Freescale Semiconductor
Application Note

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A Receiver Using Romeo2

Step-by-step Design for ISM Bands

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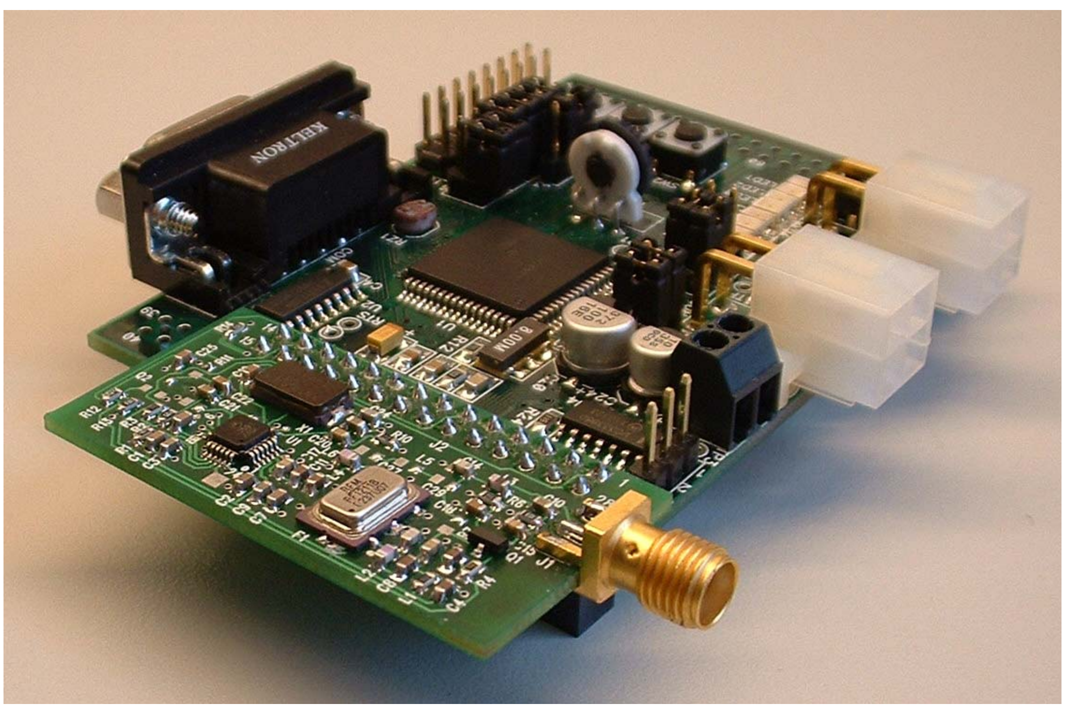


Introduction

This document provides a step-by-step approach to designing an optimized receiver using Romeo2[1].

Even though the description is based on a 433.92 MHz design, bills of material are provided for almost any ISM band: 315 MHz, 433.92 MHz, 868.3 MHz, and 916.5 MHz.

Romeo2 Presentation

Main Features

Romeo2 is a highly integrated UHF super heterodyne[2] receiver designed for data transfer application. Its local oscillator is a PLL clocked by a crystal oscillator.

Some specific features are:

- A data manager, able to detect a programmable word in a Manchester coded RF frame and to transmit the demodulated signal on the SPI port
- A strobe oscillator, to do a RUN/SLEEP cycle without the help of the MCU, for lower system power consumption
- Dual modulation type capability; Romeo2 can switch from ASK to FSK in software.
- LQFP24 package

Romeo2 is controlled through several pins:

- SCLK, MOSI, MISO, RESETB: signal for the SPI port
- STROBE: connection to the external R and C that define the oscillation frequency. Also allows Romeo2 to be driven by the MCU
- RFIN: RF signal input

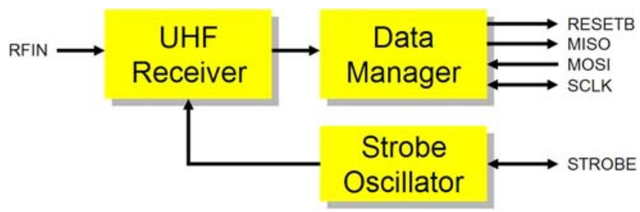


Figure 1. Romeo2

1. Romeo2 is the codename for MC33591FTA. For more technical data, refer to the MC33591FTA specification available on the Freescale Semiconductor web site at http://www.freescale.com.
2. A super heterodyne receiver converts the RF signal to an IF signal by mixing it with a local signal produced by an oscillator. The IF signal is usually at a low frequency, which simplifies filtering and amplification.

Typical Application

A simple RF receiver can be realized with few external components.

