Freescale MQX RTOS Example Guide

web_hvac example

This document explains the web_hvac example, what to expect from the example and a brief introduction to the API.

The example

This application represents the residential HVAC controller system requirements which are as follows:

Control

- Control of 3 outputs: Fan on/off, Heating on/off, A/C on/off
- Thermostat Input
- Serial interface to set the desired temperature and to monitor the status of the thermostat and outputs

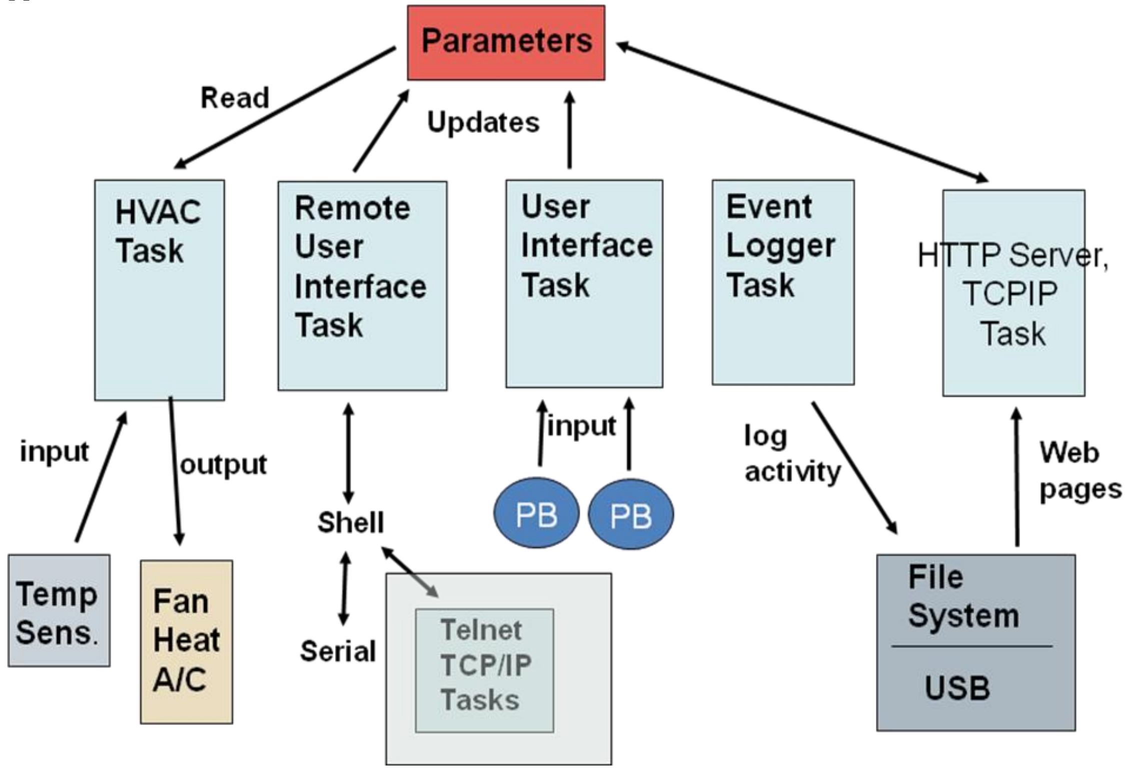
Data logging:

- Log ambient temperature and output status on a periodic basis
- Store log information on a USB Memory Stick

Ethernet:

- Provide Ethernet connectivity to facilitate monitoring and control of the device via a Telnet connection
- Support transfer of the logging information over Ethernet with FTP
- Use web pages to display status and receive setting commands

The next figure shows in detail all the parts that interacts with this demo application.



Running the example

Re-build the BSP, PSP, MFS, RTCS, Shell and USB host projects for the target platform/IDE. Then build and start the web_hvac example application on the target platform. For instructions how to do that in different IDEs and for different debuggers, see the MQX documentation (<MQX installation folder>/doc/tools).

Pay special attention for correct jumper settings of your board before running the demo. Please consult the “MQX Getting started” document.

Explanation of the example

The Web HVAC demo application implements 6 main tasks in the MQX OS. The objective of the application is to show the user an example of the resources that MQX provides as a software platform and to show the basic interface with Ethernet and USB peripherals.

The HVAC Task simulates the behavior of a Real HVAC system that reacts to temperature changes based on the temperature and mode inputs from the system. The user interacts with the demo through the serial interface with a Shell input, through the push buttons in the hardware, and with a USB Stick that contains information with File System format.

The task template list is a list of tasks (TASK_TEMPLATE_STRUCT). It defines an initial set of tasks that can be created on the processor.
At initialization, MQX creates one instance of each task whose template defines it as an auto start task. As well, while an application is running, it can create a task present on the task template or a new one dynamically.

Tasks are declared in the MQX_template_list array as next:

```
       --Tasks.c--
const TASK_TEMPLATE_STRUCT MQX_template_list[] =
{
    /* Task Index,   Function,         Stack,  Priority, Name,      Attributes,
Param,  Time Slice */
    { HVAC_TASK,    HVAC_Task,         1400,    9,      "HVAC",
MQX_AUTO_START_TASK,    0,      0           },
#if DEMOCFG_ENABLE_SWITCH_TASK
    { SWITCH_TASK,  Switch_Task,        800,   10,      "Switch",
MQX_AUTO_START_TASK,    0,      0           },
#endif
#if DEMOCFG_ENABLE_SERIAL_SHELL
    { SHELL_TASK,   Shell_Task,        2500,   12,      "Shell",
MQX_AUTO_START_TASK,    0,      0           },
#endif
#if DEMOCFG_ENABLE_AUTO_LOGGING
    { LOGGING_TASK, Logging_task,      2500,   11,      "Logging",
0,    0,      0           },
#endif
#if DEMOCFG_ENABLE_USB_FILESYSTEM
    { USB_TASK,     USB_task,         2200L,   8L,      "USB",
MQX_AUTO_START_TASK,    0,      0           },
#endif
    { ALIVE_TASK,   HeartBeat_Task,    1500,   10,      "HeartBeat",
0,    0,      0           },
    {0}
```

Some tasks in the list are auto start tasks, so MQX creates an instance of each task during initialization. The task template entry defines the task priority, the function code entry point for the task, and the stack size.

