Datasheet

LoRa/Bluetooth Low Energy (BLE) Module

Part Numbers: RM186 and RM191

Version 1.9

Revision History

Version	Date	Notes	Contributor(s)	Approver
1.0	19 May 2016	Initial version		Jonathan Kaye
1.1	20 May 2016	Updated SIG section with URL to listing		Jonathan Kaye
1.2	11 Aug 2016	Changed *Hardware Integration Guide* to *Datasheet*		Sue White
1.3	2 Nov 2016	Updated section numbers		Sue White
1.4	01 Feb 2017	Updated to include BLE Peripheral Mode		Jonathan Kaye
1.5	17 Oct 2017	Added section RM1xx VSP Service and Modes. Notes to clarify that JTAG is required when flashing between central and peripheral firmware.		Raj Khatri
1.6	3 Nov 2017	Updated Mechanical Details to indicate pin 1.		Sue White
1.7	20 Mar 2018	Fix Pin 7 in Pin Definitions Table to Pull Down		Raj Khatri
1.8	29 Oct 2018	Updated template; added Australia certification info; replaced BTv4.0 with BTv4.1	Maggie Teng	Jonathan Kaye
1.9	14 Feb 2019	Updated logos and URLs		Sue White

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Contents

1 Overview and Key Features

This Datasheet describes both the RM186 (868 MHz band for EU) and RM191 (915 MHz band for US). The differences are outlined in the radio specifications.

Every RM1xx Series module is designed to enable OEMs to add a long range LoRa radio link and either Central OR Peripheral mode Bluetooth Low Energy (BLE) to small, portable, power-conscious devices. The RM1xx modules are enabled with Laird's *smart* BASIC, an event-driven programming language that enables OEMs to make their product development quicker and simpler, significantly reducing time to market. *smart*BASIC enables customers to develop a complete embedded application inside the compact RM1xx hardware, connecting to a wide array of external sensors via its I2C, SPI, UART, ADC, or GPIO interfaces.

Based on the world-leading Nordic Semiconductor nRF51822 (BLE) and Semtech Sx1272 (LoRa) chipsets, the RM1xx modules provide ultra-low power consumption with outstanding wireless range using the LoRa radio link and local BLE connections via three dBm of transmit power. This document should be read in conjunction with the *smart* BASIC user manual.

Note: This information in this document is subject to change. Please contact Laird to obtain the most recent version of this document – https://connectivity.lairdtech.com/resources/support.

1.1 Features and Benefits

- Bluetooth v4.1 – Central OR Peripheral Mode
- On-board BLE chip antenna
- U.FL for external LoRa antenna
- *smart*BASIC programming language
- Bluetooth SIG Listed
- Compact footprint
- Long range – LoRa range up to 15 km
- BLE Programmable TX power +3 dBm to -20 dBm
- BLE TX whisper mode (-30 dBm, -55 dBm)
- BLE RX sensitivity: -91 dBm
- Ultra-low power consumption
- BLE TX: 12.7 mA peak (at +3 dBm @Vcc=3.3V) (See Note 4 in the *Power Consumption* section)
- BLE RX: 11.9 mA peak (@Vcc=3.3V See Note 4 in the *Power Consumption* section)
- Standby Doze: 4.2 uA (typical)
- Deep Sleep: 750 nA (See Note 4 in the *Power Consumption* section)
- UART, GPIO, ADC, PWM FREQ output, TIMERS, I2C, and SPI interfaces
- Fast time-to-market
- FCC/IC (RM191-SM), CE (RM186-SM)
- No external components required

1.2 Application Areas

- Public or private networks
- Irrigation/Agriculture
- Parking
- Lighting
- Asset tracking
- Tank monitoring
- Smart Home – smoke alarms, heating,
- Access control – security
- Industrial automation – factory
- Any long range, battery powered sensor application

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2 Specifications

Table 1: Specifications

Categories	Feature	Implementation	
LoRa Wireless Specification	LoRa®	LoRaWAN 1.01 (End Device)	
	Frequency	902-928MHz	RM191
		865-870 MHz	RM186
	Maximum Transmit Power Setting	15.5 dBm	RM191
		13.5 dBm	RM186
	Minimum Transmit Power Setting	1.5 dBm	
	Receive Sensitivity	-126 dBm -134 dBm	RM191 (BW 500 kHz SF 12) RM186 (BW 125kHz SF 12)
	Range	Up to 15 km in free space	
	Raw Data Rates (over the air)	250 bps – 50 kbps	RM186
		980 bps – 21.9kbps	RM191
BLE Wireless Specification	Bluetooth® (BLE)	V4.1 – Central OR Peripheral Mode	
	Frequency	2.402 - 2.480 GHz	
	Maximum Transmit Power Setting	3 dBm (into -1.5 dBi chip antenna)	
	Minimum Transmit Power Setting	-20 dBm (in four dB steps) with *smart*BASIC command -16 dBm -12 dBm -8 dBm -4 dBm 0 dBm	
	TX Whisper Mode 1 Transmit Power	-30 dBm (min.) with *smart*BASIC command	
	TX Whisper Mode 2 Transmit Power	-55 dBm (min.) with *smart*BASIC command	
	Receive Sensitivity (0.1% BER)	-91 dBm typical	
	Link Budget	95 dB (@ 1 Mbps)	
	Range	Up to 100 m in free space	
	TX Whisper Modes	Range reduction feature with TX Whisper modes with *smart*BASIC command.	
	Range (TX Whisper Mode 2)	<~30 cm	
	Raw Data Rates	1 Mbps (over the air)	
Host Interface and Peripherals	Total	14 x Multifunction I/O lines	
	UART	TX, RX, CTS, RTS DCD, RI, DTR, DSR, CTS, RTS (Note 1) Default 115200, n, 8, 1 From 1,200 to 460800 bps	
	GPIO	Up to 14 With configurable I/O direction, O/P drive strength (standard 0.5 mA or high 5 mA), pull-up/pull-down	

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Categories	Feature	Implementation	
	ADC	Four 10-bit channels (including ADC reference) 10 bit resolution 1.2 V internal reference 1/1, 2/3, 1/3 pre-scaling	
	PWM or FREQ output	PWM or FREQ output on up to two GPIO output pins:	
		PWM output duty cycle	0%-100%
		PWM output frequency	Up to 500 kHz (Note 7)
		FREQ output frequency	0 MHz-4 MHz (50% duty cycle)
	I2C	One I2C interface (up to 400 kbps) (Note 2)	
	SPI	One SPI Master interface (up to 4 Mbps) (Note 3)	
BLE Services	Services supported	GATT client and capabilities	
FW Upgrade	*smart*BASIC runtime engine FW upgrade	(1) Via UART (2) Via 2-Wire SWD Programming/Debug Interface **Note:** JTAG required for upgrading between Central and Peripheral firmware.	
Programmability	*smart*BASIC	On-board programming language similar to BASIC.	
	*smart*BASIC application download	(1) Via UART. (2) Via Over the Air (If SIO_28 pin is pulled high externally). Only for Peripheral role.	
Control Protocols	Any	User defined via *smart*BASIC	
Operating Modes	Self-contained Run mode	Selected by nAutoRun pin status: nAutoRun = LOW (0V): Then runs $autorun$ (*smart*BASIC application script) if it exists.	
	Interactive / development mode	nAutoRun = HIGH (VCC): Then runs via at+run (and "file name" of *smart*BASIC application script).	
Supply Voltage	Supply (VCC)	2.1V – 3.5V	Internal DCDC converter (Note 5)
		1.8V – 2.1V	Internal LDO
		DCDC switched on if VCC >2.1V at power-up	
BLE Power Consumption	Active modes peak current (for Max TX PWR 3 dBm)	Connected mode (Vcc=3.3V)	12.7 mA peak TX 11.9 mA peak RX
	Active modes peak current (for TX Whisper mode2 PWR -55 dBm)	Connected mode (Vcc=3.3V)	5 mA peak TX 11.9 mA peak RX
	Active modes average current	Depends on many factors. See *Power Consumption*.	
	Ultra-low power modes	Standby Doze Deep Sleep	4.2 uA typical (Note 6) 750 nA (Note 6)
Antenna Options	BLE (Internal) chip antenna	On-board ceramic chip monopole antenna -1.5 dBi	
	LoRa (External)	Dipole antenna with U.FL (IPEX) connector up to 2 dBi	

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Categories	Feature	Implementation
Physical	Dimensions	25.4 mm x 25.4 mm x 3.1 mm
	Weight	3 grams
Environmental	Operating	-40 ˚C to +85 ˚C (VCC 1.8V – 3.5 V)
	Storage	-40 ˚C to +85 ˚C
Miscellaneous	Lead Free	Lead-free and RoHS compliant
	Warranty	1-Year Warranty
Development Tools	Development Kit	Development Kit DVK-RM1xx and Free Software Tools
Approvals	Bluetooth®	SIG Listed – Declaration ID
	FCC / IC / CE	RM191-SM: FCC/IC, RM186-SM: CE

Note 1: DSR, DTR, RI, and DCD can be implemented in the *smart* BASIC application.

Note 2: With I2C interface selected, pull-up resistors on I2C SDA and I2C SCL MUST be connected externally as per I2C standard.

Note 3: SPI interface (master) consists of SPI MOSI, SPI MISO and SPI CLK. SPI CS is created by customer using any spare SIO pin within their *smart*BASIC application script allowing multi-dropping.

Note 4: RM1xx module comes loaded with *smart* BASIC runtime engine FW, but does not come loaded with any *smart* BASIC application script (as that is dependent on customer end application or use). Laird provides many sample *smart* BASIC application scripts covering the services listed. Additional applications being added every quarter.

Note 5: Laird suggests using Vcc of 3.3V +/-5% (3.13V-3.46V) for maximum LoRa output power.
WARNING: above 3.5V, the LoRa transmitter will be disabled to maintain regulatory compliance

Note 6: Deep Sleep current <750nA (typical).
Standby Doze current 4.2uA (typical).

Note 7: PWM output signal has a frequency and duty cycle property. PWM output is generated using 32-bit hardware timers. The timers are clocked by a 1MHz (1uS period) clock source. Trade-off PWM output frequency with resolution. For example:

PWM output frequency of 500kHz (2uS) results in resolution of 1:2
PWM output frequency of 100kHz (10uS) results in resolution of 1:10
PWM output frequency of 10kHz (100uS) results in resolution of 1:100
PWM output frequency of 1kHz(1000uS) results in resolution of 1:1000
Refer to the *smart*BASIC user guide for details.