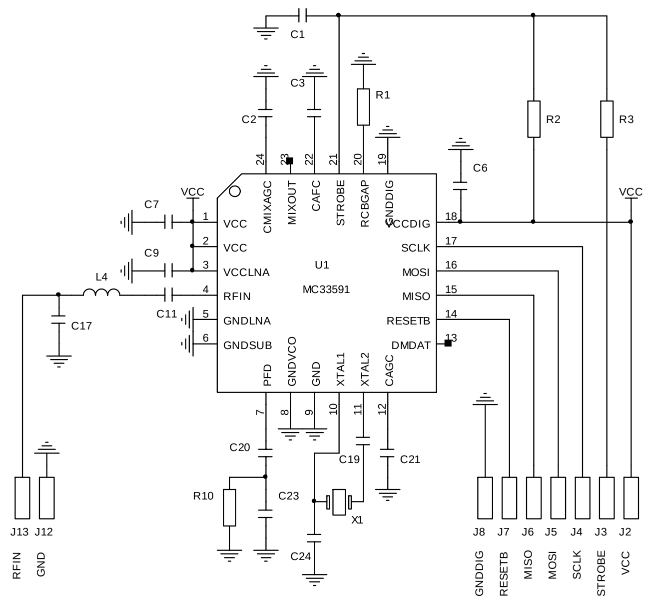


Figure 2. A Typical Application

U1 is Romeo2. The external crystal X1 defines the operating frequency of the internal PLL. The loop filter of the PLL is comprised of C20, C23, and R10.

The internal AGC[1] requires an external capacitor C2 to set its time constant.

C3 is required for AFC[2], to adjust the center frequency of the internal IF[3] amplifier.

C1 and R2 define the frequency of the strobe oscillator that sets the ON-OFF cycling of the receiver.

R3 allows the MCU to drive the state of the receiver directly.

C21 is used in OOK for the IF amplifier AGC. In the case of FSK, this capacitor is used as an internal low pass filter.

C17, L4 and C11 form a matching network to match the RFIN impedance of Romeo2 to the impedance of the antenna connected to J13.

R1 is used to set internal biasing.

1. Automatic Gain Control. This increases the dynamic range of the receiver (the difference between the smallest and the largest signal the receiver can process).
2. Automatic Frequency Control. A system that uses a reference signal to adjust the frequency of a filter or receiver.
3. Intermediate Frequency amplifier in a super heterodyne receiver.

A microcontroller is used to control RESETB, MISO, MOSI, and SCLK (and STROBE if necessary).

Romeo2 internal registers can then be programmed to adjust various parameters:

- Frequency of operation
- Strobe oscillator operation
- Data Manager operation (data rate and frame content, for example)
- Mixer Gain

This simple design has the following advantages.

- Cost effective
- Compact
- High sensitivity
- Low consumption, due to the strobe oscillator
- Low MCU overhead, due to Data Manager

However, it does have the following drawbacks.

- Poor EMC performance in noisy environments with high level RF interference due to low filtering effect between antenna and RFIN
- C21 is shared in OOK and FSK; for dual operation mode and various data rates, the value of C21 is a compromise

The proposed design should not suffer these drawbacks and should maintain a high sensitivity.

RF Module Specifications

Overview

The Romeo2 RF Module is a part of a project to make a receiver for long-range remote control[1].

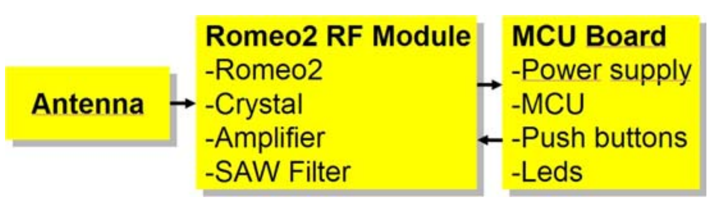


Figure 3. Receiver Using the Romeo2 RF Module

1. The range is more than one mile outdoors. Specifications are compatible with ETSI regulations.

The receiver is composed of three parts:

- An MCU board
- A Romeo2 RF Module with all RF components, reusable for other design
- An antenna

Specifications

- Sensitivity higher than -108dBm at 1200bps (Manchester coding)
- High out of band rejection, higher than 60dB at 1 MHz
- Narrow baseband bandwidth to improve Signal/Noise ratio
- Input matched to 50 Ω
- 100% ASK demodulation (OOK)
- 100kHz deviation FSK demodulation
- 5V power supply
- Low current

This lead to the following definition of Romeo2 RF Module 433 MHz:

- Romeo2 circuit with dedicated crystal
- Surface Acoustic Wave Filter (SAW filter)
- Low noise amplifier (LNA) using an external transistor

Romeo2 RF Module

Schematic

The Romeo2 RF Module is composed of three blocks.

