ARM® Cortex®-M

32-bit Microcontroller

M487
Intelligent Power Station
User Manual
NuMicro® M480 Series

For additional information or questions, please contact: Nuvoton Technology Corporation.

www.nuvoton.com

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1 OVERVIEW

This user manual aims for giving users a whole and detailed introduction about the M487 Intelligent Power Station. Figure 1-1 shows the demonstration hardware for whole the M487 Intelligent Power Station system. In this demonstration system, users can turn on or turn off the power switches of the AC sockets and USB sockets inside the M487 Power Station case thru the remote controlling by the smart phone or thru the local controlling by the touch finger on the LCD panel on the M487 Power Station case. On the other hand, users also can monitor the real-time current and power consumption that passing through on each turned-on AC or USB socket on the TFT LCD screen or on the APP of remote cellphone.

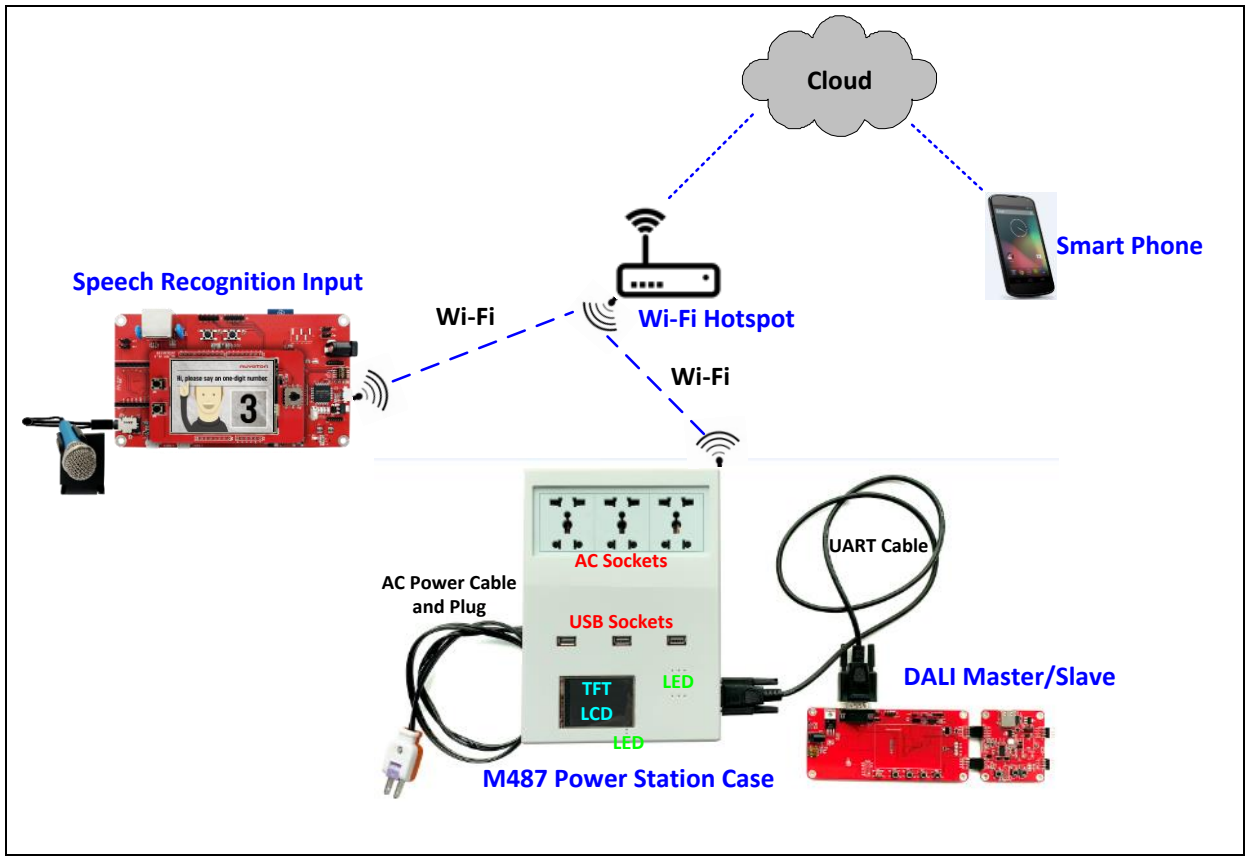

Figure 1-1 Demonstration Hardware of M487 Intelligent Power Station System

After opened the M487 Power Station case, users can find a lots of components and boards inside this M487 Power Station case that shown in the Figure 1-2 below.

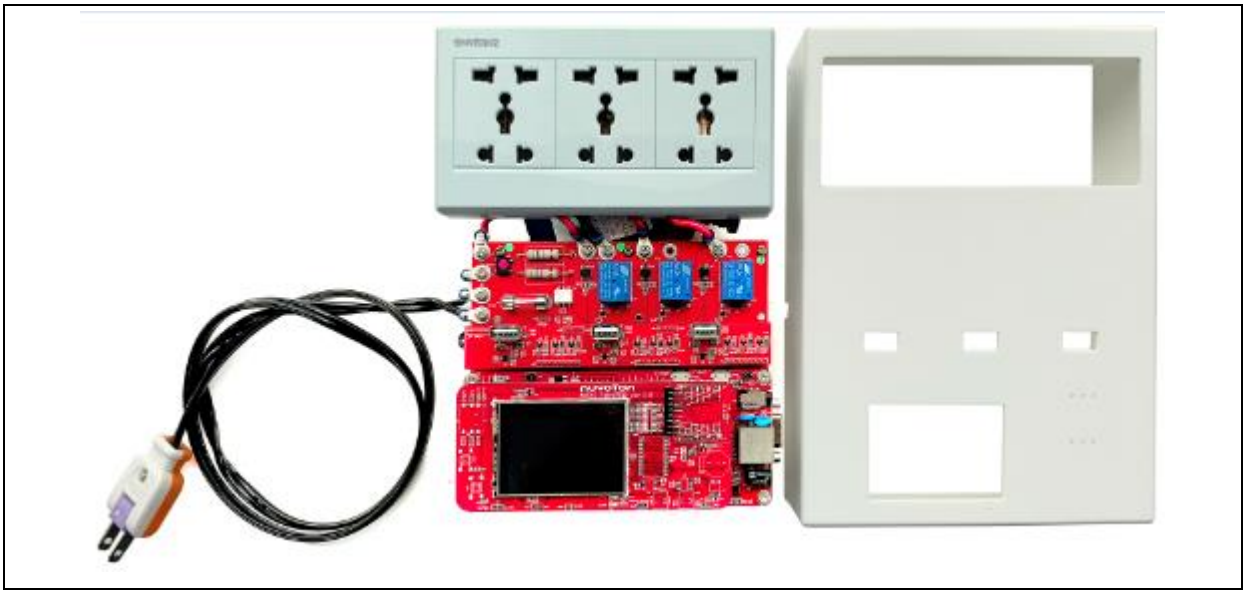

Figure 1-2 M487 Power Station Case

Figure 1-3 shows all the contents inside the M487 Power Station case. It includes mainly a NuMaker-emWin-M487D board with TFT LCD panel (top), a M487 Smart Power (V1.1) board (bottom), a Wi-Fi module board (middle), an AC-to-DC5V adaptor, three AC sockets, three USB sockets and some LED components.

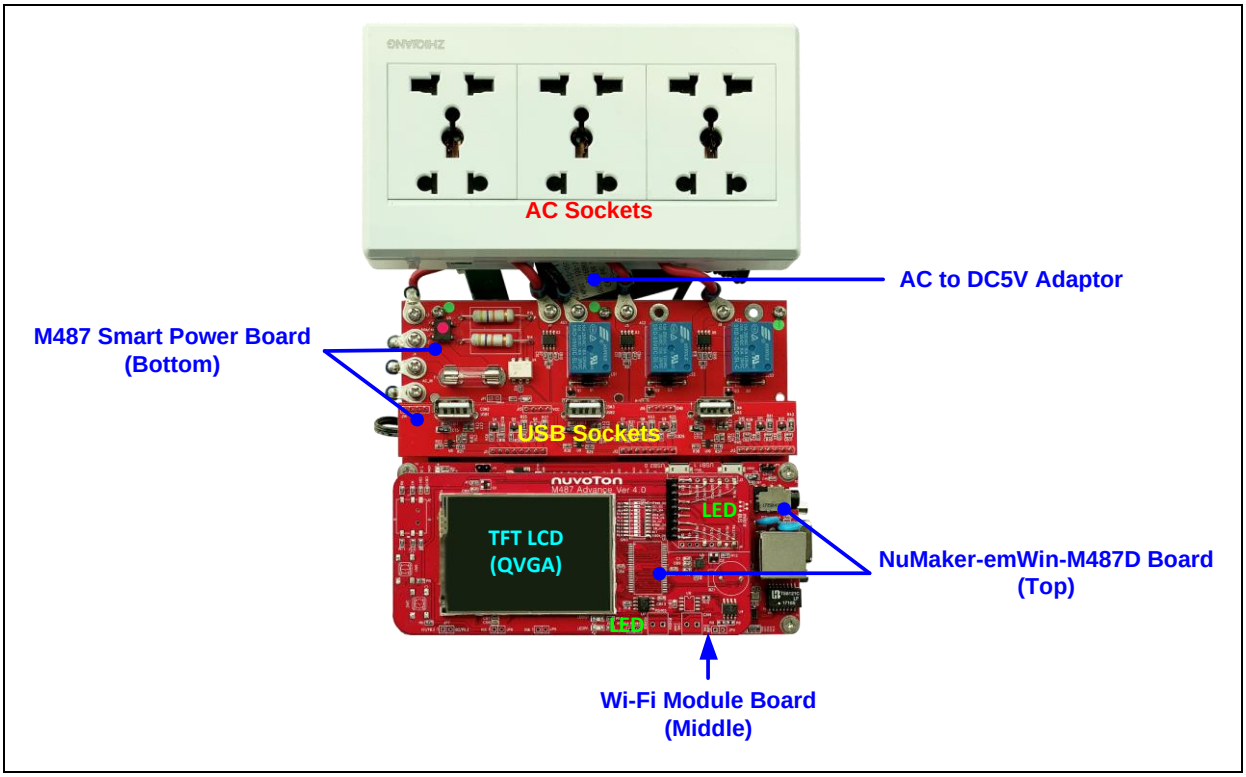

Figure 1-3 Contents inside M487 Power Station Case

Figure 1-4 shows the whole hardware structure of M487 Intelligent Power Station system. The M487 Intelligent Power Station system consists of a NuMaker-emWin-M487D board with TFT LCD panel, a M487 Smart Power board with AC and USB sockets, a NuMaker-IoT-M487 board with a microphone, a DALI combination board consisted of master and slave boards that based on the DALI 2.0 specification, a Wi-Fi hotspot and a smart phone. This whole application system uses UART interface and Wi-Fi module to communicate the commands and data between these boards.

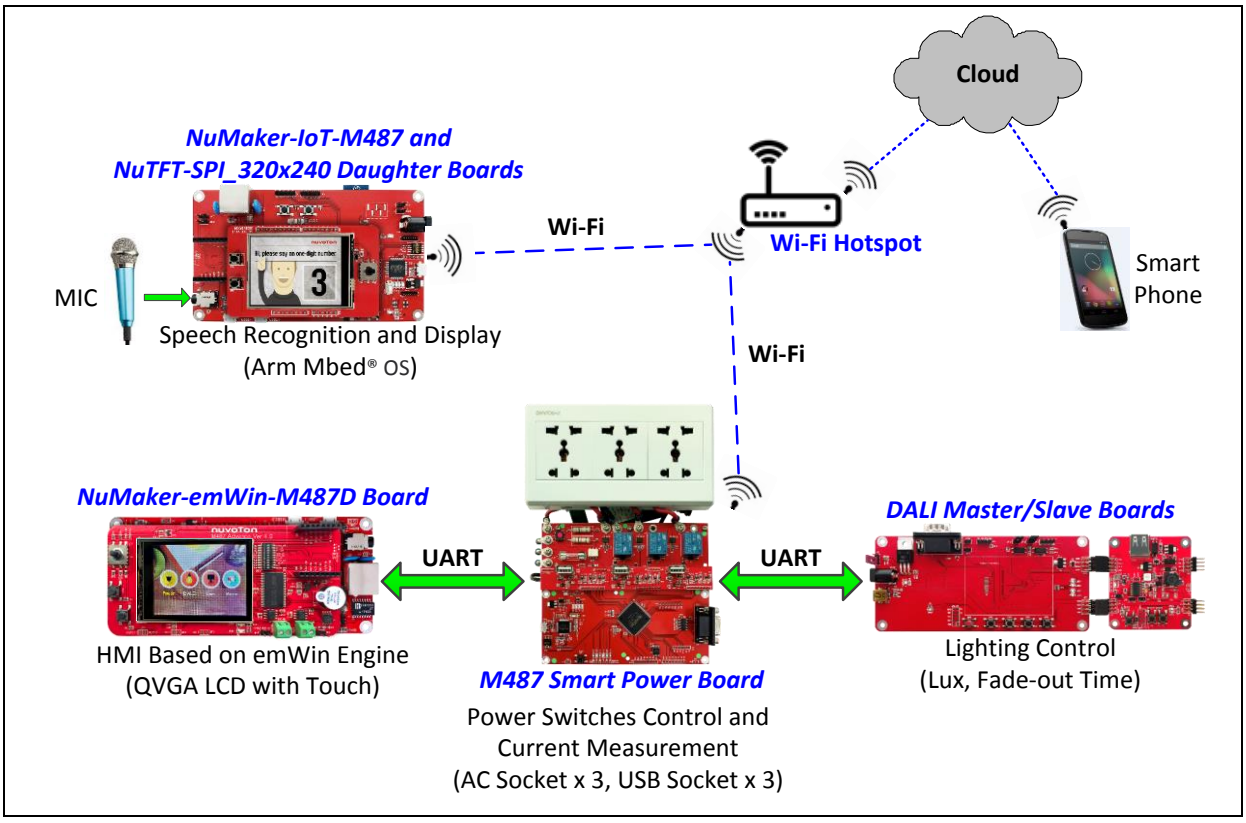

Figure 1-4 Hardware Structure of M487 Intelligent Power Station System

1.1 Brief Function Introduction on Boards

1.1.1 NuMaker-emWin-M487D Board

The NuMaker-emWin-M487D board shown in the Figure 1-5 below provides user the Human-Machine Interface (HMI) function. Users can control the power switches to turn on or turn off the power on these AC sockets and USB sockets on M487 Smart Power board by touch finger input on TFT LCD screen. On the other hand, the real-time current and power consumption of each be turned-on socket are displayed on the TFT LCD screen and the On/Off status also shown on LED.

In this M487 Intelligent Power Station application and for the destination to fit all hardware boards into the case, users can find some components of NuMaker-emWin-M487D board are be removed and be replaced with LEDs. Figure 1-6 shows the reworked NuMaker-emWin-M487D board.

This NuMaker-emWin-M487D board is a master role in this M487 Intelligent Power Station application. It arbitrates the speech recognition command passed from NuMaker-IoT-M487 board through the Wi-Fi module (UART interface) of M487 Smart Power board with the HMI input and then sends the last command by UART to control the power switches to turn on or turn off the power on these AC and USB sockets.

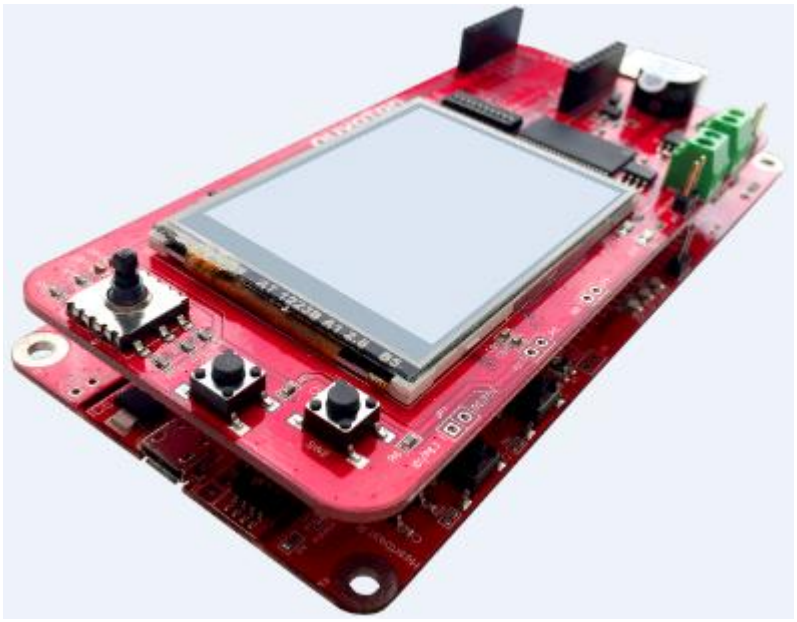

Figure 1-5 NuMaker-emWin-M487D Board

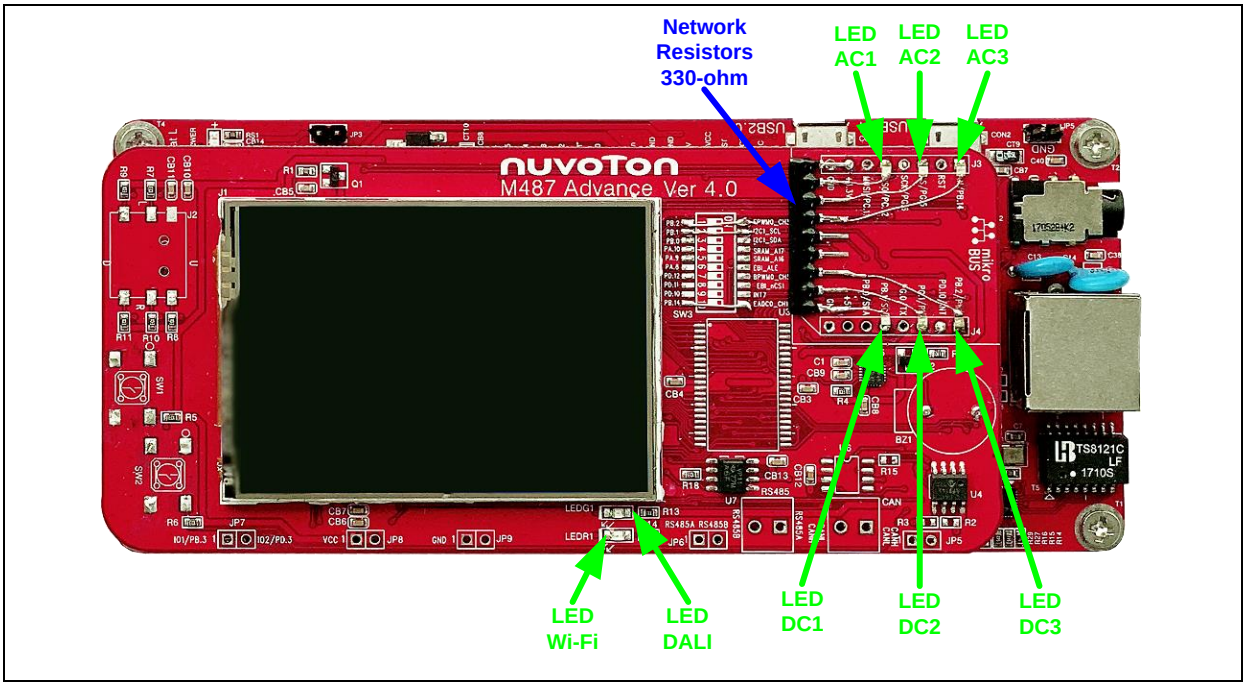

Figure 1-6 Reworked NuMaker-emWin-M487D Board

Table 1-1 Dedicated LED Components on Reworked NuMaker-emWin-M487D Board

LED Name	Dedicated for	GPIO	LED ON
LED AC1	AC1 Socket	PC.12	Socket power is turned-on
LED AC2	AC2 Socket	PG.5	Socket power is turned-on
LED AC3	AC3 Socket	PB.14	Socket power is turned-on
LED DC1	DC1/USB1 Socket	PB.1	Socket power is turned-on
LED DC2	DC2/USB2 Socket	PG.1	Socket power is turned-on
LED DC3	DC3/USB3 Socket	PB.2	Socket power is turned-on
LED Wi-Fi	Wi-Fi Module	PH.6	Wi-Fi is connecting (flashing) or connected (always on)
LED DALI	DALI Board	PH.7	DALI board is connected

1.1.2 M487 Smart Power Board

The M487 Smart Power board is based on M487JIDAE MCU chip to implement the real power switch controlling and measure the current and power consumption on each AC and USB socket if it is turned-on by the NuMaker-emWin-M487D board. It sends back the real-time current and power consumption to NuMaker-emWin-M487D board to display on the LCD module through the UART interface.

