

**ARM<sup>®</sup> Cortex<sup>®</sup>-M**  
**32-bit Microcontroller**

**NuMaker-PFM-M2351**  
**User Manual**  
**NuMicro<sup>®</sup> M23 Series**

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## 1 OVERVIEW

This user manual is aimed to introduce how to use the Nuvoton NuMaker-PFM-M2351 board.

### 1.1 Introduction to NuMaker-PFM-M2351 Board

The NuMaker-PFM-M2351 is a development board based on an Arm® Cortex®-M23 microcontroller (MCU) – M23 series which has very rich peripherals.

This board lets users easily develop the secure application program on this board. The NuMaker-PFM-M2351 also enables users to develop and verify the application programs through the peripherals and interfaces on MCU and this board.

Furthermore, this board also provides an Arduino UNO compatible interface for users to develop the specific function with any of Arduino modules or kits. Regarding to the Arduino, users can link directly to the Wikipedia website: [en.wikipedia.org/wiki/Arduino](http://en.wikipedia.org/wiki/Arduino) to get more detailed information.

The NuMaker-PFM-M2351 board consists of the M2351 Platform and Nu-Link-Me ICE Bridge. Figure 1-1 shows the NuMaker-PFM-M2351 board.

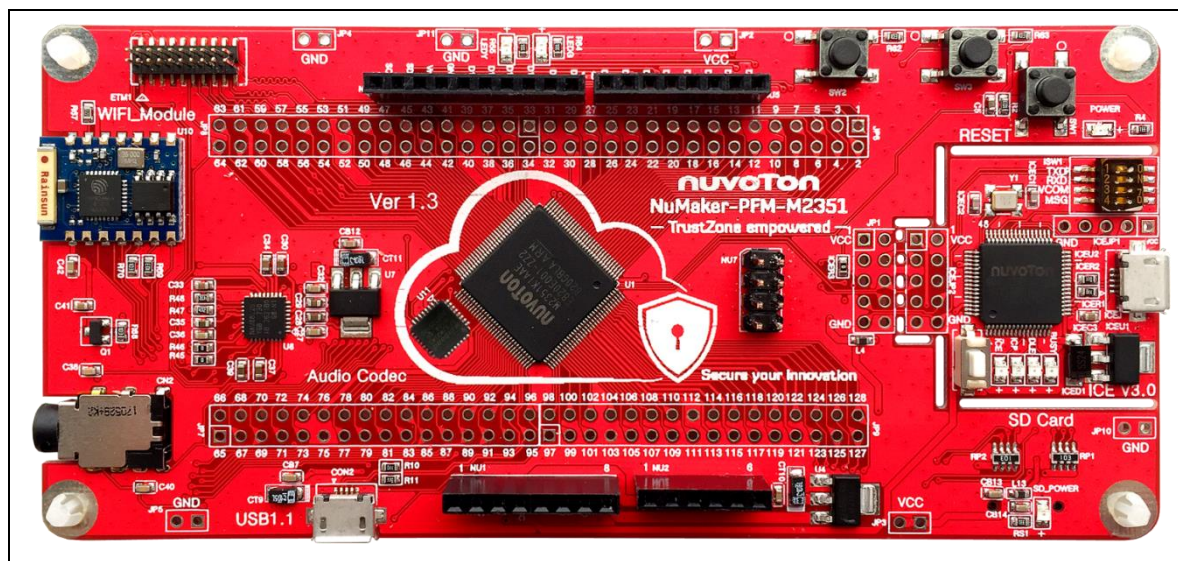


Figure 1-1 NuMaker-PFM-M2351 Board

The left portion of this board is the M2351 Platform that includes the target chip M2351 MCU based on the Arm® Cortex®-M23 core with Armv8-M architecture and TrustZone® security technologies, and the other related on-board application parts and connectors.

The right portion of this board is a Nu-Link-Me ICE Bridge based on the SWD (Serial Wire Debug) interface connected with the target chip, allowing users to program the application code to the Flash of target chip through the USB port from PC Host.

## 1.2 M2351 Series MCU Features

- M2351KIAAE in LQFP128 package
- Arm® Cortex®-M23 core running up to 64 MHz with Armv8-M architecture and TrustZone® technology
- Built-in LDO for wide operating voltage from 1.6 V to 3.6 V
- 512 Kbytes Flash
- 96 Kbytes SRAM
- 32 Kbytes Secure Boot ROM
- External Bus Interface (EBI)
- GPIO
- Peripheral DMA (PDMA)
- Timer
- EPWM and BPWM
- Quadrature Encoder Interface (QEI)
- WDT and WWDT
- RTC
- UART
- Smart Card (ISO-7816-3) Host Interface
- I<sup>2</sup>C
- SPI
- I<sup>2</sup>S
- Universal Serial Control Interface (USCI)
- USB 2.0 Full-Speed OTG / Host / Device
- CAN 2.0
- SD Host
- Cryptographic Accelerator
- CRC
- ADC
- DAC
- Comparator

### 1.3 NuMaker-PFM-M2351 Board Features

- On-board Nu-Link-Me ICE Bridge (Mass storage as USB Disk drive) for drag and drop programming
- Arduino UNO compatible interface
- M2351 extended interface connectors
- ETM (embedded trace macrocell) debug interface for instruction and data tracing of a Processor
- Secure Serial Flash (W77F32W) for secure data storage, cryptographic key storage, and general data storage
- Audio codec (NAU88L25) with Microphone In and Headphone Out
- Wi-Fi module for wireless application
- USB 2.0 Full-Speed OTG / Host / Device
- MicroSD Card slot for T-Flash
- Three push-buttons: one is for reset and the other two are for user-defined
- Three LEDs: one is for power indication and the other two are for user-defined



## 2 NUMAKER-PFM-M2351 BOARD OVERVIEW

### 2.1 Front View

Figure 2-1 shows the main components and connectors from the front side of NuMaker-PFM-M2351 board.

The following lists components and connectors from the front view:

- Target Chip: M2351KIAAE (U1)
- Nu-Link-Me ICE Bridge: ICE Controller NUC12SRE3DE (ICEU2), USB connector (ICEJ) to PC Host
- Secure Serial Flash W77F32W (U11)
- Audio: Audio Codec NAU88L25 (U8), Headphone (CN2)
- Arduino UNO compatible interface connectors (NU1, NU2, NU5, NU6, NU7)
- M2351 extended interface connectors (JP6, JP7, JP8 and JP9)
- USB: USB 2.0 Full-Speed OTG connector (CON2)
- Wi-Fi module: ESP-03 (U10)
- Push-buttons (SW2, SW3)
- LEDs (I/O1 and I/O2)

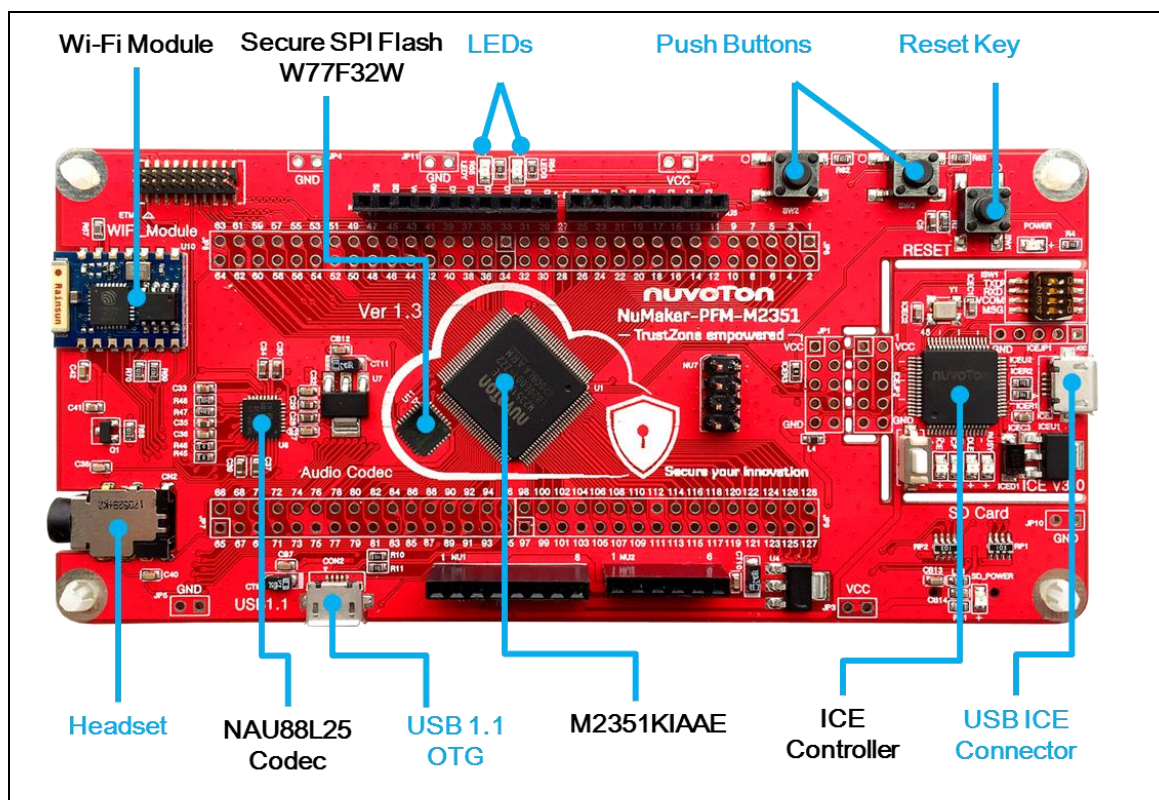


Figure 2-1 Front View of NuMaker-PFM-M2351 Board

## 2.2 Rear View

Figure 2-2 shows the main components and connectors from the rear side of NuMaker-PFM-M2351 board.