3 Hardware Specifications

3.1 Block Diagram and Pin-out

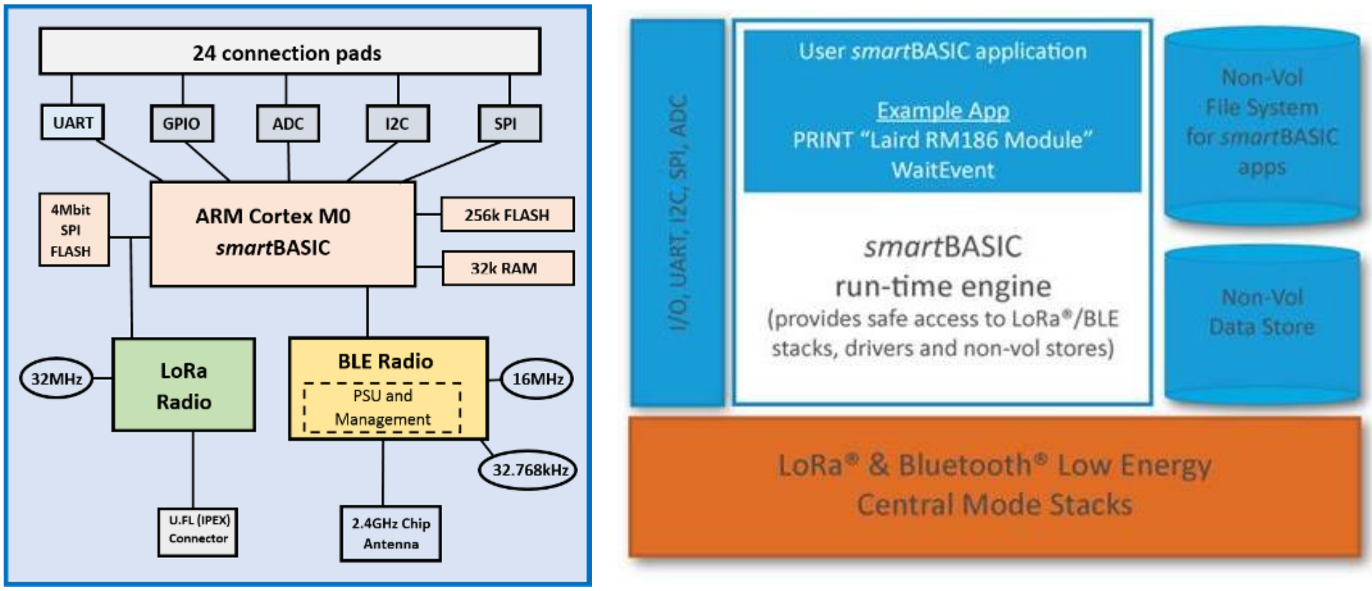

Figure 1: Functional HW and SW block diagram for RM1xx series smartBASIC modules

Figure 2: RM186/RM191 module pin-out (top view)

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3.2 Pin Definitions

Table 2: Pin definitions

Pin #	Pin Name	Default Function	Alt. Funct.	Default Direction Note14	Pull-up/ Pull-down Note14	Notes	Comment
1	GND	-	-	-	-	-	-
2	SIO_21	DIO	UART TX	OUT	Set high in FW	1,2,4,6,7	UARTCLOSE() selects DIO functionality and UARTOPEN() selects UART comms behaviour
3	SIO_22	DIO	UART RX	IN	PULL-UP	1,2,4,6,7	
4	SIO_23	DIO	UART RTS	OUT	Set low in FW	1,2,4,6,7	
5	SIO_24	DIO	UART CTS	IN	PULL-DOWN	1,2,4,6,7	
6	SIO_25	nAutoRUN/DIO	DIO	IN	NONE	IN only	Laird Devkit, UART_DSR via J10, J12
7	SIO_28	vSP/DIO	DIO	IN	PULL-DOWN	1,2,6,12,13	Laird DevKit: J6 (vSP/OTA)
8	GND	-	-	-	-	-	
9	SIO_29	DIO	I2C SCL	IN	PULL-UP	1,2,6,11	I2COPEN() in *smart*BASIC selects I2C function
10	SIO_30	DIO	I2C SDA	IN	PULL-UP	1,2,6,11	
11	GND						
12	VCC_BLE	-	-	-	-	-	Vcc for BLE Radio
13	VCC_LORA	-	-	-	-	-	Vcc for Lora Radio
14	GND	-	-	-	-	-	
15	SIO_00	DIO	SPI CLK	IN	PULL-UP	1,2,6,11	SPIOPEN() in *smart*BASIC selects SPI function, MOSI and CLK will be outputs when in SPI master mode. See note 11
16	SIO_17	DIO	SPI MISO	IN	PULL-UP	1,2,6,11	
17	SIO_03/AIN	DIO/AIN	SPI MOSI	IN	PULL-UP	1,2,3,4,5,6,11	
18	SIO_04/AIN	DIO	AIN	IN	PULL-UP	1,2,3,4,5,6,11	Laird Devkit: SPI Slave Select
19	SIO_05/AIN	DIO	AIN	IN	PULL-UP	1,2,3,4,5,6,11	Laird Devkit: Button2 or Ana Temp Sensor via J7
20	SIO_06/AIN	DIO	AIN	IN	PULL-UP	1,2,3,4,5,6,11	Laird Devkit: LED5 or Arduino A0 Via J8
21	GND						
22	nRESET			IN		9,10	System Reset (Active low)
23	NC					9	DO NOT CONNECT
24	GND						

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Note 1: Secondary function is selectable in *smart*BASIC application.

Note 2: DIO = Digital Input or Output. I/O voltage level tracks VCC.

Note 3: AIN = Analog Input

Note 4: DIO or AIN functionality is selected using the GpioSetFunc() function in *smart*BASIC.

Note 5: AIN configuration selected using GpioSetFunc() function.

Note 6: I2C, UART, SPI controlled by xxxOPEN() functions in *smart* BASIC.

Note 7: SIO_21 to SIO_24 are DIO by default when $autorun$ app runs on power up.

Note 8: N/A

Note 9: Hidden 2-Wire SWD Programming/Debug Interface (JTAG), pin22 (SWDIO) and pin23 (SWDCLK). Used for upgrading *smart*BASIC runtime engine FW with J-link programmer. Using this hidden 2-Wire SWD Programming/Debug Interface on customers host PCB requires header connector Samtec FTSH-105-01-L-DV, refer to section ***2-Wire SWD Programming/Debug Interface*** for details.
JTAG required for upgrading between Central and Peripheral firmware.

Note 10: Pull the nRESET pin (pin 22) low for minimum 100 mS to reset the module.

Note11: SPI CS is created by customer using any spare SIO pin within their *smart*BASIC application script allowing multi-dropping.

Note12: SIO_28 pin must be pulled high externally to enable OTA (over the Air) smartBASIC application download. Refer to the latest FW release documentation for details.

Note13: User must ensure that SIO_28 and AutoRUN (SIO_25) are NOT BOTH HIGH (externally), otherwise in that state the UART is bridged to Virtual Serial Port service and so the RM1xx module will not respond to AT commands and therefore cannot load smartBASIC application scripts (applies to all versions of the smart BASIC runtime engine firmware.)

Note14: *smart* BASIC runtime engine has DIO (Default Function) INPUT pins, have by default PULL-UP enabled. This was done to avoid floating inputs (which can also cause current consumption in low power modes (e.g. Standby Doze) to drift with time. In any case customer can disable the PUL-UP through their *smart* BASIC application.

All the SIO pins (with a default function of DIO are inputs – apart from SIO_21 and SIO_23, which are outputs):

- **SIO_21** (alternative function UART_TX) is an output, set high (in FW).
- **SIO_23** (alternative function UART_RTS) is an output, set low (in FW).
- **SIO_22** (alternative function UART_RX) is an input, set with internal pull-up (in FW).
- **SIO_24** (alternative function UART_CTS) is an input, set with internal pull-down (in FW).

The RM1xx module is delivered with the integrated *smart*BASIC runtime engine FW loaded (but no onboard *smart*BASIC application script). Because of this, it starts up in AT command mode by default.

At reset, all SIO lines are configured as the defaults shown above.

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SIO lines can be configured through the *smart*BASIC application script to be either inputs or outputs with pull-ups or pull-downs. When an alternative SIO function is selected (such as I2C or SPI), the firmware does not allow the setup of internal pull-up/pull-down. Therefore, when I2C interface is selected, pull-up resistors on I2C SDA and I2C SCL **MUST** be connected externally as per I2C standard.

UART_RX, UART_TX, UART_CTS are Vcc logic levels (if VCC is 3.3 V, i.e. SIO pin I/O levels track VCC). For example, when RX and TX are idle, they sit at 3.3 V (if VCC is 3.3 V). Conversely, handshaking pins CTS and RTS at 0 V are treated as assertions.

Pin 6 (nAutoRUN) is an input, with active low logic. In the development kit (DVK-RM1xx-SM) it is connected so that the state is driven by the host's DTR output line. The nAutoRUN pin must be externally held high or low to select between the following two operating modes:

- Self-contained Run mode (nAutoRUN pin held at 0 V).
- Interactive/development mode (nAutoRUN pin held at VCC).

*smart*BASIC runtime engine firmware checks for the status of nAutoRUN during power-up or reset. If it is low and if there is a *smart*BASIC application script named **$autorun$**, then the *smart*BASIC runtime engine FW executes the application script automatically; hence the name S*elf-contained Run Mode*.

3.3 Electrical Specifications

3.3.1 Absolute Maximum Ratings

Absolute maximum ratings for supply voltage and voltages on digital and analogue pins of the module are listed below; exceeding these values causes permanent damage (Table 3).

Table 3: Maximum Current Ratings

Parameter	Minimum	Maximum	Unit
Voltage at VCC_BLE and VCC_LORA pin	-0.3	+3.6 (Note 1)	V
Voltage at GND pin		0	V
Voltage at SIO pin	-0.3	VCC+0.3	V
Storage temperature	-40	+85	ºC

Note 1: Absolute Max Rating for VCC pin (max) is 3.6V, however we recommend 3.3V +/-5% as the spec for maximum Vcc. *The LoRa transmitter shuts down if the voltage exceeds 3.5V* .

3.3.2 Recommended Operating Parameters

Table 4: Power Supply Operating Parameters

Parameter	Minimum	Typical	Maximum	Unit
VCC[1]	1.8	3.3	3.5	V
VCC Maximum ripple or noise[2]			10	mV
Operating Temperature Range	-40	-	+85	ºC

Note 1: Internal DCDC is used if VCC >2.1 V on power-up; otherwise internal LDO is used.
If supply voltage is greater than 3.5V, the LoRa transmitter will be disabled.

Note 2: The maximum VCC ripple or noise (at any frequency) that does not disturb the radio.

Table 5: Signal Levels for Interface, SIO

Parameter	Minimum	Typical	Maximum	Unit

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Parameter	Minimum	Typical	Maximum	Unit
VIH Input high voltage	0.7VCC		VCC	V
VIL Input low voltage	VSS		0.3	V
VOH Output high voltage (std. drive, 0.5mA) (high-drive, 5mA) (Note 1)	 VCC-0.3 VCC-0.3		 VCC VCC	 V V
VOL Output low voltage (std. drive, 0.5mA) (high-drive, 5mA) (Note 1)	 VSS VSS		 0.3 0.3	 V V
Pull up resistance	11	13	16	kΩ
Pull down resistance	11	13	16	kΩ

Note 1: Maximum number of pins with 5mA high drive is three.

Table 6: SIO pin alternative function AIN (ADC) specification

Parameter	Minimum	Typical	Maximum	Unit
ADC Internal reference voltage	-1.5%	1.2 V	+1.5%	%
ADC pin input internal selectable scaling		1/1, 1/3, 2/3		Scaling
ADC input pin (AIN) voltage maximum without damaging ADC w.r.t VCC Prescaling 3.3 V 1/1 3.3 V 2/3 3.3 V 1/3 1.8 V 1/1 1.8 V 2/3 1.8 V 1/3			 2.4 3.6 3.6 2.1 2.1 2.1	 V V V V V V
ADC input pin (AIN) voltage maximum without saturating ADC (with 1.2V internal reference)[1] 1/1 prescaling 2/3 prescaling 1/3 prescaling			 1.2 1.8 3.6	 V V V
Time required to convert single sample in 10bit mode 9bit mode[2] 8 bit mode[2]		 68 36 20		 uS uS uS
ADC input impedance (during operation)[3]				

Note 1: Stay within internal 1.2 V reference voltage with given prescaling on AIN pin and do not violate ADC maximum input voltage (for damage) for a given VCC, e.g. If VCC is 1.8 V can only expose AIN pin to 2.1 V (VCC+0.3).