This board also plays the role of UART bridges. It passes the command from NuMaker-emWin-M487D board to the DALI master board through the UART interface with the transceiver. On the other hand, it also passes the speech recognition command through the Wi-Fi module (UART interface) from NuMaker-IoT-M487 board to NuMaker-emWin-M487D board to arbitrate the command with HMI input.

Figure 1-7 shows the M487 Smart Power (V1.1) board.

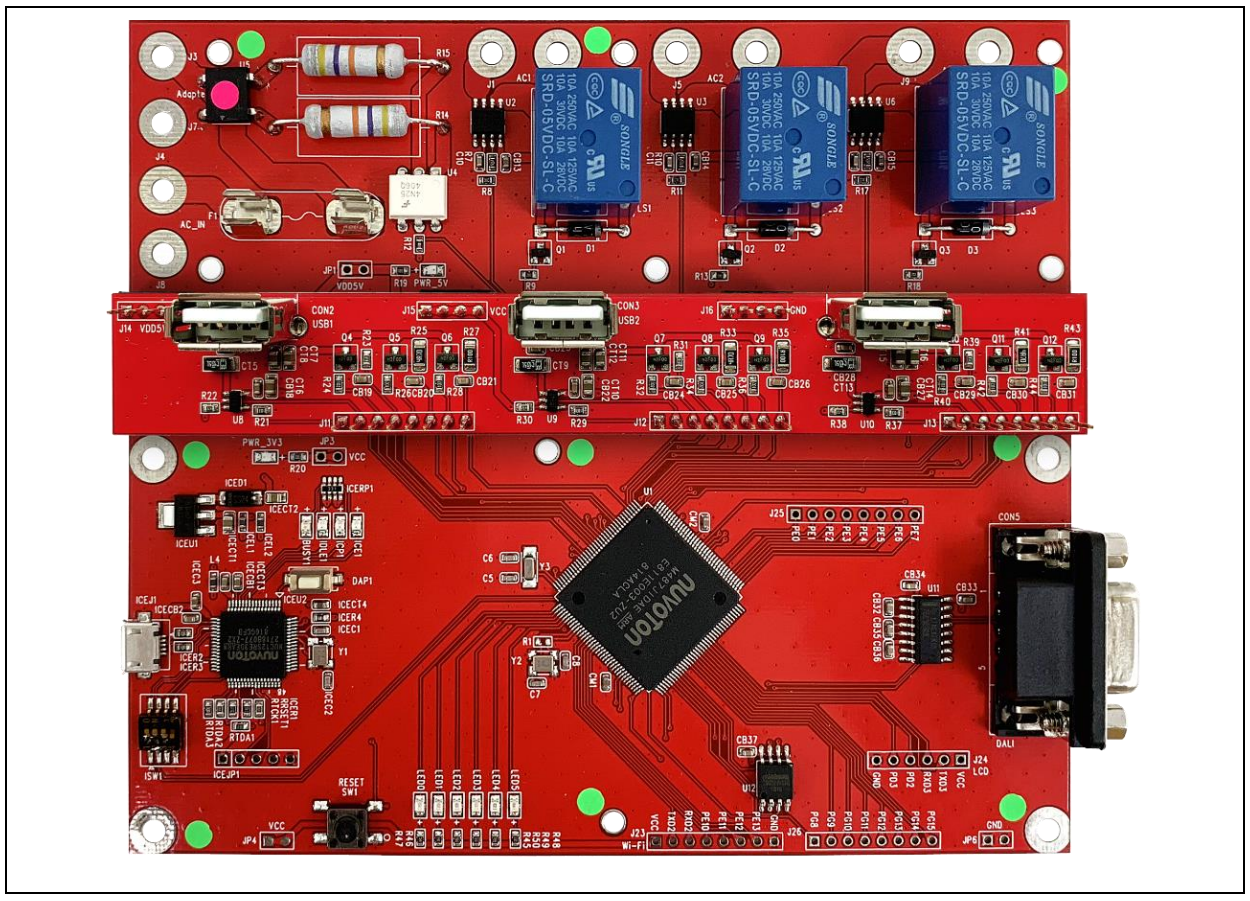

Figure 1-7 M487 Smart Power Board

1.1.3 DALI Master and Slave Boards

The DALI combination board that consists of a DALI master board and a DALI slave board is a slave device in M487 Intelligent Power Station system. It always receives the command passing through the UART interface of M487 Smart Power board from the HMI input of the NuMaker-emWin-M487D board to control the lux and fade-out time of light on the DALI slave board.

Figure 1-8 shows the combination board that combines a DALI master board with a DALI slave board and these two boards meet the DALI 2.0 specification.

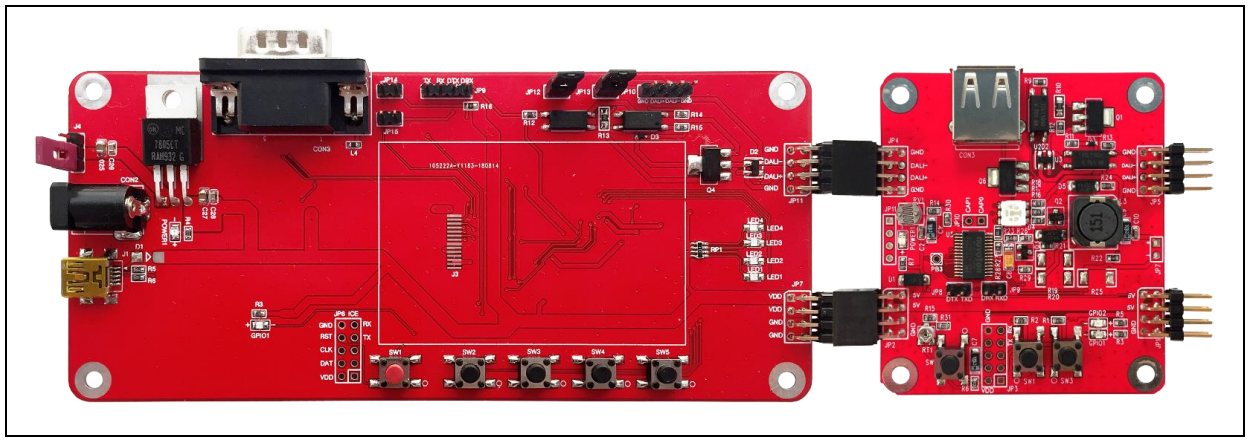

Figure 1-8 DALI Master and Slave Boards

1.1.4 NuMaker-IoT-M487 Board and NuTFT-SPI_320x240 Daughter Board

The NuMaker-IoT-M487 board is also based on M487JIDAE MCU chip to implement the rich Internet-of-Thing (IoT) applications. In this M487 Intelligent Power Station application, the firmware on the embedded flash of M487 chip has been implemented a speech recognition algorithm with machine learning. The firmware transfers the speech command based on some fixed key words to the NuMaker-emWin-M487D board thru the Wi-Fi module (UART interface) and UART interface of M487 Smart Power board. After speech recognition completed, the TFT LCD of the NuTFT-SPI_320x240 daughter board shows the digit number the result of speech recognition from M487 MCU through the SPI interface.

Figure 1-9 shows the combined picture of NuMaker-IoT-M487 V1.2 board and the NuTFT-SPI_320x240 V1.3 daughter board.

Figure 1-9 NuMaker-IoT-M487 Board and NuTFT-SPI_320x240 Daughter Board

1.2 UART Protocol between Boards

Figure 1-10 shows the function block diagram of Intelligent Power Station. There are four main boards to structure this demonstration system.

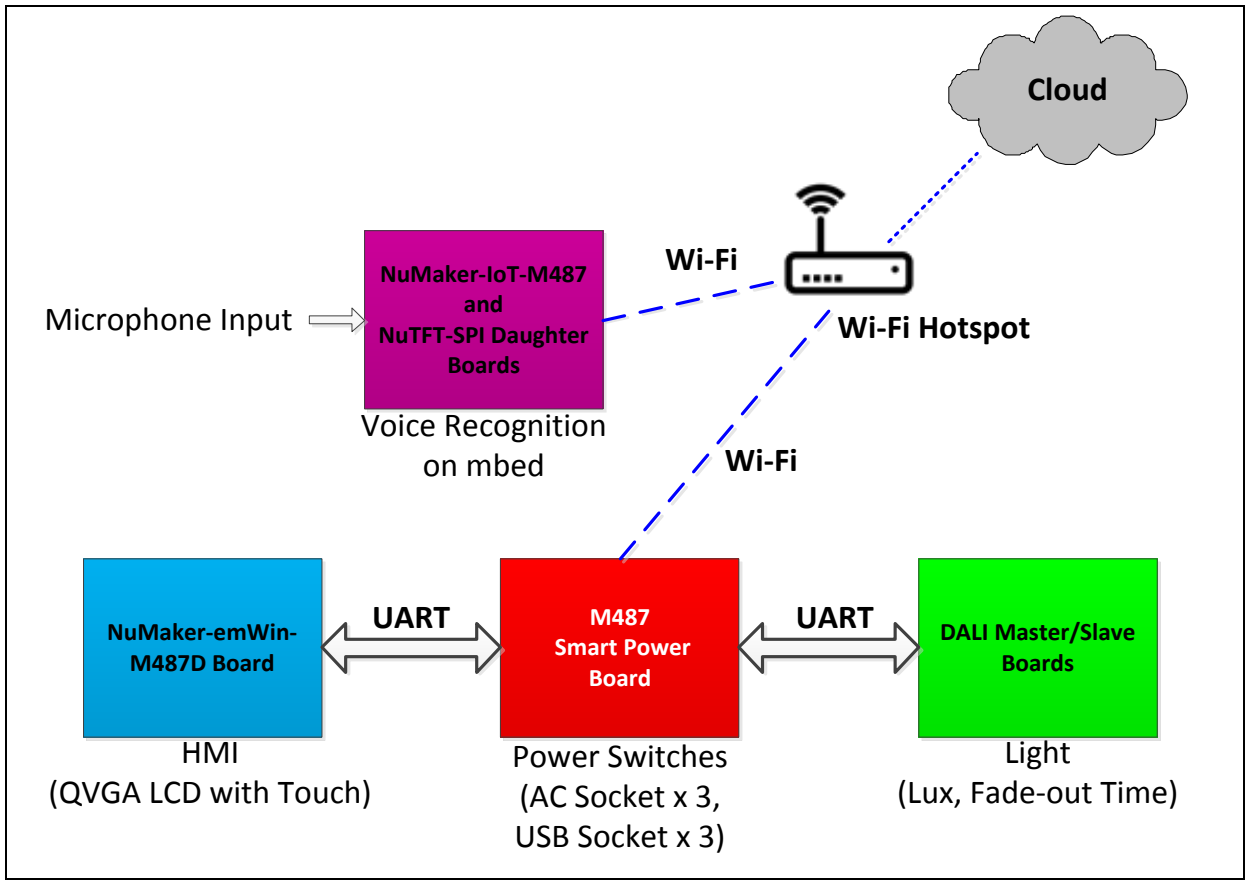

Figure 1-10 Block Diagram of Intelligent Power Station

1.2.1 Communication Protocols

Between these four boards, it uses the UART interface and Wi-Fi module (also based on UART interface) to link each board as listed below. The UART protocol format is (115200, N, 8, 1) that it means the baud-rate is 115200, non-parity check, 8-bit data and 1-bit stop.

- NuMaker-IoT-M487 Board (Master) ← Wi-Fi and AP → M487 Smart Power Board (Slave)
- NuMaker-emWin-M487D Board (Master) ← UART → M487 Smart Power Board (Slave)
- M487 Smart Power Board (Master) ← UART → DALI Master Board (Slave)

1.2.2 UART Packet Format

The length of UART packet is seven bytes and the format is listed below.

- Leading Code : '@' (one byte)
- Command Code (one byte)
  - SET_ON/OFF (0x00)
  - GET_CURRENT (0x11)
  - GET_POWER_CONSUMPTION (0x12)
- Parameters or Responses (four bytes)
- Checksum (one byte, without leading code)

1.2.3 UART Command and Status Packets

There are three commands in the UART communication protocols. The command code is the second byte in the UART packet format.

- Command Code 0x00 : SET_ON/OFF
  - Parameter:
    - Parameter1: Socket number (0~2 for AC, 3~5 DC/USB, 6 for DALI)
    - Parameter2: Action (0: Off, 1:On, 2:Toggle)
      - The Toggle command is generated by the speech recognition on the NuMaker-IoT-M487 board through the Wi-Fi. The M487 Smart Power board receives this Toggle command from the Wi-Fi and then passes it to NuMaker-emWin-M487D board to arbitrate the final command with the HMI input.
    - Parameter3: 0x00 ~ 0xFF (Lux only for DALI)
    - Parameter4: 0x00 ~ 0x0F (Fade-out time only for DALI)
  - Response:
    - Response1: Socket number (0~2 for AC, 3~5 for DC/USB, 6 for DALI)
    - Response2: On/Off Status (0: Off, 1:On, FF: Not connected with DALI)
    - Response3: 0x00 ~ 0xFF (Lux only for DALI)
    - Response4: 0x00 ~ 0x0F (Fade-out time only for DALI)

- Command Code 0x11 : GET_CURRENT
  - Parameter:
    - Parameter1: Socket number (0~2 for AC, 3~5 for DC/USB)
    - Parameter2: 0x00
    - Parameter3: 0x00
    - Parameter4: 0x00
  - Response:
    - Response1: Socket number (0~2 for AC, 3~5 for DC/USB)

- Response2: Unit (0: uA, 1: mA, 2: A)
  - AC current only supports in mA and A units.
  - DC/USB current only supports in uA and mA units.
- Response3: Low byte of current
- Response4: High byte of current
  - AC Current:
    - Current value x 1 in mA unit.
    - Current value x 16 in A unit.
  - DC/USB Current:
    - Current value x 1 in both uA and mA units.

- Command Code 0x12 : GET_POWER_CONSUMPTION
  - Parameter:
    - Parameter1: Socket number (0~2 for AC, 3~5 for DC/USB)
    - Parameter2: 0x00
    - Parameter3: 0x00
    - Parameter4: 0x00
  - Response:
    - Response1: Socket number (0~2 for AC, 3~5 for DC/USB)
    - Response2: Unit (0: mWHr, 1: WHr, 2: KWHr)
    - Response3: Low byte of power consumption
    - Response4: High byte of power consumption
      - Note: The power consumption value x 50 in both mWHr and WHr units for AC and DC/USB socket.

1.3 Setup Flows of Intelligent Power Station Demonstration

The setup flows of Intelligent Power Station demonstration are listed below.

- Open the Wi-Fi hotspot that set as the following.
  - SSID name: 'MB'
  - Password: '035770066'
- Plug-in the plug of Intelligent Power Station case to the AC power socket on the wall and power on the NuMaker-IoT-M487 board for speech recognition input.
- Check the LED status from flashing (connecting) to always-on (ready) on the Intelligent Power Station case that shown as the following Figure 1-11. When the green Wi-Fi LED is flashing, it means that the Wi-Fi module inside the Intelligent Power Station is trying to connect with the hotspot. When the green Wi-Fi LED is always ON, it means that the Wi-Fi has connected with hotspot and this Intelligent Power Station is ready to receive the speech recognition command from the NuMaker-IoT-M487 board through the Wi-Fi.

Figure 1-11 Wi-Fi LED on Intelligent Power Station Case

- Check the LED status on the NuMaker-IoT-M487 board that shown as the following Figure 1-12. When the red LED is flashing, it means that the Wi-Fi module is trying to connect with the hotspot. When the green LED is flashing, it means that the Wi-Fi has connected with the hotspot and this firmware of M487 chip on this board is ready for speech recognition application. When the yellow LED is at OFF state, it means that this board is ready to receive the speech from the microphone input. When the yellow LED is flashing, it means that this firmware of speech recognition is running.

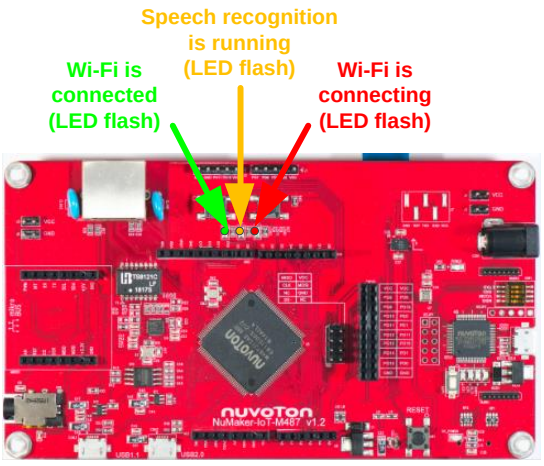

Figure 1-12 Indicated LED on NuMaker-IoT-M487 Board

- HMI touch input on the TFT LCD screen of Intelligent Power Station or microphone input for speech recognition on the NuMaker-IoT-M487 board to control the power switch ON or OFF of AC or DC/USB socket.
- Monitor the current and power consumption of the turned-on socket on TFT LCD screen.
- Monitor the current, power consumption and ON/OFF status of AC and DC/USB sockets on APP of the remote cellphone.

