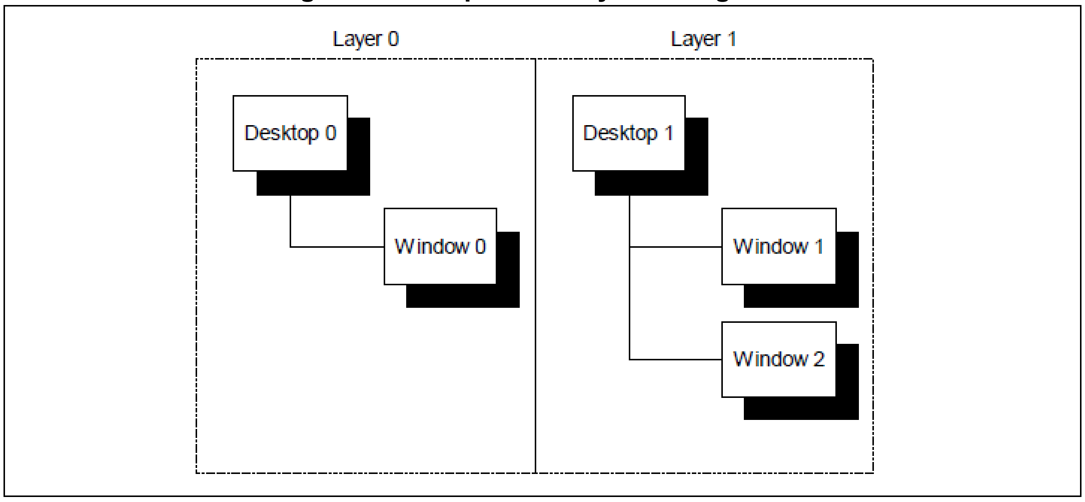


6.2 Multi layers feature

Windows can be placed in any layer or display, drawing operations can be used on any layer or display. Since there are really only smaller differences from this point of view, multiple layers and multiple displays are handled the same way (Using the same API routines) and are simply referred to as multiple layers, even if the particular embedded system uses multiple displays.

In the STM32CubeF4 demonstration, the layer 0 is dedicated for the background while the layer 1 with transparency activated is dedicated for the main desktop, this will allow to the kernel to keep the background unchanged during the desktop visual changes without refreshing the background image.

Figure 38. Independent layer management



6.3 Hardware acceleration

With the STM324x9I-EVAL and Discovery Kit demonstration, the hardware acceleration capabilities of the STM32F429/ STM32F439 cores are used. STemWin offers a set of customization callbacks to changes the default behavior based on the hardware capabilities, the optimized processes are implemented in the LCDConf.c file and implement the following features:

a) Color conversion

Internally STemWin works with logical colors (ABGR). To be able to translate these values into index values for the hardware and vice versa the color conversion routines automatically use the DMA2D for that operation if the layer work with direct color mode

This low level implementation makes sure that in each case where multiple colors or index values need to be converted the DMA2D is used.

b) Drawing of index based bitmaps

when drawing index based bitmaps STemWin first loads the palette of the bitmap into the DMA2Ds LUT instead of directly translating the palette into index values for the hardware. The drawing operation then is done by only one function call of the DMA2D.

c) Drawing of high color bitmaps

If the layer works in the same mode as the high color bitmap has its pixel data available, these bitmaps can be drawn by one function call of the DMA2D. The following function is used to set up such a function;:

LCD_SetDevFunc(LayerIndex, LCD_DEVFUNC_DRAWBMP_16BPP, pFunc);

d) Filling operations

Setting up the function for filling operations:

LCD_SetDevFunc(LayerIndex, LCD_DEVFUNC_FILLRECT, pFunc);

e) Copy operations

Setting up the functions for copy operations used by the function GUI_CopyRect():

LCD_SetDevFunc(LayerIndex, LCD_DEVFUNC_COPYRECT, pFunc);

f) Copy buffers

Setting up the function for transferring the front- to the back buffer when using multiple buffers:

LCD_SetDevFunc(LayerIndex, LCD_DEVFUNC_COPYBUFFER, pFunc);

g) Fading operations

Setting up the function for mixing up a background and a foreground buffer used for fading memory devices:

GUI_SetFuncMixColorsBulk(pFunc);

h) General alpha blending

The following function replaces the function which is used internally for alpha blending operations during image drawing (PNG or true color bitmaps) or semitransparent memory devices:

GUI_SetFuncAlphaBlending(pFunc);

i) Drawing antialiased fonts

Setting up the function for mixing single foreground and background colors used when drawing transparent ant aliased text:

GUI_SetFuncMixColors(pFunc).

7 Footprint

The purpose of the following sections is to provide the memory requirements for all the demonstration modules, including jpeg decoder and STemWin's main GUI components. The aim is to have an estimation of memory requirement in case of suppression or addition of a module or feature.

The footprint data are provided for the following environment:

- Tool chain: IAR 6.70.1
- Optimization: high size
- Board: STM32F429-EVAL.

7.1 Kernel footprint

Table 10 shows the code memory, data memory and the constant memory used for each kernel file.

Table 10. Kernel files footprint

File	code [byte]	data [byte]	const [byte]
k_bsp	260	8	0
K_calibration	972	28	48
k_Log	100	8(1)	0
k_mem	266	0	0
k_menu	3496	900	412089
k_module	214	244	0
k_module_res	98	0	207692
k_rtc	196	32	195529
k_startup	316	4	300064
k_storage	954	2844	24
main	614	4	44

1. The memory is allocated dynamically in some structures of this file.

7.2 Module footprint

Table 11 shows the code memory, data memory and the constant memory used for each kernel file.

Table 11. Modules footprint

File	code [byte]	data [byte]	const [byte]
Audio	6764	501(1)	33067
Benchmark	1320	36	32693

Table 11. Modules footprint (continued)

File	code [byte]	data [byte]	const [byte]
Camera	2467	213[1]	62629
File Browser	3062	516	69083
Game	4188	1916	33432
Image Browser	5308	1956[1]	32862
System	2486	89	33506
USB Device	540	29	195529
Video Player	6476	989[1]	32646

1. The memory is allocated dynamically in some structures of this file.

7.3 STemWin features resources

7.3.1 JPEG decoder

The JPEG decompression uses approximately 33 Kbytes of RAM for decompression independently of the image size and a size dependent amount of bytes. The RAM requirement can be calculated as follows:

Approximate RAM requirement = X-Size of image * 80 bytes + 33 Kbytes

Table 12. RAM requirements for some JPEG resolutions

Resolutiont	RAM usage [kbyte]	RAM usage, size dependent [kbyte]
160x120	45.5	12.5
320x340	58.0	25.0
480x272	70.5	37.5
640x480	83.0	50.0

The memory required for the decompression is allocated dynamically by the STemWin memory management system. After drawing the JPEG image the complete RAM will be released.

7.3.2 GUI components

The operation area of STemWin varies widely, depending primarily on the application and features used. In the following sections, memory requirements of various modules are listed, as well as the memory requirements of example applications.

Table 13 shows the memory requirements of the main components of STemWin. These values depend a lot on the compiler options, the compiler version and the used CPU. Note that the listed values are the requirements of the basic functions of each module.

Table 13. MemoSTemWin components memory requirements

Component	ROM	RAM	Description
Windows Manager	6.2 Kbytes	2.5 Kbytes	Additional memory requirements of basic application when using the Windows Manager
Memory Devices	4.7 Kbytes	7 Kbytes	Additional memory requirements of basic application when using memory devices
Antialiasing	4.5 Kbytes	2 * LCD_XSIZE	Additional memory requirements for the antialiasing software item
Driver	2-8 Kbytes	20 bytes	The memory requirements of the driver depend on the configured driver and whether a data cache is used or not. With a data cache, the driver requires more RAM
Multilayer	2-8 Kbytes	-	If working with a multi layer or a multi display configuration, additional memory is required for each additional layer, because each requires its own driver
Core	5.2 Kbytes	80 bytes	Memory requirements of a typical application without using additional software items
JPEG	12 Kbytes	36 Kbytes	Basic routines for drawing JPEG files
GIF	3.3 Kbytes	17 Kbytes	Basic routines for drawing GIF files
Sprites	4.7 Kbytes	16 bytes	Routines for drawing sprites and cursors
Font	1-4 Kbytes	-	Depends on the font size to be used

Table 14. Widget memory requirements

Component	ROM	RAM	Description
BUTTON	1.0 Kbytes	40 bytes	(1)
CHECKBOX	1.0 Kbytes	52 bytes	(1)
DROPDOWN	1.8 Kbytes	52 bytes	(1)
EDIT	2.2 Kbytes	28 bytes	(1)
FRAMEWIN	2.2 Kbytes	12 bytes	(1)
GRAPH	2.9 Kbytes	48 bytes	(1)
GRAPH_DATA_XY	0.7 Kbytes	-	(1)
GRAPH_DATA_XY	0.6 Kbytes	-	(1)
HEADER	2.8 Kbytes	32 bytes	(1)
LISTBOX	3.7 Kbytes	56 bytes	(1)
LISTVIEW	3.6 Kbytes	44 bytes	(1)
MENU	5.7 Kbytes	52 bytes	(1)
MULTIEDIT	7.1 Kbytes	16 bytes	(1)

Table 14. Widget memory requirements (continued)

Component	ROM	RAM	Description
MULTIPAGE	3.9 Kbytes	32 bytes	(1)
PROGBAR	1.3 Kbytes	20 bytes	(1)
RADIOBUTTON	1.4 Kbytes	32 bytes	(1)
SCROLLBAR	2.0 Kbytes	14 bytes	(1)
SLIDER	1.3 Kbytes	16 bytes	(1)
TEXT	1.0 Kbytes	16 bytes	(1)
CALENDAR	0.6 Kbytes	32 bytes	(1)

1. The listed memory requirements of the widgets contain the basic routines required for creating and drawing the widget. Depending on the specific widget there are several additional functions available which are not listed in the table

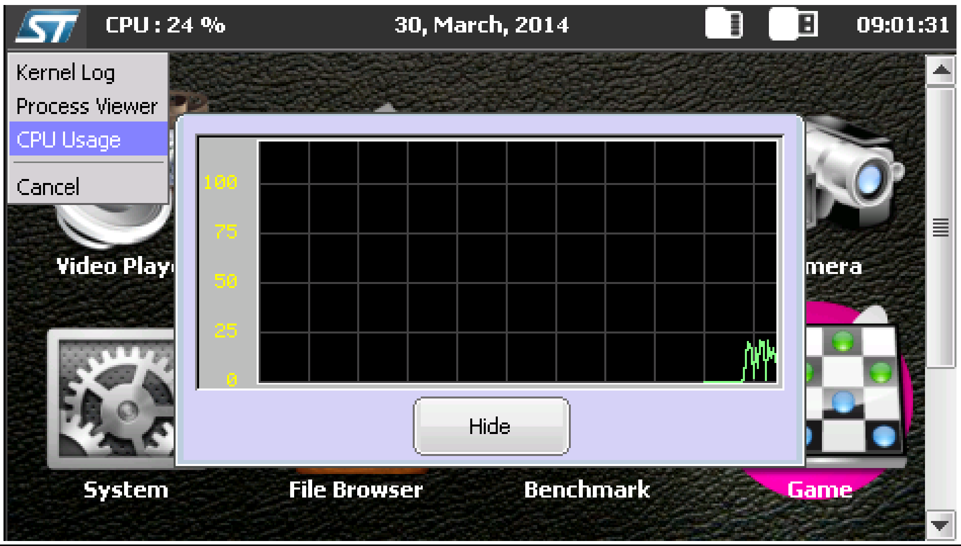
8 Demonstration functional description (STM324x9I-EVAL, STM324xG-EVAL, STM32F429I-Discovery and STM32446E-EVAL)

8.1 Kernel

The main desktop is built around two main graphical components:

- The status bar: indicates the storage units' connection status, current time and date and a system utilities button to allow getting system information like (running task, CPU usage, and kernel log).
- The icon view widget: contains the icons associated to added modules. User can launch a module by a simple click on the module icon (see *Figure 39*).

Figure 39. CPU usage display



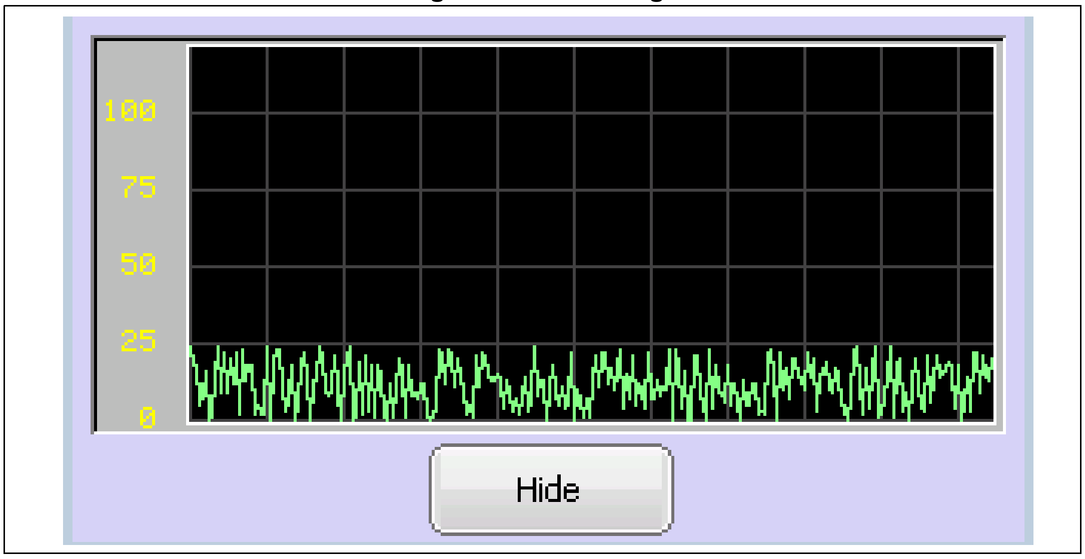
The system utilities are accessible during the STM32CubeF4 demonstration running time, using the system button (ST Logo) in top left of the main desktop. The system utilities button offers the following services:

- CPU usage history
- Kernel log messages
- Current running processes viewer

8.1.1 CPU usage

The CPU usage utility provides a graphical representation of the CPU usage evolution (*Figure 40*) during the demonstration run time starting for the first time it was launched. Note that once launched the CPU usage utilities keep running in background and can be restored in any time.

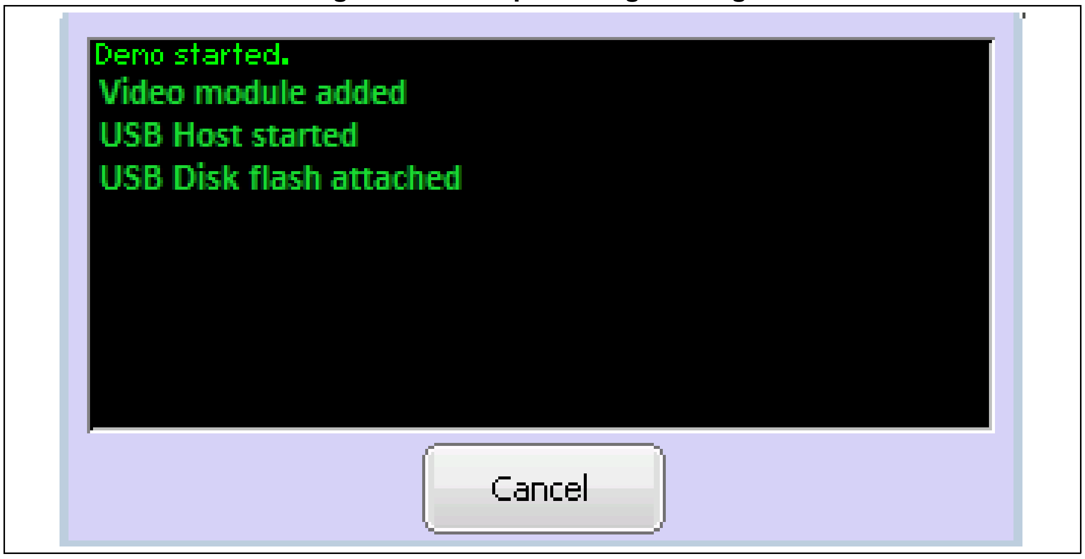
Figure 40. CPU usage



8.1.2 Kernel log

The kernel log utility gathers all the kernel and module messages and saves them into a dedicated internal buffer. The Log messages can be visualized at any time during the demonstration run time, as shown in *Figure 41*.

Figure 41. Example of Log messages



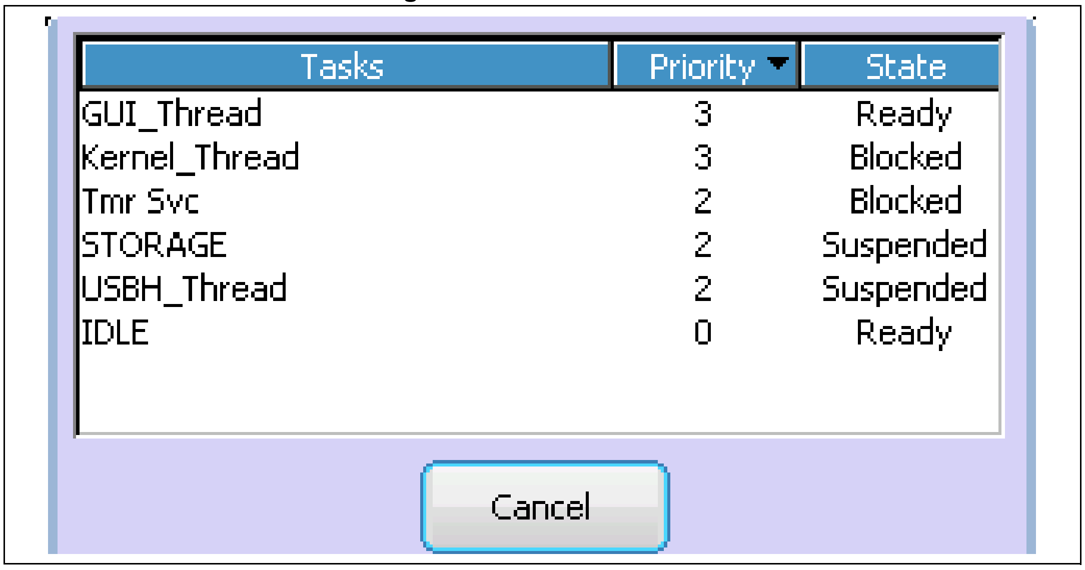
```
Demo started.
Video module added
USB Host started
USB Disk flash attached
```

8.1.3 Process viewer

The process viewer (*Figure 42*) allows users to check and to display the status of the currently running tasks (FreeRTOS) at any time during the demonstration run time. It shows the following information:

1. Current running tasks names.
2. Current running tasks priorities
3. Running tasks states (FreeRTOS statics information).

Figure 42. Process viewer



Tasks	Priority	State
GUI_Thread	3	Ready
Kernel_Thread	3	Blocked
Tmr Svc	2	Blocked
STORAGE	2	Suspended
USBH_Thread	2	Suspended
IDLE	0	Ready

8.2 Modules

8.2.1 System

Overview

The system module provides three control tabs: system information, general settings and clock settings to set the global demonstration settings. The system module retrieves demonstration information from internal kernel settings data structures and acts on the several kernel services to changes settings.

Functional description

The system module provides three graphical views:

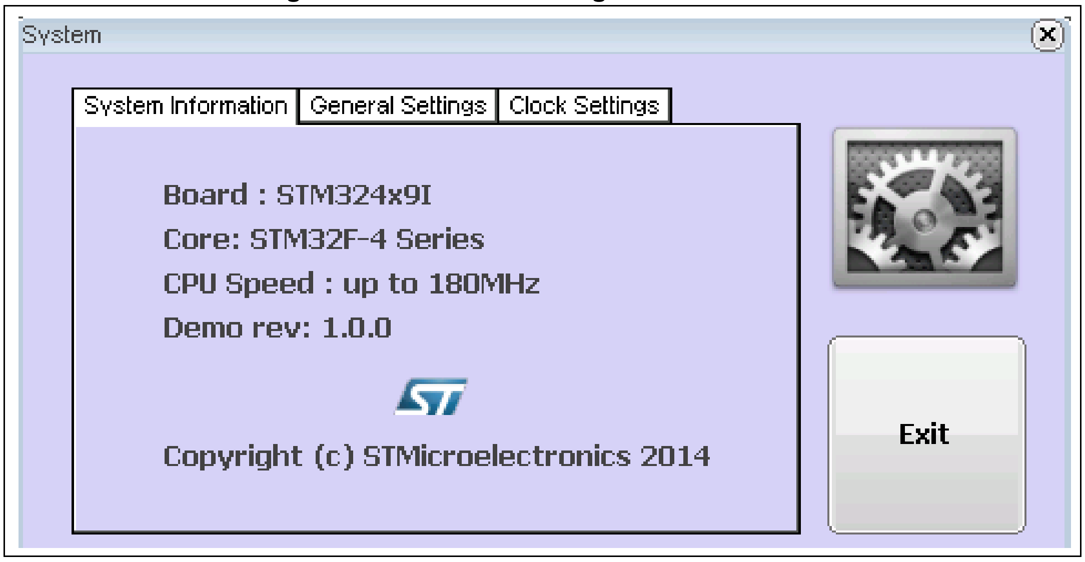
a) Demonstration global Information (*Figure 43*)

This first page shows the main demonstration information such as: Used board, STM32 core part number, and current CPU clock and demonstration revision.

b) General settings (*Figure 44*)

The general settings tab permits to change the global demonstration configuration. Note that the new settings are not applied immediately; new settings take effect after restarting the demonstration.

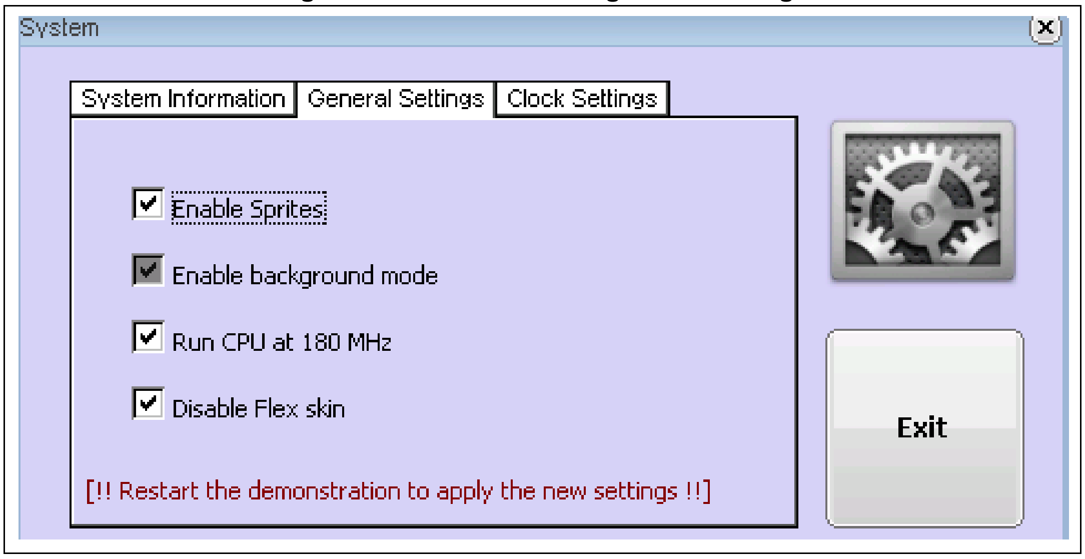
Figure 43. Demonstration global information



Board : STM324x9I
Core: STM32F-4 Series
CPU Speed : up to 180MHz
Demo rev: 1.0.0

Copyright (c) STMicroelectronics 2014

Figure 44. Demonstration general settings

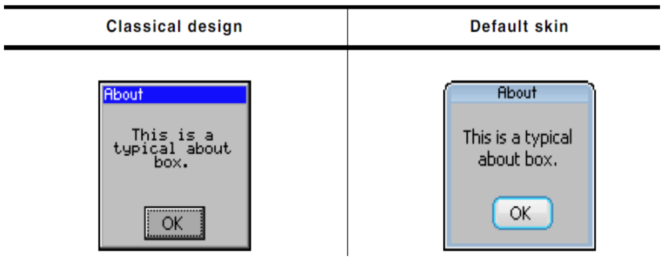


- [✓] Enable Sprites
- [✓] Enable background mode
- [✓] Run CPU at 180 MHz
- [✓] Disable Flex skin

[!! Restart the demonstration to apply the new settings !!]