Note 2: Currently, the *smart*BASIC runtime engine firmware only allows 10-bit mode.

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Note 3: ADC input impedance is estimated mean impedance of the ADC (AIN) pins. The tolerance is +/-20%. The ADC is highly sensitive to the impedance of the source. The ADC (AIN) input impedance is 200k-600k depending on your ADC gain (pre-scaling) setting. Normally, when not sampling, the ADC (AIN) impedance will have very high value and can consider it to be an open circuit. The moment ADC is sampling, ADC (AIN) impedance is 200k-600k.

3.3.3 nAutoRUN Pin and Operating Modes

Operating modes (refer to the *smart*BASIC manual for details):

- Self-contained mode
- Interactive/Development mode

Table 7: nAutoRUN pin

Signal Name	Pin #	I/O	Comments
nAutoRUN (SIO_25)	6	I	Input with active low logic. Operating mode selected by nAutoRun pin status: If Low (0V), runs $autorun$ if it exists; If High (VCC), runs via at+run (and “file name” of application).

Pin 40 (nAutoRUN) is an input, with active low logic. In the development board (DVK-RM1xx) it is connected so that the state is driven by the host’s DTR output line. nAutoRUN pin needs to be externally held high or low to select between the two RM1xx operating modes:

- Self-contained Run mode (nAutoRUN pin held at 0V).
- Interactive/Development mode (nAutoRUN pin held at VCC)

*smart*BASIC runtime engine firmware checks for the status of nAutoRUN during power-up or reset. If it is low and if there is a *smart*BASIC application named $autorun$ then the *smart*BASIC runtime engine executes the application automatically; hence the name *self-contained run mode*.

3.3.4 LoRa Output Power and Current Consumption vs Vcc

To maximize output power, the best choice for module Vcc is 3.3V +/- 5% (which results in a Vcc range of 3.14V to 3.47V). The data in Table 8 was taken at 25°C with UART on and all other peripherals turned off. It shows how the output power and transmitter current consumption falls off as a function of Vcc.

Table 8: Power consumption and output power vs Vcc

	RM186			RM191		
Vcc [V]	**Tx Current [mA]**	**Rx Current [mA]**	**Pout [dBm]**	**Tx Current [mA]**	**Rx Current [mA]**	**Pout [dBm]**
3.5	31.4	12.7	13.8	45.7	15.3	15.2
3.3	30.9	12.6	13.5	43.3	15.0	14.9
3.0	29.5	12.3	13.0	39.8	15.1	14.3
2.7	27.9	12.2	12.2	36.3	14.8	13.4
1.8	19.4	11.8	6.5	24.5	14.4	8.5

3.3.4.1 Typical LoRa Current Waveforms for Tx/Rx Cycle

The plots below (Figure 3 and Figure 4) depict a typical Transmit/Receive cycle when sending a LoRa packet to the gateway. The plots were made using a shunt current monitor and the voltage levels have been translated to currents. The current plots show a transmitted packet, the first receive window (one second later), followed by the second receive window (one

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second following the first receive window). The currents represented are the total module current (the sum of VCC_BLE and VCC_LORA pins).

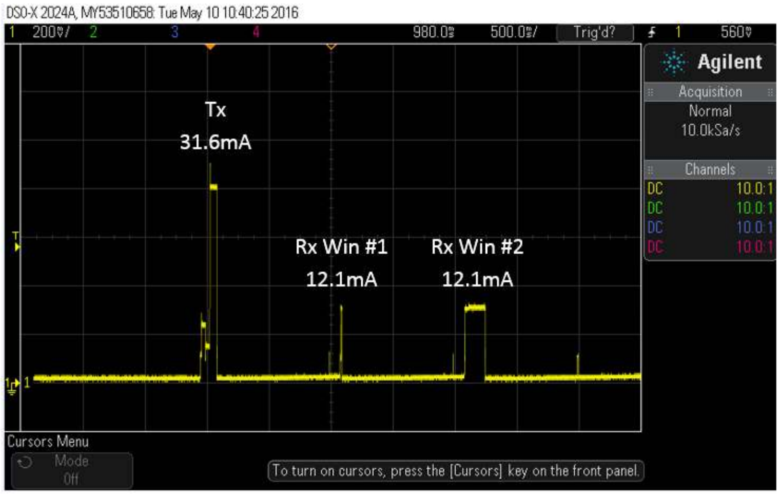

Figure 3: Typical RM186 LoRa transmit/receive cycle (full Tx power, Vcc=3.3V, @25 °C

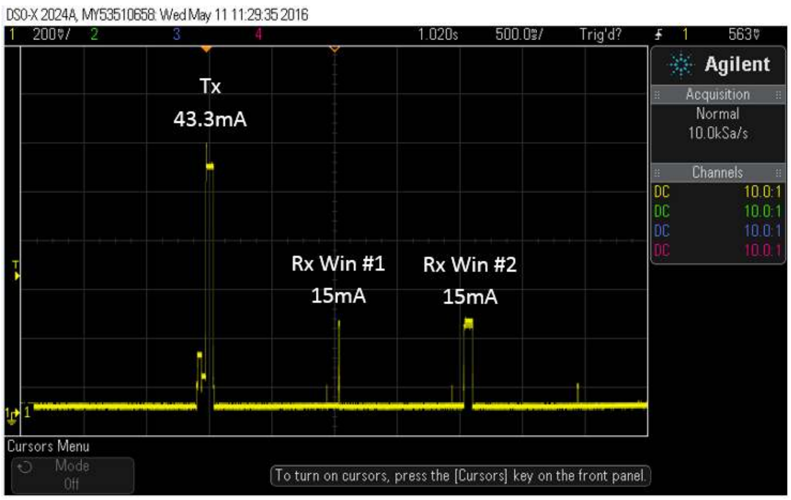

Figure 4: Typical LoRa transmit/receive cycle (full Tx power, Vcc=3.3V, @25˚C)

3.3.5 LoRa Receive Sensitivity vs Data Rate

Table 9 tabulates typical LoRa receive sensitivity as a function of the LoRa data rate. The data rate is determined by the combination of bandwidth and spreading factor of the incoming LoRa signal. The data rates in the table are the LoRaWAN data rates used by the gateway when transmitting to the end device.

Table 9: Receive sensitivity vs LoRa data rate

	DR	Bit Rate [Bits/s]	BW [kHz]	SF	Rx Sensitivity [dBm]
RM191	8	980	500	12	-126
	9	1760	500	11	-125
	10	3900	500	10	-122
	11	7000	500	9	-119

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	DR	Bit Rate [Bits/s]	BW [kHz]	SF	Rx Sensitivity [dBm]
	12	12500	500	8	-116
	13	21900	500	7	-113
RM186	0	250	125	12	-134
	1	440	125	11	-132
	2	980	125	10	-130
	3	1760	125	9	-127
	4	3125	125	8	-124
	5	5470	125	7	-121
	6	11000	250	7	-119

Note the following:

- DR = LoRaWAN data rate
- Bit rate is the effective over the air bit rate
- BW is the bandwidth of the incoming LoRa transmission
- SF is the Spreading Factor of the incoming LoRa transmission

3.3.6 BLE Power Consumption

Data taken at VCC 3.3V (see Note 1 following Table 10) and 25°C.

Table 10: Power consumption

Parameter	Min	Typical	Max	Unit
Active Mode 'peak' current – (Note 1) (Connection)				
TX only run peak current @TXpwr= + 3 dBm		12.7		mA
TX only run peak current @T pwr= 0 dBm		8.4		mA
TX only run peak current @TXpwr= -4 dBm		7.1		mA
TX only run peak current @TXpwr= -8 dBm		6.9		mA
TX only run peak current @TXpwr= -12 dBm		6.4		mA
TX only run peak current @TXpwr= -16 dBm		6.1		mA
T X only run peak current @TXpwr= -20 dBm		5.5		mA
TX Whisper Mode 1 TX only run peak current @TXpwr= -30 dBm		5.4		mA
TX Whisper Mode 2 TX only run peak current @TXpwr= -55 dBm		5.0		mA
Active Mode				
RX only 'peak' current		11.9		mA
Ultra Low Power Mode1 (Note 2)				
Standby Doze		4.2		uA
Ultra Low Power Mode2 (Note 3)				
Deep Sleep (no RAM retention)		750		nA

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Parameter	Min	Typical	Max	Unit
Active Mode Average current (Note 4)				
Connection Average Current draw				
Max with connection interval (min) 7.5 mS				
with connection interval 67.5 mS		~400		uA
Min with connection interval (max) 4000 mS		~2.6-4.1		uA

Note 1: If VCC is below 2.1V (operating range of DCDC), the peak current consumption will increase because the DCDC converter is switched off and the internal LDO is enabled.

Note 2: Standby Doze is entered automatically (when *waitevent* statement is encountered within a *smart*BASIC application script). See individual peripherals current consumption in tables in section ***Peripheral block current consumption 4.3***.

Note 3: In Deep Sleep, everything is disabled and the only wake-up sources are reset and changes on pins on which sense is enabled. A reset is required to exit Deep Sleep.

Note 4: Data taken with TX power 3 dBm and all peripherals off (UART OFF after radio event). Average current consumption depends on a number of factors (including TX power, VCC and accuracy of 16 MHz and 32.768 kHz crystals). With these factors fixed, the largest variable is the connection interval.

Connection Interval Range:
7.5 ms to 4000 ms in multiples of 1.25 ms.

For a connection event:
– The minimum average current consumption is when the connection interval is large 4000 mS

– The maximum average current consumption is with the shortest connection interval of 7.5 ms; no slave latency.

Other factors that are also related to average current consumption include whether transmitting 6 packets per connection interval & each packet contains 20 bytes (which is the maximum for each packet) and an inaccurate 32 kHz master clock accuracy would increase the average current consumption.

3.3.6.1 BLE Measured Peak Current Waveforms during Connection

Figure 5 illustrates BLE current waveforms observed as the RM1xx module performs a transmit/receive cycle with Vcc = 3.3V. The plot was made using a shunt current sensor and the voltage waveform has been manually converted to current. The current represented is the total module current which is the sum of the BLE_VCC and BLE_LORA pins.

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BLE Transmit/Receive currents at Vcc=3.3V @25˚C

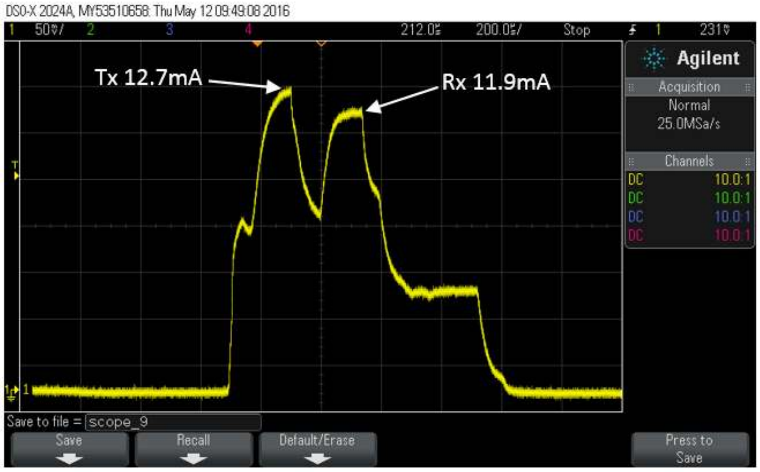

Figure 5: Typical peak current consumption profile with doze mode in effect before/after the Rx/Tx

Table 11: BLE Peak Transmit/Receive currents vs Vcc @25˚C

Vcc [V]	BLE Tx Current [mA]	BLE Rx Current [mA]
3.5	12.0	11.4
3.3	12.7	11.9
3.0	13.3	12.3
2.7	14.4	13.0
1.8	16.6	15.02

Note: This is the total module current (sum of pins VCC_BLE and VCC_LORA)

3.3.6.2 Peripheral Block Current Consumption

The values below are calculated for a typical operating voltage of 3 V.

