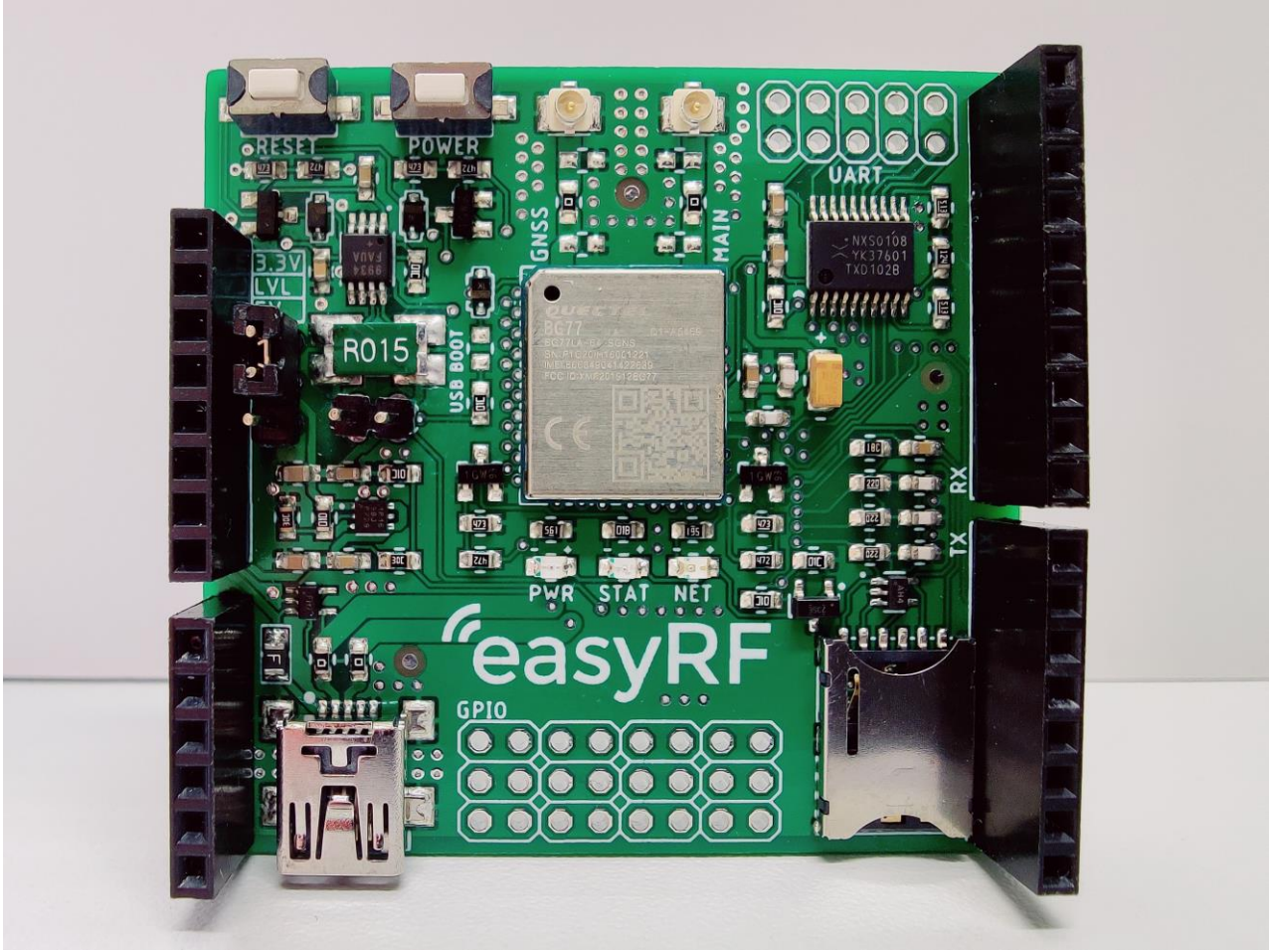
ERF3002, LTE Cat. M1, Cat. NB2 & GNSS Arduino shield



Document Information	
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Product status

Mass Production

This document applies to the following products:

Name	Type number	version	Product status
ERF3002	**ERF3002**	**1.0**	**Mass Production**

Contents

1 Functional description

1.1 Product overview

The ERF3002 Arduino shield features the BG77 of Quectel Wireless Solutions. The BG77 is an ultra-compact LPWA module supporting LTE Cat M1, LTE Cat NB2 and integrated GNSS. It is fully compliant with 3GPP Rel-14 specification and provides maximum data rates of 588 kbps downlink and 1119 kbps uplink. It features ultra-low power consumption by leveraging the integrated RAM/flash as well as the ARM Cortex A7 processor supporting ThreadX, achieving up to 70% reduction in PSM leakage and 85% reduction in eDRX current consumption compared to its predecessor.