Table 15 shows the different settings that can be changed.

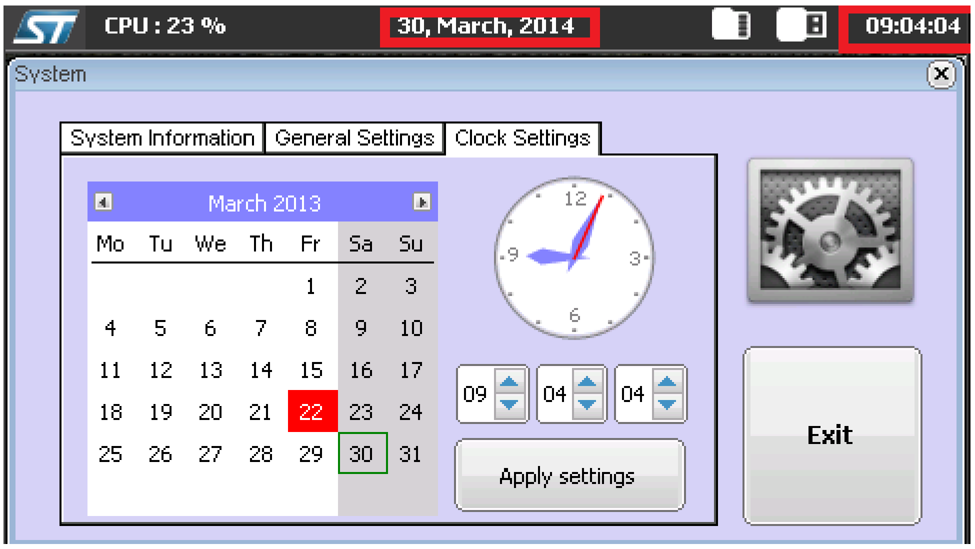
Table 15. Available settings

Configuration item	Description
Enable sprites	Checking this box allows the sprites to move on the background desktop
Enable background mode	Not used (reserved for future use)
Run CPU at 180 MHz	Allow to run the demonstration at maximum speed. Note that the device USB clock is not at compliant clock with mode. To use the USB device mass storage module, it is recommended to use the default 168 MHz CPU clock
Disable Flex skin	Unchecking this box, classical GUI skin is used. 

c) Clock settings

The clock setting tab (*Figure 45*) allows to adjust the demonstration time and date by changing the RTC configuration of the kernel.

Figure 45. Clock setting

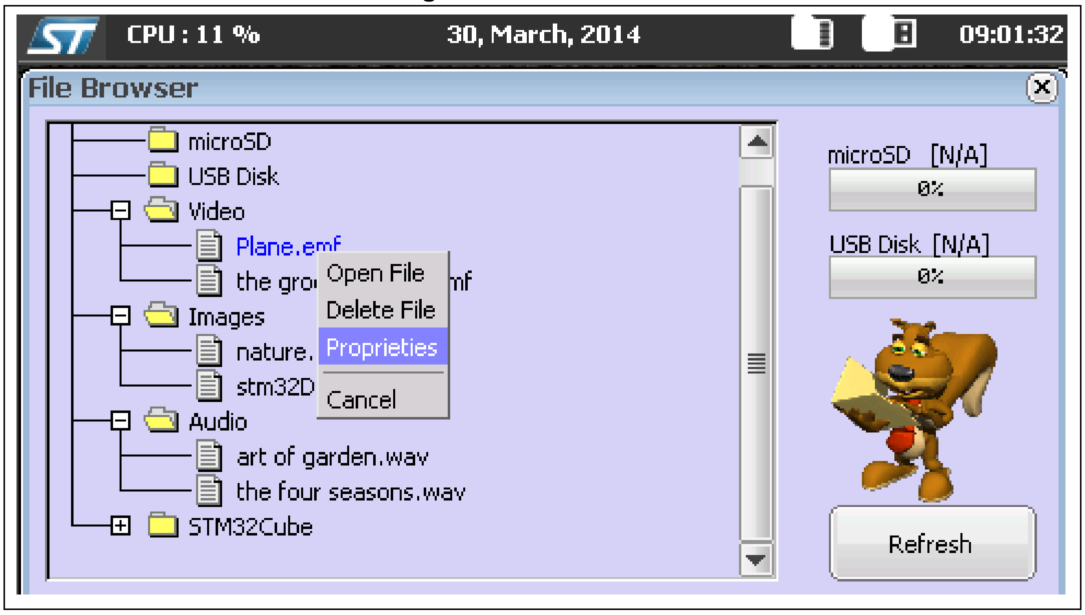


8.2.2 File browser

Overview

The File browser module is a system module that allows to explore the connected storage unit(s), to delete or to open a selected file. The file list structure is built during the media connection and updated after a connection status change of one of the used media.

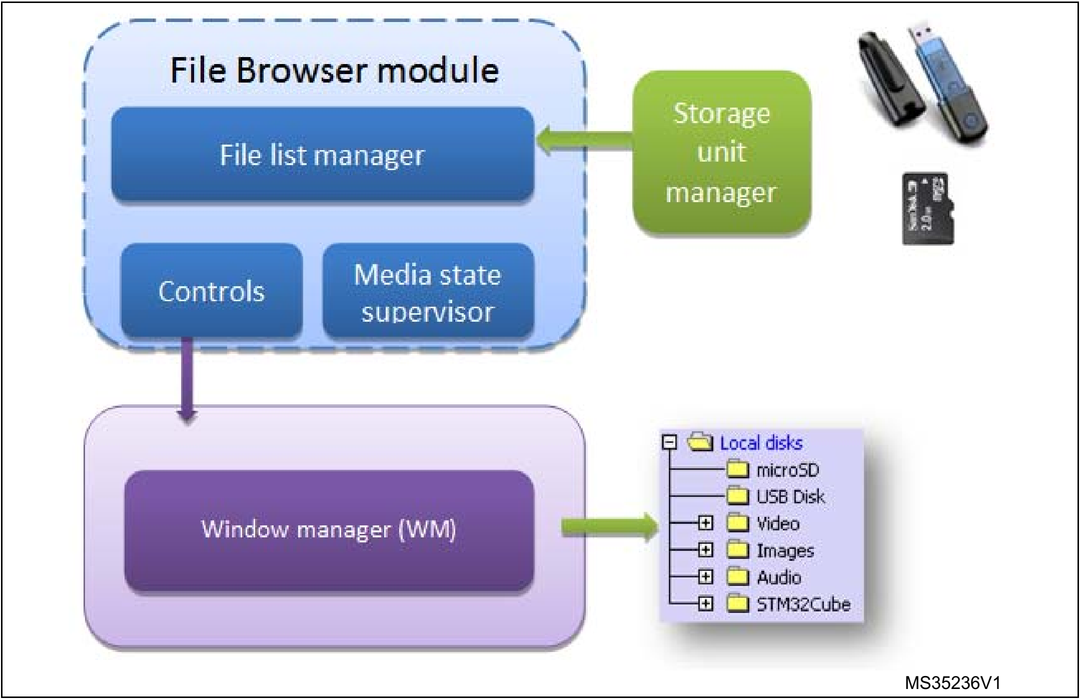
Figure 46. File browser



Functional description

The file browser is mainly used for standard file operations: explore folder, file information, file deletion and opening supported extension file when a file type is linked to the direct open file feature of the kernel (*Figure 47*). Note that Read-Only file cannot be deleted physically from media.

Figure 47. File browser module architecture



To open the contextual file menu, user has to select a file (selecting a folder has no effect).

The following actions are accessible through the contextual menu:

a) Open file: if a file extension is linked to the direct open file feature of the kernel, the associated application with this extension is launched and the file is opened automatically (*Figure 48*).

b) Delete file: selecting a file for deletion will display a confirmation message box to confirm the deletion operation. Note that Read-Only file cannot be deleted physically from media.

c) Proprieties: the File browser can be used to check file proprieties such as current location, size, and creation date,as indicated in *Figure 49*.

Note: The File browser can explore up to four levels, the maximum explorer level is defined in the kernel files (k_storage.h).

Figure 48. File opening from browser

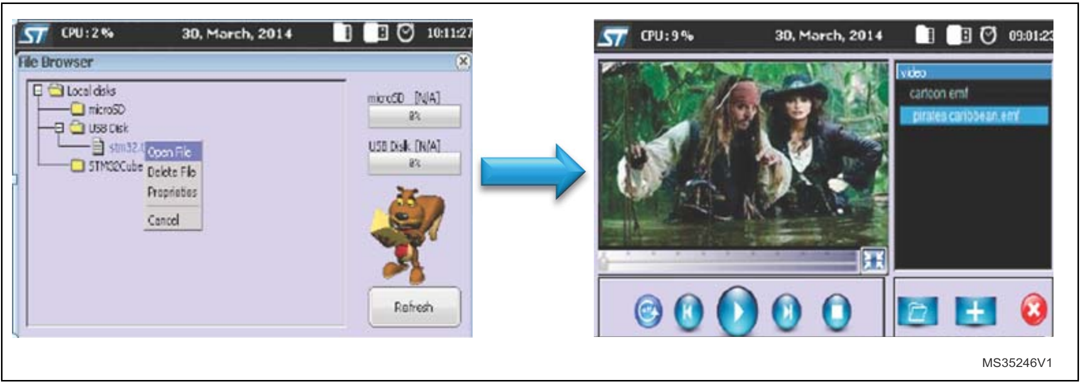
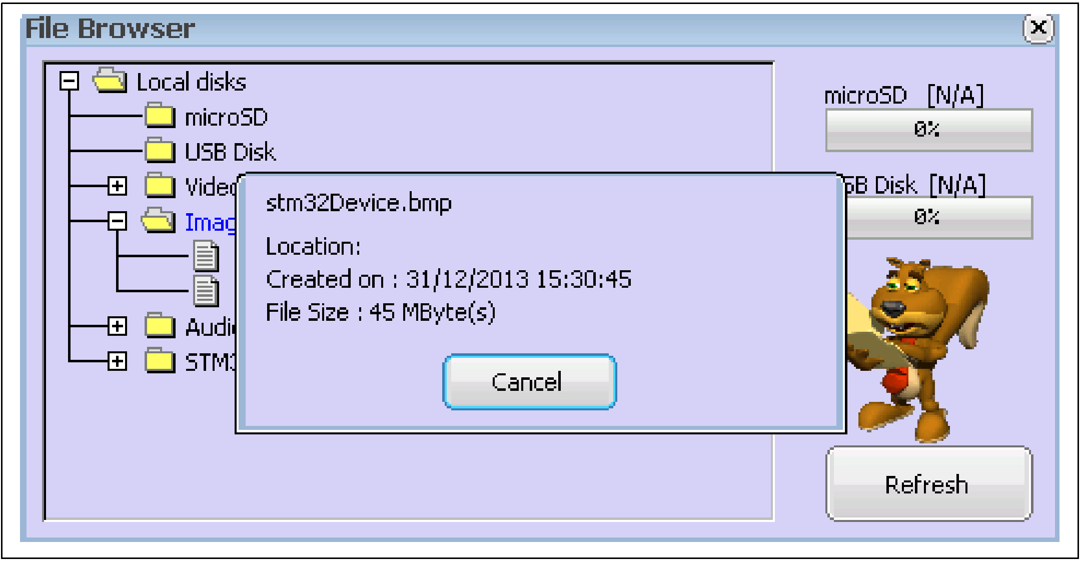


Figure 49. File properties display



stm32Device.bmp

Location:

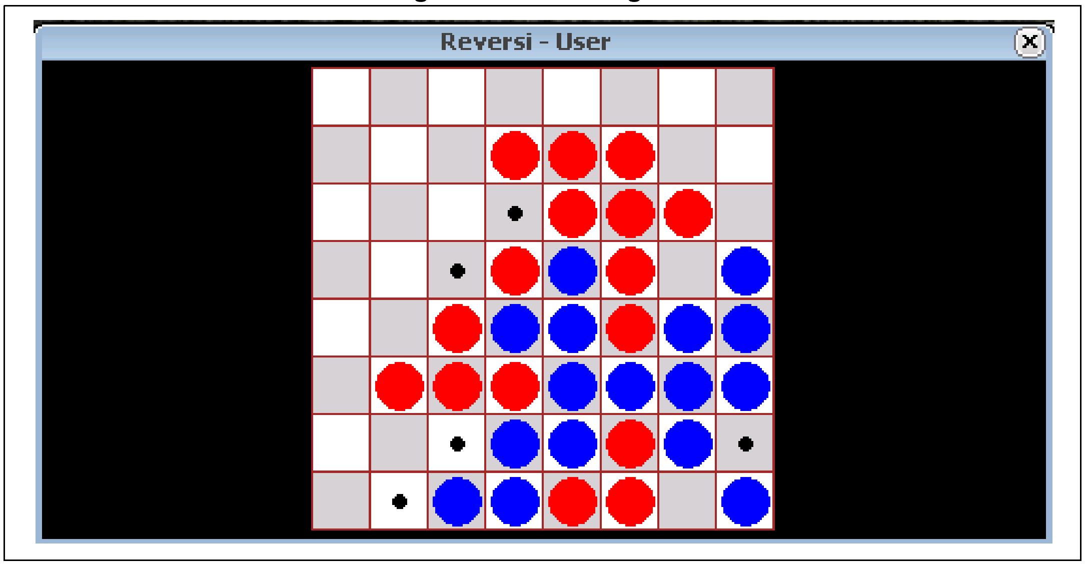
Created on : 31/12/2013 15:30:45

File Size : 45 MByte(s)

8.2.3 Game

The game coming in the STM32CubeF4 demonstration is based on the Reversi game. It is a strategy board game for two players, played on an 8×8 board. The goal of the game is to have the majority of disks turned to display your color when the last playable empty square is filled.

Figure 50. Reversi game



In this STM32CubeF4 demonstration STM32 MCU is one of the two players. The GUI will ask the user to start a new game when the ongoing one is over.

8.2.4 Benchmark

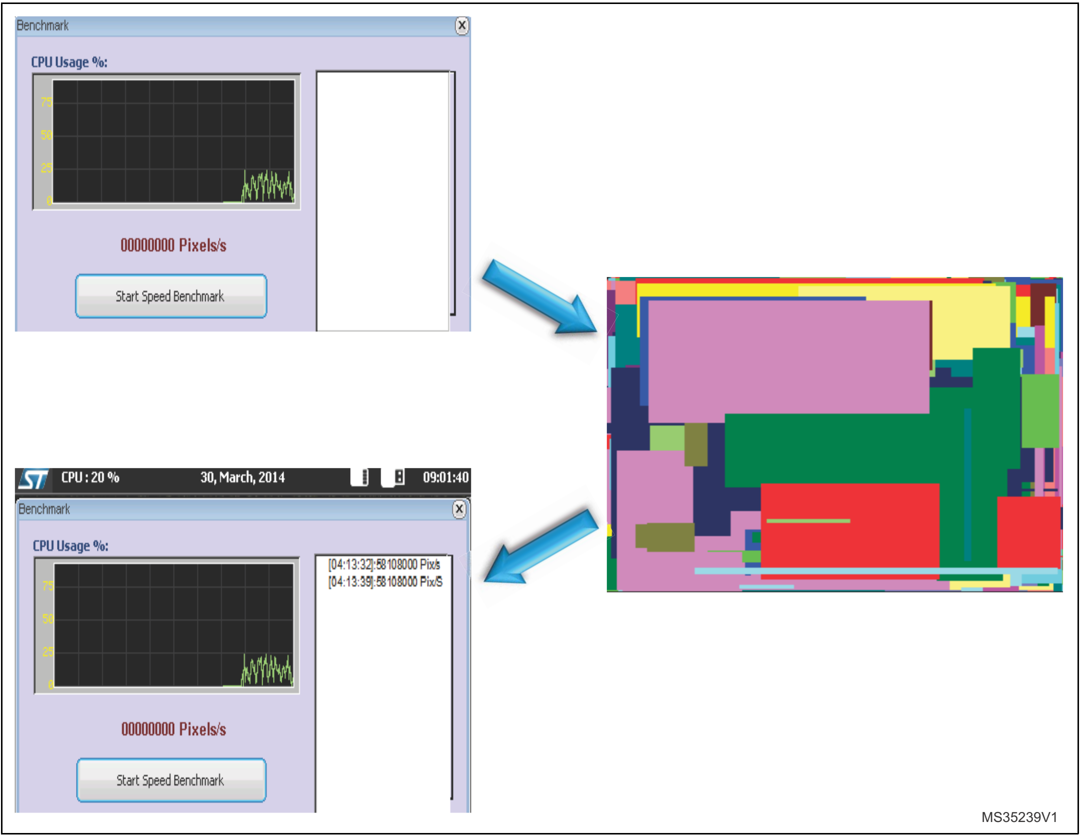
Overview

The Benchmark module is a system module that allows measure the graphical performance by measuring the time needed to draw several colored rectangles in random position with random size during a specific period. The result is given in pixel per second.

Functional description

The benchmark starts immediately once the start speed benchmark button is pressed. After few seconds the result is displayed in red below the CPU Usage graphical window and result is logged in the right list box with date and time stamp (*Figure 51*).

Figure 51. Benchmarking



```
[04:13:32]:58108000 Pix/s
[04:13:39]:58108000 Pix/S
```

8.2.5 Audio

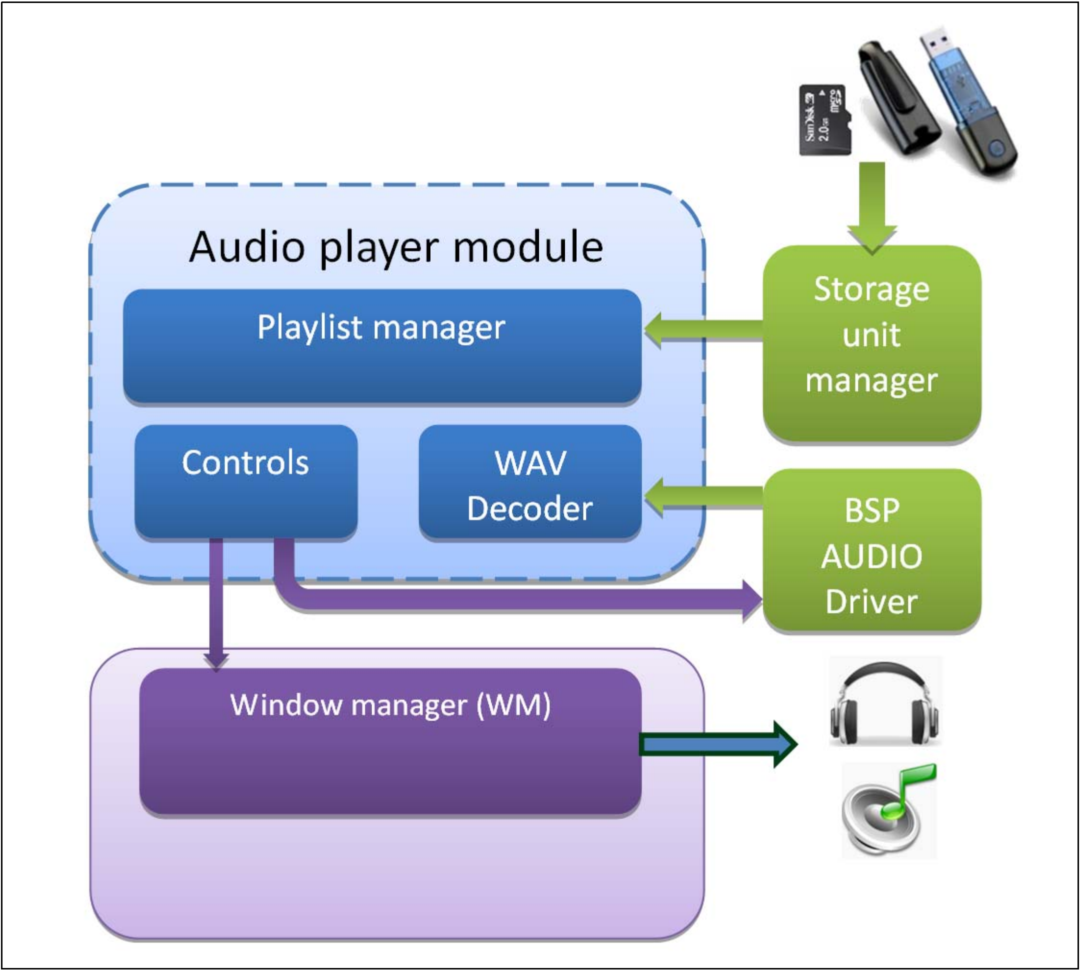
Overview

The audio player module provides a complete audio solution based on the STM32F4xx and delivers a high-quality music experience. It supports playing music in WAV format but may be extended to support other compressed formats such as MP3 and WMA audio formats.

Architecture

Figure 52 shows the different audio player parts and their connections and interactions with the external components.

Figure 52. Audio player module architecture



Data structure used

Table 16 contains the different data structure used in audio player module and a brief description of each of them.

Table 16. Data structure for audio

Structure	Description
WAV_InfoTypedef	Contains the wave file information extracted from wave file header
AUDIOPLAYER_ProcessTypdef	Contains the audio player state, the speaker state, the volume value and the pointer to the audio buffer.
AUDIOPLAYER_StateTypdef	Contains the different audio player state: – AUDIOPLAYER_STOP – AUDIOPLAYER_START – AUDIOPLAYER_PLAY – AUDIOPLAYER_PAUSE – AUDIOPLAYER_EOF – AUDIOPLAYER_ERROR

Table 16. Data structure for audio (continued)

Structure	Description
AUDIOPLAYER_ErrorTypdef	Contains the different possible error. – AUDIOPLAYER_ERROR_NONE – AUDIOPLAYER_ERROR_IO – AUDIOPLAYER_ERROR_HW – AUDIOPLAYER_ERROR_MEM – AUDIOPLAYER_ERROR_FORMAT_NOTSUPPORTED
BUFFER_StateTypeDef	Contains the different Buffer state – BUFFER_OFFSET_NONE – BUFFER_OFFSET_HALF – BUFFER_OFFSET_FULL.

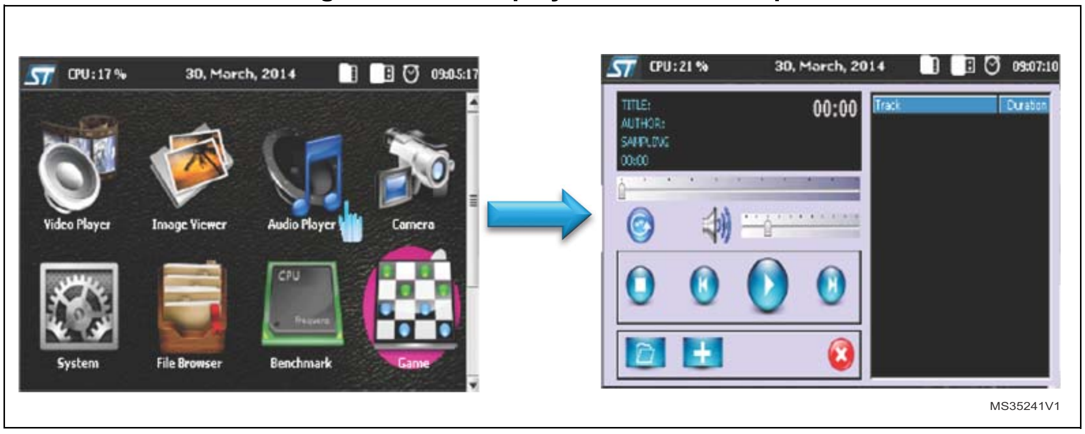
Functional description

The audio player initialization is done in startup step. In this step all the audio player states, the speaker and the volume value are initialized and only when the play button in the audio player interface is pressed to start the process.

There are two ways to start audio player module:

- From main desktop menu as shown in *Figure 53*
- Through the file browser contextual menu: direct open feature.

Figure 53. Audio player module startup



When the audio player is started, the following actions are executed:

- The graphical components are initialized:
  – The audio frame
  – The control buttons
  – The list box field

An additional memory is allocated to keep the audio list (pWavList) and the audio file information (pFileInfo).