From the antenna to the MCU, we can find:

- An LNA with Q1 and surrounding components
- A SAW filter F1
- Romeo2

Some options on the board allow various configurations to be tested:

- Romeo2 alone
- Romeo2 and SAW filter
- Romeo2, SAW filter and LNA

The LNA could be placed between Romeo2 and the SAW filter. This would offer lower sensitivity but but higher resistance to interference. Because the goal of the project is to increase the range of the system with a reasonable resistance to interference, the LNA is placed at the input of the receiver, to minimize the overall noise and maximize the sensitivity.

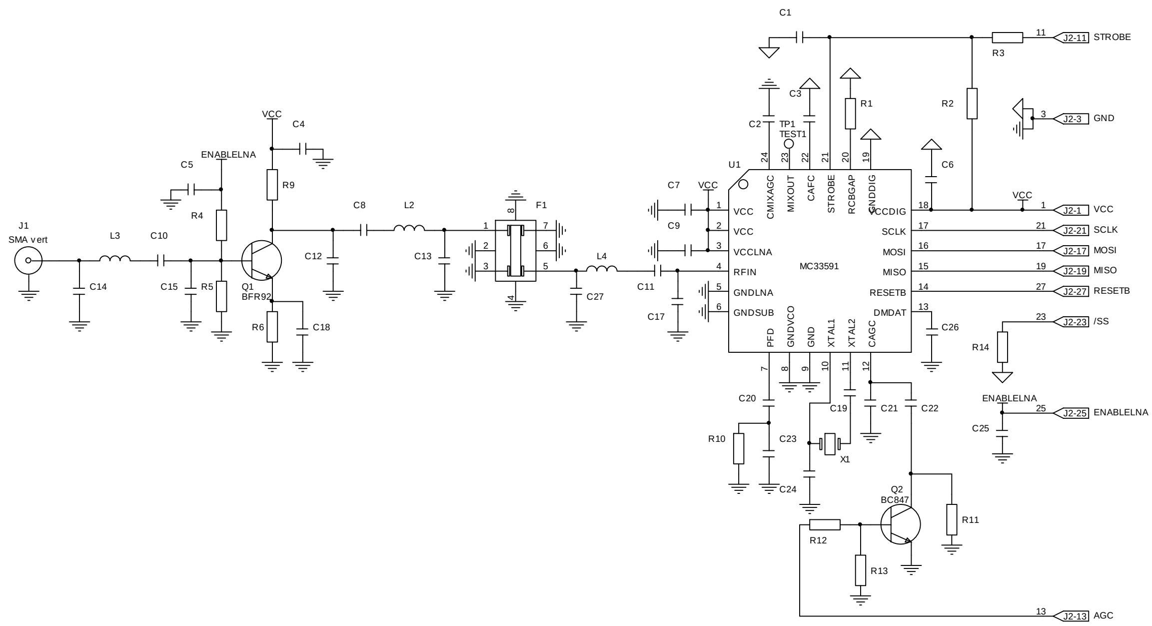


Figure 4. Initial Schematic Diagram

Around Romeo2, the typical application undergoes some minor changes.

The C21 capacitor can be paralleled with C22 switched by Q2 to adapt for different data rates or demodulation modes. R11 pre-charges C22 to avoid current spikes, which would increase the settling time.

C26 adds some low-pass filtering to reduce the bandwidth of the demodulated signal. C26 is removed for high data rate operation.

Some precautions are taken with the ground connections, to ensure that digital noise does not reduce the sensitivity. There are different grounds for the digital and analog parts of Romeo2. Both are connected to the ground of the motherboard via two different pins GNDANA and GNDDIG.

The LNA uses a BFR92. R4 and R5 set the base voltage and R6 fixes the current. L1 allows the RF signal to be present on the collector, while maximizing the collector DC voltage to increase linearity.

The LNA can be powered down by the MCU with the ENABLELNA pin, when Romeo2 is in sleep mode.

C14, L3, C10 and C15 provide a matching network between the antenna and the LNA.

Similarly, C12, C8, L2 and C13 match the LNA with the SAW F1 while C27, L4, C11 and C17 match the SAW filter to Romeo2.

The SAW filter is an RF1172B from RFM[1]. This device is available for different frequencies[2] in the same package and are pin-to-pin compatible.

Computation of Values and Optimization

Strobe Oscillator

C1 and R2 fix the period of the strobe oscillator, Tstrobe.

This time should be long enough for Romeo2 to receive an ID[3] during its wake up time. At a bit rate of 1200 bits per second, it takes 6.6 ms to receive the ID.

With C1 = 100n and R2 = 1M, Tstrobe = 12ms. This is large enough to allow Romeo2 to receive the ID and wake up.

Crystal

To compute the frequency of X1, first select a valid divide ratio (n) for the internal clock, and the value of the bit CF[4]:

- Frf around 315 MHz: n = 8 and CF = 0
- Frf around 433.92 MHz: n = 11 and CF = 1

Then, compute the frequency of the crystal like this: Fref = Frf/(32-0.66/(1.23*n))

This gives X1 = 13.58 MHz for Frf = 433.92 MHz

C24 = 10p and C19 = 10n, as specified in the data sheet.

