User's Manual

Application Example for Cloud Connectivity (AE-CLOUD2)

User's Manual

Renesas Synergy™ Platform

Synergy Tools & Kits

Tools: Connectivity

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- Ensure attached cables do not lie across the equipment.
- Reorient the receiving antenna.
- Increase the distance between the equipment and the receiver.
- Connect the equipment into an outlet on a circuit different from that which the receiver is connected.
- Power down the equipment when not in use.
- Consult the dealer or an experienced radio/TV technician for help.

Note: It is recommended that wherever possible shielded interface cables are used.

The product is potentially susceptible to certain EMC phenomena. To mitigate against them it is recommended that the following measures be undertaken:

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- The user is advised to take ESD precautions when handling the equipment.

The Renesas Synergy™ Kit does not represent an ideal reference design for an end product and does not fulfill the regulatory standards for an end product.

1. Overview

The AE-CLOUD2 is an Application Example Kit for Cloud connectivity, intended for fast prototyping of embedded systems, specifically targeting Internet of Things applications. The kit includes all components required for development and debugging of software that can collect information from a variety of sensors and communicate it securely to the Cloud.

Figure 1 Cloud Connectivity Application Example Kit

The kit includes a Wi-Fi board based on the GT202 module that uses Qualcomm® QCA4002 system on a chip. The board supports 802.11 b/g/n communication standards.

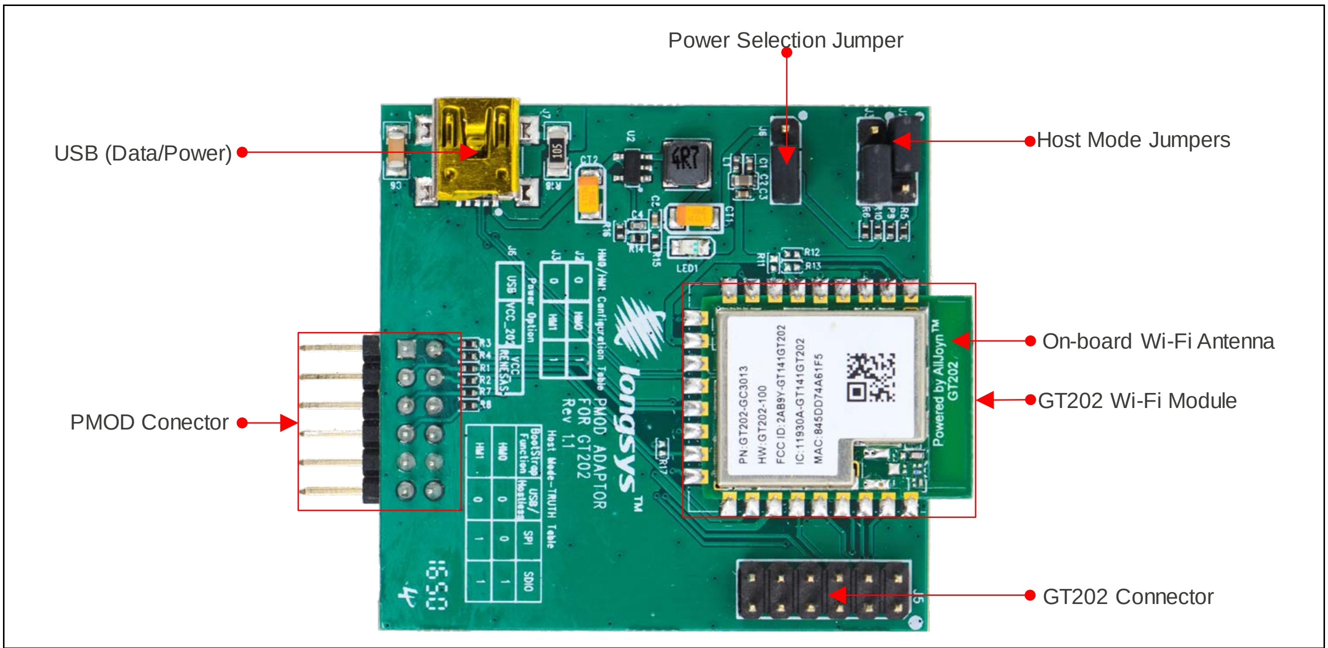


Figure 2 Wi-Fi Board based on the GT202 Module

The kit also includes a cellular connectivity shield based on the Quectel BG96 module. It provides 4G/LTE Cat-M1 (eMTC) and 4G/LTE Cat-NB1 (NB-IoT) support with fallback to 2G/EGPRS mobile networks. In addition, it integrates a GPS receiver which enables the development of position-tracking applications.

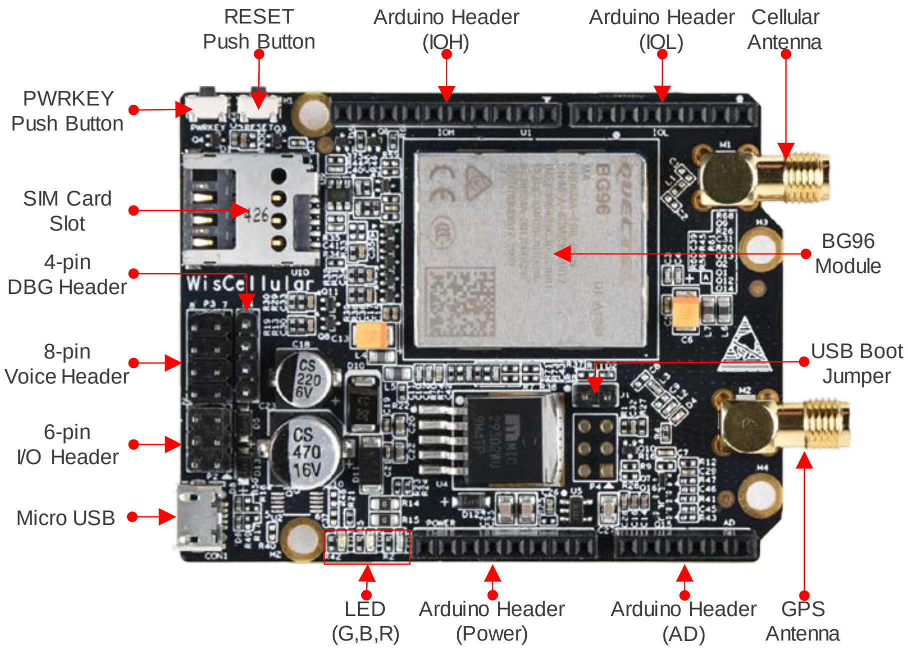


Figure 3 Arduino Shield for Cellular Network Connectivity

At the heart of the kit is the MCU board based on the Renesas Synergy™ S5D9 Microcontroller. Figure 4 describes the main board components, the interface connectors, and their purpose.

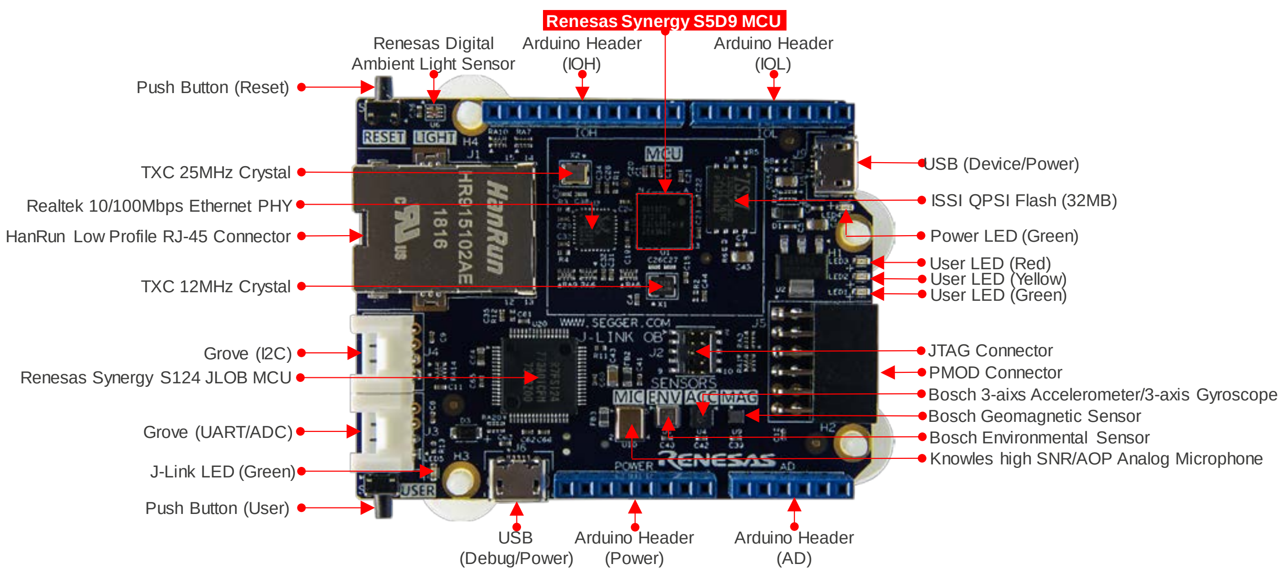


Figure 4 S5D9 Synergy MCU Board Components

1.1 Board Features

- Synergy S5D9 Arm® Cortex®-M4 Core
  - Arm®v7E-M architecture
  - Maximum operating frequency: 120 MHz
  - Secure Crypto Engine
  - Memory Protection Unit and Flash Access Window
  - Floating Point Unit
  - SWD debugging interface
- Memory
  - 640 KB SRAM
  - 2 MB Code Flash
  - 64 KB Data Flash
  - 32 MB External QSPI Flash
- Connectivity
  - Wired Ethernet (RJ45) 10/100 Mbps
  - USB 2.0 Full Speed
  - UART (through the Arduino or Seeed Grove connector)
  - I^2C (through the Arduino or Seeed Grove connector)
  - SPI (through the Arduino or Digilent PMOD connector)
- Sensors
  - Accelerometer and Gyroscope (Bosch BMI160)
  - Magnetometer (Bosch BMM150)
  - Environmental – Gas, Pressure, Temperature, Humidity (Bosch BME680)
  - Ambient Light (Renesas ISL29035)
  - Acoustic (Knowles MEMS microphone SPM0687LR5H-1)
- General Purpose I/O Ports
  - User-defined LEDs
  - User-defined button
  - Arduino Shield Headers
  - Seeed Studio's Grove Connectors
- Operating Voltage
  - 5V

2. What's in the Box

The AE-CLOUD2 kit includes the following components:

- Synergy S5D9 MCU board
- Wi-Fi module
- Cellular Arduino Shield
- Two USB cables and one Ethernet cable
- Cellular antenna
- GPS antenna
- Quick Start Guide (back side of packaging box cover)
- Important Notice and Disclaimer Card

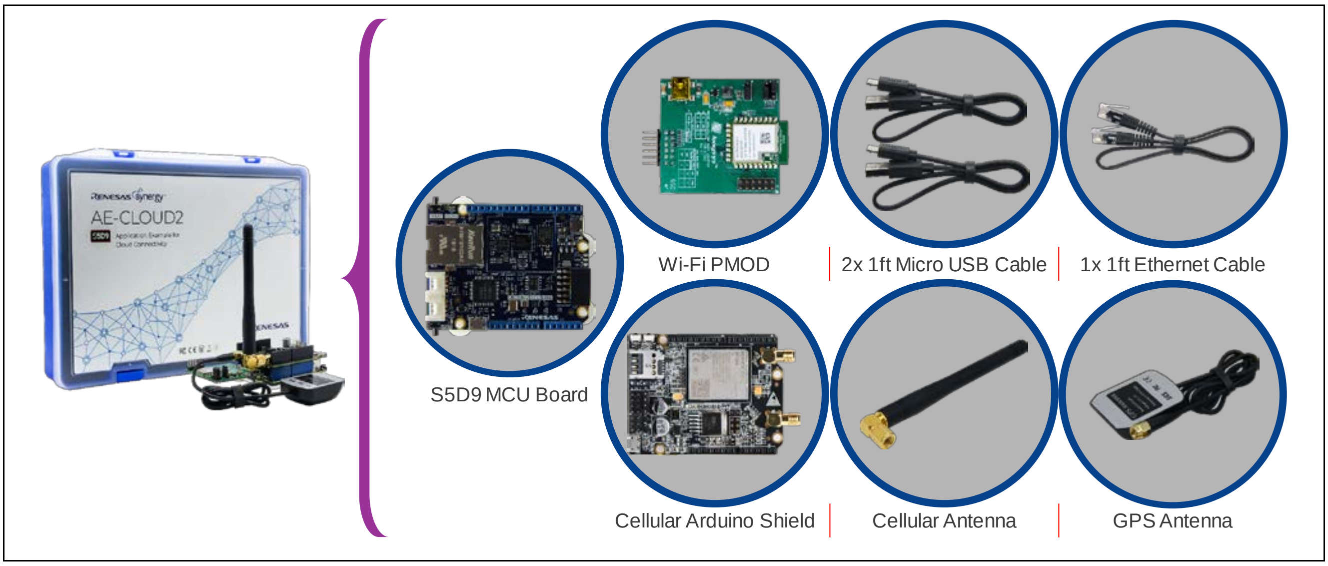


Figure 5 AE-CLOUD2 Box Contents

3. Getting Started

Before you start working with your development board, you must obtain the latest version of the Synergy Software Package (SSP), as well as the development tools needed to work with it.

If you are new to Synergy development, we encourage you to use the AE-CLOUD2 Quick Start Guide. This guide will provide detailed instructions on how to register an account on the Synergy Gallery to obtain a developer license, and how to download and install all software & tools that are required. Once you have completed these steps, please return to this section for more in-depth information on how to work with your S5D9 MCU board.

3.1 Connecting the Boards

Plug the Wi-Fi Module to the MCU board through a PMOD connector. Plug the Cellular Arduino Shield into the S5D9 MCU board. Be careful to align the Arduino Shield connector pins correctly.

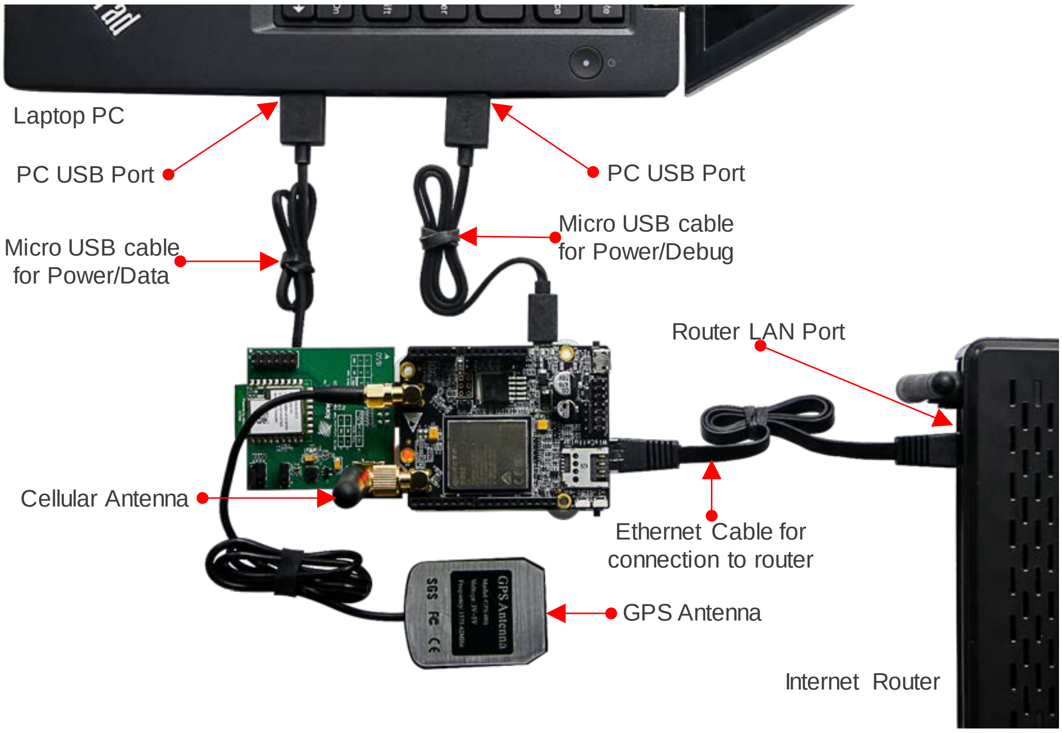


Figure 6 Connecting the Boards from the Kit

Connect the USB cables from J6 (for debugging) and from J9 (for communication) on the MCU Board to the host computer. The USB Device connector (J9) provides 5V power to the entire kit. The USB J-Link OB Debug connector (J6) provides 5V power only to the MCU board.

For cellular and GPS operation, connect the cellular antenna and the GPS antenna to their corresponding connectors on the Cellular Arduino Shield. As seen in Figure 6, the cellular antenna goes to the top connector.

3.2 Download Application Software

The kit comes without firmware pre-installed on its MCU board. The user is encouraged to download cloud connectivity example projects of their choice by searching for AE-CLOUD2 at http://renesassynergy.com.

On this kit webpage, the user can find links to the individual application projects for Microsoft Azure, Amazon Web Service (AWS), and Google Cloud Platform as well as Synergy Enterprise Cloud Toolbox demo and Medium One IoT Prototyping Sandbox tutorial.

4. S5D9 MCU Board

4.1 MCU Board Overview

Figure 7 shows the top view of the MCU Board. It is built around the versatile Renesas Synergy™ S5D9 Microcontroller. The SEGGER J-Link® On-board, using the Renesas Synergy™ S124 MCU, provides a debug interface so that no external programming probes are needed. The board is highly integrated with many sensors, external flash memory, Ethernet PHY, Arduino, Grove and PMOD connectors, buttons and LEDs. The rich functionality of the board makes it ideal for prototyping a wide range of IoT Solutions.

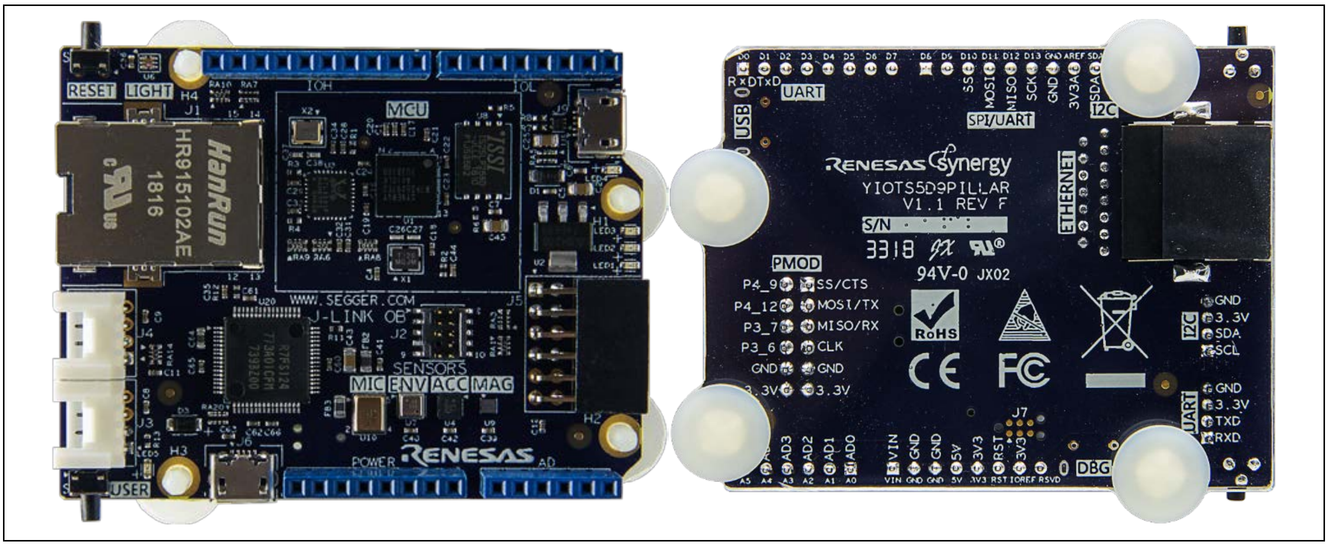


Figure 7 MCU Board

Figure 8 shows the MCU board main components. It includes all interfaces – both internal and external.