1.4 Resource Information

For the hardware and software packages, user has to visit the Applications page on Nuvoton website as the following Figure 1-13 shown to download the related resources and documents about the M487 Intelligent Power Station application.

https://www.nuvoton.com/hq/?__locale=en#

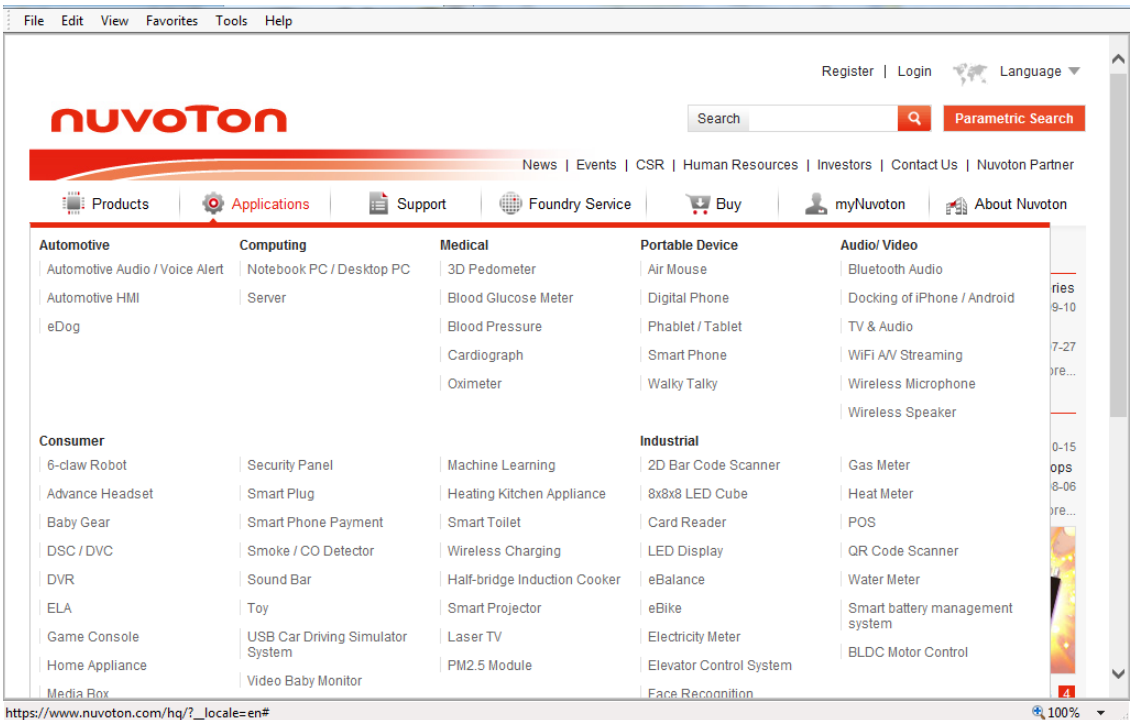

Figure 1-13 Applications on Nuvoton Website

In the downloaded software package, use can find the related example source codes for this M487 Intelligent Power Station as the following Figure 1-14 shown.

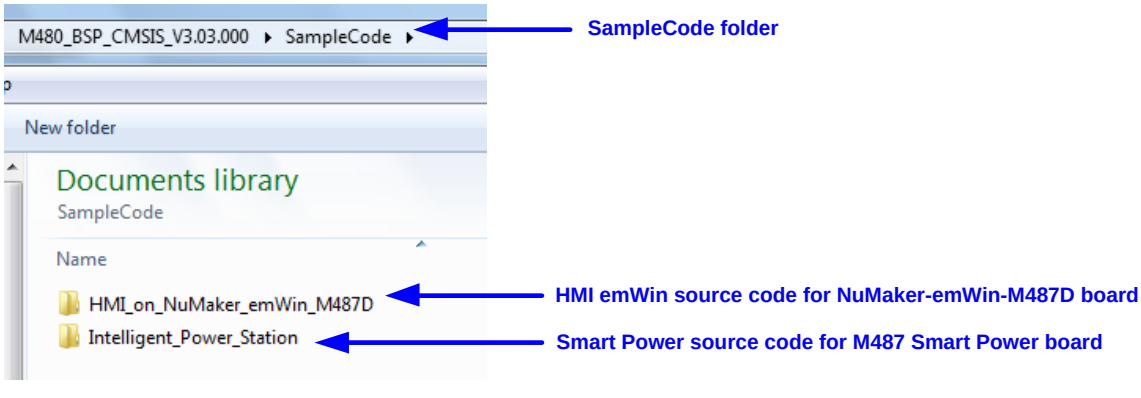

Figure 1-14 Software Package

2 NUMAKER-EMWIN-M487D BOARD

2.1 NuMaker-emWin-M487D Board Overview

The NuMaker-emWin-M487D board consists of a NuMaker-PFM-M487 (Ver 3.0) main board and a NuMaker M487 Advance (Ver 4.0) daughter board. This board provides user the development hardware board based on M487 MCU chip (M487JIDAE) to implement some dedicated applications, especially for the NuMaker emWin GUI display and HMI function on TFT LCD screen with touch input.

Figure 2-1 shows the NuMaker-emWin-M487D board that combined from a NuMaker-PFM-M487 main board (bottom) and NuMaker M487 Advance daughter board (top).

Figure 2-1 NuMaker-emWin-M487D Board

For more detailed information about the NuMaker-emWin-M487D board, please visit Nuvoton NuMicro Family ARM® Cortex® -M4 MCUs website to get the related User Manual document.

https://www.nuvoton.com/hq/products/microcontrollers/arm-cortex-m4-mcus/m487-ethernet-series/User-Manual/?__locale=en&resourcePage=Y

2.2 Human-Machine Interface (HMI)

In this M487 Intelligent Power Station application, the firmware had been implemented with Human-Machine Interface (HMI) function based on the emWin engine and the binary code also had been programmed into the embedded flash of M487 chip on the NuMaker-emWin-M487D board.

Through this HMI interface, users can control the power switches to turn on or turn off the power on these AC sockets and USB/DC sockets on M487 Smart Power board by touch finger input on TFT LCD screen. On the other hand, the real-time current and power consumption of each be turned-on socket are displayed on the TFT LCD screen and the On/Off status also shown on LED.

2.2.1 Boot Animation

For each time, user plugs the AC plug into the AC power socket on the wall to power-on the M487 Power Station case and user will see a boot animation displayed on the TFT LCD screen about three seconds. Figure 2-2 shows the boot animation displayed from some nuvonTon GIF files.

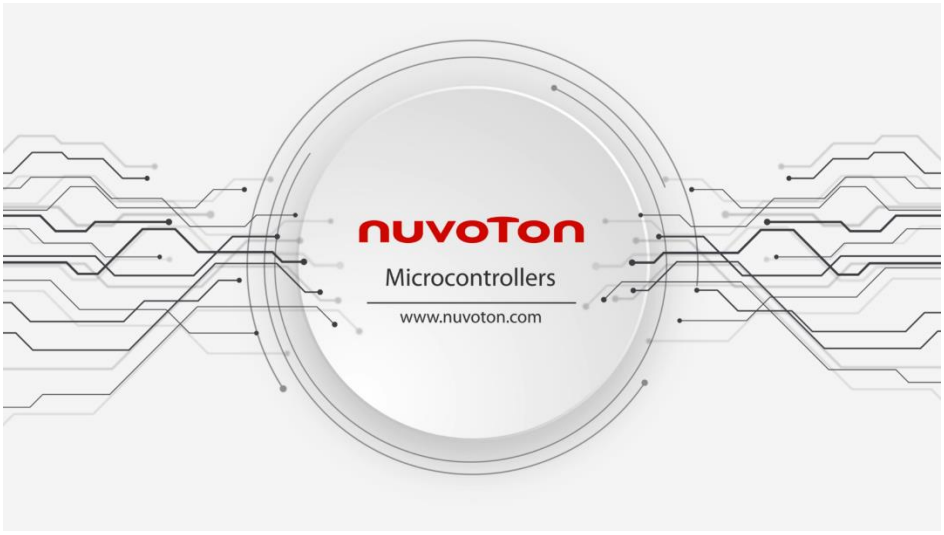

Figure 2-2 Boot Animation

2.2.2 Main Screen

After the ending of boot animation, the following is the Main screen displayed on the TFT LCD screen. The Main screen shows four function icons including Power, DALI, Cam (Camera) and Music as the Figure 2-3 shown.

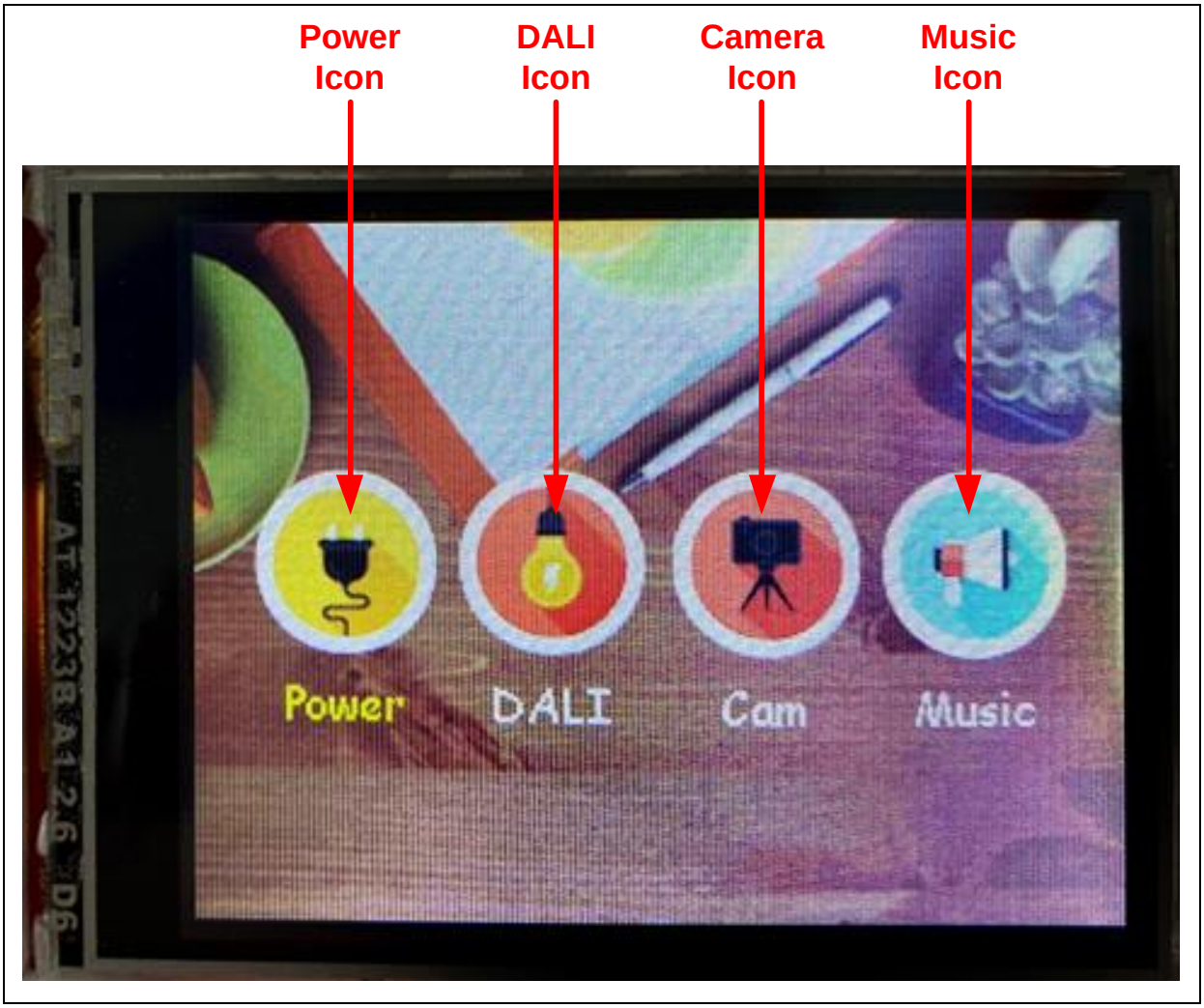

Figure 2-3 Main Screen

2.2.3 Socket Screen

After pressed the Power icon on the Main screen, the HMI emWin will enter the Socket screen and user can choose which socket will be controlled or monitored in the M487 Intelligent Power Station. The M487 Intelligent Power Station provides user three AC sockets and three USB/DC sockets to control.

When a power switch of socket is turned-on by user, the color of socket icon will be change from gray to red. On the contrary, the gray socket icon means the power switch of this socket is on OFF state. At the bottom-right corner, it is a Return icon for user to return the last screen. Figure 2-4 shows the Socket Screen that both AC1 socket and DC2/USB2 socket are on ON status.

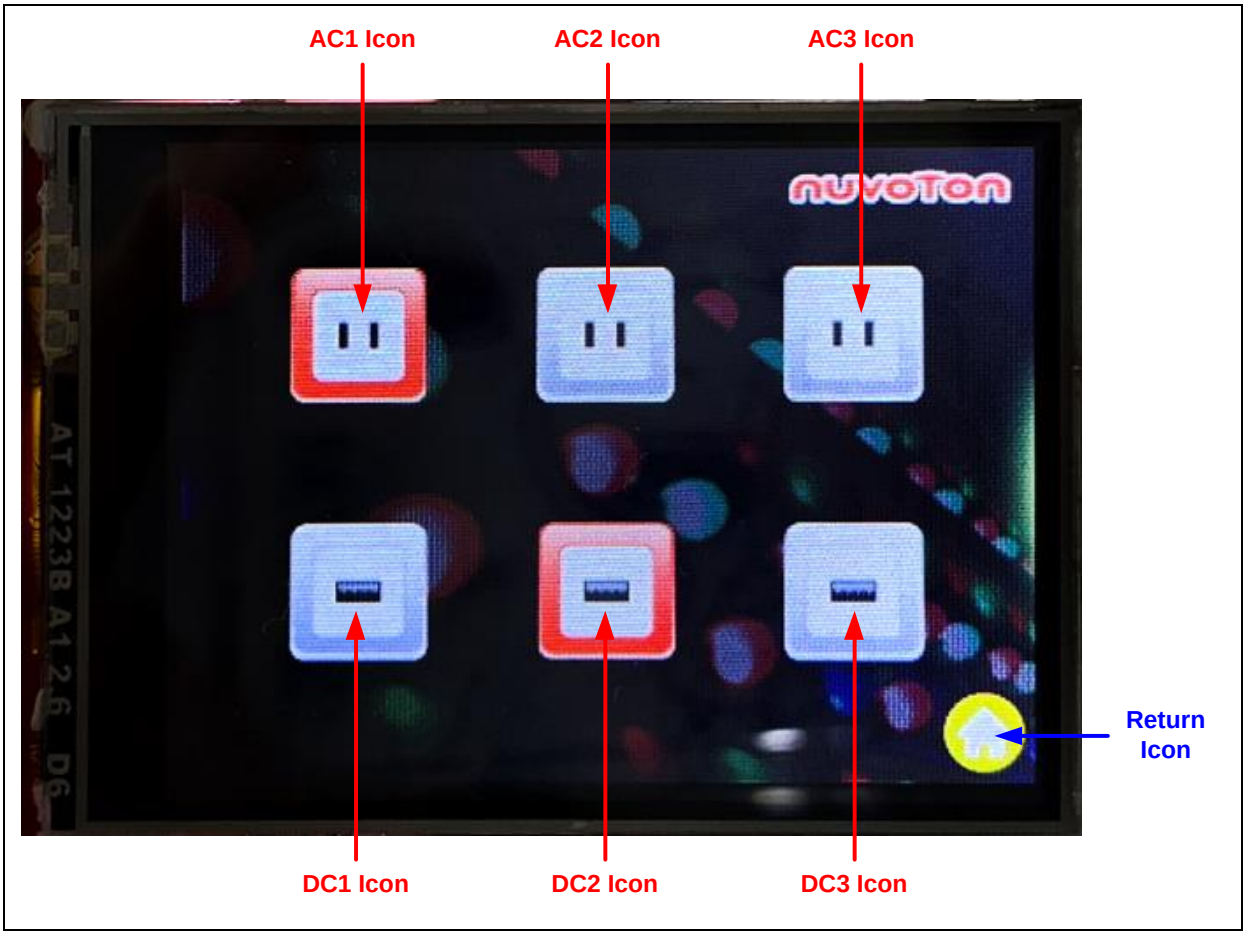

Figure 2-4 Socket Screen (Ex. AC1 and DC2/USB2 Sockets are ON)

2.2.4 Power Screen

After pressed one of socket icons on the Socket screen, the HMI emWin will enter its Power screen. There are three pages in the Power screen for each AC and DC/USB socket. These three pages are the Timer page, Current page and Cost page for user to control or monitor the power switch of socket.

2.2.4.1 Timer Page

At the top-left corner of this Timer page, user can see which socket is setting now. At the left side of this screen, user can turn on or turn off this selected socket by switching the ON/OFF icon. User also can set the turn-on time on minute and second by scrolling the wheel at the right side of this screen. For example, if user scrolls the minute wheel at 1 and then presses the ON icon, the power switch of socket will be turned on instantly and be turned off automatically after one minute. If both of minute and second are set at zero, it means the power switch of socket is always on while the socket is turned on. Figure 2-5 shows the Timer page for AC1 socket.

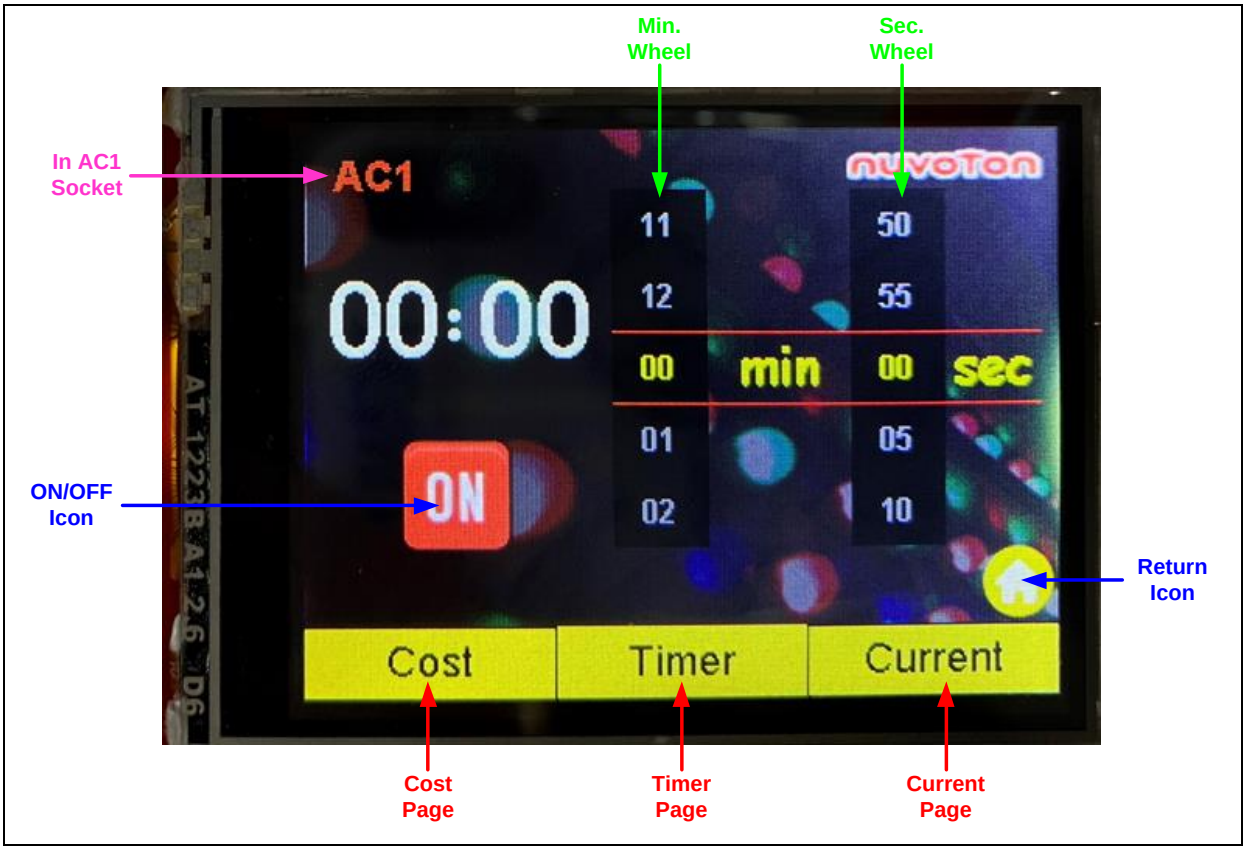

Figure 2-5 Timer Page

2.2.4.2 Current Page

On this Current page, user can monitor the real-time current that passing through this socket. If the socket is not turned on, the pointer will be kept at the 0 position. Figure 2-6 shows the Current page for AC1 socket.

