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WF121 Wi-Fi MODULE

DATA SHEET

Friday, 01 November 2013

Version 1.4.9

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VERSION HISTORY

Version	Comment
1.0	First version
1.1	FCC and IC information added
1.2	WF121-N layout guide
1.3	Added power consumption measurements, regulatory info and some corrections
1.4	Added unassociated idle consumption and a chapter about power saving modes
1.4.1	Added CE information
1.4.2	Removed details from the regulatory info
1.4.3	Corrected typos in the pad function tables
1.4.4	Reduced the list of supported coexistence schemes
1.4.5	Added links to Microchip reference guide, some notes on the coexistence
1.4.6	Added inversion notices to RTS/CTS for unambiguity
1.4.7	Added notes on the USB data pins GPIO use being input only to pin function table
1.4.8	Added note on the engineering sample order codes
1.4.9	Additions to power supply description, rewrote power consumption section

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DESCRIPTION

WF121 is a self-contained Wi-Fi module providing a fully integrated 2.4GHz 802.11 b/g/n radio and a 32-bit microcontroller (MCU) platform, making it an ideal product for embedded applications requiring simple, low-cost and low-power wireless TCP/IP connectivity. WF121 also provides flexible interfaces for connecting to various peripherals.

WF121 allows end user applications to be embedded onto the on-board 32-bit microcontroller either using a simple BGScript™ scripting language or for more sophisticated applications; ANSI C-language. This cuts out the need of an external MCU and allows the development of smaller and lower-cost products. However WF121 can also be used in modem-like mode in applications where the external MCU is needed.

With an integrated 802.11 radio, antenna, single power supply, and regulatory certifications, WF121 provides a low-risk and fast time-to-market for applications requiring Internet connectivity. This combined with Bluegiga's excellent customer service will turn your Internet-of-Things applications into reality.

APPLICATIONS:

- PoS terminals
- RFID and laser scanners
- Wi-Fi internet radios and audio streaming products
- Wireless cameras
- Video streaming
- Portable navigation devices
- Portable handheld devices
- Wi-Fi medical sensors
- Wireless picture frames

KEY FEATURES:

- 2.4GHz band IEEE 802.11 b/g/n radio
- Excellent radio performance:
    - TX power: +17 dBm
    - RX sensitivity: -97 dBm
- Host interfaces:
    - 20Mbps UART
    - USB on-the-go
- Peripheral interfaces:
    - GPIO, AIO and timers
    - I2C, SPI and UART
    - Ethernet
- Embedded TCP/IP and 802.11 MAC stacks:
    - IP, TCP, UDP, DHCP and DNS protocols
    - BGAPI host protocol for modem like usage
    - BGScript™ scripting language or native C-development for self-contained applications
- 32-bit embedded microcontroller
    - 80MHz, 128kB RAM and 512kB Flash
    - MIPS architecture
- Temperature range: -40°C to +85°C
- Fully CE, FCC and IC qualified

PHYSICAL OUTLOOK:

WF121-A

1　Ordering Information

Product code	Description
WF121-A	WF121 module with integrated antenna
WF121-E	WF121 module with U.FL connector
WF121-N	WF121 module with RF pin. Non-standard product, so minimum order quantity applies. Please contact: sales@bluegiga.com
DKWF121	WF121 development kit

Note: Modules with order code ending in –v1 are sold as engineering samples, while those with code –v2 are production units. The difference between the two is in the microcontroller version used, the –v2 version fixes a hardware bug that in some circumstances may cause rare bit errors. The modules differ in outlook in that the –v1 only has the Bluegiga logo and text "WF121" while –v2 versions also have FCC/IC ID codes and CE logo.

