



PRODUCT SPECIFICATION DOCUMENT

IEEE 802.11 b/g/n
Wi-Fi & Bluetooth MODULE

MODULE NAME: QUARTZ
CHIPSET: ESP32-D0WDQ6-V3

12/10/2020

Prepared By:

Suleman Aijaz Memon

Supervised By:

Mustafa İlker Uzun

Arçelik A.Ş.

R&D Center

34950

Tuzla/Istanbul/Turkey

ABSTRACT

Quartz module is a chip-on-board Wi-Fi solution, developed for use in white goods appliances across Arcelik. ESP32 WI-FI chipset is used which is highly integrated chip and allows the hardware development with minimal peripheral components. Bluetooth functionality is used for onboarding of the module. ATECC508A is used on Quartz module to enable the feature of embedded security. For the communication interface, SPI, UART and I2C can be used. Quartz module is a Bluetooth and Wi-Fi combo module.

Revision Number	Department	Name	Date	Revision Reason
Version 1.1	Central R&D	Suleman Aijaz Memon	12/10/2020	-
Version 2.1	Central R&D	Suleman Aijaz Memon	05/24/2021	Mechanical constraints are satisfied by revising the layout

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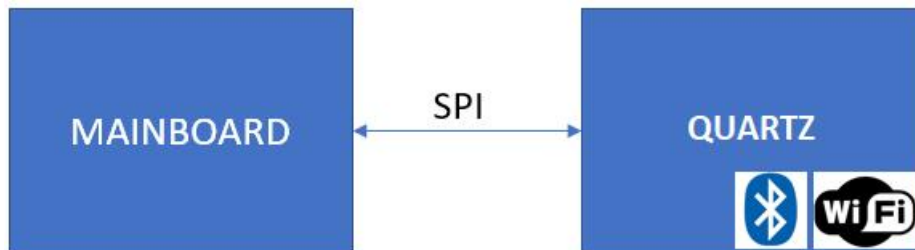
1. INTRODUCTION

Arçelik Connected products require Bluetooth and WI-FI. For this purpose, Quartz module uses a single chip WIFI, Bluetooth, MCU solution from Espressif Systems, ESP32-D0WDQ6-V3.

Quartz module is available in three different configurations according to the target appliance type.

1.1 SPI Interface

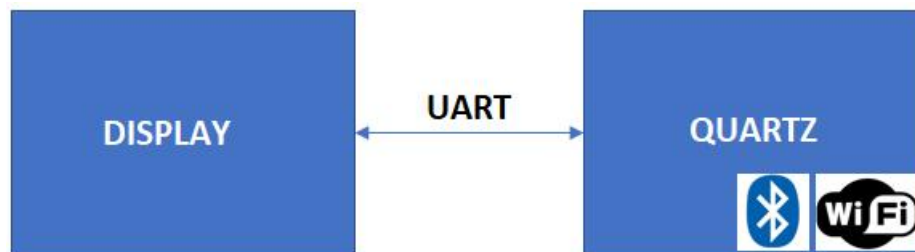
For refrigerator products, the quartz module with SPI interface will be used.



1.2 UART Interface

For washing machine, dish washer, dryer, cooker and air conditioner, the quartz module with UART will be used.

UART/SPI/I2C communication selection will be managed by software and BOM change.



1.3 I2C Interface

I2C option is also available on this board.

1.4 On-Board Antenna / External Antenna

Wifi and BT connection in the module is provided by a single antenna operating at 2.4Ghz. The module has two different antenna options, internal and external. Default antenna is on-board (PCB trace) antenna. External antenna is reserved option for future use.

NOTE: In case of BLE only products, Quartz will not be used and the BLE functionality will be supported by Display MCU.