Table 17. Audio module controls

Button	Preview	Description
Play button	▶	Changes the audio player state to “AUDIOPLAYER_PLAY” Reads the wave file from storage unit Sets the frequency Starts or resumes the audio task Starts playing audio stream from a data buffer using “BSP_AUDIO_OUT_Play” function in BSP audio driver. Replaces play button by pause button
Pause button	⏸	Suspends the audio task Pauses the audio file stream Replaces pause button by play button
Stop button	■	Close the wave file from storage unit Suspends the audio task Stops audio playing Changes the audio player state to “AUDIOPLAYER_STOP”
Previous button	⏪	Point to the previous wave file Stops audio playing Starts playing the previous wave file if play button is pressed
Next button	⏩	Point to the next wave file Stops audio playing Starts playing the next wave file if play button is pressed
Add file to playlist	+	Open file browser window and choose wave file to be added to playlist
Add folders	📂	Open file browser window and choose entire folder to be added to playlist
Repeat buttons	off 1 ALL	At the end of file: - If repeat all is selected next wave file is selected and played - If repeat once is selected the played wave file is repeated - If repeat off is selected the audio player stop
Speaker button	🔊 🔇	Sets the volume at mute (first press) Sets the volume at value displayed in volume slider (second press
Volume slider	▭	Sets the volume value
Progress slider	▭	Sets the desired position in the wave file
Close button	✖	Close audio player module

8.2.6 Video

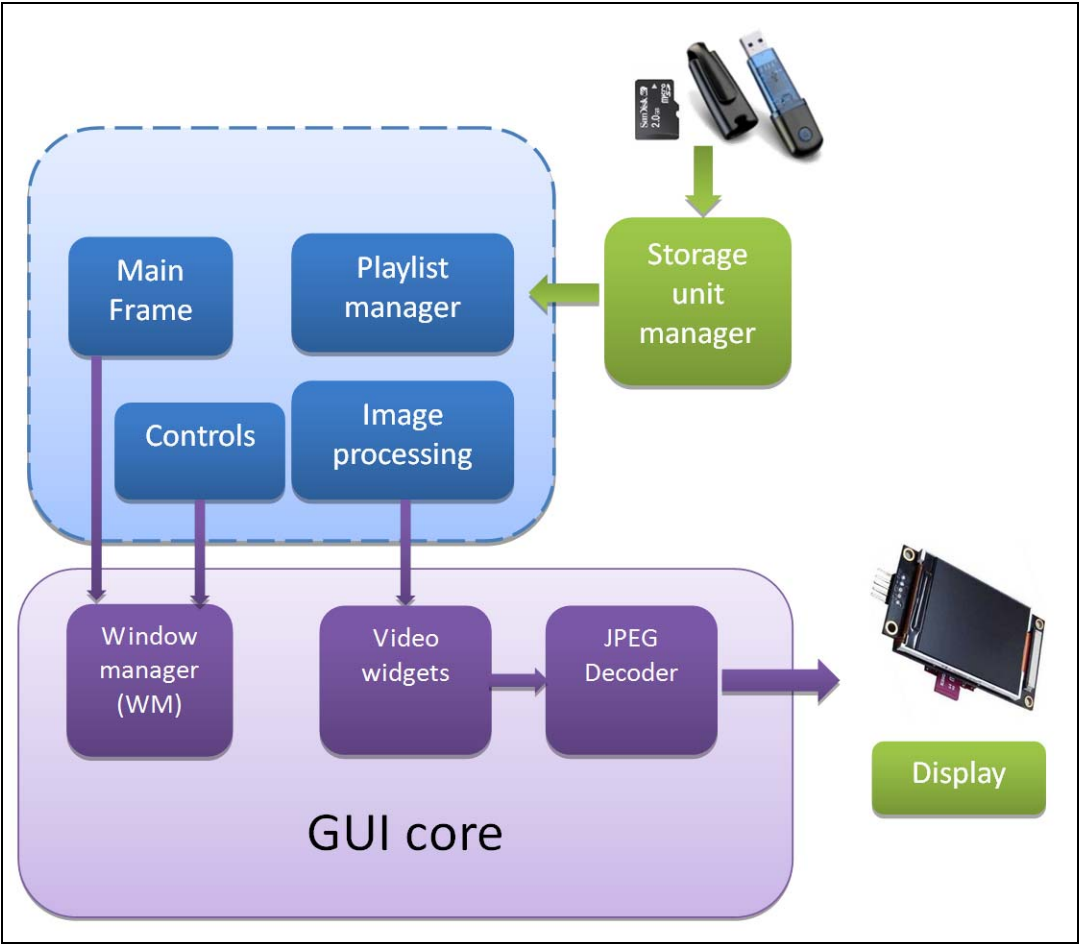
Overview

The video player module provides a video solution based on the STM32F4xx and STemWin movie API. It supports playing movie in emf format.

Architecture

Figure 54 shows the different video player modules and their connections and interactions with the external components.

Figure 54. Video player module architecture



Functional description

There are two ways to start Video player module:

- Either by touching the video player icon: *Figure 55*
- Or by using the file browser contextual menu: direct open feature.

When the video player is started, the following actions are executed:

- The graphical components are initialized:
  - The video frame
  - The control buttons
  - The list box field
- Memory is allocated to save the video list (pVideoList) and the file information (pFileInfo).

Figure 55. Video player module startup

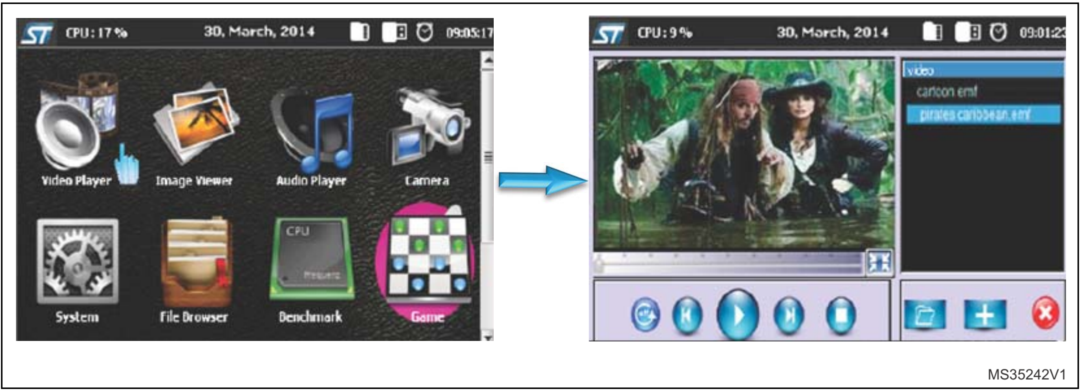


Table 18 summarizes the different actions behind each control button.

Table 18. Video module controls

Button	Preview	Description
Play button	▶	Checks if the video size is not supported Supported video size: 0 < xSize < 1024 and 0 < ySize < 768 Changes the video player state to “VIDEO_PLAY” Reads the video file from storage unit Replaces play button by pause button
Pause button	⏸	Pauses the video file stream Changes the video player state to “VIDEO_PAUSE” Replaces pause button by play button
Stop button	⏹	Closes the video file from storage unit Stops video playing Changes the video player state to “VIDEO_IDLE”
Previous button	⏪	Points to the previous video file Stops video playing Changes the video player state to “VIDEO_IDLE”

Table 18. Video module controls (continued)

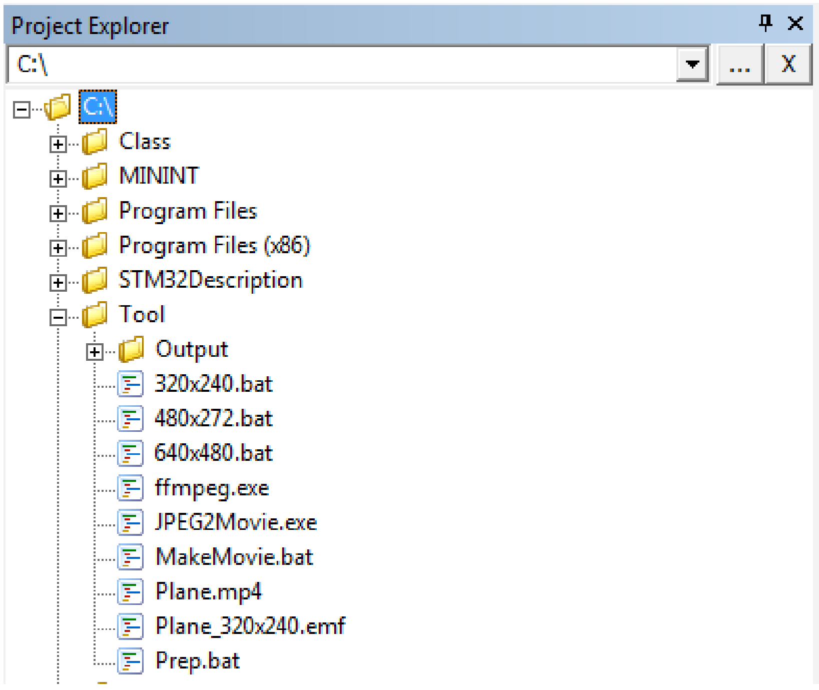
Button	Preview	Description
Next button	⏩	Points to the next video file Stops video playing Starts playing the next video file if play button is pressed
Add file to playlist	➕	Opens file browser window and choose emf file from available storage unit to be added to playlist
Add folder	📂	Opens file browser window and choose entire folder from available storage unit to be added to playlist
Repeat buttons	🔁 🔂 🔁	At the end of file: - If repeat all is selected next video file is selected and played - If repeat once is selected the played video file is repeated - If repeat off is selected the video player stops
Progress slider	▭	Sets the desired position in the emf file
Full screen button	⛶	Scales the image to be showed on full screen mode
Close button	❌	Closes video player module

Video file creation (emf)

To be able to play movies with the STemWin API functions it is required to create files of the STemWin specific EmWin movie file format. There are two steps to generate an emf file:

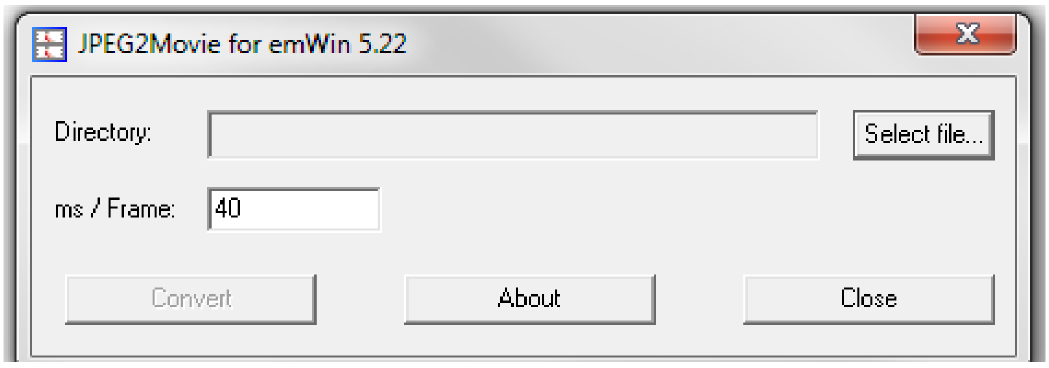
a) Convert files of any MPEG file format into a folder of single JPEG files for each frame (*Figure 56*). The free FFmpeg available at ffmpeg website can be used.

Figure 56. EMF generation environment



b) Create an emf file from JPEG file using JPEG2Movie tool available in STemWin package (see *Figure 57*).

Figure 57. JPEG2Movie overview

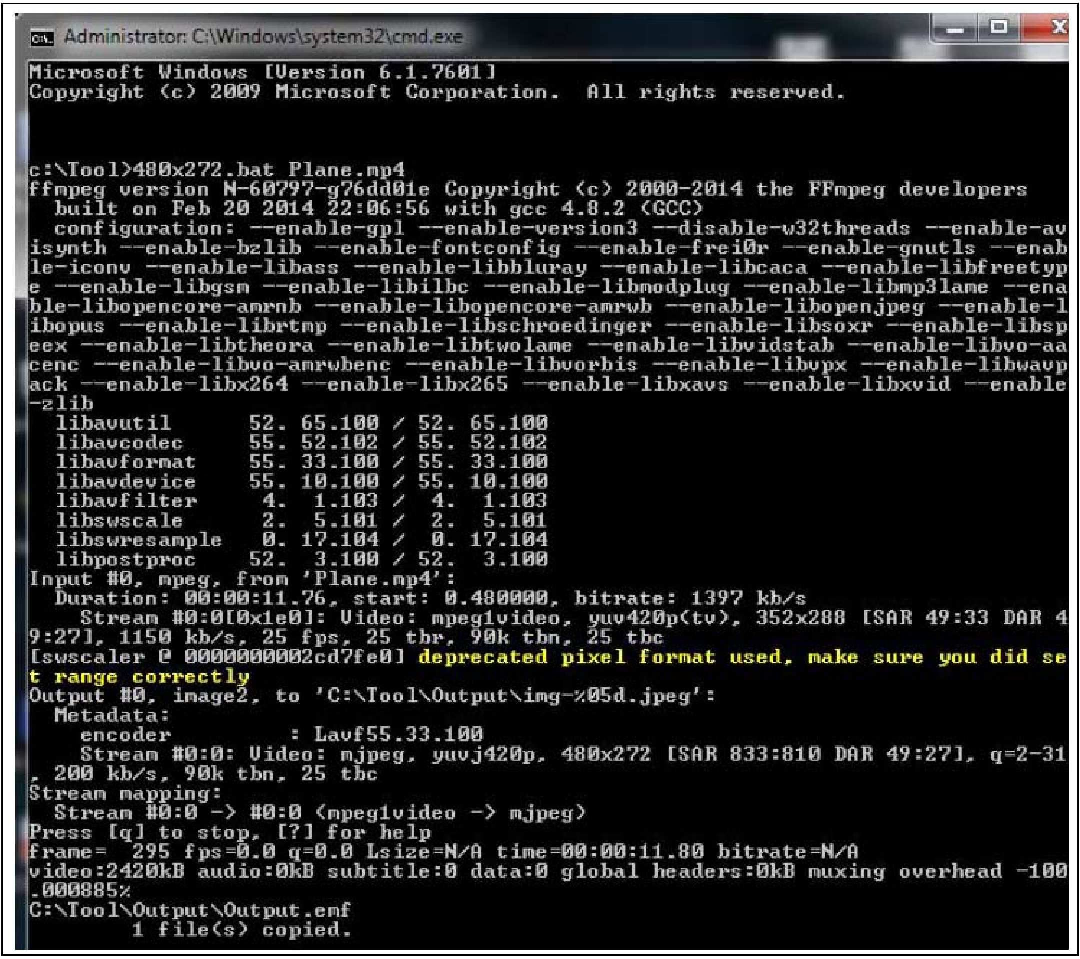


Directory:

ms / Frame: 40

The above steps could be done once using a predefined batch (included in the STemWin package) as shown in *Figure 58*.

Figure 58. EMF file generation



```
Administrator: C:\Windows\system32\cmd.exe
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.


c:\Tool>480x272.bat Plane.mp4
ffmpeg version N-60797-g76dd01e Copyright (c) 2000-2014 the FFmpeg developers
  built on Feb 20 2014 22:06:56 with gcc 4.8.2 (GCC)
  configuration: --enable-gpl --enable-version3 --disable-w32threads --enable-av
isynth --enable-bzlib --enable-fontconfig --enable-frei0r --enable-gnutls --enab
le-iconv --enable-libass --enable-libbluray --enable-libcaca --enable-libfreetyp
e --enable-libgsm --enable-libilbc --enable-libmodplug --enable-libmp3lame --ena
ble-libopencore-amrnb --enable-libopencore-amrwb --enable-libopenjpeg --enable-l
ibopus --enable-librtmp --enable-libschroedinger --enable-libsoxr --enable-libsp
eex --enable-libtheora --enable-libtwolame --enable-libvidstab --enable-libvo-aa
cenc --enable-libvo-amrwbenc --enable-libvorbis --enable-libvpx --enable-libwavp
ack --enable-libx264 --enable-libx265 --enable-libxavs --enable-libxvid --enable
-zlib
  libavutil      52. 65.100 / 52. 65.100
  libavcodec     55. 52.102 / 55. 52.102
  libavformat    55. 33.100 / 55. 33.100
  libavdevice    55. 10.100 / 55. 10.100
  libavfilter     4.  1.103 /  4.  1.103
  libswscale      2.  5.101 /  2.  5.101
  libswresample   0. 17.104 /  0. 17.104
  libpostproc    52.  3.100 / 52.  3.100
Input #0, mpeg, from 'Plane.mp4':
  Duration: 00:00:11.76, start: 0.480000, bitrate: 1397 kb/s
    Stream #0:0[0x1e0]: Video: mpeg1video, yuv420p(tv), 352x288 [SAR 49:33 DAR 4
9:27], 1150 kb/s, 25 fps, 25 tbr, 90k tbn, 25 tbc
[swscaler @ 0000000002cd7fe0] deprecated pixel format used, make sure you did se
t range correctly
Output #0, image2, to 'C:\Tool\Output\img-%05d.jpeg':
  Metadata:
    encoder         : Lavf55.33.100
    Stream #0:0: Video: mjpeg, yuvj420p, 480x272 [SAR 833:810 DAR 49:27], q=2-31
, 200 kb/s, 90k tbn, 25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (mpeg1video -> mjpeg)
Press [q] to stop, [?] for help
frame=  295 fps=0.0 q=0.0 Lsize=N/A time=00:00:11.80 bitrate=N/A
video:2420kB audio:0kB subtitle:0 data:0 global headers:0kB muxing overhead -100
.000885%
C:\Tool\Output\Output.emf
        1 file(s) copied.
```

For more information about how to use the emf generation batches, refer to the STemWin User and Reference Guide (UM3001).

Table 19. Batch files description

File	Explanation
Prep.bat	Sets some defaults to be used. Needs to be adapted as explained in *Prep.bat*.
MakeMovie.bat	Main conversion file. Not to be adapted normally.
<X_SIZE>x<Y_SIZE>.bat	Some helper files for different resolutions. Detailed explanation in *<X_SIZE>x<Y_SIZE>.bat*

Prep.bat

The Prep.bat is required to prepare the environment for the actual process. Calling it directly will not have any effect. It is called by the MakeMovie.bat. To be able to use the batch files it is required to adapt this file at first. This file sets variables used by the file MakeMovie.bat, they are listed in *Table 20*.

.

Table 20. Variables description

Variable	Description
%OUTPUT%	Destination folder for the JPEG files. Will be cleared automatically when starting the conversion with MakeMovie.bat.
%FFMPEG%	Access variable for the FFmpeg tool. Should contain the complete path required to call FFmpeg.exe.
%JPEG2MOVIE%	Access variable for the JPEG2MOVIE tool. Should contain the complete path required to call JPEG2Movie.exe.
%DEFAULT_SIZE%	Default movie resolution to be used. Can be ignored if one of the <X-SIZE>x<Y-SIZE>.bat files are used.
%DEFAULT_QUALITY%	Default quality to be used by FFmpeg.exe for creating the JPEG files. The lower the number the better the quality. Value 1 indicates that a very good quality should be achieved, value 31 indicates the worst quality. For more details please refer to the FFmpeg documentation.
%DEFAULT_FRAMERATE%	Frame rate in frames/second to be used by FFmpeg. It defines the number of JPEG files to be generated by FFmpeg.exe for each second of the movie. For more details please refer to the FFmpeg documentation.

MakeMovie.bat

This is the main batch file used for the conversion process. Normally it is not required to be change this file, but it is required to adapt Prep.bat first. It could be called with the parameters listed in *Table 21*:

Table 21. Parameters description

Parameter	Description
%1	Movie file to be converted
%2 (optional)	Size to be used. If not given %DEFAULT_SIZE% of Prep.bat is used.
%3 (optional)	Quality to be used. If not given %DEFAULT_QUALITY% of Prep.bat is used.
%4 (optional)	Frame rate to be used. If not given %DEFAULT_FRAMERATE% of Prep.bat is used.

Since the FFmpeg output can differ strongly from the output of previous actions, the MakeMovie.bat deletes all output files in the first place. The output folder is defined by in the environmental variable %OUTPUT% in Prep.bat. After that it uses FFmpeg.exe to create the required JPEG files for each frame. Afterwards it calls JPEG2Movie to create a single EMF file which can be used by STemWin directly. After the conversion operation the result can be found in the conversion folder under FFmpeg.emf. It also creates a copy of that file into the source file folder. It will have the same name as the source file with a size-postfix and .emf extension.

<X_SIZE>x<Y_SIZE>.bat

These files are small but useful helpers if several movie resolutions are required. The filenames of the batch files itself are used as parameter '-s' for FFmpeg.exe. You can simply drag-and-drop the file to be converted to one of these helper files. After that an .emf file with the corresponding size-postfix can be found in the source file folder.

8.2.7 USB mass storage device (USBD)

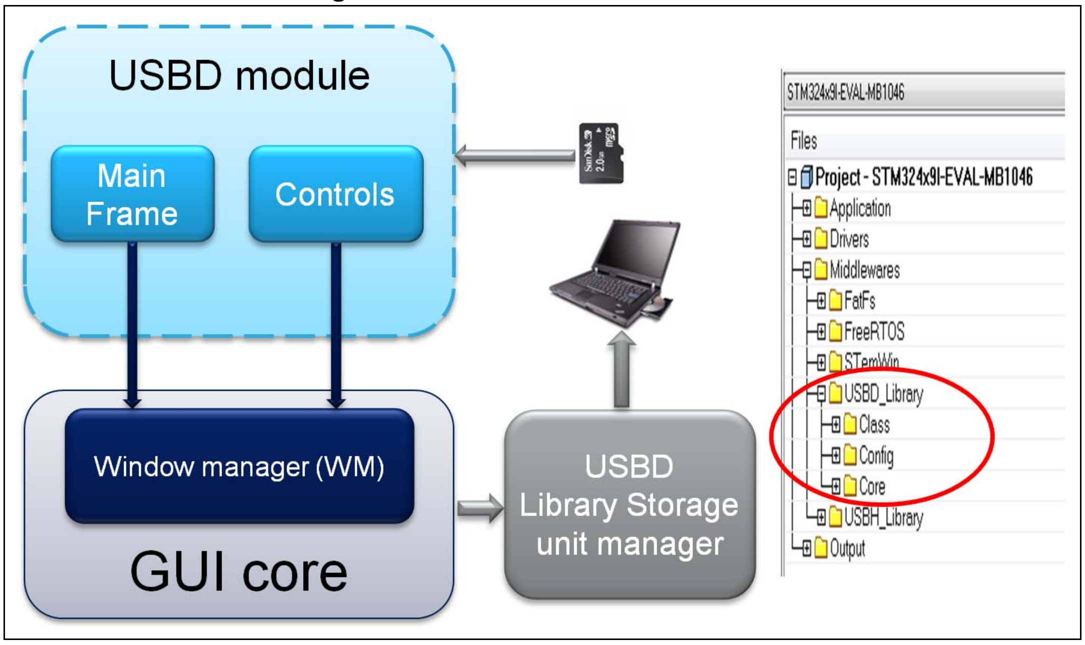
Overview

The USB device module includes mass storage device application using the MicroSD memory. It uses the USB OTG FS peripheral as the USB OTG HS is used for the USB disk Flash storage unit.

Architecture

Figure 59 shows the different USBD module components and their connections and interactions with the external components.

Figure 59. USBD module architecture



Data structure used

Table 22. Data structure for USBD module

Structure	Description
USBDSettingsTypeDef	sd_mounted: connection status

Functional description

Run USB Device demonstration by clicking USB device icon in the main desktop, as in *Figure 60*.