2   Pin-out and Terminal Descriptions
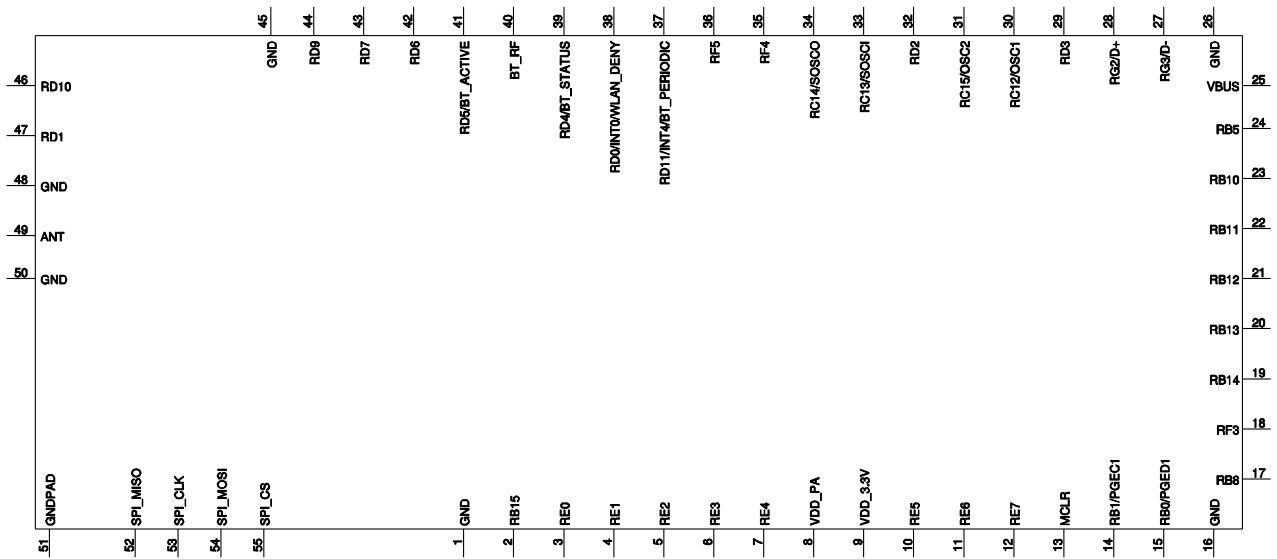
Figure 1: WF121 pinout

Pad number	Function	Description
9	VDD_3.3V	Module power supply
8	VDD_PA	RF power amplifier power supply
1, 16, 26, 45, 48, 50	GND	Ground, connected together internally but should all be connected directly to a solid ground plane
51	GNDPAD	Thermal ground pad, should be soldered to a directly to a solid ground plane for improved thermal conductance
40	BT_RF	Bluetooth coexistence antenna connection, connect to ground through a 51ohm resistor if coexistence is not used
49	ANT	Antenna connection pad in N variant of the module, in other variants not connected
25	VBUS	USB VBUS input
13	MCLR	Module reset, also used for programming using a Microchip tool. Internal pull-up, can be left floating or connected to ground through a 100nF capacitor for delayed power-up reset (note: Microchip ICSP programming tools will not work with a capacitor)

Table 1: Single function pad descriptions

PAD#	GPIO	I2C	SPI	UART	Ethernet	Timer	USB	Analog	Prog.	Parallel	Other
2	RB15 CN12				EMDC	OCFB		AN15		PMA0 PMLL	
3	RE0				ERXD1					PMD0	
4	RE1				ERXD0					PMD1	
5	RE2				ECRSDV					PMD2	
6	RE3				EREFCLK					PMD3	
7	RE4				ERXERR					PMD4	
10	RE5				ETXEN					PMD5	
11	RE6				ETXD0					PMD6	
12	RE7				ETXD1					PMD7	
14	RB1 CN3							AN1	PGEC1		
15	RB0 CN2							AN0	PGED1	PMA6	
17	RB8		SS4	nU2CTS U5RX		C1OUT		AN8			
18	RF3						OTG_ID				
19	RB14		SCK4	nU2RTS U5TX				AN14		PMA1 PMALH	
20	RB13							AN13	TDI	PMA10	
21	RB12							AN12	TCK	PMA11	
22	RB11							AN11	TDO	PMA12	
23	RB10							AN10	TMS	PMA13	
24	RB5 CN 7						VBUSON	AN5			
27	RG3 (input)						D-				
28	RG2 (input)						D+				
29	RD3	SCL3	SDO3	U1TX		OC4					
30	RC12										OSC1
31	RC15										OSC2
32	RD2	SDA3	SDI3	U1RX		OC3					
33	RC13 CN 1										SOSCI
34	RC14 CN0					T1CK					SOSCO
35	RF4 CN17	SDA5	SDI4	U2RX						PMA9	
36	RF5 CN18	SCL5	SDO4	U2TX						PMA8	
37	RD11 INT4					IC4				PMA14	BT_PERIODIC
38	RD0 INT0					OC1					WLAN_DENY
39	RD4					IC5/OC5				PMWR	BT_STATUS
41	RD5									PMRD	BT_ACTIVE
42	RD6 CN15				ETXERR						
43	RD7 CN16										
44	RD9 INT2	SDA1	SS3	nU1CTS U4RX		IC2					
46	RD10 INT3	SCL1				IC3				PMA15	
47	RD1		SCK3	nU1RTS U4TX	EMDIO	OC2					

Table 2: Multifunction pad descriptions

Note: 5V tolerant pads are marked with orange. CN pins support pull-up, pull-down and GPIO notifications

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3   Power control

3.1   Power supply requirements

WF121 consists of two separate internal blocks, the microcontroller and the radio part. The blocks have separate supply voltage inputs and the microcontroller can disable the radio part supply internally.