Table 12: UART Power Consumption

Parameter	Min	Typ	Max	Unit
UART Run current @ Max Baud Rate		230		uA
UART Run current @ 115200 bps		220		uA
UART Run current @ 1200 bps		210		uA
UART Baud rate	1200		460800	bps

Table 13: SPI Power Consumption

Parameter	Min	Typ	Max	Unit
SPI Master Run current @ 125 kbps		180		uA
SPI Master Run current @ 4 Mbps		200		uA
SPI bit rate	0.125		4	Mbps

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Table 14: I2C Power Consumption

Parameter	Min	Typ	Max	Unit
I2C Run current @ 100 kbps		380		uA
I2C Run current @ 400 kbps		400		uA
I2C Bit rate	100		400	kbps

Table 15: ADC Power Consumption

Parameter	Min	Typ	Max	Unit
ADC current during conversion		260		uA

For asynchronous interface like the UART (asynchronous as the other end can communicate at any time), the UART (on RM1xx) must kept open (by a command in *smart*BASIC application script) resulting in the base current consumption penalty.

For synchronous interface like the I2C or SPI (since RM1xx side is the master), the interface can be closed and opened only when needed (by a command in *smart* BASIC application script), resulting in current saving (no base current consumption penalty). There's a similar argument for ADC (open ADC when needed).

4 Functional Description

The RM1xx module is a self-contained LoRa/Bluetooth Low Energy product and requires only power and a user's *smart*BASIC application to implement full LoRa and BLE functionality. The LoRa radio in conjunction with an externaltwo dBi antenna implements a long range, low data rate connection to a LoRa gateway up to 15 kilometers. The integrated, high performance BLE antenna combined with the RF and base-band circuitry provides the Bluetooth Low Energy wireless link to connect to local BLE sensors. The RM1xx SIO lines provide the OEM's chosen interface connection to the wired serial/SPI/I2C/analog sensors. The user's *smart*BASIC application binds the sensors to the LoRa and BLE wireless functionality.

The variety of hardware interfaces and the *smart*BASIC programming language allow the RM1xx module to serve a wide range of wired/wireless applications, whilst reducing overall time to market and the learning curve for developing LoRa and BLE products.

To provide the widest scope for integration, a variety of physical host interfaces/sensors are provided. The major RM1xx series module functional blocks are described below.

4.1 Power Management (includes brown-out and power on reset)

Power management features:

- System Standby Doze/Deep Sleep modes
- Brownout Reset
- Open/Close peripherals (UART, SPI, I2C, SIO's and ADC). Peripherals consume current when open; each peripheral can be individually closed to save power consumption (with a command in a *smart*BASIC application script).
- Two-region RAM retention (No RAM retention in Deep Sleep mode)
- *smart*BASIC command allows the VCC voltage to be read (through the internal ADC)
- Pin wake-up system from deep sleep

Power supply features:

- Supervisor hardware to manage power on reset, brownout (and power fail).
- 1.8V to 3.5V supply range.

4.2 Clocks and Timers

4.2.1 Clocks

The integrated high accuracy (+/-20 ppm) 32.768 kHz crystal oscillator provides protocol timing and helps with radio power consumption in the system Standby Doze/Deep sleep modes by reducing the time that the RX window needs to be open. Standard accuracy clocks tend to have lower accuracy +/-250 ppm.

The integrated high accuracy 16 MHz (+/-10 ppm) crystal oscillator helps with radio operation and also helps reduce power consumption in the active modes.

4.2.2 Timers

In keeping with the event-driven paradigm of *smart*BASIC, the timer subsystem enables *smart*BASIC applications to be written which allow future events to be generated based on timeouts.

- **Regular Timer** – There are eight built-in timers (regular timers) derived from a single RTC clock which are controlled solely by *smart*BASIC functions. The resolution of the regular timer is 976 microseconds.
- **Tick Timer** – A 31-bit free running counter that increments every one millisecond. The resolution of this counter is 488 microseconds. This counter can be accessed using the functions GetTickCount() and GetTickSince().

Refer to the *smart*BASIC user guide for more information.

4.3 RF

- RM186 LoRa radio: 865 – 870 MHz (250 – 11000 bps over the air data rate)
- RM186 protocol can optionally employs 50 kbps FSK when enabled by the gateway
- RM191 Lora radio: 902 – 928 MHz (980 – 21900 bps over the air data rate)
- Bluetooth Low Energy radio: 2402–2480MHz (1 Mbps over the air data rate).
- BLE TX output power of +3 dBm programmable (via *smart*BASIC command) to -20 dBm in steps of four dB.
- BLE TX Whisper mode1 -30 dBm (via *smart*BASIC command).
- BLE TX Whisper mode2 -55 dBm (via *smart*BASIC command).
- BLE Receiver (with integrated channel filters) to achieve maximum sensitivity -91 dBm @ 1 Mbps BLE.
- BLE Antenna: Integrated monopole chip antenna on RM1xx

4.4 UART Interface

The Universal Asynchronous Receiver/Transmitter offers fast, full-duplex, asynchronous serial communication with built-in flow control support (UART_CTS, UART_RTS) in the hardware. Parity checking is supported.

UART_TX, UART_RX, UART_RTS, and UART_CTS form a conventional asynchronous serial data port with handshaking. The interface is designed to operate correctly when connected to other UART devices such as the 16550A. The signaling levels are CMOS logic levels that track VCC, and are inverted with respect to the signaling on an RS232 cable.

Two-way hardware flow control is implemented by UART_RTS and UART_CTS. UART_RTS is an output and UART_CTS is an input. Both are active low.

These signals operate according to normal industry convention. UART_RX, UART_TX, UART_CTS, UART_RTS are all CMOS logic levels that track VCC. For example, when RX and TX are idle they sit at a high logic level (VCC). Conversely for handshaking pins CTS, RTS at 0 V is treated as an assertion.

The module communicates with the customer application using the following signals (Figure 6):

- Port /TXD of the application sends data to the module's UART_RX signal line
- Port /RXD of the application receives data from the module's UART_TX signal line

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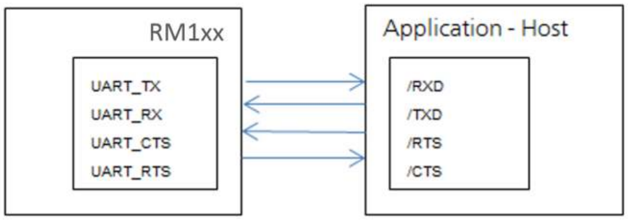

Figure 6: UART Signals

Note: The RM1xx serial module output is at CMOS logic levels that track VCC. Level conversion must be added to interface to provide an RS-232 level compliant interface.

Some serial implementations link CTS and RTS to remove the need for handshaking. Laird does not recommend linking CTS and RTS other than for testing and prototyping. If these pins are linked and the host sends data at the point that the RM1xx deasserts its RTS signal, then there is significant risk that internal receive buffers will overflow, which could lead to an internal processor crash. This will drop the connection and may require a power cycle to reset the module. Laird recommends that the correct CTS/RTS handshaking protocol be adhered to for proper operation.

Table 16: UART Interface

Signal Name	Pin #	I/O	Comments
SIO_21/UART_TX	2	O	SIO_21 (alternative function UART_TX) is an output, set high (in FW).
SIO_22/UART_RX	3	I	SIO_22 (alternative function UART_RX) is an input, set with internal pull-up (in FW).
SIO_23/UART_RTS	4	O	SIO_23 (alternative function UART_RTS) is an output, set low (in FW).
SIO_24/UART_CTS	5	I	SIO_24 (alternative function UART_CTS) is an input, set with internal pull-down (in FW).

The UART interface is also used to load customer developed *smart*BASIC application script.

4.5 SPI Bus

The SPI interface is an alternate function on SIO pins, configurable by *smart*BASIC.

The module is a master device that uses terminals SPI_MOSI, SPI_MISO, and SPI_CLK. SPI_CSB is implemented using any spare SIO digital output pins to allow for multi-dropping.

The SPI interface enables full duplex synchronous communication between devices. It supports a three-wire (SPI_MOSI, SPI_MISO, SPI_SCK,) bidirectional bus with fast data transfers to and from multiple slaves. Individual chip select signals are necessary for each of the slave devices attached to a bus, but control of these is left to the application through use of SIO signals. I/O data is double buffered.

The SPI peripheral supports SPI mode 0, 1, 2, and 3.

Table 17: Peripheral supports

Signal Name	Pin #	I/O	Comments
SPI_MOSI	17	O	This interface is an alternate function configurable by smart BASIC. Default in the FW pin 15 and 17 are inputs. SPIOPEN() in smart BASIC selects SPI function and changes pin14 and 16 to outputs (when in SPI master mode).
SPI_MISO	16	I	
SPI_CLK	15	O	

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4.6 I2C Interface

The I2C interface is an alternate function on SIO pins, configurable by *smart*BASIC command.

The two-wire interface can interface a bi-directional wired-OR bus with two lines (SCL, SDA) and has master /slave topology. The interface is capable of clock stretching. Data rates of 100 kbps and 400 kbps are supported.

An I2C interface allows multiple masters and slaves to communicate over a shared wired-OR type bus consisting two lines which normally sit at VCC. The RM1xx module can only be configured as an I2C master with additional constraint that it be the only master on the bus. The SCL is the clock line which is always sourced by the master and SDA is a bi-directional data line which can be driven by any device on the bus.

IMPORTANT: **It is essential to remember that pull-up resistors on both SCL and SDA lines are not provided in the module and MUST be provided external to the module.**

Table 18: I2C Interface

Signal Name	Pin #	I/O	Comments
I2C_SDA	10	I/O	This interface is an alternate function on each pin, configurable by *smart*BASIC. I2COPEN() in *smart*BASIC selects I2C function.
I2C_SCL	9	I/O	

4.7 General Purpose I/O, ADC and PWM/FREQ

4.7.1 GPIO

All SIO pins are configurable by *smart*BASIC. They can be accessed individually. Each has the following user configured features:

- Input/output direction
- Output drive strength (standard drive 0.5 mA or high drive 5mA)
- Internal pull up and pull down resistors (13 K typical) or no pull-up/down
- Wake-up from high or low level triggers on all pins

4.7.2 ADC

The ADC is an alternate function on four select SIO pins, configurable by *smart*BASIC. This enables sampling up to four external signals via an internal MUX to the 10 bit ADC. The ADC has configurable input pre-scaling and sample resolution.

4.7.2.1 Analog Interface (ADC)

Table 19: Analog interface

Signal Name	Pin No	I/O	Comments
AIN – Analog Input	17	I	This interface is an alternate function on each pin, configurable by *smart*BASIC. AIN configuration selected using GpioSetFunc() function. 10 bit resolution. Voltage scaling 1/1, 2/3, 1/3.
AIN – Analog Input	18	I	
AIN – Analog Input	19	I	
AIN – Analog Input	20	I	

4.7.3 PWM and FREQ Signal Output on up to Two SIO Pins

The PWM and FREQ output is an alternate function on SIO pins, configurable by *smart*BASIC.

The ability to output a PWM (Pulse Width Modulated) signal or FREQ output signal on up to two GPIO (SIO) output pins can be selected using GpioSetFunc() function.