Around Romeo2

Most values are taken from the data sheet.

The values of C6, C3, C7, and C9 are not critical, but these decoupling capacitors should be sited close to U1.

R1 = 180 kΩ, 1%

C2 = 10 nF and C3 = 100 pF, as in the data sheet.

The loop filter is also the same as the data sheet: C20 = 4.7 nF, C23 = 390 pF, R10 = 1 kΩ.

To drive Q2, R12 = 47 kΩ and R13 = 10 kΩ are suitable. The current in R12 is less than IR12 = (5-0.6)/47000 < 100 µA. It should be possible to reduce this current.

Initially, R11 is omitted.

1. RFM is a registered trademark of RF Monolithics, Inc. (www.RFM.com)
2. Available frequencies are 315 MHz, 418 MHz, 433.92 MHz, 868.35 MHz, and 916.5 MHz.
3. An ID is a 8 bit word, transmitted in the frame, that Romeo2 should detect before processing data. (See data sheet.)
4. Refer to the data sheet for information on the Romeo2 internal registers.

Optimum low-pass filtering is achieved with C26 = 4.7 nF; this increases the sensitivity to about 1 dB for a 1.2 kbd data rate.

Matching Romeo2 to the SAW Filter

A network analyzer was used to measure the parameters of the SAW filter on the final board (which is different from the one used by RFM).

At 433.92 MHz, this gives:

- S11saw = 0.933 [-43.5°]
- S21saw = 0.0410 [43°]
- S12saw = 0.0356 [41.5°]
- S22saw = 0.964 [-50°]

Note that, because S12 and S21 are low, matching to S22 is a good approximation, which will simplify the design of the matching network.

For Romeo2, the input impedance is given in the data sheet: Zromeo = 1.4pF || 1100 Ω

A possible matching network is shown in Figure 5 and described below. One coil and one capacitor are reversed, but the shapes of these two components are the same (0603), so this can be done.

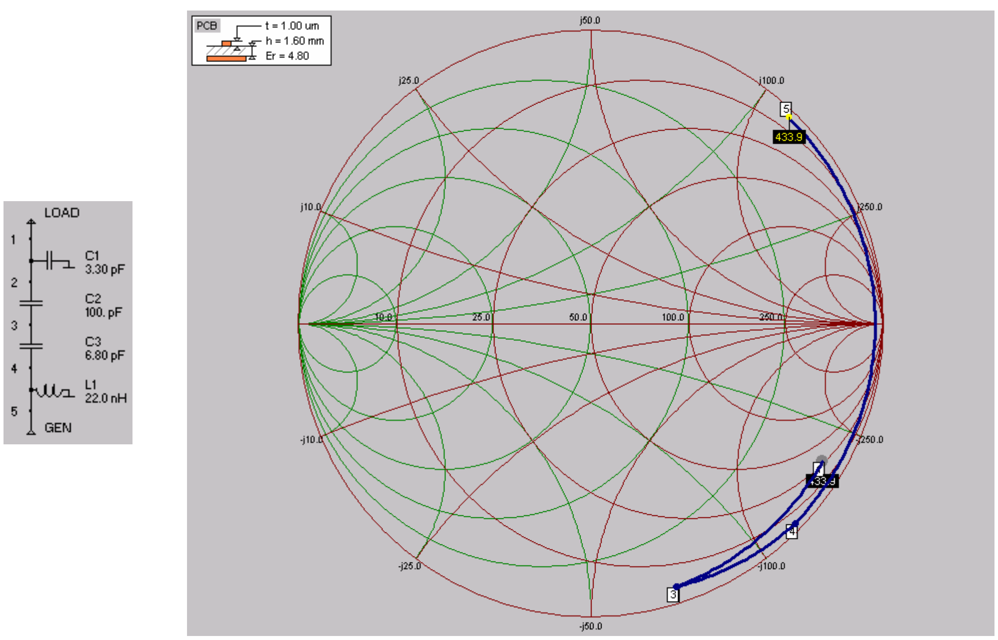


Figure 5. Matching Network and Simple Smith Chart

This gives:

- C17 = 3.3 pF

- C11 = 100 pF
- L4 = C16 = 6.8 pF
- C27 = L6 = 22 nH

With these values, the impedance reflected to the output of the SAW filter is Z*saw = 3.63 + j113.7. This is equivalent to a reflection coefficient of Γ =0.977 [47.4°], which is close to the conjugate of S22saw.

To optimize this matching network, the HF generator is connected to the input of the SAW, and the various elements are adjusted to maximize the sensitivity.