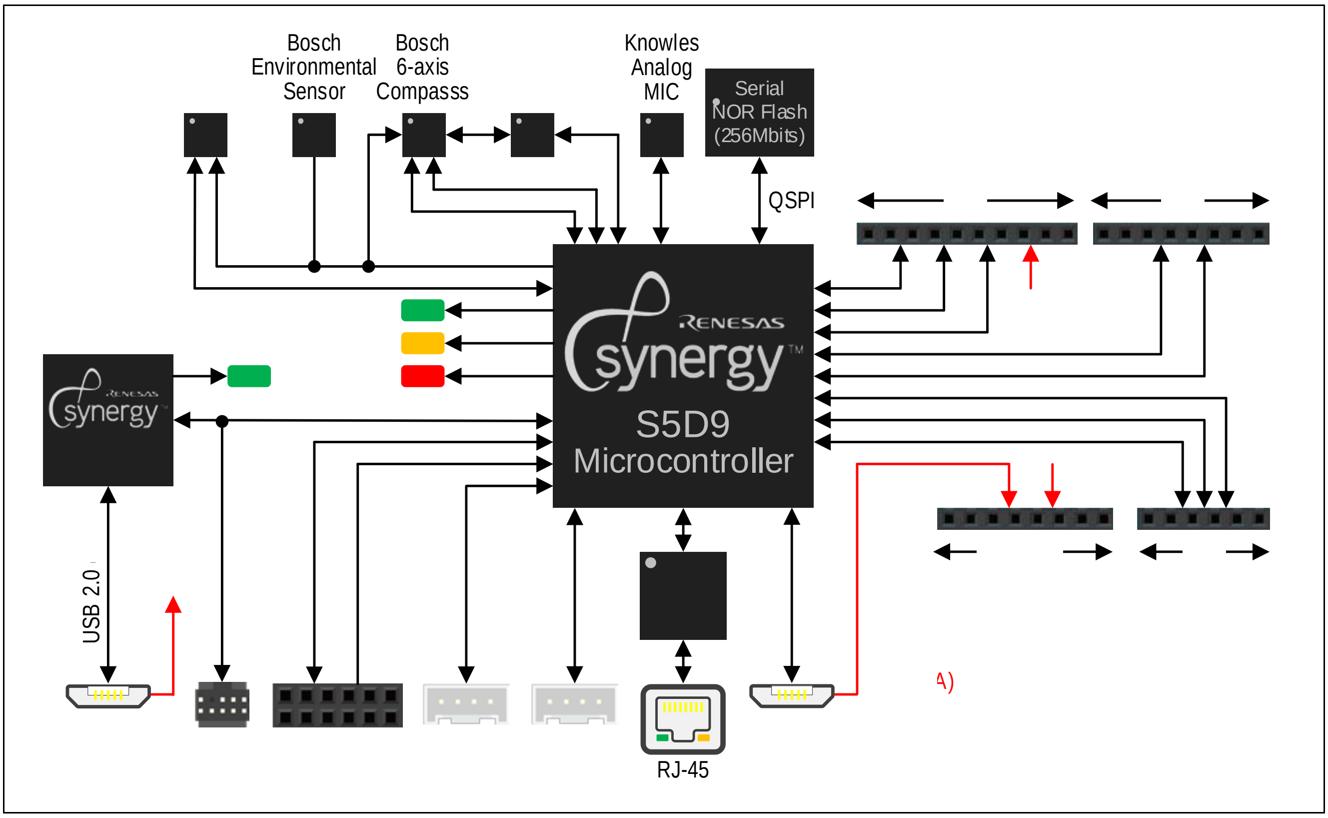


Figure 8 MCU Board System Architecture

The MCU board includes the following main components:

- The Synergy S5D9 MCU featuring 2 MB code flash/640 KB SRAM/64 KB data flash.
- A power management based on 3.3V LDO voltage regulator required for the operation of the microcontroller.
- Quad SPI flash – the MCU flash memory is expanded with external 256 Mbits (32 MB) memory device connected over a high-speed QSPI interface. The external flash can be used for storage of graphics and other digital assets, or for execution of code in place (XIP).
- User-defined LEDs – the user-defined LEDs are useful in indicating the current state of the firmware. The 3 LEDs have different colors for easy identification.
- USB device interface – the S5D9 MCU includes one USB interface operating at full speed. The USB device connector is also used to power the board.
- PMOD interface header – the board includes one 12-pin PMOD header that can be configured by a jumper to provide 3.3V on its power pins. The header enables interfacing with other devices over SPI or UART.
- Grove connectors – the Grove connectors are compatible with the Seeed Studio's line of peripheral modules that include a very large selection of sensors and actuators. One of the Grove connectors can be configured to communicate over UART and the other is dedicated for I^2C interface.
- J-Link On-Board SEGGER debugging probe based on Synergy S124 MCU.
- JTAG interface that is available on a 10-pin connector (J20) compatible with SEGGER debugging probe.
- The board includes a number of sensors described in detail in section 5.3.

4.2 Power Requirements

The AE-CLOUD2 is designed to be powered by the USB device interface on J9 connector.

The S5D9 board can supply power to the devices connected to it. The PMOD interface and the Grove connectors can power 3.3V peripherals.

The power supply requirements and current consumption specifications are listed in following table.

Table 1 Electrical Specifications

Parameter	Value	
	Minimum	Maximum
Power Supply Voltage	3.7V	5.5V
Current Consumption		500 mA
Digital Inputs Voltage	0V	3.3V
Digital Outputs Voltage	0V	3.3V
Operating Temperature	0°C	+75°C
PMOD Connector Power Voltage	3.3V	
Grove Connectors Power Voltage	3.3V	

4.2.1 Power Supply Options

The power supply source is the J9 - USB Micro-B connector providing 5 V and up to 500 mA of power.

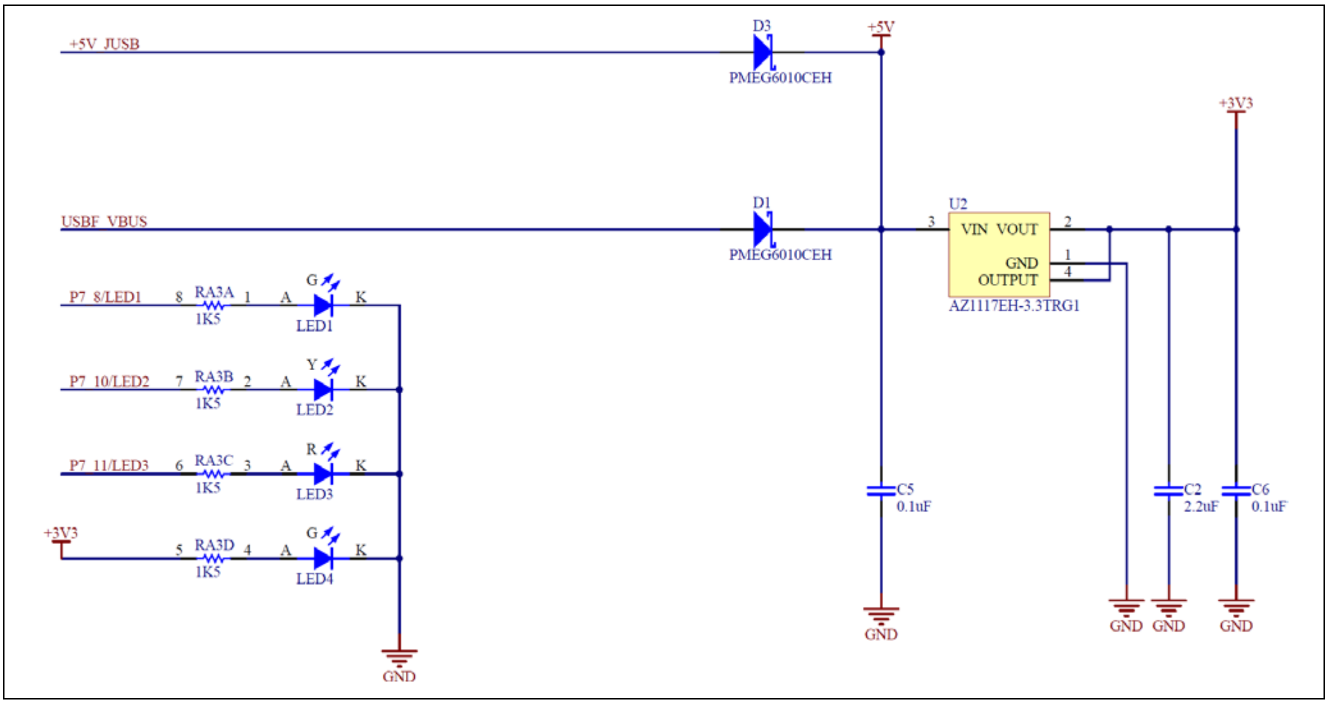


Figure 9 Power Supply Management

Note that the Schottky diodes provided are in series with the power source. This protects them from overload in case both are connected and one has higher voltage than the other.

4.2.2 Power-up Behavior

Upon power up, the MCU is idle until its RESET pin registers transition to logic 1. At this point, the MCU hardware samples the logic level of the MD pin. The MD pin level determines if the MCU will enter 'Factory Boot Mode'. In this mode, the MCU executes an internal firmware code that initializes the USB interface and prepares the device to communicate with utilities that can update the content of its memory.

The state of the MD pin at startup is defined by S2. If the button is pressed at the time of the RESET signal, then the factory bootloader will execute on startup. If S2 is not pressed at the time of the RESET signal, then the MCU will execute the code previously loaded to the MCU code flash memory.

4.3 Installed Sensors

The on-board sensors provide variety of options when it comes to prototyping IoT applications:

- **Accelerometer, Gyroscope and Magnetometer**: Bosch Sensortec - BMI160 (U4) and BMM150 (U9)
  - BMI160 is an extremely small low power and low noise 6-axis accelerometer and gyroscope.
  - The integrated accelerometer provides all functionalities of Bosch Sensortec's leading-edge 12-bit digital accelerometer, including a 32-frame FIFO buffer storing acceleration data.
  - The interface to the MCU is based on the I^{2}C protocol. The sensor has hard coded individual addresses:
    - Accelerometer = 0x68
    - Magnetometer = 0x10
  - Connected to MCU I^{2}C Channel 2 with pins configured to use Port 5 bits 11 and 12:
    - Data (SDA) = P5_11
    - Clock (SCL) = P5_12
- **Environmental Sensor**: Bosch Sensortec. – BME680 (U7)
  - The BME680 is a digital 4-in 1 sensor with gas, humidity, pressure, and temperature measurement based on proven sensing principles
  - The interface to the MCU is based on the I^{2}C protocol. The sensor has hard coded address on the I^{2}C Bus: 0x76.
  - Connected to MCU I^{2}C Channel 2 with pins configured to use Port 5 bits 11 and 12:
    - Data (SDA) = P5_11
    - Clock (SCL) = P5_12
- **Ambient Light Sensor: Renesas** - ISL29035 (U6)
  - The ISL29035 is an integrated ambient and infrared light-to-digital converter with I^{2}C bus interface. Its advanced self-calibrated photodiode array emulates human eye response with excellent IR rejection. The on-chip 16-bit ADC is capable of rejecting 50 Hz and 60 Hz flicker caused by artificial light sources. The Lux range select feature allows users to program the Lux range for optimized counts/Lux.
  - The interface to the MCU is based on the I^{2}C protocol. The sensor has hard coded address on the I^{2}C bus: 0x44
  - Connected to MCU I^{2}C Channel 2 with pins configured to use Port 5 bits 11 and 12:
    - Data (SDA) = P5_11
    - Clock (SCL) = P5_12
- MEMS Microphone: Knowles SPM0687LR5H-1 (U10)
  - The SPM0687LR5H-1 is a miniature, high-performance, low power, top port silicon microphone. It consists of an acoustic sensor, a low noise input buffer, and an output amplifier.
  - The device has the following main features:
    - 20 dB of Gain
    - Low current consumption
    - MaxRF protection
    - Ultra-stable performance
    - Omnidirectional
  - The microphone output is wired to MCU ADC Channel 1 (P0_1).

Table 2 Summary of the Sensors and their MCU Interfaces

Sensor	I2C MCU Ch 2 Bus Address	Interrupt Request	ADC Channel Number	Manufacturer
BMI160 Accelerometer	0x68	IRQ9 (INT1), IRQ8 (INT2)	N/A	Bosch
BMM150 Magnetometer	0x10	IRQ4		
BME680 Humidity and Temperature	0x76	N/A		
ISL29035 Light Sensor	0x44	IRQ7		Renesas
SPM0687LR5H-1 Microphone	N/A	N/A	1 (P0_1)	Knowles

4.4 Connectivity and Settings

4.4.1 RJ45 Ethernet Connector

The S5D9 MCU Board features standard Ethernet connector RJ45 with built-in magnetics. It is connected to RealTek PHY interface P/N: RTL8189EM-CG. The PHY is connected to the MCU via RMII interface. The RJ45 connector is HanRun Electronics Ltd. P/N: HR915102AE. Its front view is shown in Figure 10.

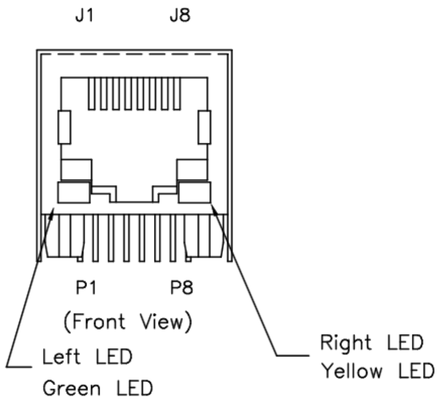


Figure 10 RJ45 Ethernet Connector

The pin mapping of the connector matches the standard for Ethernet ports. The pin mapping is shown in the following table.

Table 3 Ethernet RJ45 pin map

Pin Number	RJ45 Ethernet Port
1	TX+
2	TX-
3	RX+
4	neutral
5	neutral
6	RX-
7	neutral
8	neutral

4.4.2 PMOD Connector

The S5D9 MCU board includes one PMOD connector. It can interface with modules that require UART, I^2C, or SPI interface. The function of the PMOD is dependent on the MCU pin functions initialization. The PMOD connector pin map is shown in the following table.

Table 4 PMOD Pin Functions

Pin Number	PMOD (J5)
1	SSLB0/CTS9 – P2_5
2	MOSI/TXD9 – P2_3
3	MISO/RXD9 – P2_2
4	RSPCK/SCK9 – P2_4
5	GND
6	3.3V
7	GPIO – P4_9/IRQ6
8	GPIO – P4_12
9	GPIO – P3_7
10	GPIO – P3_6
11	GND
12	3.3V

Figure 11 shows the schematic of the PMOD interface.

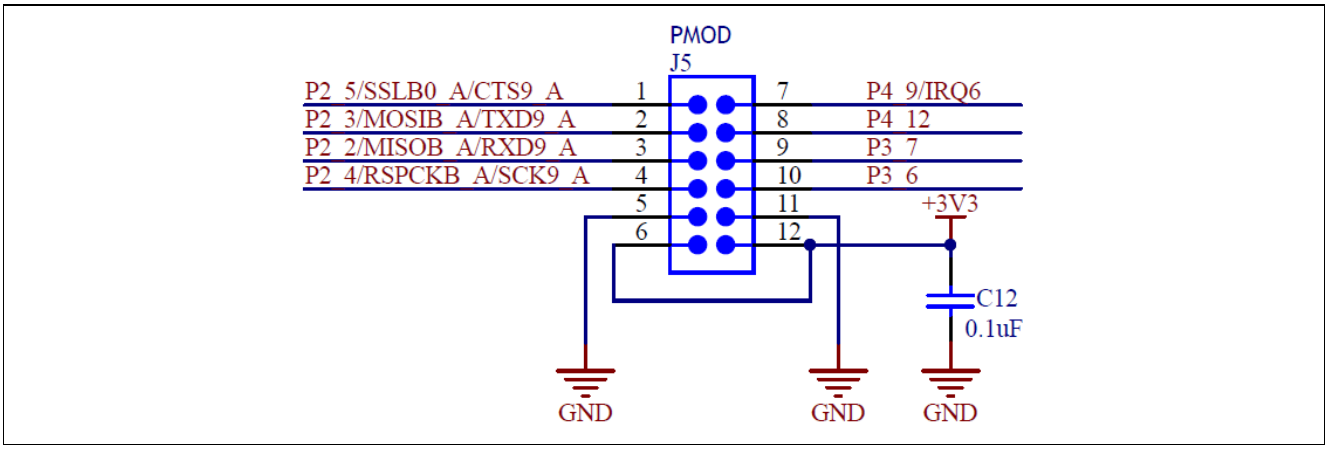


Figure 11 PMOD Interface Schematic

4.4.3 Grove A and B Connectors

The Grove connectors offer the following interfaces:

- UART / I^{2}C or Analog interface (Grove A – J3)
- I^{2}C interface (Grove B – J4)

The pin-mapping of the connectors is described in following table.

Table 5 Grove Connector Pin Mapping

Pins	Grove A (J3) UART	Grove B (J4) I^{2}C
1	P5_5/SCL6/RXD6/AN118	P1_0/SCL1
2	P5_6/SDA6/TXD6/AN019	P1_1/SDA1
3	3.3 V	3.3 V
4	GND	GND

Note that the specific function of the Grove A (J3) depends on the pin-muxing configuration controlled by the application specific needs.

Figure 12 shows the schematic of the Grove interfaces.

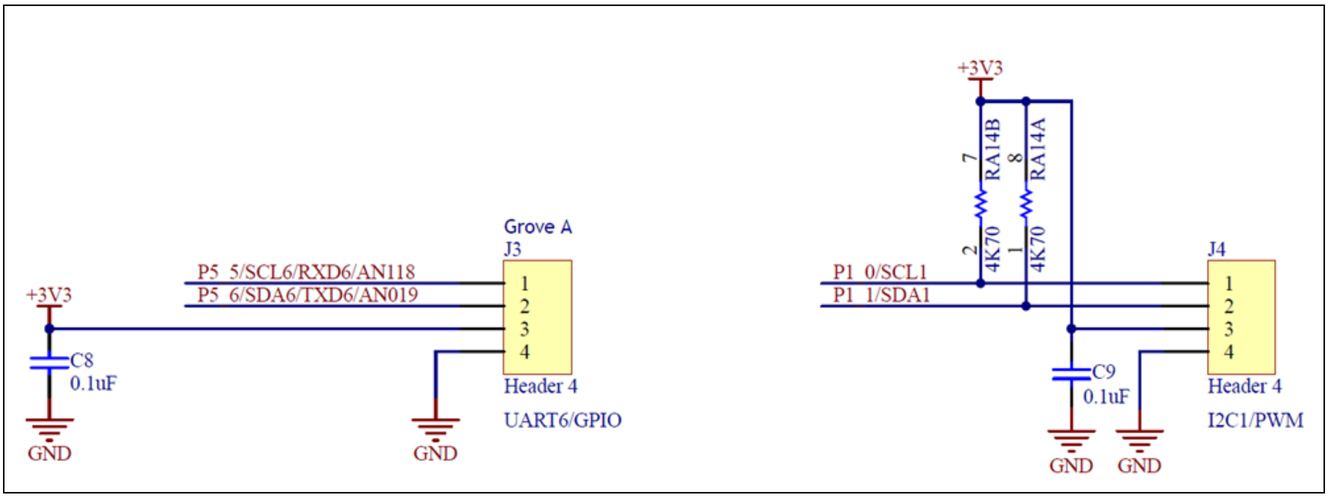


Figure 12 Grove Connectors Schematic

4.4.4 On-Board LEDs

The S5D9 MCU board provides 3 on-board LEDs for user-defined functions. A fourth LED is used to indicate 3.3V power presence. The LEDs are connected to general purpose output pins through a single resistor. The output active state is 1. The table below describes the mapping between the LEDs and the ports that drive them.

Table 6 LED to Port Mapping

LED Number	Color	Designator	Device Port/Pin
1	Green	LED1	P7_8
2	Yellow	LED2	P7_10
3	Red	LED3	P7_11
4	Green	LED4	N/A (Power indicator)

Figure 13 shows the schematic of the user LEDs.