2 HARDWARE BLOCK DIAGRAM

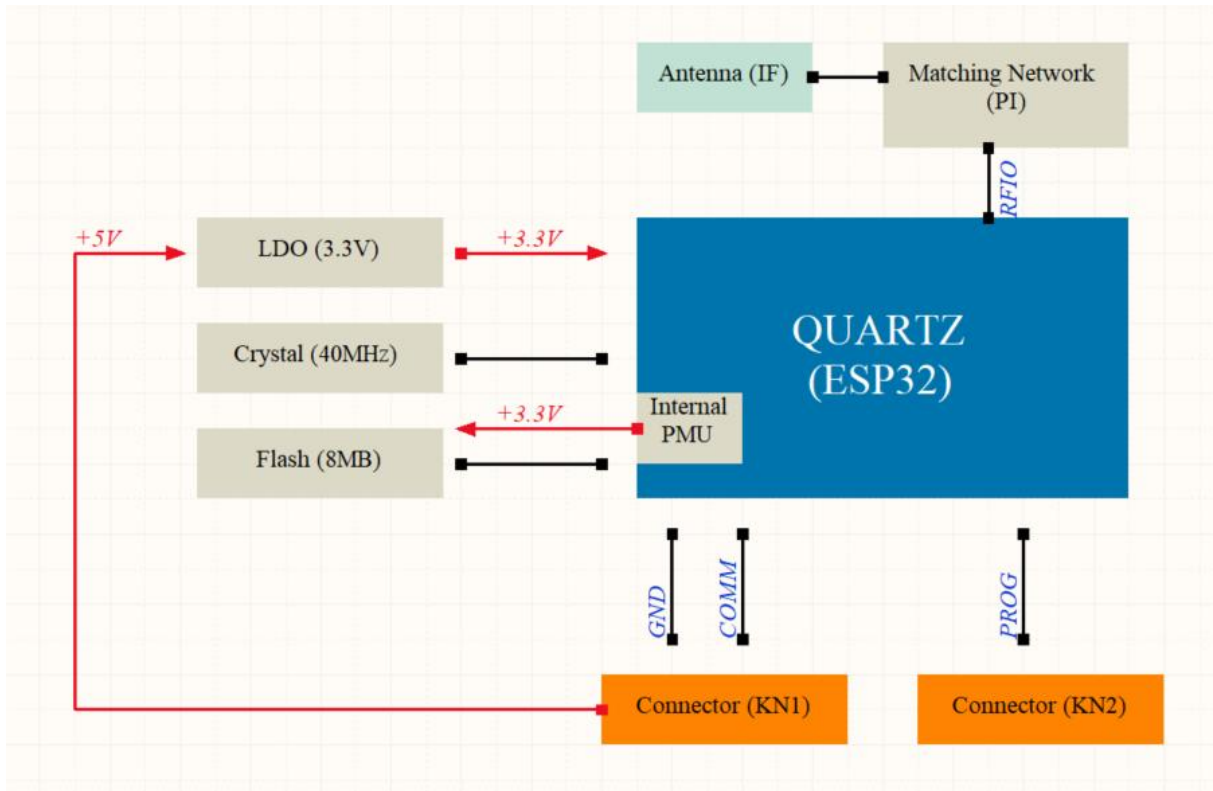


Figure 1: Block Diagram for the Module

3 MODULE SPECIFICATIONS

3.1 General Specifications

- PCB Dimension 41(+/- 0.2)mm x 45(+/-0.2)mm
- PCBA Height 4.1(+/-0.2)mm
- Main Chipset ESP32-D0WDQ6-V3
- Crystal Frequency 40MHz
- Host Interface SPI/UART/I2C
- Transmitter/Receiver 1 TX/ 1 RX
- Maximum Data Rate 150Mbps
- Operating Voltage 5.0VDC +/-5%
- Average Current 150mA
- Peak Current 500mA
- Operating Temperature -10°C ~ +85°C
- Operating Humidity 5% ~ 95%

NOTE: Temperature and humidity ranges will be updated once the testing of module on products is finalized.

3.2 Wi-Fi Radio Specifications

The ESP32 Wi-Fi Radio and Baseband support the following features:

- 802.11b/g/n
- 802.11n MCS0-7 in both 20 MHz and 40 MHz bandwidth
- 802.11n MCS32 (RX)
- 802.11n 0.4 μ s guard-interval
- up to 150 Mbps of data rate
- Receiving STBC 2x1
- Up to 20.5 dBm of transmitting power
- Adjustable transmitting power

Max conduct power for Wi-Fi 2.4G: 15.32dBm

Wi-Fi radio characteristics are shown in Figure below (copied by ESP32 datasheet).

Parameter	Condition	Min	Typical	Max	Unit
Operating frequency range ^{note1}	-	2412	-	2484	MHz
Output impedance ^{note2}	-	-	note 2	-	Ω
TX power ^{note3}	11n, MCS7	13	14	15	dBm
	11b mode	19.5	20	20.5	dBm
Sensitivity	11b, 1 Mbps	-	-98	-	dBm
	11b, 11 Mbps	-	-91	-	dBm
	11g, 6 Mbps	-	-93	-	dBm
	11g, 54 Mbps	-	-75	-	dBm
	11n, HT20, MCS0	-	-93	-	dBm
	11n, HT20, MCS7	-	-73	-	dBm
	11n, HT40, MCS0	-	-90	-	dBm
	11n, HT40, MCS7	-	-70	-	dBm
Adjacent channel rejection	11g, 6 Mbps	-	37	-	dB
	11g, 54 Mbps	-	21	-	dB
	11n, HT20, MCS0	-	37	-	dB
	11n, HT20, MCS7	-	20	-	dB

Note: Further details of the Radio features of ESP32 chipset can be found in the ESP32 datasheet, section 3.5.

3.3 Bluetooth Radio Specifications

The Bluetooth Radio and Baseband support the following features:

- Class-1, class-2 and class-3 transmit output powers, and a dynamic control range of up to 24 dB
- $\pi/4$ DQPSK and 8 DPSK modulation
- High performance in NZIF receiver sensitivity with over 97 dB of dynamic range

Espressif Systems

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ESP32 Datasheet V3.3

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3. Functional Description

- Class-1 operation without external PA
- Internal SRAM allows full-speed data-transfer, mixed voice and data, and full piconet operation
- Logic for forward error correction, header error control, access code correlation, CRC, demodulation, encryption bit stream generation, whitening and transmit pulse shaping
- ACL, SCO, eSCO and AFH
- A-law, μ -law and CVSD digital audio CODEC in PCM interface
- SBC audio CODEC
- Power management for low-power applications
- SMP with 128-bit AES

Note: BT power (max): 3.33dBm conduct power

BLE power (max): 3.97dBm conduct power

Further details on bluetooth features of ESP32 chipset can be found in the ESP32 datasheet, section 3.6.

3.4 WI-FI Radio TX/RX Priliminary Results

Frequency (MHz)	BW	TXP Result (dBm)	Calibrated TX (dBm)	Min Spec(dBm)	Max Spec(dBm)
2412	20 Mhz	12.38	14.38	10	15
2422	40 Mhz	12.34	14.34	10	15
2437	20 Mhz	12.29	14.29	10	15
2437	40 Mhz	12.14	14.14	10	15
2472	20 Mhz	12.36	14.36	10	15
2462	40 Mhz	12.14	14.14	10	15
MCS7, HT mode					
Cable Attenuation (Assumption): 2dB					

Figure 2: Average TX Burst Power

MCS Index	Modulation	Coding Rate	20MHz			40MHz		
			Minimum Sensitivity (dBm)	Measured Sensitivity (dBm)	Calibrated Sensitivity (dBm)	Minimum Sensitivity (dBm)	Measured Sensitivity (dBm)	Calibrated Sensitivity (dBm)
0	BPSK	1/2	-82	-91	-93	-82	-87	-89
1	QPSK	1/2	-79	-88	-90	-76	-84	-86
2	QPSK	3/4	-77	-85	-87	-74	-82	-84
3	16-QAM	1/2	-74	-82	-84	-71	-79	-81
4	16-QAM	3/4	-70	-79	-81	-67	-75	-77
5	64-QAM	2/3	-66	-74	-76	-63	-71	-73
6	64-QAM	3/4	-65	-72	-74	-62	-70	-72
7	64-QAM	5/6	-64	-71	-73	-61	-68	-70
2437 Mhz; HT Mode								
Cable Attenuation (Assumption): 2dB								

Figure 3: Sesitivity Measurement (%10 PER)

5 PCB LAYOUT

PCB Dimension: 45mm x 41mm; Layer: 4 Layer; Surface finish: HASL Lead Free, Thickness: 1.6mm