HVAC task
This task initializes the RTCS, the Input/Output driver, and implements the HVAC simulation state machine. The HVAC Demo implementation represents the user application and shows how to use different MQX resources.

The initial part of the HVAC task installs unexpected ISRs.

Install the MQX-provided unexpected ISR, _int_unexpected_isr(), for all interrupts that do not have an application-installed ISR. The installed ISR writes the cause of the unexpected interrupt to the standard I/O stream.

```
void HVAC_Task(uint32_t)
{
   HVAC_Mode_t mode;
   uint32_t counter = HVAC_LOG_CYCLE_IN_CONTROL_CYCLES;
```

```
   _int_install_unexpected_isr();
```

The MQX uses kernel log to analyze how the application operates and uses resources. Kernel log is not enabled by default in the demo.

Note: The "BSP_DEFAULT_MAX MSGPOOLS" has to be set to 3 or higher to ensure the example is working properly.

```
#if DEMOCFG_ENABLE_KLOG && MQX_KERNEL_LOGGING && defined(DEMOCFG_KLOG_ADDR) &&
defined(DEMOCFG_KLOG_SIZE)
```

```
   /* create kernel log */
   _klog_create_at(DEMOCFG_KLOG_SIZE, 0,(pointer)DEMOCFG_KLOG_ADDR);
```

```
   /* Enable kernel logging */
   _klog_control(KLOG_ENABLED | KLOG_CONTEXT_ENABLED |
      KLOG_INTERRUPTS_ENABLED|
      KLOG_FUNCTIONS_ENABLED|KLOG_RTCS_FUNCTIONS, TRUE);
```

```
   _klog_log_function(HVAC_Task);
#endif
```

The HVAC task initializes the RTCS, the parameters of the HVAC application and loads the Input/Output driver. RTCS and Input/Output initialization is explained with detail in the RTCS section of this document. The HVAC parameter initialization function sets the initial values for the temperature, temperature scale, fan mode, and HVAC mode variables.

```
#if DEMOCFG_ENABLE_RTCS
      HVAC_initialize_networking();
#endif
```

```
      /* Initialize operating parameters to default values */
      HVAC_InitializeParameters();
```

```
      /* Configure and reset outputs */
      HVAC_InitializeIO();
```

The ALIVE_TASK is only a monitor that helps us to see if the system is up and running.

```
       _task_create(0, ALIVE_TASK, 0);
```

```
#if DEMOCFG_ENABLE_AUTO_LOGGING
    LogInit();
    _time_delay(2000);
    Log("HVAC Started\n");
```

```
#endif
```

The HVAC main loop executes the HVAC system simulation. It controls the fan, heating and cooling based on the mode and the measured temperature. The HVAC data is stored in the HVAC_State structure.
This loop uses functions from the Input/Output driver and from the HVAC_Util.c source file. The HVAC_Util.c contains a group of functions that control all the variables required for the HVAC simulation.

```
   while (TRUE) {
      /* Read current temperature */
      HVAC_State.ActualTemperature = HVAC_GetAmbientTemperature();

      /* Examine current parameters and set state accordingly */
      HVAC_State.HVACState = HVAC_Off;
      HVAC_State.FanOn = FALSE;

      mode = HVAC_GetHVACMode();

      if (mode == HVAC_Cool || mode == HVAC_Auto)
      {
         if (HVAC_State.ActualTemperature >
(HVAC_Params.DesiredTemperature+HVAC_TEMP_TOLERANCE))
         {
            HVAC_State.HVACState = HVAC_Cool;
            HVAC_State.FanOn = TRUE;
         }
      }

      if (mode == HVAC_Heat || mode == HVAC_Auto)
      {
         if (HVAC_State.ActualTemperature < (HVAC_Params.DesiredTemperature-
HVAC_TEMP_TOLERANCE))
         {
            HVAC_State.HVACState = HVAC_Heat;
            HVAC_State.FanOn = TRUE;
         }
      }

      if (HVAC_GetFanMode() == Fan_On) {
         HVAC_State.FanOn = TRUE;
      }

      /* Set outputs to reflect new state */
      HVAC_SetOutput(HVAC_FAN_OUTPUT, HVAC_State.FanOn);
      HVAC_SetOutput(HVAC_HEAT_OUTPUT,  HVAC_State.HVACState == HVAC_Heat);
      HVAC_SetOutput(HVAC_COOL_OUTPUT,  HVAC_State.HVACState == HVAC_Cool);

      /* Log Current state */
      if (++counter >= HVAC_LOG_CYCLE_IN_CONTROL_CYCLES)
      {
         counter = 0;
         HVAC_LogCurrentState();

      }

      /* Wait for a change in parameters, or a new cycle */
      if (HVAC_WaitParameters(HVAC_CONTROL_CYCLE_IN_TICKS))
      {
        counter = HVAC_LOG_CYCLE_IN_CONTROL_CYCLES;
      }

#if DEMOCFG_ENABLE_RTCS
```

```
      ipcfg_task_poll ();
#endif
   }
}
```

The ipcfg_task_poll() function is part of the Ethernet link/bind monitoring task. This function checks for all available Ethernet devices. Configuration for each device is checked and the link and bind status are tested.

The application interfaces the HVAC variables by using the public functions listed in HVAC_public.h. These functions are implemented in HVAC_Util.c and HVAC_IO.c.

RTCS Initialization

Following macros (defined in file HVAC.h) enable various features of RTCS in this demo:

```
#define DEMOCFG_ENABLE_RTCS             1   /* enable RTCS operation */
#define DEMOCFG_ENABLE_FTP_SERVER       0   /* enable ftp server */
#define DEMOCFG_ENABLE_TELNET_SERVER    0   /* enable telnet server */
#define DEMOCFG_ENABLE_WEBSERVER        1   /* enable web server */
#define DEMOCFG_USE_WIFI                0   /* use WiFi Interface */
```

```
void HVAC_initialize_networking(void)
{
    int32_t                error;
    IPCFG_IP_ADDRESS_DATA  ip_data;
#if DEMOCFG_USE_POOLS && defined(DEMOCFG_RTCS_POOL_ADDR) &&
defined(DEMOCFG_RTCS_POOL_SIZE)
    /* use external RAM for RTCS buffers */
    _RTCS_mem_pool = _mem_create_pool((pointer)DEMOCFG_RTCS_POOL_ADDR,
DEMOCFG_RTCS_POOL_SIZE);
#endif
```