The following lists components and connectors from the rear view:

- MicroSD Card Slot: T-Flash slot (U9)

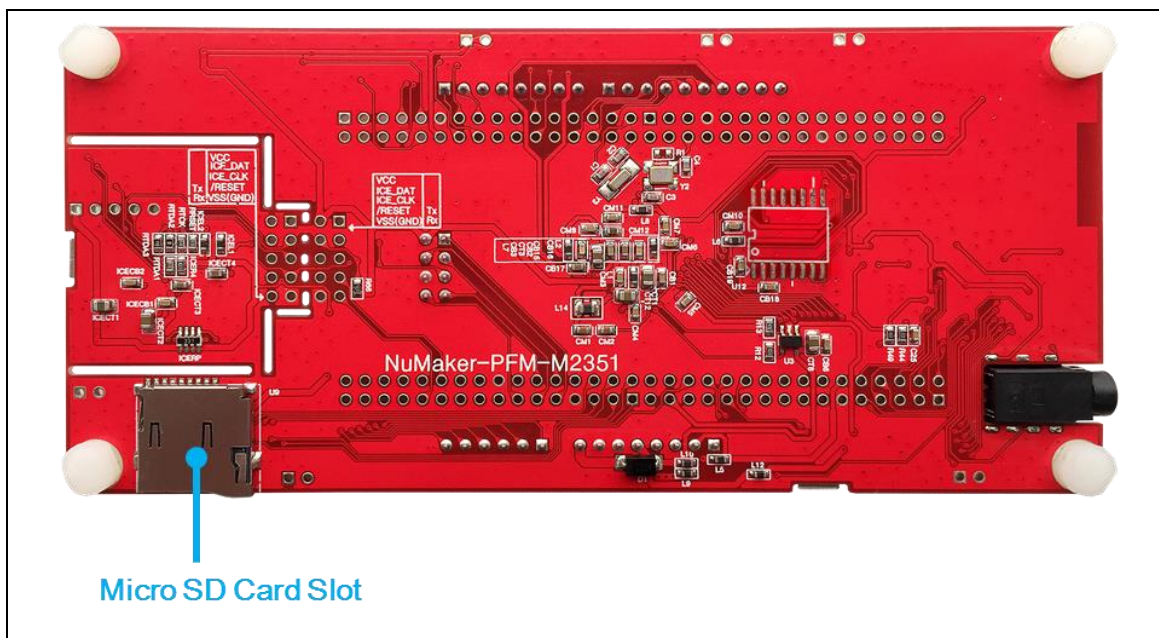


Figure 2-2 Rear View of NuMaker-PFM-M2351 Board

## 2.3 Arduino UNO Compatible Interface

Figure 2-3 shows the Arduino UNO compatible interface.

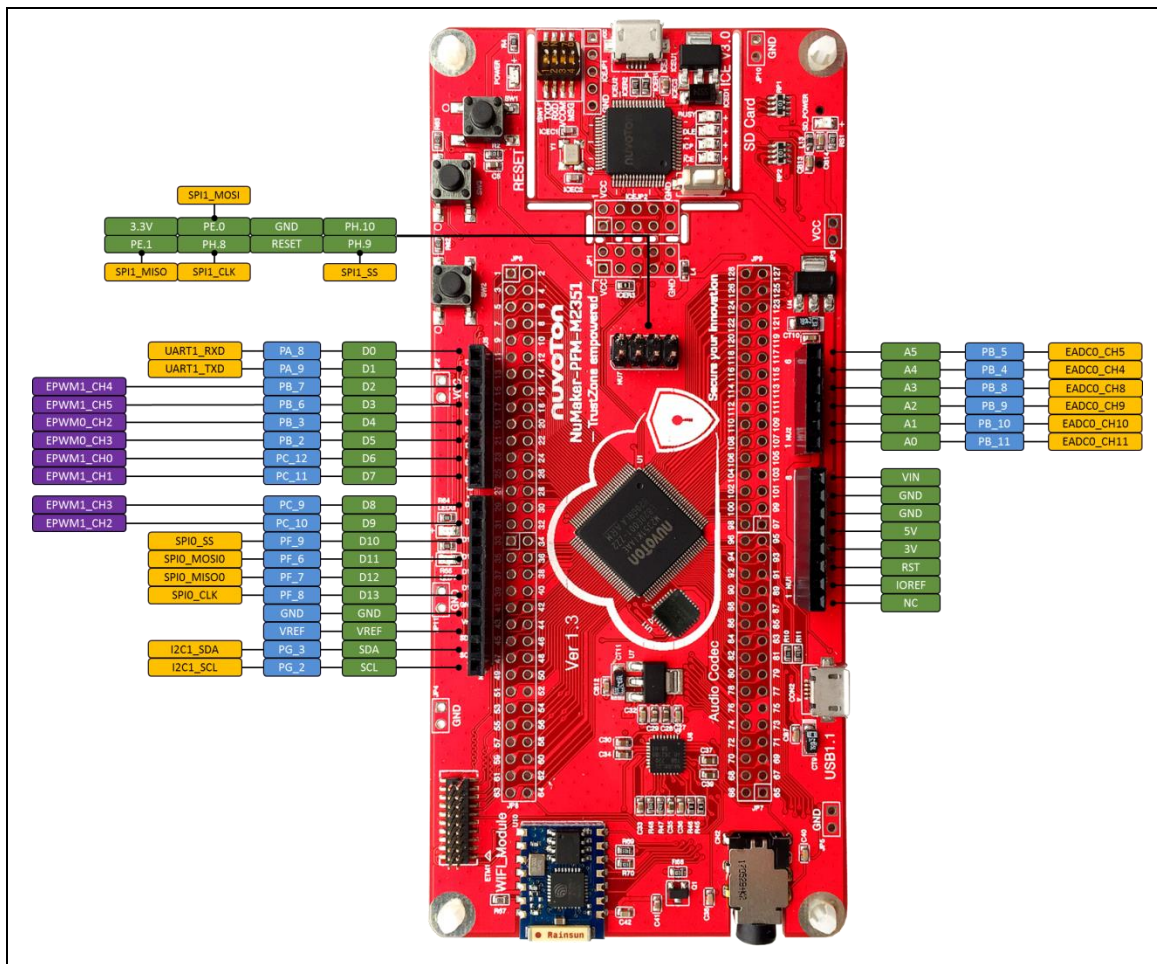


Figure 2-3 Arduino UNO Compatible Interface

Header		NuMaker-PFM-M2351		Header		NuMaker-PFM-M2351	
		Compatible to Arduino UNO	GPIO Pin of M2351			Compatible to Arduino UNO	GPIO Pin of M2351
NU1	NU1.1	NC	-	NU6	NU6.10	SCL	PG.2
	NU1.2	IOREF			NU6.9	SDA	PG.3
	NU1.3	RESET	RESET		NU6.8	VREF	-
	NU1.4	3VCC	-		NU6.7	GND	
	NU1.5	5VCC			NU6.6	D13	PF.8
	NU1.6	GND			NU6.5	D12	PF.7
	NU1.7	GND			NU6.4	D11	PF.6
	NU1.8	VIN			NU6.3	D10	PF.9
NU2	NU2.1	A0	PB.11	NU6.2	D9	PC.10	
	NU2.2	A1	PB.10	NU6.1	D8	PC.9	
	NU2.3	A2	PB.9	NU5	NU5.8	D7	PC.11
	NU2.4	A3	PB.8		NU5.7	D6	PC.12
	NU2.5	A4	PB.4		NU5.6	D5	PB.2
	NU2.6	A5	PB.5		NU5.5	D4	PB.3
NU7	NU7.1	MISO	PE.1	NU5	NU5.4	D3	PB.6
	NU7.2	VCC	3.3V				
	NU7.3	CLK	PH.8		NU5.3	D2	PB.7
	NU7.4	MOSI	PE.0		NU5.2	D1	PA.9
	NU7.5	RESET	RESET		NU5.1	D0	PA.8
	NU7.6	GND	GND				
	NU7.7	CS	PH.9				
	NU7.8	PH.10	PH.10				

Table 2-1 Arduino UNO Interface Mapping with M2351KIAAE GPIO



## 2.4 Pin Assignment for Extended Connectors

The NuMaker-PFM-M2351 provides the M2351KIAAE target chip on board and extended connectors (JP6, JP7, JP8 and JP9) for LQFP128-pin. Figure 2-4 shows the M2351KIAAE extended connectors.