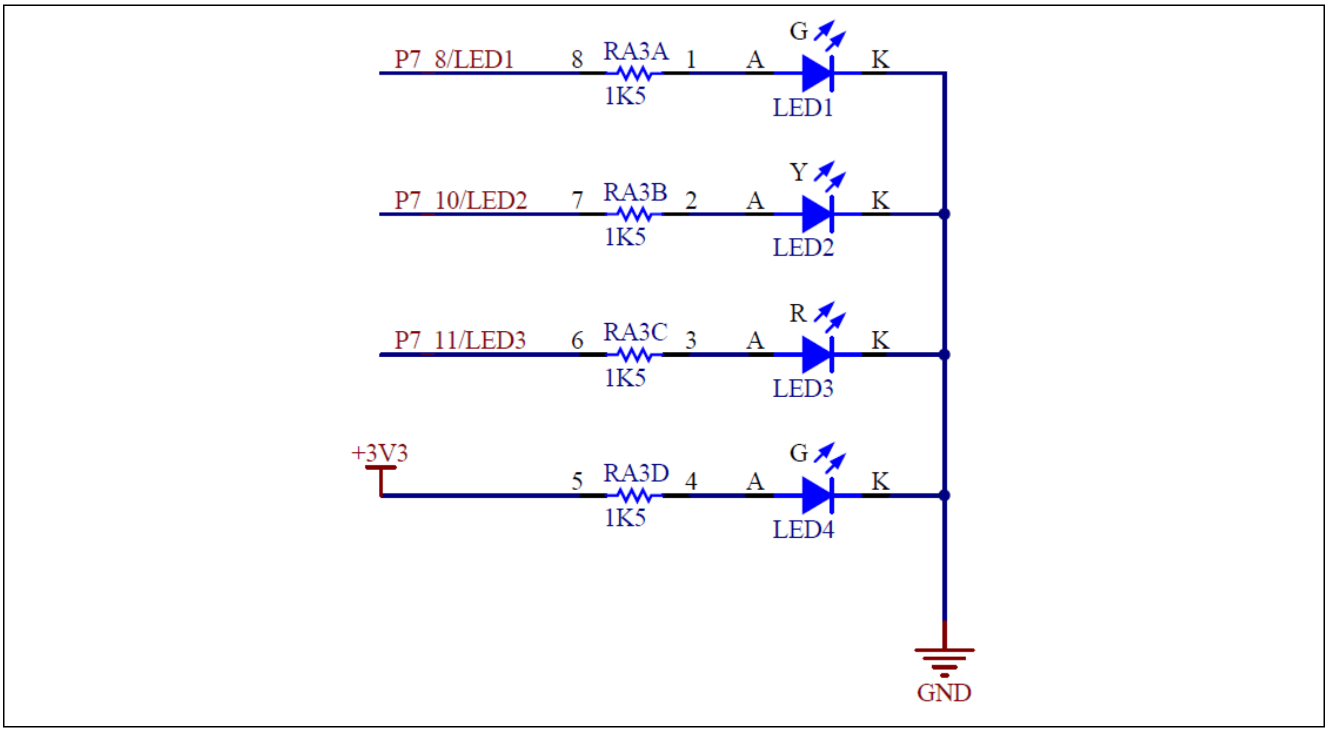


Figure 13 LED Schematic

4.4.5 USB Device

This USB Micro-B connection jack connects the S5D9 MCU to an external USB 2.0 Host, Full Speed capable. The USB power presence (VBUS) is wired to GPIO input P4_7 after it is passed through resistor divider.

Table 7 USB Device Connector to S5D9 MCU Pin Mapping

USB Device Connector		S5D9 Microcontroller	
Pin	**Description**	**Pin**	**Description**
1	VBUS, +5VDC	P4_7/USB_VBUS	USB Voltage detection
2	Data-	USB_DM	Negative data line
3	Data+	USB_DP	Positive data line
4	USB ID, jack internal switch, cable inserted	-	(Not connected)
5	Ground	VSS	Circuit Ground

Figure 14 shows the USB interface schematic.

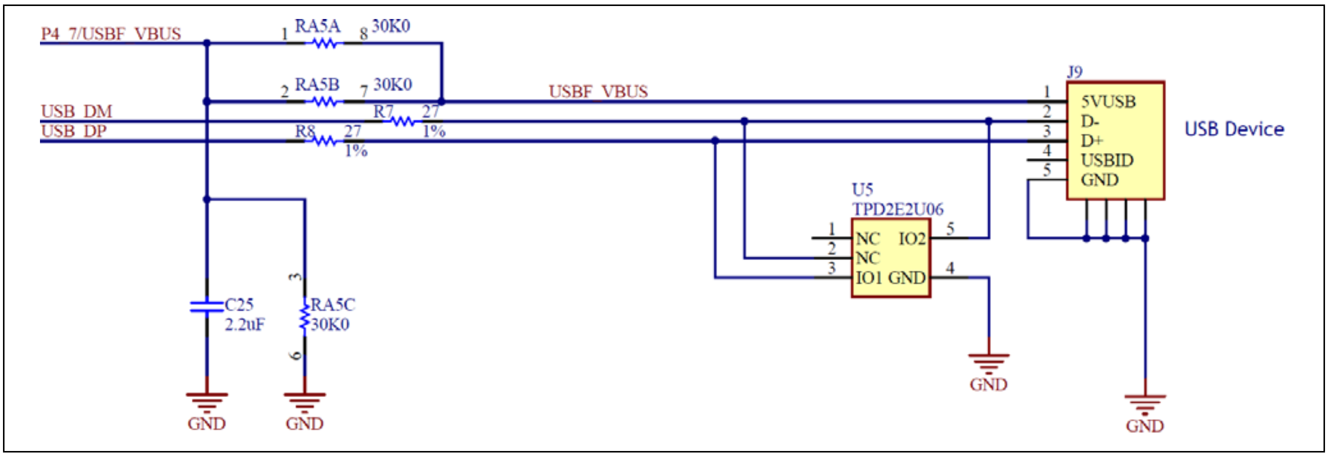


Figure 14 USB Interface Schematic

4.5 Arduino-Compatible Expansion Headers

The S5D9 MCU board includes Arduino-compatible headers that enable interfacing with a wide range of Arduino Shields and expanding its features. Most of the interface signals are connected directly to the MCU pins. This enables their configuration to change depending on the application needs. Figure 15 indicates the port and pin number for each interface signal along with its primary role. The specific function and pin-muxing depends on the application and the hardware specifics of the S5D9 MCU.

Note that the 5V power brought to the POWER header pin 4 is connected directly to the USB VBUS power rail from the USB device connector (J6).

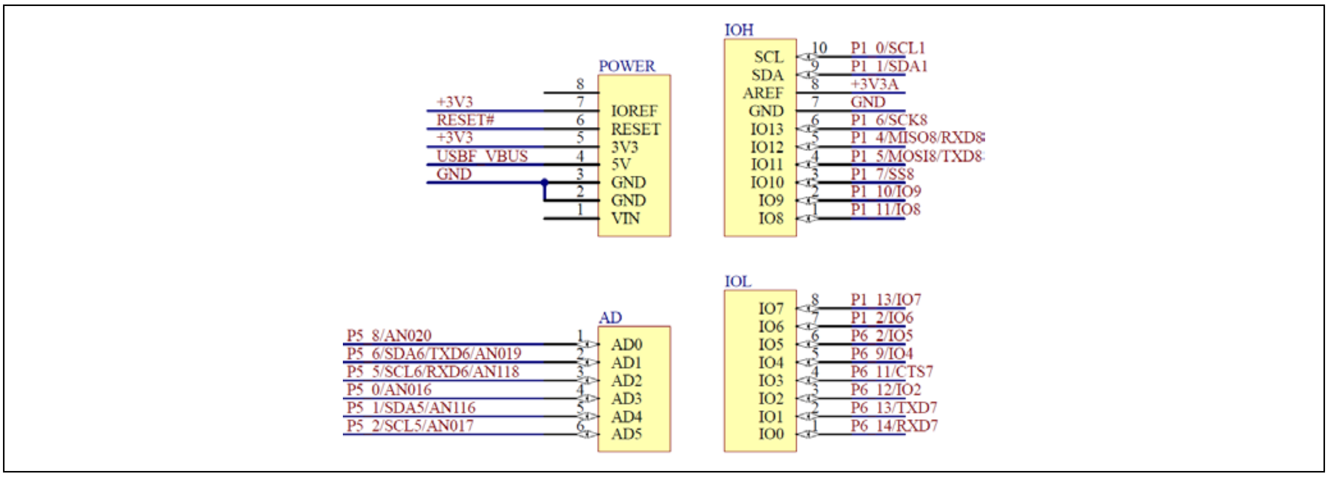


Figure 15 Parallel I/O expansion Schematic

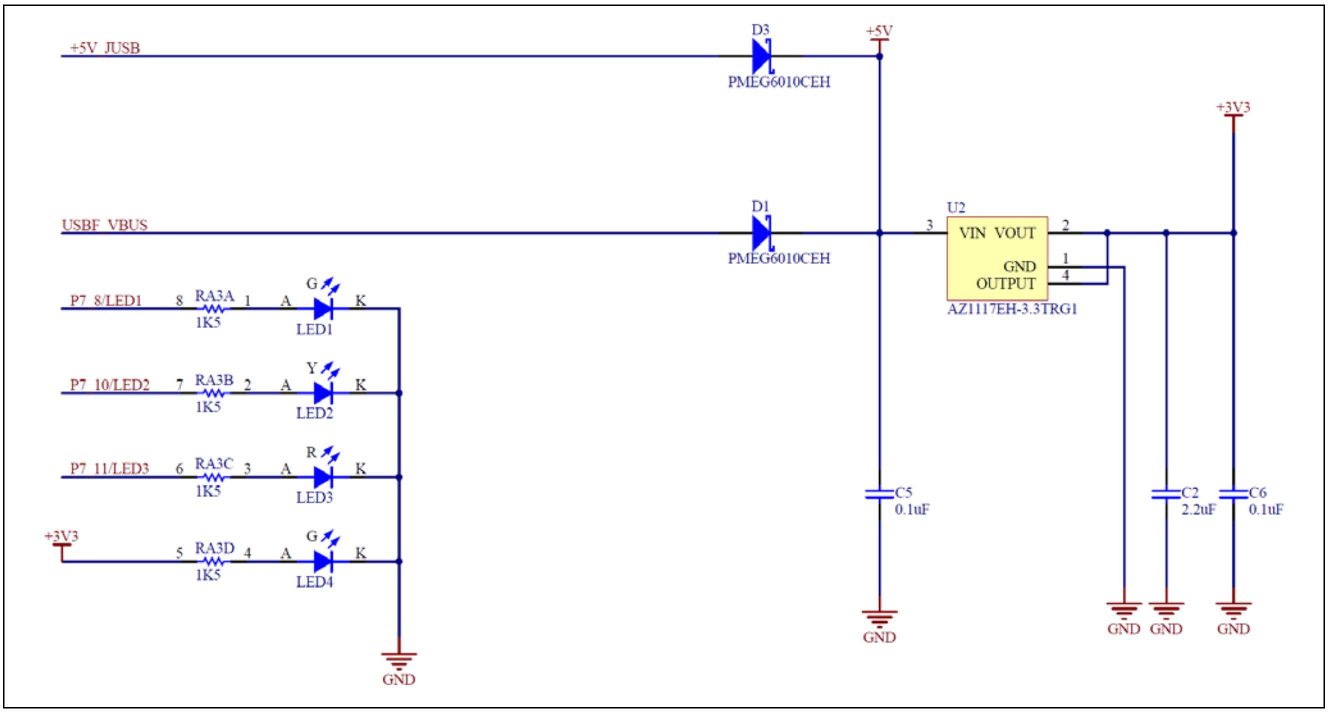
Table 8 shows the mapping between the Arduino headers pins and the MCU pins connected to them along with their primary and additional functions.

Table 8 Arduino Headers Pin Map

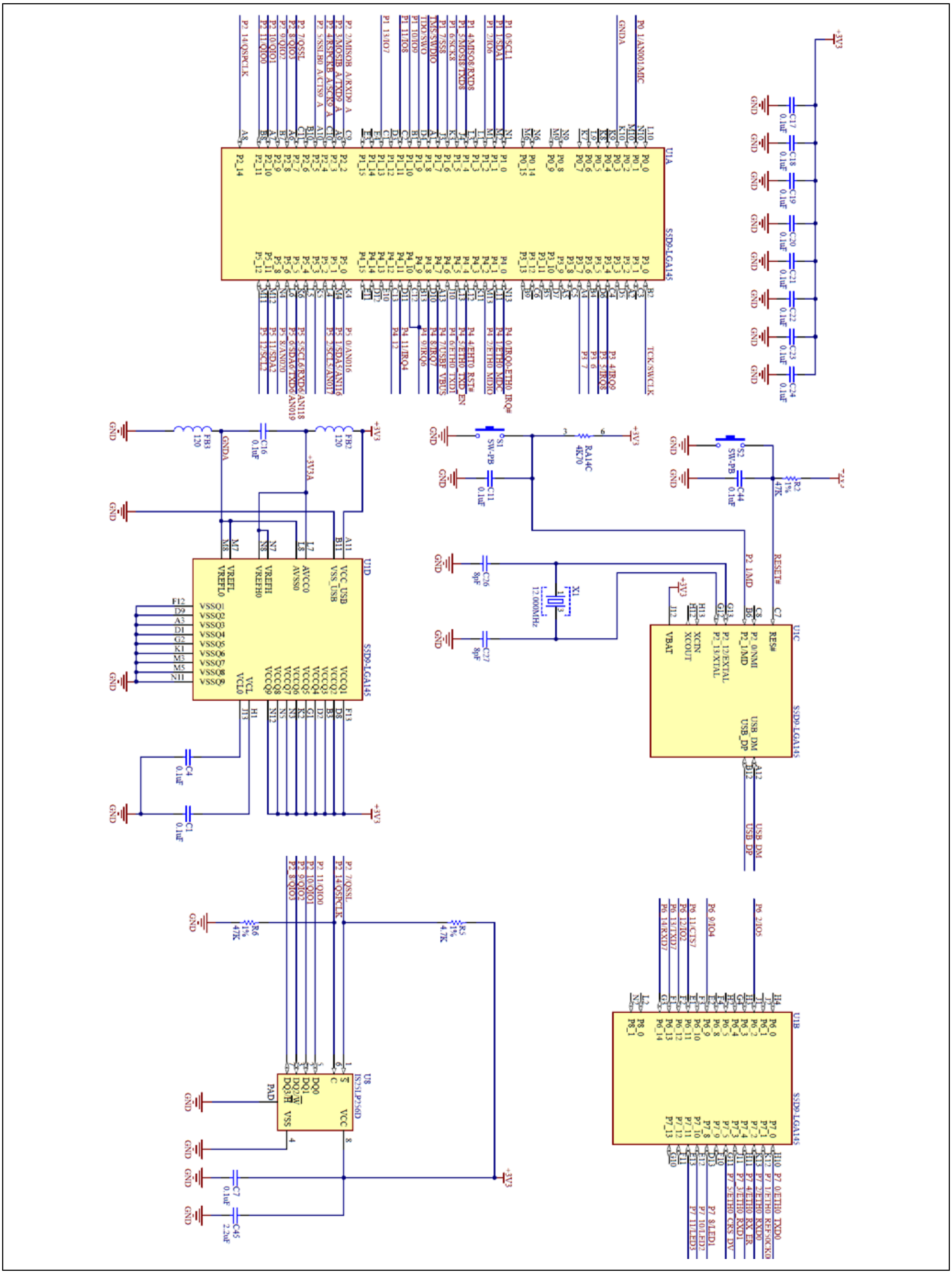
Arduino Header Pin Number	Arduino Pin Name	MCU GPIO Port	Primary Pin Function	Alternative Pin Function
POWER				
1	Vin	N/C		
2	GND	GND	Ground	
3	GND	GND	Ground	
4	5V		USB_VBUS	
5	3.3V	3.3V		
6	RESET	RESET		
7	3.3V	3.3V		
8	Reserved	N/C		
AD				
1	AD0	P5_8	AN020	
2	AD1	P5_6	AN019	SDA6 / TXD6
3	AD2	P5_5	AN118	SCL6 / RXD6
4	AD3	P5_0	AN016	
5	AD4	P5_1	AN116	SDA5 – I2C Data
6	AD5	P5_2	AN017	SCL5 – I2C Clock
IOL				
1	IO0	P6_14	GPIO	RXD7 – UART
2	IO1	P6_13	GPIO	TXD7 – UART
3	IO2	P6_12	GPIO	
4	IO3	P6_11	GPIO	CTS7 – UART
5	IO4	P6_9	GPIO	
6	IO5	P6_2	GPIO	
7	IO6	P6_1	GPIO	
8	IO7	P6_13	GPIO	
IOH				
1	IO8	P1_11	GPIO	
2	IO9	P1_10	GPIO	
3	IO10	P1_7	GPIO	SS8 – SPI Slave Select
4	IO11	P1_5	GPIO	MOSI8 – SPI MOSI
5	IO12	P1_4	GPIO	MISO8 – SPI MISO
6	IO13	P1_6	GPIO	SCK8 – SPI Clock
7	GND	GND	Ground	
8	AREF	3.3V Analog	Analog Power 3.3V Reference	
9	SDA	P1_1	GPIO	SDA1
10	SCL	P1_0	GPIO	SCL1

4.6 Electrical Schematics

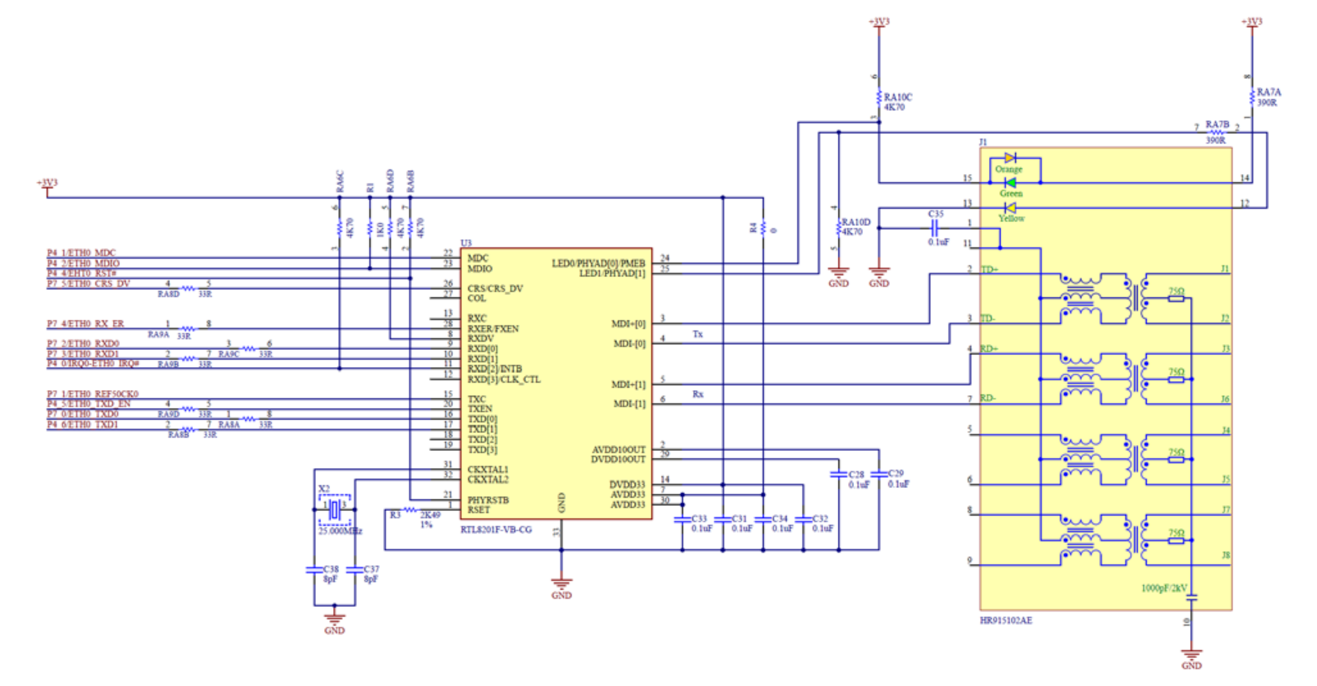
4.6.1 Power Supply, User LED Schematic



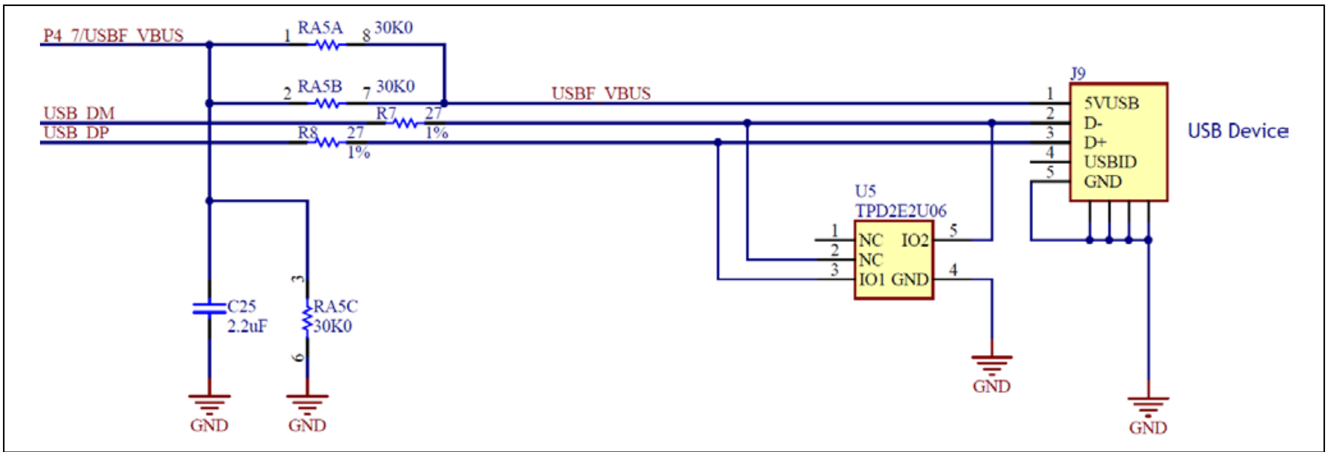
4.6.2 S5D9 MCU, Reset Circuit, QSPI Flash Memory Schematic