WF121 is designed to operate with a 3.3V nominal input voltage supplied to the two supply inputs. The VDD_3.3V pad can be fed with a voltage between 2.3V and 3.6V and is used to power the internal microcontroller. The VDD_PA pad can be supplied with a voltage between 2.7V and 4.8V and supplies the RF power amplifier and the internal switch-mode converter powering the Wi-Fi digital core.

In lithium battery powered applications, VDD_PA can be connected directly to the battery, while a regulator is needed to supply the VDD_3.3V with a lower voltage, as needed by the design.

The VDD_PA supply should be capable of providing at least 350mA, though the average consumption of the module will be much less than that. The VDD_3.3V supply will draw a peak current of less than 100mA, not including current drawn from the GPIO pins. The PA supply should preferably be bypassed with a 10 to 100µF capacitor to smooth out the current spikes drawn by the Wi-Fi power amplifier. External high frequency bypassing is not needed, the module contains the needed supply filtering capacitors.

Note that there is about 20µF worth of ceramic capacitors on the VDD_PA line inside the module. When using low drop linear regulators to generate a regulated supply for the VDD_PA line, the stability of the regulator with the low ESR provided by these capacitors should be checked. Many linear regulators (and some switched mode ones) are not stable with ceramic output capacitors.

3.2   Power saving functionality

In Wi-Fi client mode, the WF121 radio core automatically powers on the RF circuitry only when needed. The Wi-Fi core processors support automatic sleep modes when not communicating actively, allowing very low idle consumption. When used as an access point, the radio core must receive constantly and cannot enter sleep modes.

The WF121 main processor automatically enters an idle mode after a timeout period whenever it is not actively executing anything, lowering its consumption to about a third of the full while allowing instant wakeup. When the power saving functions are enabled in the hardware configuration script, the processor will after a pre-set timeout enter a deeper sleep mode to lower the consumption to much lower levels, but will take a few milliseconds to wake up from and needs an interrupt to wake up.

Keeping the WF121 associated with an access point with the power saving modes enabled will allow relatively fast response times with a low power consumption, but in some applications the consumption can be reduced further. Unassociating the Wi-Fi will allow fast re-association with lower idle consumption in applications where the module needs to transfer data only occasionally, while for applications where the absolute minimum consumption is desired and the communication intervals are long, the Wi-Fi section of the module can be fully powered off by disabling the module internal switch mode converter feeding the Wi-Fi core. Powering the Wi-Fi down fully will require a full reinitialization of the Wi-Fi core, and will take several seconds before associating with an access point.

The power saving modes are user configurable and controllable. For more information see the firmware documentation.

3.3   Reset

WF121 can be reset by the MCLR-pin (active low), system power up, the internal brown-out detector or the internal watchdog timer.

4   Microcontroller

WF121 contains a Microchip PIC32-series 32 bit microcontroller with a MIPS M4K core. At a maximum clock frequency of 80 MHz the core can reach a performance of 125 DMIPS while keeping low power consumption.

The microcontroller used in WF121 contains 512kB of Flash memory and 128kB of SRAM.

Most peripheral features are directly provided by the microcontroller and for low level information and detailed descriptions please refer to the material and datasheets of the PIC32MX695H.

5 Interfaces

5.1 General Purpose I/O pins

To see which GPIOs are multiplexed with which features, please refer to **Table 2**.

WF121 contains a number of pads that can be configured to be used as general purpose digital IO's, analog inputs or for various built-in functions. Provided functions include a Full Speed USB-OTG port, three I2C-ports, two SPI-ports, two to four UART's, Ethernet MAC with RMII connection and various timer functions. Some of the pads are 5V tolerant. All GPIO pads can drive currents of up to +/- 25 mA.

Four pins are available for implementing a coexistence scheme with a Bluetooth device. The exact order and function as well as the coexistence system desired is software configurable, with the default pad bindings shown in Table 3 for a Unity-3e+ coexistence scheme. If the pads are bound to WiFi chip pins, the CPU pins associated with the pads must be set to inputs.

5.2 Serial ports

Pad number	UART 1	UART 2	UART 4	UART 5
17		nCTS		RX
19		nRTS		TX
29	TX (output)			
32	RX (input)			
35		RX		
36		TX		
44	nCTS (input)		RX	
47	nRTS (output)		TX	

Table 3: Serial port pads

Two UART's are provided with RTS/CTS-handshaking. If handshaking is not needed, up to four UART's can be implemented. Speeds up to 20 Mbps are possible, but the higher bit rates might require the use of an external crystal for sufficient clock accuracy. The serial ports can also be used as host connections when using an external microcontroller.