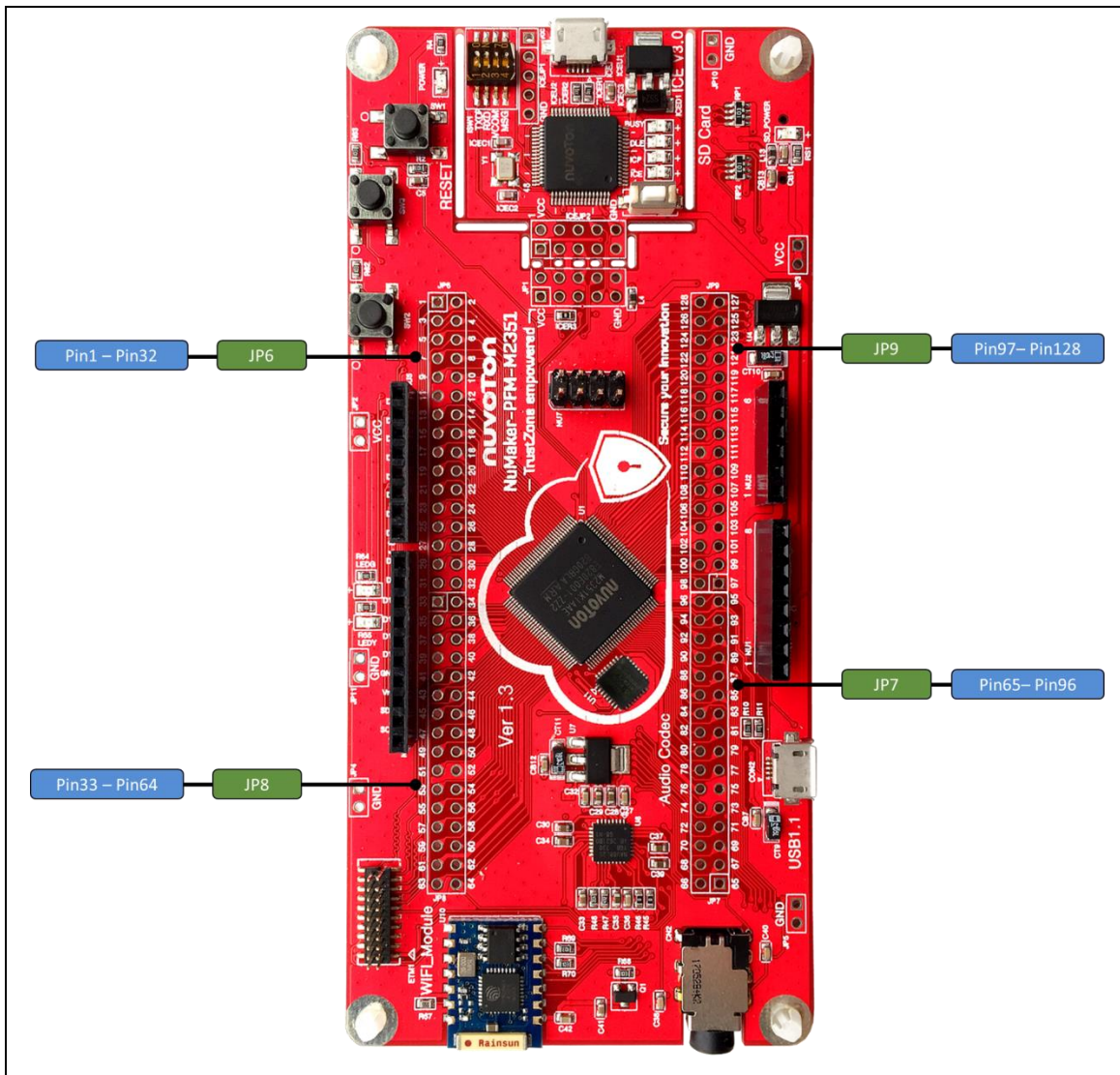


Figure 2-4 M2351KIAAE Extended Connectors

Header		M2351KIAAE		Header		M2351KIAAE	
		Pin No.	Function			Pin No	Function
<b>JP6</b>	JP6.1	1	PB.5	<b>JP6</b>	JP6.2	2	PB.4
	JP6.3	3	PB.3		JP6.4	4	PB.2
	JP6.5	5	PC.12		JP6.6	6	PC.11
	JP6.7	7	PC.10		JP6.8	8	PC.9
	JP6.9	9	PB.1		JP6.10	10	PB.0
	JP6.11	11	GND		JP6.12	12	3VCC
	JP6.13	13	PA.11		JP6.14	14	PA.10
	JP6.15	15	PA.9		JP6.16	16	PA.8
	JP6.17	17	PC.13		JP6.18	18	PD.12
	JP6.19	19	PD.11		JP6.20	20	PD.10
	JP6.21	21	PG.2		JP6.22	22	PG.3
	JP6.23	23	PG.4		JP6.24	24	PF.11
	JP6.25	25	PF.10		JP6.26	26	PF.9
	JP6.27	27	PF.8		JP6.28	28	PF.7
	JP6.29	29	PF.6		JP6.30	30	VBAT
	JP6.31	31	XT32_IN		JP6.32	32	XT32_OUT

Table 2-2 Extended Connector JP6 Interface with M2351KIAAE GPIO

Header		M2351KIAAE		Header		M2351KIAAE	
		Pin No.	Function			Pin No	Function
JP8	JP8.1	33	PH.4	JP8	JP8.2	34	PH.5
	JP8.3	35	PH.6		JP8.4	36	PH.7
	JP8.5	37	PF.3		JP8.6	38	PF.2
	JP8.7	39	GND		JP8.8	40	VCC
	JP8.9	41	PE.8		JP8.10	42	PE.9
	JP8.11	43	PE.10		JP8.12	44	PE.11
	JP8.13	45	PE.12		JP8.14	46	PE.13
	JP8.15	47	PC.8		JP8.16	48	PC.7
	JP8.17	49	PC.6		JP8.18	50	PA.7
	JP8.19	51	PA.6		JP8.20	52	GND
	JP8.21	53	VCC		JP8.22	54	LDO_CAP
	JP8.23	55	PA.5		JP8.24	56	PA.4
	JP8.25	57	PA.3		JP8.26	58	PA.2
	JP8.27	59	PA.1		JP8.28	60	PA.0
	JP8.29	61	VDDIO		JP8.30	62	PE.14
	JP8.31	63	PE.15		JP8.32	64	nRESET

Table 2-3 Extended Connector JP8 Interface with M2351KIAAE GPIO

Header		M2351KIAAE		Header		M2351KIAAE	
		Pin No.	Function			Pin No	Function
<b>JP7</b>	JP7.1	65	ICEDAT	<b>JP7</b>	JP7.2	66	ICECLK
	JP7.3	67	PD.9		JP7.4	68	PD.8
	JP7.5	69	PC.5		JP7.6	70	PC.4
	JP7.7	71	PC.3		JP7.8	72	PC.2
	JP7.9	73	PC.1		JP7.10	74	PC.0
	JP7.11	75	GND		JP7.12	76	VCC
	JP7.13	77	PG.9		JP7.14	78	PG.10
	JP7.15	79	PG.11		JP7.16	80	PG.12
	JP7.17	81	PG.13		JP7.18	82	PG.14
	JP7.19	83	PG.15		JP7.20	84	PD.7
	JP7.21	85	PD.6		JP7.22	86	PD.5
	JP7.23	87	PD.4		JP7.24	88	PD.3
	JP7.25	89	PD.2		JP7.26	90	PD.1
	JP7.27	91	PD.0		JP7.28	92	PD.13
	JP7.29	93	PA.12		JP7.30	94	PA.13
	JP7.31	95	PA.14		JP7.32	96	PA.15

Table 2-4 Extended Connector JP7 Interface with M2351KIAAE GPIO



Header		M2351KIAAE		Header		M2351KIAAE	
		Pin No.	Pin Name			Pin No	Pin Name
JP9	JP9.1	97	PE.7	JP9	JP9.2	98	PE.6
	JP9.3	99	PE.5		JP9.4	100	PE.4
	JP9.5	101	PE.3		JP9.6	102	PE.2
	JP9.7	103	GND		JP9.8	104	VCC
	JP9.9	105	PE.1		JP9.10	106	PE.0
	JP9.11	107	PH.8		JP9.12	108	PH.9
	JP9.13	109	PH.10		JP9.14	110	PH.11
	JP9.15	111	PD.14		JP9.16	112	GND
	JP9.17	113	VSW		JP9.18	114	VCC
	JP9.19	115	LDO_CAP		JP9.20	116	PB.15
	JP9.21	117	PB.14		JP9.22	118	PB.13
	JP9.23	119	PB.12		JP9.24	120	AVDD
	JP9.25	121	VREF		JP9.26	122	AVSS
	JP9.27	123	PB.11		JP9.28	124	PB.10
	JP9.29	125	PB.9		JP9.30	126	PB.8
	JP9.31	127	PB.7		JP9.32	128	PB.6

Table 2-5 Extended Connector JP9 Interface with M2351KIAAE GPIO

## 2.5 System Configuration

### 2.5.1 5V Power Source

- **ICEJ**: USB connector in Nu-Link-Me to program code and supply 5V power from PC Host.
- **CON2**: USB 2.0 Full-Speed OTG connector on the NuMaker-PFM-M2351 board to supply 5V power from PC Host.
- **NU1 pin5**: VDD5V voltage connector on the NuMaker-PFM-M2351 board to supply 5V power from external power source.

Power Source	Connector	Description
ICE_USBVBUS	ICEJ	ICEJ supplies the 5V power from PC Host. <b>Note</b> : L9 should be shorted 0 $\Omega$ .
USB_VBUS	CON2	CON2 supplies the 5V power from PC Host. <b>Note</b> : L12 should be shorted 0 $\Omega$ .
External 5V Source	NU1 pin5	NU1 pin5 supplies the 5V power from external power source. <b>Note</b> : L10 should be shorted 0 $\Omega$ .

### 2.5.2 3.3V Power Source

- **ICEU1**: The voltage regular converts the 5V source to 3.3V and supplies it to the NuMaker-PFM-M2351 board.
- **U4**: The voltage regular converts the 5V source to 3.3V and supplies it to the NuMaker-PFM-M2351 board.

Voltage Regular	5V Source	Description
ICEU1	ICE_USB_VBUS	ICEU1 converts ICE_USB_VBUS to 3.3V and supplies it to the M2351 platform board. <b>Note</b> : L4 should be shorted 0 $\Omega$ .
U4	USB_VBUS	U4 converts USB_VBUS to 3.3V and supplies it to the M2351 platform board. <b>Note</b> : L5 should be shorted 0 $\Omega$ .

### 2.5.3 1.8V Power Source

- **U7**: The voltage regular converts the VCC source to 1.8V and supplies it to the NuMaker-PFM-M2351 board.

Voltage Regular	Power Source	Description
U7	VCC	U7 converts VCC to 1.8V and supplies it to the M2351 platform board.

## 2.5.4 USB Connectors

- **ICEJ:** USB connector (ICE) in Nu-Link-Me that connects to a USB Host port on a PC to program code and supply power.
- **CON2:** USB 2.0 connector (OTG) on the NuMaker-PFM-M2351 board for USB OTG application use.

## 2.5.5 Arduino UNO Compatible Interface Connectors

- **NU1, NU2, NU5, NU6 and NU7:** Arduino UNO compatible pins on the NuMaker-PFM-M2351 board.

## 2.5.6 Extended Connectors

- **JP6, JP7, JP8 and JP9:** Extended connectors interface pins on the NuMaker-PFM-M2351 board.