For easy evaluation of this low power consumption, there is an onboard current measurement system that provides mA accuracy (Range: 0.5mA ~ 500mA). This current monitoring system is a valuable tool to analyze the modules current consumption during startup, Idle mode, Connecting, and transmitting data.

Finally, there is also a temperature sensor on the shield to provide all the necessary tools to start building your application without having to design any hardware.

The ERF3002 combines the power of the BG77 with an easy to use Arduino platform and allows for rapid testing and development.

1.2 Product features

General features			
ERF3002	**Dimensions**		52.2 x 50 x 19.5 mm (± 1)
	Weight		18 ± 1 g
	Operating Temperature		-10 ˚C to +70 ˚C
	Temperature Sensor (TMP235)	**Range**	-40˚C to + 150˚C ± 2.5˚C (maximum)
		Accuracy	± 1˚C (typical)
	Current Measurement (MAX9934T)	**Range**	0.5 mA to 500 mA
		Accuracy	± 2% (typical)
	Interfaces	**USB**	2.0 low-speed (1.5 Mbps) and full-speed (12 Mbps)
		UART	3x
		PCM	1x
		ADC	2x (ADC0 connected to TMP235 temp sensor)
		GPIO	7x
		USIM	1 x (1.8V)
		NETLIGHT	Network Status Indication
		STATUS	Power ON/OFF Status Indication
BG77	**Cat M1 Supported Bands**		LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B26/B27/B28 /B66/B85*
	Cat NB2 Supported Bands		LTE-FDD: B1/B2/B3/B4/B5/B8/B12/B13/B18/B19/B20/B25/B28/B66/B71 /B85*
	Output Power		Max. Power: 21dBm
	LTE version		3GPP E-UTRA release 14
	GNSS		GPS, GLONASS, BeiDou, Galileo, QZSS
	Cat M1 Data Speed		Max. 588 kbps (DL) / 1119 kbps (UL)
	Cat NB2 Data Speed		Max. 127 kbps (DL) / 158.5 kbps (UL)
	Protocols		PPP/TCP/UDP/SSL/TLS/FTP(S)/HTTP(S)/NITZ/PING/MQTT/LwM2M/CoAP/IPv6*
	SMS		Point to point MO and MT , SMS cell broadcast , Text and PDU mode
	Voice		VoLTE (For Cat M1 Only)
	Firmware upgrade		DFOTA(Delta Firmware Over the Air) , USB interface
	Control via AT commands		Through Arduino “Software Serial” interface , of through the USB interface on the shield