Figure 2-6 Current Page

2.2.4.3 Cost Page

On this Cost page, user can see how long has this socket been turned on and this socket's total power consumption if this socket is turned on. Figure 2-7 shows the Cost page for AC1 socket.

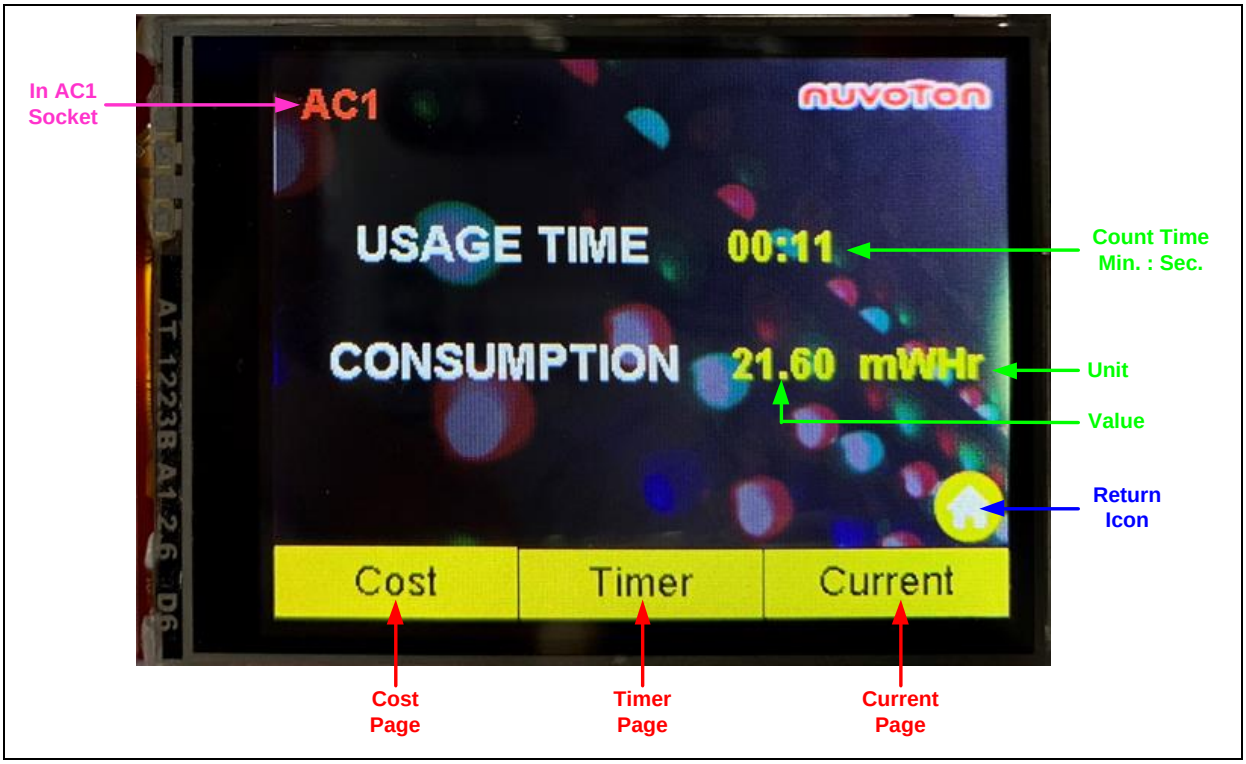

Figure 2-7 Cost Page

2.2.5 DALI Screen

After user pressed the DALI icon on the Main screen, the HMI emWin will enter the DALI screen as the following Figure 2-8. At the top-right corner of DALI screen, it shows the status whether a DALI master board has connected with this Intelligent Power Station. If a DALI master board does not connect with this Intelligent Power Station by an UART cable, the color of status will change to red. On the contrary, if a DALI master board has connected with this Intelligent Power Station by an UART cable, the color of status will change to green.

At the bottom-middle side of this screen, user can turn on or turn off the light on the DALI slave board by switching the ON/OFF icon.

The slider at the left side is for user to control the fade-out time of light on the DALI slave board. There are total 16 levels from zero to fifteen. The lesser the value means the fade-out time is shorter. At the right side of this screen, user can see an arc-slider and two +/- icons that can control the brightness (0 to 255) of light on the DALI slave board by sliding the arc-slider or by pressing the + or - icon. The greater the value means the brighter on the light. The fade-out time and brightness of the light can be adjusted immediately when the ON/OFF icon is in ON state. The DALI screen is as Figure 2-8 shown.

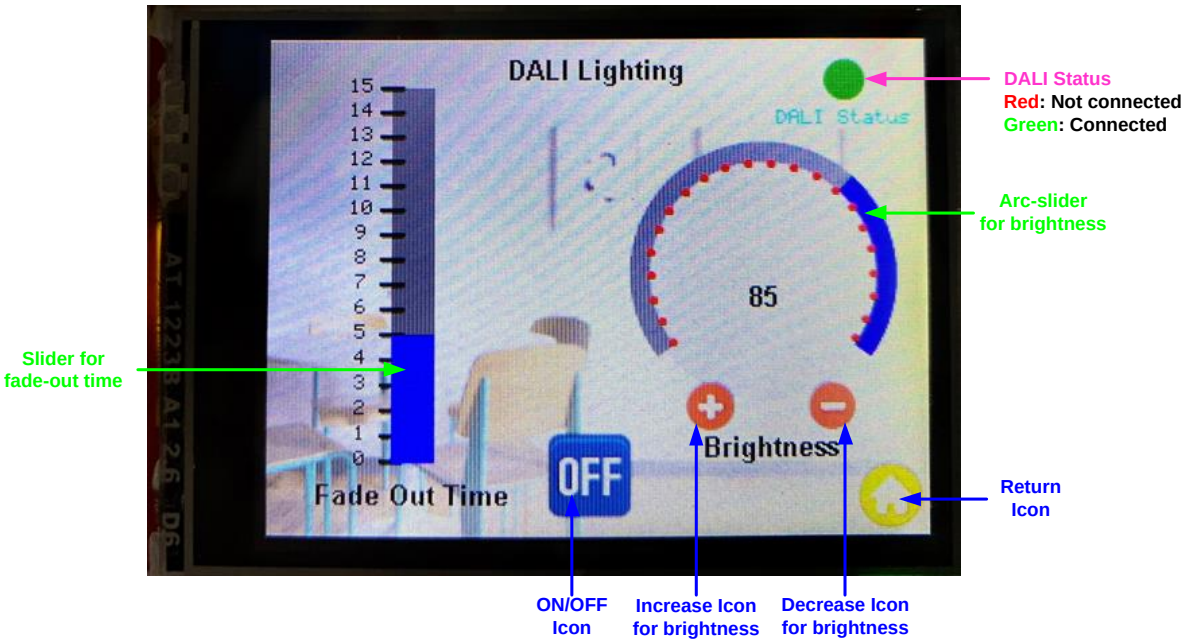

Figure 2-8 DALI Screen

2.2.6 Music Screen

After user pressed the Music icon on the Main screen, it will replay the nuvoTon GIF files on the TFT LCD screen as the following Figure 2-9 and then return to the Main screen.

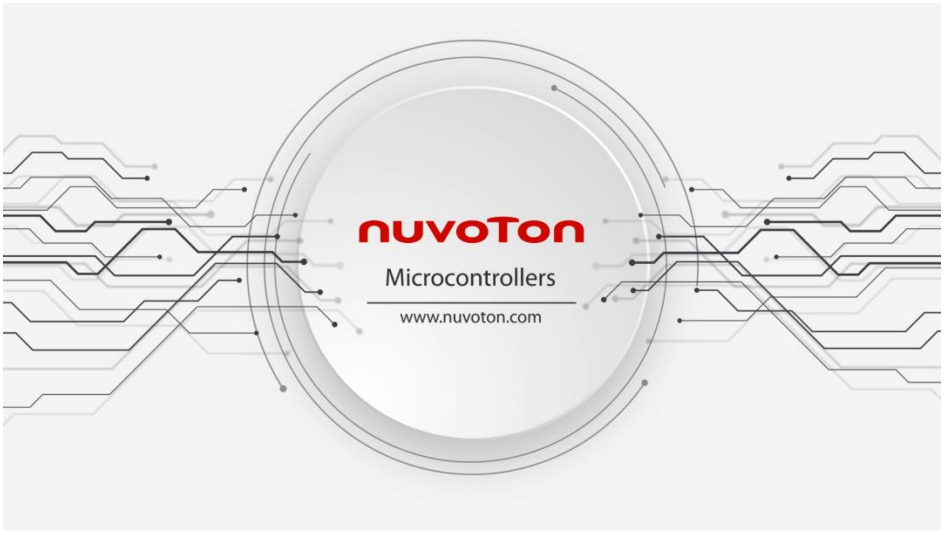

Figure 2-9 Nuvoton GIF Files Replaying

3 NUMAKER-IOT-M487 AND NUTFT-SPI_320X240 DAUGHTER BOARDS

3.1 Board Overview

3.1.1 NuMaker-IoT-M487 Board

The NuMaker-IoT-M487 is a development board using Nuvoton M487JIDAE MCU which includes Arm® Cortex® -M4 core and rich peripherals. It also has environmental sensor, motion sensor and Wi-Fi connectivity on board as well as plenty of reference materials to let user to quickly develop IoT device applications.

Furthermore, the board provides several interface and connectors for expansion. There are Arduino Uno compatible interface, mikroBUS™ interface, NuMaker Brick I²C connector, and specific I/O connector to simulate, for example, image sensor interface. Not only can various Arduino or mikroBUS™ daughter boards be used directly, but it also is convenient for users to connect other required components.

Figure 3-1 shows the NuMaker-IoT-M487 board and its components.

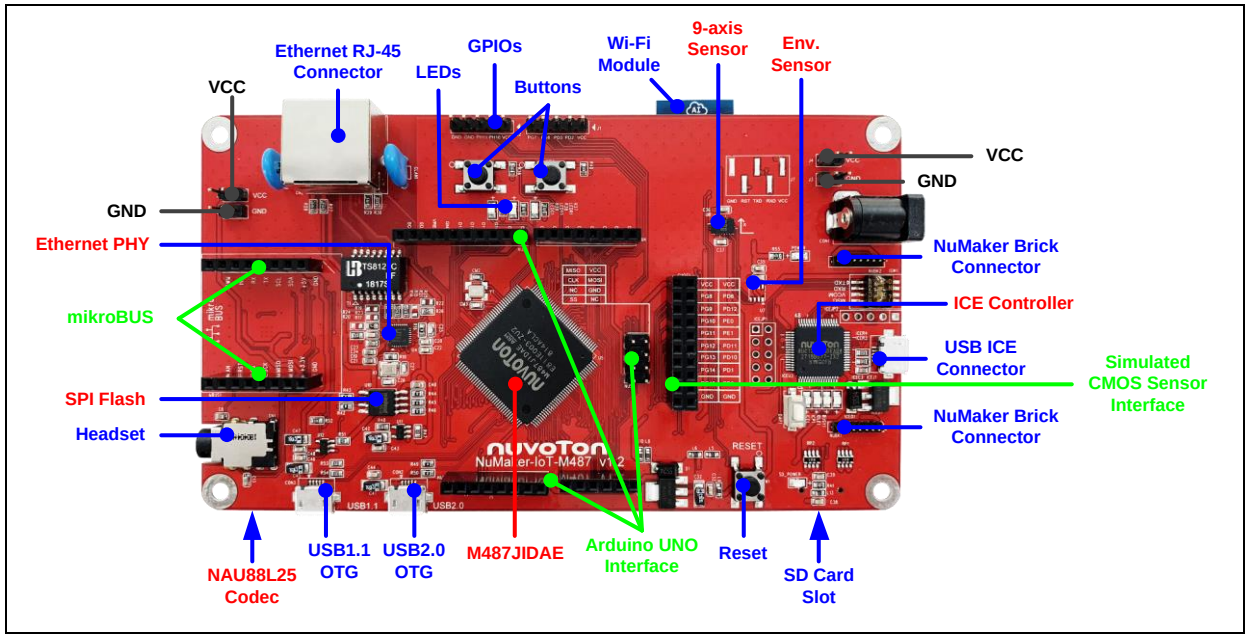

Figure 3-1 NuMaker-IoT-M487 Board

For more detailed information about the NuMaker-IoT-M487 board, please visit Nuvoton NuMicro Family ARM® Cortex® -M4 MCUs website to get the related User Manual document.

https://www.nuvoton.com/hq/products/microcontrollers/arm-cortex-m4-mcus/m487-ethernet-series/User-Manual/?__locale=en&resourcePage=Y

3.1.2 NuTFT-SPI_320x240 Daughter Board

This daughter board has a QVGA (320x240 pixels) TFT LCD module and use SPI interface that connected with MCU to control it for display. Figure 3-2 shows the NuTFT-SPI_320x240 daughter board.

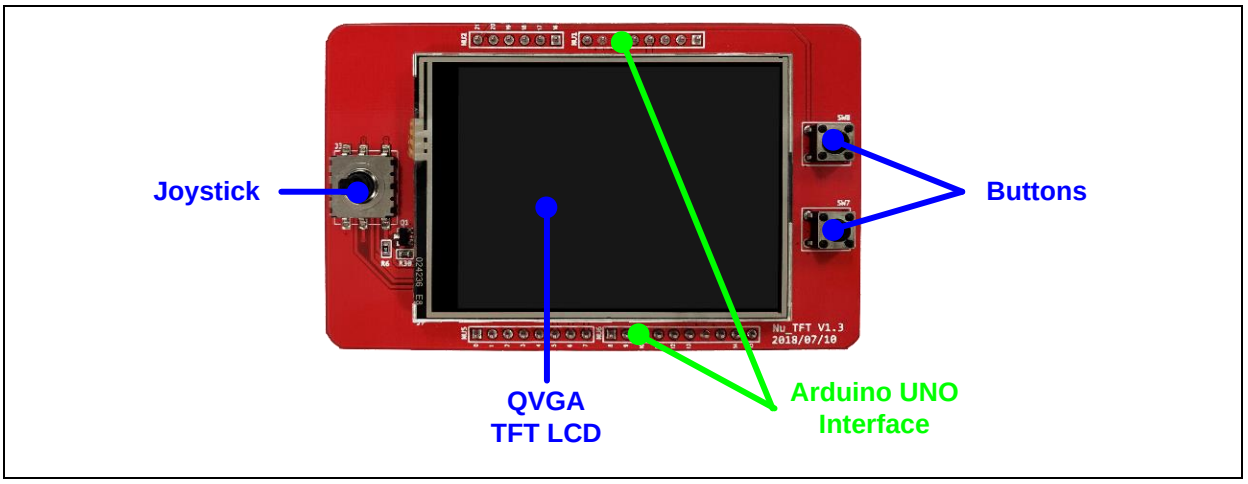

Figure 3-2 NuTFT-SPI_320x240 Daughter Board

For more detailed information about the NuTFT-SPI_320x240 daughter board, please visit Nuvoton NuMicro Family ARM® Cortex® -M0 MCUs website to get the related hardware information and User Manual document.

https://www.nuvoton.com/hq/products/iot-solution/emwin-platform/emwin-platform/numaker-emwin-nuc126/index.html?__locale=en

The Table 3-1 lists the dedicated GPIO pins of M487 chip on NuMaker-IoT-M487 board that used to connect with the TFT LCD module on the NuTFT-SPI_320x240 daughter board for displaying.

Table 3-1 GPIO Pins of M487 Chip Connected with NuTFT-SPI_320x240 Daughter Board

LCM Interface	LCM Function	M487 Chip	
		GPIO	GPIO Mode
LCM_SPI_SS	LCM SPI chip select	PA.11 (SPI2)	Output
LCM_SPI_CLK	LCM SPI clock	PA.10 (SPI2)	Output
LCM_SPI_MISO	LCM SPI data output	PA.9 (SPI2)	Input
LCM_SPI_MOSI	LCM SPI data input	PA.8 (SPI2)	Output
LCM_DC	LCM command or data	PB.2	Output
LCM_RESET	LCM reset	PB.3	Output
LCM_LED	LCM backlight	PE.5	Output

3.2 Speech Recognition

The speech recognition is based on machine learning. A complete deep learning speech recognition system requires two platforms. As Figure 3-3 shows, one is PC platform. We program the deep learning code and train the model by Tensorflow and Python. Due to the supervised learning for the training mode, it is necessary to give the system a large amount of training data and labels. Then extract the features of speech data and train the model by deep neural networks (DNN). Until the system reaches the optimization, we evaluate the accuracy by modifying the training model repeatedly. The other platform is NuMaker-IoT-M487. The speech recognition system can be implemented based on the training parameters from PC platform.