## 2.5.7 SWD / ETM Interface

The ETM is a debug interface that enables reconstruction of program execution. It provides instruction and data tracing of a processor. The traced data could be used to capture events leading to a breakpoint, or used for code coverage statistics or execution information.

- **ETM1:** SWD / ETM interface connector with 20 pins on the NuMaker-PFM-M2351 board.

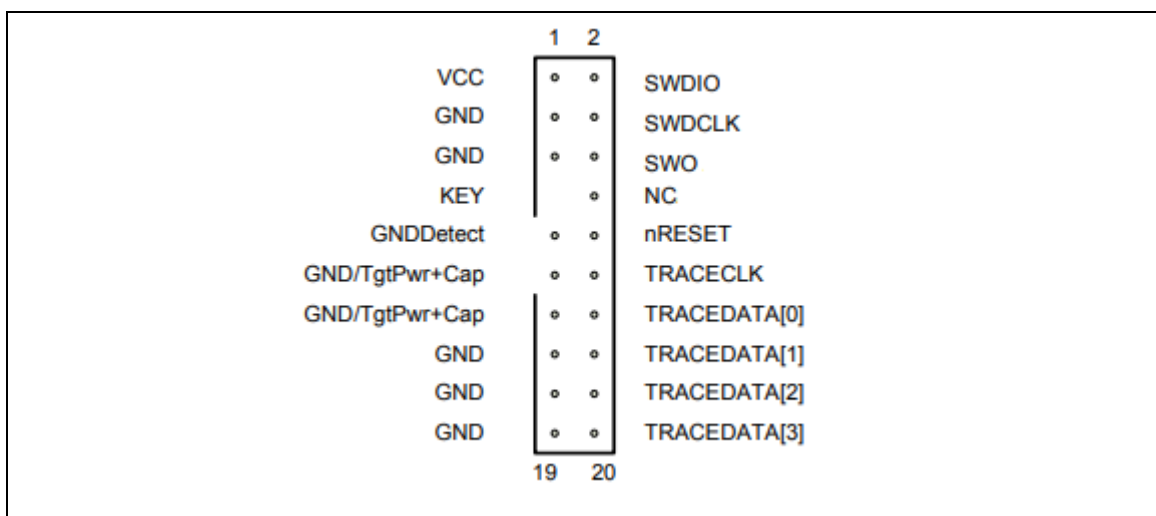


Figure 2-5 SWD / ETM Interface 20 Pin Connector

## 2.5.8 Phone Jack

- **CN2:** Phone jack connector on NuMaker-PFM-M2351 for audio application use.

## 2.5.9 MicroSD Card Slot

- **U9:** MicroSD card slot for application use.

#### 2.5.10 Push-Buttons

- **SW1:** Reset button to reset the target chip on NuMaker-PFM-M2351 board.
- **SW2, SW3:** Two Push-Buttons for user to control application process.

#### 2.5.11 LEDs

- **POWER:** The power LED indicates that the NuMaker-PFM-M2351 board is powered.
- **I/O1 and I/O2:** Only for application use.

#### 2.5.12 Power Connectors

- **JP2, JP3:** 3VCC connectors on the NuMaker-PFM-M2351 board.
- **JP4, JP5, JP10 and JP11:** GND connectors on the NuMaker-PFM-M2351 board.

## 2.6 Wi-Fi Module (ESP-03)

- **U10:** Wi-Fi Module ESP-03 on the NuMaker-PFM-M2351 board for application use.

NuMaker-PFM-M2351	ESP-03	Description
PD.7	-	Turn on/off MOSFET(Q1) to enable/disable power of ESP-03
UART3_RXD	UTXD	UART data out from ESP-03
UART3_TXD	URXD	UART data in from ESP-03
PD.4	GPIO16	General Purpose Input/Output Interface
UART3_nRTS	GPIO13	CTS pin for flow control
UART3_nCTS	GPIO15	RTS pin for flow control
PD.5	GPIO2	General Purpose Input/Output Interface
PD.6	GPIO0	General Purpose Input/Output Interface

Table 2-6 Optional Function of ESP-03

## 2.7 Secure Serial Flash (W77F32W)

The NuMaker-PFM-M2351 features a Winbond W77F32W (32M-bit) TrustME™ Secure Serial Flash device that provides a secure storage solution for systems with limited space, pins and power. The W77F32W Flash is ideal for secure data storage, cryptographic key storage, and general data storage. The W77F32W is connected to the NuMaker-PFM-M2351 via SPI bus for data input/output. Table 2-8 shows the pin mapping between the W77F32W and M2351KIAAE.

NuMaker-PFM-M2351	W77F32W(U11)	Description
QSPI0_MISO1	IO3	Data Input Output 3
VDDIO	VDD	Power Supply <b>Note:</b> The devices operate on a single 1.65V to 1.95V power supply
QSPI0_CS	CS/	Chip Select Input
QSPI0_MISO0	DO (IO1)	Data Output (Data Input Output 1)
QSPI0_MISO1	IO2	Data Input Output 2
GND	GND	Ground
QSPI0_MOSI0	DI (IO0)	Data Input (Data Input Output 0)
QSPI0_CLK	CLK	Serial Clock Input

Table 2-7 W77F32W Mapping with M2351KIAAE

## 2.8 Audio Codec (NAU88L25)

The NuMaker-PFM-M2351 features a Nuvoton NAU88L25 audio Codec which is an ultra-low power high performance audio Codec designed for headphone or headset application. It includes one I<sup>2</sup>S/PCM interface, one high quality stereo DAC, one mono ADC, a Class G stereo headphone

amplifier, and industry leading advanced headset features.

The NAU88L25 is connected to the NuMaker-PFM-M2351 via I<sup>2</sup>C bus (I<sup>2</sup>C slave address of NUA88L25 is 0x1A by default) for control, and via I<sup>2</sup>S bus (M2351 is I<sup>2</sup>S slave) for audio digital data input/output. Table 2-8 shows the pin mapping between the NUC88L25 and M2351KIAAE.

NuMaker-PFM-M2351	NAU88L25	Description
I2C2_SCL	SCLK	I <sup>2</sup> C clock output <b>Note:</b> The I <sup>2</sup> C address of NAU88L25 is 0x1A by default.
I2C2_SDA	SDIO	I <sup>2</sup> C data input/output <b>Note:</b> The I <sup>2</sup> C address of NAU88L25 is 0x1A by default.
I2S0_BCLK	BCLK	I <sup>2</sup> S bit clock output from NAU88L25
I2S0_MCLK	MCLK	I <sup>2</sup> S master clock output from M2351
I2S0_DI	ADCOUT	I <sup>2</sup> S data input to NAU88L25
I2S0_DO	DACIN	I <sup>2</sup> S data output from M2351
I2S0_LRCK	FS	I <sup>2</sup> S left right channel clock output from NAU88L25
PC.5	JKDET	To detect jack insertion and ejection

Table 2-8 NAU88L25 Mapping with M2351KIAAE

The 3.5mm phone jack CN2 is used to attach the headset with a microphone. Figure 2-6 shows the phone jack diagram.

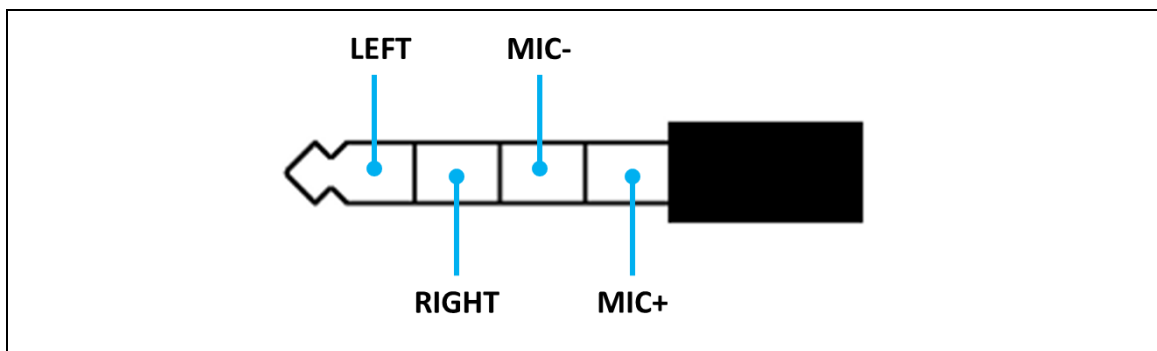


Figure 2-6 3.5mm Phone Jack Diagram

## 2.9 Nu-Link-Me

The NuMaker-PFM-M2351 features a Nu-Link-Me ICE debugger and programmer, which enables users to program M2351KIAAE and debug their application via the SWD interface, or emulate a USB pen driver when connected to the PC. Users can update their firmware by pulling a bin file to the pen driver. The Nu-link-Me can also emulate a virtual COM port, by which users can log or print debug message. Refer to Table 2-9 Table 2-9 Optional Function of Nu-Link-Me

for optional function of Nu-Link-Me.

ISW1		
Pin	Nu-Link-Me	Description
1	TXD	<b>On:</b> Connect PB.13 (UART0_TXD) of M2351KIAAE to Nu-Link-Me. <b>Off:</b> Disconnect PB.13 (UART0_TXD) of M2351KIAAE to Nu-Link-Me.
2	RXD	<b>On:</b> Connect PB.12 (UART0_RXD) of M2351KIAAE to Nu-Link-Me. <b>Off:</b> Disconnect PB.12 (UART0_RXD) of M2351KIAAE to Nu-Link-Me.
3	VCOM	<b>On:</b> Enable Nu-Link-Me virtual COM port function. <b>Off:</b> Disable Nu-Link-Me virtual COM port function.
4	MSG	<b>On:</b> Normal ICE mode, user can debug and program via SWD interface. <b>Off:</b> Mass storage mode, user can update firmware by pulling a bin file to pen driver.