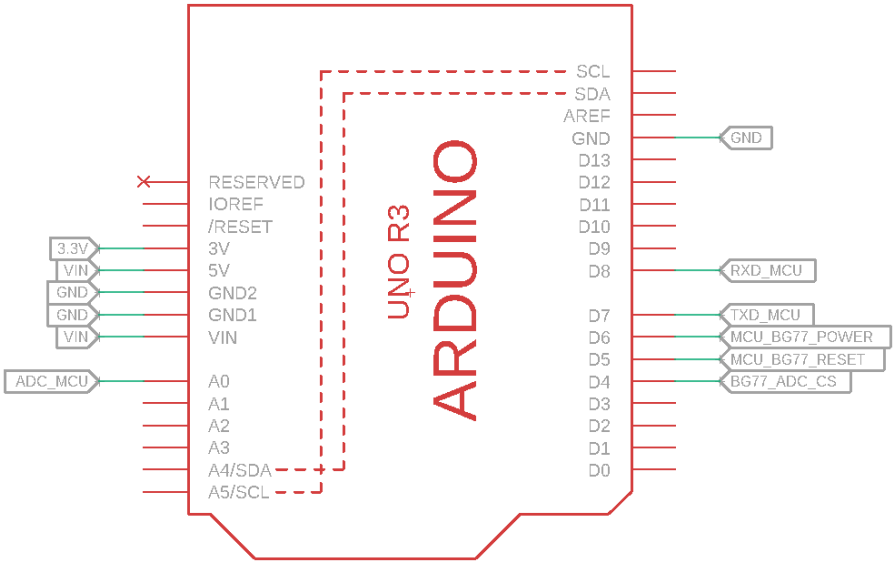
2 Pin Assignment

2.1 Arduino headers

The ERF3002 shield is designed to be an Arduino shield. Below, the interface to the Arduino board can be found.

I/O Parameter Definition

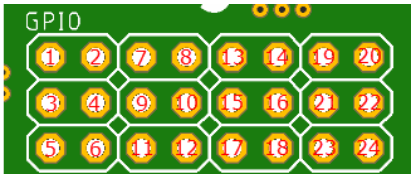
Type	Description
IO	Bidirectional
DI	Digital input
DO	Digital output
PI	Power input
PO	Power output
AI	Analog input
AO	Analog output
OD	Open drain



Header	Name	Power domain	I/O	Description
Arduino header	3.3V	3.3V	PI / PO	External input to power shield (maximum 3.3V). Can also be used to supply external board when ERF3002 is connected to USB port
Arduino header	5V (VIN)	5V	PI / PO	External input to power shield (maximum 5V). Can also be used to supply external board when ERF3002 is connected to USB port.
Arduino header	GND	-	-	Ground
Arduino header	GND	-	-	Ground
Arduino header	5V (VIN)	5V	PI / PO	External input to power shield (maximum 5V). Can also be used to supply external board when ERF3002 is connected to USB port.
Arduino header	ADC _MCU	3.3V	AO	Analog output of current measurement system
Arduino header	GND	-	-	Ground
Arduino header	RXD_MCU	V_level_shifter	DI	Receive data
Arduino header	TXD_MCU	V_level_shifter	DO	Transmit data
Arduino header	MCU_BG77_POWER	3.3V	DI	Turn module On/Off (active high)
Arduino header	MCU_BG77_RESET	3.3V	DI	Reset module (active high)
Arduino header	BG77_ADC_CS	3.3V	DI	Enable current measurement system (active high)

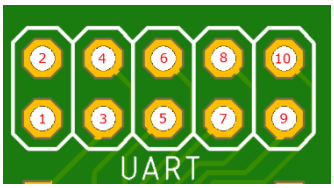
2.2 GPIO header

The GPIO header is connected to all the GPIO related I/O's from the Quectel module on the shield.



Header	Pin No.	Name	Power domain	I/O	Description
GPIO	1	BG77_GPIO4	1.8V	IO	General purpose input / output
GPIO	2	BG77_PCM_CLK	1.8V	DO	PCM clock output
GPIO	3	BG77_GPIO1	1.8V	IO	General purpose input / output
GPIO	4	BG77_PCM_DOUT	1.8V	DO	PCM data output
GPIO	5	BG77_GPIO6	1.8V	IO	General purpose input / output
GPIO	6	BG77_PCM_DIN	1.8V	DI	PCM data input
GPIO	7	BG77_GNSS_TXD	1.8V	DO	GNSS UART transmit
GPIO	8	BG77_GPIO2	1.8V	IO	General purpose input / output
GPIO	9	BG77_GNSS_RXD	1.8V	DI	GNSS UART receive
GPIO	10	BG77_I2C_SCL	1.8V	OD	I2C serial clock (external pull-up resistor is required)
GPIO	11	BG77_PCM_SYNC	1.8V	DO	PCM data frame sync
GPIO	12	BG77_ I2C_SDA	1.8V	OD	I2C serial data (external pull-up resistor is required)
GPIO	13	BG77_GPIO7	1.8V	IO	General purpose input / output
GPIO	14	BG77_ADC0	0.1V to 1.8V	AI	Analog to digital converter
GPIO	15	BG77_GPIO3	1.8V	IO	General purpose input / output
GPIO	16	BG77_AP_READY	1.8V	DI	Application processor ready
GPIO	17	BG77_GPIO5	1.8V	IO	General purpose input / output
GPIO	18	BG77_W_DISABLE	1.8V	DI	Airplane mode control
GPIO	19	BG77_ADC1	0.1V to 1.8V	AI	Analog to digital converter
GPIO	20	BG77_GRFC2	1.8V	DO	Generic RF controller (Do not pull up before startup)
GPIO	21	BG77_DBG_RXD	1.8V	DI	Debug UART receive
GPIO	22	BG77_PON_TRIGGER	1.8V	DI	Wake up the module from PSM (trigger on rising-edge)
GPIO	23	BG77_DBG_TXD	1.8V	DO	Debug UART transmit
GPIO	24	BG77_GRFC1	1.8V	DO	Generic RF controller (Do not pull up before startup)