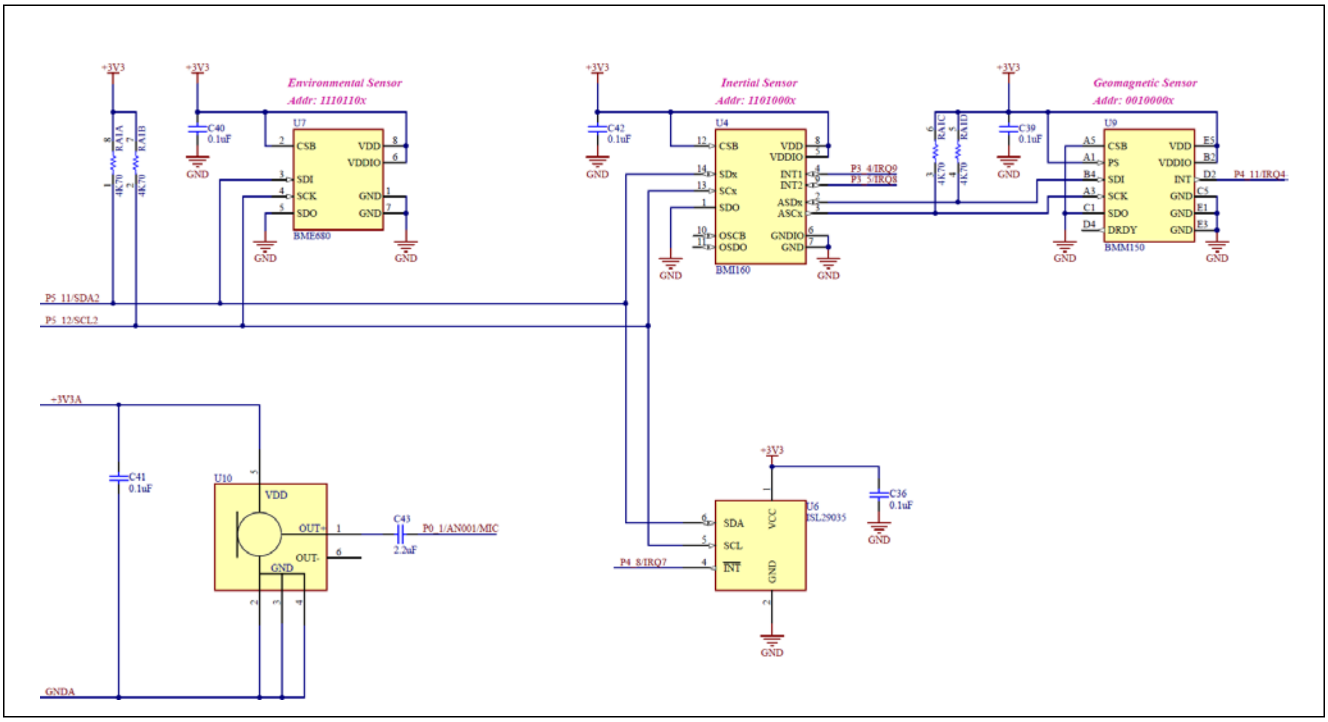
4.6.3 Ethernet Interface, PHY Schematic



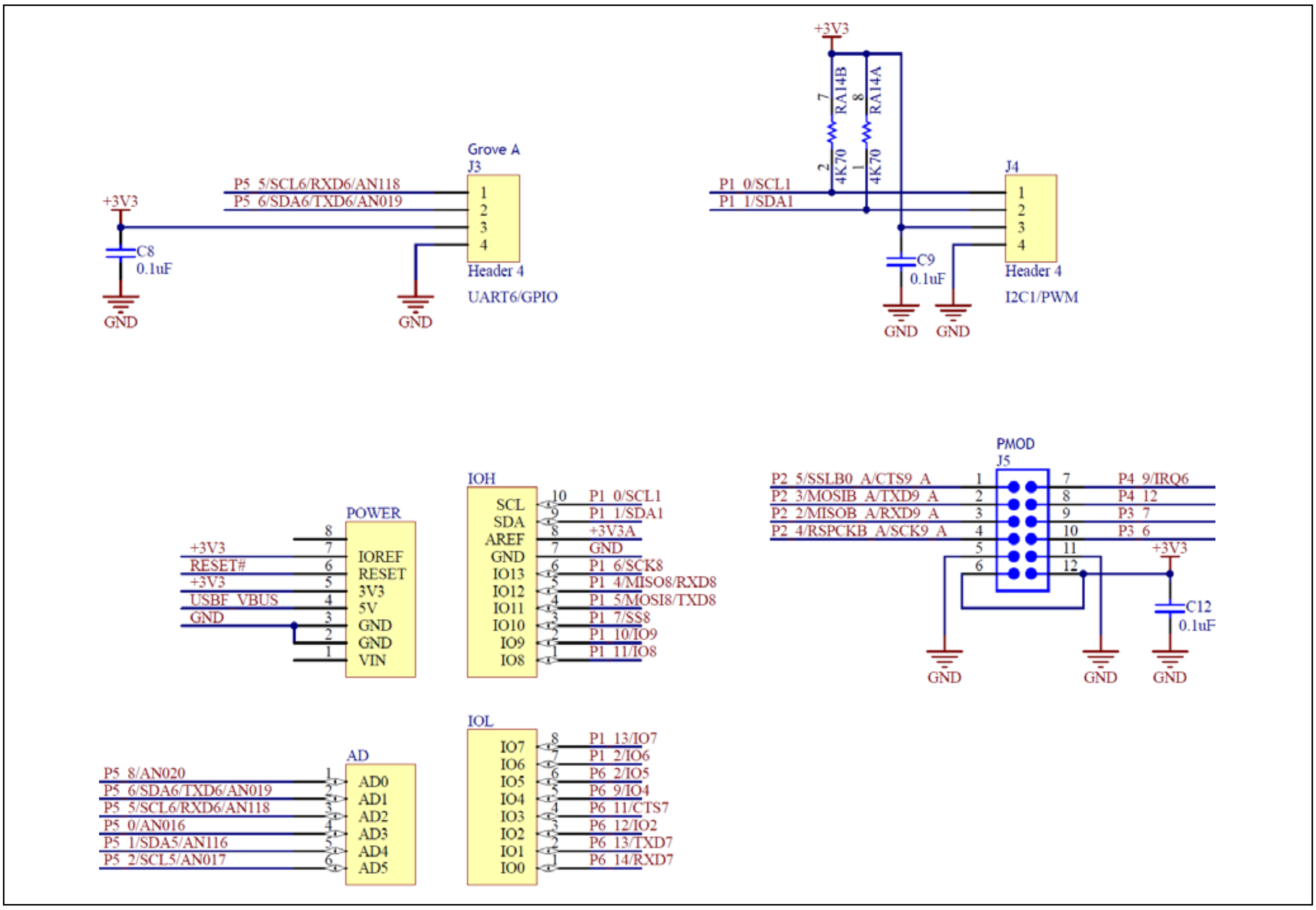
4.6.4 USB Interface Schematic



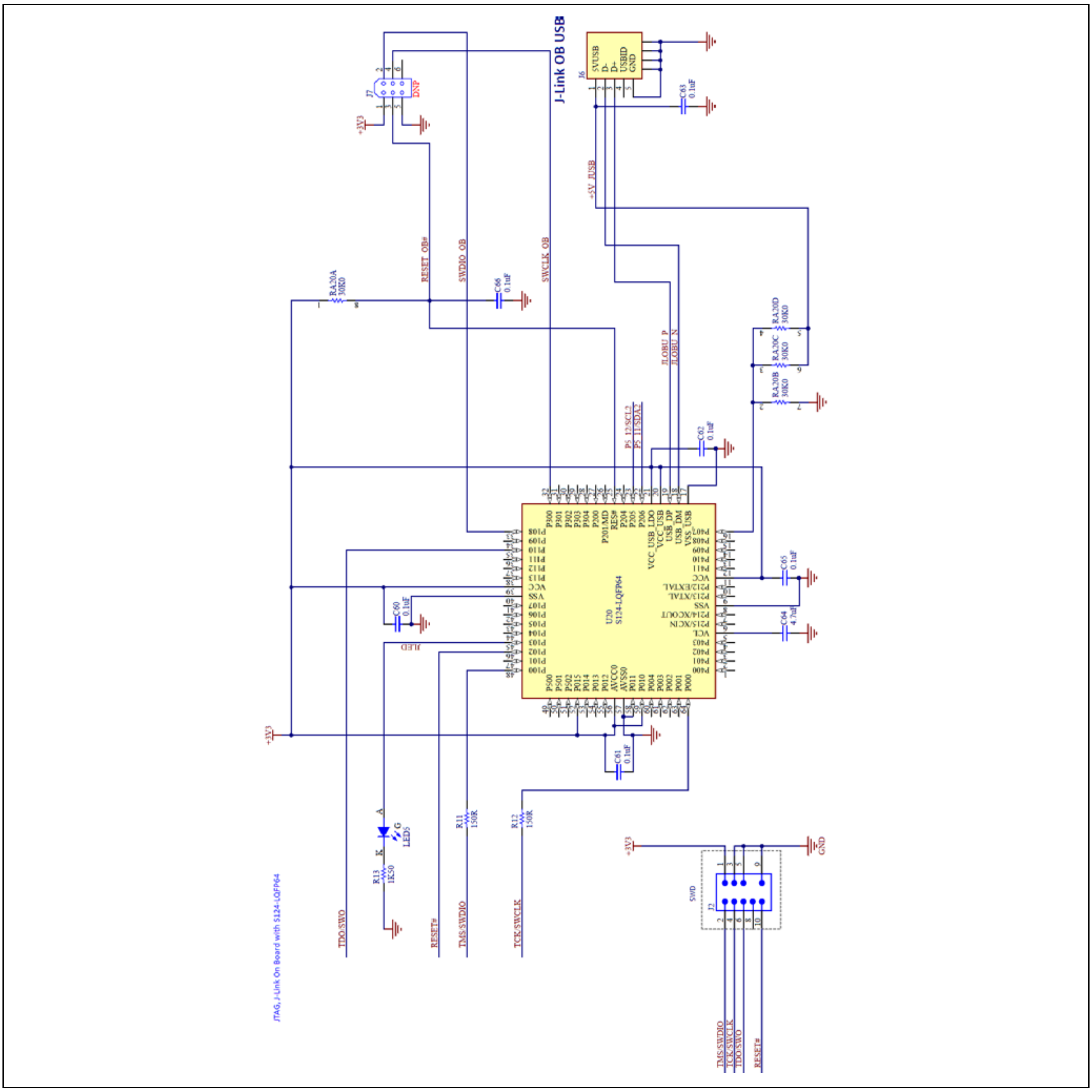
4.6.5 Sensors Schematic



4.6.6 Arduino, PMOD and Grove Connectors Schematic

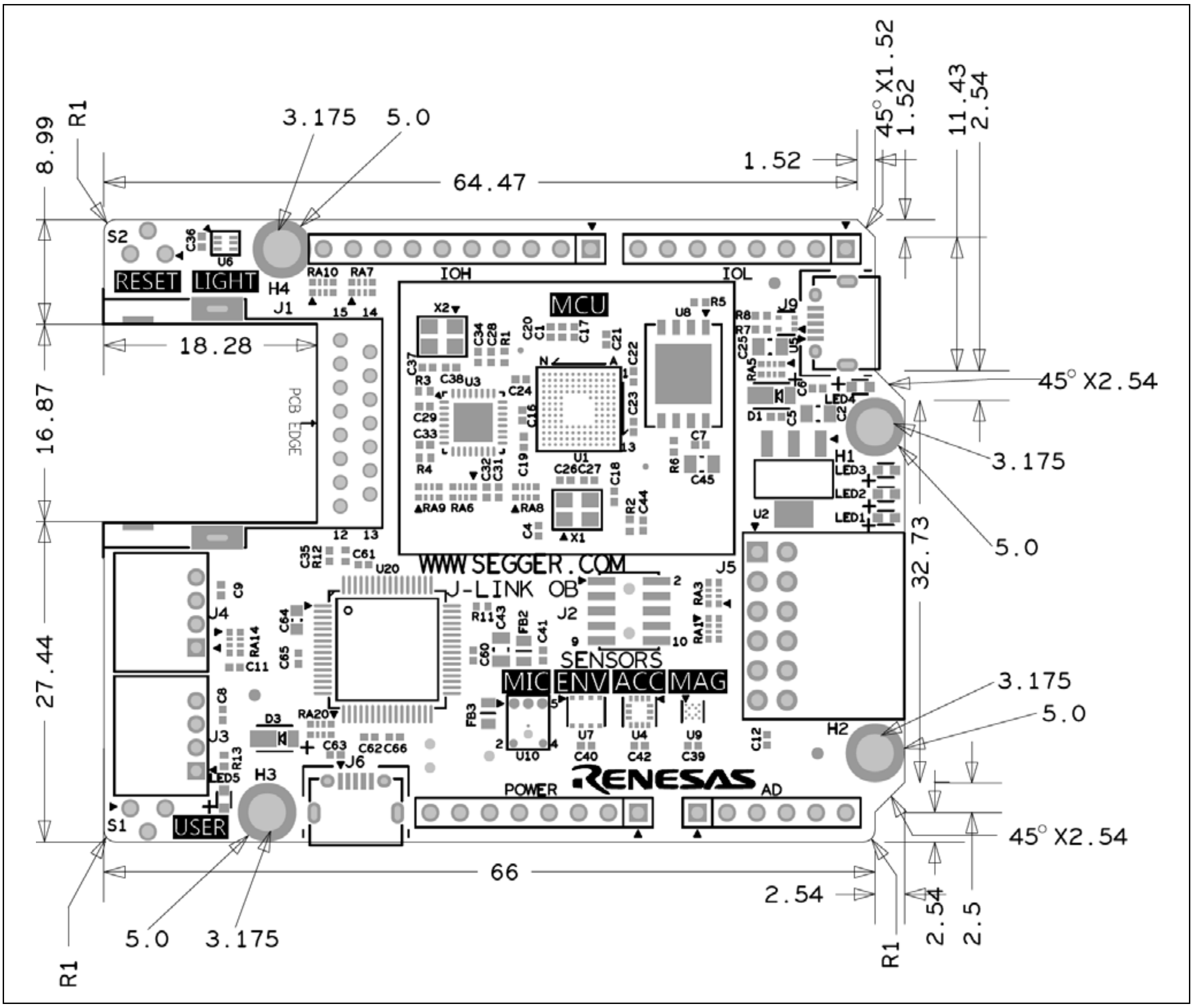


4.6.7 J-Link On-Board, JTAG Interface Schematic



4.7 MCU Board Mechanical Dimensions

(All dimensions are in millimeters)



5. Wi-Fi Board

The Wi-Fi board is based on the GT202 module. It incorporates the Qualcomm® Atheros QCA4002 device. The QCA4002 is a system on a chip (SoC), implementing the 802.11 b/g/n communication standards. It is optimized for low-power embedded applications with single-stream capability for both transmit and receive streams. The SoC has an integrated network processor with a large set of TCP/IP with IPv4/IPv6-based services. They can be accessed via high-speed SPI interface that is accessible on a 12-pin PMOD header.

Table 9 Wi-Fi Board Specifications

Parameter	Value
Size	Area: 24 x 18 x 2.5 mm Height: 3.6 mm
Operating voltage	3.3V ± 10%
Operating humidity	20-70%
Operating temperature range	10°C ~ +65°C
RF connector	U.FL of Hirose
Host interface	UART, SPI

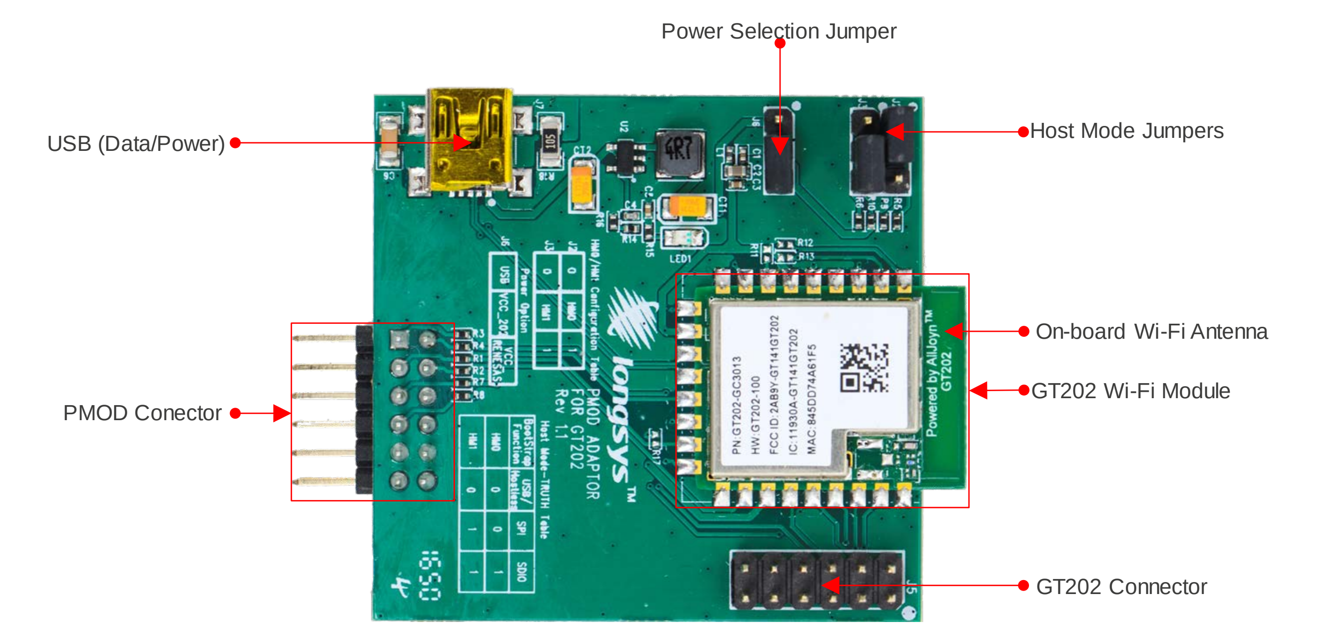


Figure 16 Main Wi-Fi Board Components

5.1 Wi-Fi Board Block Diagram

Figure 17 shows the Wi-Fi board block diagram. Its main component is the GT202 module that incorporates the QCA4002 SoC. The power options include USB and PMOD header. The 5V USB power is regulated to 3.3V with a step-down converter to 3.3V. A dedicated jumper is used to select the desired power source.

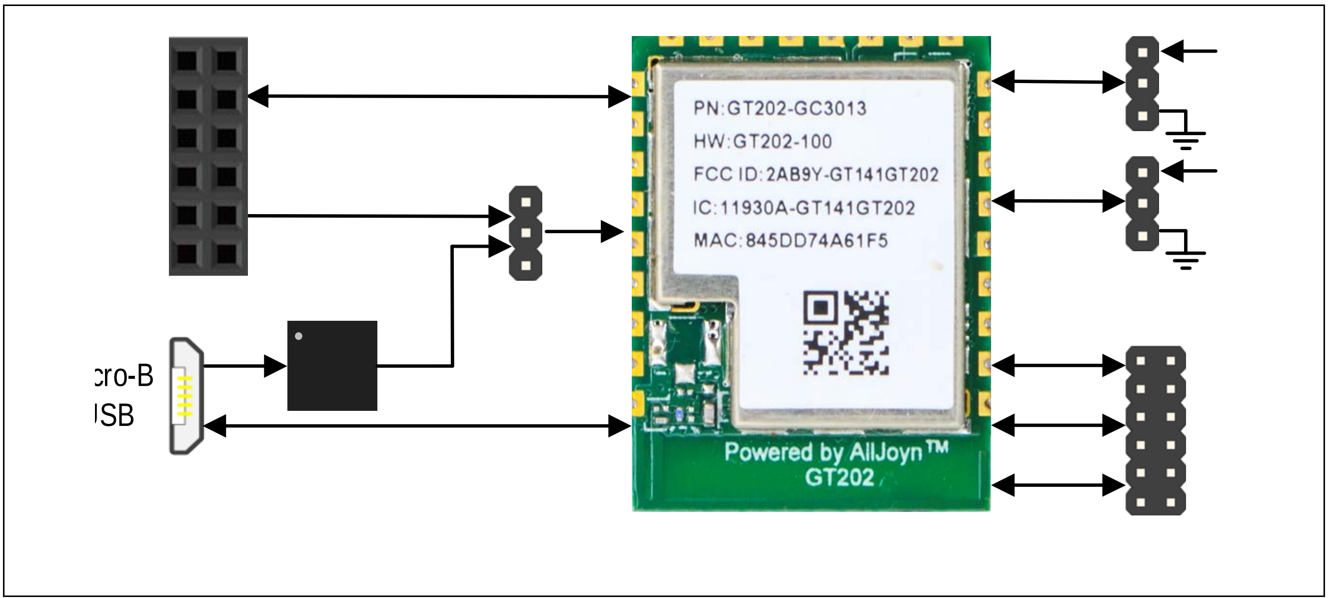


Figure 17 Wi-Fi Board Block Diagram

The GT202 Wi-Fi module integrates the QCA4002 SoC on a carrier board which brings out three different host connectivity options:

- SPI interface through the PMOD connector – used for interfacing with the AE-CLOUD2 MCU board and power supply source. This interface provides fast communication speed and access to the full networking functionality.
- SDIO / UART interface – used for rapid prototyping and low communication speeds (not utilized by the AE-CLOUD2 kit)
- USB interface / Host-less – used for fast prototyping, diagnostic and alternative power supply (not utilized by the AE-CLOUD2 kit)

5.2 Wi-Fi Board Jumper Settings

The Wi-Fi board includes jumpers that configure the desired host connectivity option. The jumper settings that control these options are described in Table 10.