Table 2-9 Optional Function of Nu-Link-Me

## 2.10 PCB Placement

Figure 2-7 and Figure 2-8 show the front and rear placement of NuMaker-PFM-M2351 board.

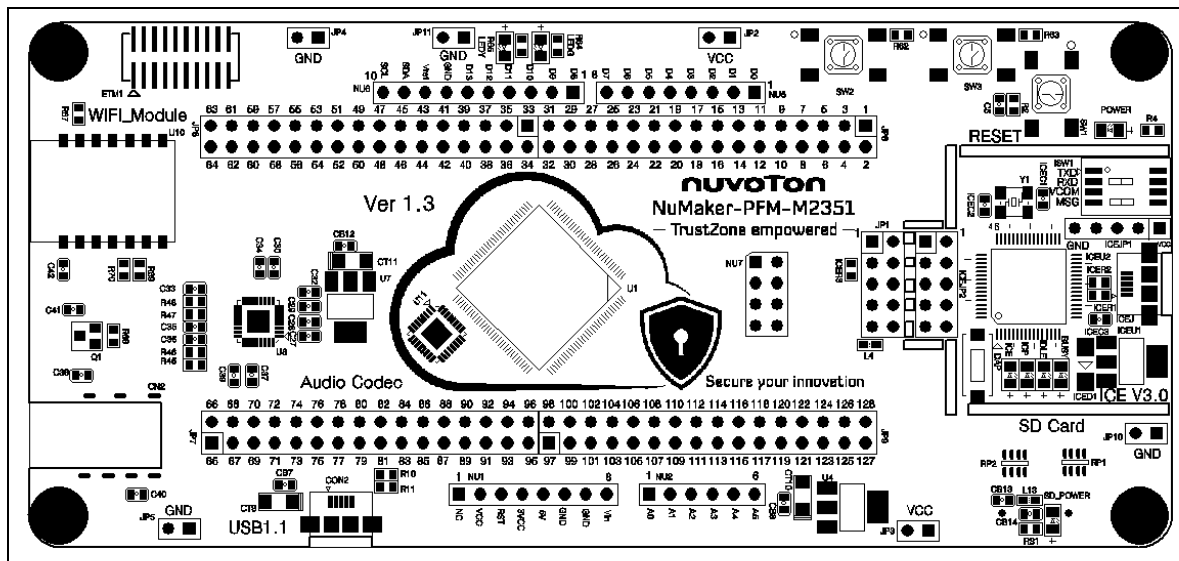


Figure 2-7 Front Placement

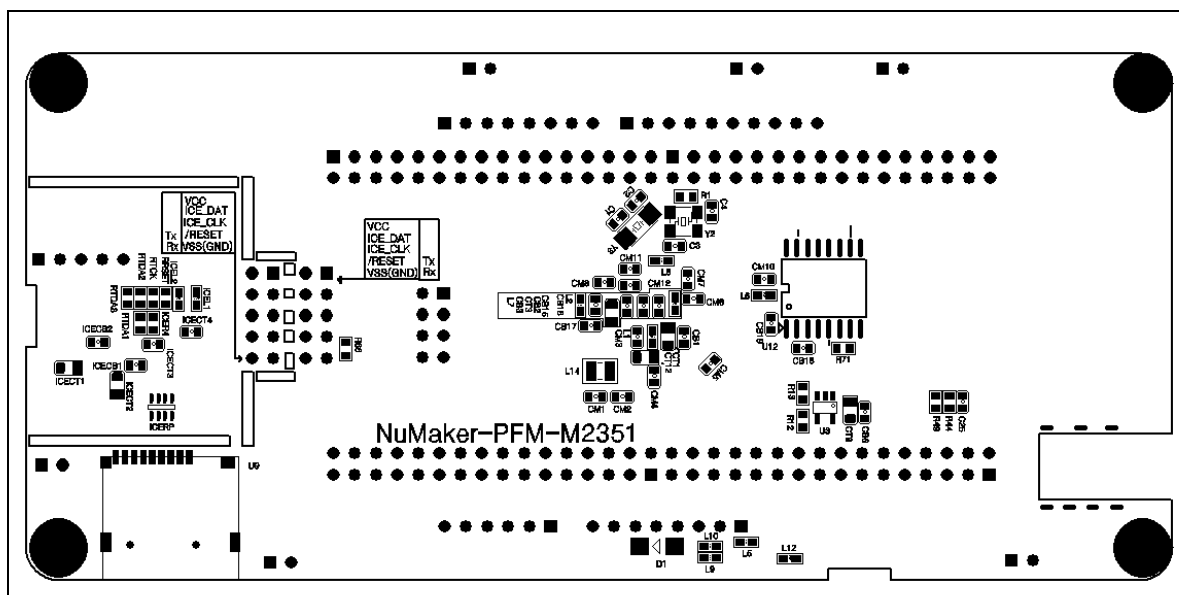


Figure 2-8 Rear Placement



### 3 NUMAKER-PFM-M2351 SCHEMATICS

### 3.1 Nu-Link-Me

Figure 3-1 shows the Nu-Link-Me circuit, which is a USB-to-SWD bridge used to program code to the target chip.

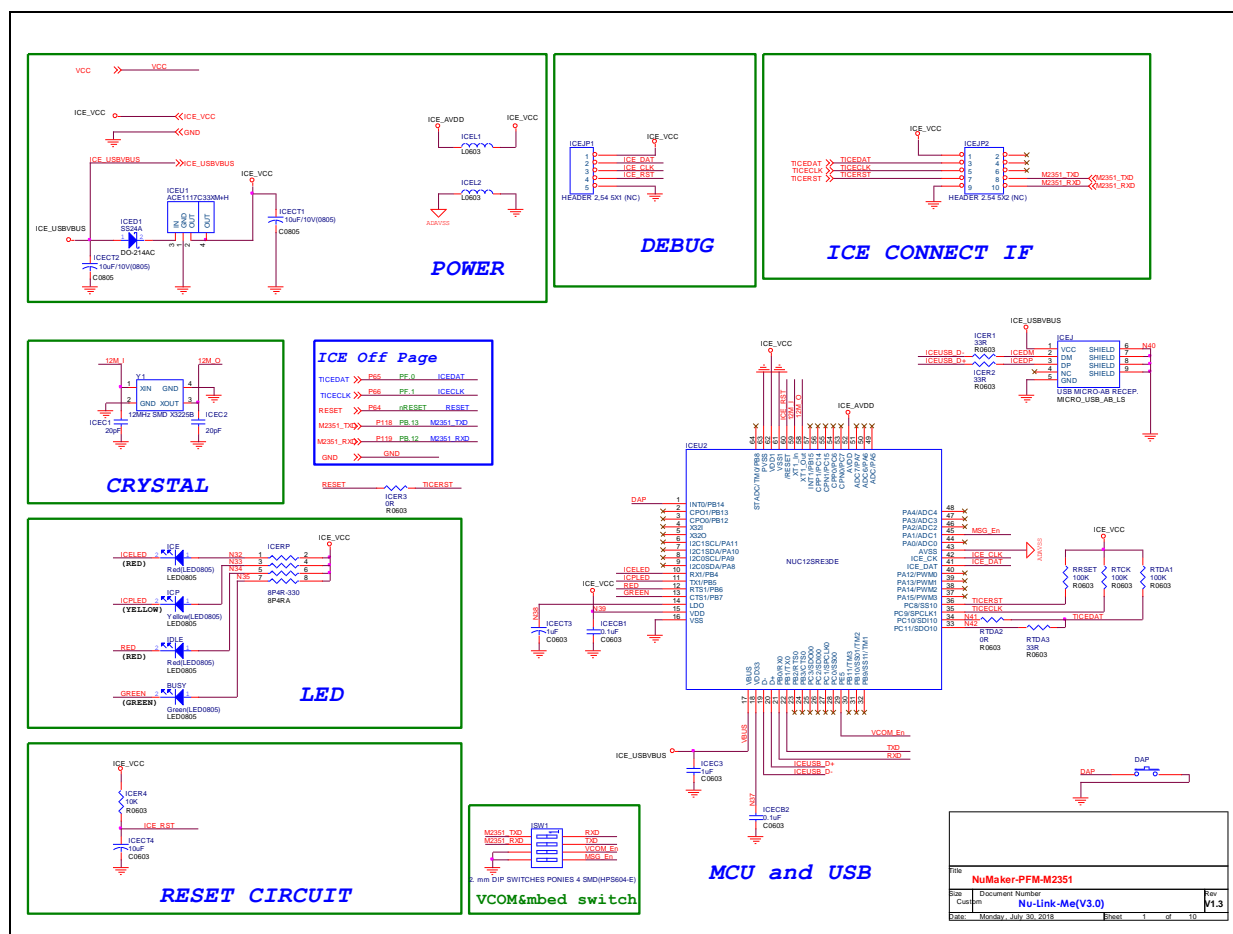


Figure 3-1 Nu-Link-Me Circuit

### 3.2 M2351KIAAE

Figure 3-2 shows the pin assignment of the M2351KIAAE.