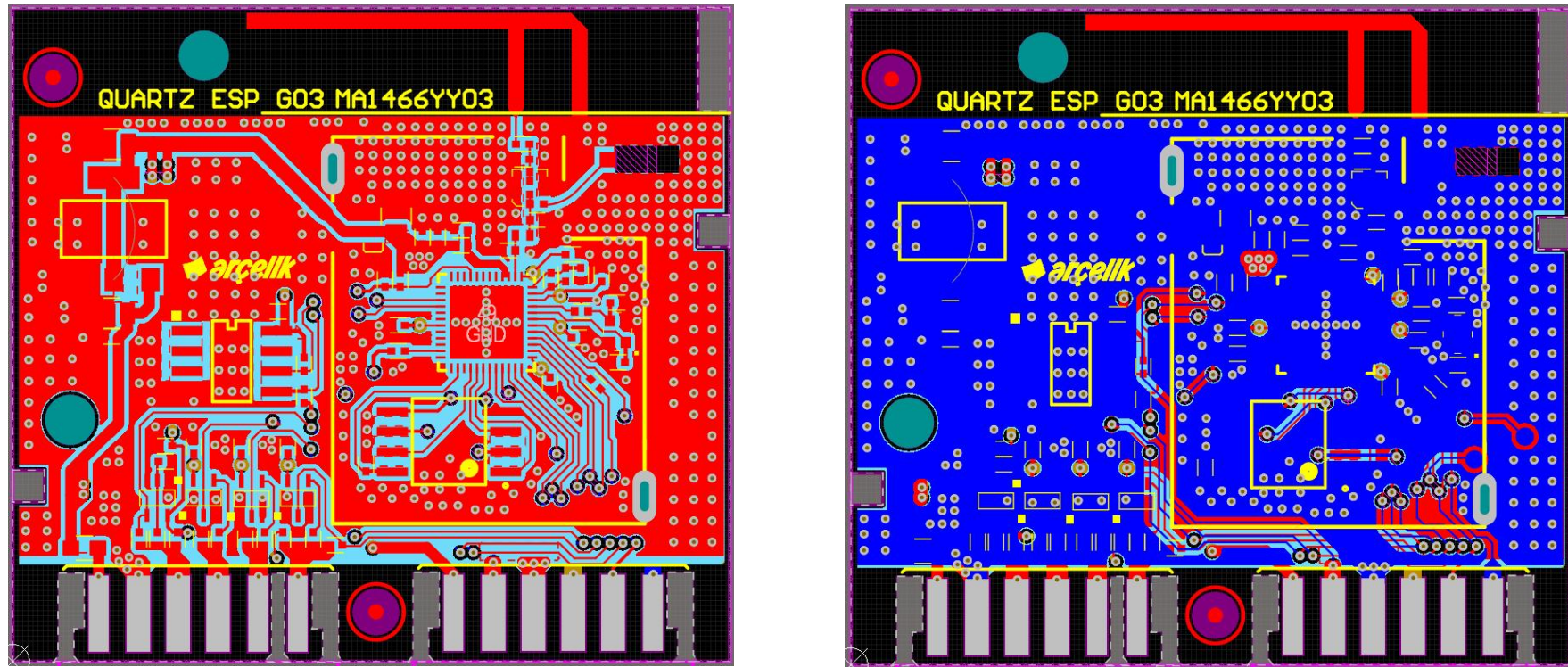


Figure 5: Updated Top and Bottom Layer Configuration

NOTE: PCB is 4 Layer and the layer stack up is given below.

	Layer Name	Type	Material	Thickness (mm)	Dielectric Material	Dielectric Constant	Pullback (mm)	Orientation	Coverlay Expansion
	Top Overlay	Overlay							
	Top Solder	Solder Mask/...	Surface Mat...	0.01016	Solder Resist	3.5			0
■ ■ ■ ■ ■ ■ ■ ■	Top Layer	Signal	Copper	0.035				Top	
■ ■ ■ ■ ■ ■ ■ ■	Dielectric 1	Dielectric	Prepreg	0.11001	FR-4	4.2			
■ ■ ■ ■ ■ ■ ■ ■	L2-GND	Signal	Copper	0.035				Not Allowed	
■ ■ ■ ■ ■ ■ ■ ■	Dielectric 2	Dielectric	Core	1.13	FR-4	4.2			
■ ■ ■ ■ ■ ■ ■ ■	L3-PWR	Signal	Copper	0.035				Not Allowed	
■ ■ ■ ■ ■ ■ ■ ■	Dielectric3	Dielectric	Prepreg	0.11001	FR-4	4.2			
■ ■ ■ ■ ■ ■ ■ ■	Bottom Layer	Signal	Copper	0.035				Bottom	
	Bottom Solder	Solder Mask/...	Surface Mat...	0.01016	Solder Resist	3.5			0
	Bottom Over...	Overlay							