For details on the hardware details of the serial port, please refer to the PIC32 Family Reference Manual on UART.

To see what other functions are present on the same pins, please refer to **Table 2**.

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5.3   I²C/SPI

Pad number	I²C	SPI
17		SS4 – Slave select SPI 4
19		SCK4 - Clock SPI 4
29	SCL3 – Clock I²C 3	SDO3 – Data out SPI 3
32	SDA3 – Data I²C 3	SDI3 – Data in SPI 3
35	SDA5 – Data I²C 5	SDI4 – Data in SPI 4
36	SCL5 – Clock I²C 5	SDO4 – Data out SPI 4
44	SDA1 – Data I²C 1	SS3 – Slave select SPI 3
46	SCL1 – Clock I²C 1	
47		SCK3 – Clock SPI 3

Table 4: Pads for I2C and SPI

Up to three I²C-ports and up to two SPI ports can be implemented, mostly multiplexed on the same pins together and with the UART signals. The I²C ports support 100 kHz and 400 kHz speed specifications, while the SPI can be operated at up to 40 Mbps. The SPI ports are also available for use as a host connection for use with an external microcontroller.

For details on the SPI/I2C hardware, please refer to Microchip documentation on SPI and I2C.

To see what other functions are present on the same pins, please refer to **Table 2**.

5.4   USB On-The-Go

Pad number	Function	Description
18	OTG_ID	USB-OTG mode identify line
25	VBUS	USB bus supply input
27	D-	Data -
28	D+	Data +
24	VBUSON	USB bus supply switch enable in host mode

Table 5: USB pads

The module contains a USB-OTG system with an integrated transceiver. Full Speed (12 Mbps) USB 2.0 profile is supported in device mode, while the host system can operate in Low Speed and Full Speed modes. For host use an external switch can be implemented to provide switched power for the connected device. Pad number 24 can be dedicated to control this switch. The USB device can be used as a host connection,

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although the embedded (simplified) USB-OTG may not be able to support every kind of USB system, like hubs.

Using the USB connection requires an external crystal for sufficient clock accuracy.

For details on the USB hardware operation please refer to the Microchip reference guide on USB.

Other functions are present on the same pins; please refer to **Table 2** for details.

5.5   Ethernet

Pad number	Function	Description
2	EMDC	Management bus clock
3	ERXD1	Receive data 1
4	ERXD0	Receive data 0
5	ECRSDV	Receive data valid
6	EREFCLK	Reference clock
7	ERXERR	Receive error
10	ETXEN	Transmit enable
11	ETXD0	Transmit data 0
12	ETXD1	Transmit data 1
42	ETXERR	Transmit error
47	EMDIO	Management bus data

Table 6: Ethernet pads

An RMII interface to an external Ethernet PHY is available. The PHY should supply EREFCLK with a 50 MHz RMII reference clock. Other functions are present on the same pads; please refer to **Table 2** for details. For more details on the Ethernet operation, please refer to the Microchip reference guide on Ethernet MAC.

5.6　Analog inputs

Pad number	Function
2	AN15
14	AN1
15	AN0
17	AN8
19	AN14
20	AN13
21	AN12
22	AN11
23	AN10
24	AN5

Table 7: ADC pads

The microcontroller provides a 10-bit Analog to digital converter (ADC) with sampling speeds up to 1MSps. The measurement can be done on any of the input pins listed in the table above. For further information see the PIC32MX695H data sheet and related documents.

For details on the ADC operation, please refer to the Microchip reference guide on ADC.

5.7　Timers

The module processor contains 5 timers with various functions including capture & compare. For more information see the PIC32MX695H data sheet.

5.8　Parallel master port

An 8-bit master/slave port is also available for transferring parallel data at a high speed to or from the module microcontroller. For more information, see Microchip reference guide on Parallel Master Port.

5.9　Microcontroller programming interface

Pad number	Pad function	Description
13	MCLR	Reset
14	PGEC1	Programming Clock
15	PGED1	Programming Data
20	TDI	JTAG Test Data In

21	TCK	JTAG Test Clock
22	TDO	JTAG Test Data out
23	TMS	JTAG Test Machine State

Table 8: Programming and JTAG pads

An ICSP (In-Circuit Serial Programming) interface (PGEC1, PGED1, MCLR) is provided to allow device re-flashing using a Microchip tool. A JTAG connection is also provided which can be used for system debugging purposes or device programming. For information on JTAG operation, please refer to Microchip documentation.