PWM output signal has a frequency and duty cycle property. PWM output is generated using 32-bit hardware timers. The timers are clocked by a one-MHz clock source. Frequency is adjustable (up to 1 MHz) and the Duty cycle can be set over

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range from 0% to 100% (both configurable by *smart*BASIC command). Note, the frequency driving each of the wo SIO pins is the same but the duty cycle can be independently set for each pin.

FREQ output signal frequency can be set over a range of 0 Hz to 4 MHz (with 50% mark-space ratio).

4.8 nRESET Pin

Table 20: nRESET pin

Signal Name	Pin No	I/O	Comments
nRESET	22	I	HW reset (active low). Pull the nRESET pin low for minimum 100mS in order for the RM1xx to reset.

4.9 nAutoRUN Pin

Refer to section *nAutoRUN pin and Operating Modes* regarding operating modes and the nAutoRUN pin.

- Self-contained Run mode
- Interactive / Development mode

4.10 RM1xx VSP Service and Modes

This section discusses VSP Command mode through pulling SIO_28 high and nAutoRUN low externally. Read this section in conjunction with the VSP Configuration chapter of the RM1xx BLE Peripheral smartBASIC Extensions Guide, available under the documentation tab of the Laird RM1xx product page, available at:

https://connectivity.lairdtech.com/wireless-modules/lorawan-solutions/sentrius-rm1xx-lora-ble-modules

Note: vSP modes are only available in peripheral firmware.

Figure 7 shows the difference between VSP Bridge to UART mode and VSP Command mode and how SIO_28 and nAutoRUN need to be configured to select between these two modes.

- **VSP Bridge to UART mode** takes data sent from phone or tablet (over BLE) and sends to RM1XX to be sent out of the RM1XX UART (therefore data not stored on RM1XX).
- **VSP Command mode** takes data sent from phone of tablet and sends to RM1XX and stores that data in the RM1XX. The OTA Android or iOS application can be used to download any *smart*BASIC application script over the air to the RM1XX.

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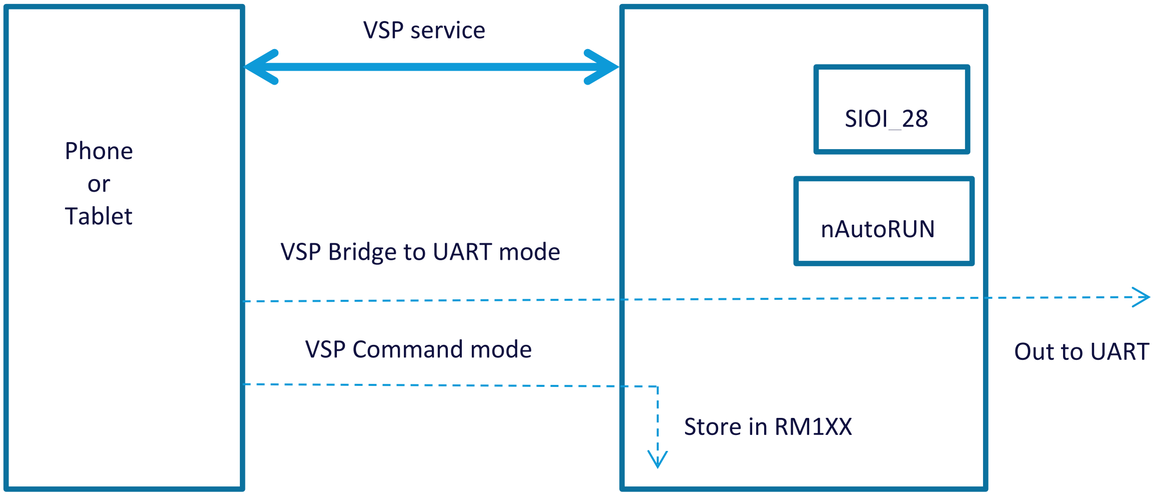

Figure 7: Difference between VSP bridge to UART mode and VSP Command mode

Table 21: vSP Modes

Mode	SIO_28 pin	nAutoRUN pin
VSP Bridge to UART Mode	Externally held HIGH	Externally held HIGH
VSP Command Mode	Externally held HIGH	Externally held LOW

SIO_28 High (externally) selects the VSP service, and together when nAutoRUN is also Low (externally) selects VSP Command mode. If SIO_28 is High and whilst nAutoRUN is High (externally), this selects VSP Bridge to UART mode.

When SIO_28 on module is set HIGH (externally), VSP is enabled and auto-bridged to UART when connected. However, for VSP Command mode, auto-bridge to UART is not required. With SIO_28 set to **High** and nAutoRUN set to Low, VSP Command mode is entered and you can then download the smartBASIC application onto the module over the air (OTA) from the phone (or tablet).

4.11 Two-Wire SWD Programming/Debug Interface

Note: JTAG required for upgrading between Central and Peripheral firmware.

Signal Name (hidden name)	Pin No	I/O	Comments
nRESET (SWDIO)	22	I/O	
NC (SWDCLK)	23	I	

The connector for the (2-Wire SWD Programming/Debug Interface) MPN is as follows:

Reference	Part	Description
JP1 Note1	FTSH-105	Header, 1.27mm, SMD, 10-way, FTSH-105-01-L-DV Samtec

Note 1: Reference the RM1xx development board schematic. Figure 8 shows the wiring for the 2-Wire SWD Programming/Debug Interface connector and RM1xx module hidden 2-Wire SWD Programming/Debug Interface pins.

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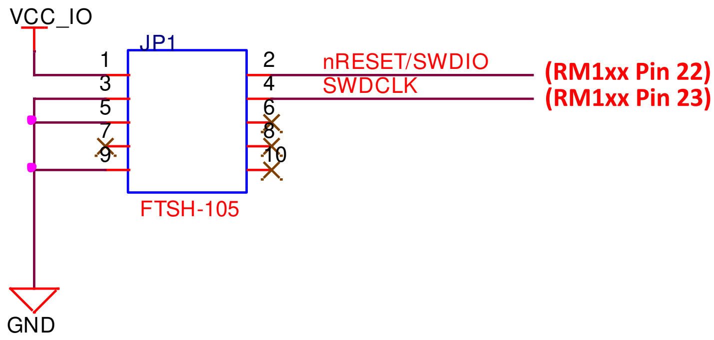

Figure 8: Wiring for 2-Wire SWD Programming/Debug Interface connector to SWD Programming/Debug interface on RM1xx module

4.12 RM1xx on-board chip antenna characteristics

The RM1xx on-board chip monopole antenna radiated performance depends on the host PCB layout.

RM1xx development board was used for RM1xx development and antenna performance evaluation. To obtain similar performance follow guidelines in section *PCB Layout on Host PCB for RM1xx* to allow the on-board antenna to radiate and reduce proximity effects due to nearby host PCB GND copper or metal covers.

RM1xx on-board antenna part number: ACX: AT5020-E3R0HBANT/LF

5 Hardware Integration Suggestions

5.1 Circuit

The RM1xx-series module is easy to integrate requiring no external components on the customer's board apart from those required by customer for development and in customers end application.

Checklist (for Schematic):

- **VCC**
  The module Vcc should be chosen to optimize either range or power consumption and must be within the valid operating range and noise/ripple specification of RM1xx. Pins VCC_BLE and VCC_LORA should be tied together and decoupling capacitors for filtering should be added close to the module VCC pins. The supply must be able to deliver enough current for the sum of the BLE and LoRa transmitter currents for the chosen Vcc (plus reasonable headroom). Power-on reset circuitry within RM1xx series module incorporates brown-out detector, thus simplifying power supply design. Upon application of power, the internal power-on reset ensures module starts correctly.
- **AIN (ADC) and SIO pin IO voltage levels**
  RM1xx SIO operating voltage levels are from 0V to VCC. Ensure input voltage levels into SIO do not exceed VCC also (if VCC source is a battery whose voltage will drop). Ensure ADC pin maximum inpu voltage for damage is not violated.
- **AIN (ADC) impedance and external voltage divider setup**
  If one wanted to measure with ADC, a voltage higher than 3.6V then one can connect a high impedance voltage divider to lower the voltage to the ADC input pin. Other methods are to use a voltage buffer or FET transistor in conjunction with a low resistance voltage divider.
  High impedance values of a voltage divider connected to an AIN pin will introduce ADC inaccuracy. Laird recommends the following solution for setup of a voltage divider when used with the RM1xx ADC:
  - Connect a capacitor between AIN and ground (if the voltage divider presents high impedance).
    Normally, when ADC is not sampling, the ADC (AIN) impedance is a very high value and can be considered an open circuit. The moment ADC is sampling, ADC (AIN) impedance is 200k-600k and lowers the AIN voltage. However, when the capacitor is connected it

should keep the AIN voltage at previous level for an adequate time period while sampling, minimizing the effect of the high resistance value of the external voltage divider. The capacitor should be big enough to hold voltage up for the required time period, i.e. 20 us for 8 bit sampling or 68 us for 10 bit sampling. If you use a FET transistor to open the current flow through the circuit momentarily before sampling, allow enough time for the capacitor to fully charge before sampling. During the sampling period, multiple samples are made and the ADC output value is the mean value from the sample pool. The sample pool is created during 20 us period for 8 bit sampling, 36 us period for 9 bit sampling, and 68 bit period for 10 bit sampling.

- **Two-Wire SWD Programming/Debug Interface (JTAG)**
  Add 2-Wire SWD Programming/Debug Interface as detailed in section *2-Wire SWD Programming/Debug Interface*.

  Note: Required if upgrading between central and peripheral firmware capability will be necessary during production.

- **UART**
  The UART is required for loading customer *smart*BASIC application and firmware. Add connector to allow UART to be interfaced to PC (via UART –RS232 or UART- USB).

  Note: Not capable of upgrading between central and peripheral firmware via UART.

- **UART_RX and UART_CTS**
  SIO_22 (alternative function UART_RX) is an input, set with internal weak pull-up (in FW). The pull-up prevents the module from going into deep sleep when UART_RX line is idling.
  SIO_24 (alternative function UART_CTS) is an input, set with internal weak pull-down (in FW). This pull-down ensures the default state of the UART_CTS will be asserted which means can send data out of the UART_TX line. In the case when UART_CTS is not connected (which we do not recommend).
- **nAutoRUN pin and operating mode selection**
  nAutoRUN pin needs to be externally held high or low to select between the two RM1xx operating modes at power-up:
  - Self-contained Run mode (nAutoRUN pin held at 0V).
  - Interactive/development mode (nAutoRUN pin held at VCC).
- Make provision to allow operation in the required mode. Add jumper to allow nAutoRUN pin to be held high or low (via 10K resistor) OR driven by host GPIO.
- **I2C**
  It is essential to remember that pull-up resistors on both I2C_SCL and I2C_SDA lines are not provided in the RM1xx module and MUST be provided external to the module as per I2C standard.
- **SPI**
  Implement SPI chip select using any unused SIO pin within your *smart*BASIC application script then SPI_CS is controlled from *smart*BASIC application allowing multi-dropping.
- **SIO pin direction**
  RM1xx modules shipped from production with *smart*BASIC runtime engine FW, all SIO pins (with “default function” of “DIO”) are mostly digital inputs (see Pin Definitions Table 2). Use your *smart*BASIC application script to change the direction of any SIO pin that is required to be an output in your design. Also these SIO pins that are inputs have by default (in FW) an internal pull-up or pull-down resistor-enabled (see Pin Definitions Table 2). This was done to avoid floating inputs (which can also cause current consumption in low power modes (e.g. Standby Doze) to drift with time. In any case customer can disable the PULL-UP through their *smart*BASIC application.
- **SIO_28 pin** and Over the Air *smart*BASIC application download feature
  SIO_28 is an input, set with internal pull-down (in FW). Refer to latest FW release documentation on how SIO_28 is used for Over the Air *smart*BASIC application download feature. SIO_28 pin has to be pulled high externally to enable

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the feature. Decide if this feature is required in production. When SIO_28 is high, ensure SIO_25 (nAutoRun) is NOT high at same time, otherwise you cannot load the *smart*BASIC application script.