2.3 UART header



The UART header is connected to all UART1 related I/O's from the Quectel module on the shield. All these signals are connected to the level shifter. Depending on the position of the level shift header, the voltage of the signals will be 3.3V or 5.0V.

Header	Pin No.	Name	Power domain	I/O	Description
UART	1	GND	-		Ground
UART	2	GND	-		Ground
UART	3	VCC_LVL	V_level_shifter	PO	Can be used to supply external board with V_level_shifter
UART	4	RXD	V_level_shifter	DI	Receive data
UART	5	RTS	V_level_shifter	DI	Request to send
UART	6	TXD	V_level_shifter	DO	Transmit data
UART	7	CTS	V_level_shifter	DO	Clear to send
UART	8	DTR	V_level_shifter	DI	Data terminal ready (Sleep mode control)
UART	9	DCD	V_level_shifter	DO	Data carrier detection
UART	10	RI	V_level_shifter	DO	Ring indicator

3 Interfaces

3.1 Power

The ERF3002 shield must be supplied through the USB connector, or the VIN pins (5V max.) on the Arduino header. Voltage must be stable during module operation, taking into account that the current drawn from VCC pins may vary significantly based on the power consumption profile of the IoT system.

Alternatively the shield can also be powered directly through the Arduino header 3.3V pin*.

*When powering the shield through an 3.3V Arduino pin, please keep in mind the voltage must be stable and can't exceed 3.3V.

3.1.1 Electrical Characteristics

Electrical characteristics (ERF3002)				
Parameter	**Min.**	**Typ.**	**Max.**	**Unit**
VIN	4.8	5.0	5.2	V
VCC (after LDO)	3.0	3.3	3.5	V
Current draw	-	-	500	mA

Current consumption (BG77 module)			
Consumption	**LTE Cat M1 (typical)**	**Power saving mode**	3.2uA
		Idle State	19.7mA
		Sleep State	1.63mA @DRX=1.28s 0.76mA @e-I-DRX=80.92s, PTW = 20.48s
		LTE Connected Mode	228mA @21dBm GNSS off
	LTE Cat NB1 (typical)	**Power saving mode**	3.2uA
		Idle State	15.8mA
		Sleep State	1.5mA @DRX=1.28s 0.79mA @e-I-DRX=81.92s, PTW = 20.48s
		LTE Connected Mode	165mA @21dBm, GNSS off

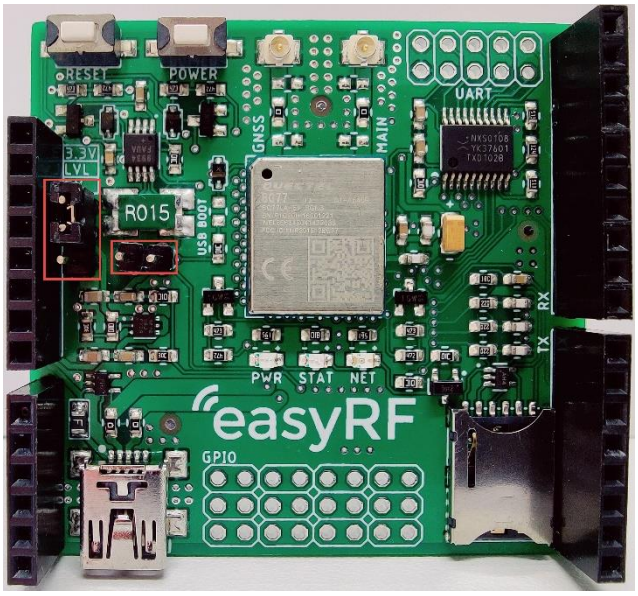
3.1.2 Power headers

The Shield has 2 power headers, the level shift header and the current measurement header. These are marked with a red box on the following picture:

The level shift header must be placed on either 3.3V (pin 1 and 2) or 5V (Pin 2 and 3), this depends on the microprocessor board used in combination with the shield.