5.10 RF Debug Interface

Pad number	Pad function	Description
52	SPI_MISO	RF Debug data out
53	SPI_CLK	RF Debug clock
54	SPI_MOSI	RF Debug data in
55	SPI_CS	RF Debug chip select

Table 9: RF Debug SPI pads

Four pads are provided for the debug interface of the WiFi chipset in the module bottom. This is meant for RF calibration and testing during module production and product certification measurements. These should in most applications be left unconnected, but should be taken into account when doing the application board layout. Avoid placing vias or signals without a solder mask under these pads. If separate radiated emission compliance measurements need to made for the application, these should be connected to a header. More information on the certification measurements can be obtained from Bluegiga support.

5.11 *Bluetooth* co-existence

Bluetooth coexistence systems allow co-located WiFi and Bluetooth devices to be aware of each other and to avoid simultaneous transfers that would degrade link performance. The most common coexistence schemes combine host driver-side prioritizing with hardware connections between the different radio devices where the hardware interface is used to communicate the exact timings for driver pre-defined events.

WF121 has up to 4 pins available for implementing the hardware connection, but as the internal host processor is not running the *Bluetooth* stack too, it is not possible to implement any priorities for the separate radio devices. The hardware connections by themselves will still enable a crude form of coexistence, with the Wi-Fi side controlling the communications.

Wi-Fi data will always have priority over *Bluetooth* data, and with high duty cycle Wi-Fi transfers (low bit rate, high throughput) the *Bluetooth* might not be able to transfer any data. Mostly however the Wi-Fi duty cycle will be less than 100% and the *Bluetooth* device may be able to transfer significant amounts of data.

5.12 Antenna switch for *Bluetooth* coexistence

WF121 supports sharing the integrated antenna or antenna connector with a *Bluetooth* device through the BT_RF pad. The module contains a bypass switch to route the *Bluetooth* signal directly to the antenna, and supports using the internal LNA for *Bluetooth* reception. The switch is controlled through the coexistence

interface. Use of the antenna switch requires the use of Unity-3e scheme, as there are not enough pins available to implement a separate antenna control which requires two extra signals.

While antenna sharing will ease antenna placement and general application design, it will also cause a number of problems.

- There will be additional losses on the *Bluetooth* path due to the switch, reducing range.

- Throughput reductions due to the coexistence operation will be increased and there may occur Wi-Fi timeouts due to *Bluetooth* scans reserving the full use of the antenna.

- Wi-Fi power-off may also cause poor ranges for the *Bluetooth* device.

- Sharing a single antenna will require a re-certification for at least FCC of both modules as the RF paths will have changed significantly from the scheme specified in the original certification setups.

For use with CSR-based Bluetooth (BC4 to BC6 with firmware version 21 or later, BC7 and onwards with all versions), Unity-3e is recommended as the coexistence scheme. Unity-3e is an enhanced version of the traditional 3-wire Unity-3 –scheme that uses tighter timings and uses the three control lines also for antenna switch control, removing the need for the two separate switch control signals.

The BT_PERIODIC signal is related to the Unity+ -standard, which allows more reliable audio throughputs, but it is not currently supported for WF121.

Pad number	Function
37	BT_PERIODIC
38	WLAN_DENY
39	BT_STATUS
41	BT_ACTIVE

Table 10: Bluetooth co-existence interface

Industry standard 3-wire and 4-wire, as well as Unity-3, Unity-4, and Unity-3e coexistence schemes are supported and the associated signals can be assigned to the GPIO pads. In default mode these pins are tied to CPU GPIO functions. Antenna sharing is possible with the Unity-3e scheme.

For more detailed information about implementing co-existence, see WF111 datasheet.

5.13   CPU Clock

Pad number	Function	Description
30	OSC1	External crystal input
31	OSC2	External crystal output

Table 11: Clocking pads

WF121 uses an internal 26 MHz crystal as the WiFi reference clock. The internal processor uses an integrated 8MHz RC oscillator and associated phase locked loop (PLL) to create its clock signals, but cannot share the internal crystal-stabilized WiFi clock. The internal CPU uses a PLL to create an 80MHz core clock.

To use the USB functionality an external crystal and the associated capacitors must be implemented on the application board to provide a sufficiently accurate clock. A crystal with its associated capacitors can be connected to pads OSC1 and OSC2. If an external crystal is not needed, these pads are available for GPIO

use. The USB clock synthesizer requires an internal reference frequency of 4MHz, so the crystal for USB use must be a multiple of 4MHz.

An external oscillator can also be used to generate the CPU clock frequency. The voltage levels should be 3.3V logic level.

Note: The present WF121 default firmware only supports 8MHz crystals or oscillators.

The internal clock divider generating the reference frequency for the internal PLL's cannot be changed by the firmware, and to support automatic switchover between the internal RC oscillator and the external crystal, the default firmware needs an 8MHz clock. A custom firmware can be ordered with support for desired frequencies for easier crystal availability, for achieving desired UART baud rates and other applications.