Global variables from the RTCS library are initialized to configure the amount of Packet Control Block and the size of the message pool to be allocated when the RTCS is created. These values are set to default by the library and don’t require an initialization from the user.

```
       --RTCS.c--
#if RTCS_MINIMUM_FOOTPRINT
   /* runtime RTCS configuration for devices with small RAM, for others the
default BSP setting is used */
   _RTCSPCB_init = 4;
   _RTCSPCB_grow = 2;
   _RTCSPCB_max = 20;
   _RTCS_msgpool_init = 4;
   _RTCS_msgpool_grow = 2;
   _RTCS_msgpool_max  = 20;
   _RTCS_socket_part_init = 4;
   _RTCS_socket_part_grow = 2;
   _RTCS_socket_part_max  = 20;
#endif
```

After setting the parameters RTCS is created by calling RTCS_create() function. The function allocates resources that RTCS needs and creates TCP/IP Task. For more details on how the RTCS_create function works please look at the RTCS source code located in \<MQX installation folder>\rtcs\.

```
    error = RTCS_create();
```

The RTCS is configured by setting IP address, IP mask, and Gateway. Address of LWDNS server is set to the same value as the gateway. The ip_data structure is a local object used later on in the bind process.

```
       LWDNS_server_ipaddr = ENET_IPGATEWAY;
      ip_data.ip = ENET_IPADDR;
      ip_data.mask = ENET_IPMASK;
      ip_data.router = ENET_IPGATEWAY;
```

These variables are initialized with macros defined in the HVAC.h file. The ENET_IPADDR and ENET_IPMASK macros may be changed to modify the IP address of the device.

A combination of the Ethernet Device and the IP address is used to generate the MAC address. The ipcfg_init_device() is in turn called to set the MAC address of the device to the generated value.

```
    ENET_get_mac_address (DEMOCFG_DEFAULT_DEVICE, ENET_IPADDR, enet_address);
    error = ipcfg_init_device (DEMOCFG_DEFAULT_DEVICE, enet_address);
```

If a WiFi device is being used, initialization and connection to a wireless network is performed.

```
#if DEMOCFG_USE_WIFI
    iwcfg_set_essid (DEMOCFG_DEFAULT_DEVICE,DEMOCFG_SSID);
    if ((strcmp(DEMOCFG_SECURITY,"wpa") == 0)||strcmp(DEMOCFG_SECURITY,"wpa2")
== 0)
    {
        iwcfg_set_passphrase (DEMOCFG_DEFAULT_DEVICE,DEMOCFG_PASSPHRASE);

    }
    if (strcmp(DEMOCFG_SECURITY,"wep") == 0)
    {
      iwcfg_set_wep_key
(DEMOCFG_DEFAULT_DEVICE,DEMOCFG_WEP_KEY,strlen(DEMOCFG_WEP_KEY),DEMOCFG_WEP_KEY
_INDEX);
    }
    iwcfg_set_sec_type (DEMOCFG_DEFAULT_DEVICE,DEMOCFG_SECURITY);
    iwcfg_set_mode (DEMOCFG_DEFAULT_DEVICE,DEMOCFG_NW_MODE);
#endif
```

The ipcfg_init_device() function is called with ip_data structure to set the IP address of the device and to perform the bind operation.

```
    error = ipcfg_bind_staticip (DEMOCFG_DEFAULT_DEVICE, &ip_data);
```

The http server requires a root directory and an index page. Web content of the Demo is stored in the tfs_data.c. This file was generated from files in the web_pages directory using the mktfs.exe tool located in the \<MQX installation folder>\tools\ directory.

The external symbol tfs_data holds the web page information as an array. This array is installed as a Trivial File System using _io_tfs_install() function. This allows the RTCS to access the web page data stored in arrays in the “tfs:” partition.

If no error occurs the server initializes with the specified root_dir and with the “\\mqx.shtml” file as the index page. Before the server runs it is configured with the CGI information. The cgi_lnk_tbl contains a list of the different available CGI services.

The fn_lnk_tbl contains an event that notifies the client when a USB event occurs. For the demo this changes the layout of the web page when a USB stick is connected or disconnected.

```
#if DEMOCFG_ENABLE_WEBSERVER
    {
        HTTPSRV_ALIAS http_aliases[] = {
          {"/usb/", "c:\\"},
          {NULL, NULL}
        };
        uint32_t server;
        extern const HTTPSRV_CGI_LINK_STRUCT cgi_lnk_tbl[];
        extern const HTTPSRV_SSI_LINK_STRUCT fn_lnk_tbl[];
        extern const TFS_DIR_ENTRY tfs_data[];
        HTTPSRV_PARAM_STRUCT params;

        error = _io_tfs_install("tfs:", tfs_data);
        if (error) printf("\nTFS install returned: %08x\n", error);

        /* Setup webserver parameters */
        _mem_zero(&params, sizeof(HTTPSRV_PARAM_STRUCT));
    #if RTCSCFG_ENABLE_IP4
        params.af |= AF_INET;
    #endif
    #if RTCSCFG_ENABLE_IP6
        params.af |= AF_INET6;
    #endif
        params.root_dir = "tfs:";
        params.alias_tbl = (HTTPSRV_ALIAS*)http_aliases;
        params.index_page = "\\mqx.shtml";
        params.cgi_lnk_tbl = (HTTPSRV_CGI_LINK_STRUCT*)cgi_lnk_tbl;
        params.ssi_lnk_tbl = (HTTPSRV_SSI_LINK_STRUCT*)fn_lnk_tbl;
        params.script_stack = 2500;

        server = HTTPSRV_init(&params);
        if(!server)
        {
            printf("Error: HTTP server init error.\n");
        }
    }
#endif
```

The call to function HTTPSRV_init() initialize the server and opens a socket at port 80 to listen for new connections.