The current measurement header can be used a reference point for the current measurement system, or this header can be used to supply external boards with 3.3V and use the ERF3002 current measurement to measure the consumed current of external electronics*.

*For more information regarding the current measurement, please see the ERF3002_User_guide.pdf



3.2 Antennas

The ERF3002 uses 2 antennas, 1 GNSS antenna and 1 cellular antenna. The Cellular antenna should be connected to the U.FL connector marked by MAIN. The GNSS antenna should be connected on the U.FL marked with GNSS.

3.2.1 GNSS_ANT

The YME001BA antenna is a GNSS Flex antenna. The antenna can be used in the frequency band of 1559~1609 MHz making it suitable for GNSS applications.

*For more information see the Quectel_YME001AA datasheet

3.2.2 Cellular_ANT

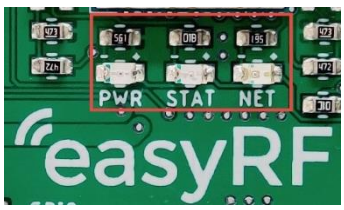
The ERF4061 antenna is a GSM PCB antenna. The antenna can be used in the frequency band of 800~900 / 1500 / 2100~2300 MHz. The antenna can be used for applications, GSM, M2M, NB-IoT and CAT-M.

*For more information see the ERF4061 datasheet

3.3 Status LED's

The shield has 3 LED's to give an indication of the current status of the shield. Please see below image for their locations:

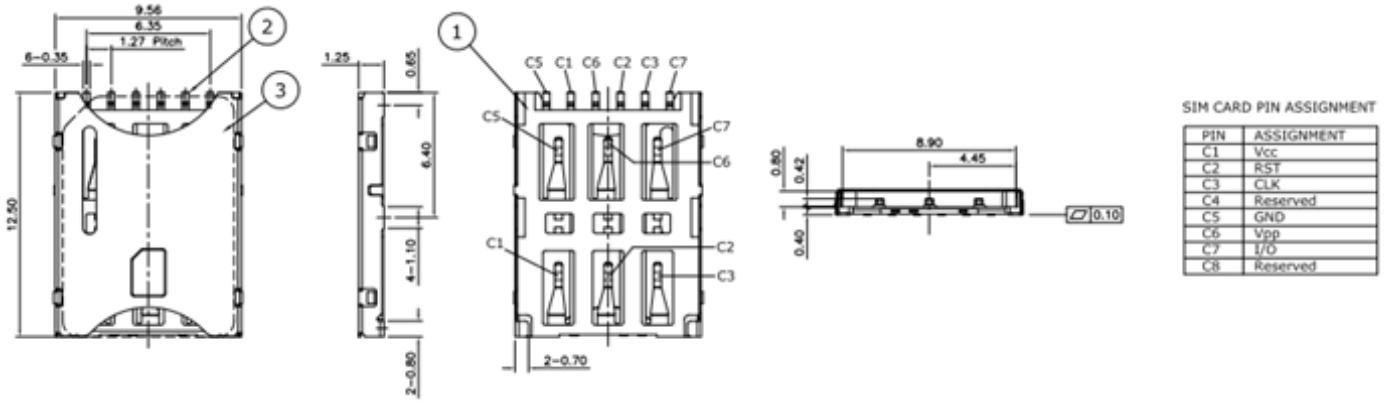
Led	Color	State	Description
PWR	Green	Always on	Shield is powered
		Always off	Shield is not powered
STAT	Yellow	Always on	Module on
		Always off	Module off
NET	Red	0.2s on/1.8 off	Searching for network
		1.8s on/0.2s off	Connected to network
		0.125s on/0.125s off	Data transfer is ongoing
		Always on	Voice calling



3.4 SIM interface

To register and connect to a network, a SIM card needs to be inserted and activated.
When an activated SIM is inserted, the functionality of the SIM card should be checked with AT+CIMI and AT+QCCID.*
The Attend model number of the SIM card socket is 115U-A000.