- **nRESET pin (active low)**
  Hardware reset. Wire out to push button or drive by host.
  By default module is out of reset when power applied to VCC pin.

5.2 PCB Layout on Host PCB – General

Checklist (for PCB):

- MUST locate RM1xx module close to the edge of PCB (mandatory for RM1xx for on-board chip antenna to radiate properly).
- Use solid GND plane on inner layer (for best EMC and RF performance).
- All module GND pins MUST be connected to host PCB GND.
- Place GND vias close to module GND pads as possible.
- Unused PCB area on the top layer can be flooded with copper but place GND vias regularly to connect copper flood to inner GND plane. If GND flood copper exists on the top PCB layer (under of the RM1xx module), then connect with GND vias to inner GND plane and ensure that it is covered with solder mask.
- Route traces to avoid noise being picked up on VCC supply and AIN (analogue) and SIO (digital) traces.
- Ensure no exposed copper beneath the module (refer to land pattern of RM1xx development board).

5.2.1 BLE Chip Antenna Keep-out on Host PCB

- Ensure there is no copper in the antenna keep-out area on any layers of the host PCB. Keep all mounting hardware and metal clear of the area to allow proper antenna radiation.
- For best antenna performance, place the RM1xx module on the edge of the host PCB, preferably in the corner with the antenna facing the corner.
- The RM1xx development board has the RM1xx module on the edge of the board (not in the corner). The antenna keep-out area is defined by the RM1xx development board which was used for module development (and antenna performance evaluation) is shown in Figure 9, where the antenna keep-out area is composed of PCB dielectric (no copper) sitting under the RM1xx antenna.
- A different host PCB thickness dielectric will have small effect on antenna.
- The antenna-keep-out defined in Host PCB Land Pattern and Antenna Keepout applies when the RM1xx is placed in the corner of the host PCB. When RM1xx-SM cannot be placed as such, it must be placed on the edge of the host PCB and the antenna keep out must be observed. An example is shown in Figure 9.

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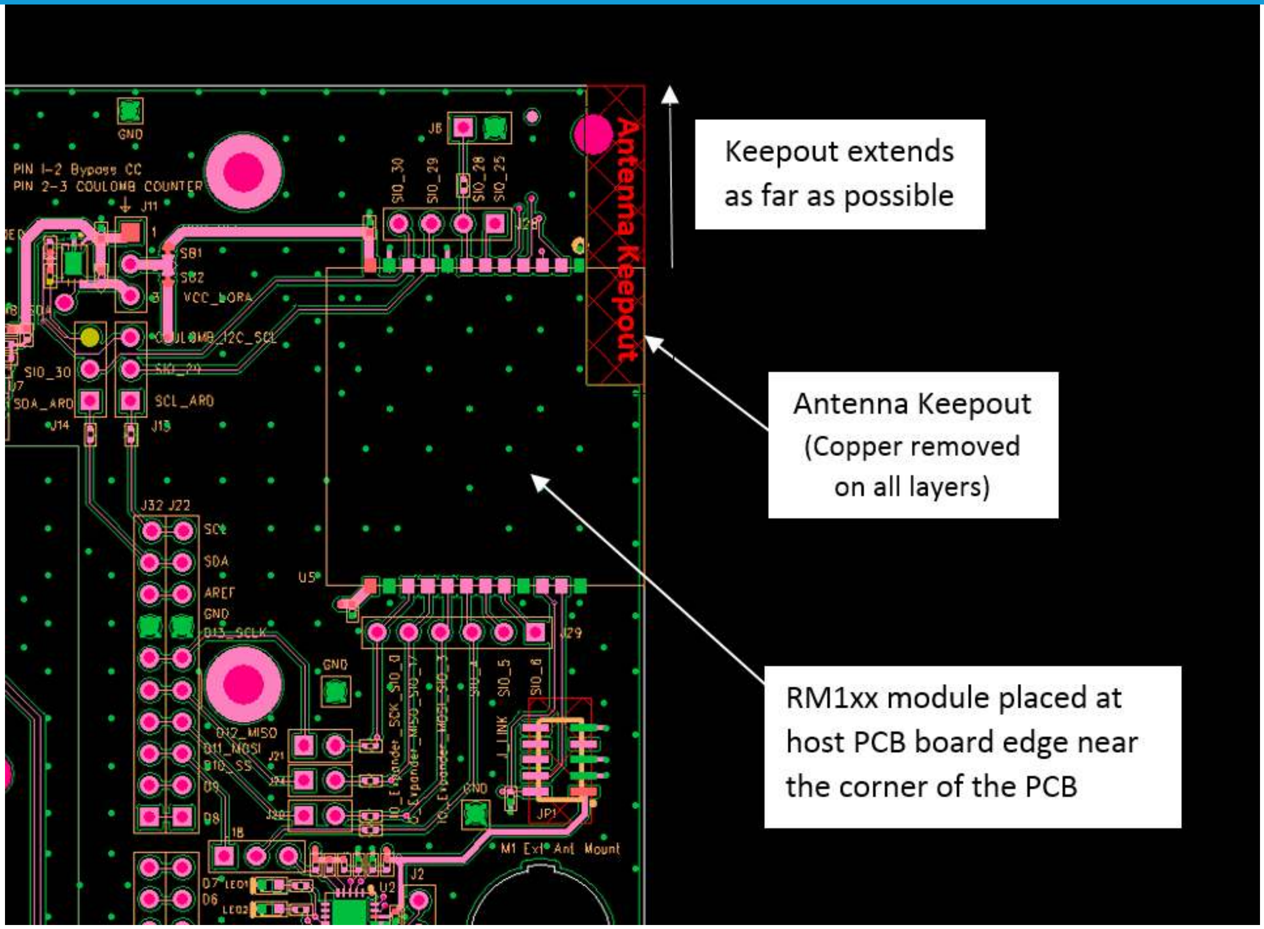

Figure 9: Antenna keepout on DVK-RM1xx PCB (shown in red) with RM1xx module placed near the corner.

Note: 1. RM1xx module placed on edge of host PCB (close to the corner of the PCB).

2. Copper cut-away on all layers in "antenna Keep-out" for a host PCB.

5.2.2 Antenna Keep-out and Proximity to Metal or Plastic

Checklist (for metal /plastic enclosure):

- Minimum safe distance for metals without seriously compromising the antenna (tuning) is 40mm top/bottom and 30mm left or right.
- Metal close to the RM1xx chip monopole antenna (bottom, top, left, right, any direction) will have degradation on the antenna performance. How much; that is entirely system dependent which means some testing by customer required (in their host application).
- Anything metal closer than 20mm will start to significantly degrade performance (S11, gain, radiation efficiency).
- It is best that the customer tests the Range with mock-up (or actual prototype) of the product to assess effects of enclosure height (and material whether metal or plastic).

5.3 LoRa External Antenna Integration with RM1xx

Please refer to the regulatory sections for FCC/IC, and CE, for details of use of RM1xx with external antennas.

The RM1xx has been designed to operate with the below external antennas (with a maximum gain of 2dBi). The required antenna impedance is 50 ohms. See Table 22.

Table 22: LoRa External antennas for the RM1xx

External Antenna Part Number	Laird Part Number	Mfg.	Type	Gain (dBi)	Connector Type	RM1xx Part number
RFDPA131015IMBB301	0600-00060	Walsin	Dipole	0.9	U.FL	RM191/RM186
WPANTDP036-R5A	-	World Products	Dipole	2.0	U.FL	RM191/RM186
S152CL-L-PX-915S	-	Nearson	Dipole	2.0	U.FL	RM191
S152CL-L-PX-868S	-	Nearson	Dipole	2.0	U.FL	RM186

6 Mechanical Details

6.1 RM1xx Mechanical Details

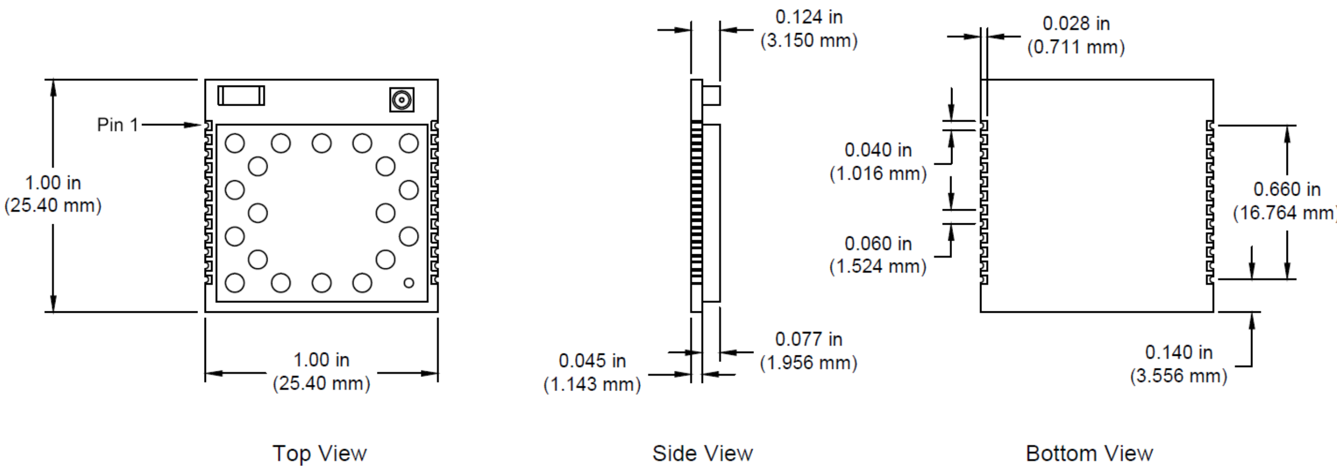

Figure 10: RM1xx Mechanical drawings

Development Kit Schematics can be found in the Documentation tab of the RM1xx product page:
https://connectivity.lairdtech.com/wireless-modules/lorawan-solutions/sentrius-rm1xx-lora-ble-modules

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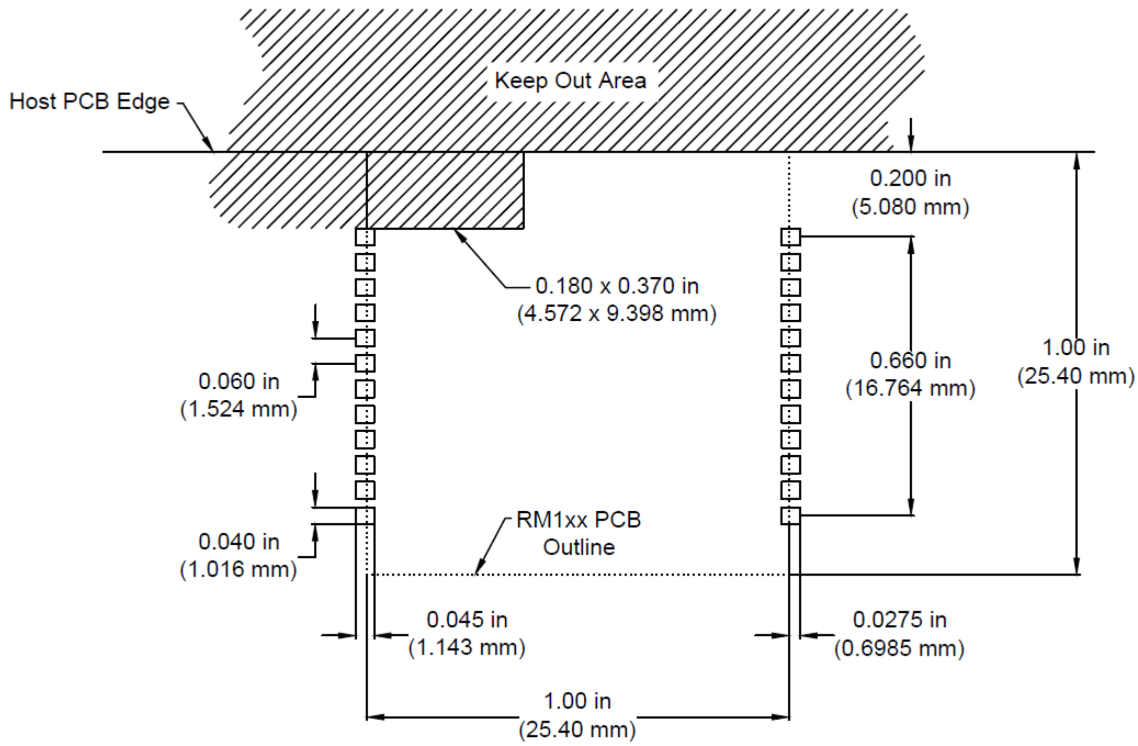
6.2 Host PCB Land Pattern and Antenna Keep-out for RM1xx



Application Notes

1. Ensure there is no copper in the antenna 'keep out area' on any layers of the host PCB. Also keep all mounting hardware or any metal clear (Refer to 5.2.2) on of the area to reduce effects of proximity detuning the antenna and to help antenna radiate properly.