The last part of the function initializes other servers if applicable. The FTPSRV_init() provides FTP server feature to the Freescale MQX.

```
#if DEMOCFG_ENABLE_FTP_SERVER
    {
        FTPSRV_PARAM_STRUCT  params = {0};
        uint32_t             ftpsrv_handle;
        #if RTCSCFG_ENABLE_IP4
        params.af |= AF_INET;
        #endif
        #if RTCSCFG_ENABLE_IP6
        params.af |= AF_INET6;
        #endif
        params.auth_table = (FTPSRV_AUTH_STRUCT*) ftpsrv_users;
        params.root_dir = "c:";

        ftpsrv_handle = FTPSRV_init(&params);
        if (ftpsrv_handle != 0)
        {
            printf("FTP Server Started. Root directory is set to \"%s\", login:
\"%s\", password: \"%s\".\n",
                params.root_dir,
                ftpsrv_users[0].uid,
                ftpsrv_users[0].pass);
        }
        else
        {
            printf("Failed to start FTP server.\n");
        }
    }
#endif
```

The TELNETSRV_init() function initializes the telnet shell.

```
const RTCS_TASK Telnetd_shell_template = {"Telnet_shell", 8, 2000,
Telnetd_shell_fn, NULL};

#if DEMOCFG_ENABLE_TELNET_SERVER
   TELNETSRV_init("Telnet_server", 7, 2000, (RTCS_TASK_PTR)
&Telnetd_shell_template );
#endif

}
```

This is the list of available Telnet commands that are passed to the new Shell task.

```
const SHELL_COMMAND_STRUCT Telnet_commands[] = {
   { "exit",      Shell_exit },,
   { "fan",       Shell_fan },,
   { "help",      Shell_help },,
   { "hvac",      Shell_hvac },,
   { "info",      Shell_info },,
#if DEMOCFG_ENABLE_USB_FILESYSTEM
   { "log",       Shell_log },,
#endif

#if DEMOCFG_ENABLE_RTCS
#if RTCSCFG_ENABLE_ICMP
   { "ping",      Shell_ping },,
#endif
#endif

   { "scale",     Shell_scale },,
   { "temp",      Shell_temp },,
   { "?",         Shell_command_list },,

   { NULL,        NULL }
};
```

HVAC I/O Interface
The inputs and outputs of the system are defined using macros. The macros LED_1 through LED_4 and BSP_BUTTON1 through BSP_BUTTON3 define the pins used as the interface of the application with the user.

The macros are used to initialize lwgpio handles led1 through led4 and button1 through button3 using lwgpio_init function. Functionality options of the pins are set according to BSP_xxx_MUX_GPIO macros. Directions of the pins are set appropriately.

```
bool HVAC_InitializeIO(void)
{

    /* Init Gpio for Leds as output to drive LEDs (LED10 - LED13) */
#ifdef LED_1
       output_port = lwgpio_init(&led1, LED_1, LWGPIO_DIR_OUTPUT,
LWGPIO_VALUE_NOCHANGE);
       if(!output_port){
          printf("Initializing LWGPIO for LED1 failed.\n");
       }
       lwgpio_set_functionality(&led1, BSP_LED1_MUX_GPIO);
       /*Turn off Led */
       lwgpio_set_value(&led1, LWGPIO_VALUE_LOW);
#endif

#ifdef  LED_2
       output_port = lwgpio_init(&led2, LED_2, LWGPIO_DIR_OUTPUT,
LWGPIO_VALUE_NOCHANGE);
       if(!output_port){
          printf("Initializing LWGPIO for LED2 failed.\n");

       }
       lwgpio_set_functionality(&led2, BSP_LED2_MUX_GPIO);
       /*Turn off Led */
       lwgpio_set_value(&led2, LWGPIO_VALUE_LOW);
#endif

#ifdef LED_3
       output_port = lwgpio_init(&led3, LED_3, LWGPIO_DIR_OUTPUT,
LWGPIO_VALUE_NOCHANGE);
       if(!output_port){
          printf("Initializing LWGPIO for LED3 failed.\n");
       }
       lwgpio_set_functionality(&led3, BSP_LED3_MUX_GPIO);
       /*Turn off Led */
       lwgpio_set_value(&led3, LWGPIO_VALUE_LOW);
#endif

#ifdef LED_4
       output_port = lwgpio_init(&led4, LED_4, LWGPIO_DIR_OUTPUT,
LWGPIO_VALUE_NOCHANGE);
       if(!output_port){
          printf("Initializing LWGPIO for LED4 failed.\n");
       }
       lwgpio_set_functionality(&led4, BSP_LED4_MUX_GPIO);
       /*Turn off Led */
       lwgpio_set_value(&led4, LWGPIO_VALUE_LOW);
#endif

#ifdef BSP_BUTTON1
        /* Open and set port DD as input to read value from switches */
           input_port = lwgpio_init(&button1, TEMP_PLUS, LWGPIO_DIR_INPUT,
LWGPIO_VALUE_NOCHANGE);
           if(!input_port)
           {
               printf("Initializing LW GPIO for button1 as input failed.\n");
               _task_block();
           }
           lwgpio_set_functionality(&button1 ,BSP_BUTTON1_MUX_GPIO);
           lwgpio_set_attribute(&button1, LWGPIO_ATTR_PULL_UP,
LWGPIO_AVAL_ENABLE);
#endif
#ifdef BSP_BUTTON2
           input_port = lwgpio_init(&button2, TEMP_MINUS, LWGPIO_DIR_INPUT,
LWGPIO_VALUE_NOCHANGE);
           if(!input_port)
           {
               printf("Initializing LW GPIO for button2 as input failed.\n");
               _task_block();
           }
           lwgpio_set_functionality(&button2, BSP_BUTTON2_MUX_GPIO);
           lwgpio_set_attribute(&button2, LWGPIO_ATTR_PULL_UP,
LWGPIO_AVAL_ENABLE);
#endif

#ifdef BSP_BUTTON3
           input_port = lwgpio_init(&button3, TEMP_MINUS, LWGPIO_DIR_INPUT,
LWGPIO_VALUE_NOCHANGE);
           if(!input_port)
           {
               printf("Initializing LW GPIO for button3 as input failed.\n");
               _task_block();
           }
           lwgpio_set_functionality(&button3, BSP_BUTTON3_MUX_GPIO);
           lwgpio_set_attribute(&button3, LWGPIO_ATTR_PULL_UP,
LWGPIO_AVAL_ENABLE);
#endif

#if BUTTONS
    return (input_port!=0) && (output_port!=0);
#else
   return (output_port!=0);
#endif
}
```

The obtained lwgpio handles are used to reference pins in calls to lwgpio driver functions.