Figure 60. USBD module startup

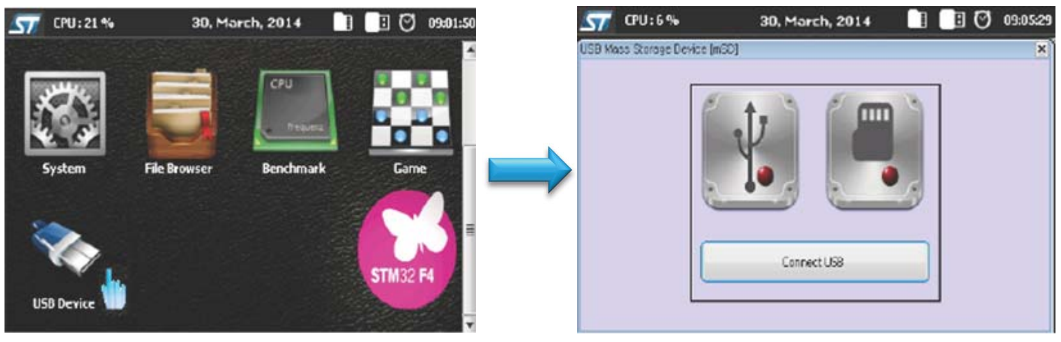


Table 23. USBD module controls

Button	Preview	Description
Connect USB		Changes the USB logo as follows: Changes the USBD status as CONNECTED
Disconnect USB		Changes the USB logo as follows: Changes the USBD status as DISCONNECTED

Table 23. USBD module controls (continued)

Button	Preview	Description
Insert microSD card	NA	Changes the microSD logo as follows:
Remove microSD card	NA	Changes the microSD logo as follows:
Close	⊠	Closes USBD module

8.2.8 Camera

Overview

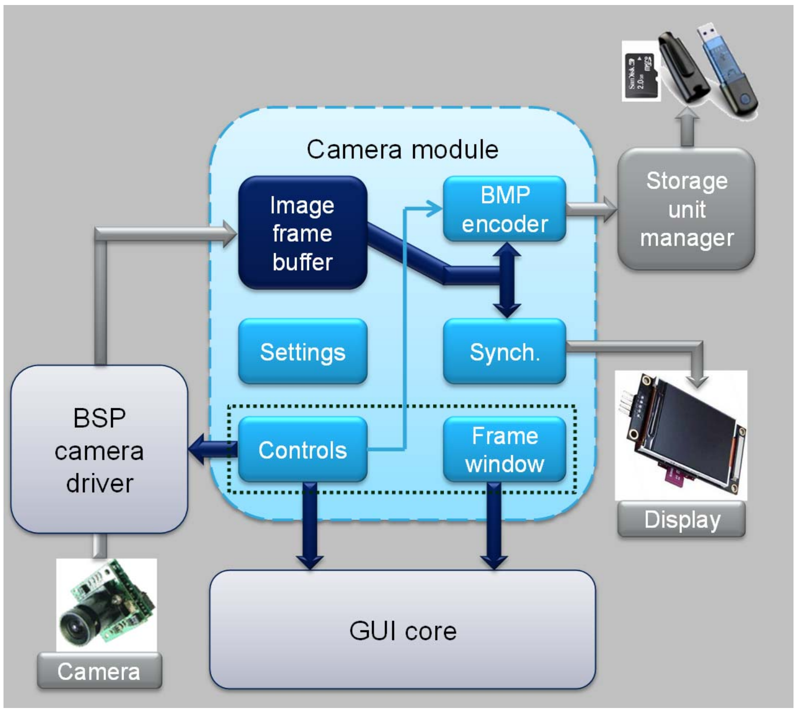
The camera application allows to directly and permanently display on the LCD the image captured using the camera module. It is also possible to take a snapshot and save it to a customizable location in the storage unit.

In addition to brightness and contrast which are adjustable, several effects can be applied to the output image: black and white, negative, antique...etc. Note that all these effects can be applied in runtime.

Architecture

Figure 61 shows the different camera module parts and their respective connections and interactions with the external components.

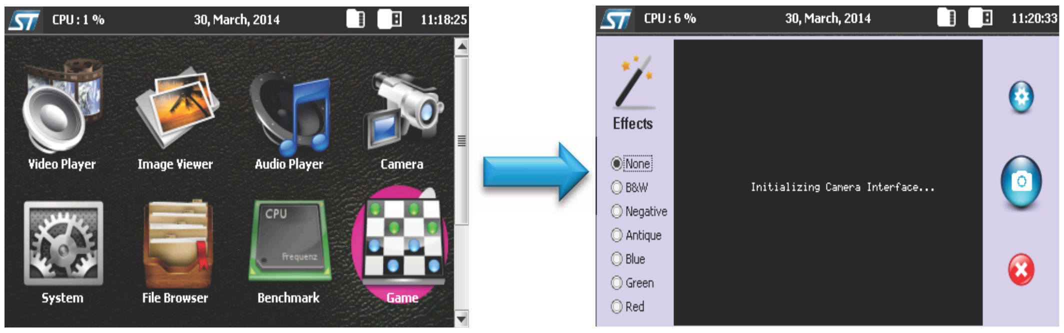
Figure 61. Camera module architecture



Functional description

To start the camera module click on the Camera icon, as indicated in *Figure 62*.

Figure 62. Camera module startup



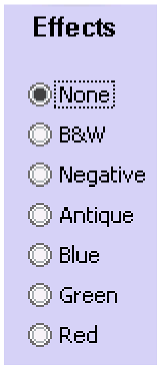
Initializing Camera Interface...

When the camera module is started, the following actions are executed:

- The graphical components are initialized.
- Memory is allocated to save the capture folder location (pFileInfo).
- The saved parameters (brightness and contrast) are restored from the RTC backup register.

Table 24 summarizes the different actions behind each control button.

Table 24. Camera module controls

Button	Preview	Description
Settings	⚙	Creates and shows the settings dialog
Capture	📷	Checks the camera state Displays a popup message ("Saving image...") Saves the current image to the specified file (default path is the root) Deletes the popup message
Close	❌	Frees allocated memory during the initialization Stops the camera module Ends the module dialog
Effects	 Effects [✓ None] B&W Negative Antique Blue Green Red	Applies the selected effect on the fly via the BSP camera driver commands

8.2.9 Image viewer

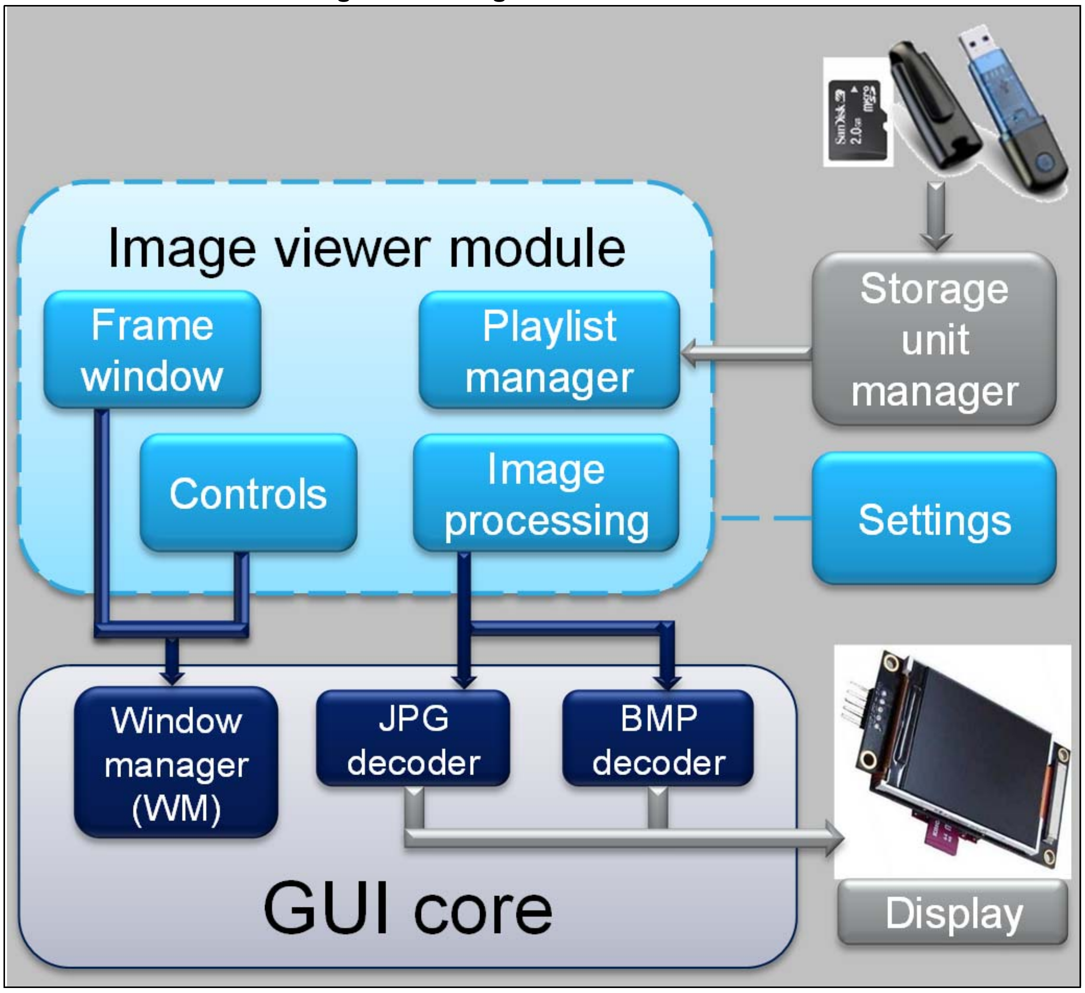
Overview

The Image viewer module allows displaying bmp and jpg pictures. It is possible to load the full images list from a folder or to add the images manually to the playlist. Once the playlist is created, navigation between pictures can be done either via Next and previous buttons or by enabling the slide show mode. The slide show timer can be changed on the fly (there is no need to restart the module).

Architecture

Figure 63 shows the different image viewer parts and their respective connections and interactions with the external components.

Figure 63. Image viewer architecture



Functional description

There are two ways to start Image viewer module:

- Either by touching the Image viewer icon (*Figure 64*);
- Or by using the file browser contextual menu: direct open feature.

When the image viewer is started, the following actions are executed:

- The graphical components are initialized:
  - The image frame
  - The control buttons
  - The list box field
- Memory is allocated to save the image list (pImageList) and the file information (pFileInfo).
- The saved parameters are restored from the RTC backup register.

Figure 64. Image viewer startup

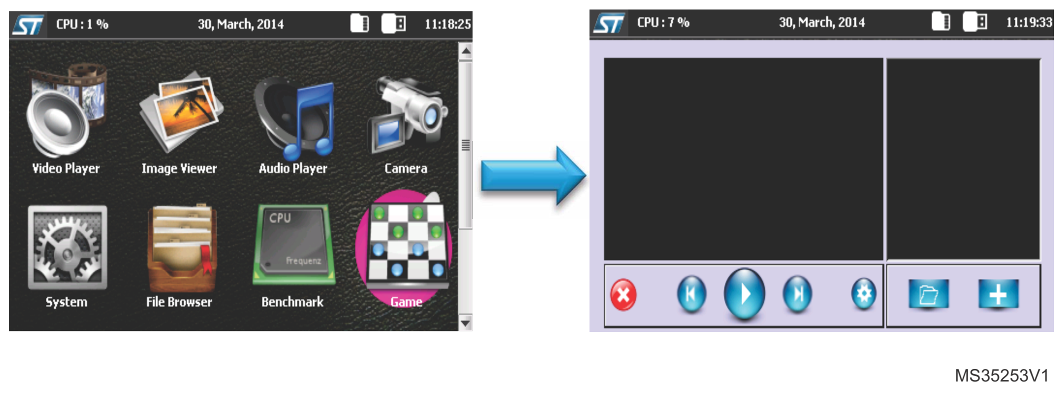


Table 25 summarizes the different actions behind each control button.

Table 25. Image viewer module controls

Button	Preview	Description
Close	✖	Frees allocated memory Ends the module dialog
Previous	⏪	Closes the current image Opens the previous image Refreshes the image frame Updates the selection in the playlist
Start slideshow	▶	Closes the current image Opens the next image Refreshes the image frame Creates the slideshow timer
Next	⏩	Closes the current image Opens the next image Refreshes the image frame Updates the selection in the playlist
Settings	⚙	Creates and shows the settings dialog
Add folder	📂	Opens the directory chooser to allow selection of an entire folder and then adds all the images included in this folder to the playlist
Add file	➕	Opens the file chooser to allow selection of an image which will be added to the playlist.

9 Demonstration functional description (STM32F479I-EVAL and STM32F469I-DISCO)

9.1 Modules

9.1.1 Audio

Overview

The audio player module provides a complete audio solution based on the STM32F4xx and delivers a high-quality music experience. It supports playing music in WAV format but may be extended to support other compressed formats such as MP3 and WMA audio formats.

Features

- Audio Format: WAV format without compression with 8k to 96 k sampling
- Embeds an equalizer and loudness control
- Performance: MCU Load < 5%
- Audio files stored in USB Disk flash (USB High Speed)
- Support background mode feature
- Only 8 Kbytes of RAM required for Audio processing

MP3 Format is not supported but can be easily added (separate demonstration)

Architecture and performance

Figure 65 shows the different audio player parts and their connections and interactions with the external components, while *Figure 66* details the mechanisms.

Figure 65. Audio player module architecture

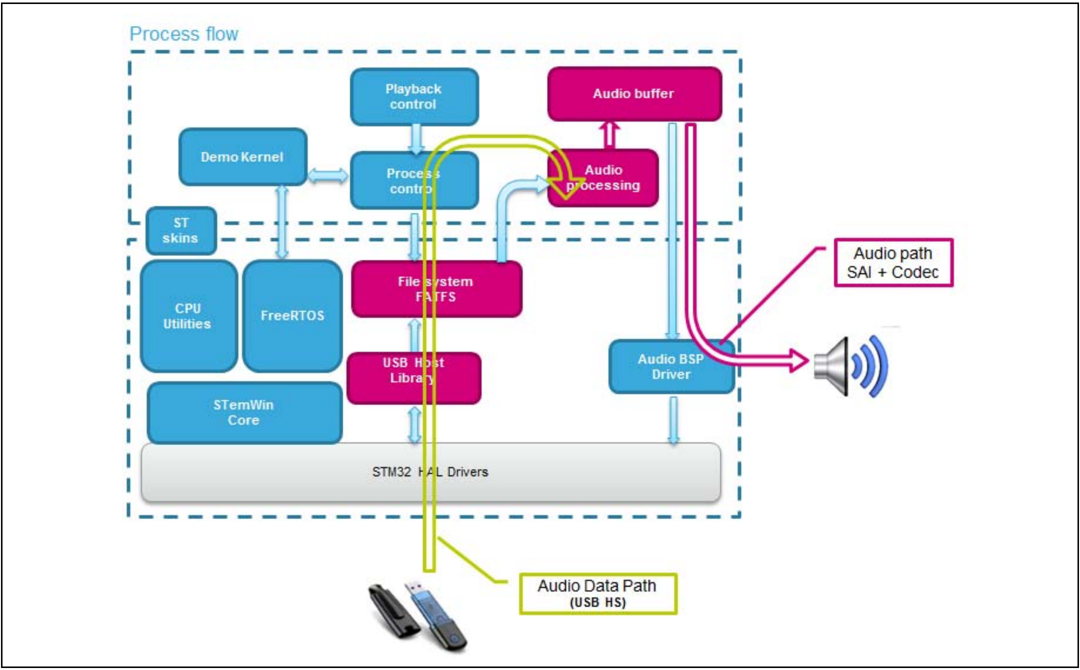
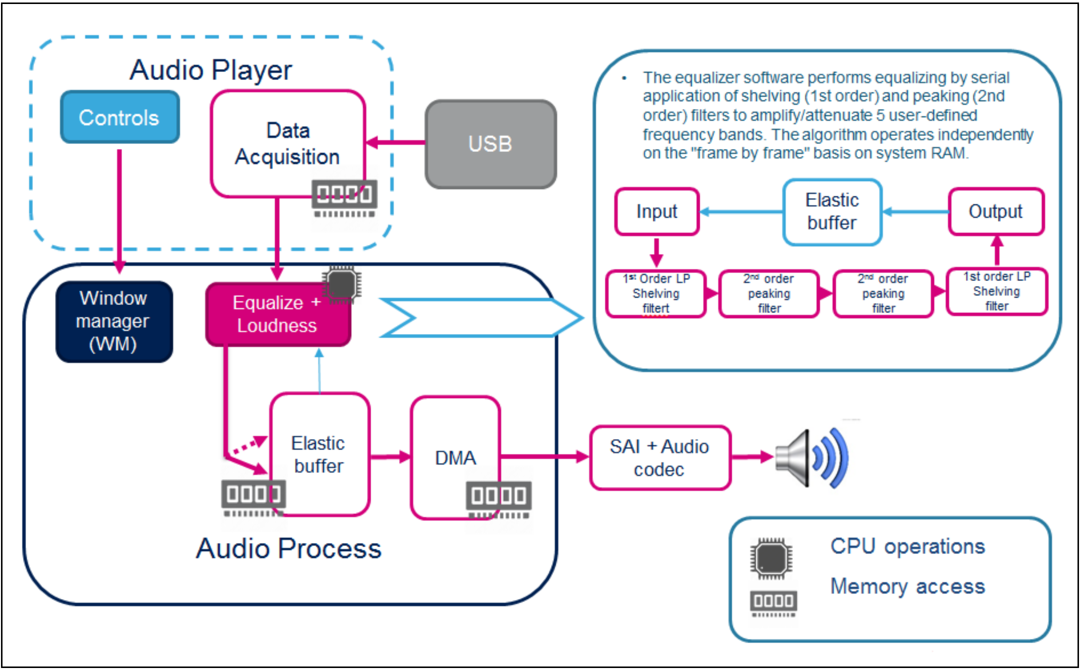


Figure 66. Audio player module performance mechanisms


Audio Player
Controls
Data Acquisition
USB
Window manager (WM)
Equalize + Loudness
Elastic buffer
DMA
Audio Process
SAI + Audio codec
The equalizer software performs equalizing by serial application of shelving (1st order) and peaking (2nd order) filters to amplify/attenuate 5 user-defined frequency bands. The algorithm operates independently on the "frame by frame" basis on system RAM.
Input
Elastic buffer
Output
1st Order LP Shelving filtert
2nd order peaking filter
2nd order peaking filter
1st order LP Shelving filter
CPU operations
Memory access

Functional description

The audio player initialization is carried out in the startup step: all the audio player states, the speaker and the volume value are initialized (when the Play button in the audio player interface is pressed to start the process):

- start audio player module from main desktop menu, as shown in *Figure 67*;
- add audio file to play list (*Figure 68*);
- click on the Equalizer icon to open the equalizer and loudness frame (*Figure 69*);
- activate background (*Figure 70*).

Figure 67. Start audio player

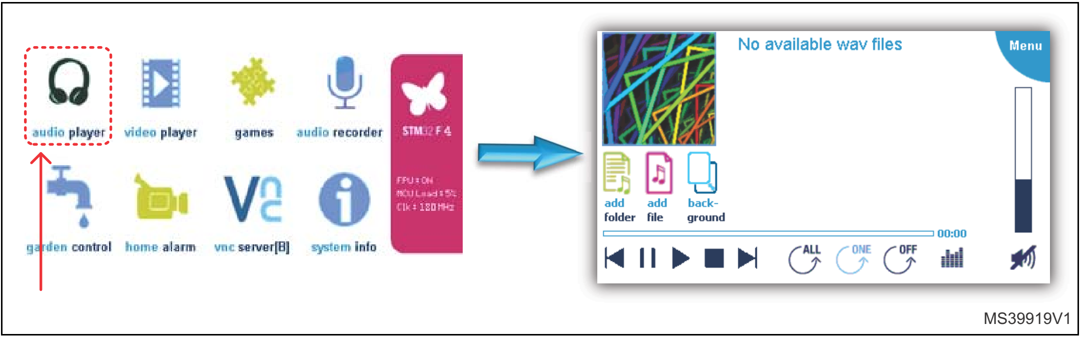
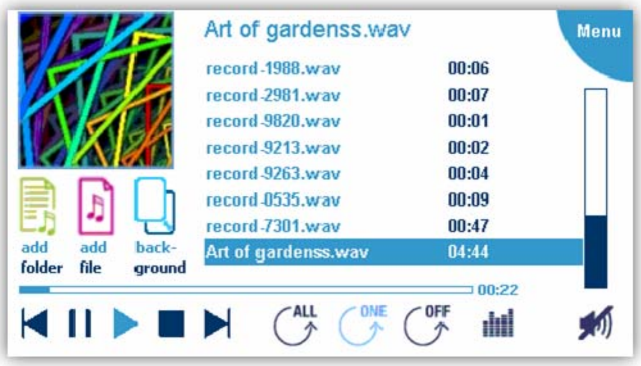


Figure 68. Adding audio files to the playlist



Art of gardenss.wav

record-1988.wav	00:06
record-2981.wav	00:07
record-9820.wav	00:01
record-9213.wav	00:02
record-9263.wav	00:04
record-0535.wav	00:09
record-7301.wav	00:47
Art of gardenss.wav	04:44

Figure 69. Equalizer and loudness frame

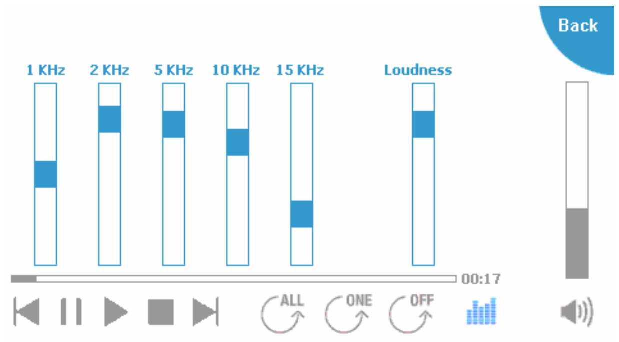
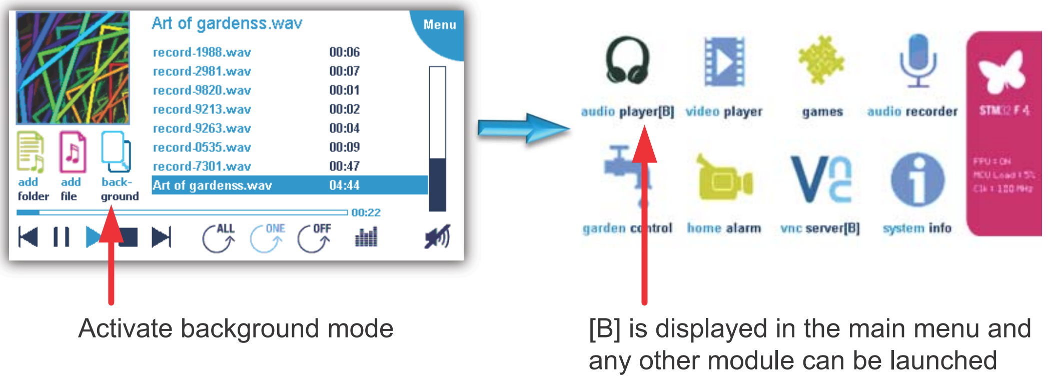


Figure 70. Background mode



Art of gardenss.wav

record-1988.wav	00:06
record-2981.wav	00:07
record-9820.wav	00:01
record-9213.wav	00:02
record-9263.wav	00:04
record-0535.wav	00:09
record-7301.wav	00:47
Art of gardenss.wav	04:44

MS39922V1

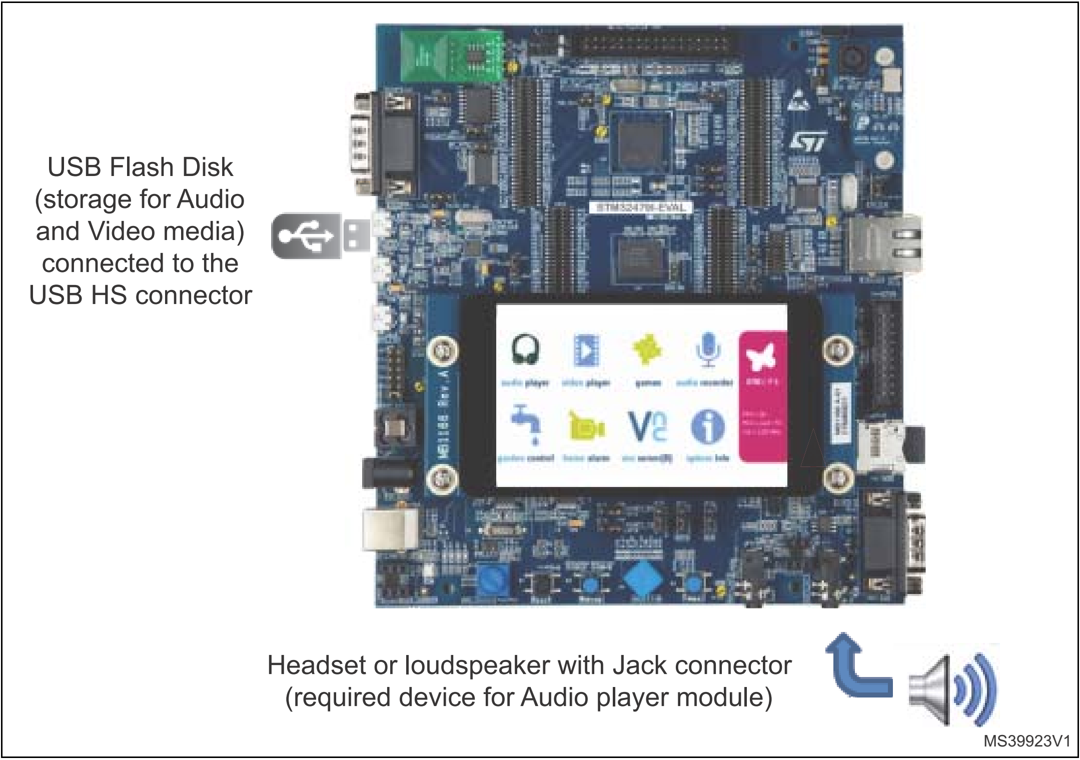

USB Flash Disk (storage for Audio and Video media) connected to the USB HS connector
Headset or loudspeaker with Jack connector (required device for Audio player module)
MS39923V1

Figure 71. Hardware connectivity

Table 26. Image viewer module controls

Button	Preview	Description
Play	▶	Changes the audio player state to “AUDIOPLAYER_PLAY” Reads the wave file from storage unit Sets the frequency Starts or resumes the audio task Starts playing audio stream from a data buffer using “BSP_AUDIO_OUT_Play” function in BSP audio driver. Replaces play button by pause button
Pause	❚❚	Suspends the audio task Pauses the audio file stream Replaces pause button by play button
Stop	■	Close the wave file from storage unit Suspends the audio task Stops audio playing Changes the audio player state to “AUDIOPLAYER_STOP”
Previous	⏮	Point to the previous wave file Stops audio playing Starts playing the previous wave file if play button is pressed

Table 26. Image viewer module controls (continued)

Button	Preview	Description
Next	⏭	Point to the next wave file Stops audio playing Starts playing the next wave file if play button is pressed
Add file to playlist	🎵	Open file browser window and choose wave file to be added to playlist
Add folder	🎵	Open file browser window and choose entire folder to be added to playlist
Repeat	OFF ONE ALL	At the end of file: – If repeat all is selected next wave file is selected and played – If repeat once is selected the played wave file is repeated – If repeat off is selected the audio player stop
Speaker	🔊 🔇	Sets the volume at mute (first press) Sets the volume at value displayed in volume slider (second press)
Equalizer	📶	Starts the equalizer frame
Menu	Menu	Closes audio player module
Background	⧉	Activates background, any other module can be started

9.1.2 Video

Overview

The video player module provides a video solution based on the STM32F4xx and STemWin movie API. It supports playing movie in .emf format.