*For more information see: BG77_AT_Manual.pdf



3.5 UART interface

The ERF3002 shield provides 3 UART ports:

Interface	Supported Baud rates	Description
Main UART	9600, 19200, 38400, 57600, 115200, 230400, 460800 and 921600bps (115200 is the default value)	The main UART port, this is used for data transmission and AT command communication
Debug UART	115200bps	The debug UART port, used for debugging and log output
GNSS UART	115200bps	The GNSS UART port, used for outputting GNSS and NMEA sentences

The Main UART interface can be found on the UART header. All signals are routed through a level shifter. The voltage of the signals can either be 3.3V or 5.0V. this is dependent on the position of the level shift header.

Both the Debug and GNSS UART can be found on the GPIO header, both are in the 1.8V domain.

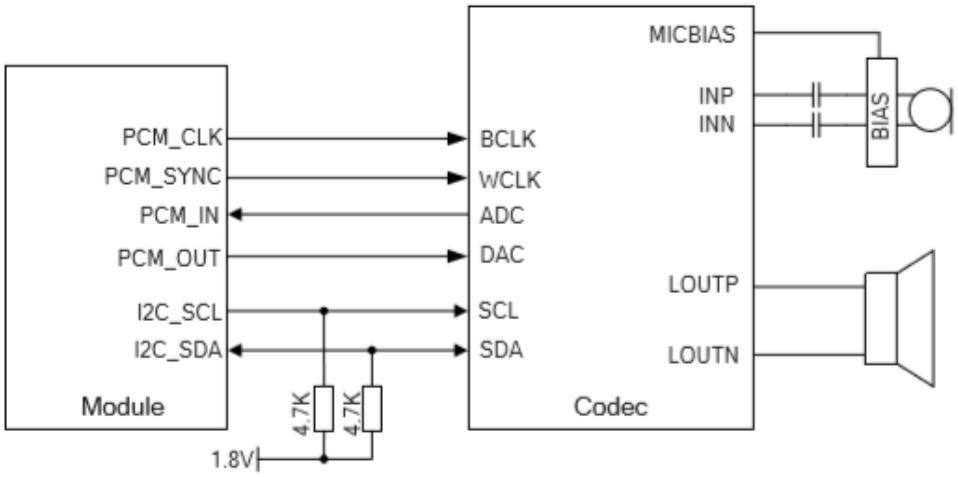
Please see chapter 2.2 GPIO header and 2.3 UART header for more details regarding the exact location of the UART signals.

3.6 PCM and I2C interface

The BG77 provides one Pulse Code Modulation (PCM) digital interface and one I2C interface. These can be used in combination with an audio codec.

The following figure shows a reference design of PCM and I2C interfaces with an external codec.

Both the PCM and I2C signals can be found on the GPIO header.



3.7 ADC interface

The module provides two analog-to-digital converter (ADC) interfaces.
The onboard temperature sensor is connected to ADC0.
AT+QADC=0 command can be used to read the voltage value on ADC0 pin.
AT+QADC=1 command can be used to read the voltage value on ADC1 pin.
For more details about the AT command, please refer to BG77_AT_Manual.pdf

Parameter	Min.	Typical	Max.	Unit
Voltage range*	0.1		1.8	V
Resolution		64.979		µV
Analog Bandwidth		500		kHz
Sample Clock		4.8		MHz
Input Resistance	10			MΩ

*ADC input voltage must not exceed 1.8V , and it is prohibited to supply any voltage to ADC pin when VBAT is removed. Finally use of a resistor divider is recommended

3.8 GPIO Interaface

The module provides seven* general-purpose input and output (GPIO) interfaces.
AT+QCFG="gpio" command can be used to configure the status of GPIO pins.
For more details about the AT command, please refer to BG77_AT_Manual.pdf.
*GPIO5 is a BOOT_CONFIG pin. Don't pull up before module power on.
*GPIO7 can be multiplexed as fast shutdown pin.