Manipulation of outputs is done using HVAC_SetOutput function. The function compares the desired state to the actual state of the output stored in the HVAC_OutputState global array. When the requested state is different to the actual one lwgpio_set_value function is called to actually set the output value.

```
void HVAC_SetOutput(HVAC_Output_t signal,bool state)
{
   if (HVAC_OutputState[signal] != state) {
      HVAC_OutputState[signal] = state;
      if (output_port) {
          switch (signal) {
#ifdef LED_1
              case HVAC_FAN_OUTPUT:
                  (state) ? lwgpio_set_value(&led1,
LWGPIO_VALUE_HIGH):lwgpio_set_value(&led1, LWGPIO_VALUE_LOW);
                   break;
#endif
#ifdef LED_2
              case HVAC_HEAT_OUTPUT:
                  (state) ? lwgpio_set_value(&led2,
LWGPIO_VALUE_HIGH):lwgpio_set_value(&led2, LWGPIO_VALUE_LOW);
                   break;
#endif
#ifdef LED_3
             case HVAC_COOL_OUTPUT:
                  (state) ? lwgpio_set_value(&led3,
LWGPIO_VALUE_HIGH):lwgpio_set_value(&led3, LWGPIO_VALUE_LOW);
                   break;
#endif
#ifdef LED_4
             case HVAC_ALIVE_OUTPUT:
                  (state) ? lwgpio_set_value(&led4,
LWGPIO_VALUE_HIGH):lwgpio_set_value(&led4, LWGPIO_VALUE_LOW);

                  break;
#endif
         }
      }
   }
}
```

Input pins are accessed through HVAC_GetInput function which in turn calls lwgpio_get_value with a handle corresponding with signal parameter. Finally the HVAC_GetInput function returns a boolean value representing state of the input.

```
bool HVAC_GetInput(HVAC_Input_t signal)
{
   bool  value=FALSE;
    if (input_port){
        switch (signal) {
#ifdef BSP_BUTTON1
            case HVAC_TEMP_UP_INPUT:
                value = !lwgpio_get_value(&button1);
                break;
#endif
#ifdef BSP_BUTTON2
            case HVAC_TEMP_DOWN_INPUT:
                value = !lwgpio_get_value(&button2);
                break;
#endif
#if defined(FAN_ON_OFF)
         case HVAC_FAN_ON_INPUT:
            value = !lwgpio_get_value(&button3);
            break;
#endif
   }
  }
   return value;
}
```

The HVAC_ReadAmbienTemperature function simulates temperature change across time in the Demo. The _time_get(); function returns the amount of milliseconds since MQX Started. Using this RTOS service the function updates temperature every second. Depending on the state of the output temperature is increased or decreased by HVAC_TEMP_UPD_DELTA.

```
void HVAC_ReadAmbientTemperature(void)
{
   TIME_STRUCT time;

   _time_get(&time);
   if (time.SECONDS>=(LastUpdate.SECONDS+HVAC_TEMP_UPDATE_RATE)) {
      LastUpdate=time;
      if (HVAC_GetOutput(HVAC_HEAT_OUTPUT)) {
         AmbientTemperature += HVAC_TEMP_UPD_DELTA;
      } else if (HVAC_GetOutput(HVAC_COOL_OUTPUT)) {
         AmbientTemperature -= HVAC_TEMP_UPD_DELTA;
      }
   }
}
```

Shell task

This task uses the shell library to set up the available commands in the HVAC demo. The Shell library provides a serial interface where the user can interact with the HVAC demo features.

```
void Shell_Task(uint32_t param)
{
   /* Run the shell on the serial port */
   for(;;)  {
      Shell(Shell_commands, NULL);
      printf("Shell exited, restarting...\n");
   }
}
```

The shell library source code is available as a reference. To understand the execution details of the Shell function review the source code for the library located in:
\<MQX installation folder>\shell\source\

The Shell function takes an array of commands and a pointer to a file as parameters. The Shell_commands array specifies a list of commands and relates each command to a function. When a command is entered into the Shell input the corresponding function is executed.

```
typedef struct shell_command_struct  {
   char  *COMMAND;
   int32_t      (*SHELL_FUNC)(int32_t argc, char *argv[]);
} SHELL_COMMAND_STRUCT, * SHELL_COMMAND_PTR;
```

Each shell command definition includes a string containing name of the command and the function executed when the command is typed.

```
const SHELL_COMMAND_STRUCT Shell_commands[] = {
#if DEMOCFG_ENABLE_USB_FILESYSTEM
   { "cd",        Shell_cd },
   { "copy",      Shell_copy },
   { "del",       Shell_del },
   { "dir",       Shell_dir },
   { "log",       Shell_log },
   { "mkdir",     Shell_mkdir },
   { "pwd",       Shell_pwd },
   { "read",      Shell_read },
   { "ren",       Shell_rename },
   { "rmdir",     Shell_rmdir },
   { "type",      Shell_type },
   { "write",     Shell_write },
#endif
   { "exit",      Shell_exit },
   { "fan",       Shell_fan },
   { "help",      Shell_help },
   { "hvac",      Shell_hvac },
   { "info",      Shell_info },
   { "scale",     Shell_scale },
   { "temp",      Shell_temp },

#if DEMOCFG_ENABLE_RTCS
   { "netstat",   Shell_netstat },
   { "ipconfig",  Shell_ipconfig },
#if DEMOCFG_USE_WIFI
   { "iwconfig",  Shell_iwconfig },
#endif
#if RTCSCFG_ENABLE_ICMP
   { "ping",      Shell_ping },
#endif
#endif
   { "?",         Shell_command_list },
   { NULL,        NULL }
};
```

Some of the functions executed using the Shell are provided by the MQX RTOS. For example, functions that are related to the file system are implemented within the MFS library. HVAC specific functions are implemented within HVAC_Shell_Commands.c source file.

```
extern int32_t Shell_fan(int32_t argc, char *argv[] );
extern int32_t Shell_hvac(int32_t argc, char *argv[] );
extern int32_t Shell_scale(int32_t argc, char *argv[] );
extern int32_t Shell_temp(int32_t argc, char *argv[] );
extern int32_t Shell_info(int32_t argc, char *argv[] );
extern int32_t Shell_log(int32_t argc, char *argv[] );
```

The functions implemented in HVAC_Shell_Commands.c are listed in the corresponding header file. These functions use the terminal to display the user how to use the particular command. Every function validates the input of the Shell. When commands are entered correctly a specific HVAC command is executed.