This gives:

- C17 = 3.9 pF
- C11 = 100 pF
- L4 = C16 = 8.2 pF
- C27 = L6 = 15 nH

LNA polarization

To reduce the current consumption, 1 mA is a maximum limit for the collector current of Q1. To reduce the variation of this current with temperature, it is recommended to use an emitter feedback bias network[1].

Let us make the following assumptions:

- Vcc = 5V
- Ic = 1mA
- Vbe = 0.7V
- VR6 = 1V
- Q1 = 100
- IR5 = 100µA

We then find:

- R6 = VR6/Ic = 1k
- VR5 = VR6+Vbe
- R5 = VR5/IR5 = 17000 Ωs
- R4 = (Vcc-VR5)/(IR5+Ic/β) = 16500 Ωs

So R5 = 18k and R4 = 15k.

Some adjustments were made on the final design to have precisely 1 mA at 25°C. Those changes are:

- R6 = 1k
- R5 = 10k
- R4 = 15k

1. A very useful (and free) tool to compute current variations with temperature and transistor parameters is AppCad from Agilent Technologies. www.agilent.com

LNA S-parameters

The data sheet of the BFR92 gives no S-parameter for the chosen polarization. We then need to make some measurements on the LNA to match it.

With the network analyzer, we found, at 433.92 MHz:

- S11lna = 0.845 [-70°]
- S21lna = 3.49 [131°]
- S12lna = 0.154 [66°]
- S22lna = 0.871 [-21.2°]

It seems easy now to make a matching network; however, the analysis of S11lna was done with a large span, and it has been discovered that S11lna was greater than unity for frequencies above 200 MHz, which means a negative resistance or a potential instability[1].

Some changes have been done on the LNA to make it unconditionally stable. L1 was replaced by a resistor R9, and C18 was increased to 10 nF. With R9 = 1 kΩ, VCE is reduced to 3V but this does not lead to a change in current, and R4, R5 and R6 do not require to be modified.

The measured LNA parameters are shown in Table 1.

Table 1. Measured LNA Parameters

F (MHz)	S11 mod	arg	S21 mod	arg	S12 mod	arg	S22 mod	arg
0.3	0.979	-10.4	0.761	-54.8	0.015	-82	0.960	-2.72
1	0.979	-1.1	0.739	-113	0.011	-74	0.958	-2.66
10	0.950	-2.33	3.53	-173	0.0026	72	0.920	-2.04
100	0.907	-18.3	3.50	157.3	0.026	76	0.890	-9.44
200	0.829	-35	3.457	133.5	0.05	62	0.850	-18.5
315	0.710	-51.9	3.19	103.8	0.074	43.5	0.789	-26.9
418	0.605	-63.5	2.79	82.9	0.077	33.3	0.746	-32.68
434	0.600	-65.52	2.681	81.14	0.087	32.2	0.748	-33.9
600	0.458	-80.8	2.288	50.58	0.107	16.2	0.686	-42.55
700	0.395	-88.6	2.121	35.27	0.123	9.22	0.658	-48.03
868	0.293	-100.9	1.911	7.58	0.150	-5.2	0.607	-56.64
1000	0.248	-108.4	1.708	-8.57	0.167	-11.5	0.592	-65.43
1500	0.0548	-157.5	1.353	-77.7	0.281	-57.1	0.460	-100
2000	0.148	23.1	1.157	-143.2	0.448	-112.3	0.379	-156.8

1. For an active element, the S-parameters should always be verified in a larger frequency span than the band of interest. An oscillation in the LNA can reduce the sensitivity or lead to bad EMC performances.

Table 1. Measured LNA Parameters (Continued)

F (MHz)	S11 mod	arg	S21 mod	arg	S12 mod	arg	S22 mod	arg
2500	0.323	-24.2	0.887	156.2	0.541	-175	0.330	124.7
3000	0.452	-64.2	0.780	104.6	0.615	123.6	0.320	54

So, at 433.92 MHz:

- S11lna = 0.6 [-65.52°]
- S21lna = 2.681 [81.14°]
- S12lna = 0.087 [32.2°]
- S22lna = 0.748 [-33.9°]

The gain of the LNA is slightly reduced (S21lna is lower), but the isolation is increased (S12lna is lower too), thus increasing the stability.

Matching the SAW to the LNA

A Touchstone file has been made with the S-parameters of the LNA. This allows the impedance and gain of the system to be computed.

The load is the SAW with saw = 0.933 [-43.5°].

The matching network is adjusted in the software to provide maximum gain of the system. In this configuration, the computed gain is about 10 dB with the input of the LNA not yet matched.