Figure 6: PCB Layer Stack-Up

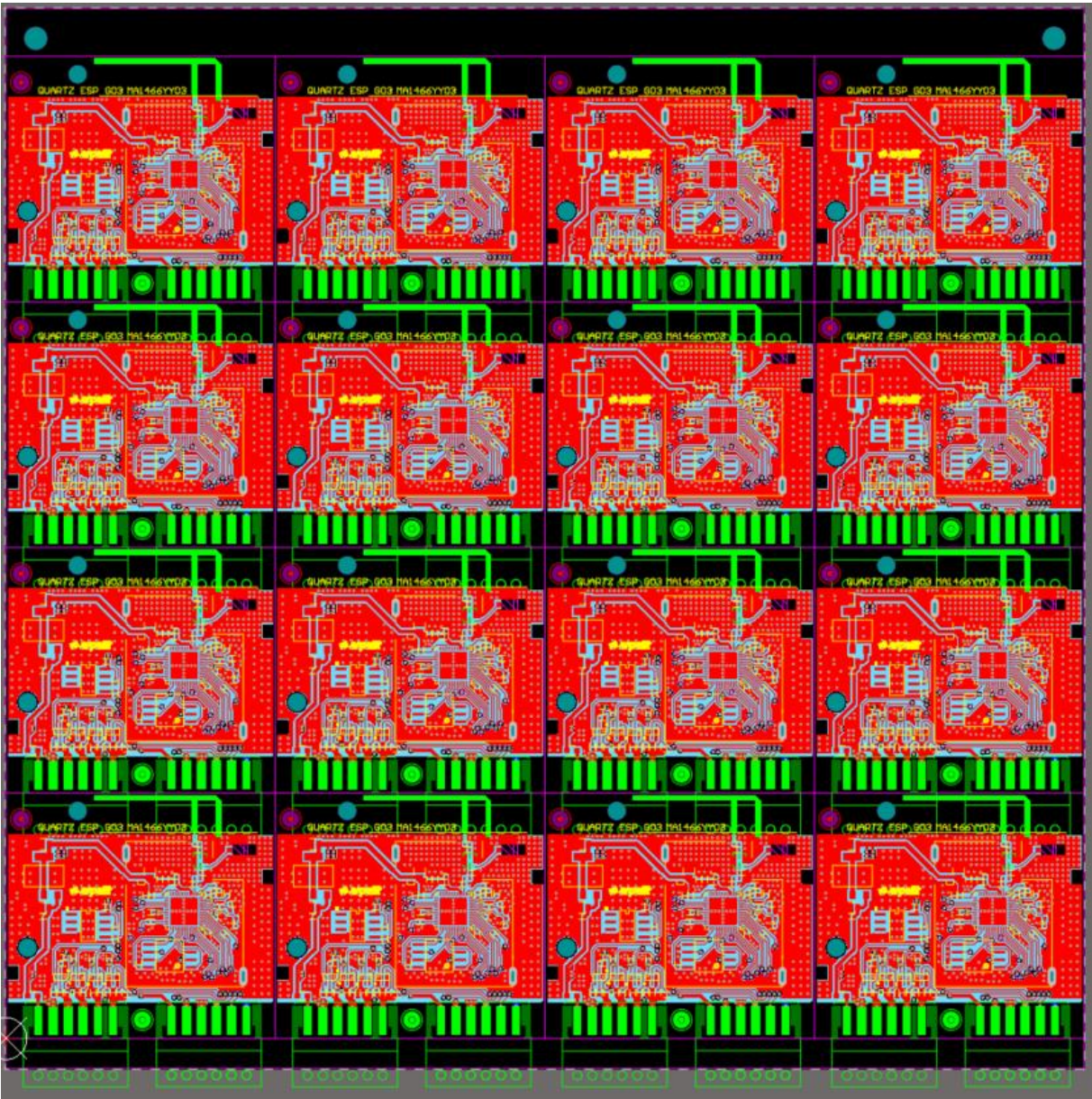


Figure 7: PCB Panel (4x4)

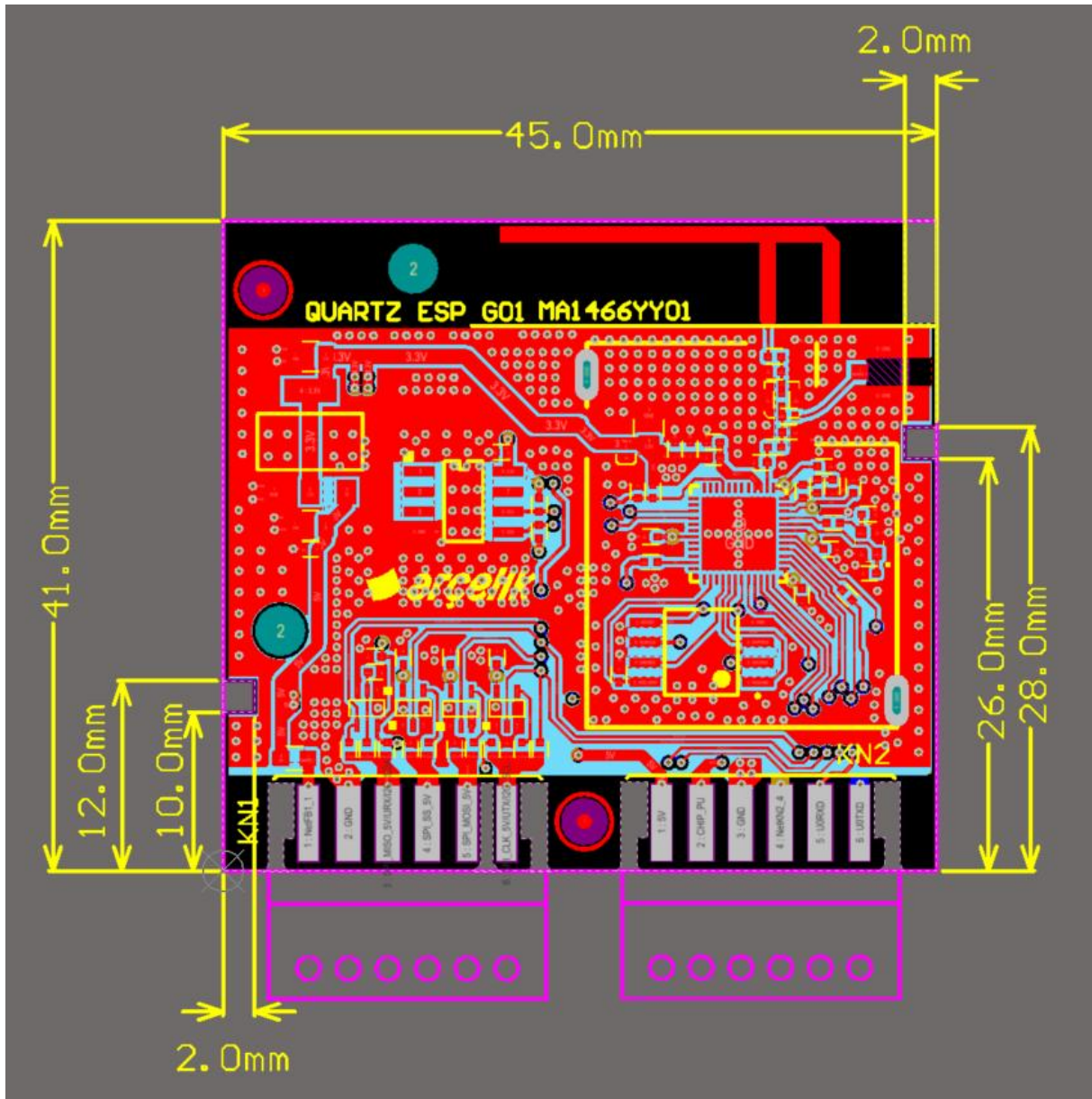
6 MECHANICAL DESIGN

Below step data could be referred for safir module mechanical adaptation.



QUARTZ_ESP_G03_STEP.zip

For the card holder guiding, two notch with size of 2mm x 2mm are available as shown in the figure below.



NOTE: The hole close to Antenna is not for mounting purposes. Its only used by manufacturer during production.