As an example, the Shell_fan function:

```
int32_t  Shell_fan(int32_t argc, char *argv[] )
{
   bool           print_usage, shorthelp = FALSE;
   int32_t            return_code = SHELL_EXIT_SUCCESS;
   FAN_Mode_t        fan;

   print_usage = Shell_check_help_request(argc, argv, &shorthelp );

   if (!print_usage)  {
      if (argc > 2) {
         printf("Error, invalid number of parameters\n");
         return_code = SHELL_EXIT_ERROR;
         print_usage=TRUE;
      } else {
         if (argc == 2) {
            if (strcmp(argv[1],"on")==0) {
               HVAC_SetFanMode(Fan_On);
            } else if (strcmp(argv[1],"off")==0) {
               HVAC_SetFanMode(Fan_Automatic);
            } else {
               printf("Invalid fan mode specified\n");
            }
         }

         fan  = HVAC_GetFanMode();
         printf("Fan mode is %s\n", fan == Fan_Automatic ? "Automatic" : "On");
      }
   }

   if (print_usage)  {
      if (shorthelp)  {
         printf("%s [<mode>]\n", argv[0]);
      } else  {
        printf("Usage: %s [<mode>]\n", argv[0]);
        printf("   <mode> = on or off (off = automatic mode)\n");
     }
   }
   return return_code;
}
```

The mode specified to the “fan” command in the shell input is compared to “on” and “off” strings. When the string received through the shell command is “on” the function HVAC_SetFanMode(Fan_On) is executed. When the string received through the shell command is “off” the function HVAC_SetFanMode(Fan_Automatic) is executed.
After the fan mode is set the function HVAC_GetFanMode() reads and displays the fan mode. The usage of the function is printed as a short help message for the user if needed.

Other functions within HVAC_Shell_Commands.c execute different HVAC functionalities but the implementation is similar to the example.

Shell is implemented as a separate library that interfaces with MQX. The MQX related commands as well as RTCS and MFS commands may be executed from the shell. Other custom Shell commands may be created by the user to execute application specific operations.

USB task

The USB Task creates a message queue related to the USB resource. The message informs the rest of the application code about an event. In the case of this demo events are attaching or detaching of a USB memory stick. The message notifies the availability of a valid USB stick connected to the Demo. After the USB stick is detected the file system is installed. The other tasks then can access the file system. They are informed with signaled semaphore.

The ClassDriverInfoTable array contains the class information supported in the application. This array also relates the Vendor and Product ID to a specific USB class and sub-class. Callback functions for each class is also included as a part of the elements of the array. In this case any event related to the USB 2.0 hard drive executes the usb_host_mass_device_event() function.

```
/* Table of driver capabilities this application want to use */
static const USB_HOST_DRIVER_INFO ClassDriverInfoTable[] =
{
   /* Vendor ID Product ID Class Sub-Class Protocol Reserved Application call
back */
   /* Floppy drive */
   {{0x00,0x00}, {0x00,0x00}, USB_CLASS_MASS_STORAGE, USB_SUBCLASS_MASS_UFI,
USB_PROTOCOL_MASS_BULK, 0, usb_host_mass_device_event },

   /* USB 2.0 hard drive */
   {{0x00,0x00}, {0x00,0x00}, USB_CLASS_MASS_STORAGE, USB_SUBCLASS_MASS_SCSI,
USB_PROTOCOL_MASS_BULK, 0, usb_host_mass_device_event},

   /* USB hub */
   {{0x00,0x00}, {0x00,0x00}, USB_CLASS_HUB, USB_SUBCLASS_HUB_NONE,
USB_PROTOCOL_HUB_ALL, 0, usb_host_hub_device_event},

   /* End of list */
   {{0x00,0x00}, {0x00,0x00}, 0,0,0,0, NULL}
};
```

The usb_host_mass_device_event() function executes when a device is attached or detached. The function tests the event_code to identify which type of event caused the callback. In the case of an attach event the device structure is filled with the USB_DEVICE_ATTACHED code and the sets USB_Event created in the USB_Task() function. Detach events are similar to attach events. In the case of a detach event the device structure is filled with the USB_DEVICE_DETACHED code and the message is sent.

```
void usb_host_mass_device_event
   (
      /* [IN] pointer to device instance */
      _usb_device_instance_handle      dev_handle,

      /* [IN] pointer to interface descriptor */
      _usb_interface_descriptor_handle intf_handle,

      /* [IN] code number for event causing callback */
      uint32_t           event_code
   )
{
   DEVICE_STRUCT_PTR          device;
   usb_msg_t                  msg;

   switch (event_code) {
      case USB_CONFIG_EVENT:
         /* Drop through into attach, same processing */
      case USB_ATTACH_EVENT:
         /* Here, the device starts its lifetime */
         device = (DEVICE_STRUCT_PTR) _mem_alloc_zero(sizeof(DEVICE_STRUCT));
         if (device == NULL)
            break;

         if (USB_OK != _usb_hostdev_select_interface(dev_handle, intf_handle,
&device->ccs))
            break;
         msg.ccs = &device->ccs;
         msg.body = USB_EVENT_ATTACH;
         if (LWMSGQ_FULL == _lwmsgq_send(usb_taskq, (uint32_t *) &msg, 0)) {
            printf("Could not inform USB task about device attached\n");
         }
         break;

      case USB_INTF_EVENT:
         if (USB_OK != usb_class_mass_get_app(dev_handle, intf_handle,
(CLASS_CALL_STRUCT_PTR *) &device))
            break;
         msg.ccs = &device->ccs;
         msg.body = USB_EVENT_INTF;
         if (LWMSGQ_FULL == _lwmsgq_send(usb_taskq, (uint32_t *) &msg, 0)) {
            printf("Could not inform USB task about device interfaced\n");
         }
         break;

      case USB_DETACH_EVENT:
         if (USB_OK != usb_class_mass_get_app(dev_handle, intf_handle,
(CLASS_CALL_STRUCT_PTR *) &device))
            break;
         msg.ccs = &device->ccs;
         msg.body = USB_EVENT_DETACH;
         if (LWMSGQ_FULL == _lwmsgq_send(usb_taskq, (uint32_t *) &msg, 0)) {
            printf("Could not inform USB task about device detached\n");
         }
         _mem_free(device);
         break;

      default:
         break;
   }
}
```