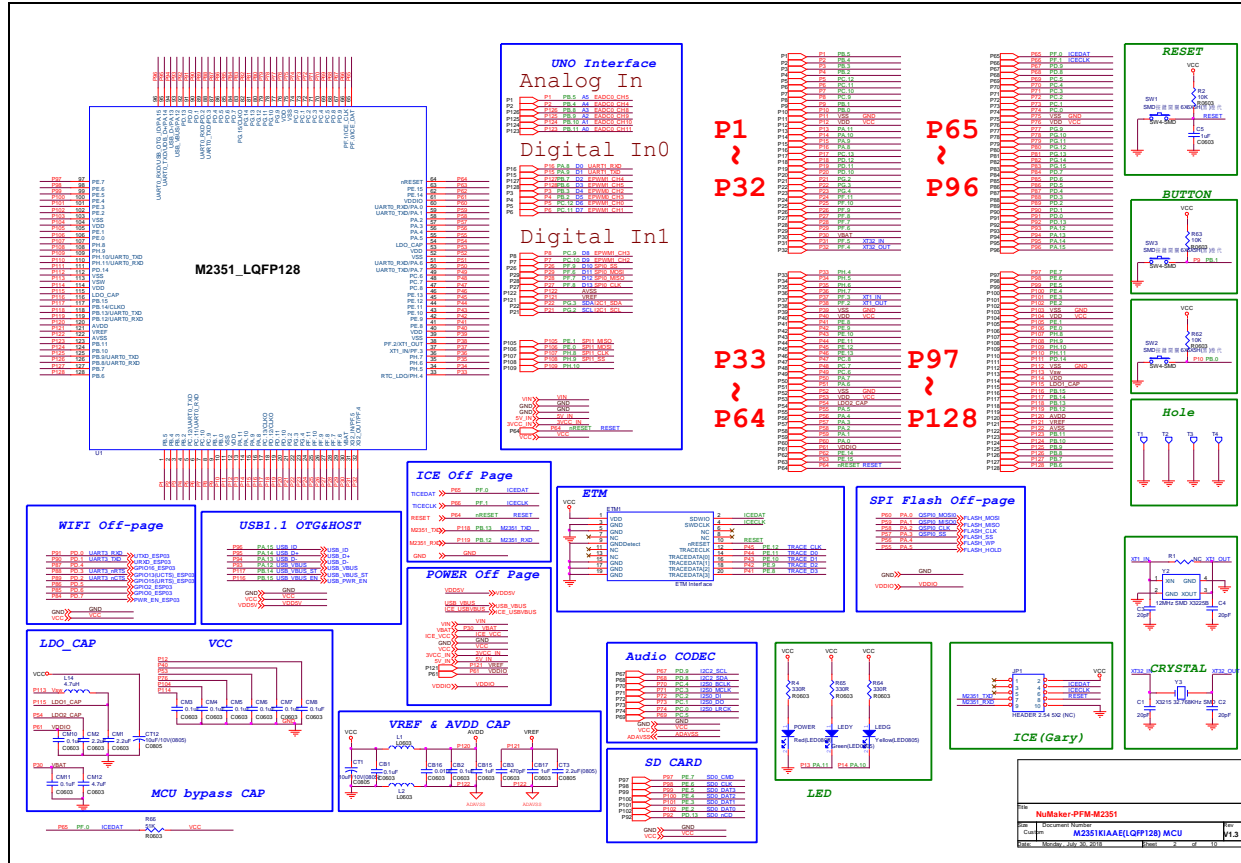


Figure 3-2 M2351KIAAE Pin Assignment



3.4 Power Supply

Figure 3-4 shows power configurations of NuMaker-PFM-M2351 board.

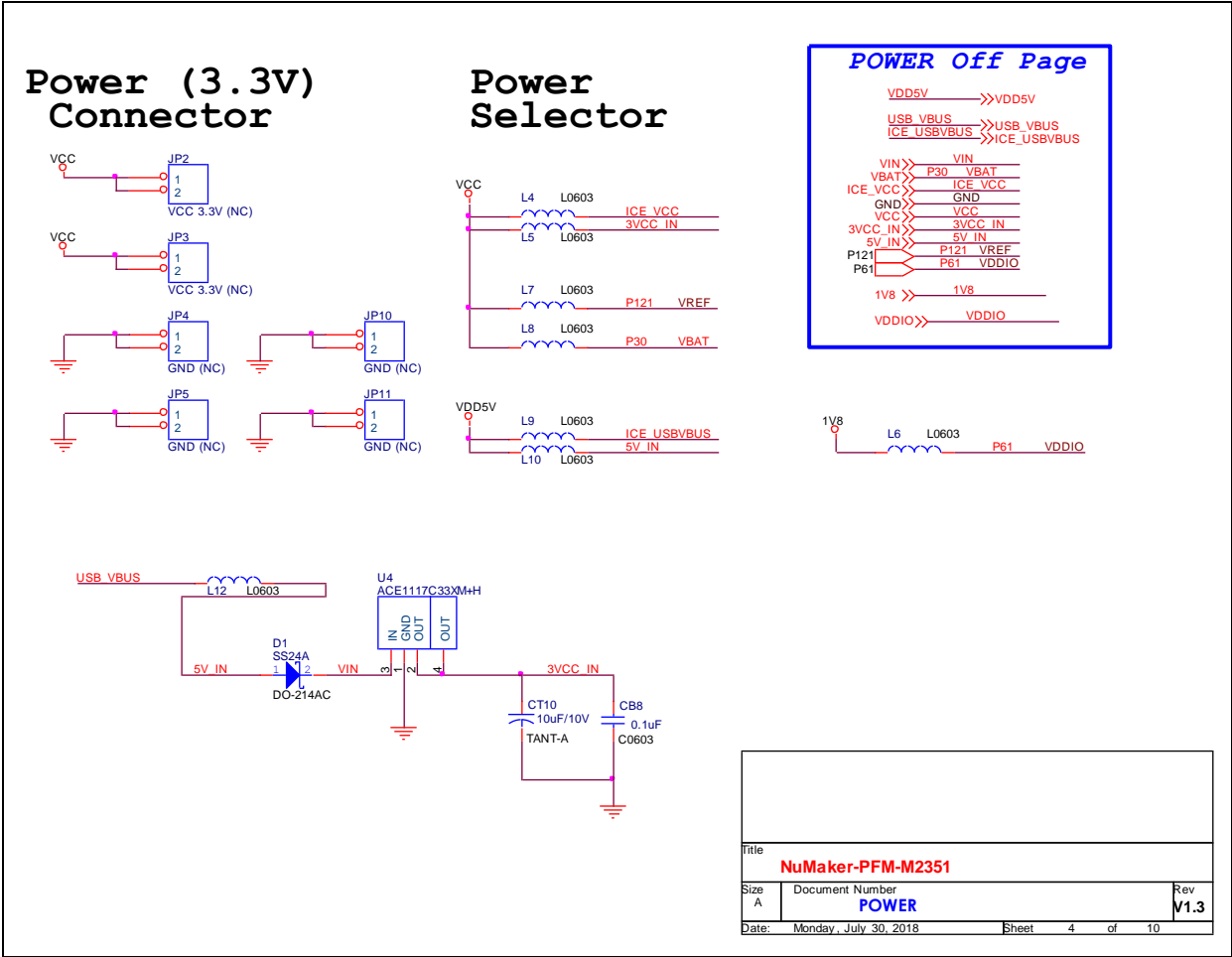
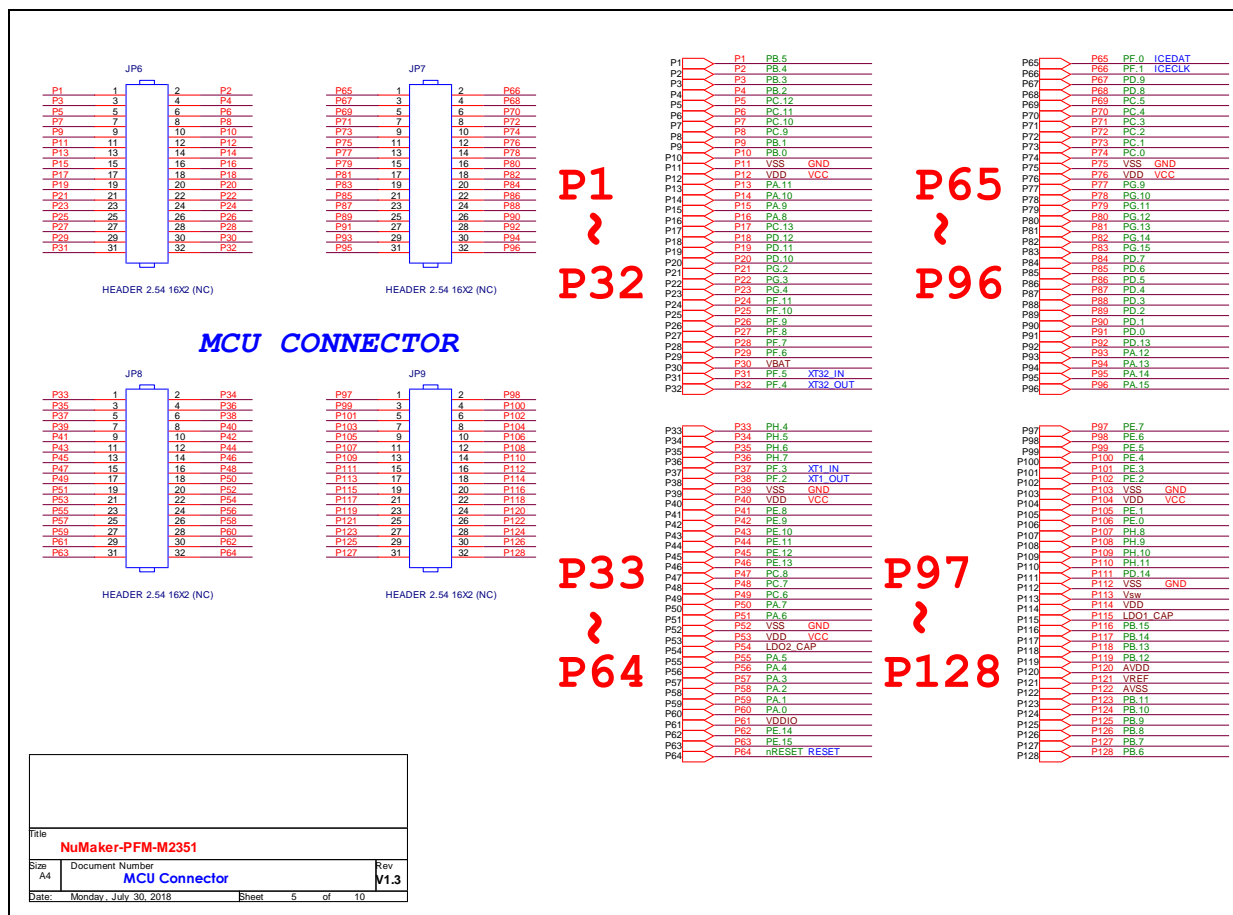


Figure 3-4 Power Circuit and Configurations

### 3.5 MCU Connector

Figure 3-5 shows the MCU Connector of JP6 to JP9 connectors.