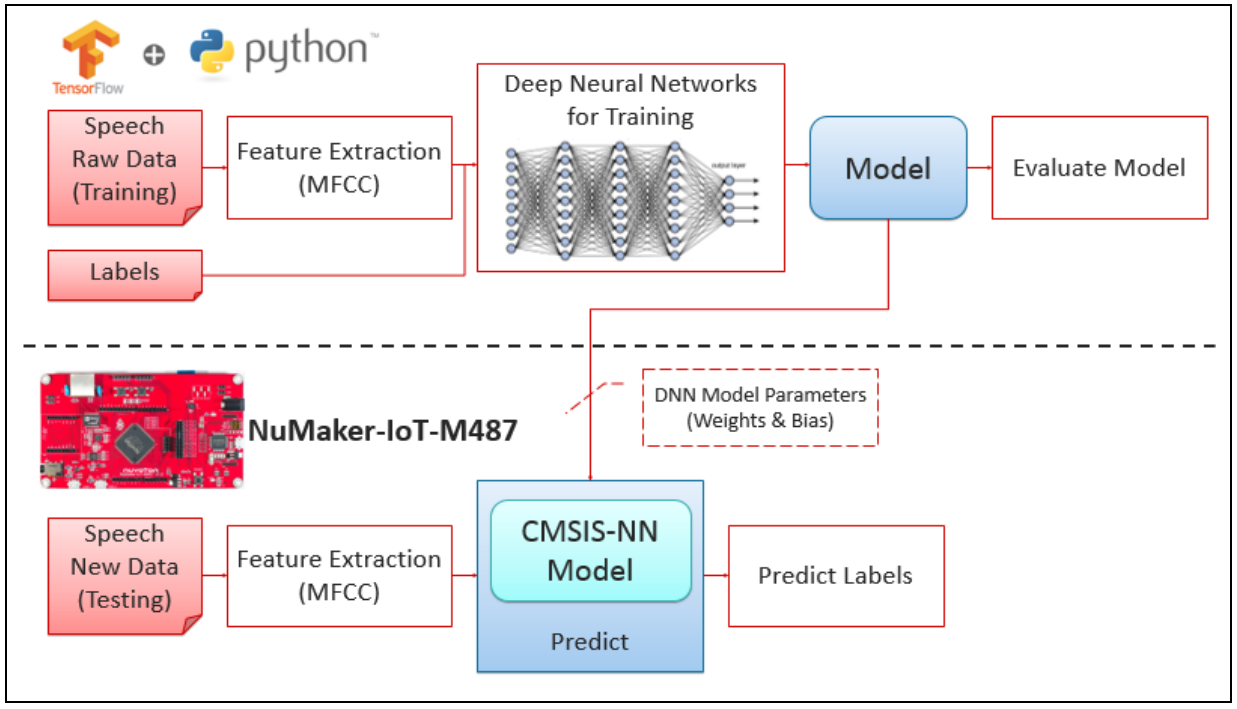

Figure 3-3 The Flow of Speech Recognition

There are ten English digits used for this recognition scheme: One, Two, Three, Four, Five, Six, Seven, Eight, Nine and Zero. The NuMaker-IoT-M487 and the Nu TFT LCD GUI development platforms are utilized in the speech recognition system. When the user says “One” to the microphone, the number “1” will be shown on the LCD panel by identifying the keyword correctly. And the number command will be transferred to the M487 Intelligent Power Station via Wi-Fi to toggle the power switches of the AC sockets (number 1~3) or DC/USB sockets (number 4~6).

For more detailed information about the speech recognition reference design, please visit Nuvoton NuMicro Family ARM® Cortex® -M4 MCUs website to get the related application note document and sample code.

https://www.nuvoton.com/hq/resource-download.jsp?tp_GUID=EC0120180911100446

4 M487 SMART POWER BOARD

4.1 M487 Smart Power Board Overview

This M487 Smart Power (V1.1) board consists of a main board and a daughter board.

The main board controls and supplies the AC power for the AC power sockets and supplies a stable DC 5V power thru an AC-DC5V adaptor for the system. This board also uses a M487JIDAE chip as microcontroller to control the whole operations on this system. The M487 MCU controls the relay switches for the AC power sockets and measures the currents from the current sensors that monitoring on these AC power sockets by 3-channel ADC inputs of MCU.

The daughter board consists of three sets of MOSFET devices and three USB type-A sockets. The M487 MCU also controls the USB switch devices to supply the DC 5V for these USB type-A sockets and switches the MOSFET devices to measure the currents that passing through these sockets by 9-channel ADC inputs of MCU. These control signals and ADC channels come are connected with the main board thru three connectors.

Figure 4-1 shows the M487 Smart Power (V1.1) board that combined from a main board (bottom) and a daughter board (top).

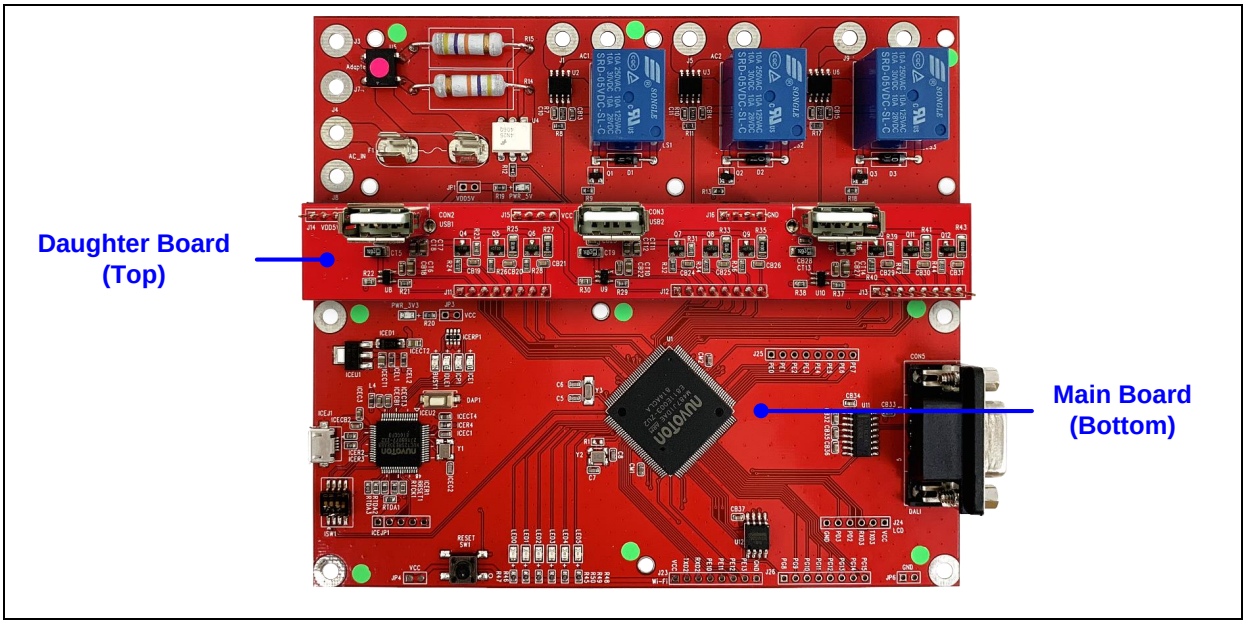

Figure 4-1 M487 Smart Power Board

4.2 M487 Smart Power Board Features

- Main board
  - M487JIDAE MCU (512KB flash, 160KB SRAM).
  - Nu-Link-Me ICE bridge circuit to download the firmware binary code or to trace the source code in debug mode. It also provides the USB VCOM function to show debugging messages that depended by user.
  - One DC power jack for an AC-DC5V adaptor input to supply stable 5V power.
  - Three sets of pair connector pads to connect with three AC power sockets.
  - Three relay (SRD-05VDC-SL-C) devices.
  - Three current sensor (ACS714ELCTR-20A-T) devices.
  - One fuse (20A/250V) to protect the system.
  - Bridge rectifier (DF1510) and phototransistor coupler (4N25) to detect the zero-cross point of AC power.
  - DB9 connector with RS232 Transceiver (TI 75C3232E) for DALI interface.
  - Wi-Fi connector (UART interface) to communicate with NuMaker-IoT-M487 board for speech command input and transmit data to cloud thru the NuMaker-IoT-M487 board.
  - LCD connector (UART interface) to communicate with NuMaker-emWin-M487D board for HMI (Human-Machine Interface).
  - SPI flash (Winbond W25Q32) device for SPIM of MCU to extend the flash memory.
  - Six LEDs
- Daughter board
  - Three USB switch (TPS2065CDBVR-2) devices are controlled by MCU to supply the 5V power to three USB type-A sockets and to detect whether there is an over current on each USB type-A socket.
  - Three sets of MOSFET (SI2302AD) devices. Each set of MOSFET devices can be switched to three different resistor paths by MCU to measure the current that passing through one USB type-A socket.
  - Three USB type-A sockets.

4.3 Front View of Main Board

Figure 4-2 shows the main components and connectors from the front side of the main board on M487 Smart Power board.

The following lists components and connectors from the front view:

- M487JIDAE target chip (U1).
- Nu-Link-Me ICE bridge circuit (ICEU2, ICEJ1) and switches (ISW1) for the USB VCOM function.
- Pair connector pads J4 and J8 are for the AC power input that from the outside of case.
- Pair connector pads J3 and J7 are for the AC power input to AC-DC5V adaptor.
- Pair connector pads J1 and J2, J5 and J6, J9 and J10 are used to connect with AC power sockets.
- 20A/250V Fuse (F1).
- Bridge rectifier DF1510 (U5) and phototransistor coupler 4N25 (U4).
- DC power jack (CON1) is for AC-DC5V adaptor 5V input.
- Relay (SRD-05VDC-SL-C) devices. (LS1, LS2 and LS3)
- Current sensor (ACS714ELCTR-20A-T) devices. (U2, U3 and U6)
- DB9 connector (CON5) with RS232 Transceiver (U11, TI 75C3232E) for DALI application.
- Wi-Fi connector (J23) to communicate with NuMaker-IoT-M487 board for data transaction.
- LCD connector (J24) to communicate with NuMaker-emWin-M487D board for HMI.
- Connector J20 (VDD5V), connector J21 (VCC = 3.3V), connector J22 (GND) and the other three connectors (J17, J18 and J19) are for the combination with the daughter board.
- SPI flash (U12, Winbond W25Q32) device for SPIM.
- Six LEDs. (LED0 ~ LED5)
- Two GPIO connectors. (J25 and J26)

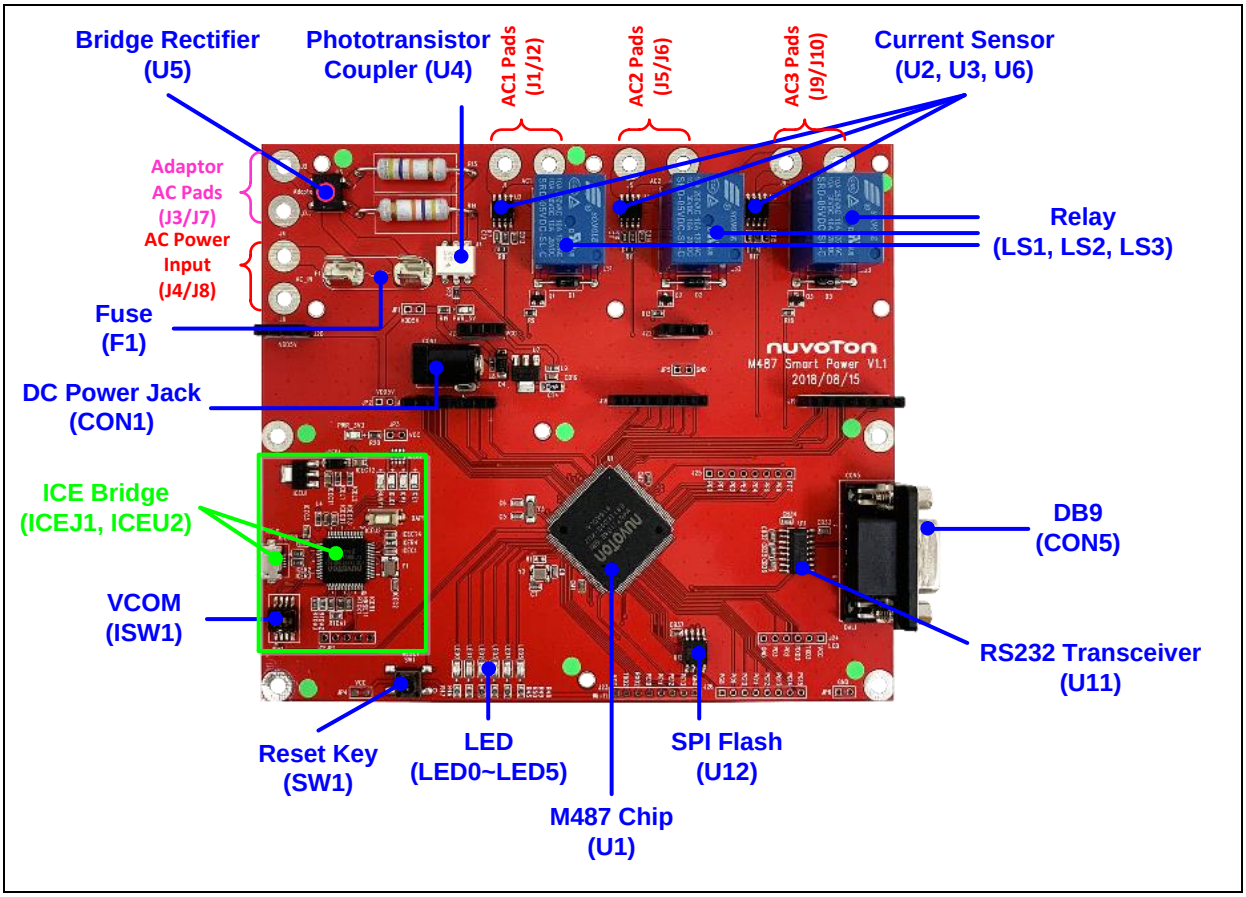

Figure 4-2 Front View of Main Board on M487 Smart Power Board

4.4 Rear View of Main Board

Figure 4-3 shows the rear side of the main board on M487 Smart Power board.

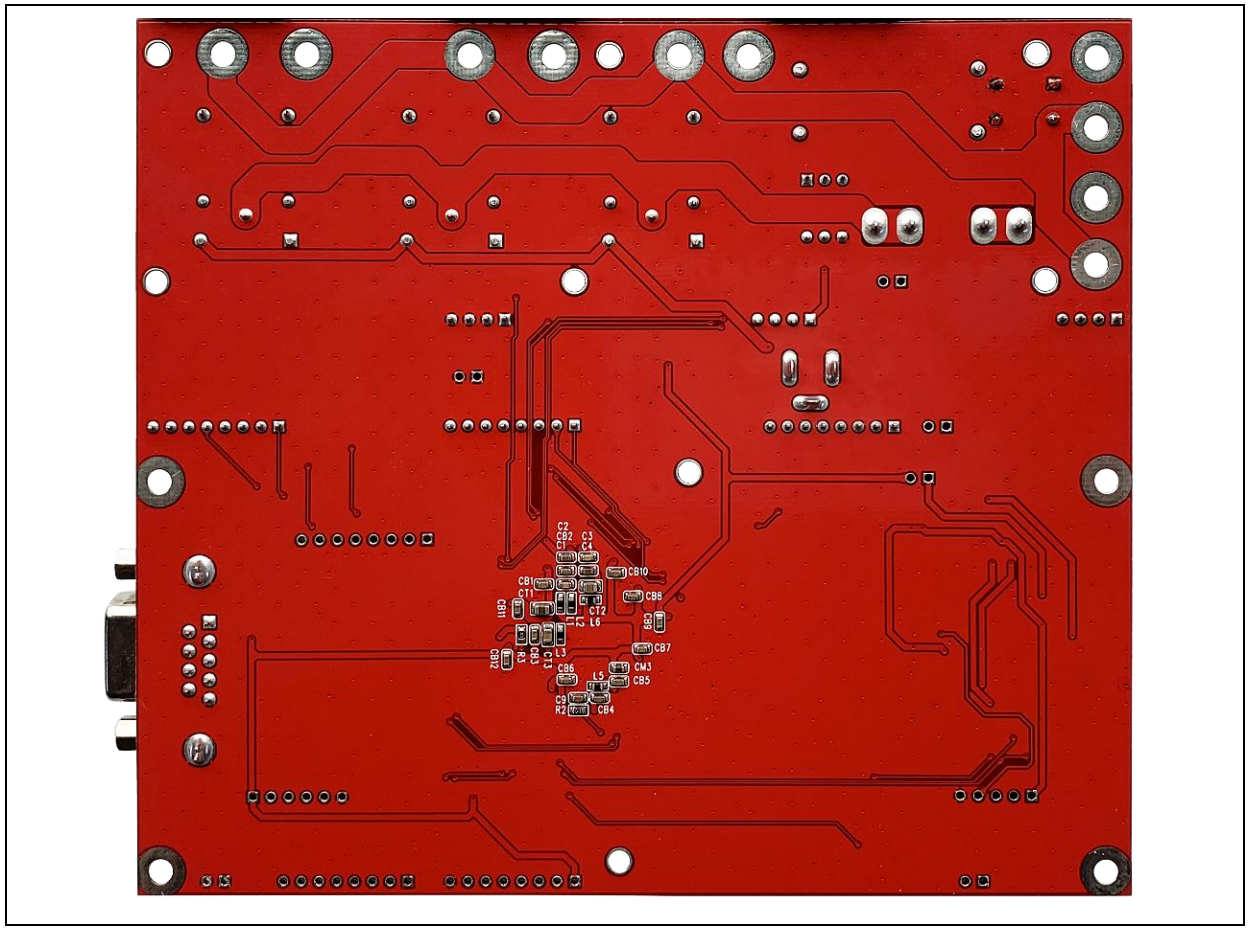

Figure 4-3 Rear View of Main Board on M487 Smart Power Board

4.5 Front View of Daughter Board

Figure 4-4 shows the main components and connectors from the front side of the daughter board on M487 Smart Power board.

The following lists components and connectors from the front view:

- USB switch (TPS2065CDBVR-2) devices. (U8, U9 and U10)
- Three sets of MOSFET (SI2302AD) devices. (Q4/Q5/Q6, Q7/Q8/Q9 and Q10/Q11/Q12)
- Three USB type-A sockets. (CON2, CON3 and CON4)
- Connector J14 (VDD5V), connector J15 (VCC = 3.3V), connector J16 (GND) and the other three connectors (J11, J12 and J13) are for the combination with the main board.

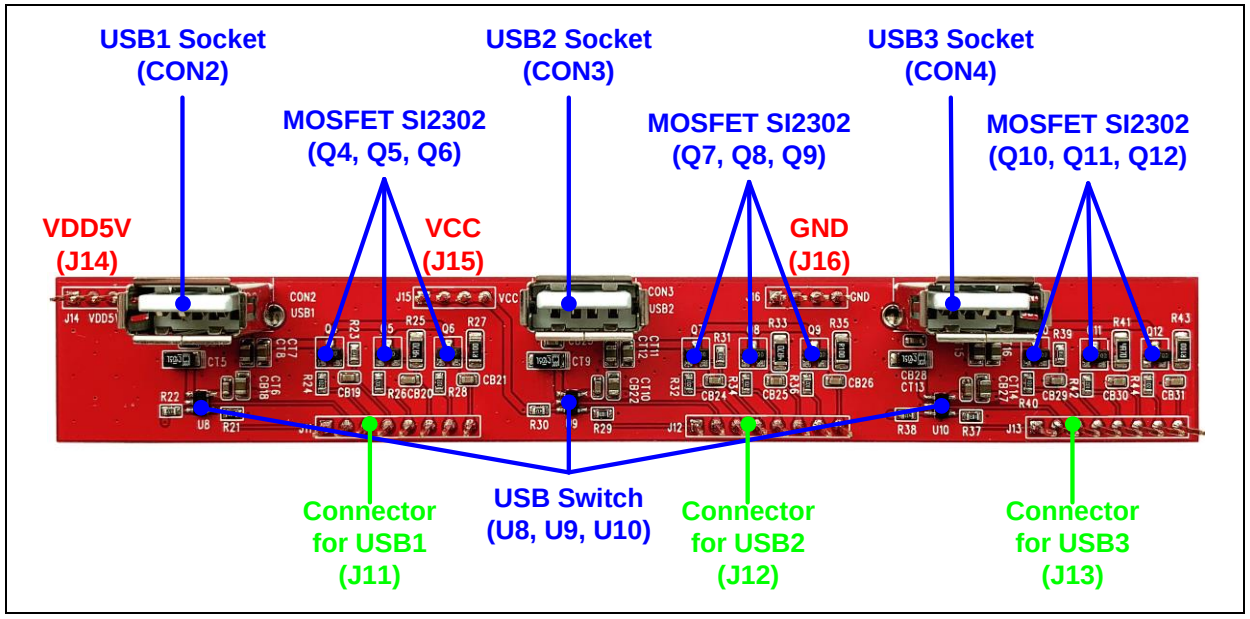

Figure 4-4 Front View of Daughter Board on M487 Smart Power Board

4.6 Rear View of Daughter Board

Figure 4-5 shows the rear side of daughter board on M487 Smart Power board.