The USB_task function creates a message queue. The message is sent from the callback (see above) when a USB Stick is connected and ready for read/write operations. The messages for the task are read by _lwmsgq_receive function.

```
void USB_task(uint32_t param)
{
    _usb_host_handle     host_handle;
    USB_STATUS           error;
    void                *usb_fs_handle = NULL;
    usb_msg_t            msg;
    /* Store mounting point used. A: is the first one, bit #0 assigned, Z: is
the last one, bit #25 assigned */
    uint32_t              fs_mountp = 0;

#if DEMOCFG_USE_POOLS && defined(DEMOCFG_MFS_POOL_ADDR) &&
defined(DEMOCFG_MFS_POOL_SIZE)
    _MFS_pool_id = _mem_create_pool((void *)DEMOCFG_MFS_POOL_ADDR,
DEMOCFG_MFS_POOL_SIZE);
#endif

    /* This event will inform other tasks that the filesystem on USB was
successfully installed */
    _lwsem_create(&USB_Stick, 0);

    if (MQX_OK != _lwmsgq_init(usb_taskq, 20, USB_TASKQ_GRANM)) {
        // lwmsgq_init failed
        _task_block();
    }

    USB_lock();
    _int_install_unexpected_isr();
    if (MQX_OK != _usb_host_driver_install(USBCFG_DEFAULT_HOST_CONTROLLER)) {
      printf("\n Driver installation failed");
      _task_block();
   }

    error = _usb_host_init(USBCFG_DEFAULT_HOST_CONTROLLER, &host_handle);
    if (error == USB_OK) {
        error = _usb_host_driver_info_register(host_handle, (void *)
ClassDriverInfoTable);
        if (error == USB_OK) {
            error = _usb_host_register_service(host_handle,
USB_SERVICE_HOST_RESUME,NULL);
        }
    }

    USB_unlock();
```

The first step required to act as a host is to initialize USB component in the MQX. The stack in host mode is initialized afterwards. This allows the stack to install a host interrupt handler and initialize the necessary memory required to run the stack.

The host is now initialized and the driver is installed. The next step is to register driver information so that the specific host is configured with the information in the ClassDriverInfoTable array. The _usb_host_driver_info_register links the classes specified in the array with the callback function that each class executes on events.

```
    error = _usb_host_init(USBCFG_DEFAULT_HOST_CONTROLLER, &host_handle);
    if (error == USB_OK) {
        error = _usb_host_driver_info_register(host_handle, (void *)
ClassDriverInfoTable);
        if (error == USB_OK) {
            error = _usb_host_register_service(host_handle,
USB_SERVICE_HOST_RESUME,NULL);
        }
    }
```

This must be done in defined state of USB, so USB_lock() and USB_unlock() is placed here to define the critical section.

Once initialization and configuration finishes the task loop executes. The message informs the loop about the event.

```
    for (;;) {
        /* Wait for event sent as a message */
        _lwmsgq_receive(&usb_taskq, (_mqx_max_type *) &msg,
LWMSGQ_RECEIVE_BLOCK_ON_EMPTY, 0, 0);
```

After a message is received the message body is read. If the USB stick has been successfully enumerated the file system is installed on top of it.

```
        if (msg.body == USB_EVENT_ATTACH) {
          /* This event is not so important, because it does not inform about
successfull USB stack enumeration */
        } else if (msg.body == USB_EVENT_INTF && fs_mountp != 0x3FFC)  { /* if
mountpoints c: to z: are already used */

            // Install the file system, use device->ccs as a handle
            usb_fs_handle = usb_filesystem_install( (void *) msg.ccs, "USB:",
"PM_C1:", "c:");
```

After correct file system installation the USB_Stick semaphore is posted to indicate the other tasks that there is a USB Mass storage device available as a resource. In the case of a detach event the _lwsem_wait() function blocks until it is safe to uninstall the filesystem.

```
        } else if (msg.body == USB_EVENT_DETACH) {
            DEVICE_STRUCT_PTR dsp = (DEVICE_STRUCT_PTR) msg.ccs;

            if (dsp->mount >= 'a' && dsp->mount <= 'z') {
                // Lock the USB_Stick = mark as unavailable
                _lwsem_wait(&USB_Stick);
                // Remove the file system
                usb_filesystem_uninstall(usb_fs_handle);
                // Mark file system as unmounted
                fs_mountp &= ~(1 << (dsp->mount - 'a'));
            }
```

MFS

The partition manager device driver is designed to be installed under the MFS device driver. It lets MFS work independently of the multiple partitions on a disk. It also enforces mutually exclusive access to the disk, which means that two concurrent write operations from two different MFS devices cannot conflict. The partition manager device driver can remove partitions, as well as create new ones. The partition manager device driver is able to work with multiple primary partitions. Extended partitions are not supported.

The usb_filesystem_install() function receives the USB handler, the block device name, the partition manager name, and the file system name. Several local variables are used to execute each step of the file system installation process.

The usb_fs_ptr value is returned after the execution of the file system install process. The first step of the process allocates zeroed memory with the required size for a USB file system structure.

```
void *usb_filesystem_install(
    void    *usb_handle,
    char    *block_device_name,
    char    *partition_manager_name,
    char    *file_system_name )
{
    uint32_t                   partition_number;
    unsigned char             *dev_info;
    int32_t                    error_code;
    USB_FILESYSTEM_STRUCT_PTR  usb_fs_ptr;


    usb_fs_ptr = _mem_alloc_system_zero(sizeof(USB_FILESYSTEM_STRUCT));
    if (usb_fs_ptr==NULL)
    {
        return NULL;
    }
```

The USB device is installed with the _io_usb_mfs_install() function with the device name and the USB handle as parameters. After installation the DEV_NAME of the usb_fs_ptr variable is set to “USB:”.

```
   _io_usb_mfs_install(block_device_name, 0, (void*)usb_handle);
   usb_fs_ptr->DEV_NAME = block_device_name;
```

A 500 milliseconds delay is generated using the _time_delay() function. Next, the USB device is open as a mass storage device. Function fopen() opens the USB device and the resulting handle is assigned to the DEV_FD_PTR element of the usb_fs_ptr structure. If the fopen operation fails an error message is displayed.

```
   /* Open the USB mass storage  device */
   _time_delay(500);
   usb_fs_ptr->DEV_FD_PTR = fopen(block_device_name, 0);

   if (usb_fs_ptr->DEV_FD_PTR == NULL) {
      printf("\nUnable to open USB disk");
      usb_filesystem_uninstall(usb_fs_ptr);
      return NULL;
   }
```