Features

- Video Format: STemWin emf Video Format (Motion-Jpeg)
- Performance: MCU Load < 70% / Rate: up to 15 fps
- Video files stored in USB Disk flash (USB High Speed)
- Use of the 2 LCD layers (Playback control/ Video display)
- 64 Kbytes of RAM required for JPEG decoding

Architecture and performance

Figure 72 shows the different audio player parts and their connections and interactions with the external components, while *Figure 73* details the mechanisms.

Figure 72. Video player module architecture

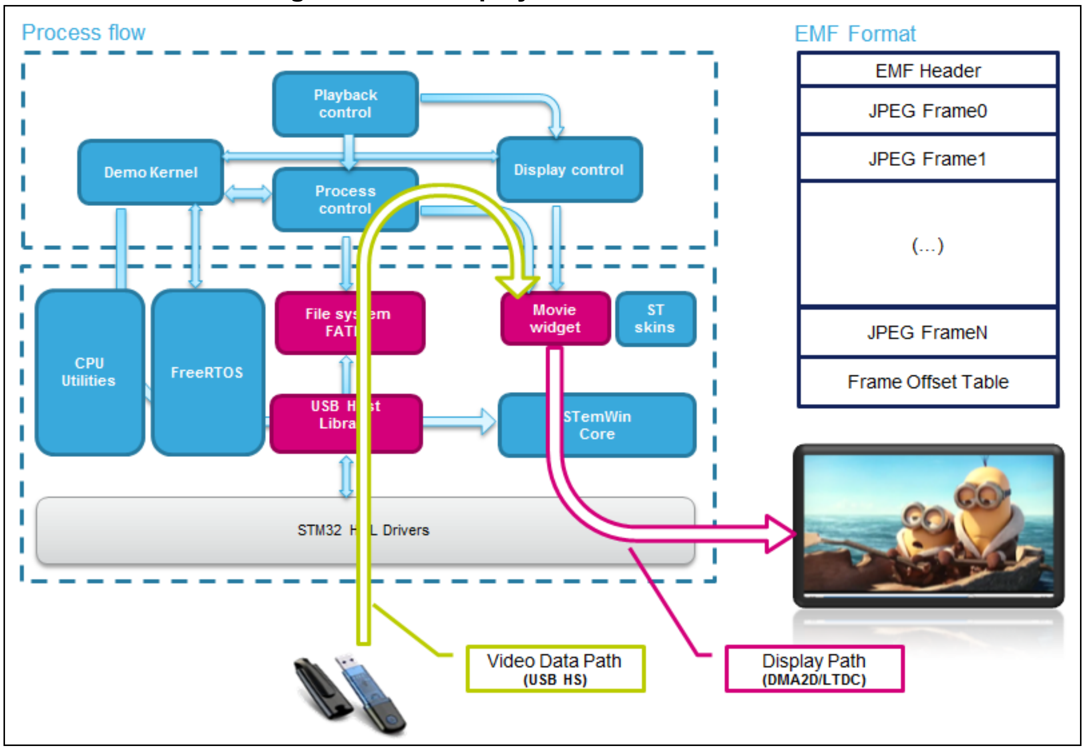
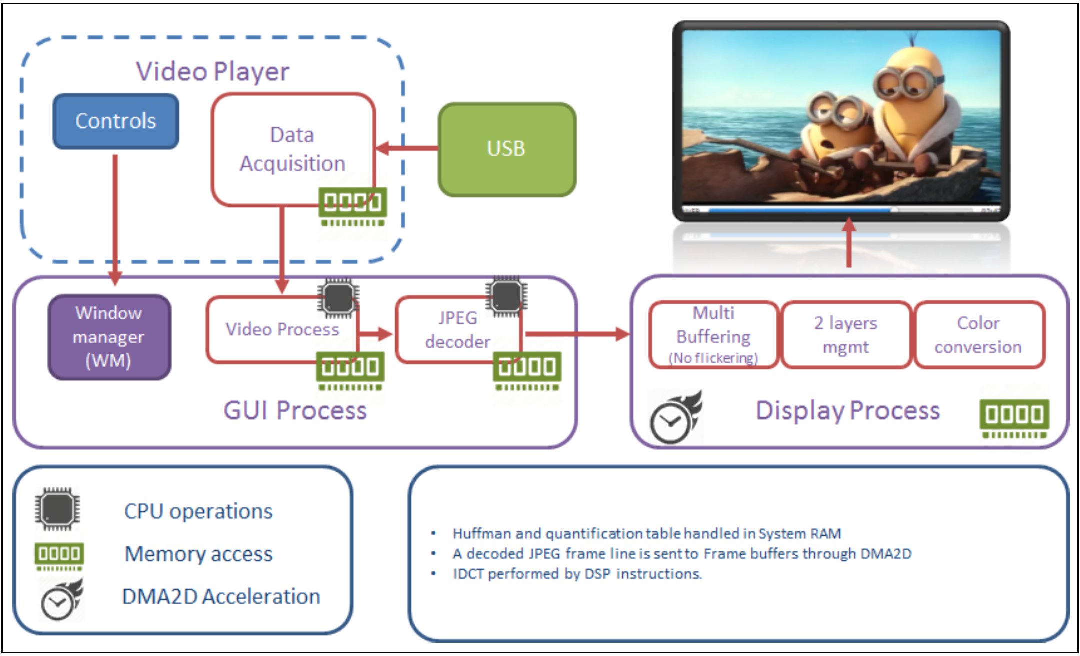


Figure 73. Video player module performance


Video Player
Controls
Data Acquisition
USB
Window manager (WM)
Video Process
JPEG decoder
GUI Process
Multi Buffering (No flickering)
2 layers mgmt
Color conversion
Display Process
CPU operations
Memory access
DMA2D Acceleration
Huffman and quantification table handled in System RAM
A decoded JPEG frame line is sent to Frame buffers through DMA2D
IDCT performed by DSP instructions.

Functional description

- Start Video player module by touching the video player icon
- When the video player is started, the icon shown in *Figure 74* is displayed
- Add video file to playlist by touching “Add to playlist” icon, as in *Figure 75*
- Play video file by touching “Play video” icon
- If there is no video file selected the popup shown in *Figure 76* appears
- Else, the video file starts playing (*Figure 77*)
- Touch the screen to hide control keys, hardware information and video file information (see *Figure 78*).

Figure 74. Start video player

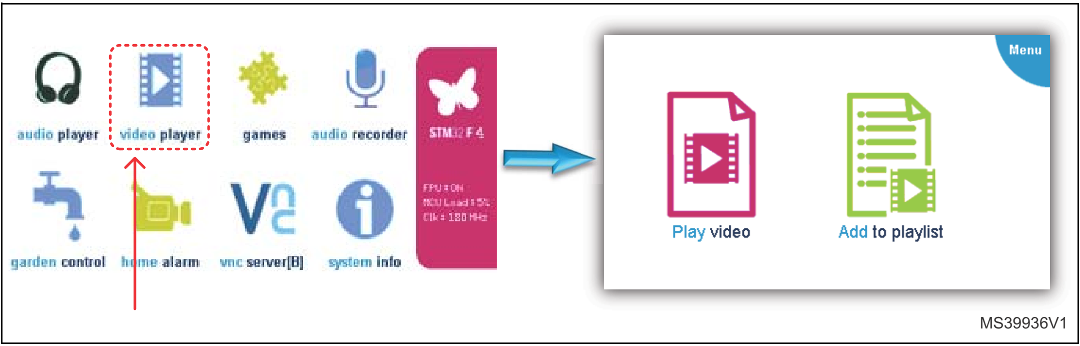
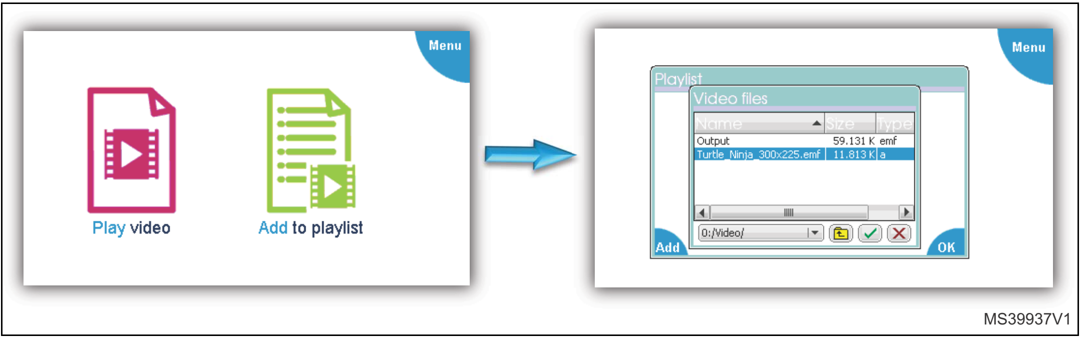
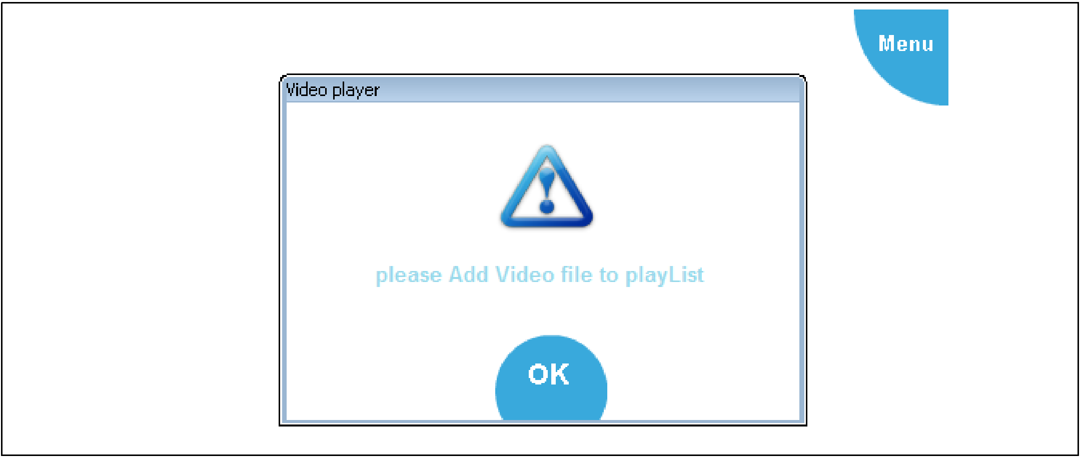


Figure 75. Adding files to the playlist



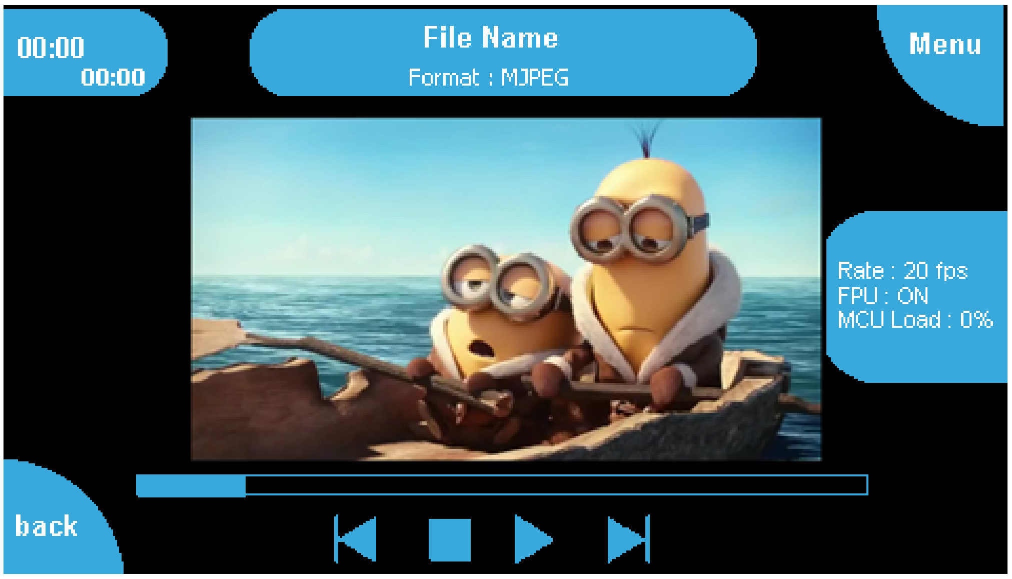
Name	Size	Type
Output	59.131 K	emf
Turtle_Ninja_300x225.emf	11.813 K	a

Figure 76. Warning popup



please Add Video file to playList

Figure 77. Video is playing



Format : MJPEG

Rate : 20 fps
FPU : ON
MCU Load : 0%

Figure 78. Hiding control keys and other information

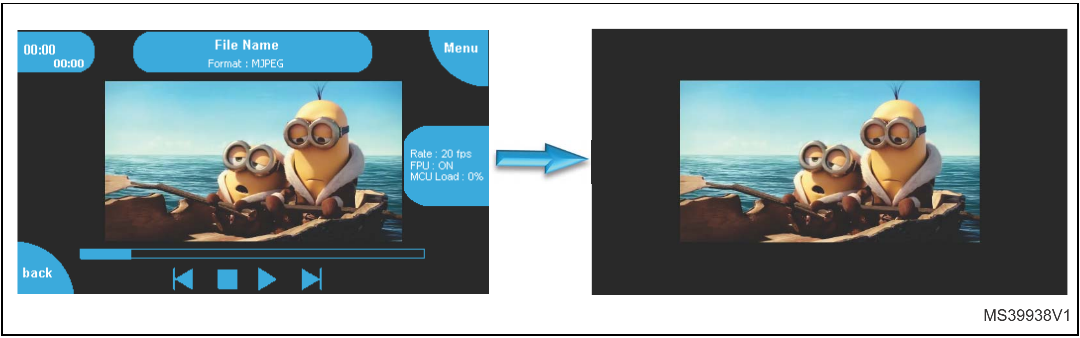


Table 27. Video module controls

Button	Preview	Description
Play	▶	Checks if the video size is not supported Supported video size: 0 < xSize < 1024 and 0 < ySize < 768 Changes the video player state to “VIDEO_PLAY” Reads the video file from storage unit Replaces play button by pause button
Pause	❚❚	Pauses the video file stream Changes the video player state to “VIDEO_PAUSE” Replaces pause button by play button
Next	⏭	Points to the next video file Stops video playing Starts playing the next video file if play button is pressed
Previous	⏮	Point to the previous video file Stops video playing Changes the video player state to “VIDEO_IDLE”
Stop	■	Closes the video file from storage unit Stops video playing Changes the video player state to “VIDEO_IDLE”
Back	back	Back to previous video player frame to add new video file
Menu	Menu	Closes video player module

Video file creation (emf)

To be able to play movies with the STemWin API functions it is required to create files of the STemWin specific EmWin movie file format. There are two steps to generate an emf file:

1. Convert files of any MPEG file format into a folder of single JPEG files for each frame (see *Figure 79*). The free FFmpeg available at ffmpeg website can be used.
2. Create an emf file from JPEG file using JPEG2Movie tool available in STemWin package (*Figure 80*).

Figure 79. EMF generation format

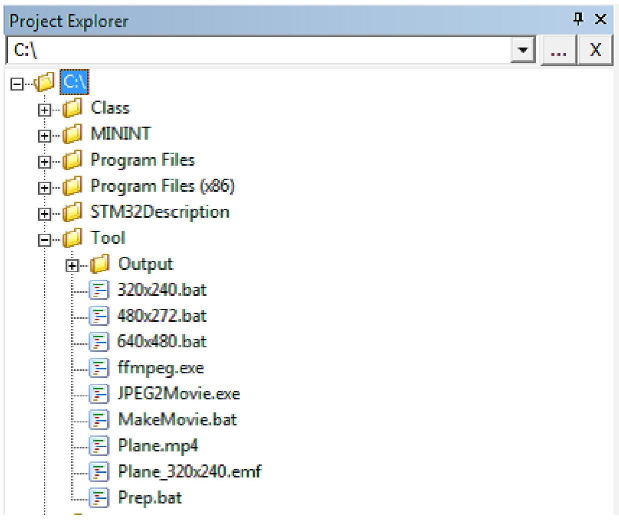
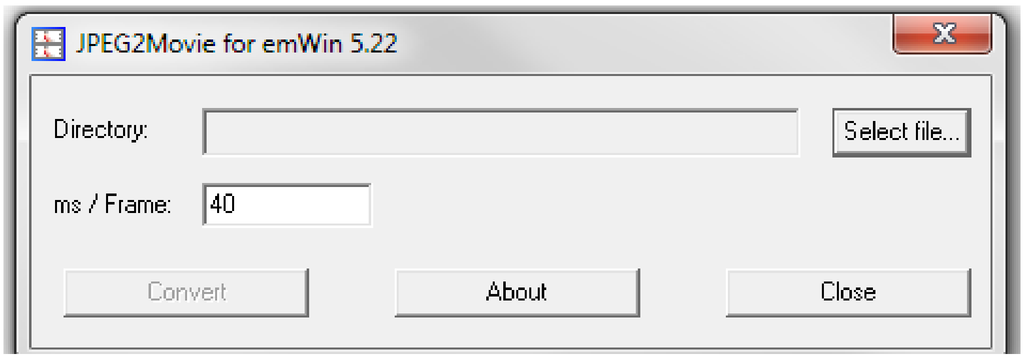


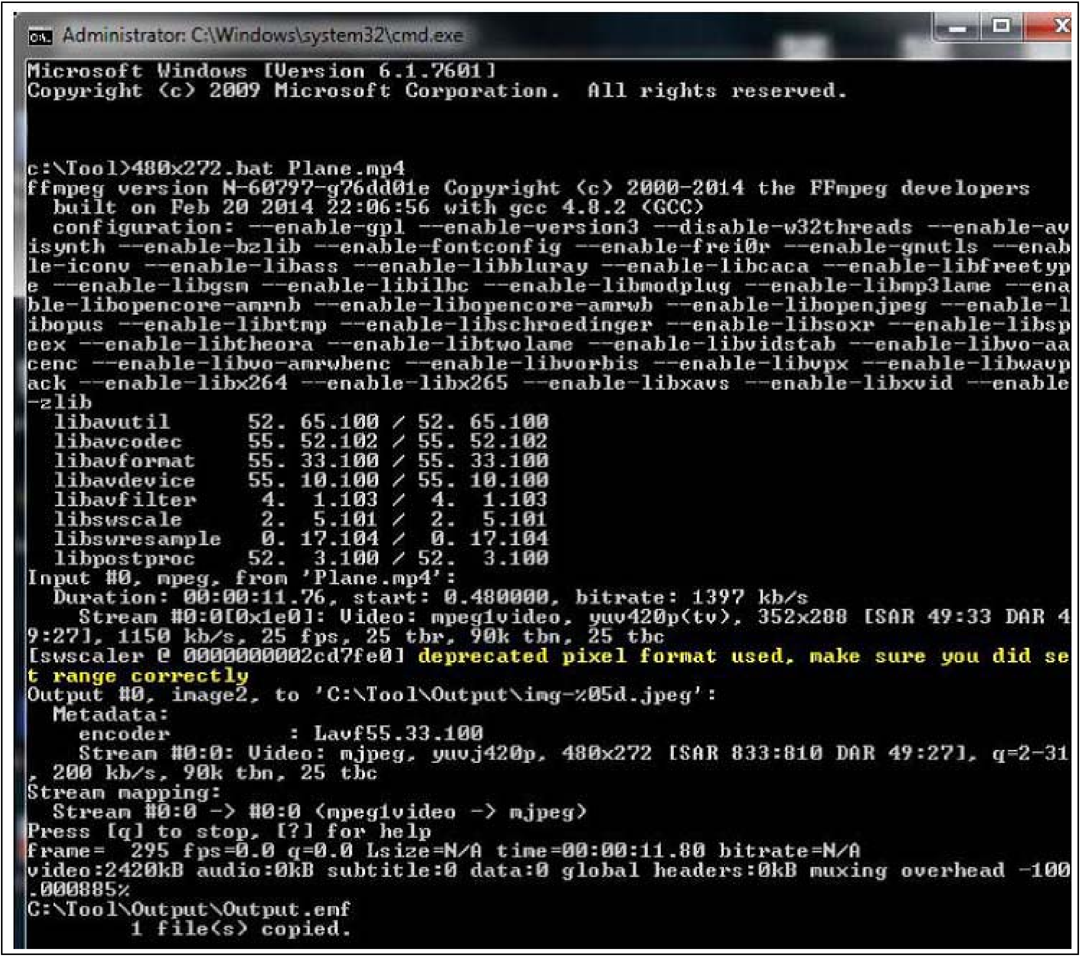
Figure 80. JPEG2Movie overview



These steps can be done once using a predefined batch (included in the STemWin package) as shown in *Figure 81*.

For more information about how to use the emf generation batches, refer to the STemWin User and Reference Guide (UM3001).