The Ethernet connection requires the external PHY to provide the 50MHz RMII reference clock. A crystal is not required for the module CPU for Ethernet operation.

5.14   32.768 kHz External Reference Clock

Pad number	Function	Description
33	SOSCI	External 32.768 kHz crystal input
34	SOSCO	External 32.768 kHz crystal output

Table 12: Slow clock

The module contains integrated RC oscillators for sleep timing, one in the WiFi chipset, one in the CPU. The sleep clocks are used to periodically wake up the module while in power save modes. If more accurate timing is required, an external 32.768 kHz crystal and the associated capacitors can be placed to pads SOSCI and SOSCO. If an accurate sleep clock is not needed, the pads are available for GPIO use.

An external oscillator can also be used to generate the sleep clock. The voltage levels should be 3.3V logic level.

This low frequency clock is shared for both the CPU and the WiFi chipset. The default WiFi configuration uses only the internal oscillator, if support for a crystal stabilized WiFi sleep clock is required, please contact Bluegiga technical support.

The Wi-Fi packet timing during active data transfer is derived from the internal 26MHz crystal and so is unaffected by the tolerances of the sleep clock.
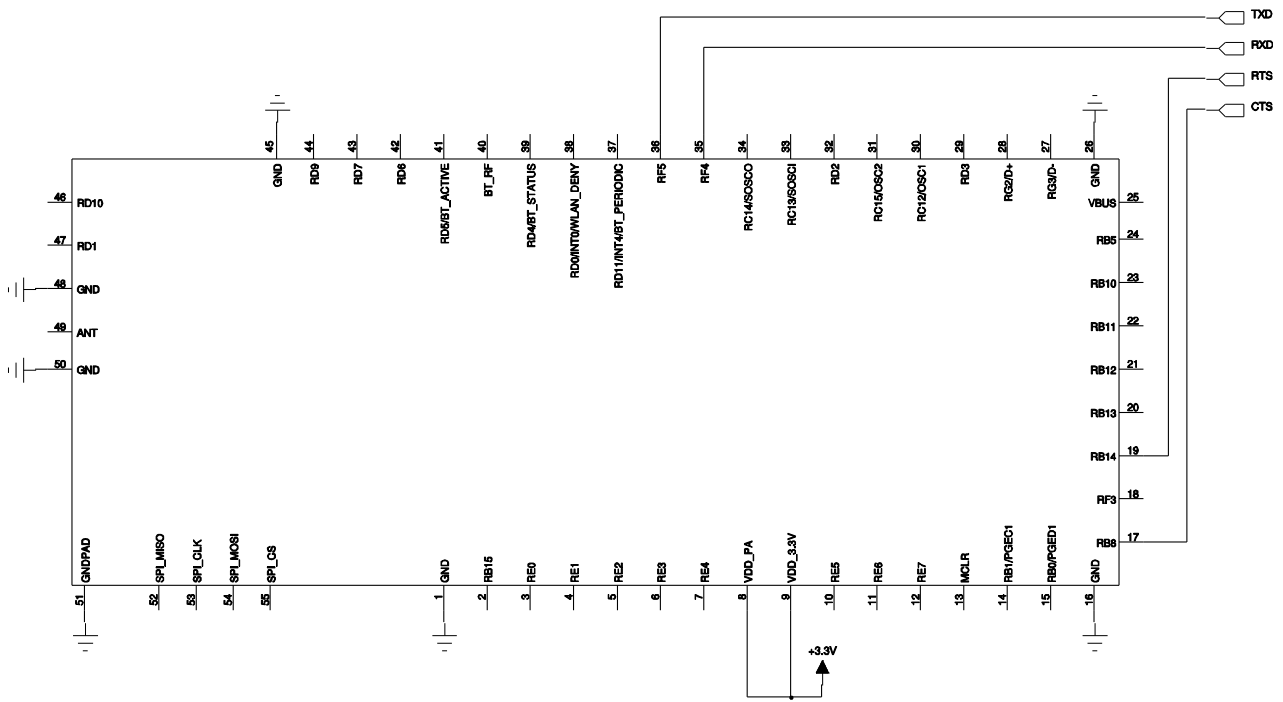
6   Example schematic

Figure 2: Minimal system required for UART host connection

7 802.11 Radio

7.1 Wi-Fi Receiver

The receiver features direct conversion architecture. Sufficient out-of-band blocking specification at the Low Noise Amplifier (LNA) input allows the receiver to be used in close proximity to GSM and WCDMA cellular phone transmitters without being desensitized. High-order baseband filters ensure good performance against in-band interference.

7.2 Wi-Fi Transmitter

The transmitter features a direct IQ modulator. Digital baseband transmit circuitry provides the required spectral shaping and on-chip trims are used to reduce IQ modulator distortion. Transmitter gain can be controlled on a per-packet basis, allowing the optimization of the transmit power as a function of modulation scheme.