7 HARDWARE STRUCTURE

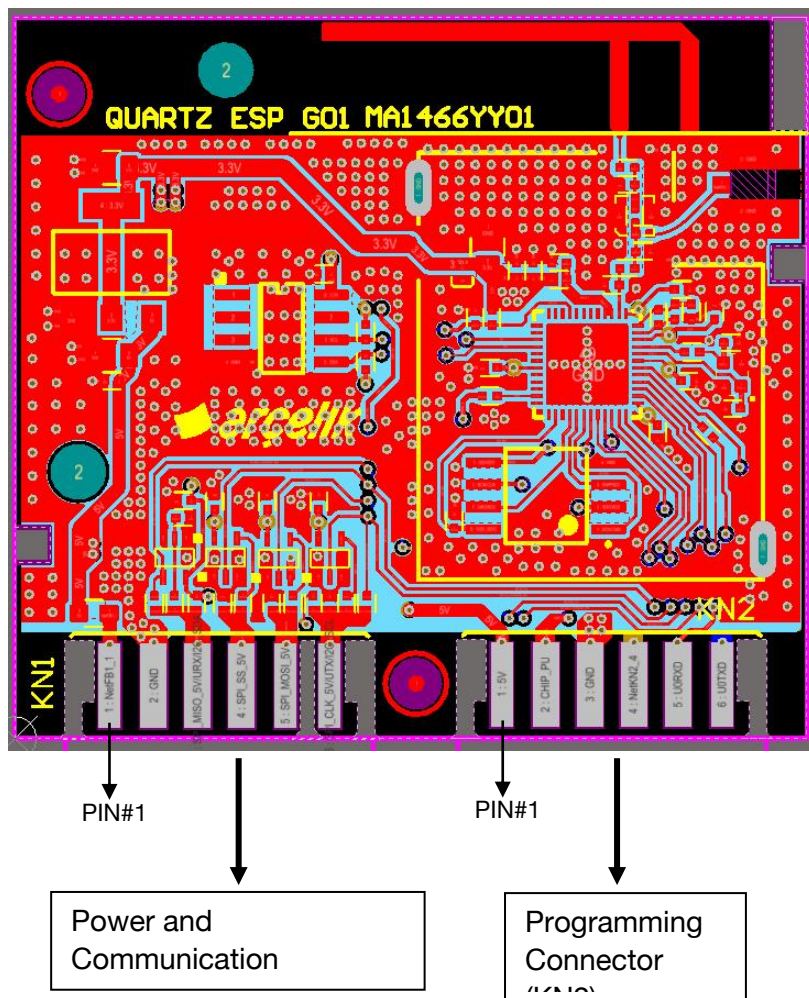
7.1 Communication interface

Quartz module has two separate 2.5mm pitch board edge connectors. Connector (KN1) to be used in the cable group of the module is given in the following file.



5744130000.pdf

(Top View)



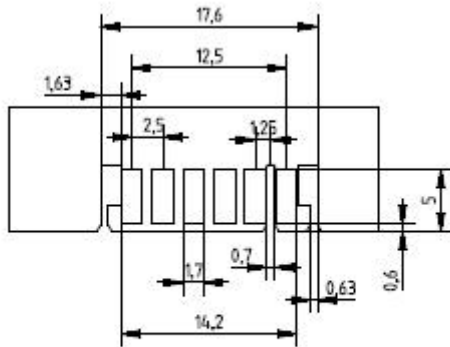
7.1.1 KN1 Pin Order – Communication and Power Connector

Quartz module will support UART, SPI and I2C Communication protocols. Only one of these three protocols will be active in the module. The protocol to be used will be managed by software and BOM variation.

SPI and UART interfaces are 5V logic and I2C interface is 3.3V logic. Main board or display board communication interfaces must be compatible with the required logic level of Quartz module.

Pin No.	Quartz (SPI)	Quartz (UART)	Quartz (I2C)
1	5V	5V	5V
2	GND	GND	GND
3	MISO(module input)	UART RX (module input)	SDA (module IO)
4	SS(module output)	NC	NC
5	MOSI(module output)	NC	NC
6	CLK(module output)	UART TX (module output)	SCL (module output)

KN1 connector must have 0.7mm notch between pins 5 and 6. When preparing the cable assembly edge connector must comply with the following technical drawing.



PCB LAYOUT FOR 6 CCT CONNECTOR

7.1.2 KN2 Pin Order – Programming Connector

Programming connector will be used only during the development. In final product, this connector will not be used.

Pin No.	Net Label
1	5V
2	EN
3	GND
4	IO0
5	RXD (module input)
6	TXD (module output)

7.2 Antenna Configuration

The Quartz module supports external and on-board antenna. Antenna option to be used and the placement of the antenna is one of the most critical parameters in terms of wifi performance of the final product. By default, module uses on-board (PCB Trace) antenna. To use the external antenna, position and placement in the final product should be decided with the approval of the Central R&D RF specialist.