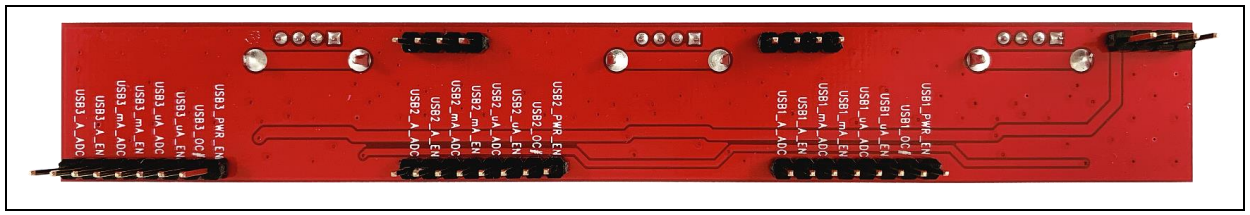

Figure 4-5 Rear View of Daughter Board on M487 Smart Power Board

4.7 The Pin Function of M487 Chip on M487 Smart Power Board

The M487JIDAE chip provides many GPIO pins in LQFP144 package. Each pin has multi-functions that can be configured by user in the firmware. On this M487 Smart Power board, we used and defined a lot of pins that each used pin has a dedicated function for this system application.

The Table 4-1 to Table 4-4 shows the dedicated function tables on each used pin of M487 chip on this M487 Smart Power board.

Table 4-1 Dedicated Function on Pin1~36 of M487 Chip

M487 Chip		M487 Smart Power Board	M487 Chip		M487 Smart Power Board
Pin #	**GPIO**	**Function**	**Pin #**	**GPIO**	**Function**
1	PB.5	USB2_A_ADC (CH5)	19	PD.11	USB1_uA_EN
2	PB.4	USB2_mA_ADC (CH4)	20	PD.10	USB1_PWR_EN
3	PB.3	USB2_uA_ADC (CH3)	21	VSS	GND
4	PB.2	USB1_A_ADC (CH2)	22	VDD	VCC (3.3V)
5	PC.12	USB3_A_EN	23	PG.0	USB1_OC#
6	PC.11	USB3_mA_EN	24	PG.1	USB2_OC#
7	PC.10	USB3_uA_EN	25	PG.2	USB3_OC#
8	PC.9	USB3_PWR_EN	26	PG.3	-
9	PB.1	USB1_mA_ADC (CH1)	27	PG.4	-
10	PB.0	USB1_uA_ADC (CH0)	28	PF.11	-
11	VSS	GND	29	PF.10	-
12	VDD	VCC (3.3V)	30	PF.9	-
13	PA.11	USB2_A_EN	31	PF.8	-
14	PA.10	USB2_mA_EN	32	PF.7	-
15	PA.9	USB2_uA_EN	33	PF.6	-
16	PA.8	USB2_PWR_EN	34	VDD	VCC (3.3V)
17	PC.13	USB1_A_EN	35	PF.5	XT32_I
18	PD.12	USB1_mA_EN	36	PF.4	XT32_OUT-

Table 4-2 Dedicated Function on Pin37~72 of M487 Chip

M487 Chip		M487 Smart Power Board	M487 Chip		M487 Smart Power Board
Pin #	**GPIO**	**Function**	**Pin #**	**GPIO**	**Function**
37	PH.0	LED0	55	PC.8	-
38	PH.1	LED1	56	PC.7	-
39	PH.2	LED2	57	PC.6	-
40	PH.3	LED3	58	PA.7	-
41	PH.4	LED4	59	PA.6	-
42	PH.5	LED5	60	VSS	GND
43	PH.6	-	61	VDD	VCC (3.3V)
44	PH.7	-	62	LDO	LDO_CAP1
45	PF.3	XT1_IN	63	PA.5	-
46	PF.2	XT1_OUT	64	PA.4	-
47	VSS	GND	65	PA.3	UART1_TXD (DALI)
48	VDD	VCC (3.3V)	66	PA.2	UART1_RXD (DALI)
49	PE.8	UART2_TXD (Wi-Fi)	67	PA.1	-
50	PE.9	UART2_RXD (Wi-Fi)	68	PA.0	-
51	PE.10	MCU_PE10	69	VDDIO	VCC (3.3V)
52	PE.11	MCU_PE11	70	PE.14	-
53	PE.12	MCU_PE12	71	PE.15	-
54	PE.13	MCU_PE13	72	nRESET	RESET

Table 4-3 Dedicated Function on Pin73~108 of M487 Chip

M487 Chip		M487 Smart Power Board	M487 Chip		M487 Smart Power Board
Pin #	GPIO	Function	Pin #	GPIO	Function
73	PF.0	ICEDAT	91	PG.15	MCU_PG15
74	PF.1	ICECLK	92	PD.3	MCU_PD3
75	PD.9	-	93	PD.2	MCU_PD2
76	PD.8	-	94	PD.1	UART3_TXD (LCD)
77	PC.5	SPIM_D2	95	PD.0	UART3_RXD (LCD)
78	PC.4	SPIM_D3	96	PD.13	-
79	PC.3	SPIM_SS	97	PA.12	-
80	PC.2	SPIM_CLK	98	PA.13	-
81	PC.1	SPIM_MISO	99	PA.14	-
82	PC.0	SPIM_MOSI	100	PA.15	-
83	VSS	GND	101	HSUSB_VRES	-
84	VDD	VCC (3.3V)	102	HSUSB_VDD33	-
85	PG.9	MCU_PG9	103	HSUSB_VBUS	-
86	PG.10	MCU_PG10	104	HSUSB_D-	-
87	PG.11	MCU_PG11	105	HSUSB_VSS	-
88	PG.12	MCU_PG12	106	HSUSB_D+	-
89	PG.13	MCU_PG13	107	HSUSB_VDD12_CAP	-
90	PG.14	MCU_PG14	108	HSUSB_ID	-

Table 4-4 Dedicated Function on Pin109~144 of M487 Chip

M487 Chip		M487 Smart Power Board	M487 Chip		M487 Smart Power Board
Pin #	GPIO	Function	Pin #	GPIO	Function
109	PE.7	MCU_PE7	127	PG.8	MCU_PG8
110	PE.6	MCU_PE6	128	VSS	GND
111	PE.5	MCU_PE5	129	LDO	LDO_CPA2
112	PE.4	MCU_PE4	130	VDD	VCC (3.3V)
113	PE.3	MCU_PE3	131	PC.14	
114	PE.2	MCU_PE2	132	PB.15	
115	VSS	GND	133	PB.14	
116	VDD	VCC (3.3V)	134	PB.13	UART0_TXD (VCOM)
117	PE.1	MCU_PE1	135	PB.12	UART0_RXD (VCOM)
118	PE.0	MCU_PE0	136	AVDD	VCC (3.3V)
119	PH.8	-	137	VREF	VCC (3.3V)
120	PH.9	-	138	AVSS	ADAVSS
121	PH.10	-	139	PB.11	AC3_ADC (CH11)
122	PH.11	-	140	PB.10	AC2_ADC (CH10)
123	PD.14	ZERO_CROSS	141	PB.9	AC1_ADC (CH9)
124	PG.5	AC1_RLY_EN	142	PB.8	USB3_A_ADC (CH8)
125	PG.6	AC2_RLY_EN	143	PB.7	USB3_mA_ADC (CH7)
126	PG.7	AC3_RLY_EN	144	PB.6	USB3_uA_ADC (CH6)

4.8 PCB Placement

Figure 4-6 shows the front placement of main board of M487 Smart Power board.

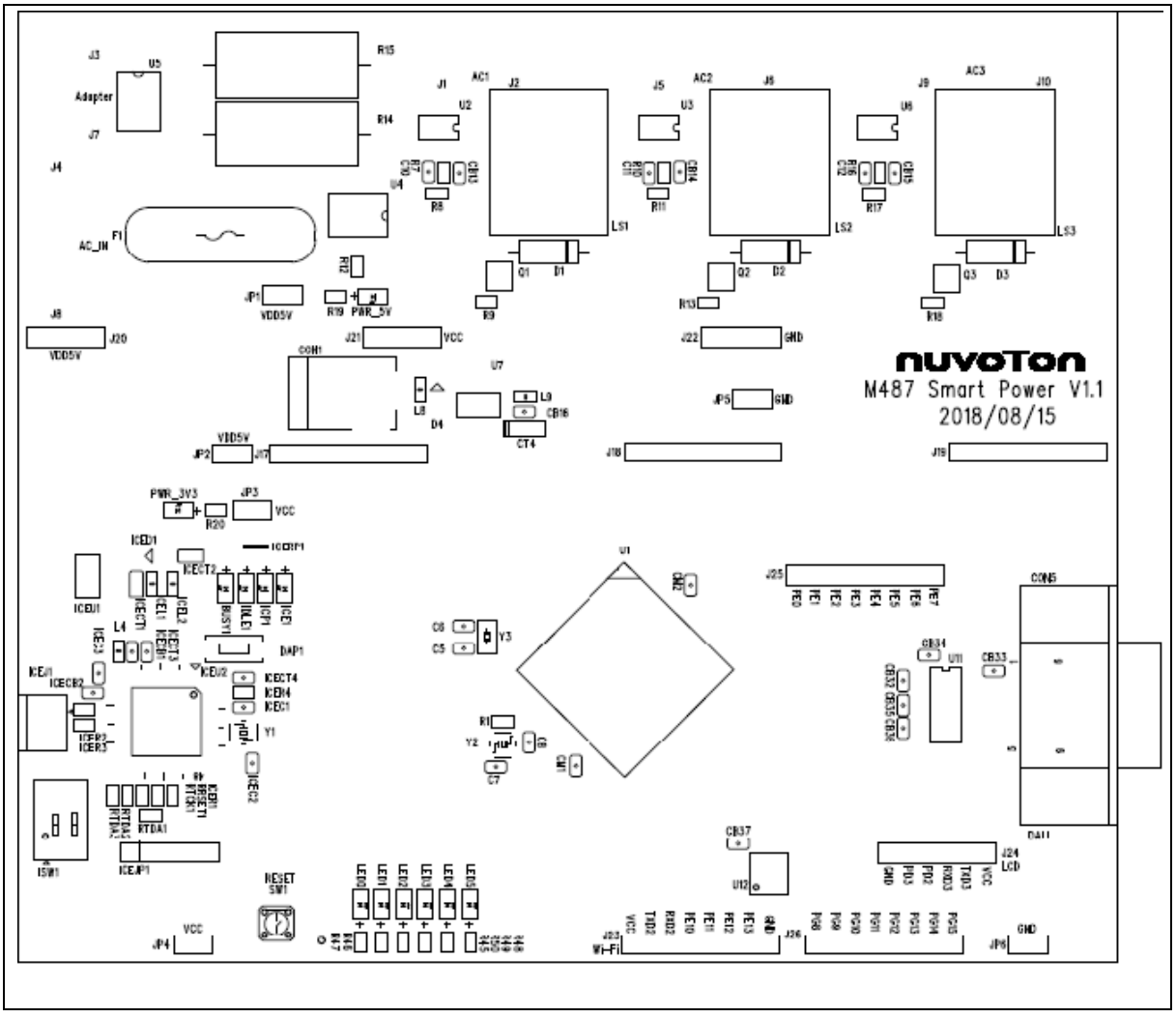

Figure 4-6 Front Placement of Main Board

Figure 4-7 shows the front placement of daughter board of M487 Smart Power board.

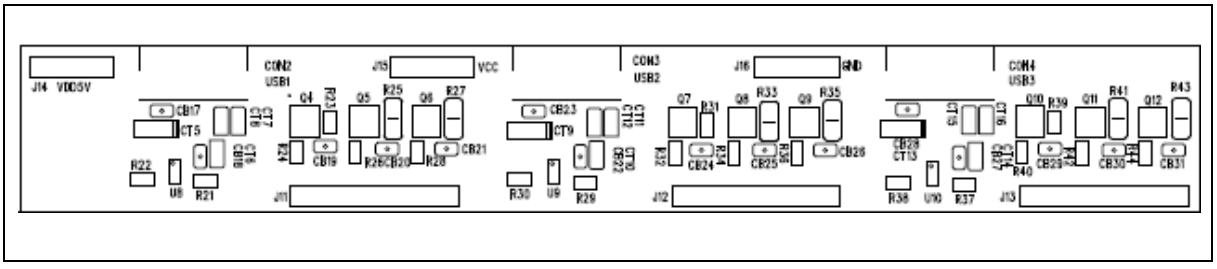

Figure 4-7 Front Placement of Daughter Board

4.9 M487 Smart Power Schematics

4.9.1 Nu-Link-Me (ICE Bridge)

Figure 4-8 shows the Nu-Link-Me circuit. This Nu-Link-Me circuit is an ICE bridge designed by Nuvoton, user can utilize this hardware circuit to download the firmware binary code to the embedded flash of Nuvoton's MCU with Nuvoton software ICP Programming Tool or microcontroller software development kit like Keil/IAR/GCC or to trace the firmware source code in the debug mode of these microcontroller software development kits. Note, user should install the Nuvoton software tool and driver at first before using these software functions.

The software ICP Programming Tool:

https://www.nuvoton.com/hq/support/tool-and-software/software/programmer/?__locale=en

The Nu-Link Driver for Keil and IAR:

https://www.nuvoton.com/hq/support/tool-and-software/software/development-tool/?__locale=en

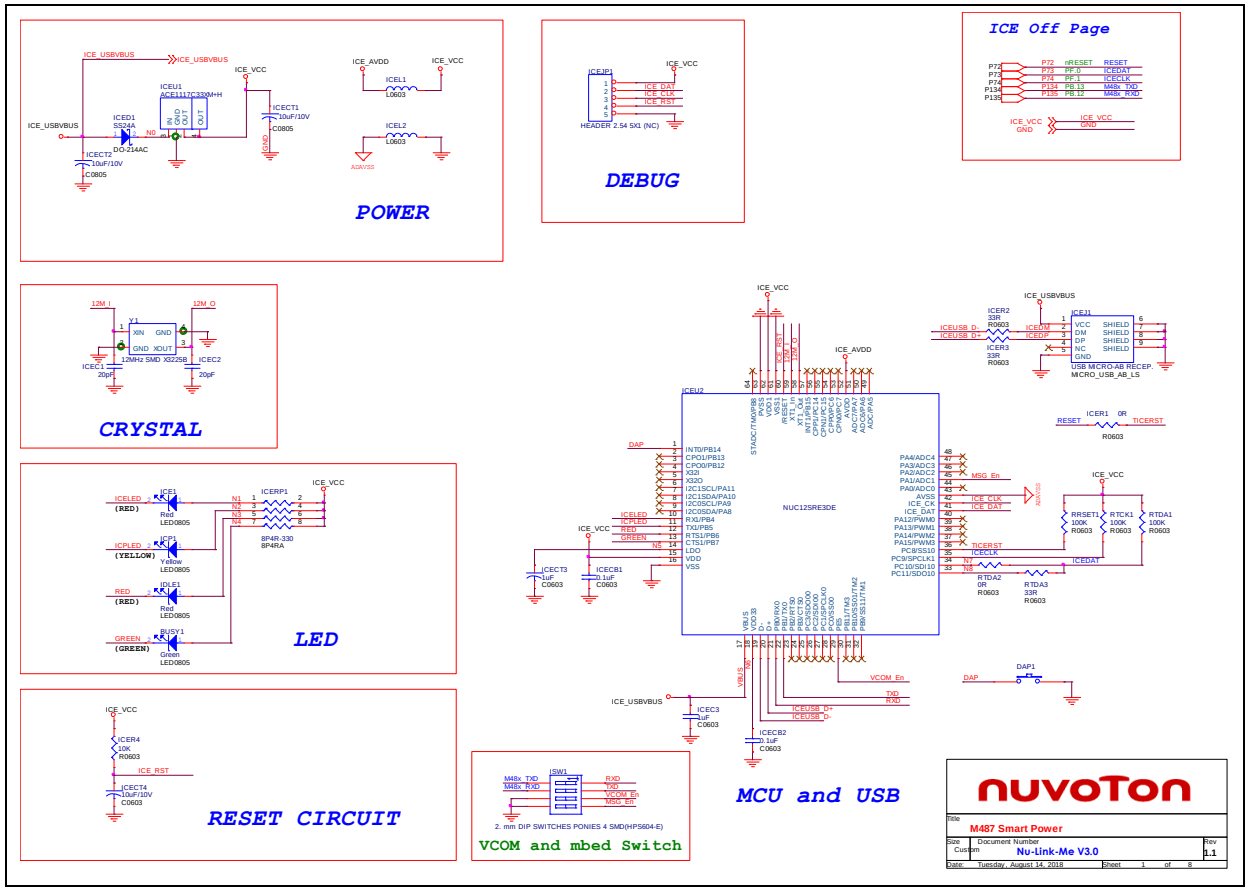

Figure 4-8 Nu-Link-Me Circuit

4.9.2 N487 Chip

Figure 4-9 shows all GPIO pins and their dedicated functions of M487 chip (LQFP-144pin) and its basic circuit with some external necessary devices.