The internal Power Amplifier (PA) has a maximum output power of +15dBm for IEEE 802.11g/n and +17dBm for IEEE 802.11b. The module internally compensates for PA gain and reference oscillator frequency drifts with varying temperature and supply voltage.

7.3 Regulatory domains

WF121 uses the IEEE 802.11d standard to select the available channels based on the regulatory domain setting of the access point.

8   Firmware

WF121 incorporates firmware which implements a full TCP/IP stack and Wi-Fi management. Exact features will depend on the firmware version used. Please see the documentation of the firmware for exact details.

There are three main ways to use the module: Host controlled, script controlled or native application controlled.

Host controlled means an external host is physically connected to the module and it sends simple commands to the module and one of several different host interfaces can be used. The module provides high level APIs for managing Wi-Fi as well as data connections. Bluegiga provides a thin API layer (BGLib) written in ANSI C for the host which can take care of creating and parsing the messages sent over the transport. For evaluation purposes GUI tools and a library for python are also provided.
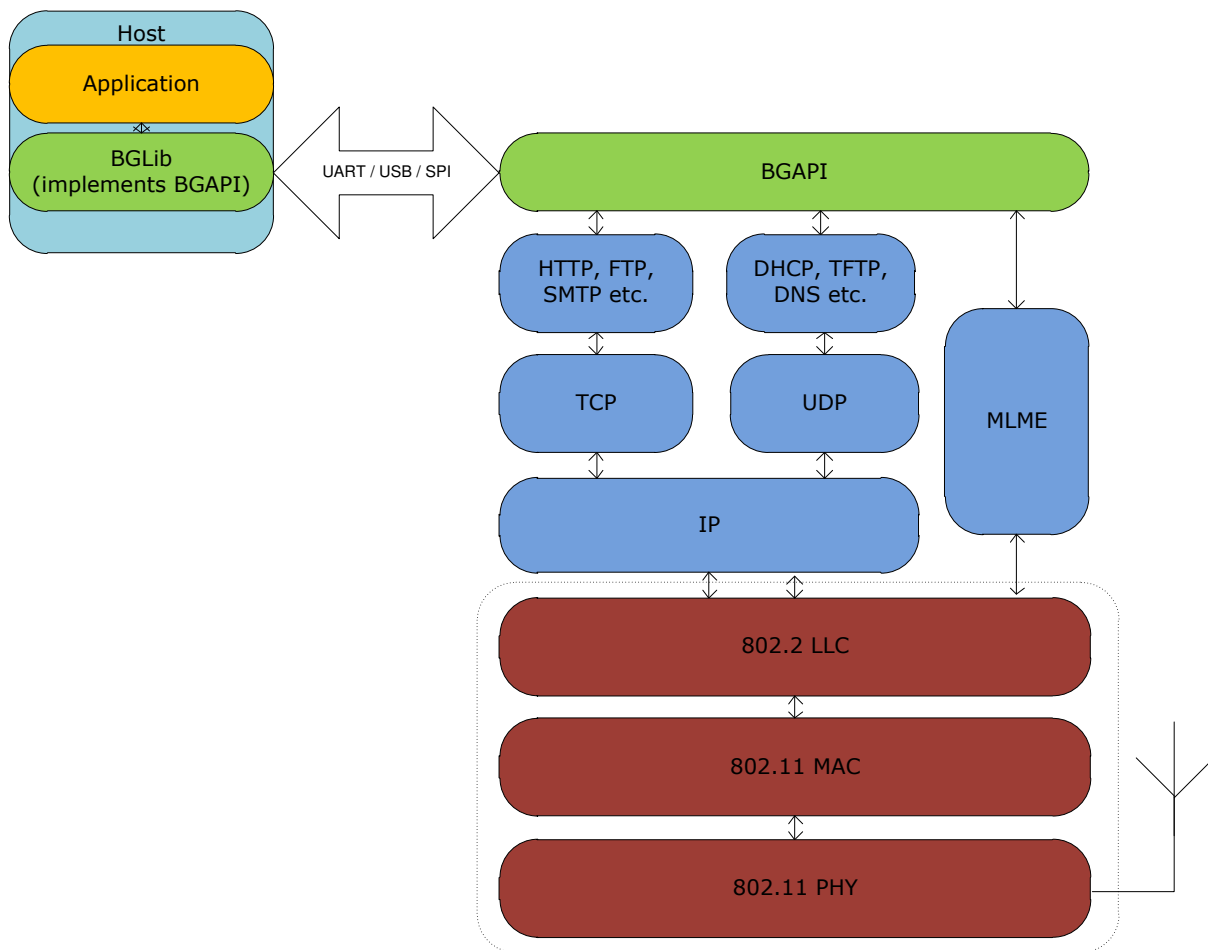
Figure 3: WF121 software

Data can be routed either through the API or through another physical interface. For example if the first UART is used for sending and receiving command events, a TCP/IP socket can be bound to the second UART and data written to the UART will seamlessly be passed to the TCP/IP socket. For information about the latest capabilities of the firmware, please refer to the *WF121 API reference documentation* accompanying it.