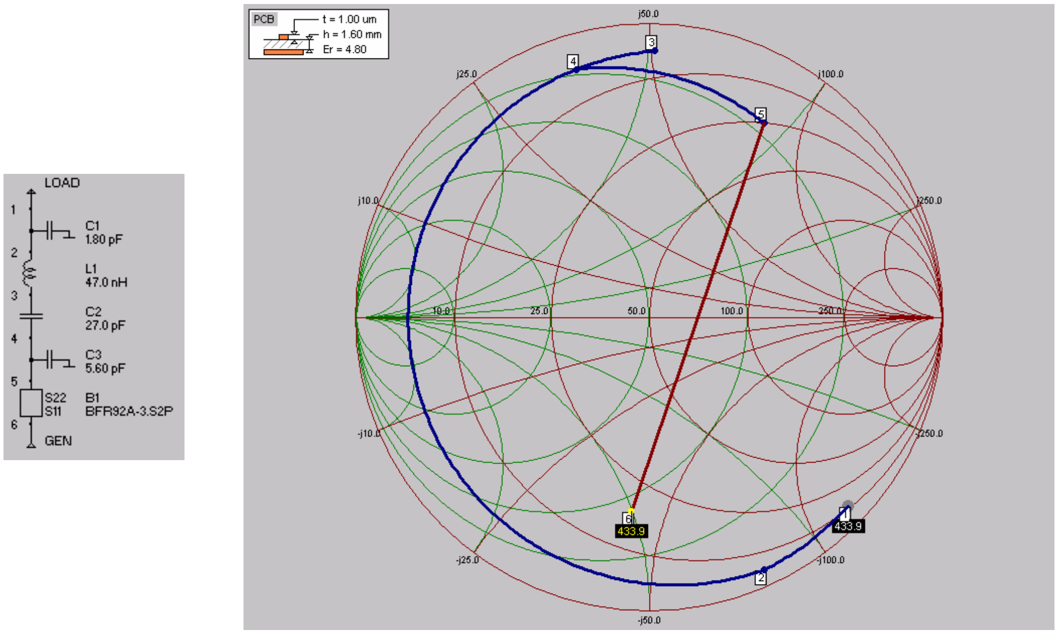


Figure 6. Matching the SAW to the LNA

This gives:

- C13 = 1.8 pF
- L2 = 47 nH
- C8 = 27 pF
- C12 = 5.6 pF

To optimize this matching network, the HF generator is connected to the input of the LNA, and the various elements are adjusted to increase the sensitivity[1].

This gives:

- C13 = 1.8 pF
- L2 = 47 nH
- C8 = 27 pF
- C12 = 3.3 pF

Once matched to the SAW, the input impedance of the LNA is ZinLNA = 6.2 - j48.4

1. This approach neglects the impedance change during optimization at the input of the LNA. But some simulations showed that this lead to a minor error.

Matching the LNA to 50

A rule of thumb to match the input of a LNA correctly, to achieve maximum sensitivity of the system, is first to do a normal matching network and then to adjust it. The optimum is normally not the power matching but the minimum noise matching. This matching is most often slightly different.

This network matches the LNA to 50 with a reasonable mismatch (VSWR = 1.2), which is equivalent to a loss of 0.036 dB.

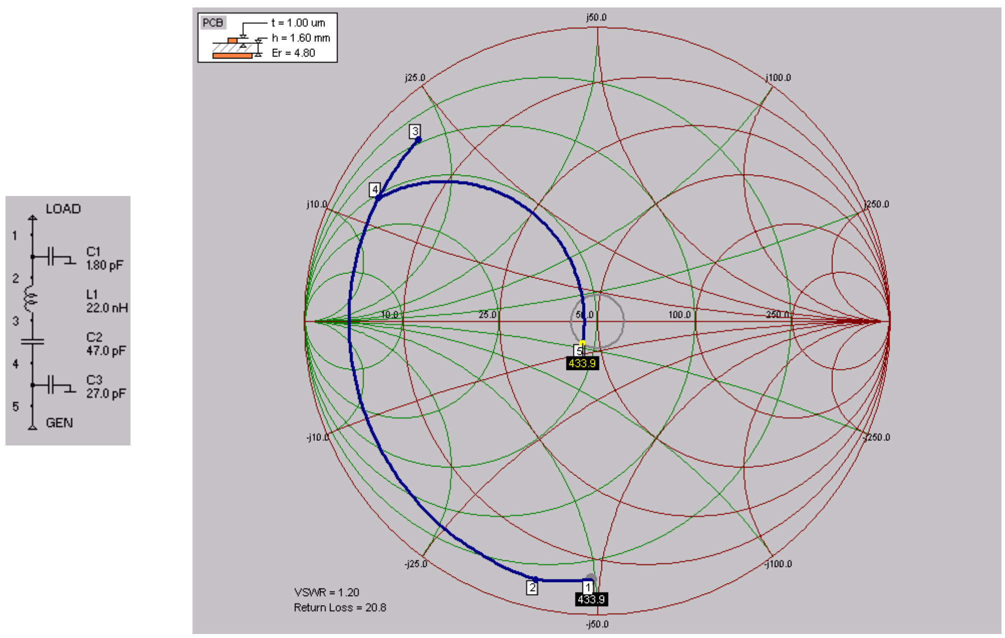


Figure 7. Matching the LNA to 50

This gives:

- C15 = 1.8 pF
- C10 = 47 pF
- L3 = 22 nH
- C14 = 22 pF

The optimization process showed that the sensitivity was not much affected by those components.