Figure 81. EMF file generation



```
Microsoft Windows [Version 6.1.7601]
Copyright (c) 2009 Microsoft Corporation.  All rights reserved.


c:\Tool>480x272.bat Plane.mp4
ffmpeg version N-60797-g76dd01e Copyright (c) 2000-2014 the FFmpeg developers
  built on Feb 20 2014 22:06:56 with gcc 4.8.2 (GCC)
  configuration: --enable-gpl --enable-version3 --disable-w32threads --enable-av
isynth --enable-bzlib --enable-fontconfig --enable-frei0r --enable-gnutls --enab
le-iconv --enable-libass --enable-libbluray --enable-libcaca --enable-libfreetyp
e --enable-libgsm --enable-libilbc --enable-libmodplug --enable-libmp3lame --ena
ble-libopencore-amrnb --enable-libopencore-amrwb --enable-libopenjpeg --enable-l
ibopus --enable-librtmp --enable-libschroedinger --enable-libsoxr --enable-libsp
eex --enable-libtheora --enable-libtwolame --enable-libvidstab --enable-libvo-aa
cenc --enable-libvo-amrwbenc --enable-libvorbis --enable-libvpx --enable-libwavp
ack --enable-libx264 --enable-libx265 --enable-libxavs --enable-libxvid --enable
-zlib
  libavutil      52. 65.100 / 52. 65.100
  libavcodec     55. 52.102 / 55. 52.102
  libavformat    55. 33.100 / 55. 33.100
  libavdevice    55. 10.100 / 55. 10.100
  libavfilter     4.  1.103 /  4.  1.103
  libswscale      2.  5.101 /  2.  5.101
  libswresample   0. 17.104 /  0. 17.104
  libpostproc    52.  3.100 / 52.  3.100
Input #0, mpeg, from 'Plane.mp4':
  Duration: 00:00:11.76, start: 0.480000, bitrate: 1397 kb/s
    Stream #0:0[0x1e0]: Video: mpeg1video, yuv420p(tv), 352x288 [SAR 49:33 DAR 4
9:27], 1150 kb/s, 25 fps, 25 tbr, 90k tbn, 25 tbc
[swscaler @ 0000000002cd7fe0] deprecated pixel format used, make sure you did se
t range correctly
Output #0, image2, to 'C:\Tool\Output\img-%05d.jpeg':
  Metadata:
    encoder         : Lavf55.33.100
    Stream #0:0: Video: mjpeg, yuvj420p, 480x272 [SAR 833:810 DAR 49:27], q=2-31
, 200 kb/s, 90k tbn, 25 tbc
Stream mapping:
  Stream #0:0 -> #0:0 (mpeg1video -> mjpeg)
Press [q] to stop, [?] for help
frame=  295 fps=0.0 q=0.0 Lsize=N/A time=00:00:11.80 bitrate=N/A
video:2420kB audio:0kB subtitle:0 data:0 global headers:0kB muxing overhead -100
.000885%
C:\Tool\Output\Output.emf
        1 file(s) copied.
```

Table 28. Batch file description

File	Description
Prep.bat	Sets some defaults to be used. Needs to be adapted as explained in *Prep.bat*.
MakeMovie.bat	Main conversion file. Not to be adapted normally.
<X_SIZE>x<Y_SIZE>.bat	Some helper files for different resolutions. Detailed explanation in *<X_SIZE>x<Y_SIZE>.bat*

Prep.bat

The *Prep.bat* file is required to prepare the environment for the actual process. Calling it directly will not have any effect. It is called by the *MakeMovie.bat*. To be able to use the batch files it is required to adapt this file at first. This file sets variables used by the file *MakeMovie.bat*, listed in Table 29.

Table 29. Variable description

Variable	Description
%OUTPUT%	Destination folder for the JPEG files. Will be cleared automatically when starting the conversion with *MakeMovie.bat*.
%FFMPEG%	Access variable for the FFmpeg tool. Should contain the complete path required to call *FFmpeg.exe*.
%JPEG2MOVIE%	Access variable for the JPEG2MOVIE tool. Should contain the complete path required to call *JPEG2Movie.exe*.
%DEFAULT_SIZE%	Default movie resolution to be used. Can be ignored if one of the *<X-SIZE>x<Y-SIZE>.bat* files are used.
%DEFAULT_QUALITY%	Default quality to be used by FFmpeg.exe for creating the JPEG files. The lower the number the better the quality (value 1 indicates the best, value 31 the worst). For more details refer to the FFmpeg documentation.
%DEFAULT_FRAMERATE%	Frame rate in frames/second to be used by FFmpeg. It defines the number of JPEG files to be generated by FFmpeg.exe for each second of the movie. For more details please refer to the FFmpeg documentation.

MakeMovie.bat

This is the main batch file used for the conversion process. Normally it is not required to be changing this file, but it is required to adapt *Prep.bat* first. It could be called with the parameters listed in *Table 30*.

Table 30. Parameters description

Parameter	Description
%1	Movie file to be converted
%2 (optional)	Size to be used. If not given %DEFAULT_SIZE% of *Prep.bat* will be used.
%3 (optional)	Quality to be used. If not given %DEFAULT_QUALITY% of *Prep.bat* will be used.
%4 (optional)	Frame rate to be used. If not given %DEFAULT_FRAMERATE% of *Prep.bat* will be used.

Since the FFmpeg output can differ strongly from the output of previous actions, the MakeMovie.bat deletes all output files in the first place. The output folder is defined by in the environmental variable %OUTPUT% in Prep.bat. After that it uses FFmpeg.exe to create the required JPEG files for each frame. Afterwards it calls JPEG2Movie to create a single EMF file which can be used by STemWin directly. After the conversion operation the result can be found in the conversion folder under FFmpeg.emf. It also creates a copy of that file into the source file folder. It will have the same name as the source file with a size-postfix and .emf extension.

<X_SIZE>x<Y_SIZE>.bat

These files are small but useful helpers if several movie resolutions are required. The filenames of the batch files itself are used as parameter '-s' for *FFmpeg.exe*. User can simply drag and drop the file to be converted to one of these helper files. After that an .emf file with the corresponding size-postfix can be found in the source file folder.

9.1.3 Audio recorder

Overview

The audio recorder module can be used to record audio frames in WAV format, save them in the storage unit and play them later.

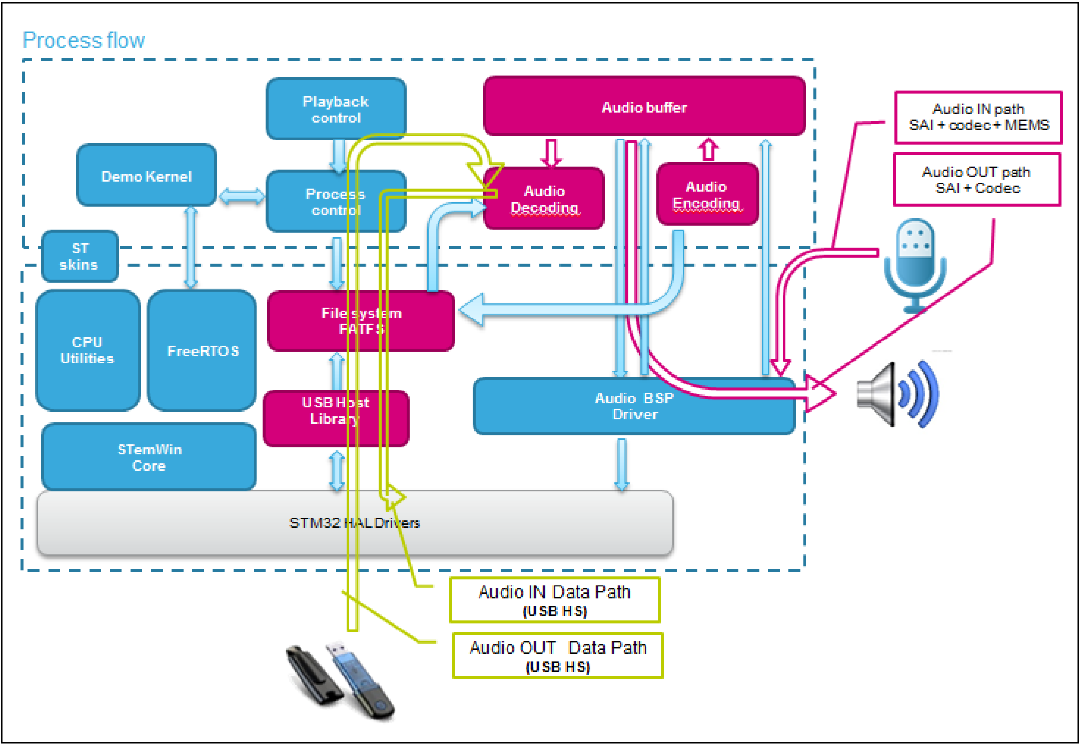
Features

- Audio Format: WAV format without compression with 16k sampling stereo
- Performance: MCU Load < 5%
- Recorded files stored in USB Flash Disk (USB High Speed)
- Embeds quick audio player
- Only 8 Kbytes of RAM required for Audio processing
- MP3 format is not supported, but can be easily added (separate demonstration)

Architecture

Figure 82 shows the different audio recorder parts and their connections and interactions with the external components.

Figure 82. Audio recorder module architecture



Functional description

- Start audio recorder module by touching the audio recorder icon as shown in *Figure 83*
- Press on the Record icon to start recording (see *Figure 84*)
- Click on Stop icon to save the recorded data in USB disk or Click cancel to discard them (*Figure 85*)
- Click on Play to listen to the last recorded data or Click on stop to return to the recorder (*Figure 86*)

Figure 83. Audio recorder module startup

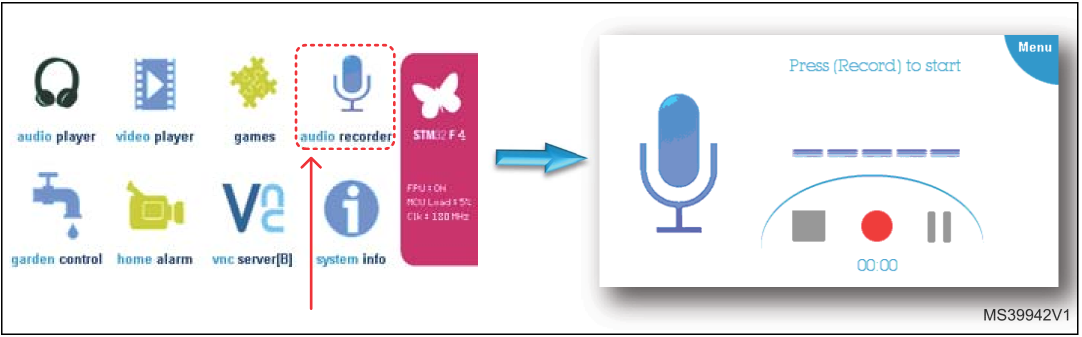


Figure 84. Start Audio recording

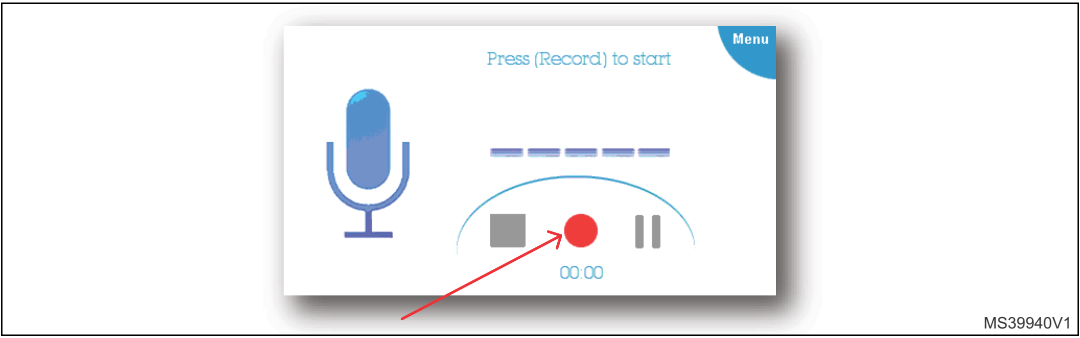


Figure 85. Stop Audio recording

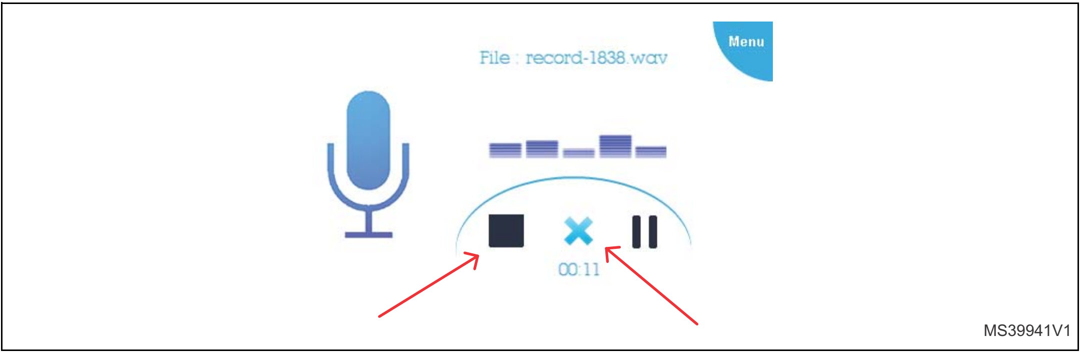


Figure 86. Play the recorded wave file

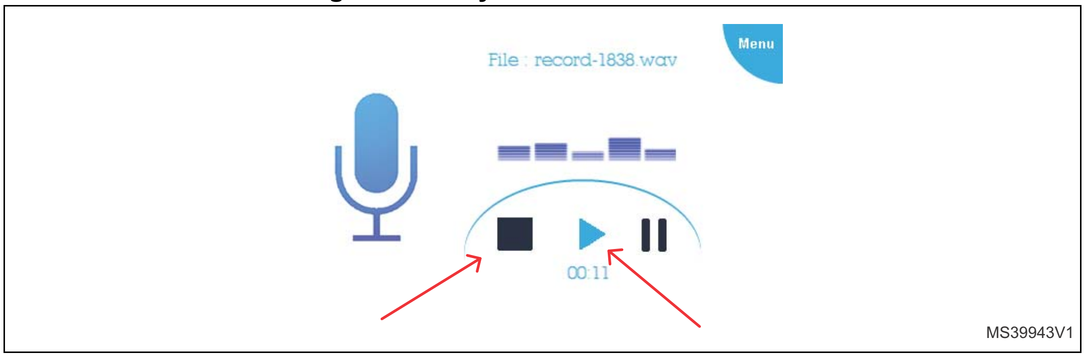


Figure 87. Hardware connectivity

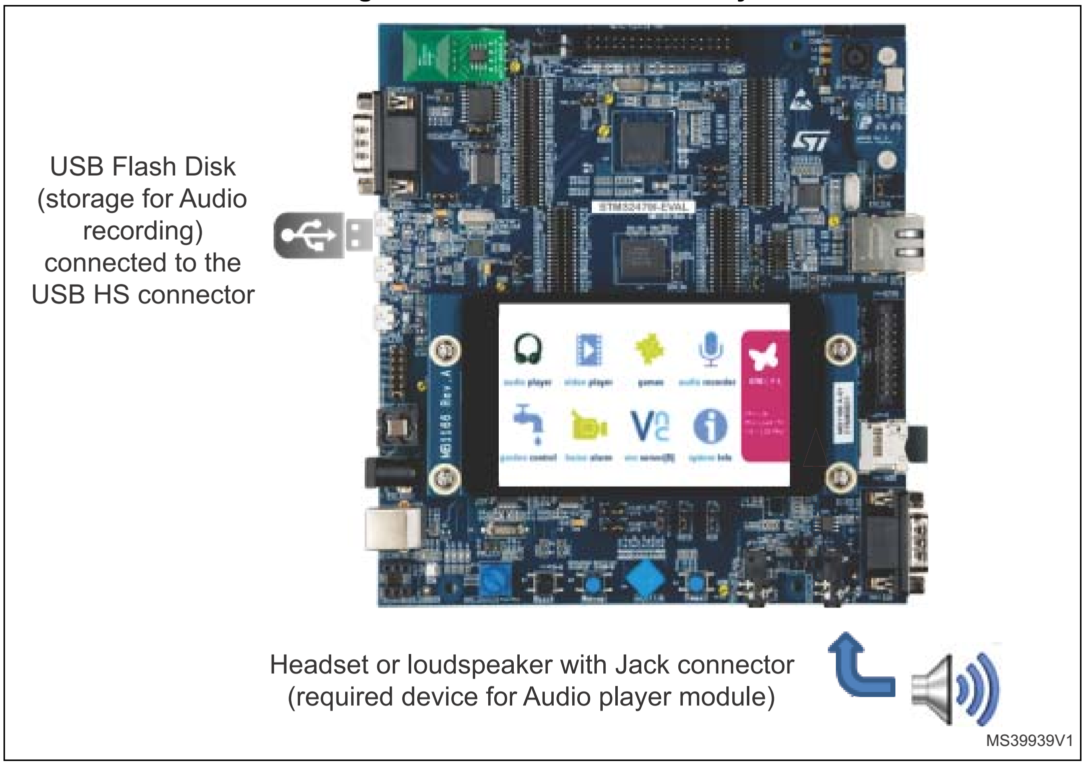

USB Flash Disk (storage for Audio recording) connected to the USB HS connector
Headset or loudspeaker with Jack connector (required device for Audio player module)
MS39939V1

Table 31. Audio module controls

Button	Preview	Description
Play	▶	Reads the recorded wave file from storage unit Replaces Discard/start button by play button
Pause	❚❚	Suspends the audio task Pauses the audio file record

Table 31. Audio module controls (continued)

Button	Preview	Description
Stop	■	Save the recorded file in storage unit Suspends the audio task Stops audio recording
Start	●	Starts audio recording
Cancel	✕	Stops audio recoding Discard the recorded wave
Menu	Menu	Closes Audio recording module

9.1.4 VNC server

Overview

The VNC server module allows controlling the demonstration from a remote machine. It is based on the TCP/IP LwIP stacks. The background mode is supported.

Note: The VNC server module is applicable only to STM32479I-EVAL.

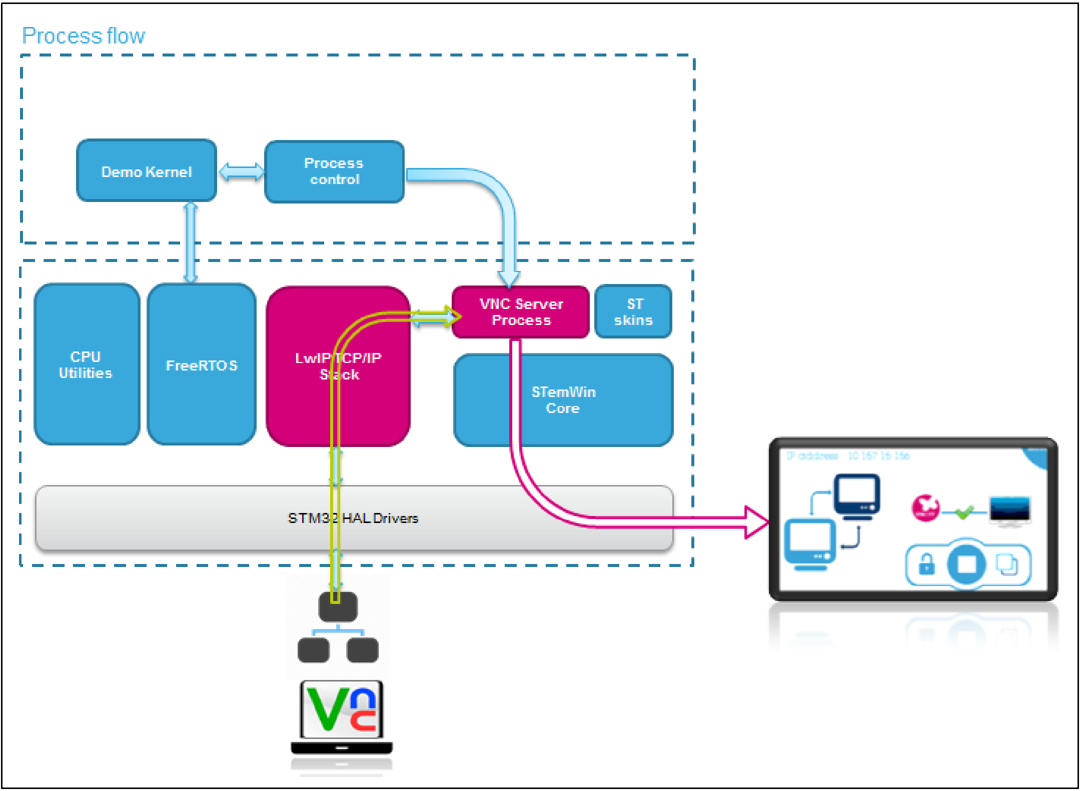
Features

- Based on the TCP/IP LwIP stacks (socket)
- IP address assigned by DHCP
- Secured mode supported (DES encryption)
- Performance: MCU load < 4% (standalone)
- Background mode support

Architecture

Figure 88 shows the different VNC server modules and their connections and interactions with the external components.

Figure 88. Video player module architecture



Functional description

- Click on the VNC Server icon (*Figure 89*)
- Enable or disable secure mode (*Figure 90*)
- Start the VNC server (*Figure 91*)
- Check that VNC Connection is established and IP Address assigned (*Figure 92*)
- Run any VNC Client or the emVNC software and connect to server (*Figure 93*)
- Activate background (*Figure 94*)