The module can also be controlled by a script running on the module. This is especially useful for simple applications as it eliminates the need for a host controller and can drastically cut development time. In combination with a host it can also be used automate certain features such as the serial to TCP/IP functionality described above.

Native application development is also possible as the stack will not require all of the available flash or memory. Please see the material accompanying the firmware release about more details of this option.

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9 Host interfaces

9.1 UART

The module can be controlled over the UART interface. In order for the communication to be reliable, hardware flow control signals (RTS and CTS) must be present between the host and the module. When using high UART transfer speeds (between 1 and 20Mbps) an external crystal is required for sufficient clock accuracy.

9.2 USB

When using the USB host interface, the module will appear as a USB CDC/ACM device enumerating as virtual COM port. The same protocol can be used as with the UART interface.

9.3 SPI

Please refer to the Bluegiga WF121 API reference documentation supplied with the firmware regarding using SPI as the Host interface.

10 Electrical characteristics

10.1 Absolute maximum ratings

Rating	Min	Max	Unit
Storage Temperature	-40	85	°C
VDD_PA	-0.3	6	V
VDD_3.3V	-0.3	3.6	
5V tolerant GPIO Voltages	-0.3	5.5	V
Other Terminal Voltages	VSS-0.3	VDD_3.3V+0.3	V
Maximum output current sourced or sunk by any GPIO pad		25	mA
Maximum current on all GPIO pads combined		200	mA

Table 13: Absolute maximum ratings

10.2 Recommended operating conditions

Rating	Min	Max	Unit
Operating Temperature Range *	-40	85	°C
VDD_3.3V	2.3	3.6	V
VDD_PA	2.7	4.8	V

Table 14: Recommended operating conditions

*Note: The module may heat up depending on use, at high constant transmit duty cycles (high throughput, low bitrate for more than a few seconds) the maximum operating temperature may need to be derated to keep below the maximum ratings.

10.3   Input/output terminal characteristics

10.4   Digital

Digital terminals	Min	Typ	Max	Unit
Input voltage levels				
V_{IL} input logic level low 1.7V ≤ VDD ≤ 3.6V	VSS-0.3V	-	0.15VDD	V
V_{IH} input logic level high 1.7V ≤ VDD ≤ 3.6V	0.8VDD	-	VDD+0.3V	V
Output voltage levels				
V_{OL} output logic level low, Vdd = 3.6 V, Iol = 7 mA	-	-	0.4	V
V_{OH} output logic level high Vdd = 3.6 V, Ioh = -12 mA	2.4	-	VDD	V

Table 15: Digital terminal electrical characteristics

	Min	Typ	max	
Frequency	32.748	32.768	32.788	kHz
Deviation @25°C	-20		+20	ppm
Deviation over temperature	-150		+150	ppm
Duty cycle	30	50	70	%
Rise time			50	ns
Input high level	0.625Vdd		Vdd+0.3	V
Input low level	-0.3		0.25Vdd	V

Table 16: External sleep clock specifications

10.5   Reset

Power-on Reset	Min	Typ	Max	Unit
Power on reset threshold	1.75	-	2.1	V
VDD rise rate to ensure reset	0.05	-	115	V/ms

Table 17: Power on reset characteristics

10.6 Power consumption

Consumption type	Current	Unit	Supply domain	Description
Total maximum	400	mA	both	Absolute peak current during packet transmission (<5μs)
CPU average	100	mA	VDD_3.3V	Typical average program execution consumption
CPU idle	35	mA	VDD_3.3V	Idle mode, instant wakeup
CPU sleep	60	μA	VDD_3.3V	Sleep mode, clocks off, WDT on, wakeup in milliseconds
Wi-Fi core active	68	mA	VDD_PA	Receiving, transmitting, idle out of deep sleep, AP mode
Wi-Fi core idle	110	μA	VDD_PA	Idle, between packet transfers, automatic deep sleep enabled (in client mode)
Wi-Fi PA	240	mA	VDD_PA	Peak during packet transmission
Wi-Fi LNA	12	mA	VDD_PA	Peak during packet reception
Wi-Fi total sleep	10	μA	VDD_PA	Leakage when fully powered off

Table 18: Power consumption for different operating modes

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