Maximum sensitivity was achieved with:

- C15 = 1.8 pF
- C10 = 100pF
- L3 = 33 nH
- C14 = nc

Final Schematic

The final schematic is the result of the optimization process.

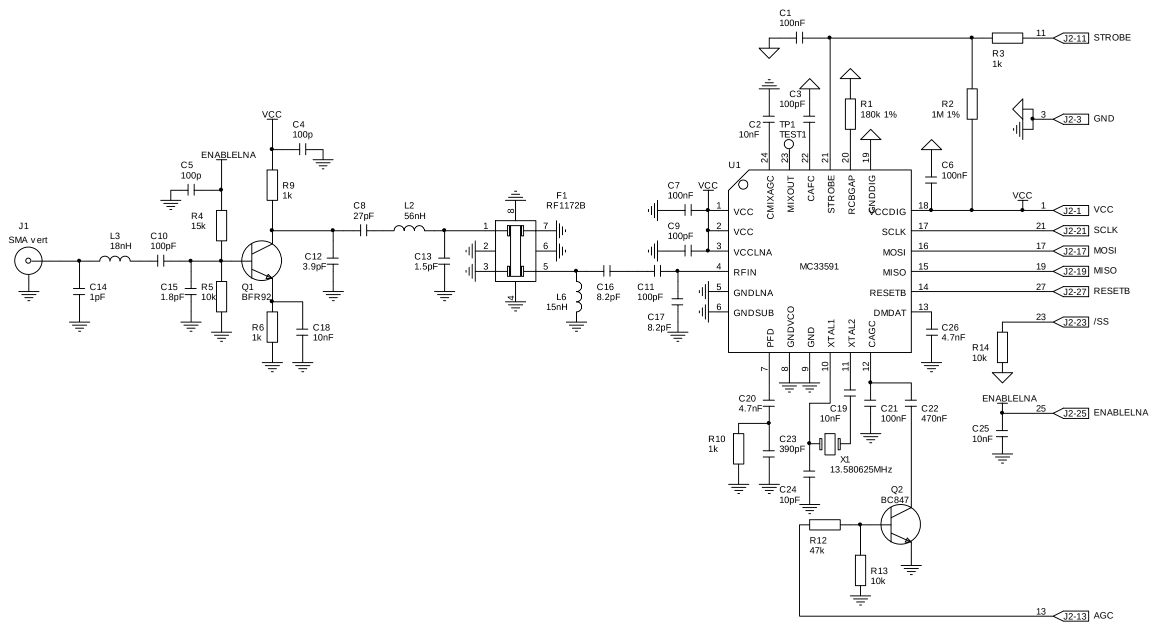


Figure 8. Final Optimized Schematic Diagram

How to use the Romeo2 RF Module

All the logic level signals available on J1 are referred to VCC and GND.

NOTE

Do not apply any signal higher than VCC or lower than GND to the module.

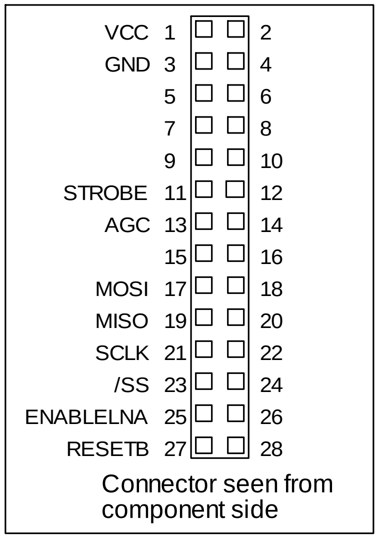


Figure 9. Connector J1 Connections

Table 2. Connector J1 Pin Assignments and Functions

Number	Name	Type	Function
1	VCC	Power supply	5V for Romeo2 and LNA.
3	GND	Power supply	To be connected to a large ground plane
11	STROBE	Input	Strobe oscillator control 0 = strobe oscillator is stopped 1 = strobe oscillator is stopped and Romeo2 is wake up highZ = strobe oscillator is running
13	AGC	Input	AGC speed control/FSK demodulator settling time 0 = FSK at 1.2kbps 1 = OOK at 1.2kbps
17	MOSI	Input/Output	Serial data for the SPI port
19	MISO	Output	Serial data for the SPI port
21	SCLK	Input/Output	Serial clock for the SPI port
25	ENABLELNA	Input	LNA bias control 0 = LNA is OFF. 1 = LNA is ON. Normal mode during reception
27	RESETB	Input	Configuration mode/Normal mode control for the SPI port

Software and MCU Board

Refer to AN2707 for more information concerning software drivers for this Romeo2 RF Module.