### Figure 3-5 MCU Connector

3.6 Arduino UNO Compatible Interface

Figure 3-6 shows the Arduino UNO compatible interface of NU1 to NU5 connectors.

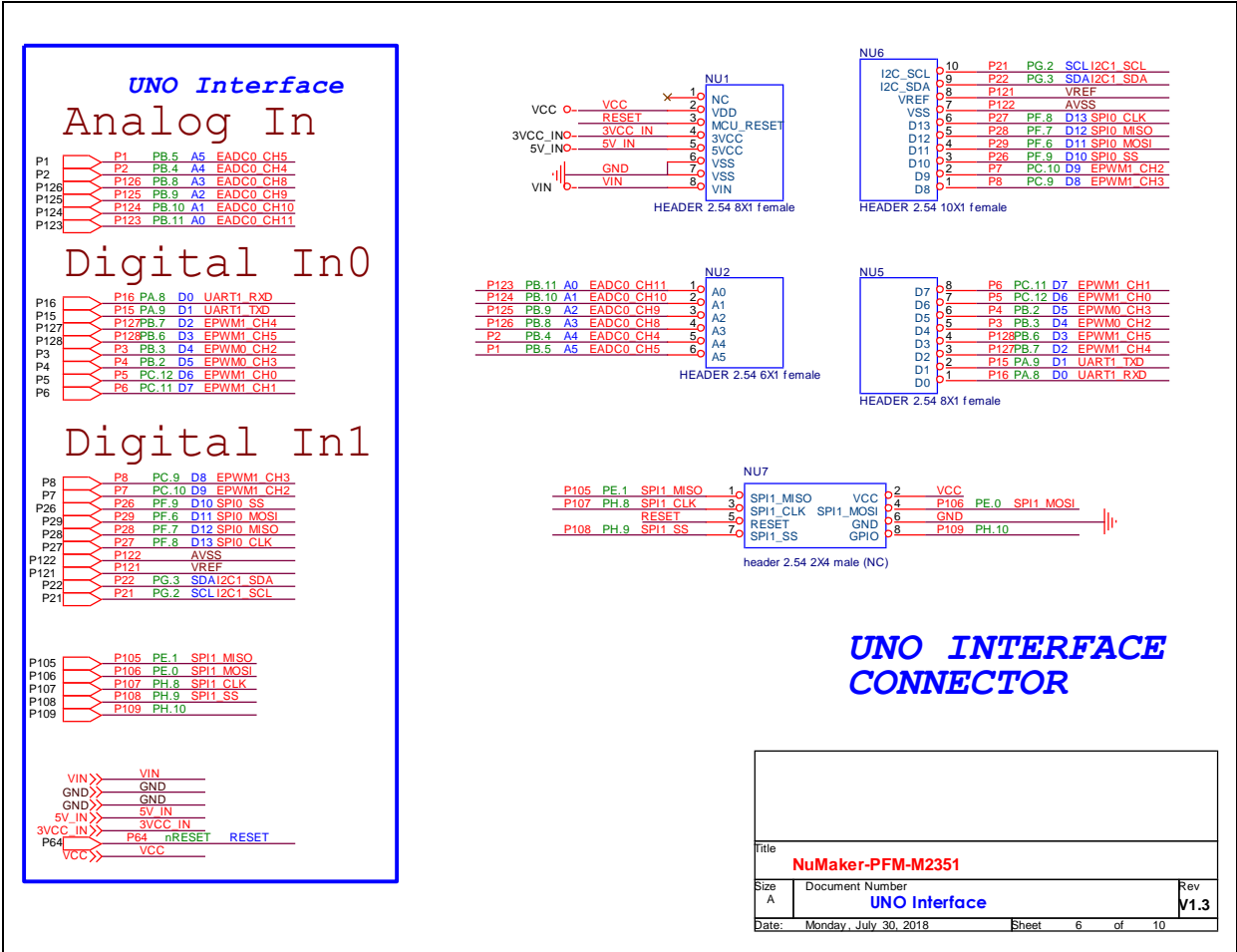


Figure 3-6 Arduino UNO Compatible Interface

### 3.7 Audio Codec (NAU88L25)

Figure 3-7 shows the audio codec application circuit based on NAU88L25 to simplify implementation of complete audio system solutions.

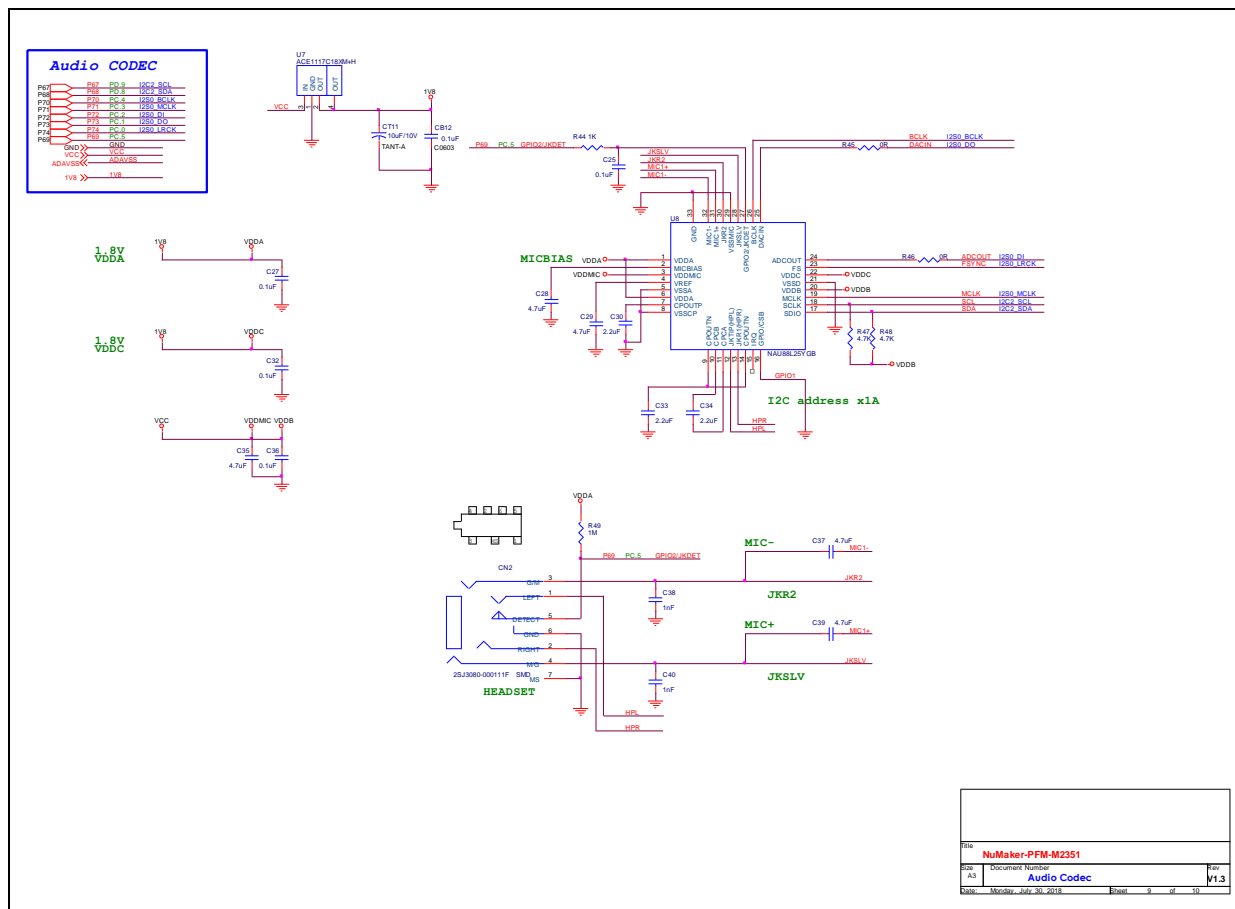


Figure 3-7 Audio Codec Circuit

3.8 MicroSD Card

Figure 3-8 shows the MicroSD Card circuit on the NuMaker-PFM-M2351 board.