Table 10 Jumper Settings Controlling Host Connectivity Options

Jumper J2 bridge pins	Jumper J3 bridge pins	Communication Interface
1 - 2	1 - 2	USB
1 - 2	2 - 3	SPI
2 - 3	2 - 3	SDIO/UART

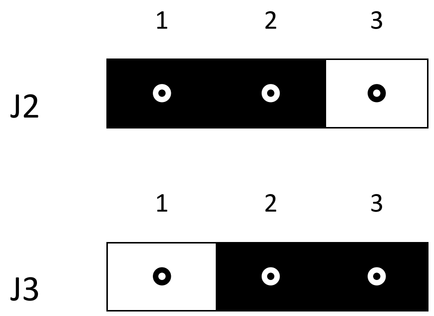
The power selection jumper setting is described in Table 11.

Table 11 Power Selection Jumper Settings

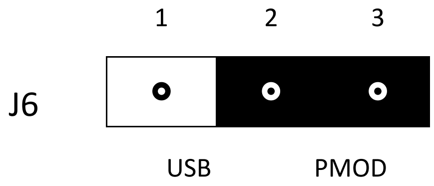
Jumper J6 bridge pins	Power Source
1 - 2	USB
2 - 3	PMOD

The settings required for the operation of the AE-CLOUD2 kit are defined as follows:

Host mode jumpers (J2 and J3) to select SPI Communication Interface



Power selection jumper (J6) to select PMOD



Wi-Fi Board PMOD Connector pin map is described as follows. The PMOD specification allows for configurable voltage. However, this Wi-Fi PMOD board is a 3.3V device. The S5D9 MCU board is configured to provide 3.3V to the PMOD interface.

Table 12 PMOD Pin Map

Pin Number	Function	Pin Number	Function
1	CS	7	Interrupt (Out)
2	MOSI	8	Power Down (In)
3	MISO	9	N.C.
4	CLK	10	N.C.
5	GND	11	GND
6	3.3V	12	3.3V

5.3 Wi-Fi Board Schematic

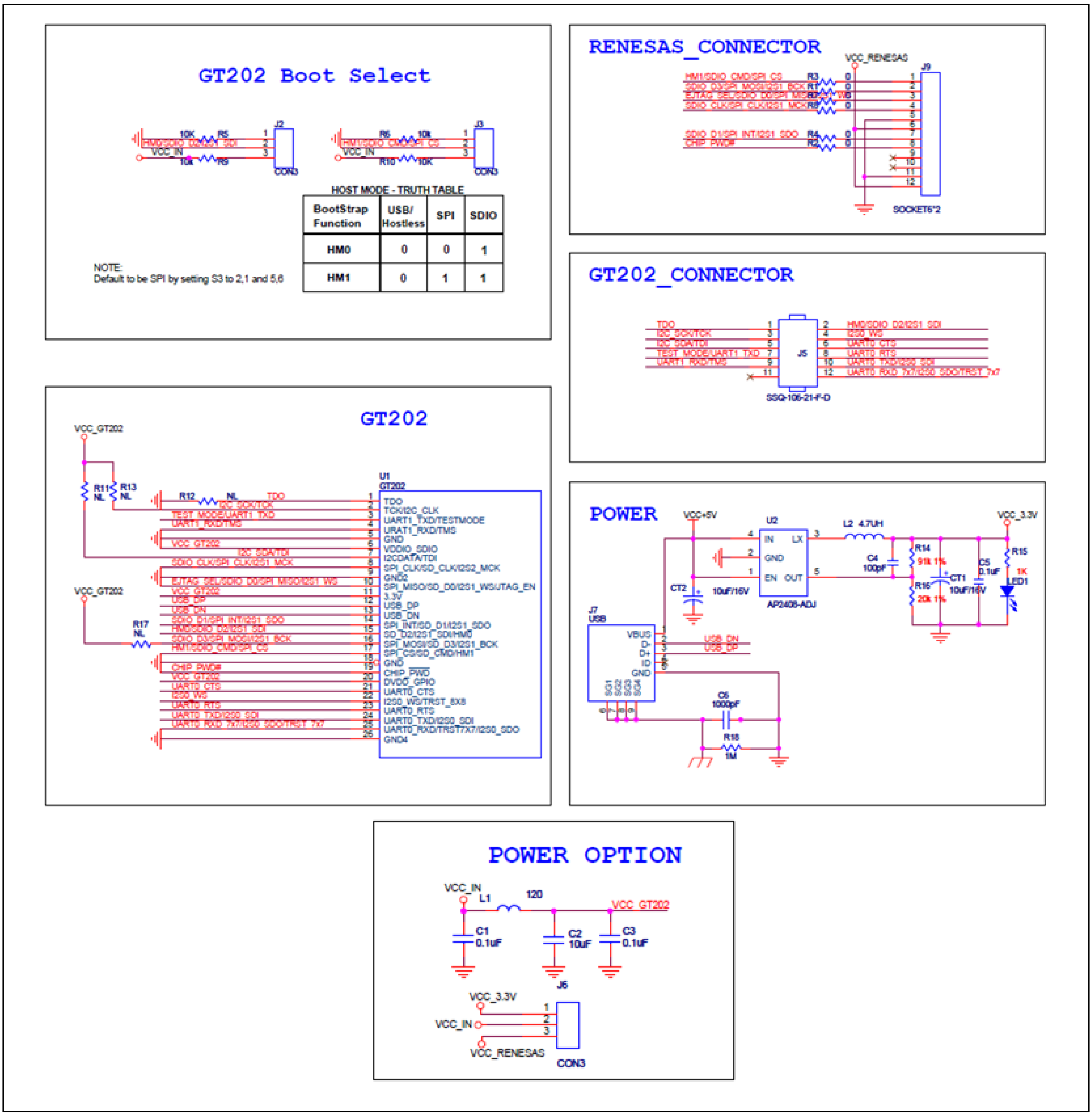


Figure 18 Wi-Fi Board Schematic

5.4 Wi-Fi Board Mechanical Dimensions

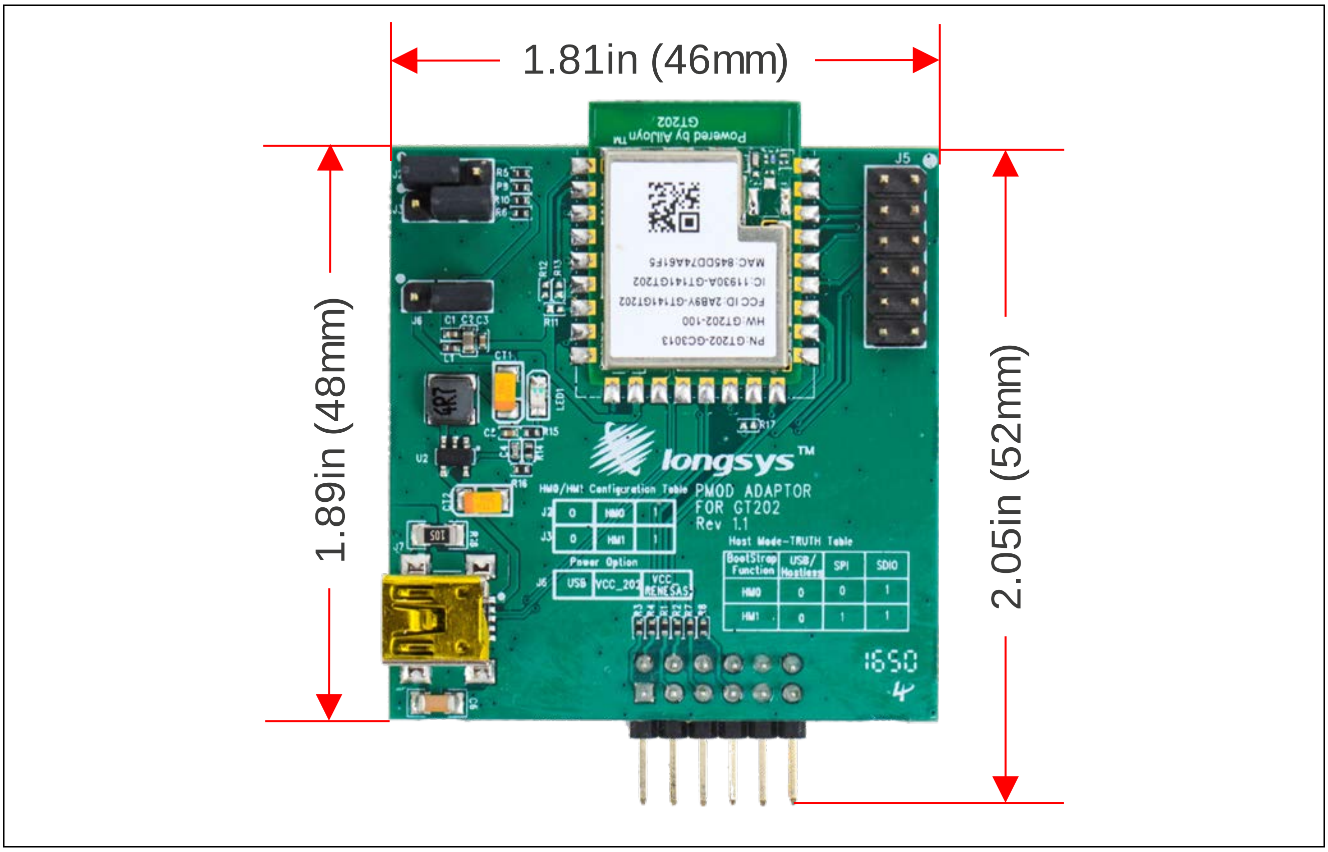


Figure 19 Wi-Fi Board Mechanical Dimensions

6. Cellular Connectivity Board

The AE-CLOUD2 provides cellular connectivity by utilizing Quectel BG96 modem, installed on an Arduino Shield board. The BG96 module supports multiple cellular standards as well as a GPS receiver that enables the prototyping of position tracking applications.

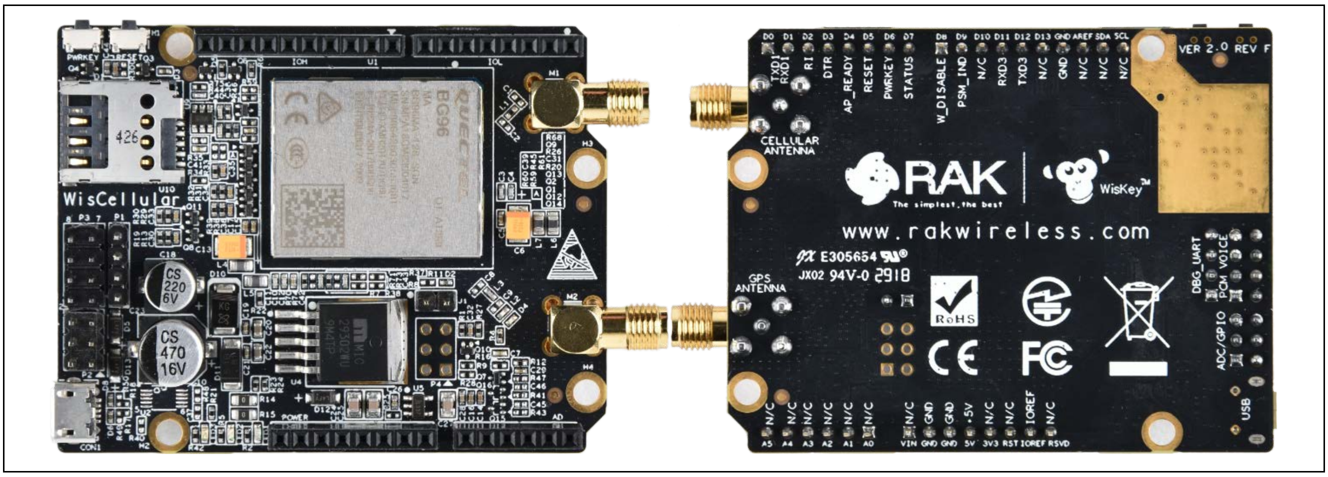


Figure 20 Cellular Connectivity Board

6.1 Cellular Arduino Shield Block Diagram

Figure 21 shows the BG96 module connections to the main components and headers.

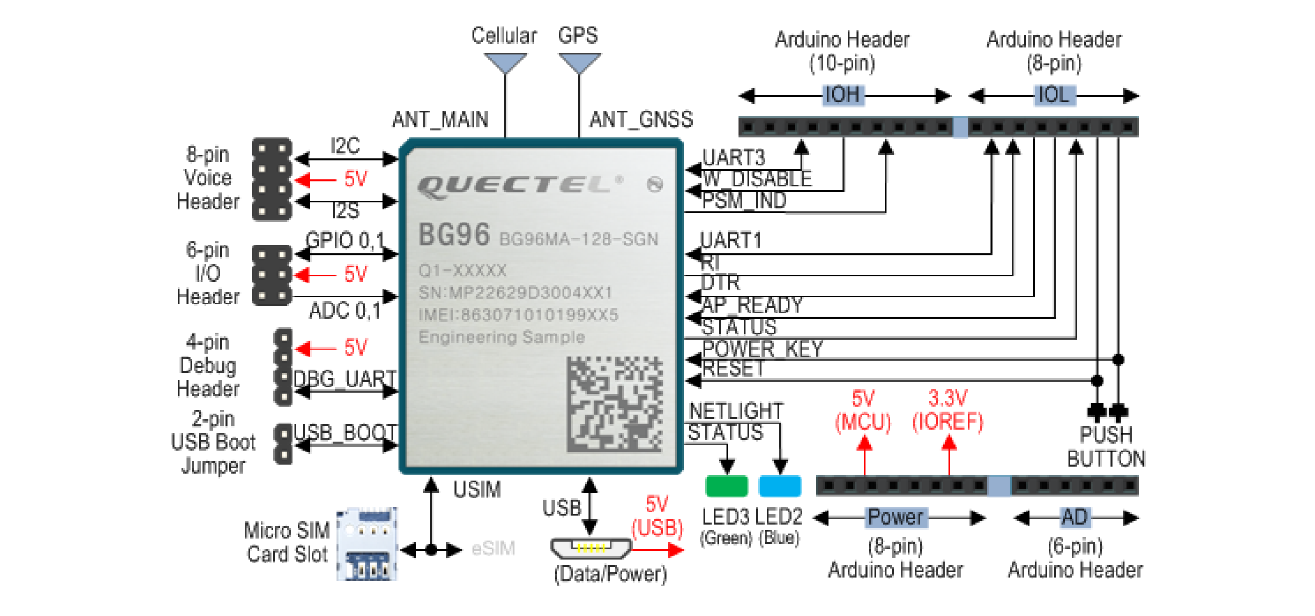


Figure 21 BG96 Module Connections

6.2 Cellular Arduino Shield Connectors, Jumper Settings, and LEDs

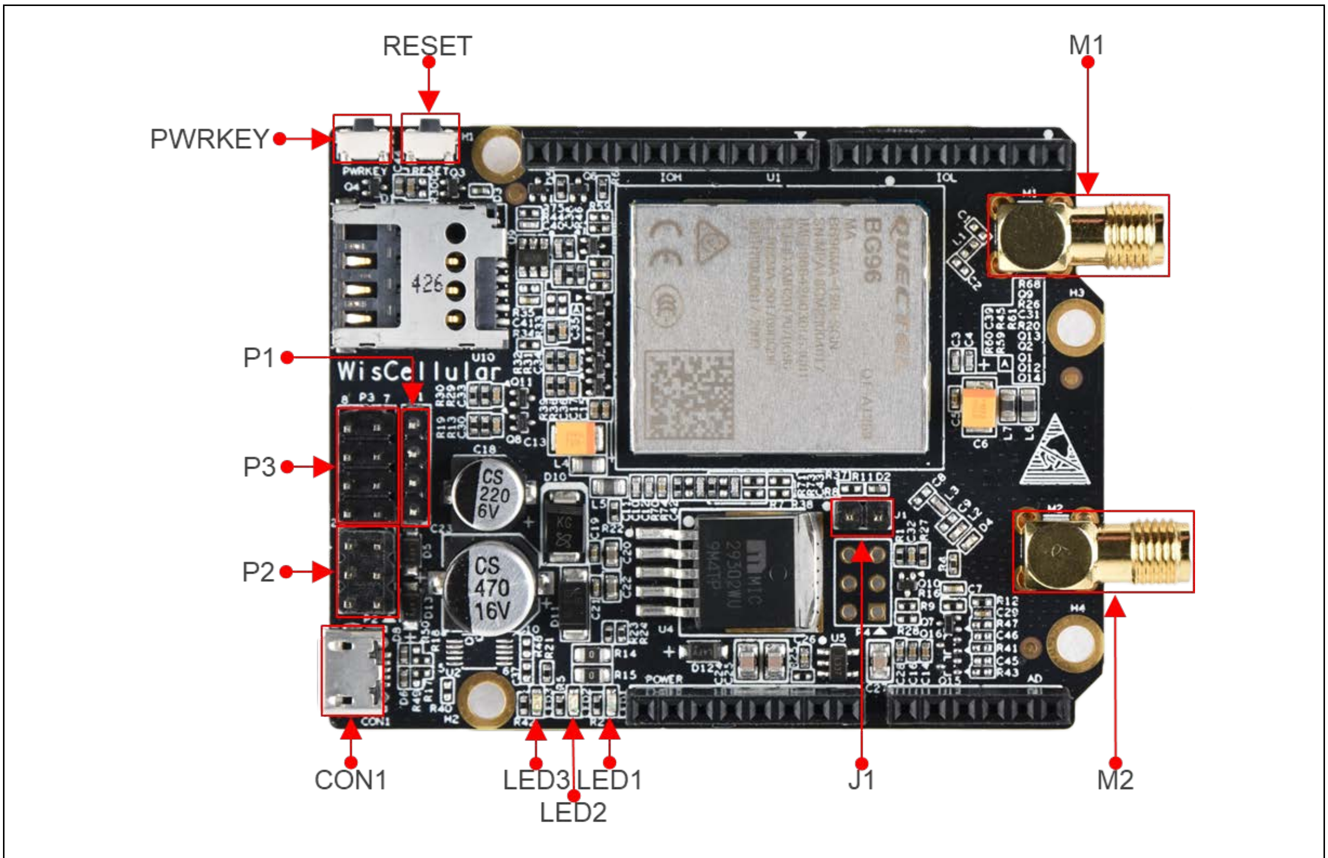


Figure 22 Cellular Arduino Shield Connectors, Jumper Settings, and LEDs

Table 13 Summary of Connectors and Switches

Label	Function	Description
P1	Debug UART interface	Serial port (UART2) interface for debug and log output
P2	Analog Input and Digital I/O interface	2xAnalog input and 2xGPIO
P3	PCM Voice Interface	Interface for an external CODEC board for voice communication
RESET	RST Key	Reset the BG96 module
PWRKEY	Power Key	Turn the BG96 module on/off
CON1	Micro USB	USB Interface for power and control
J1	USB BOOT	Force the BG96 module to boot from USB port for firmware upgrade
M1	Cellular Antenna	SMA connector for cellular antenna
M2	GPS Antenna	SMA connector for GPS antenna

Table 14 P1 – Debug UART Interface

Pin Number	Name	Description
1	VCC_5V	+5V supply voltage
2	DBG_RxD	BG96 Module UART2 RxD
3	DBG_TxD	BG96 Module UART2 TxD
4	GND	GROUND

Table 15 P2 – Analog Input and Digital I/O interface

Pin Number	Name	Description
1	GPIO0	General input/output 0
2	GPIO1	General input/output 1
3	ADC0	Analog input 0
4	ADC1	Analog input 1
5	GND	GROUND
6	VCC_5V	+5V supply voltage

Table 16 P3-PCM Voice Interface

Pin Number	Name	Description
1	I2S_SCL	I2C serial clock
2	I2S_SDA	I2C serial data
3	PCM_SYNC	PCM frame sync output
4	PCM_CLK	PCM clock output
5	PCM_IN	PCM data input
6	PCM_OUT	PCM data output
7	GND	GROUND
8	VCC_5V	+5V supply voltage

On-Board LEDs

The Cellular Arduino Shield provides 3 on-board LEDs to display its working status. Table 17 describes the mapping between the LEDs and the ports that drive them.