Figure 89. VNC server module startup

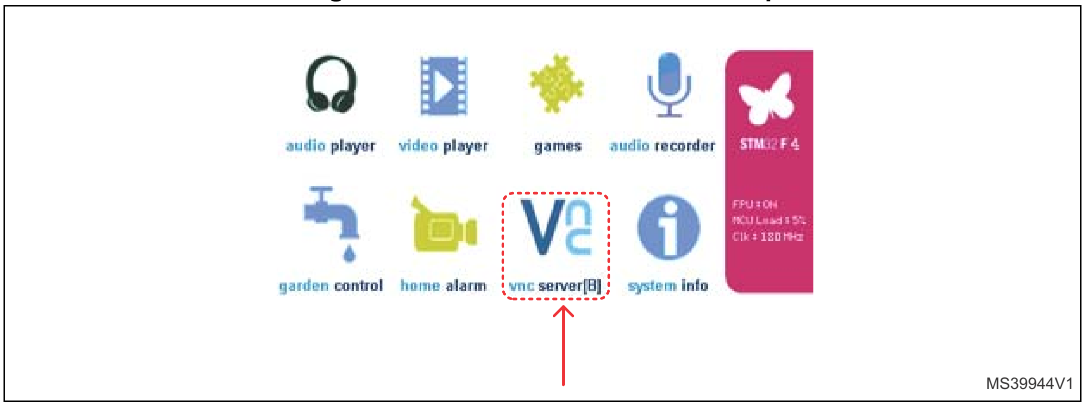


Figure 90. Enable / Disable secure mode

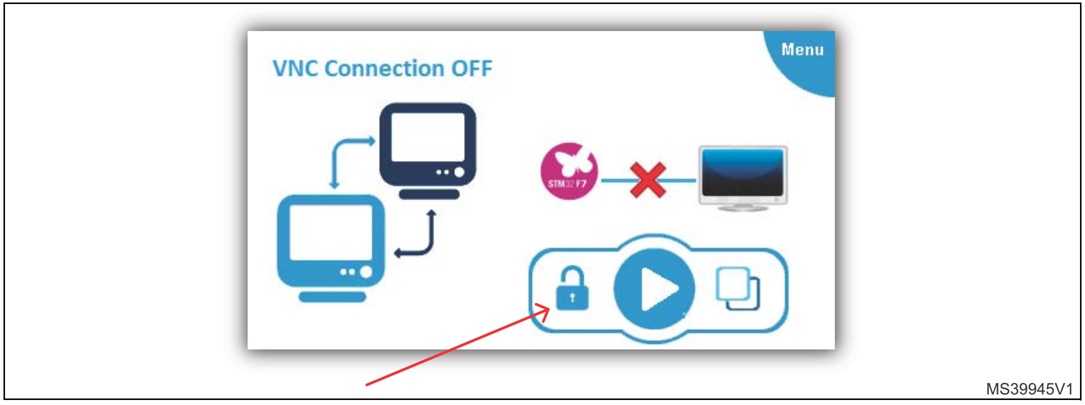


Figure 91. Start VNC server

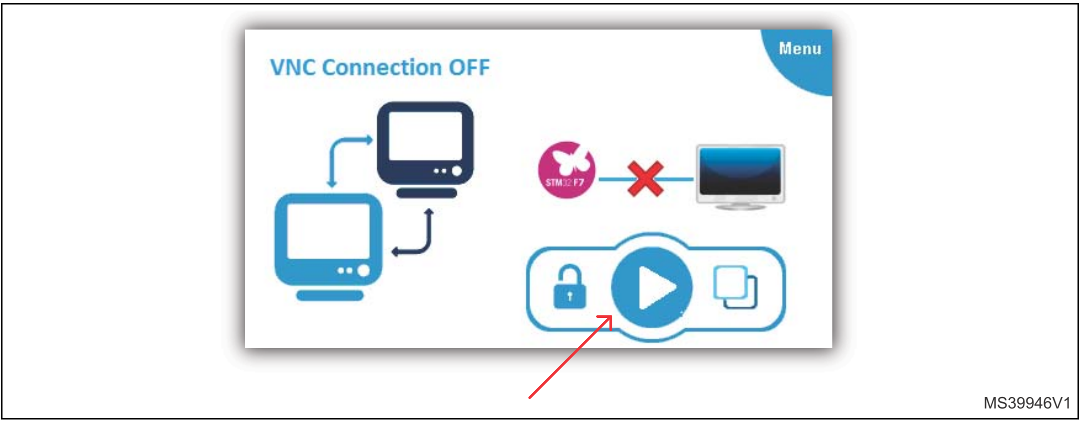


Figure 92. IP address assigned

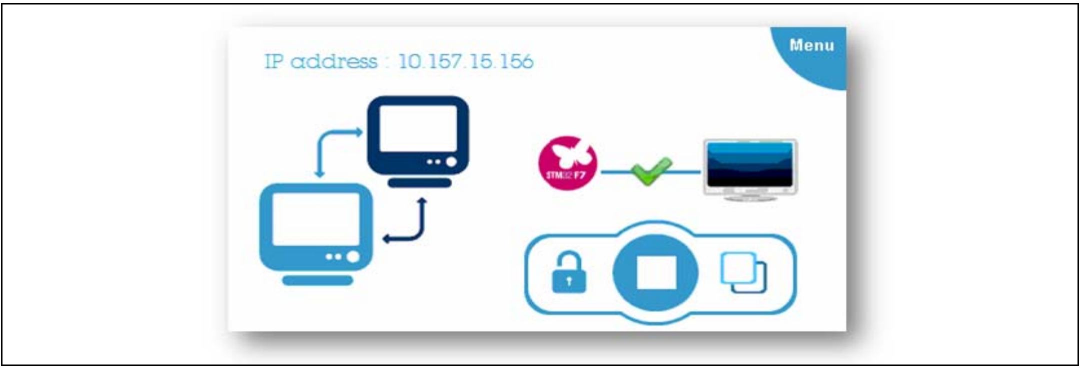


Figure 93. Run VNC Client

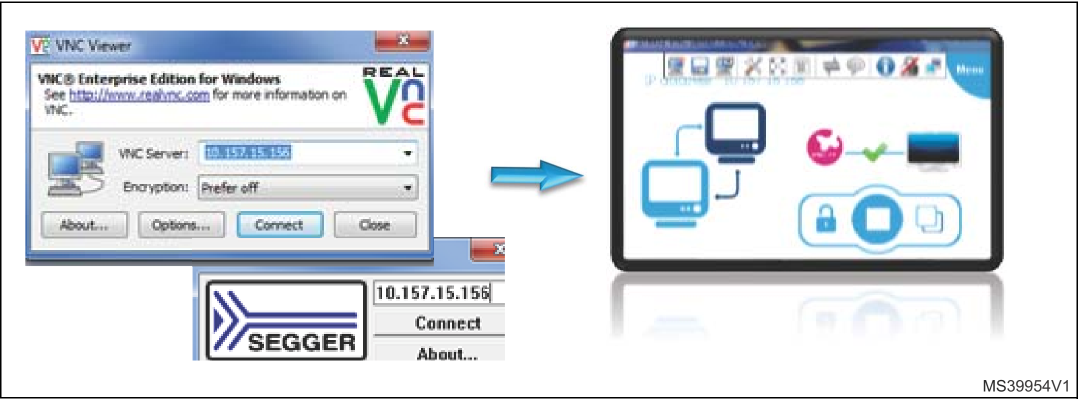
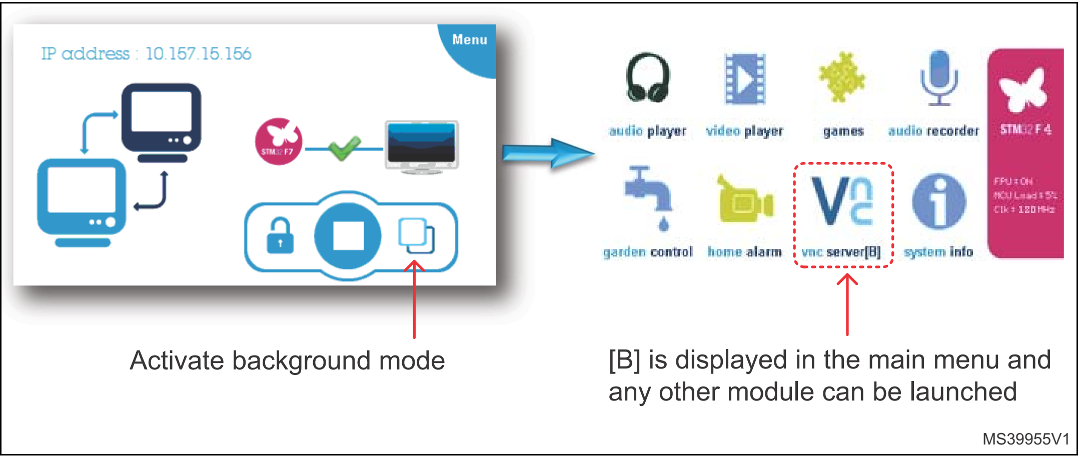


Figure 94. Background mode



Hardware connectivity

Figure 95. Hardware connectivity

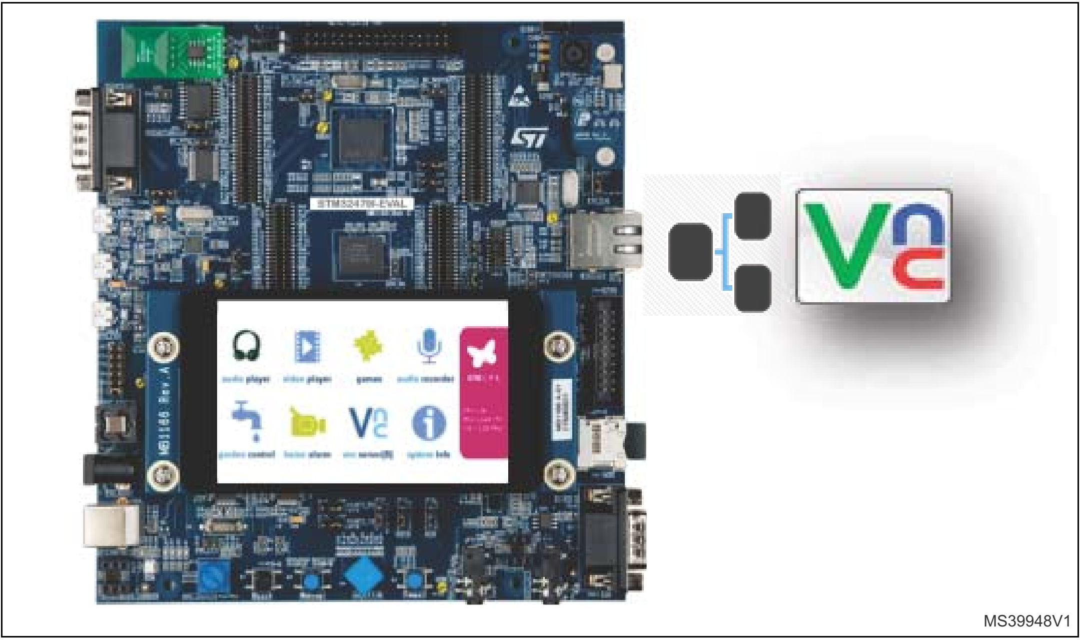


Table 32. VNC server module controls

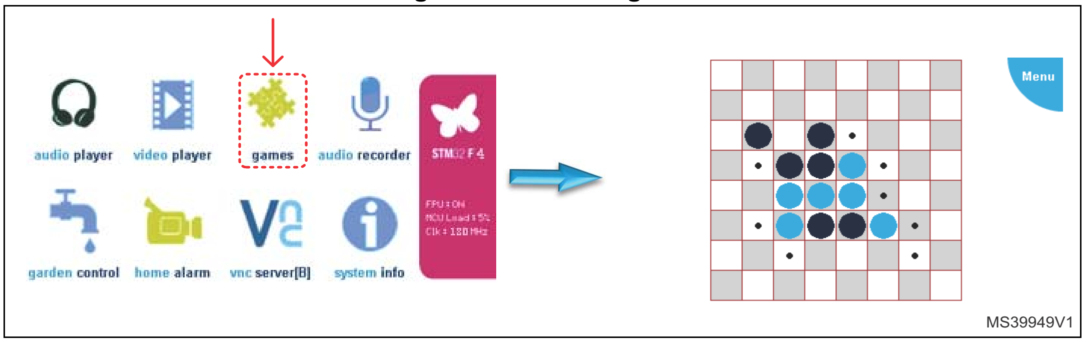
Button	Preview	Description
Background	⧉	Activates background and any other module can be started
Stop	■	Stops the VNC server
Play	▶	Starts the VNC server
Secure	🔓	Enables or disables secure mode
Menu	Menu	Closes VNC server module

9.1.5 Game

Overview

Similarly to what seen in *Section 8.2.3*, the game for this demonstration is based on the Reversi game, the microcontroller being one of the two players (*Figure 96*).

Figure 96. Reversi game



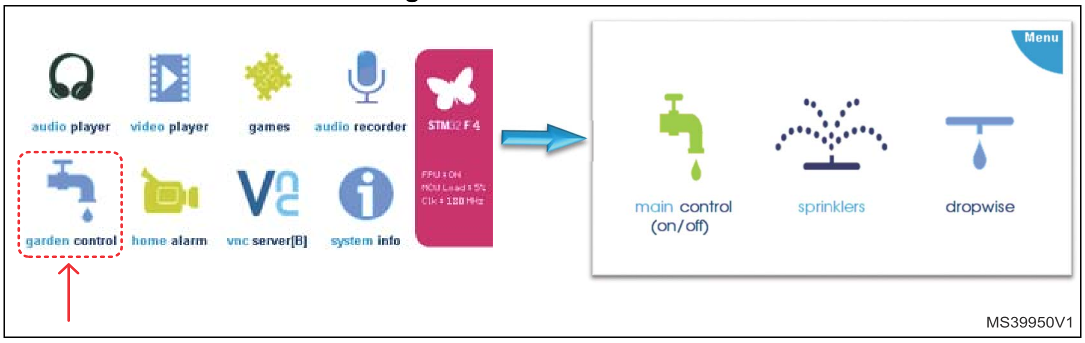
The GUI will ask the user to start a new game when the ongoing one is over.

9.1.6 Garden control

Overview

Control a garden watering system behavior, made with 2 independent circuits, one for a series of sprinklers and another for a drop-wise system (*Figure 97*).

Figure 97. Garden control



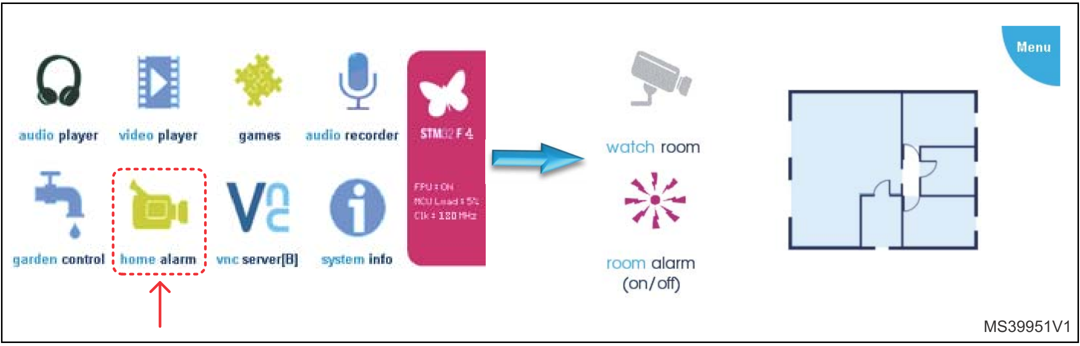
Caution: This module is still in alpha version: only controls are shown in the main frame. Final version will be released later.

9.1.7 Home alarm

Overview

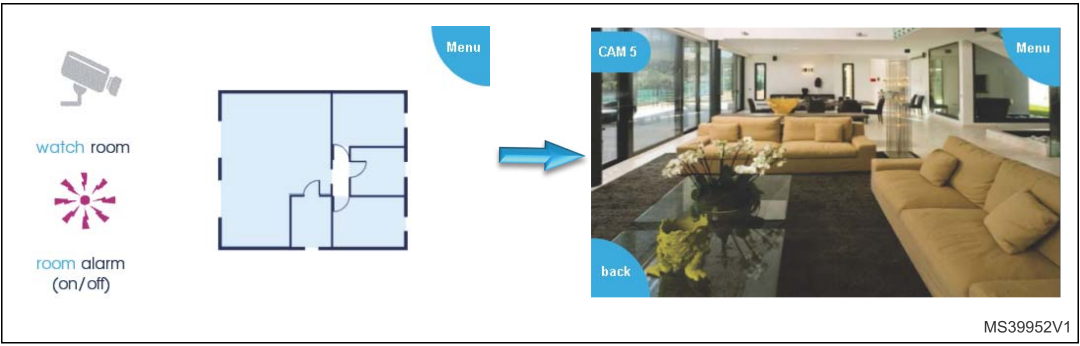
The home alarm system based on the integrated camera (in emulation mode fixed pictures are displayed for each room).

Figure 98. Home alarm



Choose a room and click on “watch room” to show a static picture simulated as home camera, as indicated in *Figure 99*.

Figure 99. Watching a room



Note: *Static pictures are used instead of camera streaming.*

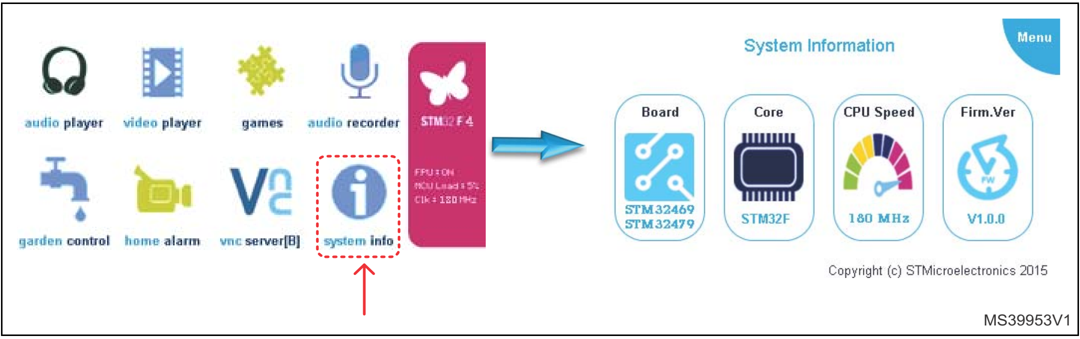
9.1.8 System information

Overview

The system information shows the main demonstration information (*Figure 100*), namely:

- used board
- STM32 core part number
- current CPU clock
- demonstration revision.

Figure 100. System information



10 Demonstration functional description (STM32F412G-DISCO and STM32F413H-DISCO)

10.1 Modules

10.1.1 Audio player

Overview

The audio player module provides a complete audio solution based on the STM32Fxxx and delivers a high-quality music experience. It supports playing music in WAV format but may be extended to support other compressed formats, such as MP3 and WMA.

The audio player module can be controlled through either buttons or speech recognition.

Note: The speech recognition functionalities and beam-forming processing are available only for STM32F413H-DISCO demonstration.

Features

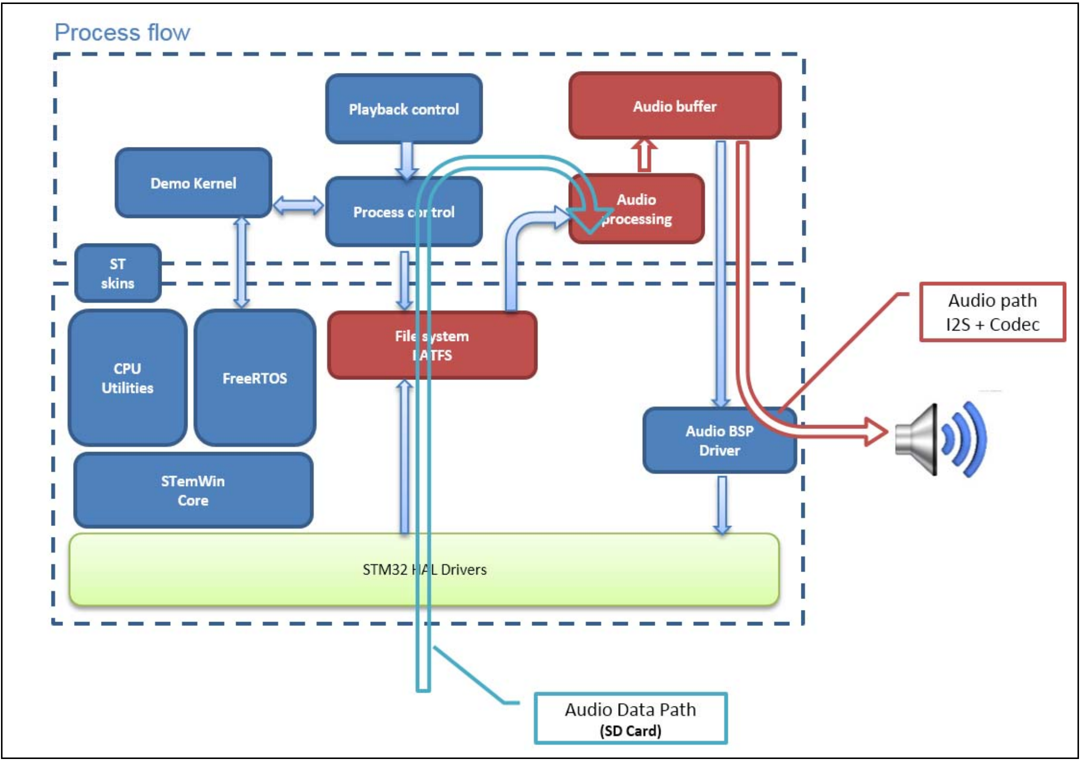
- Audio format: WAV format without compression, with 8 k to 96 k sampling
- Audio files stored in SD Card
- Only 8 Kbytes of RAM required for audio processing
- Only 16 kHz and 48 kHz WAV files are supported.

The MP3 format is not supported, but can be easily added (separate demonstration).

Architecture

Figure 101 shows the different audio player modules, and their connections and interactions with the external components.

Figure 101. Audio player module architecture

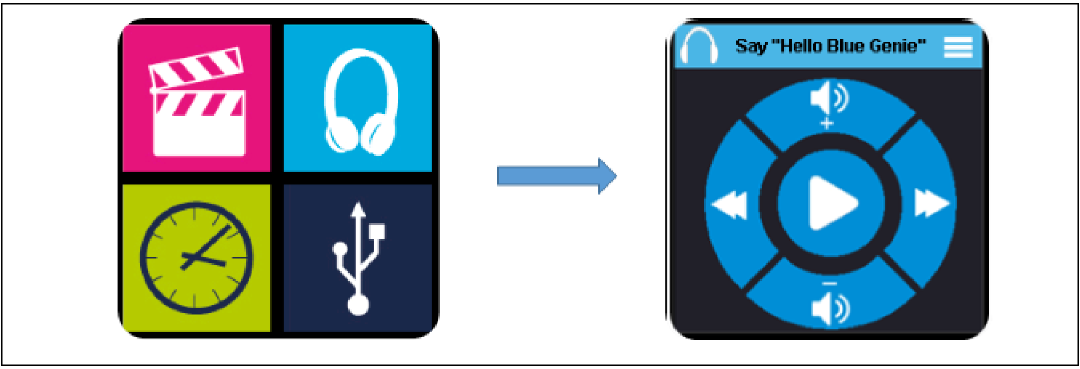


Process description

The audio player initialization is done in the startup step. In this step all the audio player states, the speaker and the volume value are initialized, and only when the play button in the audio player interface is pressed the process can start.

Start the audio player module from the main desktop menu as shown in *Figure 102*.

Figure 102. Audio player module startup



The audio player can also be controlled by voice, thanks to speech recognition and beam-forming processing, a signal processing technique that uses the two on-board microphones to increase directivity. Beam-forming improves voice detection in a noisy environment. In a quiet environment, off the axis sounds can be taken into account, however to get a good recognition, user should always speak in the axis of the two microphones.The commands are listed in *Table 34*.

Table 33. Audio player module controls

Button	Preview	Description
Play / Pause	▶ ⏸	Reads the wave file from storage unit Starts or resumes the audio task Starts playing audio stream Replaces Play button with Pause button
Next	⏩	Points to the next wave file Stops audio playing Starts playing the next wave file if Play button is pressed
Previous	⏪	Points to the previous wave file Stops audio playing Starts playing the previous wave file if Play button is pressed
Volume up	🔊 +	Increases the volume
Volume down	− 🔉	Decreases the volume
Output device	🎧 🔊	Selects the sound output device used and activates beam-forming processing in speaker mode for better speech recognition.
Exit	☰	Closes the module

Table 34. Audio player module voice controls

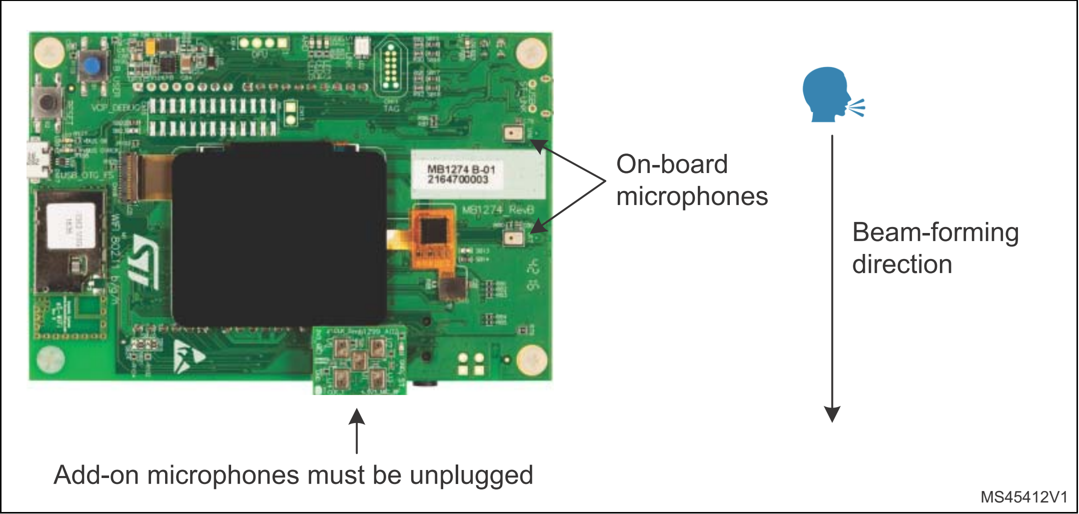
Command	Description
Hello Blue Genie	Enables the voice commands
Play music	Starts playing the audio stream
Pause music	Pauses playing
Stop music	Stops playing
Next song	Plays following song
Previous song	Plays previous song

Table 34. Audio player module voice controls (continued)

Command	Description
Volume up	Increases the volume
Volume down	Decreases the volume

Note: *The detected speech command is displayed in the header of the audio module frame. All the available speech commands are scrolled in the header of the audio module frame. The speech recognition is only functional with the two on-board MCUs, see Figure 103.*

Figure 103. Board for beam-forming implementation



10.1.2 Audio recorder

Overview

The audio recorder module can be used to record audio frames in WAV format, save them in the storage unit, and play them later.

Features

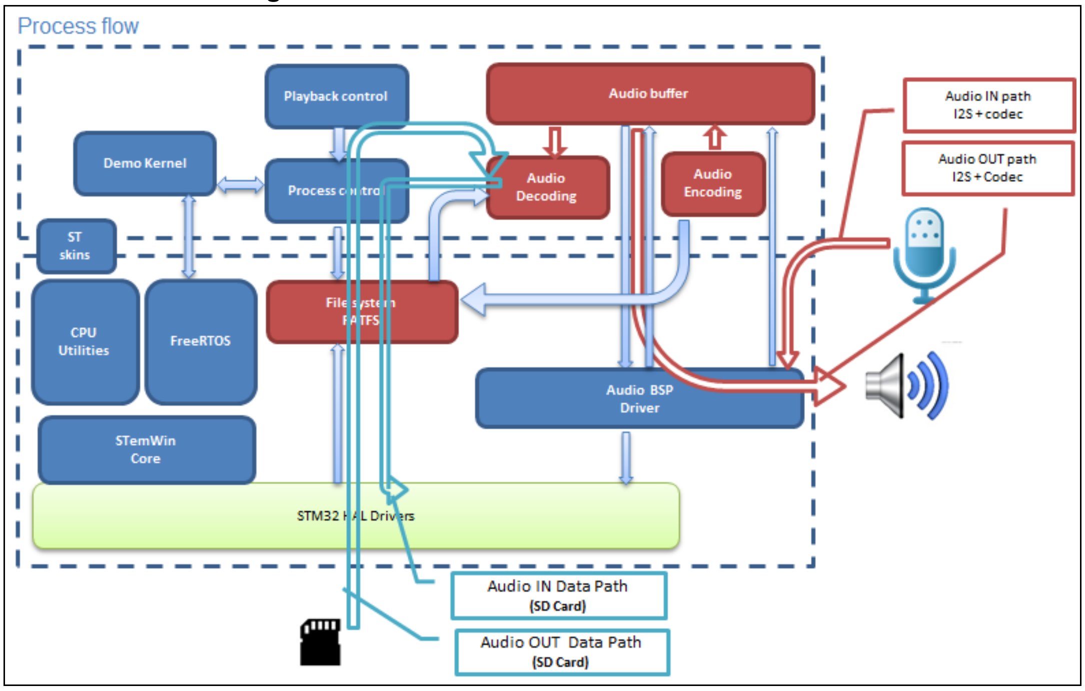
- Audio Format: WAV format without compression with 16 k sampling stereo
- Recorded files stored in SD Card
- Embeds quick audio player
- Only 8 Kbytes of RAM required for audio processing

The MP3 format is not supported, but can be easily added (separate demonstration).