Logic Levels of the GPIO interfaces

Parameter	Min.	Max.	Unit
$V_{Input\ Low}$	-0.3	0.6	V
$V_{Input\ High}$	1.2	2.0	V
$V_{Output\ Low}$	0	0.45	V
$V_{Output\ High}$	1.35	1.8	V

3.9 GRFC Interface

The BG77 module provides two generic RF control interfaces for the control of external antenna tuners.

Logic levels of GRFC interface

Parameter	Min.	Max.	Unit
V_{OL}	0	0.45	V
V_{OH}	1.35	1.8	V

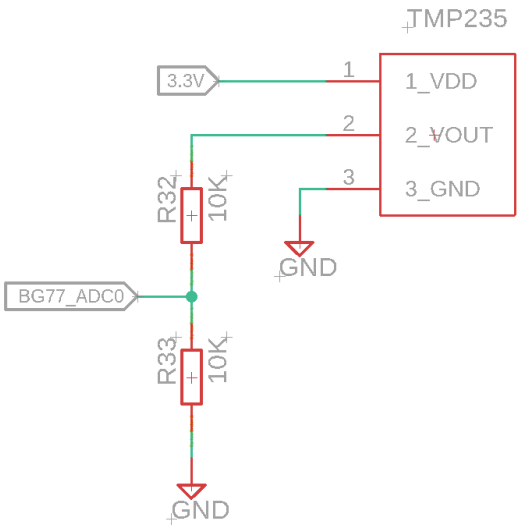
Truth table of GRFC interface

GRFC1 Level	GRFC2 Level	Frequency Range (MHz)	Band
Low	Low	880-2200	B1, B2, B3, B4, B8, B25, B66
Low	High	791-894	B5, B18, B19, B20, B26, B27
High	Low	698-803	B12, B13, B14, B28, B85
High	High	617-698	B71

3.10 Temperature Sensor

The TMP235 Temperature sensor is connected to ADC0 on the BG77, and can be read out using AT+QADC=0.

Because the TMP235 has a 3.3V max analog output signal, a resistor divider is used to lower the output voltage. The resistor divider consists of 2x 10 KΩ + / - 0.1% resistors to effectively cut the analog output voltage in half and keep it from crossing the 1.8V boundary.



To convert the voltage read from the ADC0 pin on the BG77 module into temperature, please use the following table and formula:

$T_{A,RANGE}$ (°C)	V_{RANGE} (mv)	T_{INFL} (°C)	T_C (mV/°C)	V_{OFFS} (mV)
-40 to +100	< 1500	0	10	500
+100 to +125	1500 to 1752.5	100	10.1	1500
+125 to +150	>1752.5	125	10.6	1752.5

$$T_A = \frac{((2*V_{OUT})-V_{OFFS})}{(T_C+T_{INFL})}$$

Example:

```
AT+QADC=0
+QADC: 1,390

OK
```

$$T_A = \frac{((2 * 390) - 500)}{(10 + 0)} = 28^{\circ}C$$

3.11 Current Measurement

The MAX9934F current sense chip can be used to measure the current consumption of the BG77 module during the different modes. When this data is plotted vs. time you can get a good graphical image of the consumed current by the module.

To convert the voltage measured on the ADC pin into current, please use the table and formula:

Parameter	Value	Unit	Description
V_{CC}	3.3	V	Voltage coming from LDO
R_{Sense}	0.015	Ω	Sense resistor
G_M	25	µA/mV	Gain of the current sense chip
R_{Out}	16.9	kΩ	Output resistor Current sense chip
ADC_{res}	1024	bits	Arduino UNO ADC resolution is 10 bit ($2^{10} = 1024$)
ADC_{read}	-	bits	ADC value read from ADC pin A0 on the Arduino header
I_{Load}	-	A	Current consumption

$$I_{Load} = \frac{V_{CC} \cdot ADC_{read}}{(R_{Sense} \cdot R_{Out} \cdot G_M \cdot ADC_{res})}$$