Table 17 LED to Port Mapping

LED Number	Color	Designator	Device Port/Pin
1	Red	LED1	Indicate the BG96 module’s power status
2	Blue	LED2	Indicate the BG96 module’s network activity status
3	Green	LED3	Indicate the BG96 module’s network operation status

6.3 Cellular Arduino Shield Arduino-Compatible Expansion Headers

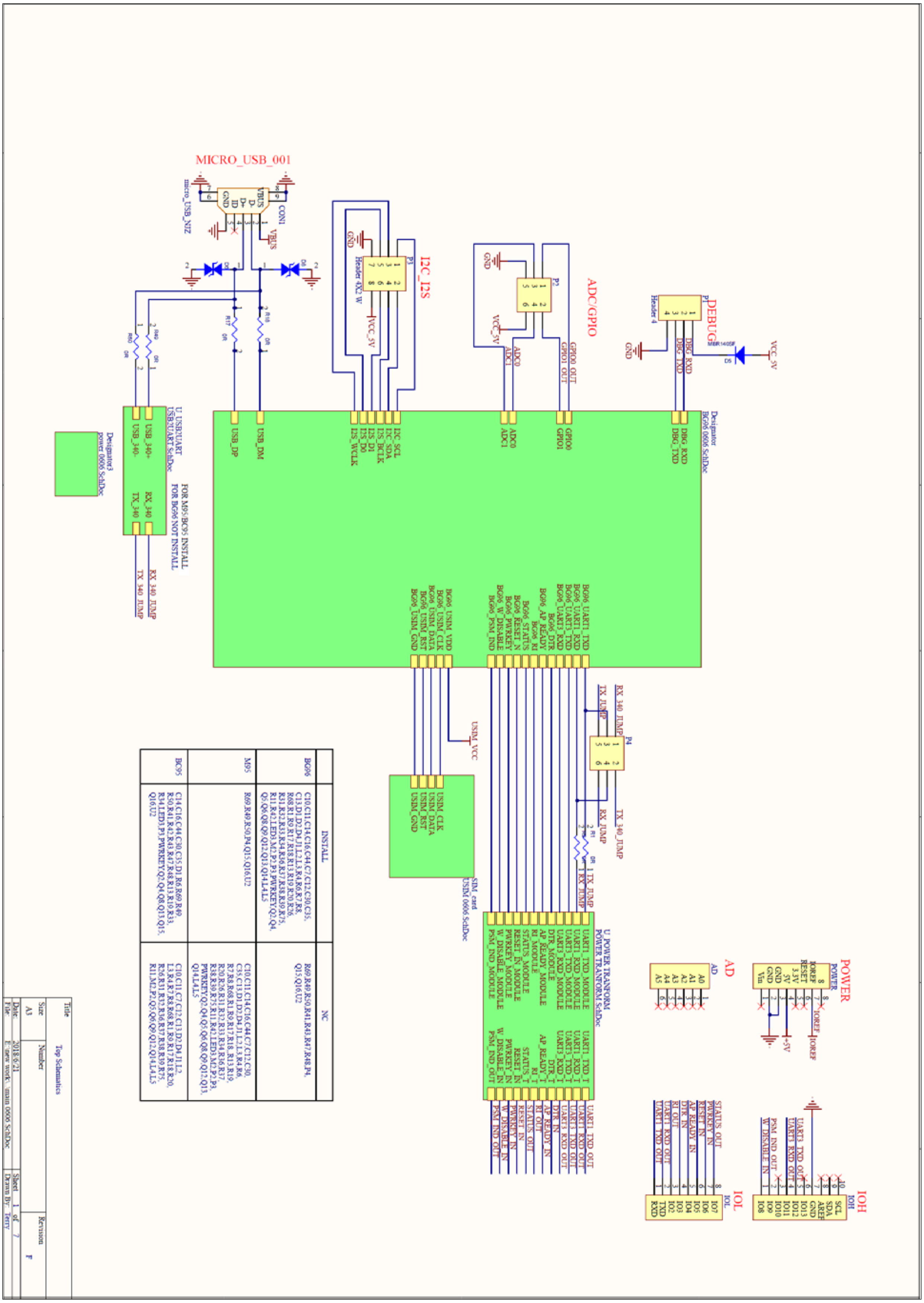
The Cellular Arduino Shield includes Arduino-compatible headers that enable interfacing with S5D9 MCU board. Most of the interface signals are connected directly to the BG96 module pins. This enables direct control of BG96 module depending on the application needs.

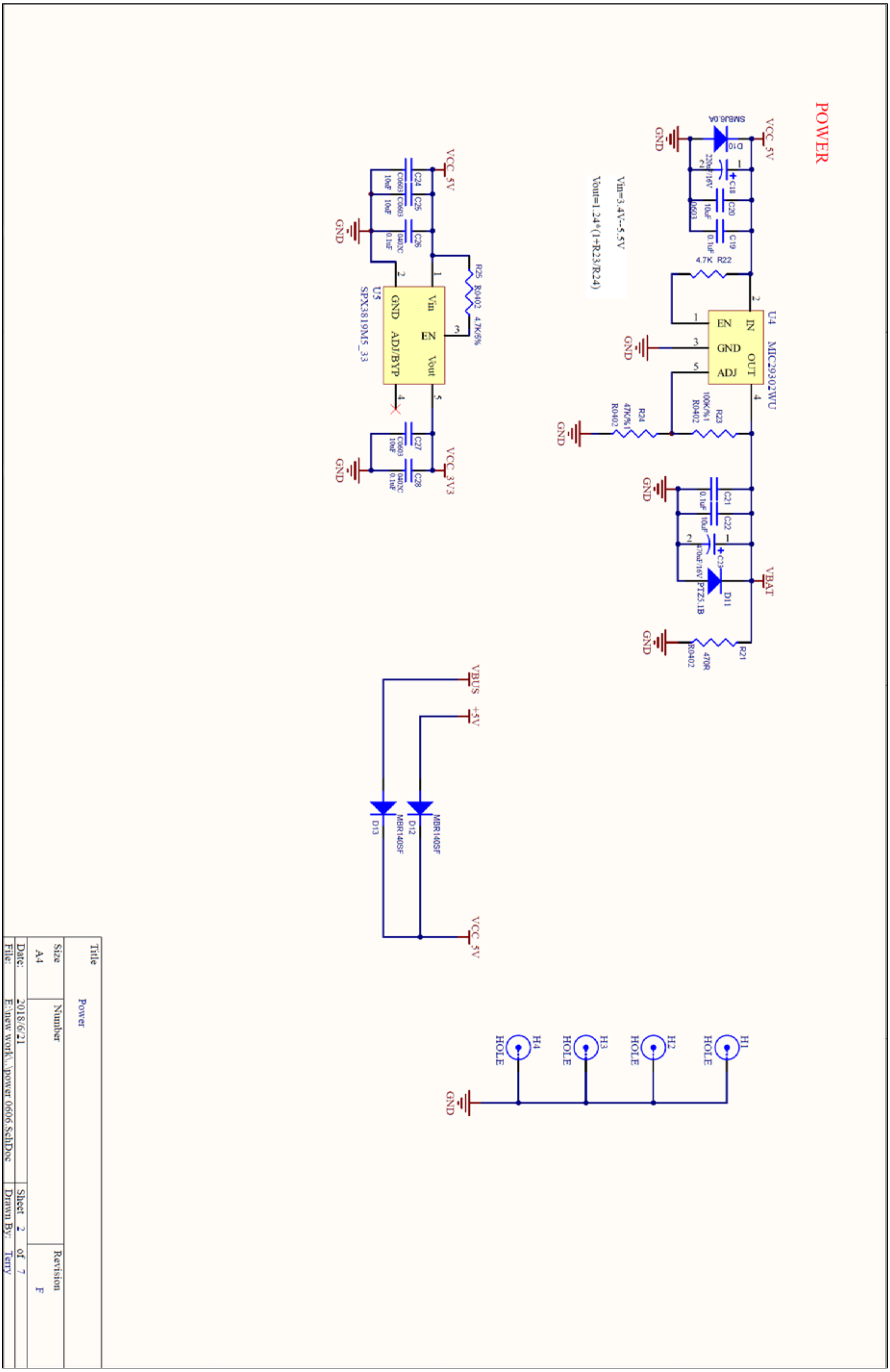
The table below shows the mapping between the Arduino headers pins and the BG96 module pins connected to them along with their primary functions.

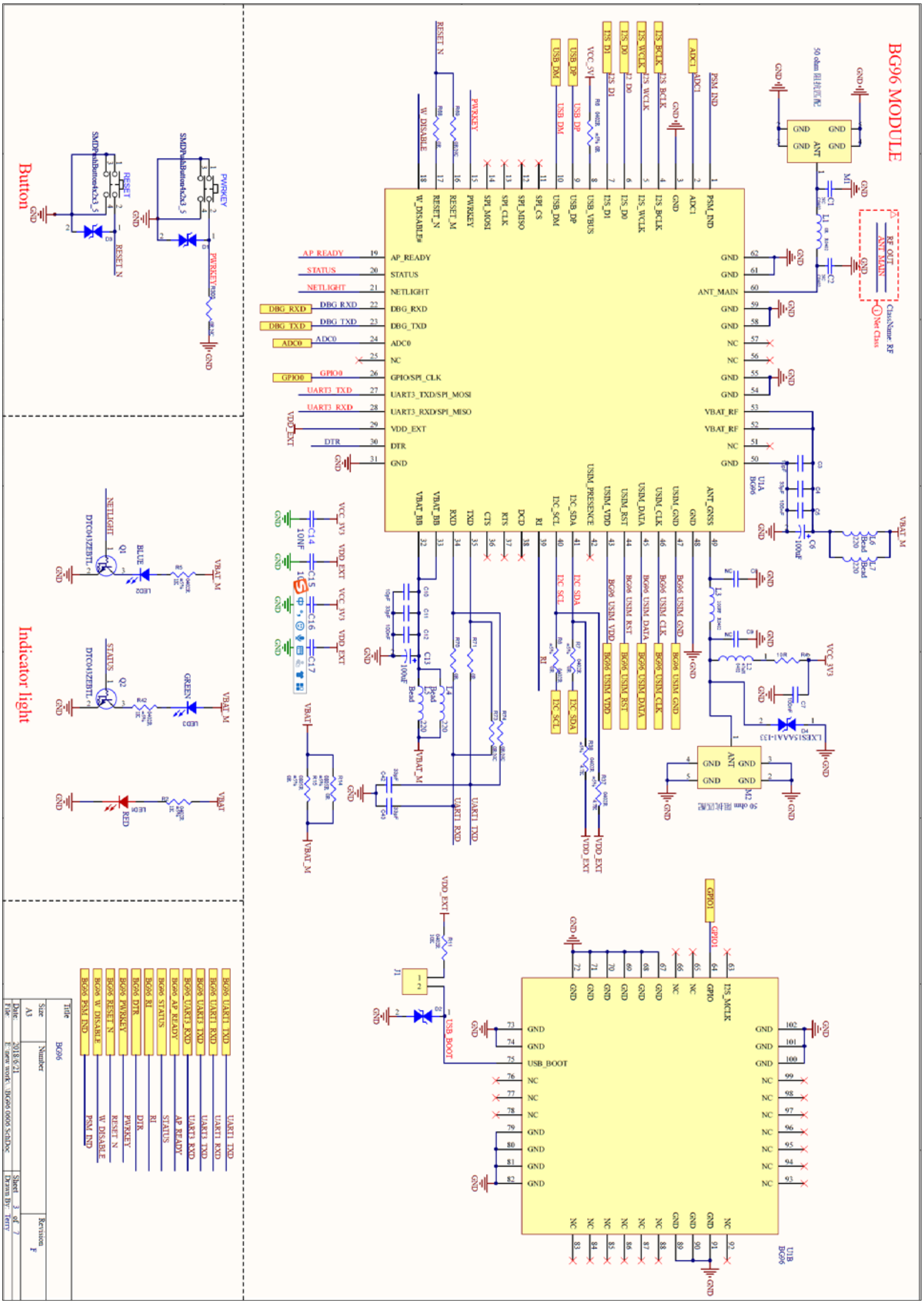
Table 18 Arduino Header Pins and BG96 Module Pin Primary Functions

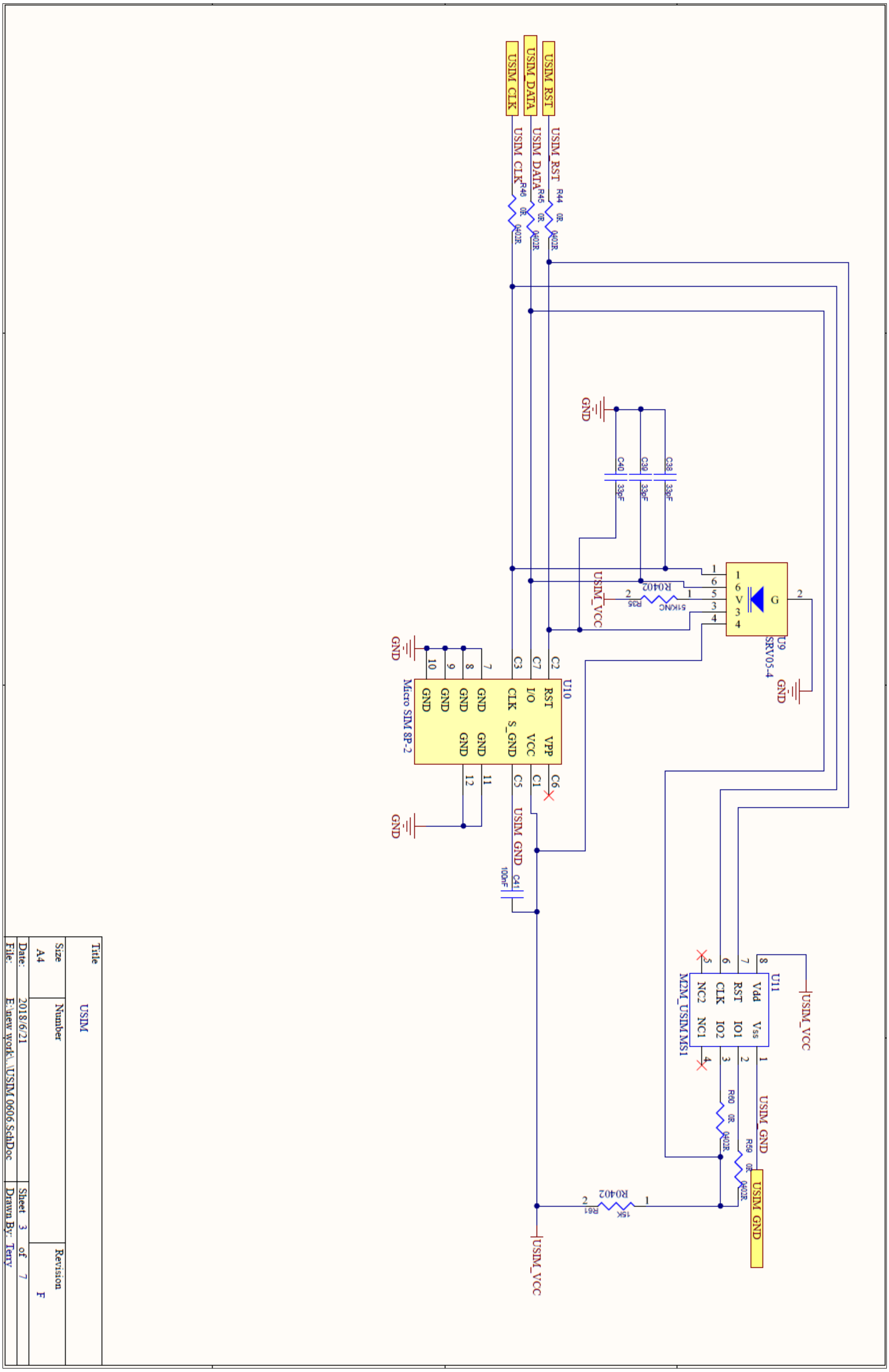
Arduino Header Pin Number	Arduino Pin Name	BG96 module Pin	Primary Pin Function
POWER			
1	Vin	N/C	
2	GND	GND	Ground
3	GND	GND	Ground
4	5V		Cellular Arduino Shield power supply (+5V)
5	3.3V	N/C	
6	RESET	N/C	
7	3.3V		Cellular Arduino Shield I/O reference voltage (+3.3V)
8	Reserved	N/C	
AD			
1	AD0	N/C	
2	AD1	N/C	
3	AD2	N/C	
4	AD3	N/C	
5	AD4	N/C	
6	AD5	N/C	
IOL			
1	IO0	PIN 35	UART1_RxD
2	IO1	PIN 34	UART1_TxD
3	IO2	PIN 39	RI
4	IO3	PIN 30	DTR
5	IO4	PIN 19	AP_READY
6	IO5	PIN 16/17	RESET
7	IO6	PIN 15	PWRKEY
8	IO7	PIN 20	RESET
IOH			
1	IO8	PIN 18	W_DISABLE
2	IO9	PIN 1	PSM_IND
3	IO10	N/C	
4	IO11	PIN 28	UART3_RxD
5	IO12	PIN 27	UART3_TxD
6	IO13	N/C	
7	GND	GND	Ground
8	AREF	N/C	
9	SDA	N/C	
10	SCL	N/C	

6.4 Cellular Arduino Shield Schematics




POWER
VCC_5V
VCC_3V3
VBAT
VBUS
+5V
GND
U4
MIC29302WU
U5
SPX3819M5_33
Vin=3.4V~5.5V
Vout=1.24*(1+R23/R24)
MBR140SF
H1
H2
H3
H4
HOLE
Title
Power
Size
A4
Number
Revision
F
Date: 2018/6/21
Sheet 2 of 7
File: E:\new work\..\power 0606.SchDoc
Drawn By: Terry