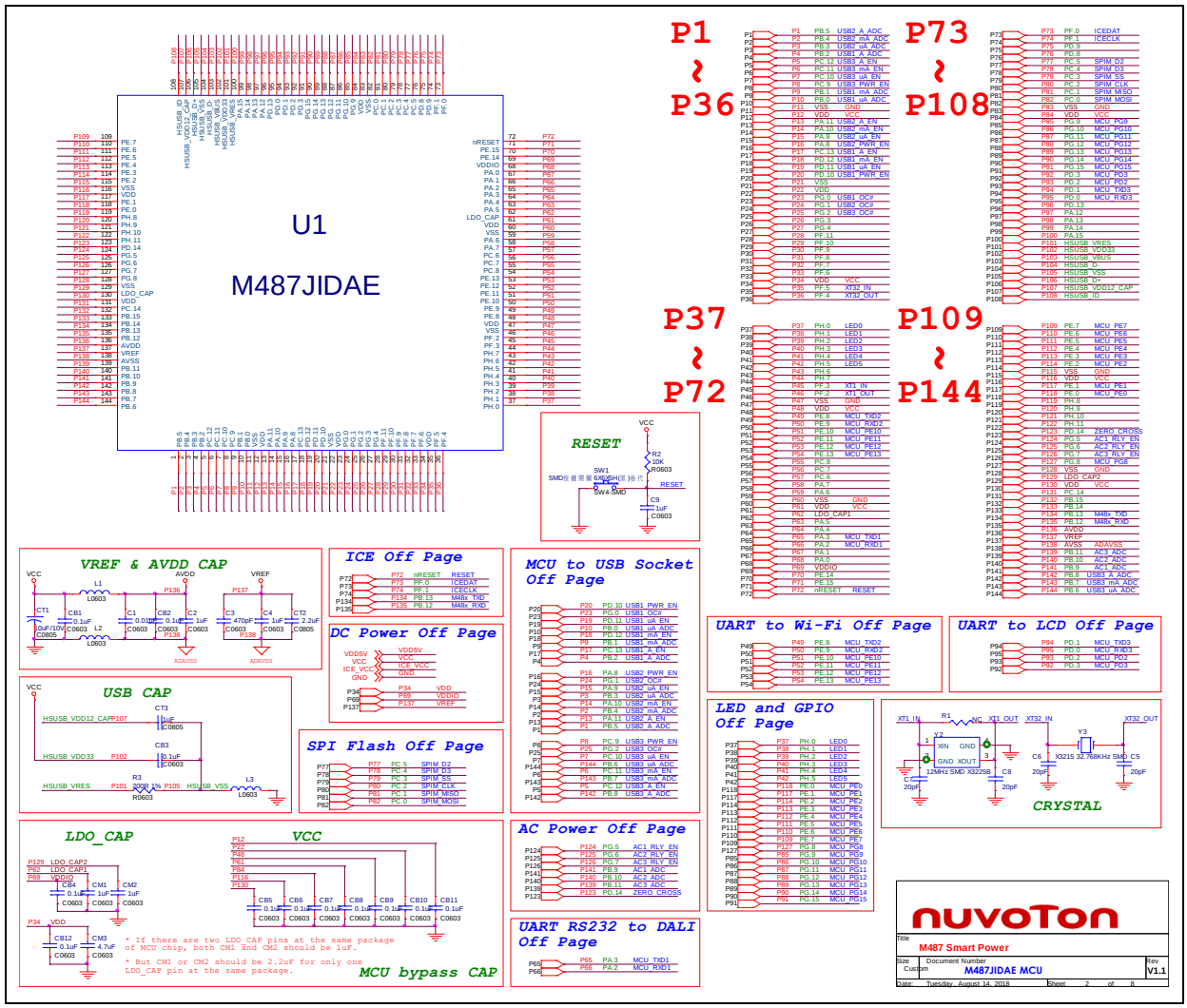

Figure 4-9 M487 Chip Circuit

4.9.3 AC Power

Figure 4-10 shows the AC power, relays and current sensor devices circuit. In this circuit, the bridge rectifier DF1510 (U5) and phototransistor coupler 4N25 (U4) can be used to detect the zero-cross of AC input power. The relay (LS1, LS2 or LS3) is a switch device that controlled by a GPIO pin of M487 MCU to enable or disable AC power supplying to the external AC socket. The current passing through the AC socket will be transformed by the current sensor (U2, U3 or U6) and its output can be monitored by the ADC channel of M487 MCU.

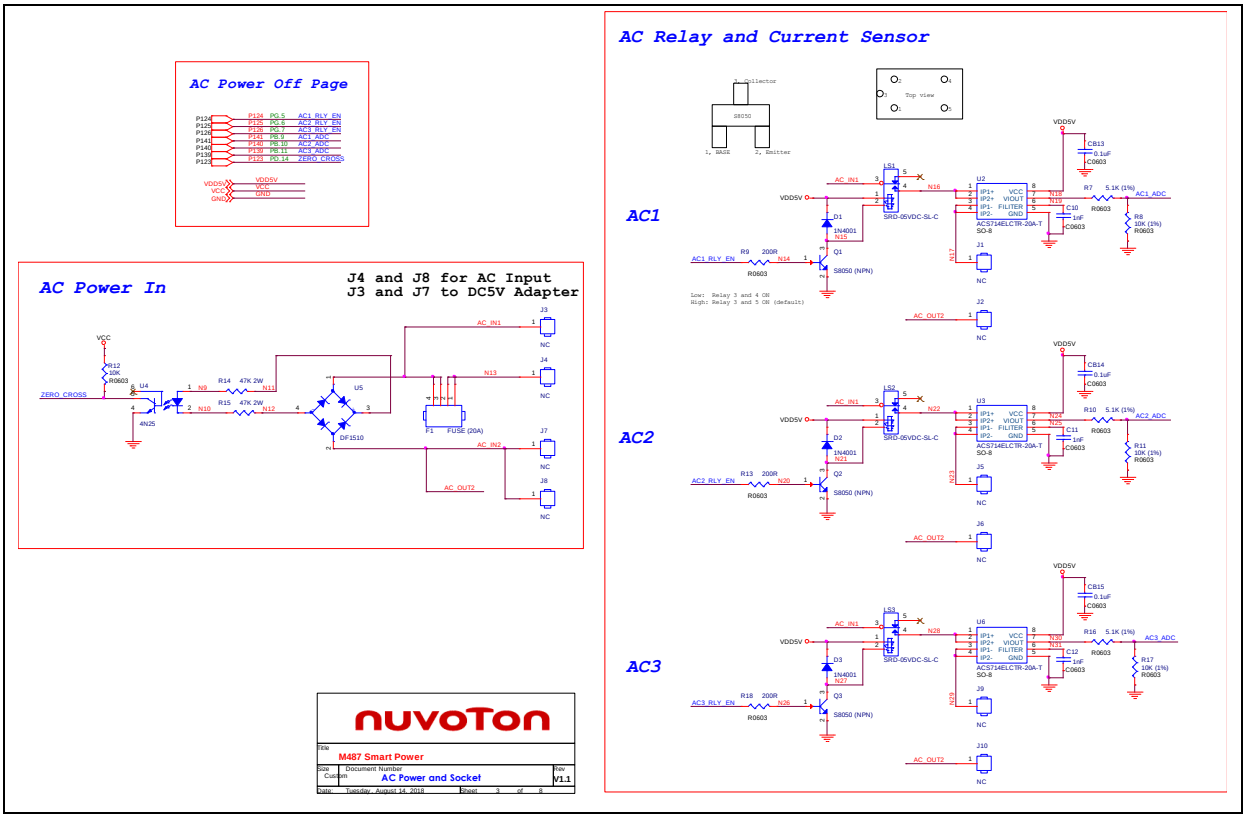

Figure 4-10 AC Power Circuit

4.9.4 DC Power

Figure 4-11 shows the DC power VDD5V and VCC (3.3V) circuit. An additional AC-DC5V adaptor is added to this M487 Smart Power Station to supply a stable 5V power at the Power Jack (CON1) and is connected to the AC pads (J3 and J7) on the M487 Smart Power main board.

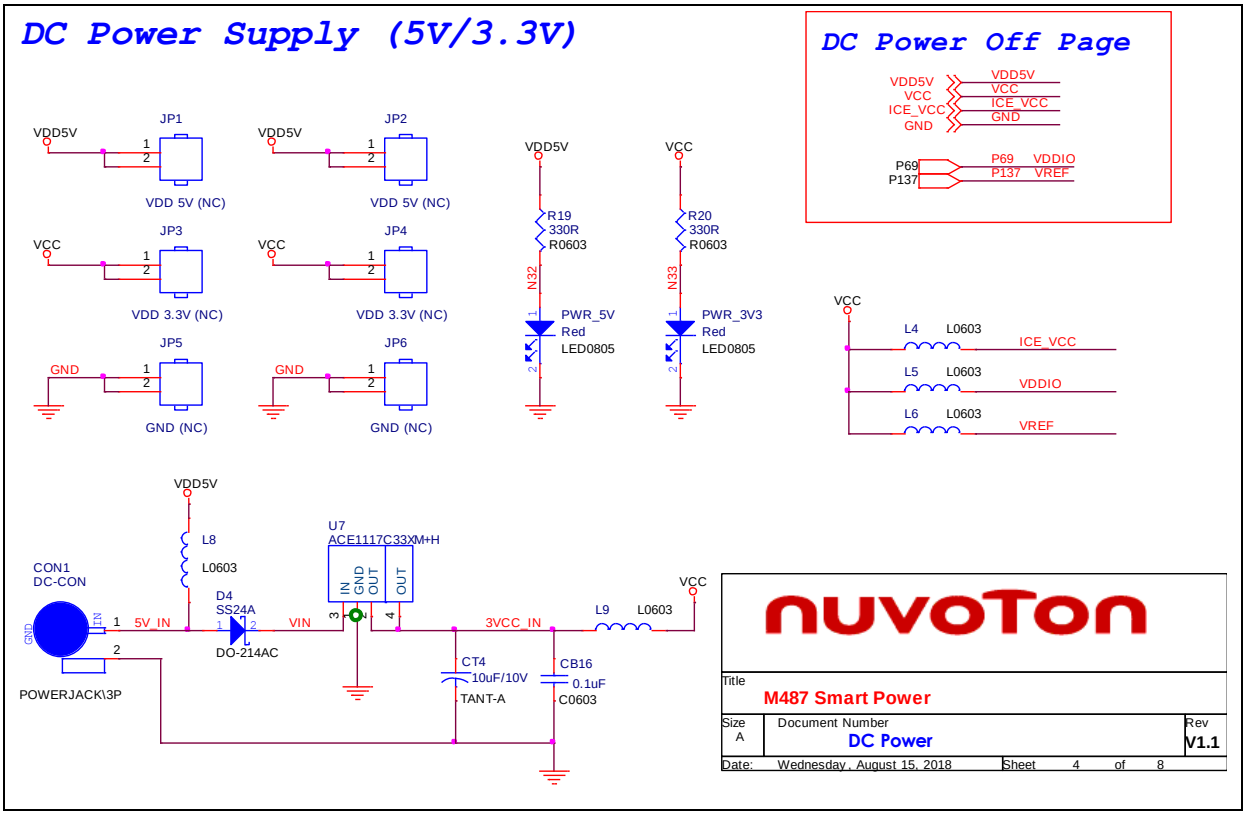

Figure 4-11 DC Power Circuit

4.9.5 MCU Connector

Figure 4-12 shows the MCU connector circuit for the connection with the USB daughter board.

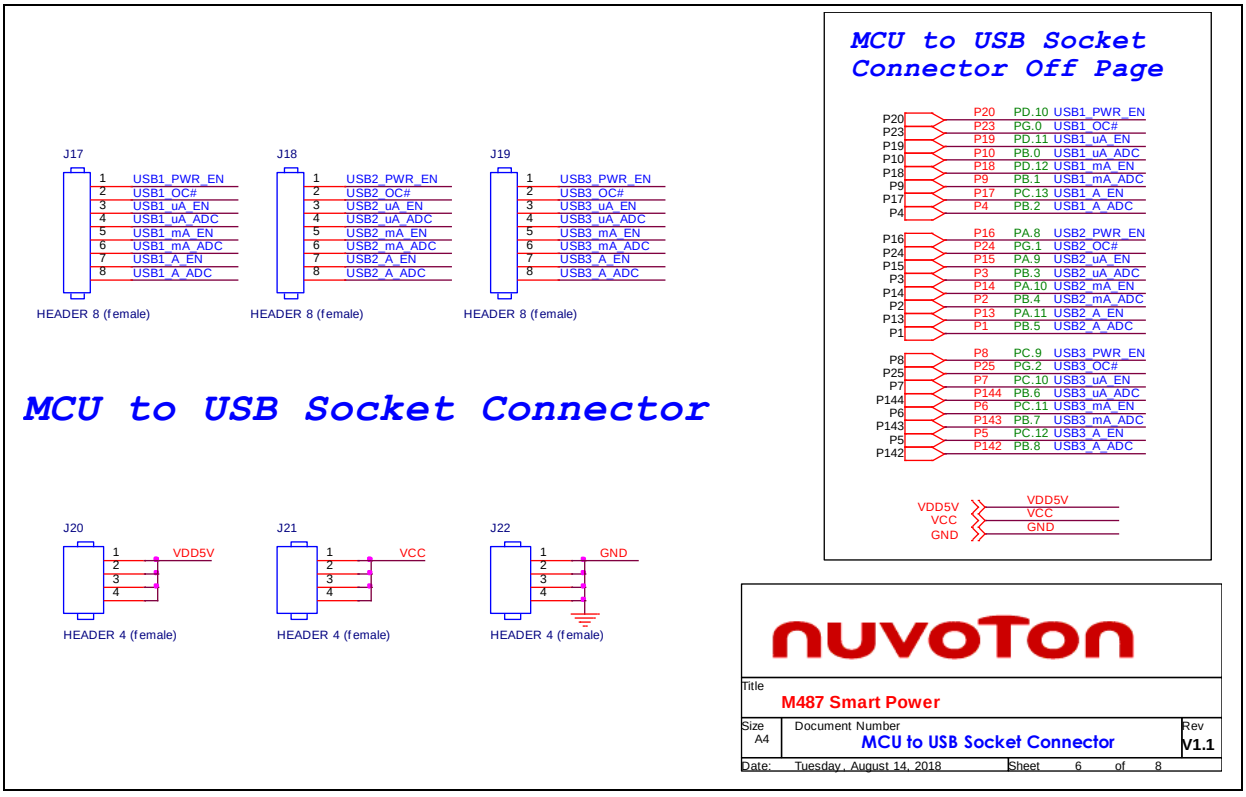

Figure 4-12 MCU Connector Circuit

4.9.6 SPI Flash

Figure 4-13 shows the SPI flash device circuit for SPIM of M487 chip to extend the flash memory for MCU if it is necessary.

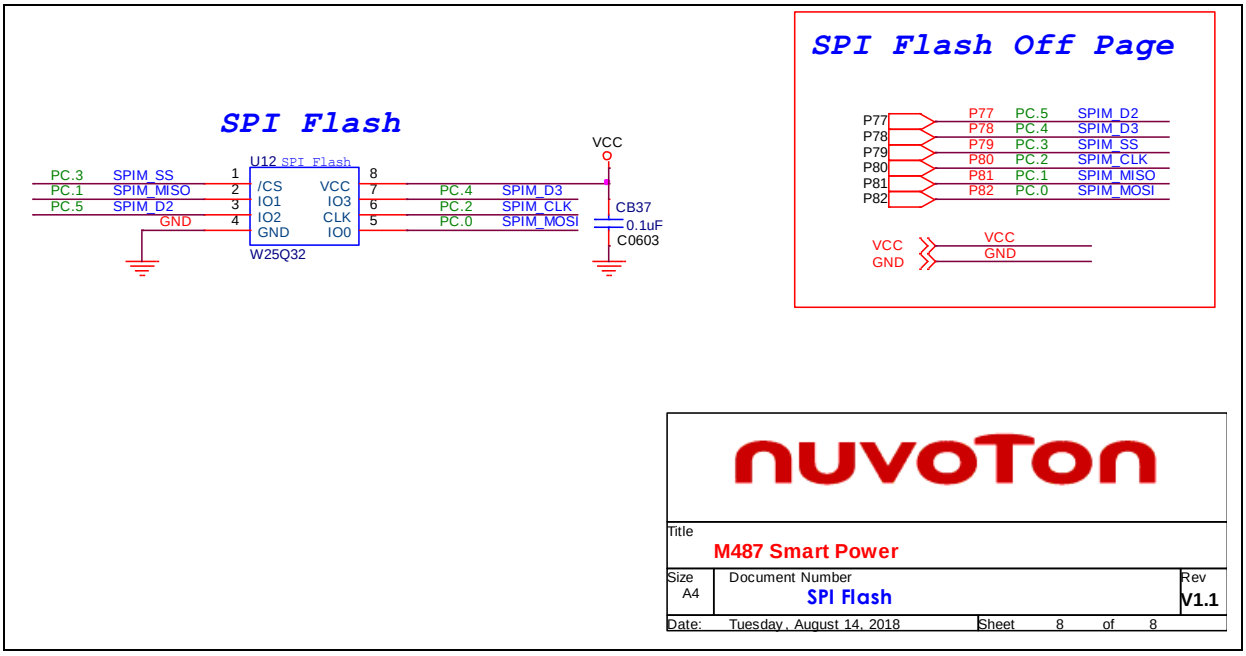

Figure 4-13 SPI Flash Circuit

4.9.7 UART to DALI

Figure 4-14 shows the UART to DALI circuit for the data communication with the DALI master board to control the brightness and fade-out time of light on the DALI slave board.

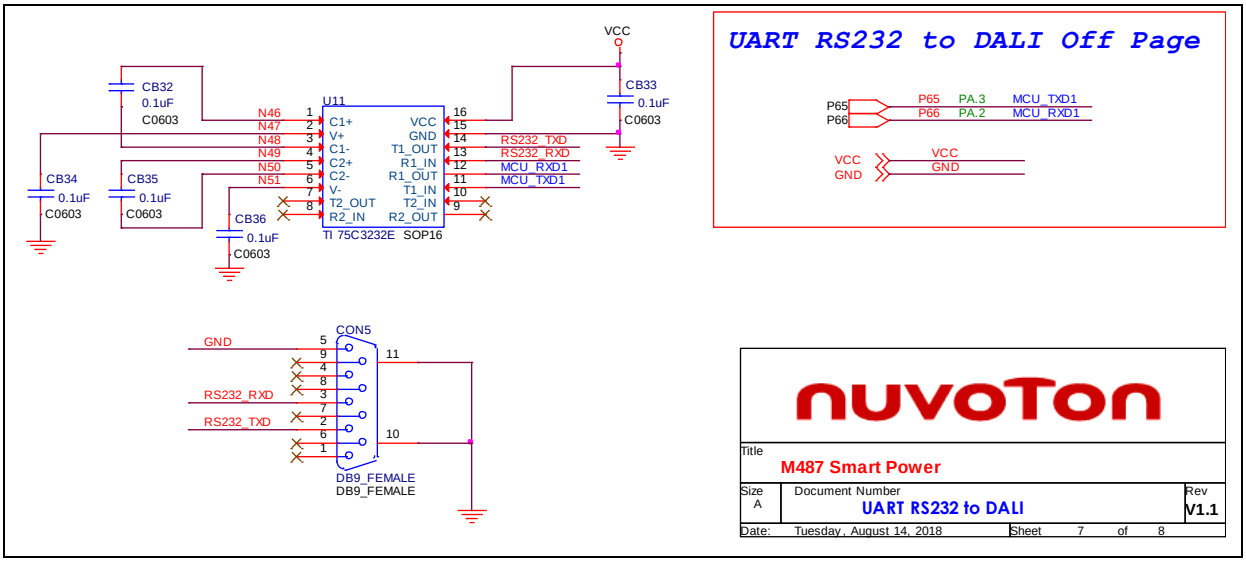

Figure 4-14 UART to DALI Circuit

4.9.8 UART to Wi-Fi

Figure 4-15 shows the UART to Wi-Fi module circuit on M487 Smart Power board for the data communication with the NuMaker-IoT-M487 board to support the speech recognition command and send the current, power consumption and ON/OFF status of turned-on socket to the cloud thru Wi-Fi hotspot.