3. For best BLE chip antenna performance, the module MUST be placed on the edge of the host PCB (preferably in the corner) with the antenna facing the corner. If RM1xx is not placed in corner, but on edge of host PCB, the antenna "Keep Out Area" is extended (see Note 4).

4. RM1xx development board has an RM1xx placed on the edge of the PCB board (and not in corner) the Antenna keep out area is extended out to the corner of the development board, see section *PCB Layout on Host PCB - General*. This was used for module development and antenna performance evaluation.

5. Ensure no exposed copper under module on host PCB.

6. The user may modify the PCB land pattern dimensions based on their experience and / or process capability.

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7 Application Note for Surface Mount Modules

7.1 Introduction

Laird Technologies surface mount modules are designed to conform to all major manufacturing guidelines. This application note is intended to provide additional guidance beyond the information that is presented in the User Manual. This Application Note is considered a living document and will be updated as new information is presented.

The modules are designed to meet the needs of a number of commercial and industrial applications. They are easy to manufacture and conform to current automated manufacturing processes.

Shipping

Modules are shipped in ESD (Electrostatic Discharge) safe trays that can be loaded into most manufacturers pick and place machines. Layouts of the trays are provided in Figure 11.

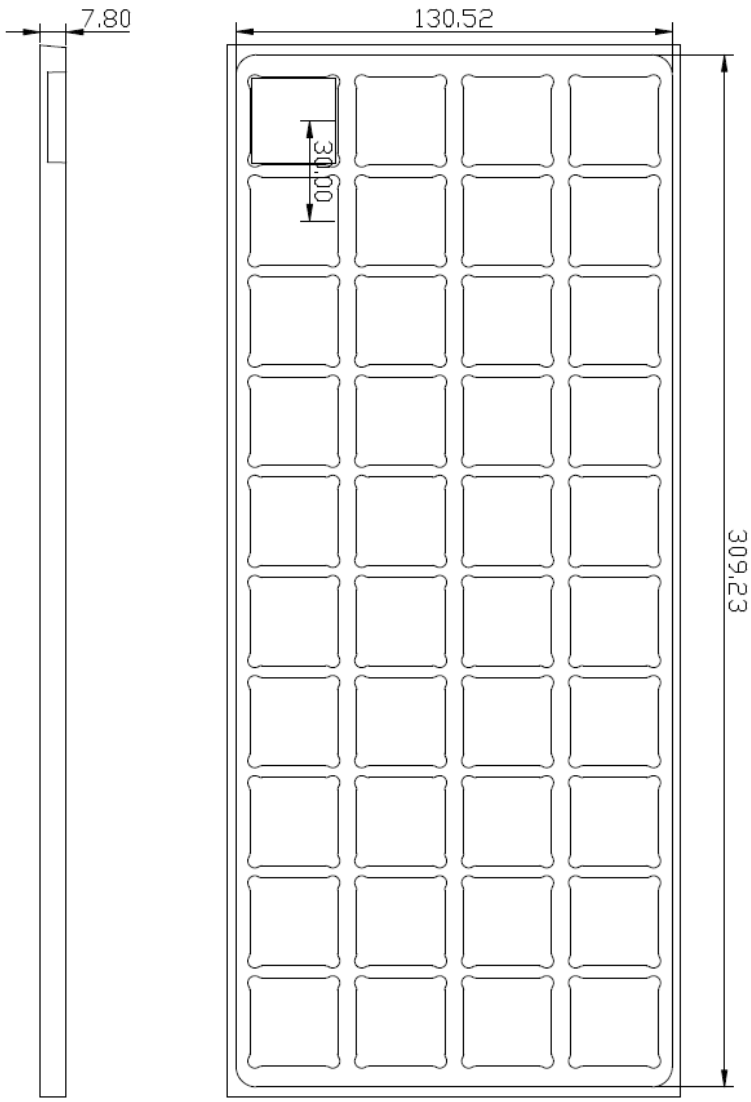

Figure 11: RM1xx Shipping Tray Details

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7.2 Reflow Parameters

Prior to any reflow, it is important to ensure the modules were packaged to prevent moisture absorption. New packages contain desiccate (to absorb moisture) and a humidity indicator card to display the level maintained during storage and shipment. If directed to *bake units* on the card, see Table 23 and follow instructions specified by IPC/JEDEC J-STD-033. A copy of this standard is available from the JEDEC website: http://www.jedec.org/sites/default/files/docs/jstd033b01.pdf

Note: The shipping tray cannot be heated above 65°C. If baking is required at the higher temperatures displayed in in Table 23, the modules must be removed from the shipping tray.

Any modules not manufactured before exceeding their floor life should be re-packaged with fresh desiccate and a new humidity indicator card. Floor life for MSL (Moisture Sensitivity Level) 3 devices is 168 hours in ambient environment ≤30°C/60%RH.

Table 23: Recommended baking times and temperatures

MSL	125°C Baking Temp.		90°C/≤ 5%RH Baking Temp.		40°C/ ≤ 5%RH Baking Temp.	
	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%	Saturated @ 30°C/85%	Floor Life Limit + 72 hours @ 30°C/60%
3	9 hours	7 hours	33 hours	23 hours	13 days	9 days

Laird surface mount modules are designed to be easily manufactured, including reflow soldering to a PCB. Ultimately it is the responsibility of the customer to choose the appropriate solder paste and to ensure oven temperatures during reflow meet the requirements of the solder paste. Laird surface mount modules conform to J-STD-020D1 standards for reflow temperatures.

Important: During reflow, modules should not be above 260° and not for more than 30 seconds.

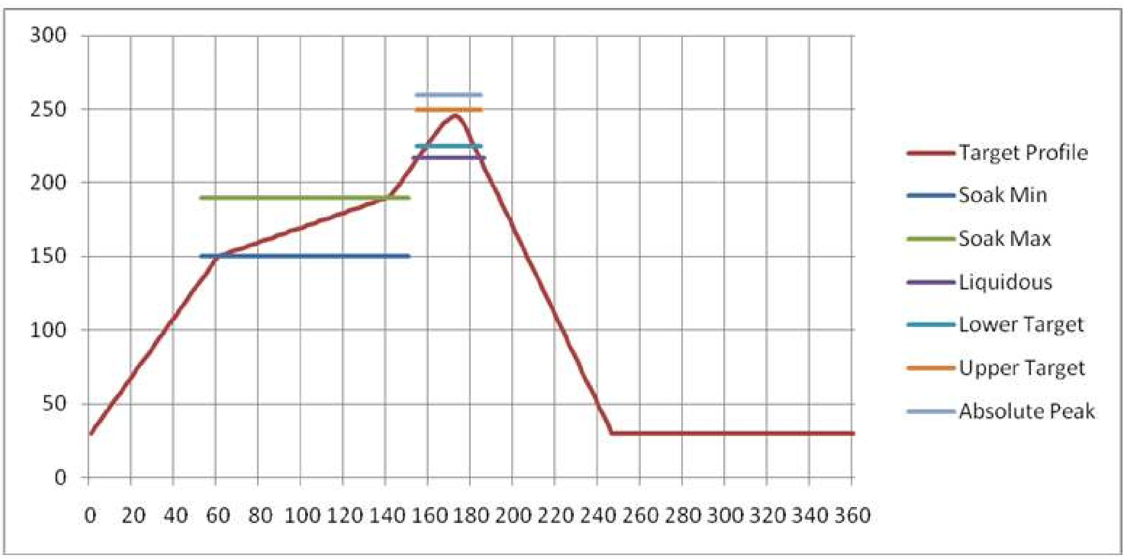

Figure 12: Recommended Reflow Temperature

Temperatures should not exceed the minimums or maximums presented in Table 24.

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Table 24: Recommended Maximum and minimum temperatures

Specification	Value	Unit
Temperature Inc./Dec. Rate (max)	1~3	°C / Sec
Temperature Decrease rate (goal)	2-4	°C / Sec
Soak Temp Increase rate (goal)	.5 - 1	°C / Sec
Flux Soak Period (Min)	70	Sec
Flux Soak Period (Max)	120	Sec
Flux Soak Temp (Min)	150	°C
Flux Soak Temp (max)	190	°C
Time Above Liquidous (max)	70	Sec
Time Above Liquidous (min)	50	Sec
Time In Target Reflow Range (goal)	30	Sec
Time At Absolute Peak (max)	5	Sec
Liquidous Temperature (SAC305)	218	°C
Lower Target Reflow Temperature	240	°C
Upper Target Reflow Temperature	250	°C
Absolute Peak Temperature	260	°C

8 FCC and IC Regulatory Statements

Model	US/FCC	CANADA/IC
RM191-SM	SQG-RM191	3147A-RM191

The OEM must follow the regulatory guidelines and warnings listed below to inherit Laird' modular approval.

The RM191-SM holds full modular approvals and has been certified for integration to products only by OEM integrators under the following conditions:

1. *The antenna(s) must be installed such that a minimum separation distance of 30mm is maintained between the radiator (antenna) and all persons at all times.*
2. *The transmitter module must not be operating in conjunction with any other antenna or transmitter, except in accordance with FCC multi-transmitter product procedures.*

As long as the two conditions above are met, further transmitter testing 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.).

IMPORTANT NOTE: In the event that these conditions cannot be met (for certain configurations or co-location with another transmitter), then the FCC and Industry Canada authorizations are no longer considered valid and the FCC ID and IC Certification Number 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 and Industry Canada authorization.

The RM191-SM LoRa transmitter has been designed and approved to operate with the antennas listed below with a maximum gain of 2 dBi. The required antenna impedance is 50 ohms.

External Antenna Part Number	Laird Part Number	Mfg.	Type	Gain (dBi)	Connector Type	RM1xx Part Number
RFDPA131015IMBB301	0600-00060	Walsin	Dipole	0.9	U.FL	RM191-SM

WPANTDP036-R5A	-	World Products	Dipole	2.0	U.FL	RM191-SM
S152CL-L-PX-915S	-	Nearson	Dipole	2.0	U.FL	RM191-SM

Note: For the LoRa (external) dipole antenna, the OEM is free to choose another vendor's antenna of like type and equal or lesser gain (2dBi) and still maintain compliance. Reference FCC Part 15.204(c)(4) for further information on this topic.