BG96 MODULE
Button
Indicator light


USIM_CLK
USIM_DATA
USIM_RST
R44
R45
R46
0R
0402R
GND
C40
C39
C38
33pF
USIM_VCC
R0402
R35
510KNC
U9
SRV05-4
G
U10
Micro SIM 8P-2
RST
I/O
CLK
VPP
VCC
S_GND
GND
USIM_GND
C41
100nF
U11
M2M_USIM MS1
Vdd
Vss
IO1
IO2
NC1
NC2
R60
R59
R61
15K
Title
USIM
Size
A4
Number
Revision
F
Date:
2018/6/21
Sheet 3 of 7
File:
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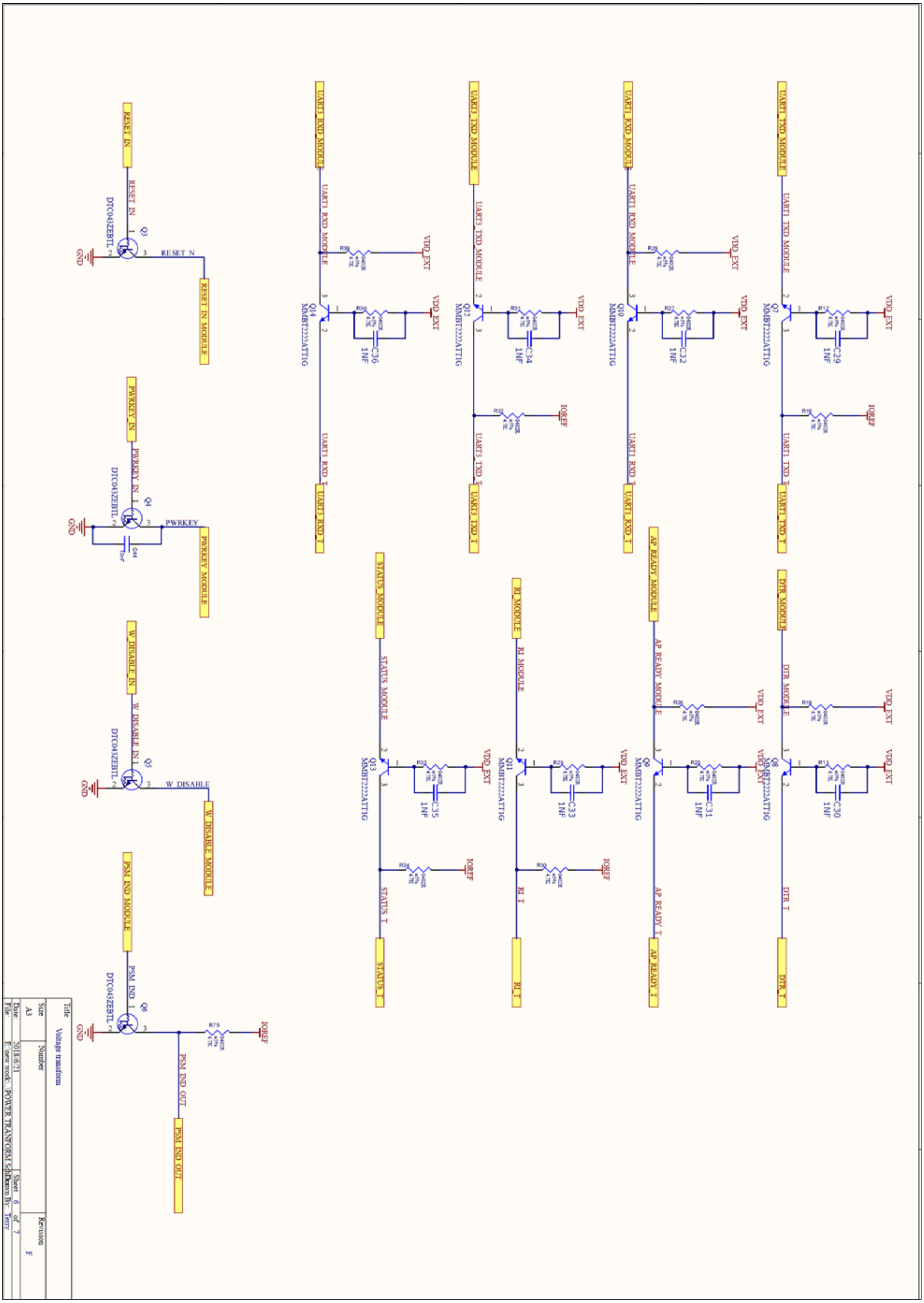
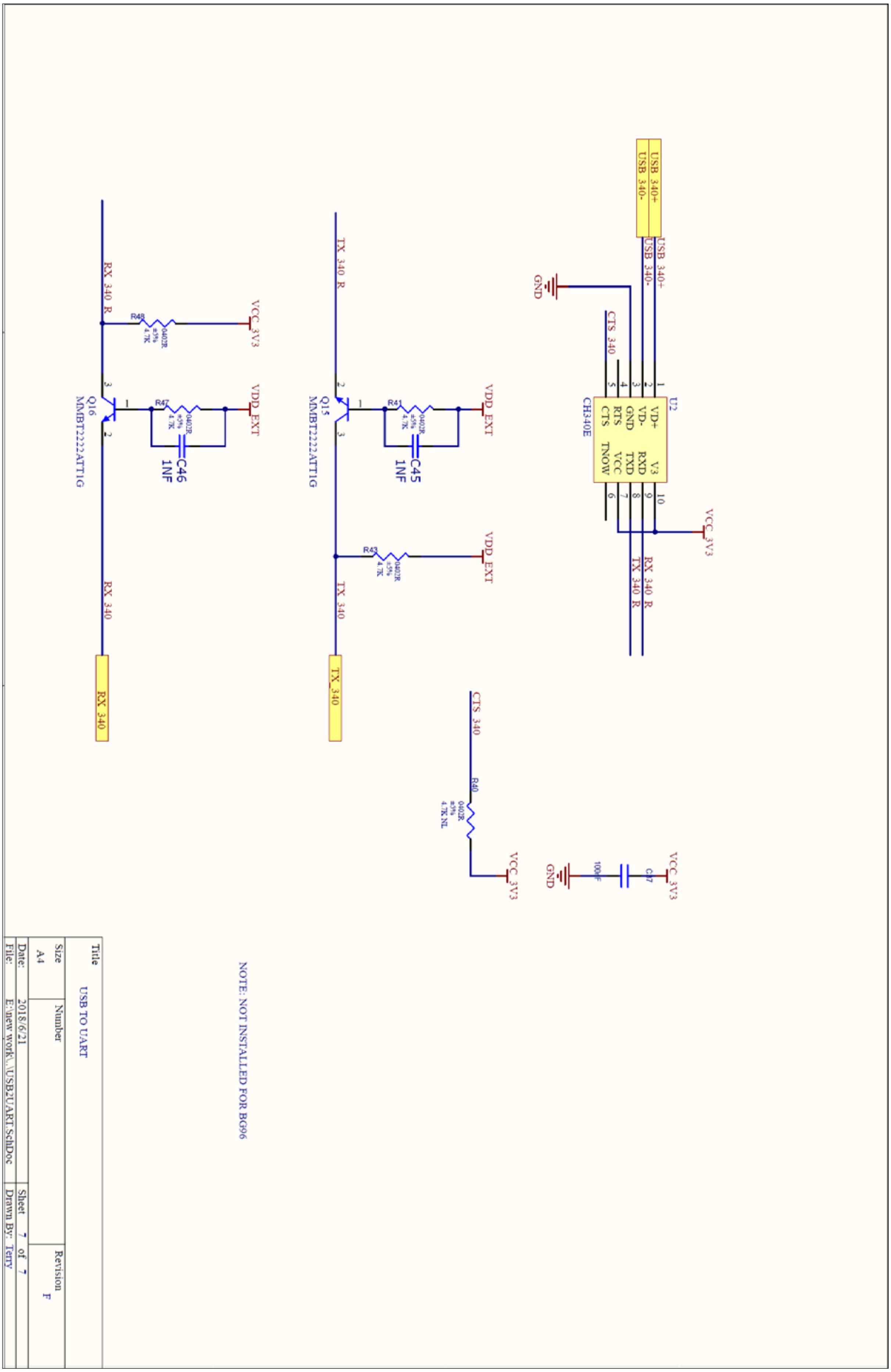
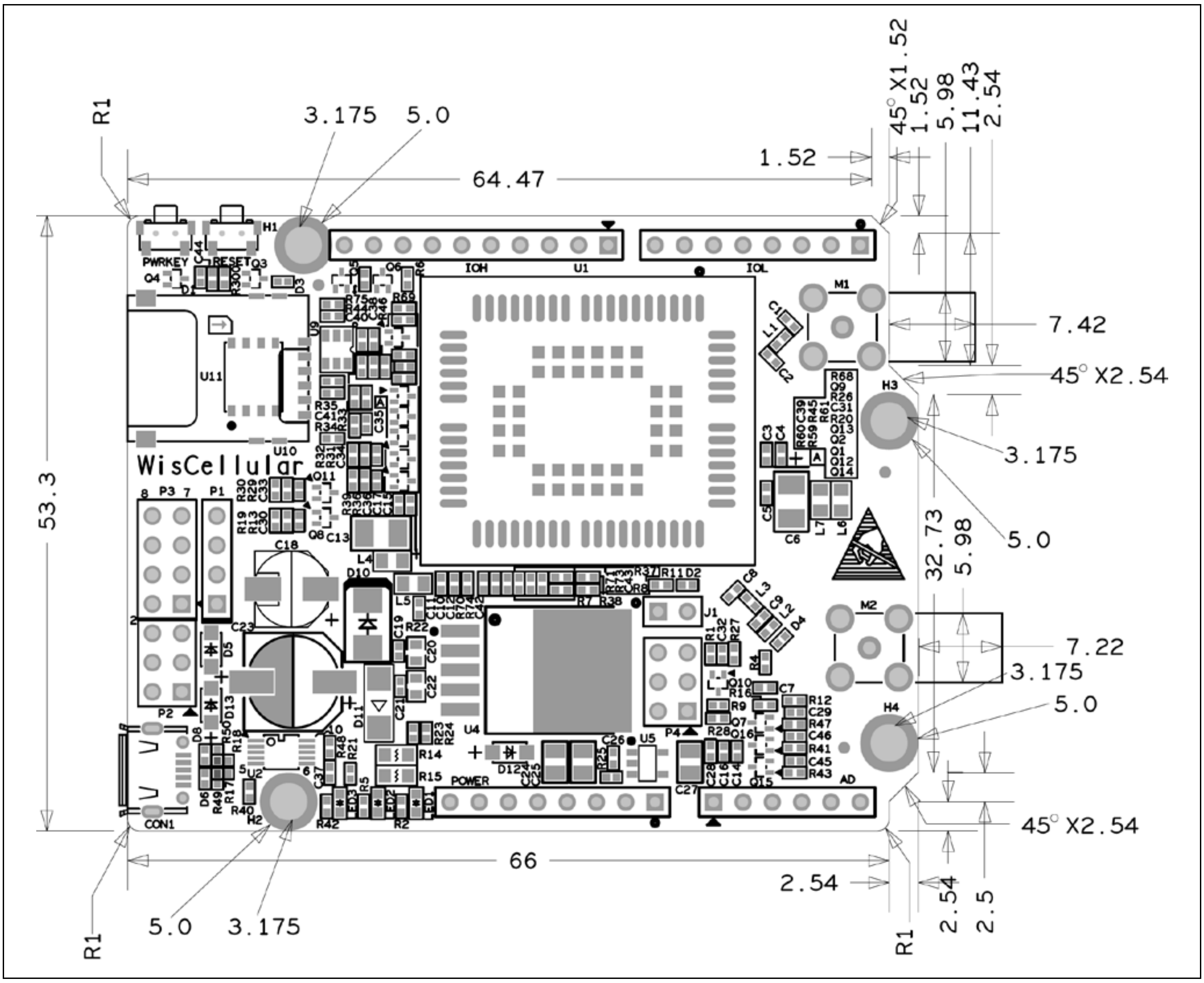
Drawn By: Terry


RESET_IN
RESET_IN_MODULE
PWRKEY_IN
PWRKEY_MODULE
W_DISABLE_IN
W_DISABLE_MODULE
PSM_IND_MODULE
PSM_IND_OUT
UART3_RXD_MODULE
UART3_TXD_MODULE
UART1_RXD_MODULE
UART1_TXD_MODULE
UART3_RXD_T
UART3_TXD_T
UART1_RXD_T
UART1_TXD_T
STATUS_MODULE
RI_MODULE
AP_READY_MODULE
DTR_MODULE
STATUS_T
RI_T
AP_READY_T
DTR_T
VDD_EXT
IOREF
GND
Voltage transform
A3
2018/6/21
Sheet 6 of 7
Drawn By Terry
Revision F


USB 340+
USB 340-
GND
CTS 340
U2
CH340E
VD+
VD-
GND
RTS
CTS
V3
RXD
TXD
VCC
TNOW
VCC_3V3
RX 340 R
TX 340 R
RX 340
TX 340
R48
R47
R41
R43
R40
C46
1NF
C45
1NF
C47
100nF
Q16
Q15
MMBT2222ATT1G
VDD_EXT
NOTE: NOT INSTALLED FOR BG96
Title
USB TO UART
Size
A4
Number
Revision
F
Date:
2018/6/21
Sheet 7 of 7
File:
E:\new work\..\USB2UART.SchDoc
Drawn By:
Terry

6.5 Cellular Arduino Shield Mechanical Dimensions

(All dimensions are in millimeters)

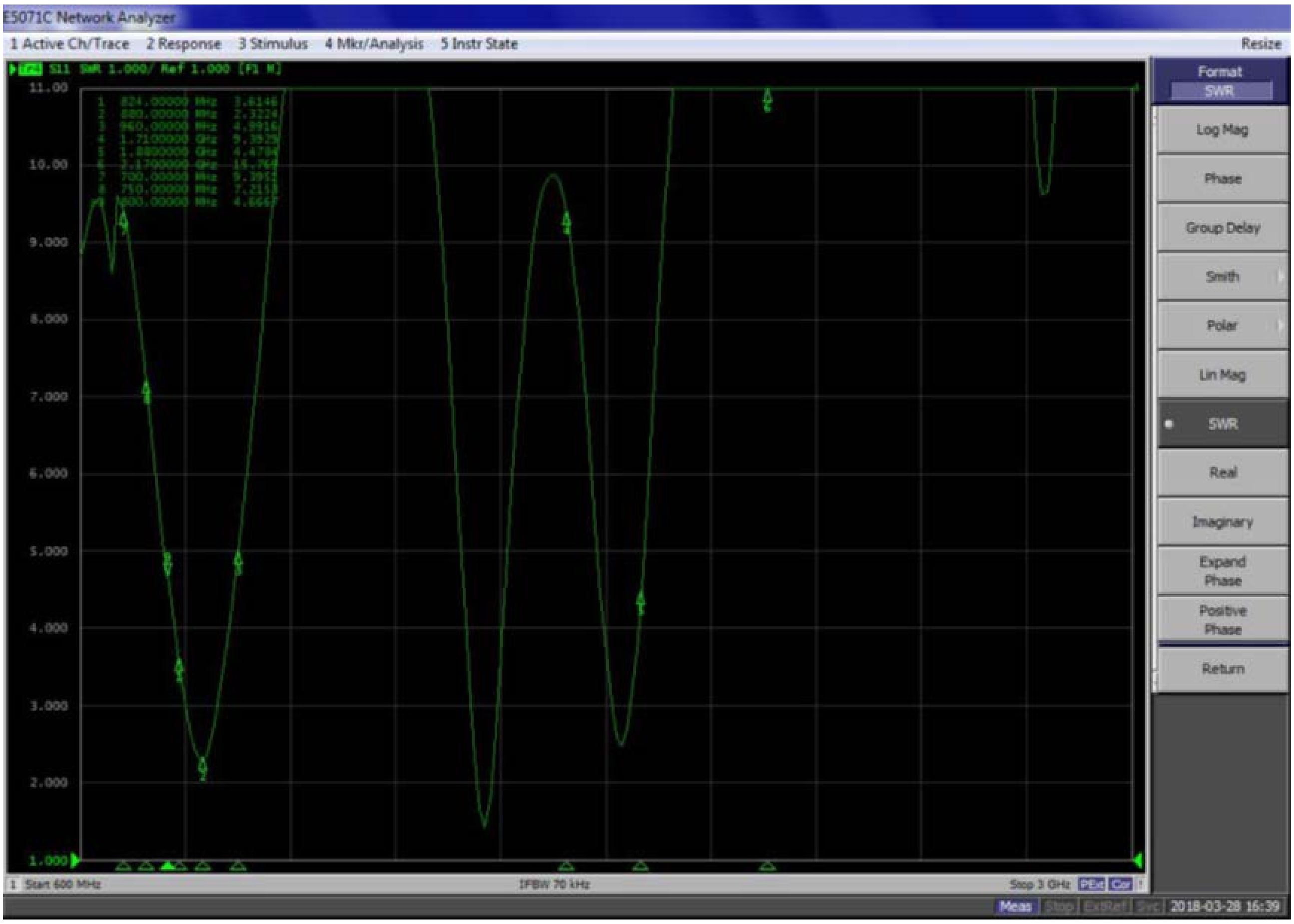


6.6 Cellular Antenna

The cellular antenna for Cellular Arduino Shield is shown Figure 23. It covers working frequency band from 824 MHz to 2690 MHz.

Figure 23 Cellular Antenna for Cellular Arduino Shield

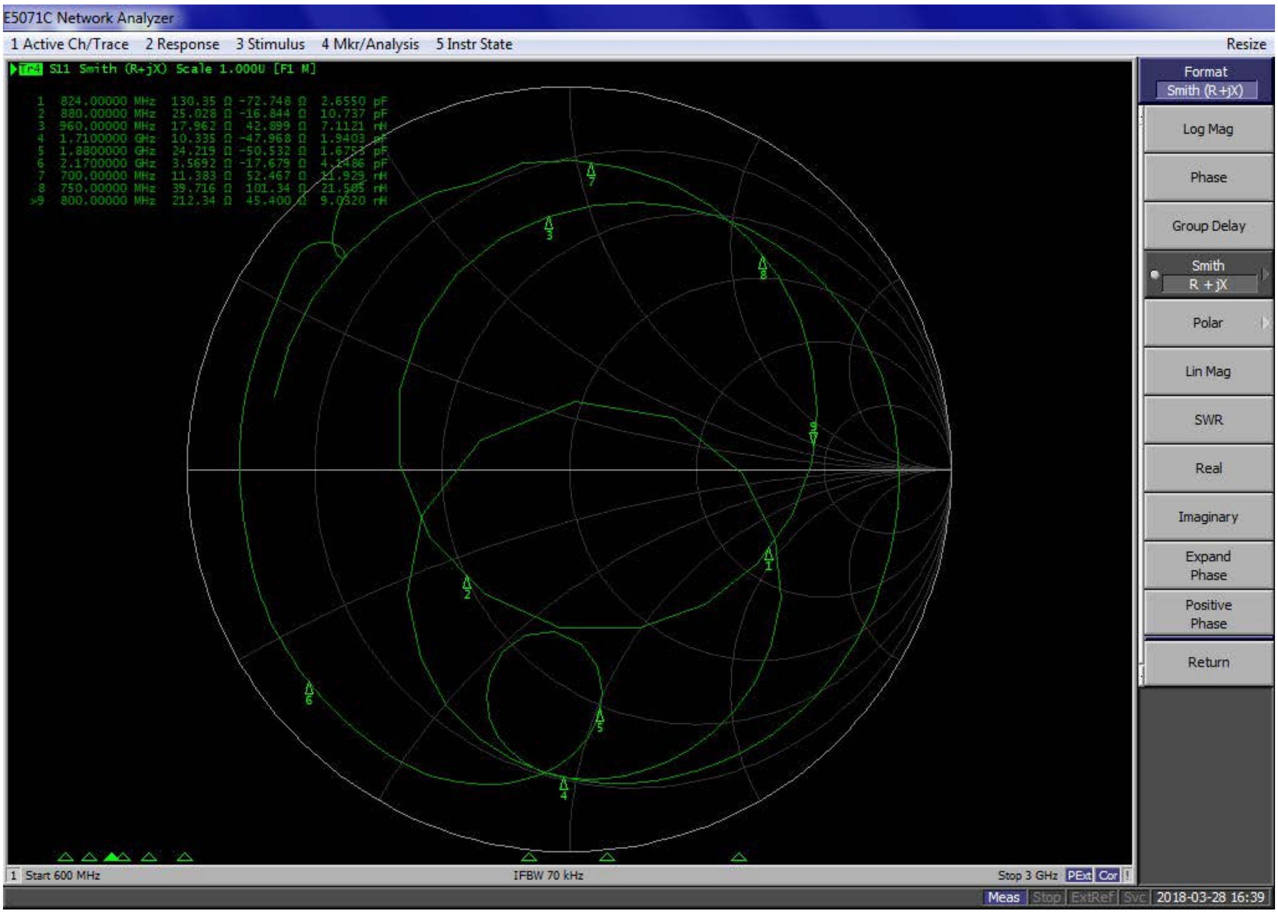
Voltage Standard Wave Ratio (VSWR) plot is shown as follows.



VSWR data is shown in the following table.

Frequency (MHz)	Voltage Standard Wave Ratio (VSWR)
700	9.3
800	4.6
880	3.6
960	4.9
1,710	9.3
1,880	4.4
2,170	15

Smith Plot is shown as follows.



Radiation Pattern H-plane is shown as follows.

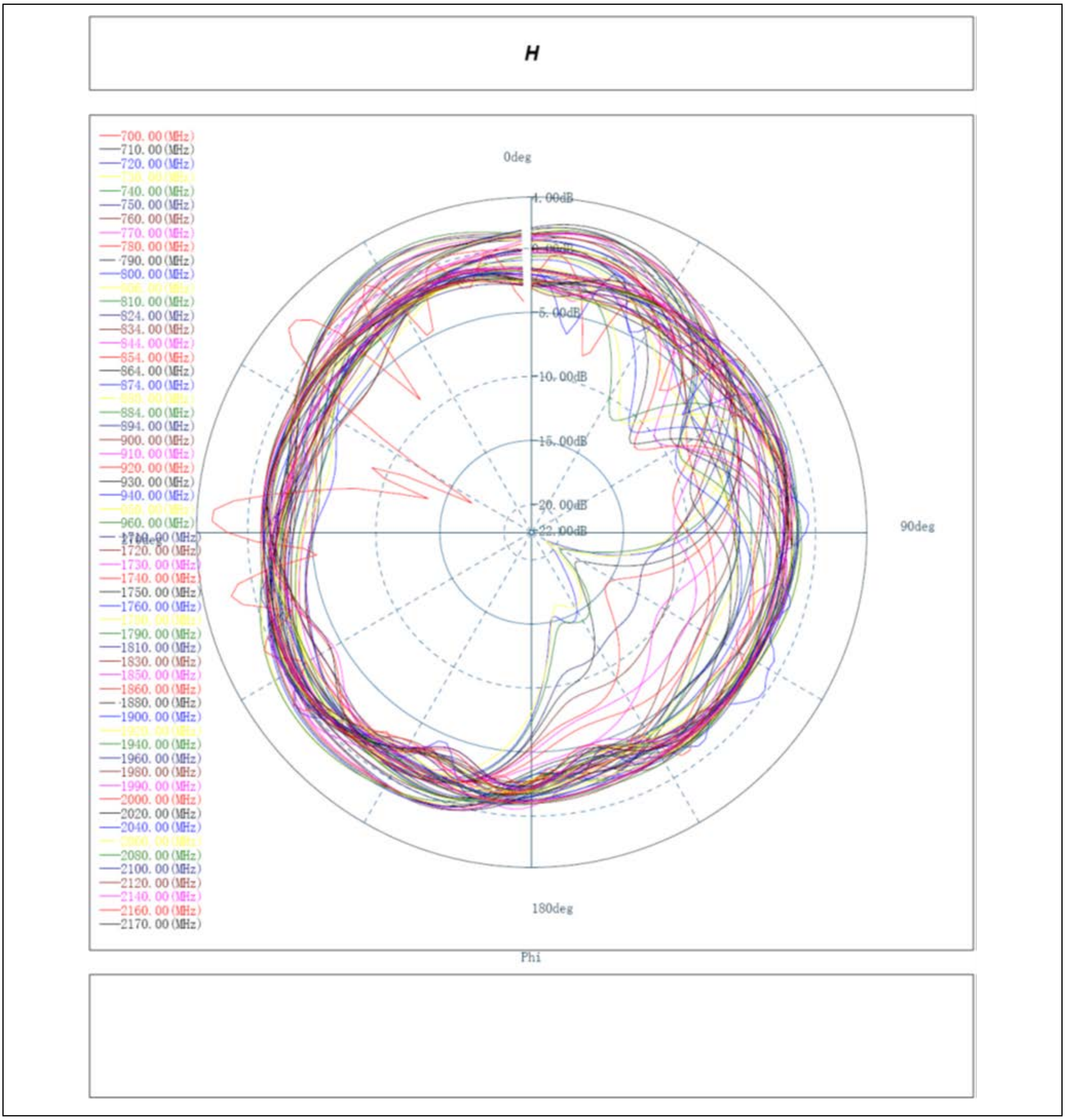


Figure 24 Radiation Pattern H-plane

Radiation Pattern E-plane is shown in the following graphics.