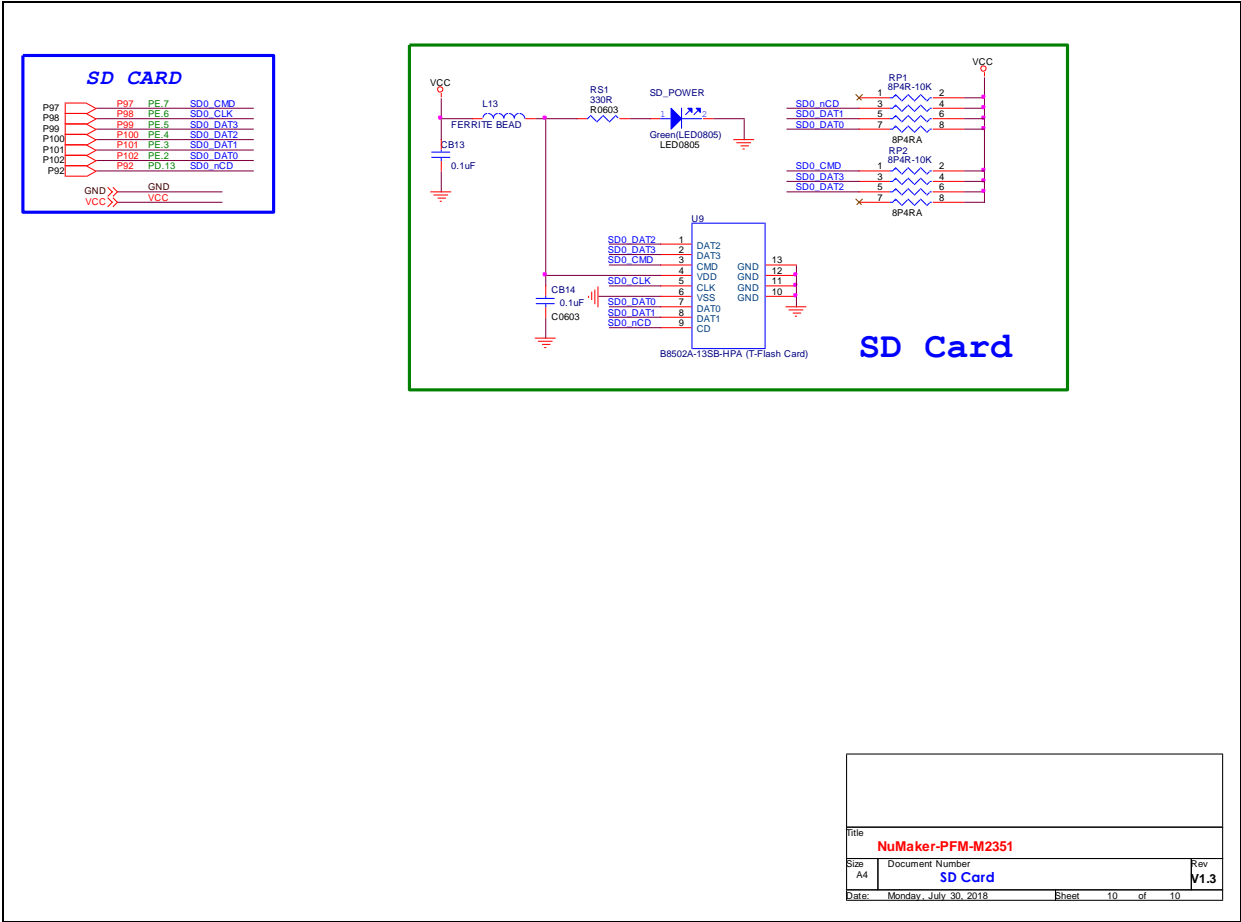


Figure 3-8 MicroSD Card Circuit



### 3.9 Wi-Fi Module (ESP-03)

Figure 3-9 shows the Wi-Fi Module (ESP-03) for wireless application on the NuMaker-PFM-M2351 board.

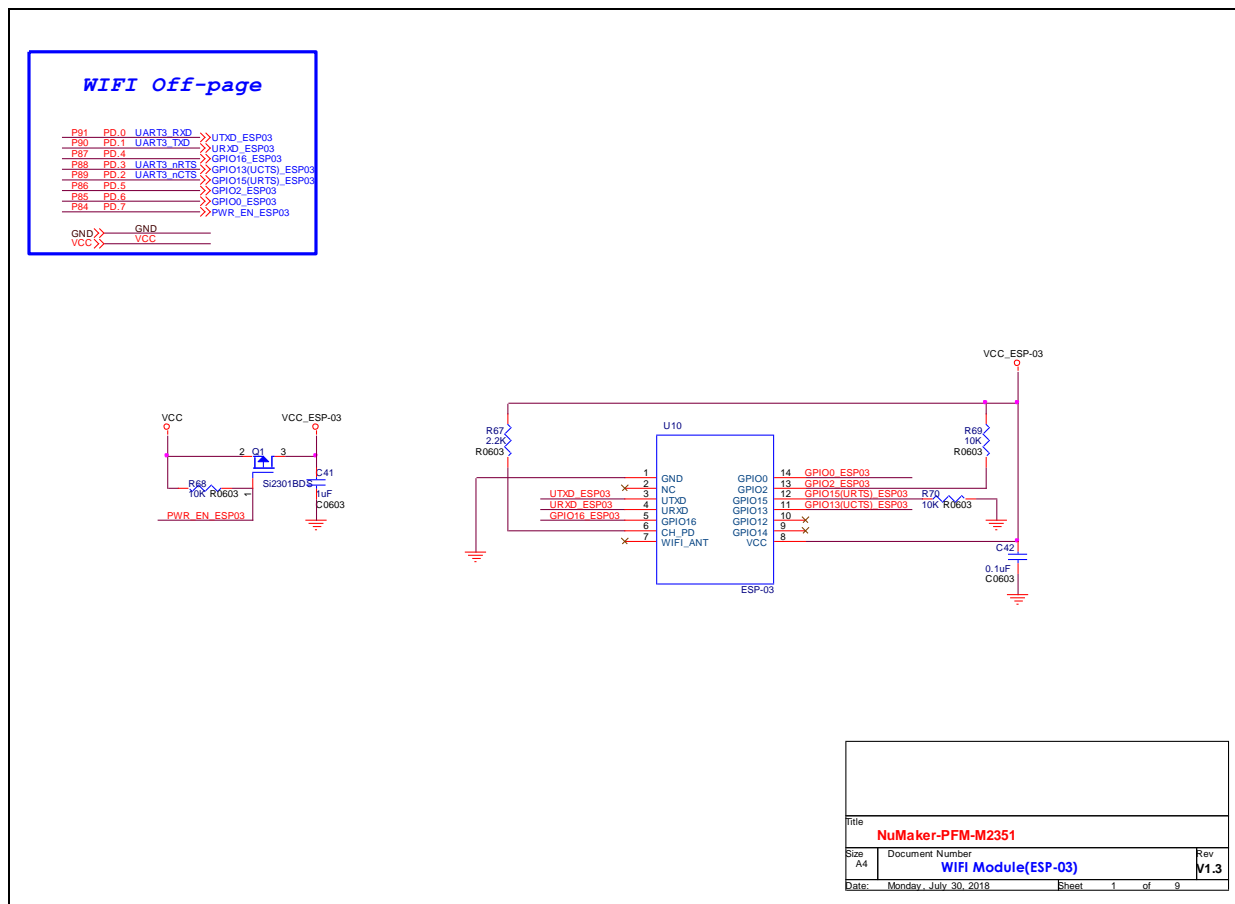


Figure 3-9 Wi-Fi Module Circuit

### 3.10 Secure Serial Flash (W77F32W)

Figure 3-10 shows the Secure Serial Flash (W77F32W) circuit on the NuMaker-PFM-M2351 board.

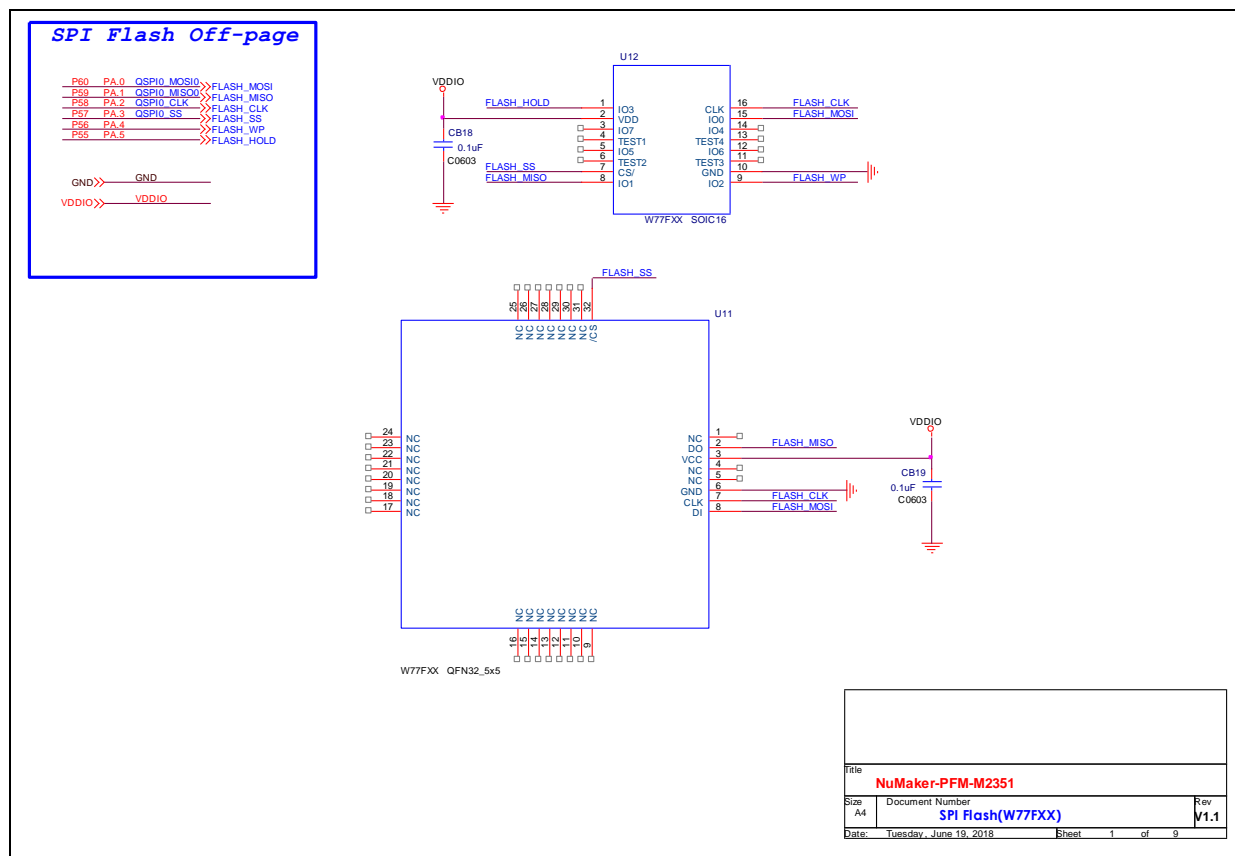


Figure 3-10 MicroSD Card Circuit

## 4 REVISION HISTORY

Date	Revision	Description
2018.08.29	1.00	Initially issued.

### Important Notice

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