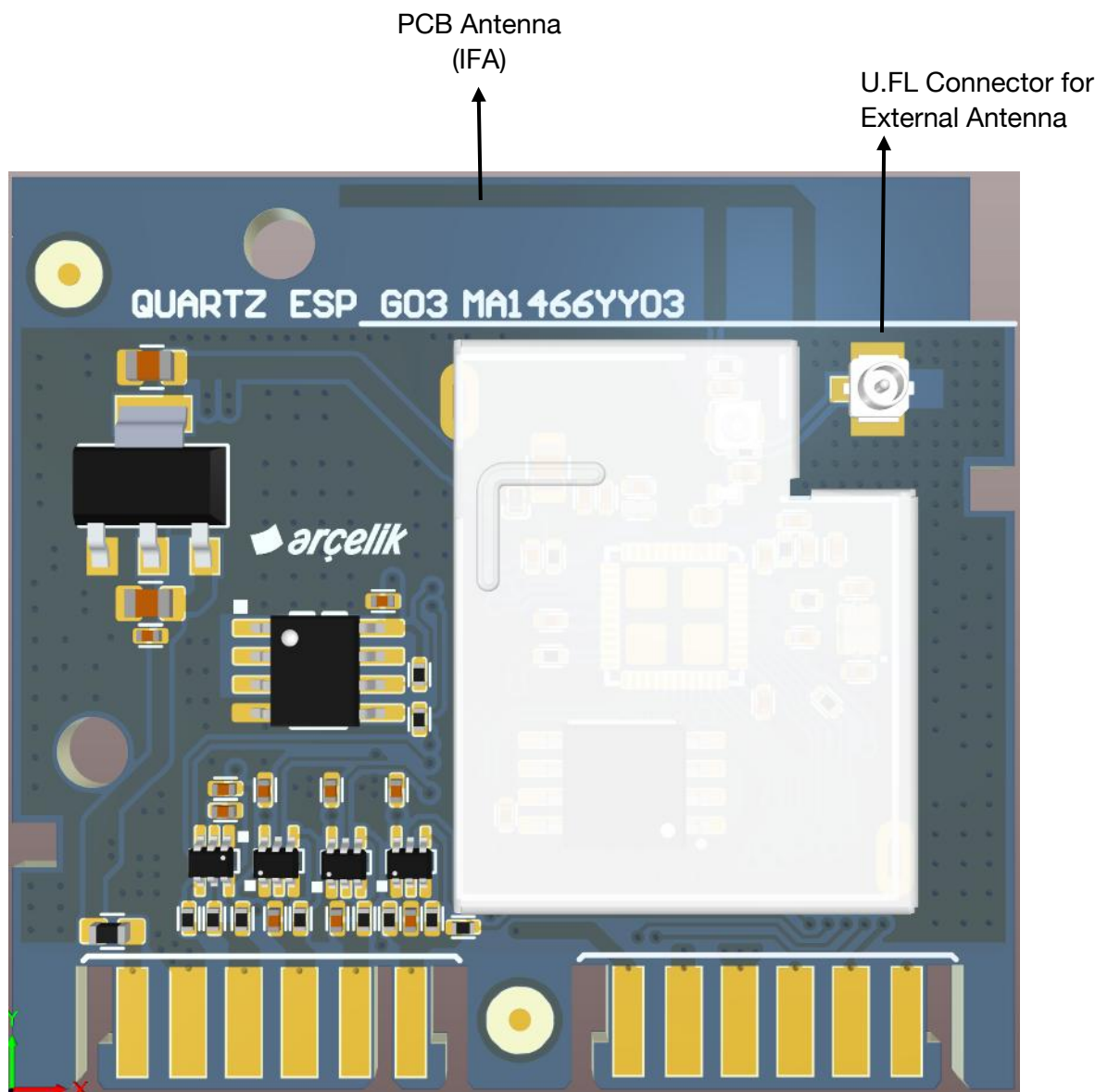


Figure 8: 3D data showing on-board antenna and connection for external antenna.

7.2.1 On-Board Antenna

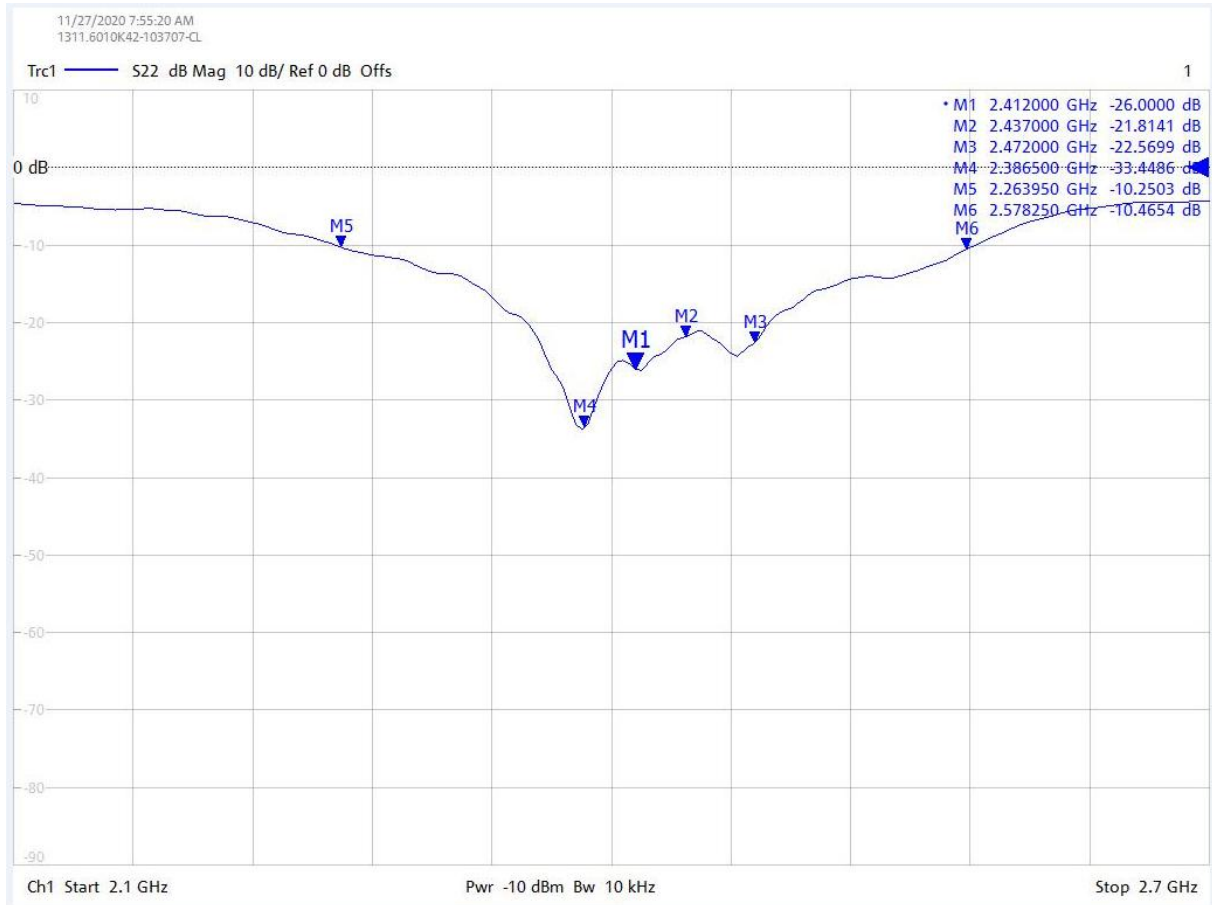


Figure 9: S22 Measurement of Antenna

Worst case efficiency was measured at 2475MHz -1.4443 dB (71.71%) with the peak gain of 4.4979 dBi.

Further details for Antenna measurements can be found in the following document.



QUARTZ_ESP_G01.pdf

Note: Final test report from the test lab will be attached when available.

7.2.2 External Antenna

50ohm U.FL connector option is available on Quartz module for external antenna connection. This type of 50 ohm connector is manufactured by different manufacturers under different names (AMC, UMCC, IPX) and in different sizes. Technical drawing of the connector used in the Quartz module is given below. On the external antenna, it is important that the cable matches the connector specified in the technical drawing. The external antenna to be used in the Quartz module should be determined by the studies to be performed on the final product and is excluded from the scope of this document. We strongly recommend the use of on-board antenna.