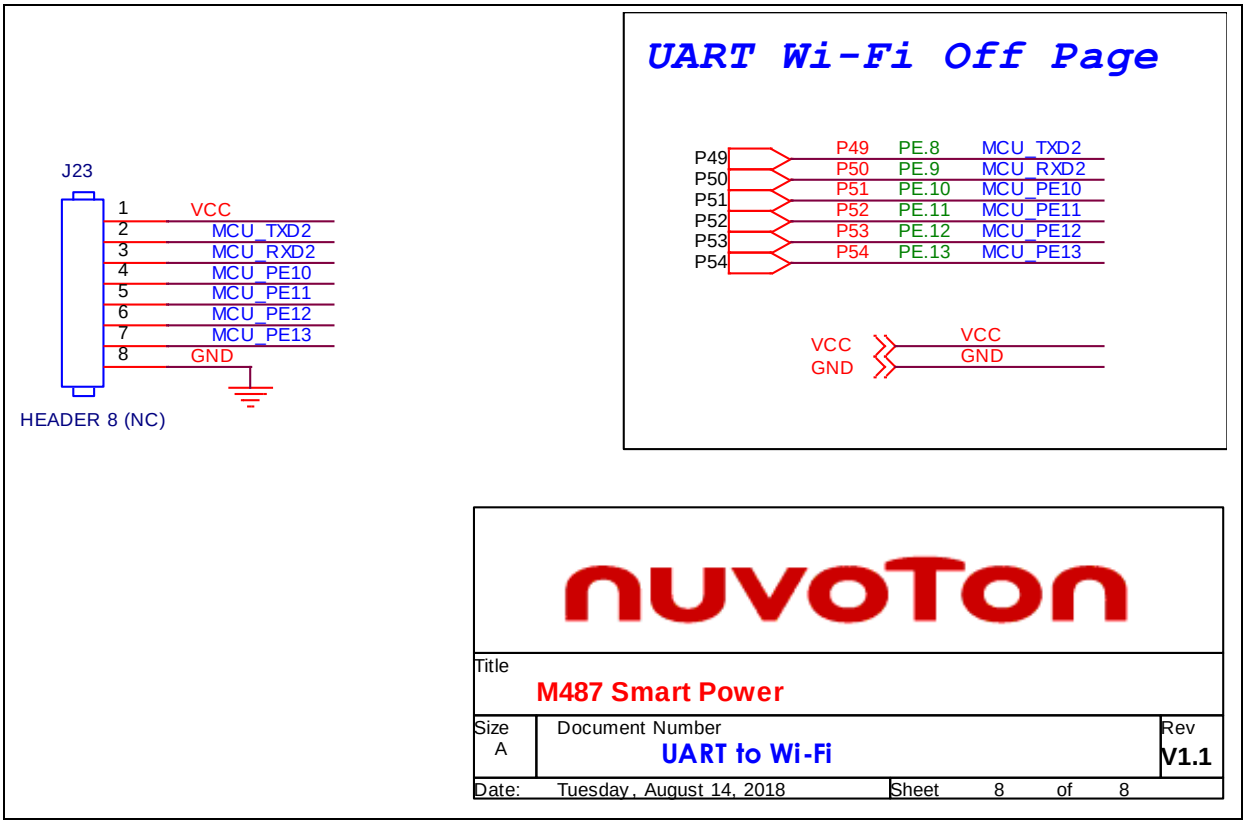

Figure 4-15 UART to Wi-Fi Circuit

Figure 4-16 shows the Wi-Fi module daughter board and Figure 4-17 shows the circuit of Wi-Fi daughter board. The following Table 4-5 lists the connection pins between Wi-Fi module daughter board and M487 Smart Power board.

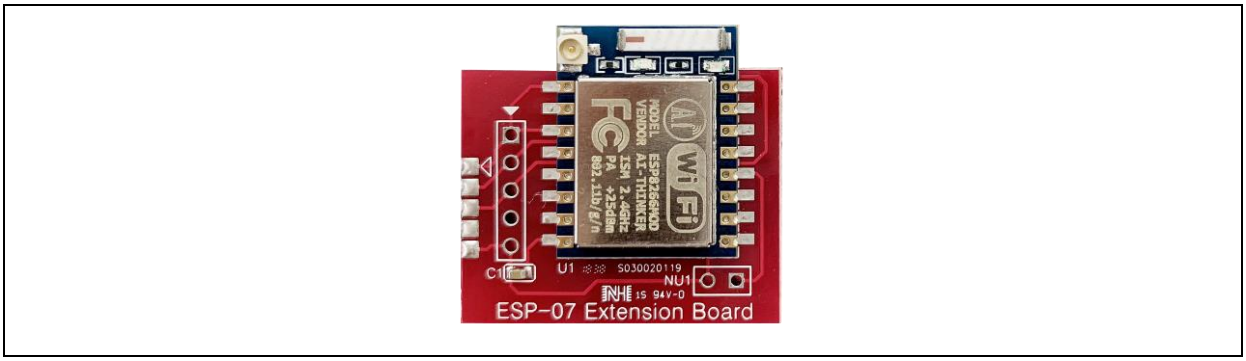

Figure 4-16 Wi-Fi Module Daughter Board

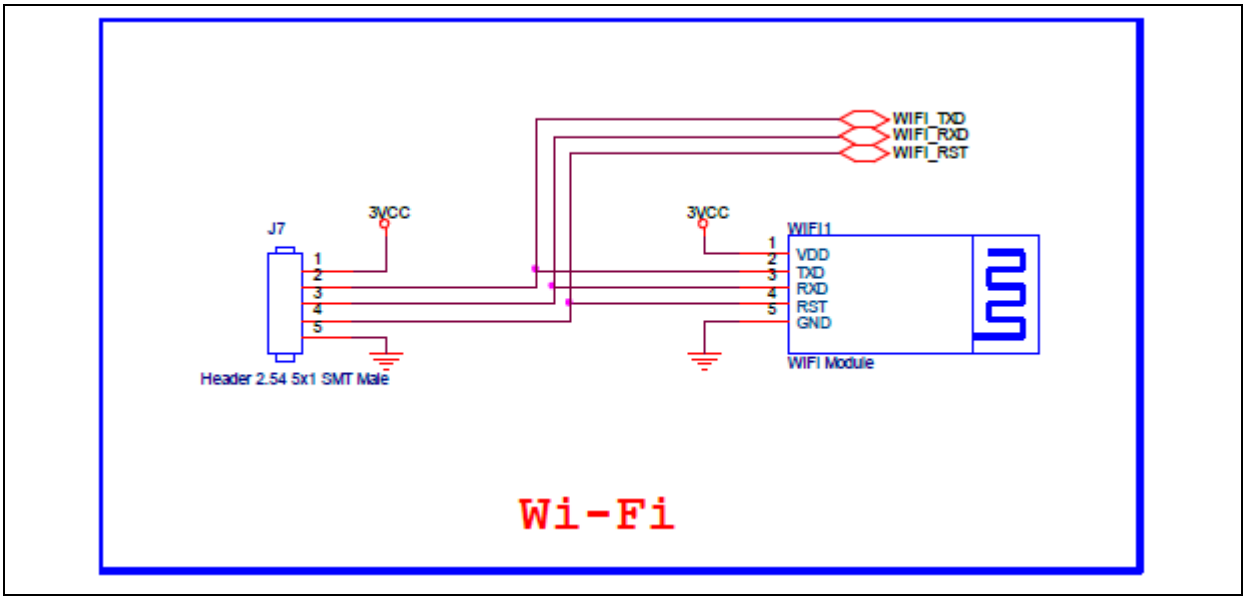

Figure 4-17 Wi-Fi Daughter Board Circuit

Table 4-5 UART Connection between Wi-Fi Daughter and M487 Smart Power Boards

Wi-Fi Daughter Board			**M487 Smart Power Board**		
Connector	I/O Mode	Function	Connector	I/O Mode	Function
J7.1	Power	3VCC	J23.1	Power	VCC (3.3V)
J7.2	Input	Wi-Fi_TXD	J23.3	Output	UART2 RXD (PE.9)
J7.3	Output	Wi-Fi_RXD	J23.2	Input	UART2 TXD (PE.8)
J7.4	Input	Wi-Fi_RST	-	-	NC
J7.5	Power	GND	J23.8	Power	GND

4.9.9 UART to LCD

Figure 4-18 shows UART to LCD circuit for the connection with NuMaker-emWin-M487D board to support the Human-Machine Interface (HMI) function based on the emWin engine on the NuMaker-emWin-M487D board. The UART connection pins between NuMaker-emWin-M487D board and M487 Smart Power board are listed in the following Table 4-6.

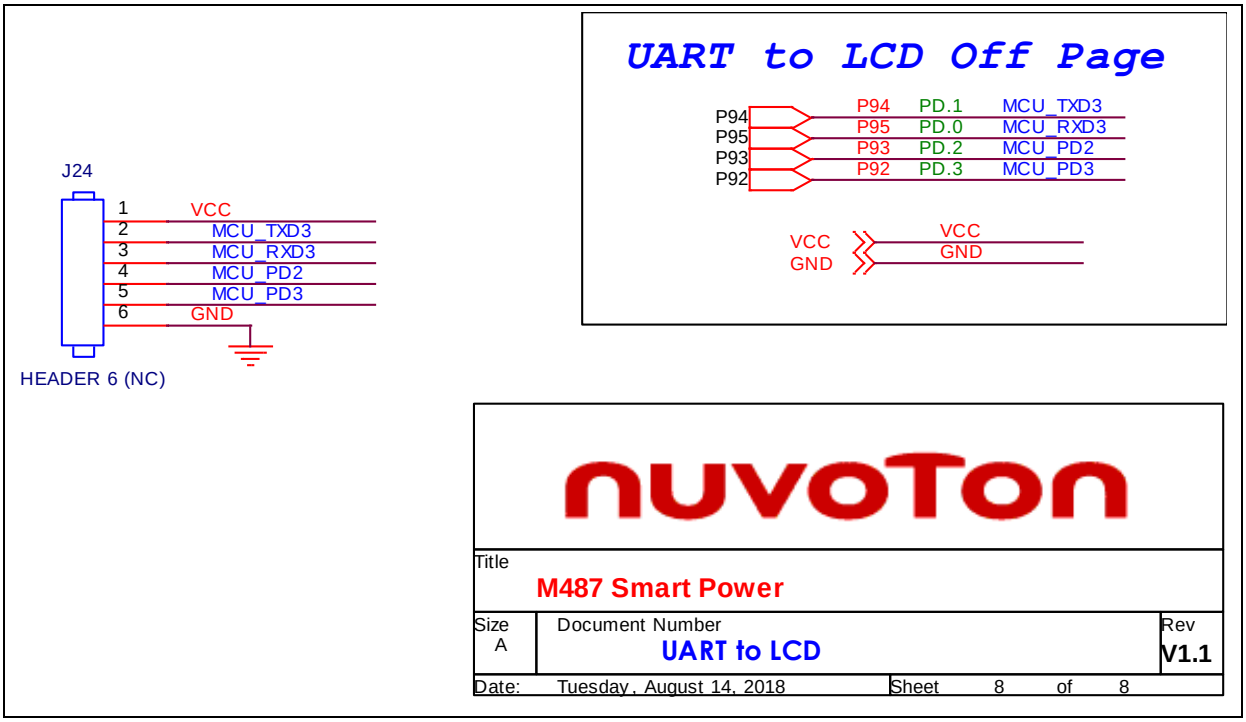

Figure 4-18 UART to LCD Circuit

Table 4-6 UART Connection between NuMaker-emWin-M487D and M487 Smart Power Boards

NuMaker-emWin-M487D Board			M487 Smart Power Board			Comment	
GPIO	I/O Mode	Function	GPIO	I/O Mode	Function	0	1
PA.2	Input	UART1 RXD	PD.1	Output	UART3 TXD	-	
PA.3	Output	UART1 TXD	PD.0	Input	UART3 RXD	-	
PB.0	Input	Wi-Fi Check	PD.2	Output	Wi-Fi Check	Checking	Done
PD.10	Input	Wi-Fi Status	PD.3	Output	Wi-Fi Status	No Wi-Fi	Wi-Fi Connected

4.9.10 LED and GPIO Connector

Figure 4-19 shows the LED and GPIO connector circuit. The LED shows the On/Off status of these AC and USB sockets and these two GPIO connectors are for user to extend the functions on this M487 Smart Power board.

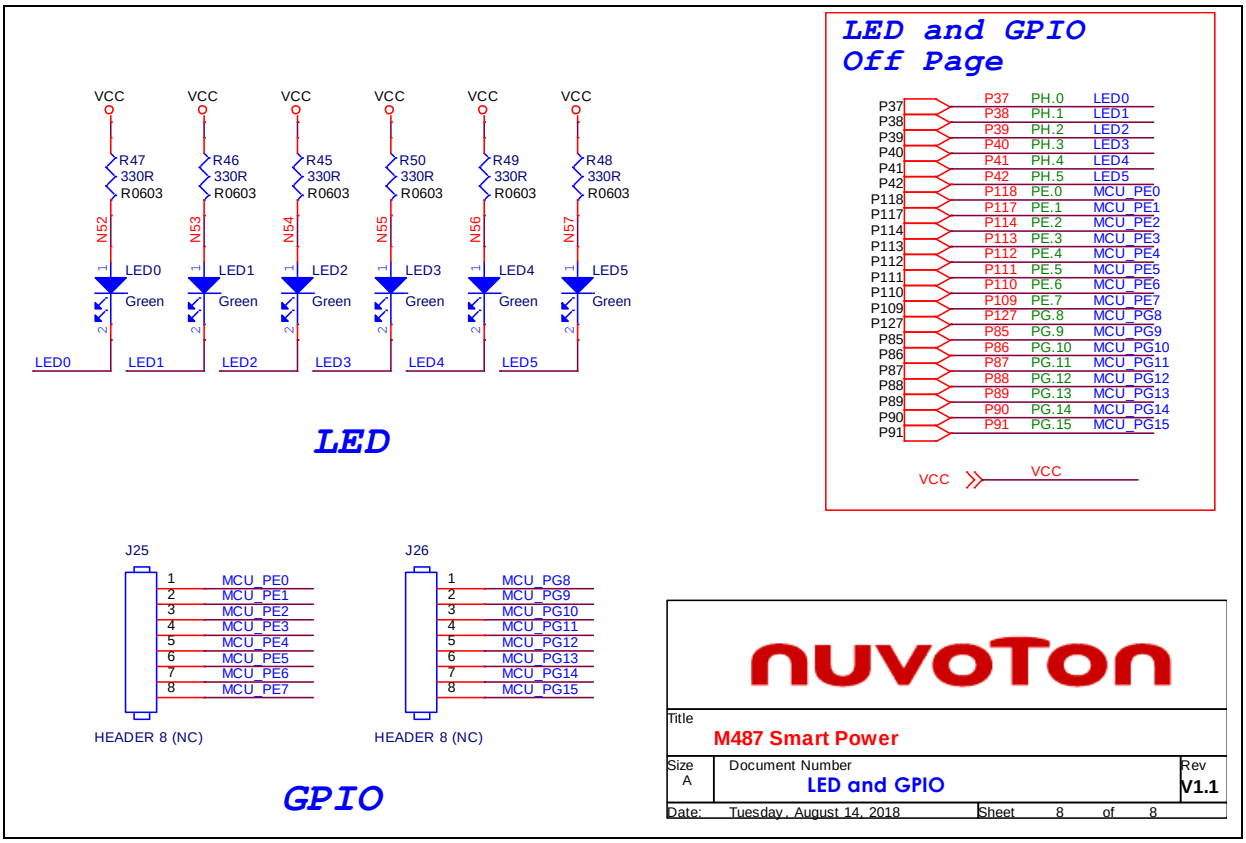

Figure 4-19 LED and GPIO Connector Circuit

4.9.11 USB Daughter Board

Figure 4-20 shows the USB daughter board circuit. The Power-distribution Switch (U8, U9 or U10) is a switch device that controlled by a GPIO pin of M487 MCU to enable or disable DC 5V power supplying to the USB socket. This switch device will generate a LOW output on its #OC pin to indicate MCU to disable the 5V output when it detects an over current on the 5V output power. For each USB socket, the circuit utilizes three MOSFET devices (Q4/Q5/Q6, Q7/Q8/Q9 or Q10/Q11/Q12) that can be switched to three different resistor paths by three GPIO pins of MCU. The current passing through the USB socket will be measured by the one of three ADC channels of M487 MCU.

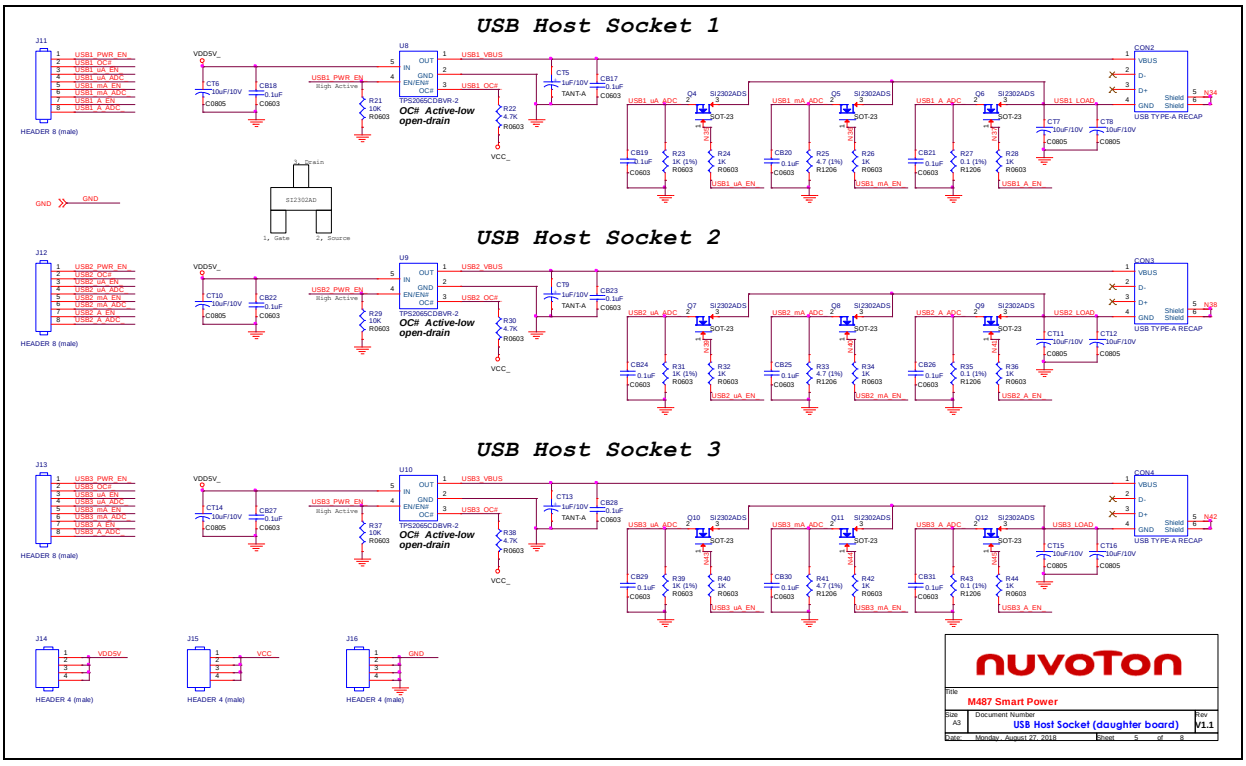

Figure 4-20 USB Daughter Board Circuit

5 REVISION HISTORY

Date	Revision	Description
2018.11.28	1.00	1. Initially issued.

Important Notice

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