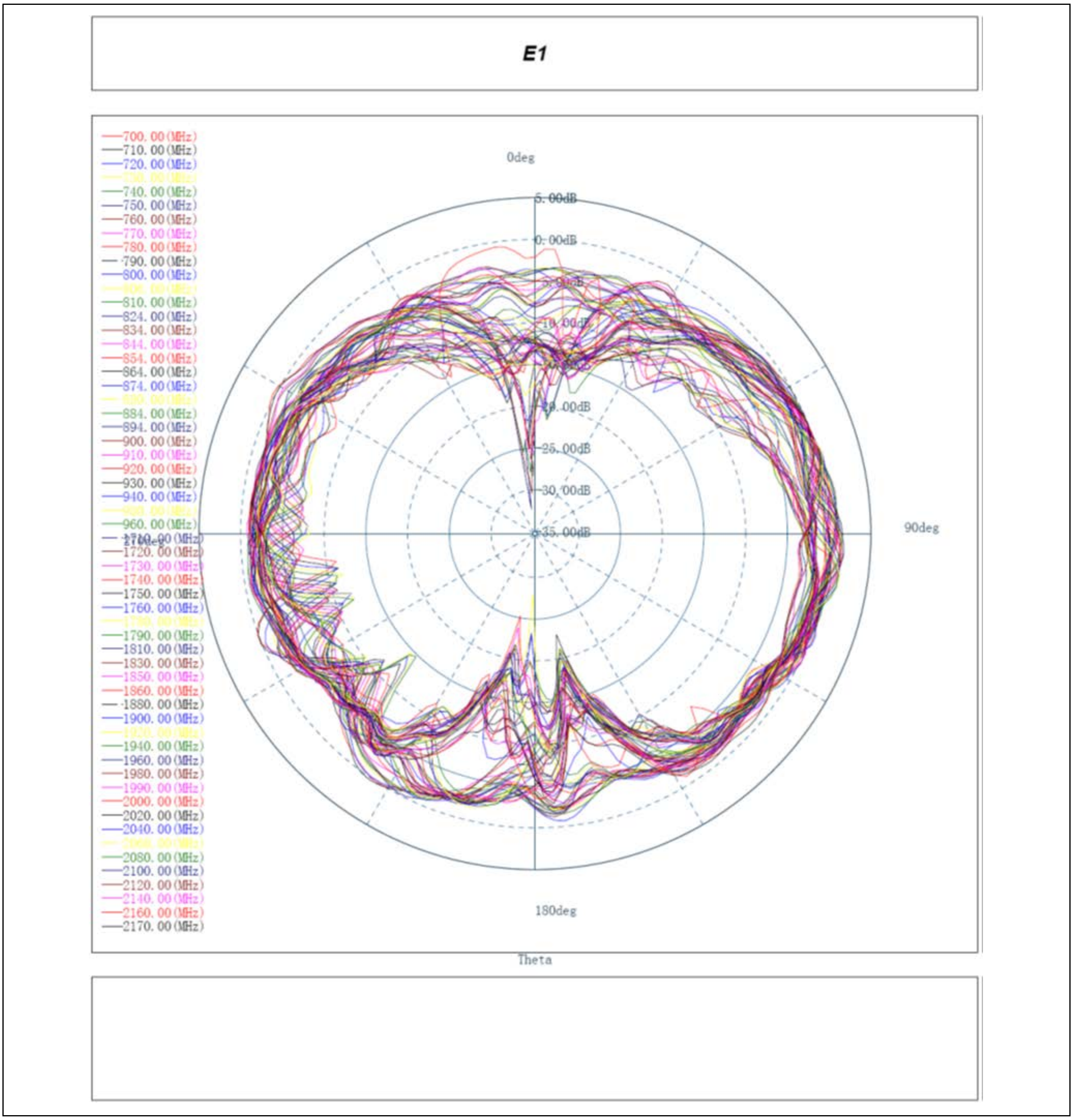


Figure 25 Radiation Pattern E-plane (E1)

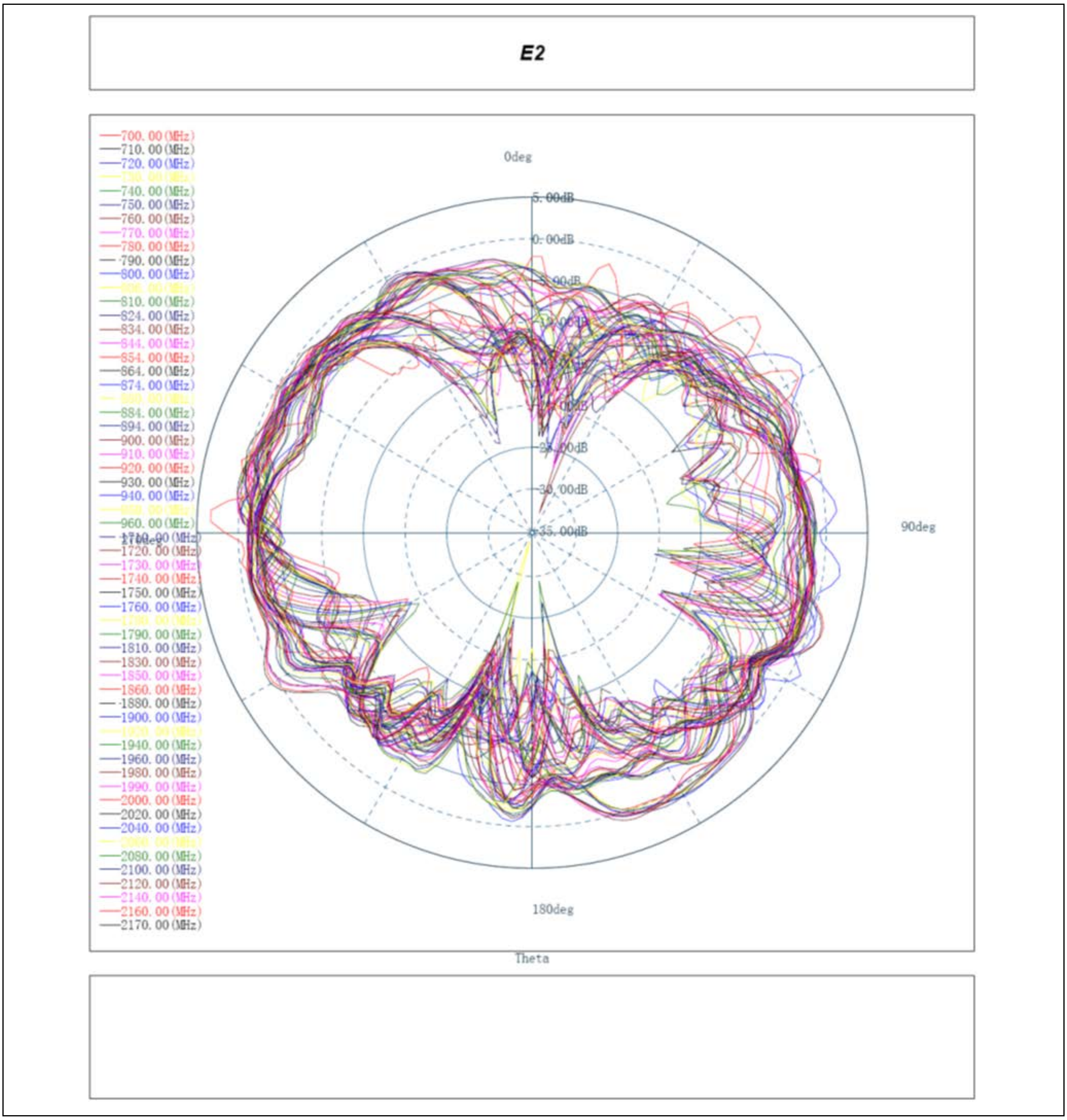


Figure 26 Radiation Pattern E-plane (E2)

UGAIN and Efficiency is listed in the table below

Table 19 Gain and Efficiency at Different Frequencies

Frequency [Hz]	Efficiency	Gain [dBi]
7E+08	49%	1.632948
7.1E+08	51%	1.826395
7.2E+08	49%	1.833288
7.3E+08	44%	1.600659
7.4E+08	46%	1.896142
7.5E+08	50%	1.936788
7.6E+08	50%	1.721112
7.7E+08	46%	1.406281

7.8E+08	45%	1.491829
7.9E+08	47%	1.8309
8E+08	45%	1.843967
8.06E+08	41%	1.714366
8.1E+08	45%	2.215538
8.24E+08	42%	1.97312
8.34E+08	44%	1.890023
8.44E+08	42%	1.407188
8.54E+08	42%	1.453714
8.64E+08	47%	2.111646
8.74E+08	46%	1.93289
8.8E+08	48%	1.960958
8.84E+08	46%	1.930333
8.94E+08	52%	2.347337
9E+08	50%	2.192946
9.1E+08	50%	2.265394
9.2E+08	49%	2.081987
9.3E+08	48%	2.005751
9.4E+08	49%	2.128994
9.5E+08	49%	2.305449
9.6E+08	48%	2.233022
1.71E+09	35%	0.02584
1.72E+09	35%	0.0088
1.73E+09	36%	0.647356
1.74E+09	44%	0.806863
1.75E+09	35%	0.03676
1.76E+09	46%	0.549059
1.78E+09	34%	0.14522
1.79E+09	35%	0.41562
1.81E+09	36%	0.35094
1.83E+09	34%	0.30882
1.85E+09	38%	0.430313
1.86E+09	35%	0.33059
1.88E+09	37%	0.008792
1.9E+09	43%	0.479122
1.92E+09	40%	0.111459
1.94E+09	46%	0.407999
1.96E+09	44%	0.037526
1.98E+09	48%	0.405617
1.99E+09	48%	0.112167
2E+09	47%	0.144104
2.02E+09	46%	0.14634
2.04E+09	47%	0.033818
2.06E+09	45%	0.112366
2.08E+09	51%	0.672779
2.1E+09	48%	0.291807
2.12E+09	54%	0.939911
2.14E+09	54%	1.161325
2.16E+09	59%	1.631935
2.17E+09	59%	1.967355

The cellular antenna mechanical dimensions are shown as follows.

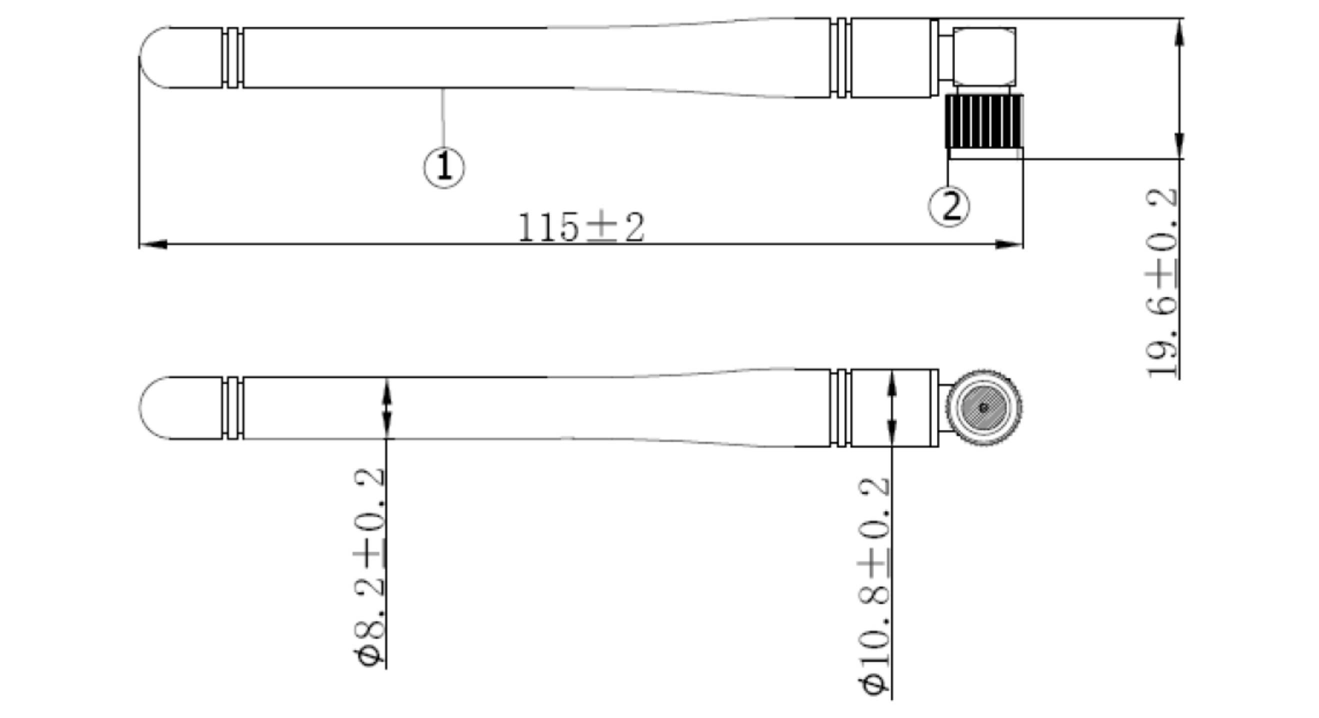


Figure 27 Mechanical Dimensions of the Cellular Antenna

6.7 GPS Antenna

The GPS antenna for Cellular Arduino Shield is shown as follows.

Figure 28 Cellular Arduino Shield GPS Antenna

Antenna specifications are listed in the following table.

Table 20 Antenna Specifications

Item	Specifications	Post Environmental Tolerance
Range of Receiving Frequency	1575.42 ± 1.1	± 2.5
Center Frequency (MHz) (w/ 30mm^2 GND plane)	1575.42	± 3.0
Bandwidth (MHz) (Return Loss ≤ -10dB)	≥10	± 0.5
VSWR (in Center Frequency)	≤2.0	± 0.5
Gain (Zenith) (dBi Typ) (w/ 70mm^2 GND Plane)	4.5	± 0.5
Axial Ratio (dB) (w/ 70mm^2 GND Plane)	3.0	± 0.2
Polarization	Right-Handed Circular	-
Impedance (Ω)	50	-
Frequency Temperature Coefficient (ppm/ºC)	0 ± 10	-

Amplifier Specifications are listed in the following table.

Table 21 Amplifier Specifications

Item	Specifications
Frequency Range	1575.42 MHz
Gain	27 dB
VSWR	≤2.0
Noise Coefficient	≤2.0 dB
DC Voltage	3 to 5V
DC Current	5 ± 2 mA

Environmental test performance specifications are listed in the following table.

Table 22 Environmental Test Performance Specifications

	Normal Temperature	High Temperature[1]	Low Temperature[2]
Amplifier Gain	27 dB ± 2.0	27 dB ± 2.0	27 dB ± 2.0
VSWR	≤ 2.0	≤ 2.0	≤ 2.0
Noise Coefficient	≤ 2.0	≤ 2.0	≤ 2.0

Notes: 1. High temperature test: soap in temperature (85ºC) and humidity (95%) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.

2. Low temperature test: soap in temperature (-40ºC) chamber for 24-hour and return to normal temperature (at least for 1-hour) without visual shape change.

The GPS antenna mechanical dimensions are shown in the following figure.

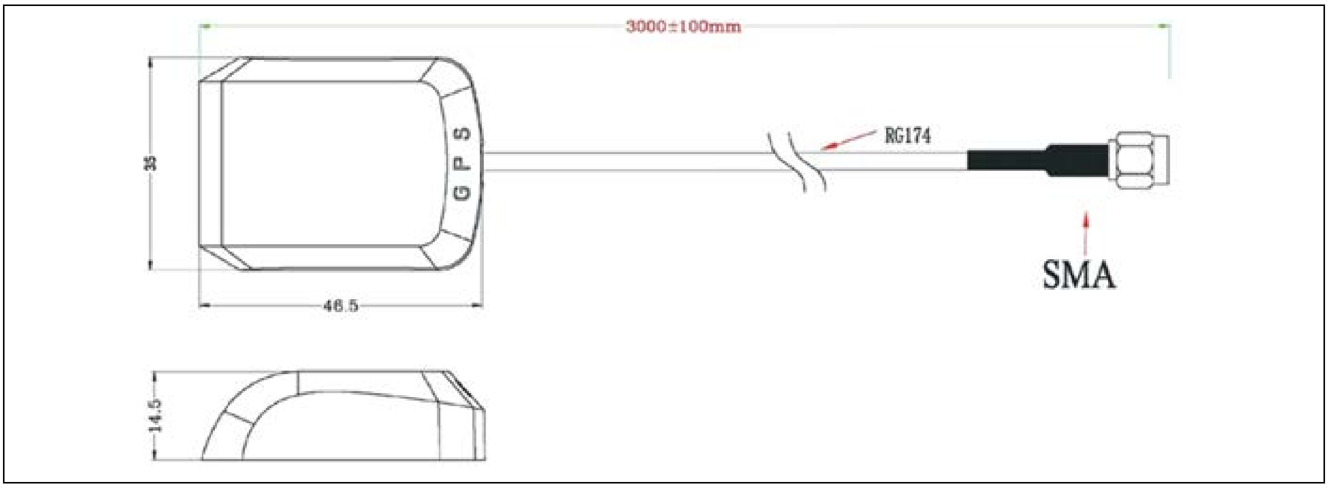


Figure 29 GPS Antenna Mechanical Dimensions

The antenna environmental requirements are listed in the following table.

Table 23 GPS Antenna Environmental Requirements

Conditions	Temperature	Humidity
Working	-35ºC to +80ºC	0% to 95%
Storage	-40ºC to +85ºC	0% to 95%

7. Certifications

AE-CLOUD2 has been certified to comply with the following standards

7.1 CE

Wireless Coverage:

- Wi-Fi: IEEE 802.11n 2.4G single band
- 2G/EGPRS: 900/1800
- 4G/LTE: B1/3/8/20/28

Band	Conducted Power
GSM 900	880MHz - 915MHz @ 35 dBm
DCS 1800	1710MHz - 1785MHz @ 32 dBm
LTE Band 1 Cat-M1& Cat-NB1	1920MHz - 1980MHz @ 25.7 dBm
LTE Band 3 Cat-M1& Cat-NB1	1710MHz - 1785MHz @ 25.7 dBm
LTE Band 8 Cat-M1& Cat-NB1	880MHz - 915MHz @ 25.7 dBm
LTE Band 20 Cat-M1& Cat-NB1	832MHz - 862MHz @ 25.7 dBm
LTE Band 28 Cat-M1& Cat-NB1	703MHz - 748MHz @ 25.7 dBm
802.11b/g/n (HT20/40)	2412MHz - 2472 MHz @ 18.5 dBm

Standard Compliance:

- EN 301 489-1/17/19/52
- EN 55032
- EN 55035
- EN 301511
- EN 301 908-1
- EN 300328
- EN 303 413
- EN 62311
- EN 60950-1

7.2 FCC (no FCC ID required)

Standard Compliance

- FCC part 2/15B

7.3 RoHS

Standard Compliance

- RoHS Directive 2015/863/EU amending Annex II to 2011/65/EU
- IEC 62321-2:2013
- IEC 62631-1:2013
- IEC 62631-3-1:2013
- IEC 62631-5:2013
- IEC 62631-4:2013
- IEC 62631-7-1:2015
- IEC 62631-7-2:2017 & ISO 17075-1:2017
- IEC 62631-6:2015

7.4 WEEE

Standard Compliance

- Directive 2012/19/EU

7.5 Japan MIC

Standard Compliance

- Terminal Equipment (T)
  - Cellular Module: D180034003
  - Wi-Fi Module: D180063003
- Radio Equipment (R)
  - Cellular Module: 003-180062
  - Wi-Fi Module: 018-150012

Website and Support

Visit the following vanity URLs to learn about key elements of the Synergy Platform, download components and related documentation, and get support.

Synergy Software	renesassynergy.com/software
Synergy Software Package	renesassynergy.com/ssp
Software add-ons	renesassynergy.com/addons
Software glossary	renesassynergy.com/softwareglossary
Development tools	renesassynergy.com/tools
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Revision History

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		Page	Summary
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Application Example for Cloud Connectivity (AE-CLOUD2)
User's Manual

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Renesas Synergy™ Platform
Application Example for Cloud Connectivity
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