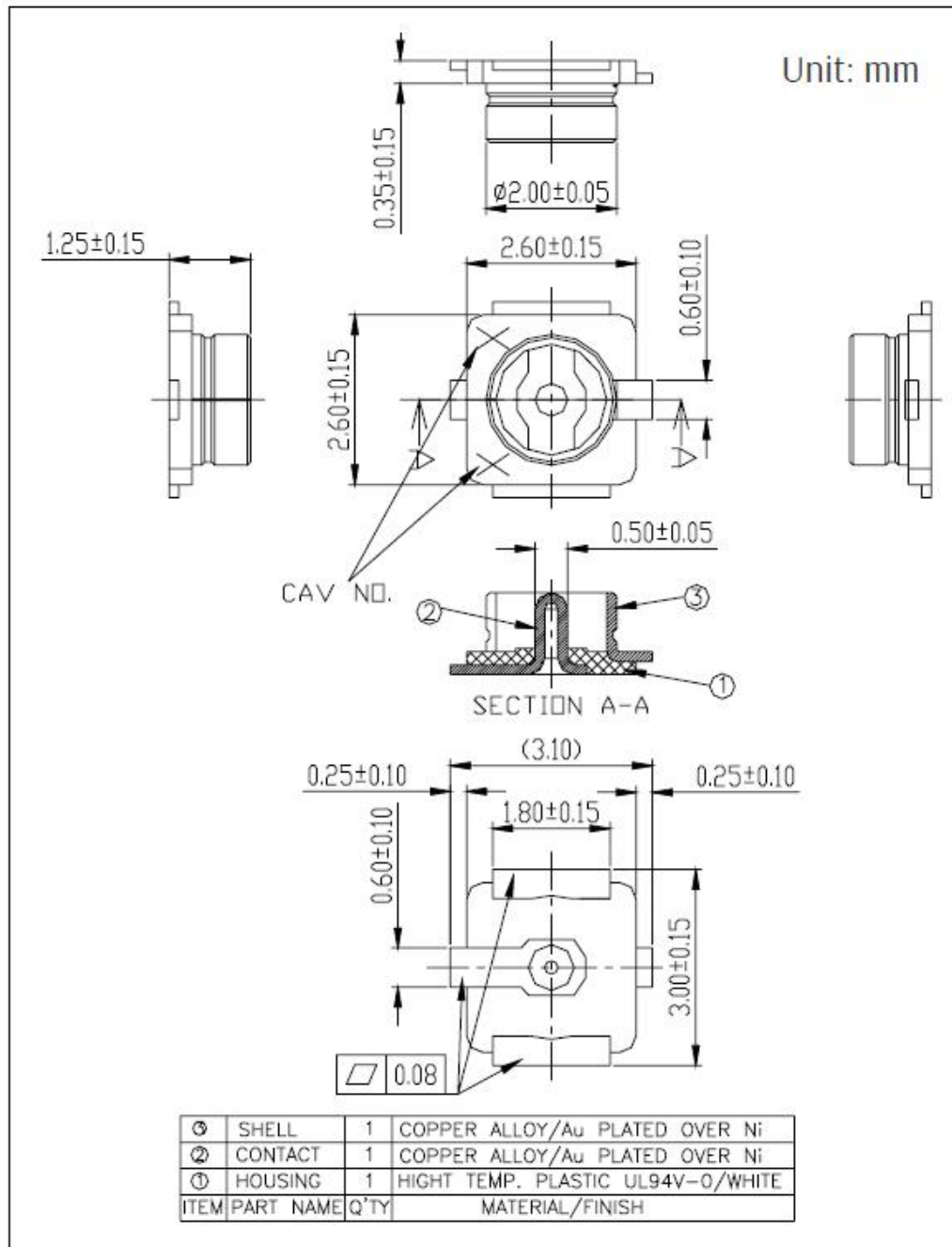
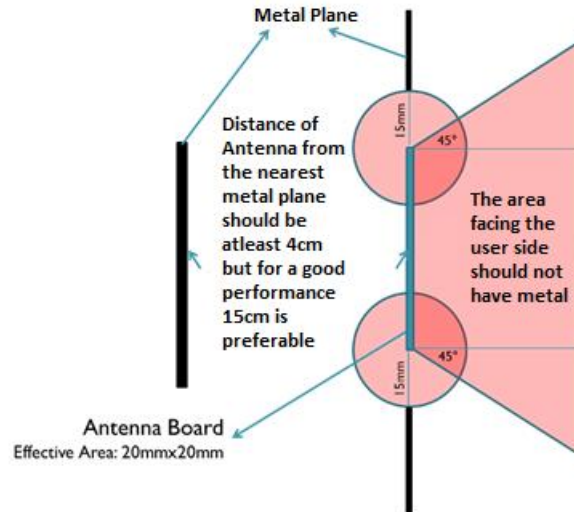


Figure 10: U.FL Connector Drawing

7.2.3 Antenna Placement

Following figure shows desired position of antenna for good RF performance. Similarly, if another metal structure is present, the same conditions apply. In cases where this guide cannot be followed, support should be requested from central R&D RF engineer for antenna placement. In cases where the mechanical structure is not suitable, an external antenna solution can also be applied, explained in previous section.



8 FLASH PROGRAMMING

ESP32 PROG tool is used for ESP32 flash programming.

Programming steps:

1. Quartz Module “KN2” connector and ESP-PROG “Prog 1.27mm” connector should be connected together with 6-pin cable.
2. The two jumpers indicated on the ESP-Prog picture must be installed.
3. Software must be installed by using the .bat file released by IOT team

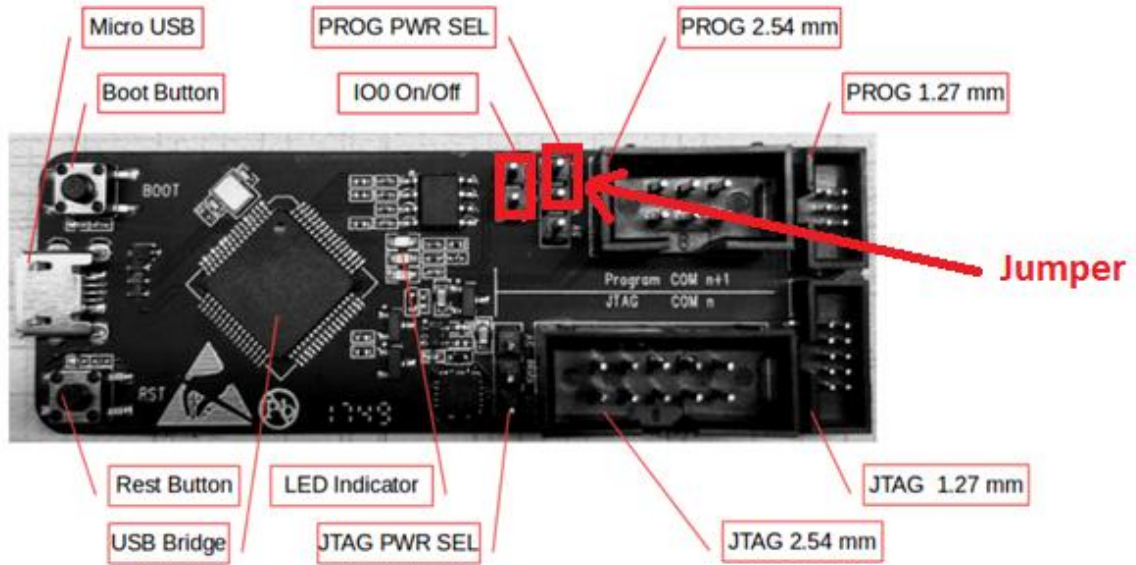


Figure 11: ESP Programmer

9 LABEL SPECIFICATIONS

Package Label is as given below.