The _io_ioctl() function accesses the mass storage device and set it to Block Mode. When access to the device is available the vendor information, the product ID, and the Product Revision are read and printed to the console.

```
   _io_ioctl(usb_fs_ptr->DEV_FD_PTR, IO_IOCTL_SET_BLOCK_MODE, NULL);

   /* get the vendor information and display it */
```

```
printf("\n*******************************************************************
***\n");
    _io_ioctl(usb_fs_ptr->DEV_FD_PTR, IO_IOCTL_GET_VENDOR_INFO, &dev_info);
    printf("Vendor Information:     %-1.8s Mass Storage Device\n",dev_info);
    _io_ioctl(usb_fs_ptr->DEV_FD_PTR, IO_IOCTL_GET_PRODUCT_ID, &dev_info);
    printf("Product Identification: %-1.16s\n",dev_info);
    _io_ioctl(usb_fs_ptr->DEV_FD_PTR, IO_IOCTL_GET_PRODUCT_REV, &dev_info);
    printf("Product Revision Level: %-1.4s\n",dev_info);

printf("*******************************************************************
*\n");
```

The partition manager device driver is installed and opened like other devices. It must also be closed and uninstalled when an application no longer needs it.

Partition Manager is installed with the _io_part_mgr_install() function. The device number and partition manager name are passed as parameters to the function. If an error occurs during partition manager installation a message is displayed on the console. On successful partition manager installation the PM_NAME element of the usb_fs_ptr structure is set to “PM_C1:”.

```
    /* Try to install the partition manager */
    error_code = _io_part_mgr_install(usb_fs_ptr->DEV_FD_PTR,
partition_manager_name, 0);
    if (error_code != MFS_NO_ERROR)
    {
        printf("Error while initializing partition manager: %s\n",
MFS_Error_text((uint32_t)error_code));
        usb_filesystem_uninstall(usb_fs_ptr);
        return NULL;
    }
    usb_fs_ptr->PM_NAME = partition_manager_name;
```

A call to fopen() opens the partition manager and the resulting file pointer is assigned to the PM_FD_PTR element of the usb_fs_ptr structure. In the case of an error a message is displayed on the console and the file system is uninstalled.

```
    /* Open partition manager */
    usb_fs_ptr->PM_FD_PTR = fopen(partition_manager_name, NULL);
    if (usb_fs_ptr->PM_FD_PTR == NULL)
    {
        error_code = ferror(usb_fs_ptr->PM_FD_PTR);
        printf("Error while opening partition manager: %s\n",
MFS_Error_text((uint32_t)error_code));
        usb_filesystem_uninstall(usb_fs_ptr);
        return NULL;
    }

    /* Select partition */
    partition_number = 1;
    error_code = _io_ioctl(usb_fs_ptr->PM_FD_PTR, IO_IOCTL_SEL_PART,
&partition_number);
```

The partition_number parameter of the _io_ioctl() function is passed by reference. This value is modified inside the function. If an error code is returned by _io_ioctl() the partition manager handle is closed with the fclose() function. The partition manager is then uninstalls using the _io_part_mgr_uninstall() function.

In such a case an attempt to install the MFS without partition manager is performed using _io_mfs_install() function.

MFS is installed with the device handle pointer, a file system name and a default partition value of 0.

If the partition number is valid the MFS installs with the same handle and file system name but using the partition number as third parameter.

If the partition number is not valid then MFS tries to install the file system over the entire device without partition table.

```
    if (error_code == MFS_NO_ERROR)
    {
        printf("Installing MFS over partition...\n");

        /* Validate partition */
        error_code = _io_ioctl(usb_fs_ptr->PM_FD_PTR, IO_IOCTL_VAL_PART, NULL);
        if (error_code != MFS_NO_ERROR)
        {
            printf("Error while validating partition: %s\n",
MFS_Error_text((uint32_t)error_code));
            printf("Not installing MFS.\n");
            usb_filesystem_uninstall(usb_fs_ptr);
            return NULL;
        }

        /* Install MFS over partition */
        error_code = _io_mfs_install(usb_fs_ptr->PM_FD_PTR, file_system_name,
0);
        if (error_code != MFS_NO_ERROR)
        {
            printf("Error initializing MFS over partition: %s\n",
MFS_Error_text((uint32_t)error_code));
        }
    }
    else {

        printf("Installing MFS over USB device...\n");

        /* Install MFS over USB device driver */
        error_code = _io_mfs_install(usb_fs_ptr->DEV_FD_PTR, file_system_name,
0);
        if (error_code != MFS_NO_ERROR)
        {
            printf("Error initializing MFS: %s\n",
MFS_Error_text((uint32_t)error_code));
        }
    }
```

After the file system installation the status of the MFS is tested. The FS_NAME element of the usb_fs_ptr structure is set to “a:”.

The fopen() function takes the file system name as parameter. If no error occurs the file system is ready to be used by the application and the usb_fs_ptr structure is returned.

```
    if (error_code == MFS_NO_ERROR)
    {
        usb_fs_ptr->FS_NAME = file_system_name;
        usb_fs_ptr->FS_FD_PTR = fopen(file_system_name, NULL);
        error_code = ferror(usb_fs_ptr->FS_FD_PTR);
        if (error_code == MFS_NOT_A_DOS_DISK)
        {
            printf("NOT A DOS DISK! You must format to continue.\n");
        }
        else if (error_code != MFS_NO_ERROR)
        {
            printf("Error opening filesystem: %s\n",
MFS_Error_text((uint32_t)error_code));
            usb_filesystem_uninstall(usb_fs_ptr);
            return NULL;
        }

        printf("USB device installed to %s\n", file_system_name);
    }
    else {

        usb_filesystem_uninstall(usb_fs_ptr);
        return NULL;
    }

    return (void *)usb_fs_ptr;
}
```

WEB Folder

MQX includes the MKTFS.exe application that converts web pages files into a source code file to be used in MQX. The tool is available in the \<MQX installation folder>\tools\ folder.

Tool Usage:
```
mktfs.exe <Folder to be converted> <Output source file name>
```

The tool is executed using a batch file. The converted output of the web_pages folder is stored in the tfs_data.c file which is compiled and linked with the application. Information is accessed by the application through the tfs_data array.