The RM191 BLE transmitter contains an on-board 2.4GHz chip antenna…

Item	Part Number	Mfg.	Type	Gain (dBi)	RM1xx Part Number
1	AT5020-E3R0HBANT/LF	ACX	Ceramic	-1.5	RM191-SM

8.1 Power Exposure Information

Federal Communication Commission (FCC) Radiation Exposure Statement:

To comply with FCC RF exposure limits for general population / uncontrolled exposure, the antenna(s) used for this transmitter must be installed to provide a separation distance of at least 30mm from all persons and operating in conjunction with any other antenna or transmitter.

OEM Responsibilities

WARNING: The OEM must ensure that FCC and Industry Canada labelling requirements are met. This includes a clearly visible label on the outside of the OEM enclosure specifying the appropriate Laird FCC identifier for this product.

Contains FCC ID: SQG-RM191
Contains IC: 3147A-RM191

The OEM of the RM191-SM module must only use the approved antenna(s) listed above, which have been certified with this module. The OEM integrator has to be aware not to provide information to the end user regarding how to install or remove this RF module or change RF related parameters in the user manual of the end product.

The user manual for the end product must also include the following information in a prominent location:

To comply with FCC and Industry Canada RF exposure limits for general population / uncontrolled exposure, the antenna(s) used for this transmitter must be installed to provide a separation distance of at least 30mm from all persons and operating in conjunction with any other antenna or transmitter, except in accordance with FCC multi-transmitter product procedures.
If the size of the end product is larger than 8x10cm, then the following FCC part 15.19 statement has to also be available on visible on outside of device:

The enclosed device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) This device must accept any interference received, including interference that may cause undesired operation

Label and text information should be in a size of type large enough to be readily legible, consistent with the dimensions of the equipment and the label. However, the type size for the text is not required to be larger than eight point.

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CAUTION: The OEM should have their device which incorporates the RM191-SM tested by a qualified test house to verify compliance with FCC Part 15 Subpart B limits for unintentional radiators.

WARNING: Changes or modifications not expressly approved by Laird could void the user's authority to operate the equipment.

FCC Interference Statement

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 correct the interference by one or more of the following measures:

- Re-orient or relocate the receiving antenna
- Increase the separation between the equipment and the receiver
- Connect the equipment to 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.

FCC Warning:

"THIS DEVICE COMPLIES WITH PART 15 OF THE FCC RULES OPERATION IS SUBJECT TO THE FOLLOWING TWO CONDITIONS: (1) THIS DEVICE MAY NOT CAUSE HARMFUL INTERFERENCE, AND (2) THIS DEVICE MUST ACCEPT ANY INTERFERENCE RECEIVED, INCLUDING INTERFERENCE THAT MAY CAUSE UNDESIRED OPERATION.

Industry Canada (IC) Warning:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

French equivalent is:

Le présent appareil est conforme aux CNR d'Industrie Canada applicable aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

IC Radiation Exposure Statement

To comply with Industry Canada RF exposure limits for general population / uncontrolled exposure, the antenna(s) used for this transmitter must be installed to provide a separation distance of at least 30mm from all persons and must not be operating in conjunction with any other antenna or transmitter.

REMARQUE IMPORTANTE

Déclaration IC d'exposition aux radiations

Pour se conformer à Industrie Canada RF limites d'exposition pour la population générale / exposition non contrôlée, l'antenne utilisée pour ce transmetteur doit être installée pour fournir une distance d'au moins 30 mm de toutes les personnes et ne doit pas fonctionner en conjonction avec toute autre antenne ou transmetteur.

Modular Approval

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.).

Approbation modulaire

OEM intégrateur est toujours responsable de tester leur produit final pour les exigences de conformité supplémentaires

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nécessaires à ce module installé (par exemple, les émissions de périphériques numériques, les exigences de périphériques PC, etc.)

IMPORTANT NOTE:

In the event that these conditions cannot be met (for example certain laptop configurations or co-location with another transmitter), then the Canada authorization is no longer considered valid and the IC ID 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 Canada authorization.

NOTE IMPORTANTE:
Dans le cas où ces conditions ne peuvent être satisfaites (par exemple pour certaines configurations d'ordinateur portable ou de certaines co-localisation avec un autre émetteur), l'autorisation du Canada n'est plus considéré comme valide et l'ID IC ne peut pas être utilisé sur le produit final. Dans ces circonstances, l'intégrateur OEM sera chargé de réévaluer le produit final (y compris l'émetteur) et l'obtention d'une autorisation distincte au Canada.

Le produit final doit être étiqueté dans un endroit visible avec l'inscription suivante: " RM191-SM Contient des IC: 3147A-RM191";

9 CE Regulatory

The RM186 has been tested for compliance with relevant standards for the EU market. The RM186 module has been tested with a 2.0dBi external dipole antenna for LoRa, and the -1.5dBi on-board chip antenna for the BLE transmitter. For the external LoRa dipole antenna, the OEM can operate any other type of antenna but must ensure that the gain does not exceed 2.0dBi to maintain the Laird Technologies approval.

The OEM should consult with a qualified test house before entering their device into an EU member country to make sure all regulatory requirements have been met for their complete device.

Reference the Declaration of Conformities listed below for a full list of the standards that the modules were tested to. Test reports are available upon request.

9.1 Antenna Information

The external flying lead U.FL dipole antennas for the 868MHz LoRa radio listed below were tested for use with the RM186. For CE mark countries, the OEM is free to use any manufacturer's antenna and type of antenna as long as the gain is less than or equal to the highest gain approved for use (2.0dBi) Contact a Laird Technologies representative for more information regarding adding antennas.

Item	LoRa Antenna Part#	Laird Part Number	Mfg.	Type	Gain (dBi)
1	RFDPA131015IMBB301	0600-00060	Walsin	Dipole	0.9
2	WPANTDP036-R5A		World Products	Dipole	2.0
3	S152CL-L-PX-868S		Nearson	Dipole	2.0

The BLE transmitter on board the RM186 has been approved with an on-board -1.5dBi chip antenna…

Item	Part Number	Mfg.	Type	Gain (dBi)	RM1xx Part Number
1	AT5020-E3R0HBANT/LF	ACX	Ceramic	-1.5	RM191-SM

Note: The RM186 module internal BLE chipset IC pins are rated 4 kV (ESD HBM). ESD can find its way through the external *2-Wire SWD Programming/Debug Interface* connector (if used on the customers design), if discharge is applied directly. Customer should ensure adequate protection against ESD on their end product design (using the RM186 module) to meet relevant ESD standard (for CE, this is EN301-489).

10 EU Declarations of Conformity

10.1 RM186-SM

Manufacturer:	Laird
Product:	RM186-SM
EU Directive:	RTTE 1995/5/EC
Conformity Assessment:	Annex IV

Reference standards used for presumption of conformity:

Article Number	Requirement	Reference standard(s)
3.1a	Health and Safety	EN60950-1:2006+A2:2013
3.1b	Protection requirements with respect to electromagnetic compatibility	EN 301 489-1 V1.9.2 (2011-09) EN 301 489-3 V1.6.1 (2013-08) EN 301 489-17 V2.2.1 (2012-09) Emissions: EN55022:2006/A1:2007 (Class B) Immunity: EN61000-4-2:2009 EN61000-4-3:2006/A1:2008/A2:2010
3.2	Means of the efficient use of the radio frequency spectrum	EN 300 220-2 V2.4.1 (2012-05) EN 300 328 V1.9.1 (2015-02)

Declaration:

We, Laird, declare under our sole responsibility that the essential radio test suites have been carried out and that the above product to which this declaration relates is in conformity with all the applicable essential requirements of Article 3 of the EU Directive 1999/5/EC, when used for its intended purpose.

Place of Issue:	Laird W66N220 Commerce Court, Cedarburg, WI 53012 USA tel: +1-262-375-4400 fax: +1-262-364-2649
Date of Issue:	April 2016
Name of Authorized Person:	Thomas T Smith, Director of EMC Compliance

11 Ordering Information

Part Number	Description
RM186-SM	Intelligent LoRa/BLE Module [868MHz LoRa for Europe] featuring *smart*BASIC
RM191-SM	Intelligent LoRa/BLE Module [915MHz LoRa for US] featuring *smart*BASIC
DVK – RM186-SM	Development board with RM186-SM module soldered in place
DVK – RM191-SM	Development board with RM191-SM module soldered in place

11.1 General Comments

This is a preliminary datasheet. Please check with Laird for the latest information before commencing a design. If in doubt, ask.

12 Bluetooth SIG Qualification

12.1 Overview

The RM186 and RM191 modules are listed on the Bluetooth SIG website as qualified End Products.

Design Name	Owner	Declaration ID	Link to listing on the SIG website
RM186-SM	Laird	D030952	https://www.bluetooth.org/tpg/QLI_viewQDL.cfm?qid=30952
RM191-SM	Laird	D030952	https://www.bluetooth.org/tpg/QLI_viewQDL.cfm?qid=30952

It is a mandatory requirement of the Bluetooth Special Interest Group (SIG) that every product implementing Bluetooth technology has a Declaration ID. Every Bluetooth design is required to go through the qualification process, even when referencing a Bluetooth Design that already has its own Declaration ID. The Qualification Process requires each company to register as a member of the Bluetooth SIG – www.bluetooth.org

The following is a link to the Bluetooth Registration page: https://www.bluetooth.org/login/register/

For each Bluetooth Design it is necessary to purchase a Declaration ID. This can be done before starting the new qualification, either through invoicing or credit card payment. The fees for the Declaration ID will depend on your membership status, please refer to the following webpage:

https://www.bluetooth.org/en-us/test-qualification/qualification-overview/fees

For a detailed procedure of how to obtain a new Declaration ID for your design, please refer to the following SIG document, (login is required to views this document):

https://www.bluetooth.org/DocMan/handlers/DownloadDoc.ashx?doc_id=283698&vId=317486

Qualification Steps When Referencing a Laird End Product Design

To qualify your product when referencing a Laird end-product design, follow these steps:

1. To start a listing, go to: https://www.bluetooth.org/tpg/QLI_SDoc.cfm

   Note: A user name and password are required to access this site.

2. In step 1, select the option, New Listing and Reference a Qualified Design.
3. Enter D030952 in the End Product table entry.
4. Select your pre-paid Declaration ID from the drop down menu or go to the Purchase Declaration ID page.

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Note: Unless the Declaration ID is pre-paid or purchased with a credit card, you cannot proceed until the SIG invoice is paid.

5. Once all the relevant sections of step 1 are finished, complete steps 2, 3, and 4 as described in the help document accessible from the site.

   Your new design will be listed on the SIG website and you can print your Certificate and SDoC.

For further information please refer to the following training material:

https://www.bluetooth.org/en-us/test-qualification/qualification-overview/listing-process-updates

Note: If using the RM1xx with Laird Firmware and *smart*BASIC script, you can skip Controller Subsystem, Host Subsystem, and Profile Subsystem.

12.2 Additional Assistance

Please contact your local sales representative or our support team for further assistance:

Laird Technologies Connectivity Products Business Unit
Support Centre: https://connectivity.lairdtech.com/resources/support

Email: wireless.support@lairdtech.com

Phone: Americas: +1-800-492-2320
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Web: https://connectivity.lairdtech.com/wireless-modules/lorawan-solutions/sentrius-rm1xx-lora-ble-modules