Architecture

Figure 104 shows the different audio player modules, and their connections and interactions with the external components.

Figure 104. Audio recorder module architecture



Functional description

Start audio recorder module by touching the audio recorder icon, as indicated in *Figure 105*.

Figure 105. Audio recorder module startup

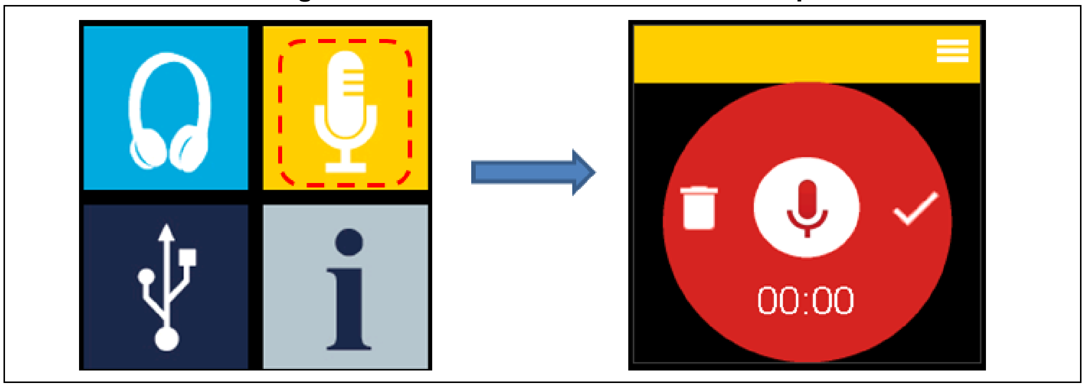


Figure 106. Audio recorder - Process description

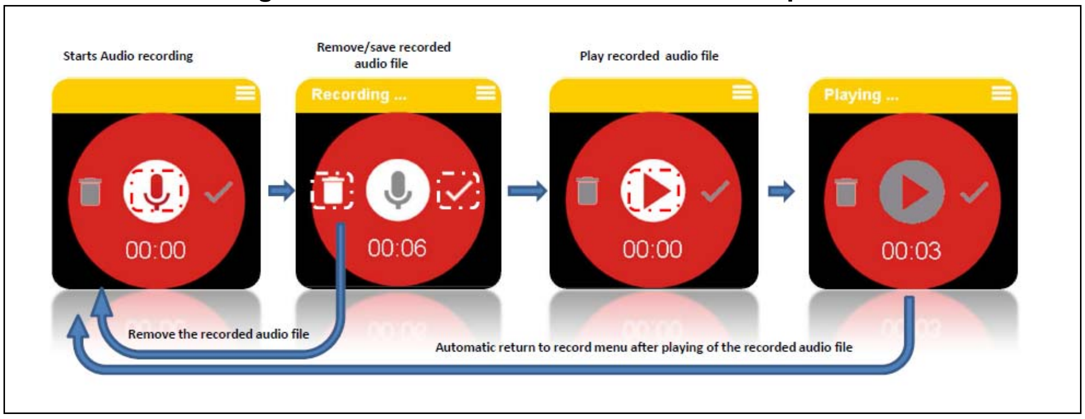

Starts Audio recording
Remove/save recorded audio file
Play recorded audio file
Recording ...
Playing ...
00:00
00:06
00:00
00:03
Remove the recorded audio file
Automatic return to record menu after playing of the recorded audio file

Table 35. Audio recorder module controls

Button	Preview	Description
Record	🎙	Starts recording audio Replaces record button by pause button
Play	▶	Reads the recorded wave file from the storage unit
Save	✓	Saves the recorded file in the storage unit Suspends the audio task Stops audio recording
Remove	🗑	Stops audio recoding Discards the recorded wave
Exit	☰	Closes the module

10.1.3 Video module

Overview

The video player module provides a video solution based on the STM32F4xxx and the STemWin movie APIs. It supports the AVI format.

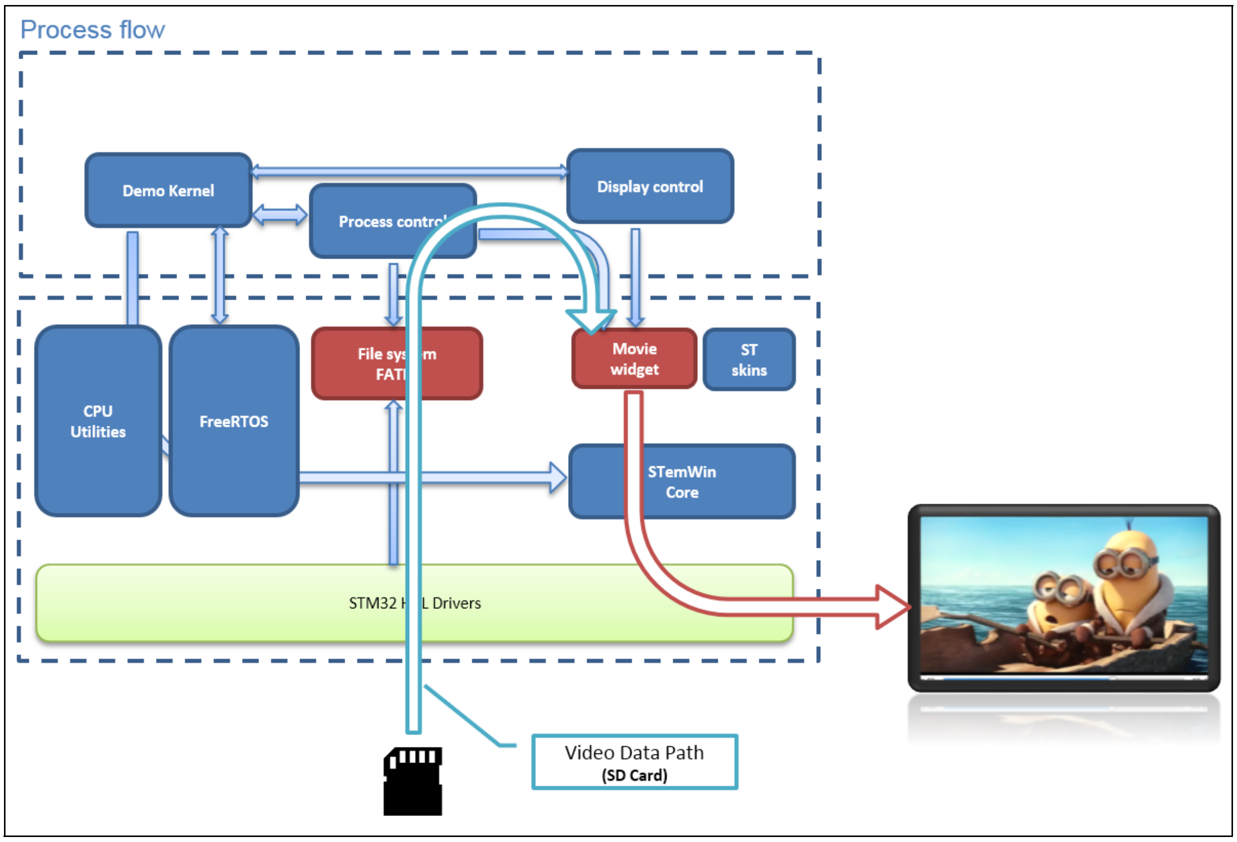
Features

- Video Format: AVI
- Performance: frame rate up to 13 fps
- Video files stored in SD Card

Architecture

Figure 107 shows the different video player modules, and their connections and interactions with the external components.

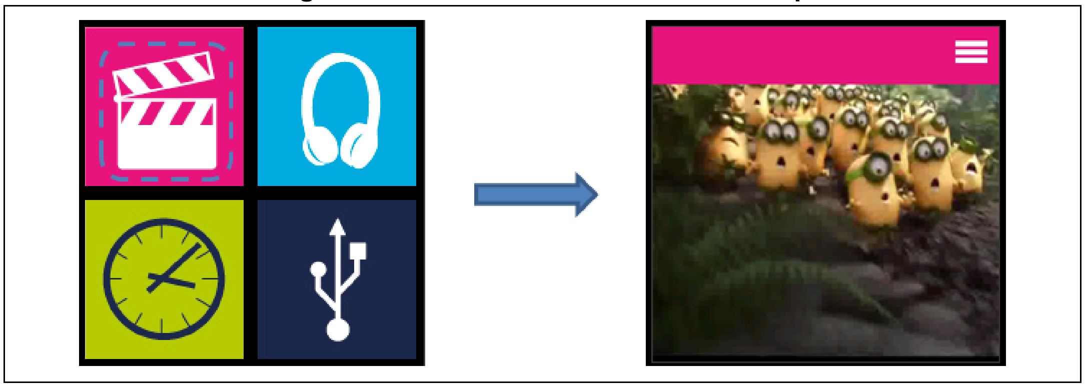
Figure 107. Video recorder module architecture



Functional description

Start video recorder module by touching the audio recorder icon, as indicated in *Figure 108*. When the video player is started, the first AVI file stored in the storage unit starts playing.

Figure 108. Video recorder module startup



10.1.4 Analog clock module

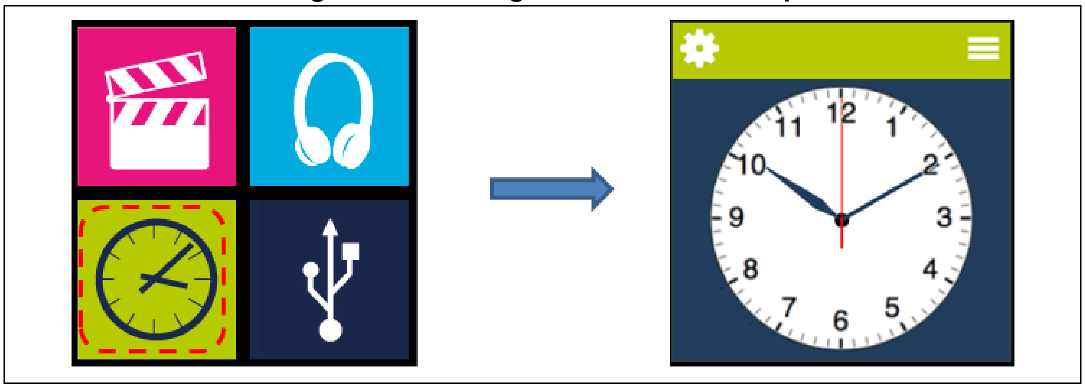
Overview

The analog clock module enables to show and adjust the analog time by changing the RTC configuration.

Functional description

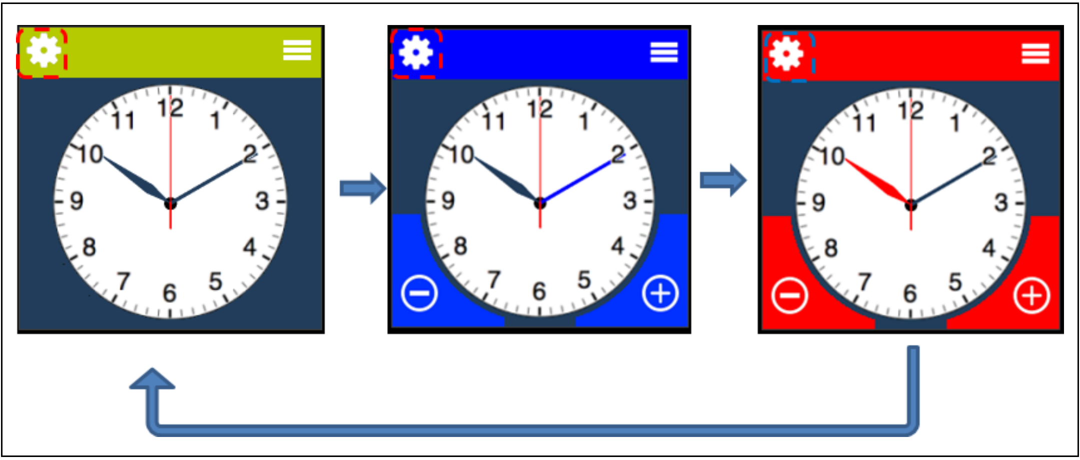
1. Start analog clock module by touching the analog clock icon (*Figure 109*).

Figure 109. Analog clock module startup



2. Press on settings button a first time to adjust minutes, and a second time to adjust hours (*Figure 110*).

Figure 110. Analog clock setting



10.1.5 USB devices module

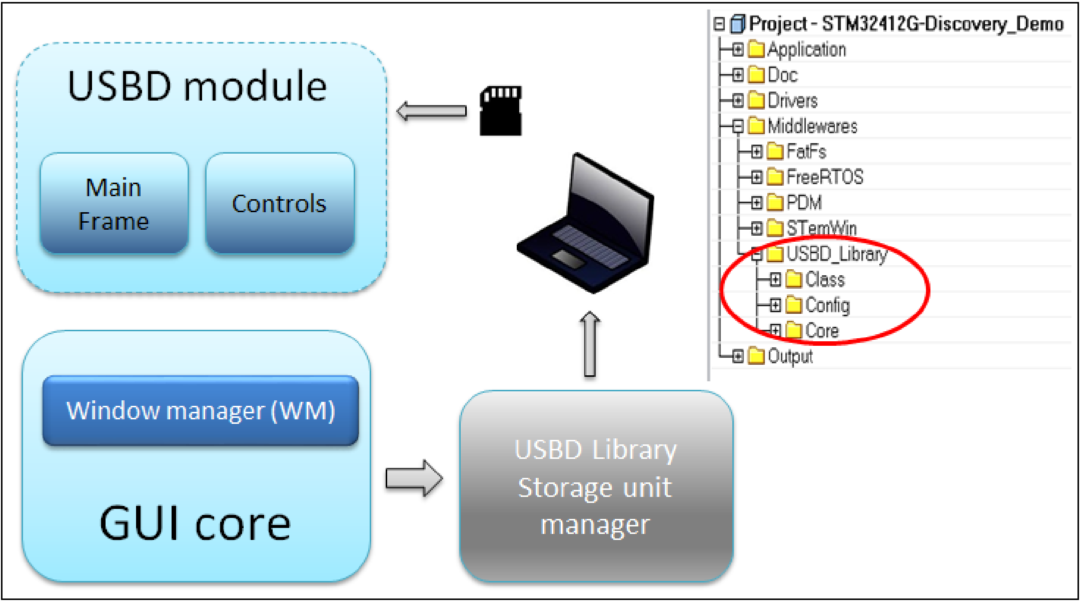
Overview

The USB device (USBD) module includes mass storage device application using the Micro SD memory.

Architecture

Figure 111 shows the different video player modules, and their connections and interactions with the external components.

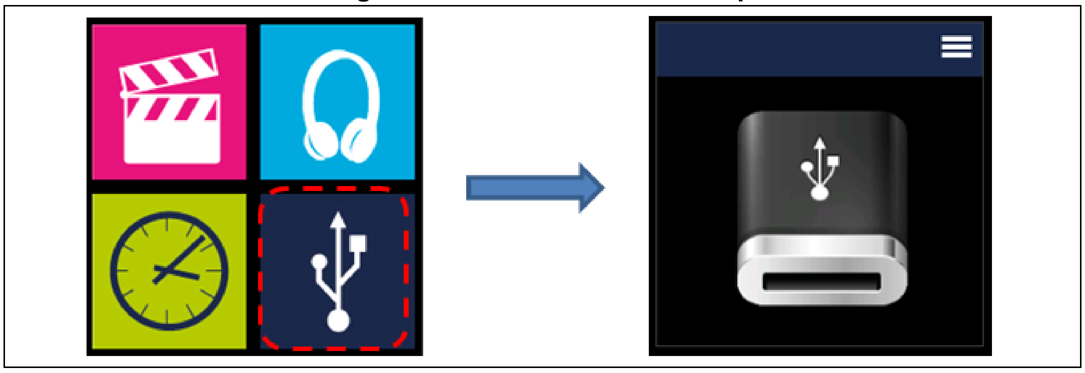
Figure 111. USBD module architecture



Functional description

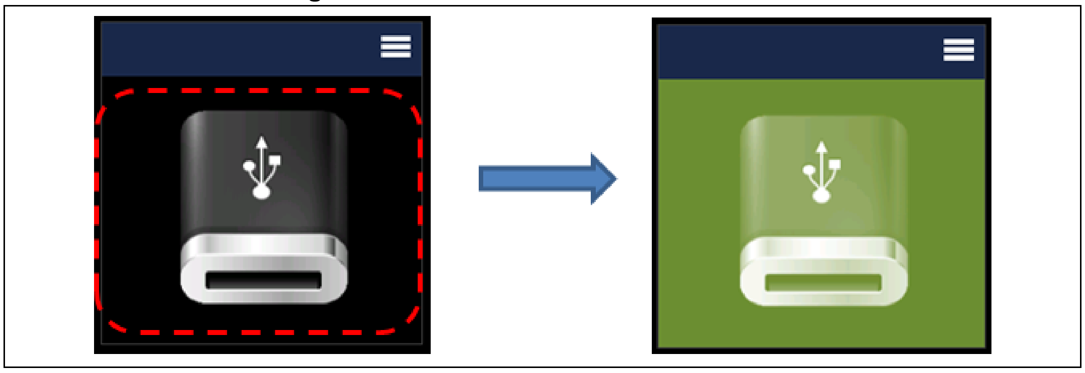
1. Start USBD module by touching the USB device icon (*Figure 112*)

Figure 112. USBD module startup



2. Connect the USB device by touching the screen (except the header zone), as indicated in *Figure 113*

Figure 113. Connection of an USB device



10.1.6 System information

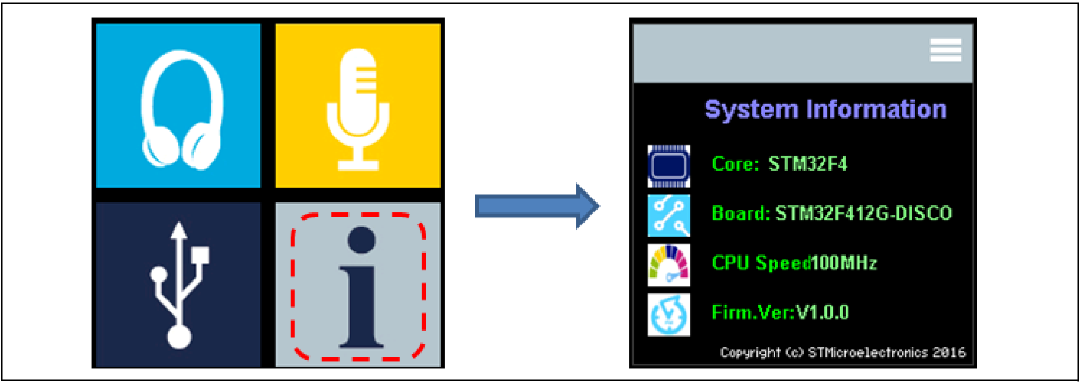
Overview

The system information module shows key information, such as used board, part number, the current CPU clock and demonstration revision.

Functional description

The system information module is activated by touching the dedicated icon, as indicated in *Figure 114*.

Figure 114. System information module startup



System Information

Core: STM32F4

Board: STM32F412G-DISCO

CPU Speed100MHz

Firm.Ver:V1.0.0

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11 Revision history

Table 36. Document revision history

Date	Revision	Changes
24-Apr-2014	1	Initial release.
20-Mar-2015	2	Introduced STM32446E-EVAL demonstration. Added: – *Figure 5: Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations*; – *Figure 7: Main desktop window for STM32446E-EVAL demonstration*; – *Figure 14: Status bar for STM32446E-EVAL demonstration*; – *Figure 16: Icon view widget for STM32446E-EVAL demonstration*; – *Figure 19: Starting file execution for STM32446E-EVAL demonstration*; – *Figure 23: Detection of storage units for STM32446E-EVAL demonstration*; – *Figure 26: Memory heap for STM32CubeF4 demonstration*; – footnote *1* in *Section 4.5: Module's direct open*; – note in *Section 6: Performance*. Updated: – *Introduction* and figure on Cover page; – *Section 3.1: Overview*; – *Section 3.2: Kernel initialization*; – *Section 3.3: Kernel processes and tasks*; – *Section 3.8: Direct open feature*; – *Figure 5: Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations*; – *Figure 28: STM32Cube demonstration boards*; – *Section 3.12: Memory management*; – *Section 3.16: Hardware settings*; – *Table 7: Jumpers for different demonstration boards*; – *Section 5.4.2: Touch screen configuration*; – *Figure 58: EMF file generation*.

Table 36. Document revision history (continued)

Date	Revision	Changes
09-Oct-2015	3	Introduced STM32F479I-EVAL and STM32F469I-DISCO boards. Added: – *Section 3.5: ST widget add-ons* and its subsections; – *Section 9: Demonstration functional description (STM32F479I-EVAL and STM32F469I-DISCO)* and its subsections; – *Figure 8: Main desktop window for STM32479I-EVAL demonstration*; – *Figure 9: Main desktop window for STM32469I-DISCO demonstration*; – *Figure 11: Icon view widget*; – *Figure 12: Slider skin*; – footnote *1* in *Section 4.5: Module's direct open*; – notes in *Section 3.11: Clock and date*, *Section 3.12: Memory management*, *Section 5.3: Touchscreen calibration* and *Section 6: Performance*. Updated: – *Introduction* and figure on Cover page; – *Section 3.2: Kernel initialization*; – *Section 3.3: Kernel processes and tasks*; – *Section 3.6: Kernel menu management*; – *Section 3.7: Modules manager*; – *Section 3.8: Direct open feature*; – title of *Figure 5: Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations*; – *Figure 28: STM32Cube demonstration boards*; – *Section 3.12: Memory management*; – *Section 3.16: Hardware settings*; – *Table 7: Jumpers for different demonstration boards*; – *Table 8: LCD frame buffer locations* – *Section 5.4.2: Touch screen configuration*.
15-Jul-2016	4	Introduced STM32F412G-Discovery board, hence added *Section 10: Demonstration functional description (STM32F412G-DISCO and STM32F413H-DISCO)* and its subsections. Updated *Introduction*, *Section 3.2: Kernel initialization*, *Section 3.3: Kernel processes and tasks*, *Section 3.6: Kernel menu management*; *Section 3.7: Modules manager*, *Section 3.12: Memory management*, *Section 3.16: Hardware settings*, *Section 5.2: Layers management* and *Section 5.4.2: Touch screen configuration*. Updated *Table 7: Jumpers for different demonstration boards*. Updated image on cover page and *Figure 28: STM32Cube demonstration boards*. Added *Figure 10: Main desktop window for STM32412G-DISCO and STM32413H-DISCO demonstrations*. Updated caption of *Figure 5: Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations* and of *Table 32: VNC server module controls*.

Table 36. Document revision history (continued)

Date	Revision	Changes
22-Mar-2017	5	Introduced STM32F413H-Discovery board. Updated *Introduction*, *Section 3.6: Kernel menu management*, *Section 3.7: Modules manager*, *Section 3.16: Hardware settings*, *Section 5.4.2: Touch screen configuration* and *Section 10.1.1: Audio player*. Updated *Note:* in *Section 3.11: Clock and date* and title of *Section 10: Demonstration functional description (STM32F412G-DISCO and STM32F413H-DISCO)*. Updated image on cover page, *Figure 1: STM32Cube block diagram* and *Figure 28: STM32Cube demonstration boards*. Added *Figure 103: Board for beam-forming implementation*, *Figure 106: Audio recorder - Process description* and *Table 34: Audio player module voice controls*. Updated caption of *Figure 5: Startup window for STM32446E-EVAL, STM32F479I-EVAL, STM32F469I-DISCO, STM32F412G-DISCO and STM32F413H-DISCO demonstrations* and of *Figure 10: Main desktop window for STM32412G-DISCO and STM32413H-DISCO demonstrations*. Updated *Table 7: Jumpers for different demonstration boards*, *Table 33: Audio player module controls* and *Table 35: Audio recorder module controls*.