Arçelik AŞ. PN:1524510100	RoHS
Carton ID:CXXXXYMMDD001X	
	
Model No: DNSE-A32	Q'ty: XXX 
Part No: 81DNSE01.G02	
	
General Desc: DNSE-A32, 802.11N IOT MODULE, 1524510100	
QC Inspected OK	

Module label location on will be as in the following figures.



Note: These are draft labels and final drawings will be added in report after first serial production.

10.CE Statement

The minimum distance between the user and/or any bystander and the radiating structure of the transmitter is 20cm.

Hereby, We, ARCELİK A.S. declares that the radio equipment type Quartz is in compliance with the Directive 2014/53/EU.

11.U.S. FCC Statement

FCC ID: 2A3WF-QUARTZ04

The device complies with KDB 996369 D03 OEM Manual v01. Below are integration instructions for host product manufacturers according to the KDB 996369 D03 OEM Manual v01.

List of Applicable FCC Rules

FCC Part 15 Subpart C 15.247

Specific Operational Use Conditions

The module has WiFi, BR, EDR, and BLE functions.

- Operation Frequency:
 - WiFi: 2412 ~ 2462 MHz
 - Bluetooth: 2402 ~ 2480 MHz
- Number of Channel:
 - WiFi: 11
 - Bluetooth: 40
- Modulation:
 - WiFi: DSSS; OFDM
 - Bluetooth: GFSK; $\pi/4$ DQPSK; 8 DPSK
- Type: On-board PCB Antenna
- Gain: 4.59 dBi Max

The module can be used for IoT applications with a maximum 3.26 dBi antenna. The host manufacturer installing this module into their product must ensure that the final composite product complies with the FCC requirements by a technical assessment or evaluation to the FCC rules, including the transmitter operation. The host manufacturer has to be aware not to provide information to the end user regarding how to install or remove this RF module in the user's manual of the end product which integrates this module. The end user manual shall include all required regulatory information/warning as show in this manual.

Limited Module Procedures

Not applicable. The module is a single module and complies with the requirement of FCC Part 15.212.

Trace Antenna Designs Not applicable. The module has its own antenna, and does not need a host's printed board microstrip trace antenna, etc.

RF Exposure Considerations

The module must be installed in the host equipment such that at least 20cm is maintained between the antenna and users' body; and if RF exposure statement or module layout is changed, then the host product manufacturer required to take responsibility of the module through a change in FCC ID or new application. The FCC ID of the module cannot be used on the final product. In these circumstances, the host manufacturer will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

Antennas

Antenna specification are as follows:

- Type: PCB Antenna
- Gain: 4.59 dBi

This device is intended only for host manufacturers under the following conditions:

- The transmitter module may not be co-located with any other transmitter or antenna.
- The module shall be only used with the external antenna(s) that has been originally tested and certified with

this module.

- The antenna must be either permanently attached or employ a 'unique' antenna coupler.

As long as the conditions above are met, further transmitter test will not be required. However, the host

manufacturer is still responsible for testing their end-product for any additional compliance requirements required

with this module installed (for example, digital device emissions, PC peripheral requirements, etc.).

Label and Compliance Information

Host product manufacturers need to provide a physical or e-label stating "Contains FCC ID: 2A3WF-QUARTZ04" with their finished product.

Information on test modes and additional testing requirements

- Operation Frequency:
 - WiFi: 2412 ~ 2462 MHz
 - Bluetooth: 2402 ~ 2480 MHz
- Number of Channel:
 - WiFi: 11
 - Bluetooth: 40
- Modulation:
 - WiFi: DSSS; OFDM

– Bluetooth: GFSK; $\pi/4$ DQPSK; 8 DPSK

Host manufacturer must perform test of radiated and conducted emission and spurious emission, etc., according to the actual test modes for a stand-alone modular transmitter in a host, as well as for multiple simultaneously transmitting modules or other transmitters in a host product. Only when all the test results of test modes comply with FCC requirements, then the end product can be sold legally.

Additional testing, Part 15 Subpart B compliant

The modular transmitter is only FCC authorized for FCC Part 15 Subpart C 15.247 and that the host product manufacturer is responsible for compliance to any other FCC rules that apply to the host not covered by the modular transmitter grant of certification. If the grantee markets their product as being Part 15 Subpart B compliant (when it also contains unintentional-radiator digital circuitry), then the grantee shall provide a notice stating that the final host product still requires Part 15 Subpart B compliance testing with the modular transmitter installed.

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications.

However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions:

- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.

Caution:

Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

This equipment complies with FCC RF radiation exposure limits set forth for an uncontrolled environment. This device and its antenna must not be co-located or operating in conjunction with any other antenna or transmitter.

The antennas used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be co-located or operating in conjunction with any other antenna or transmitter.

OEM Integration Instructions

This device is intended only for OEM integrators under the following conditions:

- The transmitter module may not be co-located with any other transmitter or antenna.
- The module shall be only used with the external antenna(s) that has been originally tested and certified with this module.

As long as the conditions above are met, further transmitter test will not be required. However, the OEM integrator is still responsible for testing their end-product for any additional compliance requirements required with this module installed (for example, digital device emissions, PC peripheral requirements, etc.).

Validity of Using the Module Certification

In the event that these conditions cannot be met (for example certain laptop configurations or co-location with another transmitter), then the FCC authorization for this module in combination with the host equipment is no longer considered valid and the FCC ID of the module cannot be used on the final product. In these circumstances, the OEM integrator will be responsible for re-evaluating the end product (including the transmitter) and obtaining a separate FCC authorization.

End Product Labeling

The final end product must be labeled in a visible area with the following: "Contains Transmitter Module FCC ID: 2A3WF-QUARTZ04".