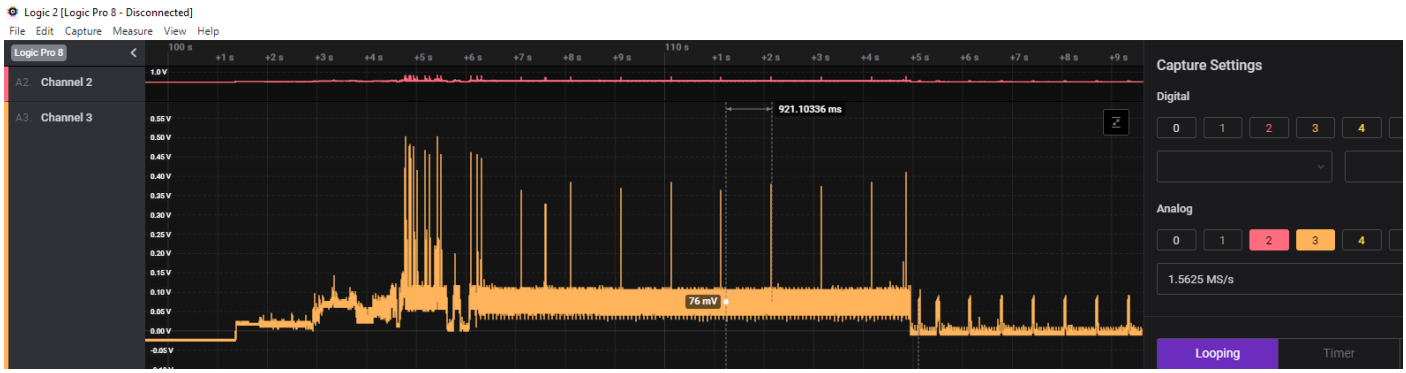
Examples:

$$I_{Load,min} = \frac{3.3 \cdot 1}{(0.015 \cdot 16.9 \cdot 25 \cdot 1024)} = 0.509 \text{ mA}$$

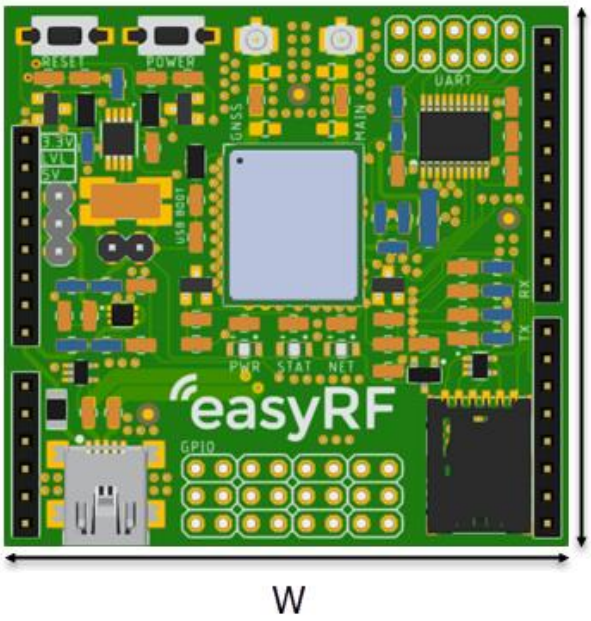
$$I_{Load,max} = \frac{3.3 \cdot 1024}{(0.015 \cdot 16.9 \cdot 25 \cdot 1024)} = 520.71 \text{ mA}$$

Example of plotted data:

*Captured on ERF3002 shield with Saleae Logic Analyser



4 Mechanical specifications



Parameter	Dimension
W (Width)	50 ± 1 mm
L (Length)	52 ± 1 mm
H (Height)	19.5 ± 1 mm

5 Product handling

Handle with ESD safety care.

6 Related documents

Document	Distributor
ERF4061 GSM Datasheet	easyRF
TBD GNSS Datasheet	TBD
Quectel_BG77_AT_Commands_Manual.pdf	Quectel / TOP-electronics
ERF3002_User_Guide.pdf	easyRF

Ordering information

Ordering can be done via www.summit-electronics.com or via info@summit-electronics.com. Please contact us for more information. Customisation of the product is available on request.
The shield is available as the following packages:

Package	ERF3002
Includes	- BG77 Arduino shield - GSM antenna - GNSS antenna - USB cable

Technical support

For all product questions please contact us via info@summit-electronics.com