Measurements

Supply Current

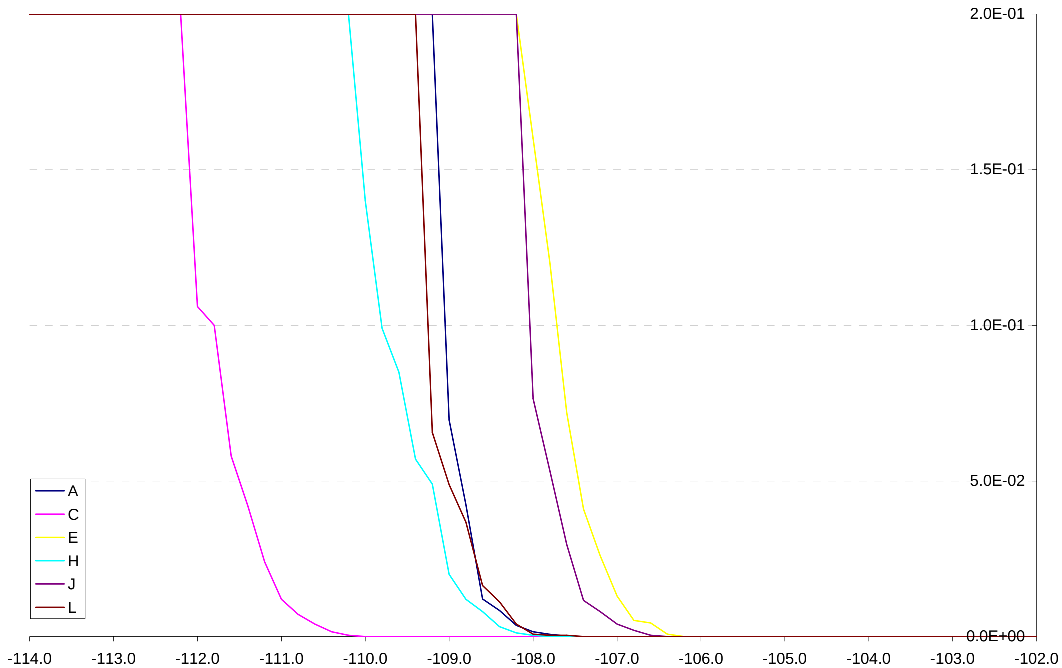
Supply current is measured in various configurations at Vcc = 5V.

Ref :	**1110**	**1111**	**1120**	**1121**	**1131**	**1141**
LNA+SAW :	**yes**	**no**	**yes**	**no**	**no**	**no**
Frequency :	**315MHz**	**315MHz**	**433.92MHz**	**433.92MHz**	**868.3MHz**	**916.5MHz**
Romeo2 ref :	**MC33591**	**MC33591**	**MC33591**	**MC33591**	**MC33593**	**MC33593**
	Supply Current (mA)					
Strobe=1 ENLNA=0	5.42	xxxxx	5.65	xxxxx	xxxxx	xxxxx
Strobe=0 ENLNA=0	0.21	xxxxx	0.21	xxxxx	xxxxx	xxxxx
Strobe=1 ENLNA=1	6.57	5.32	6.80	5.33	7.06	7.15
Strobe=0 ENLNA=1	1.27	0.19	1.28	0.17	0.18	0.18

OOK Sensitivity (BER Method)

A data analyzer is used to measure the BER at various RF signal levels. The RF signal is OOK modulated.

Ref :	**1111**	**1110**	**1121**	**1120**	**1131**	**1141**
LNA+SAW :	**no**	**yes**	**no**	**yes**	**no**	**no**
Frequency :	**315MHz**	**315MHz**	**433.92MHz**	**433.92MHz**	**868.3MHz**	**916.5MHz**
Romeo2 ref :	**MC33591**	**MC33591**	**MC33591**	**MC33591**	**MC33593**	**MC33593**
Data rate :	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**
Modulation :	**OOK**	**OOK**	**OOK**	**OOK**	**OOK**	**OOK**
Cagc :	**ON**	**ON**	**ON**	**ON**	**ON**	**ON**
	Data Analyzer Setup					
Data Rate :	2400 bps NRZ or 1200 bps Manchester					
Pattern :	0101 0101 (NRZ)					
	Measurements over 2500 bits					
Curve :	A	C	E	H	J	L
Sensitivity for 1e-2 BER :	-108.6	-111.0	-107.0	-108.8	-107.4	-108.4



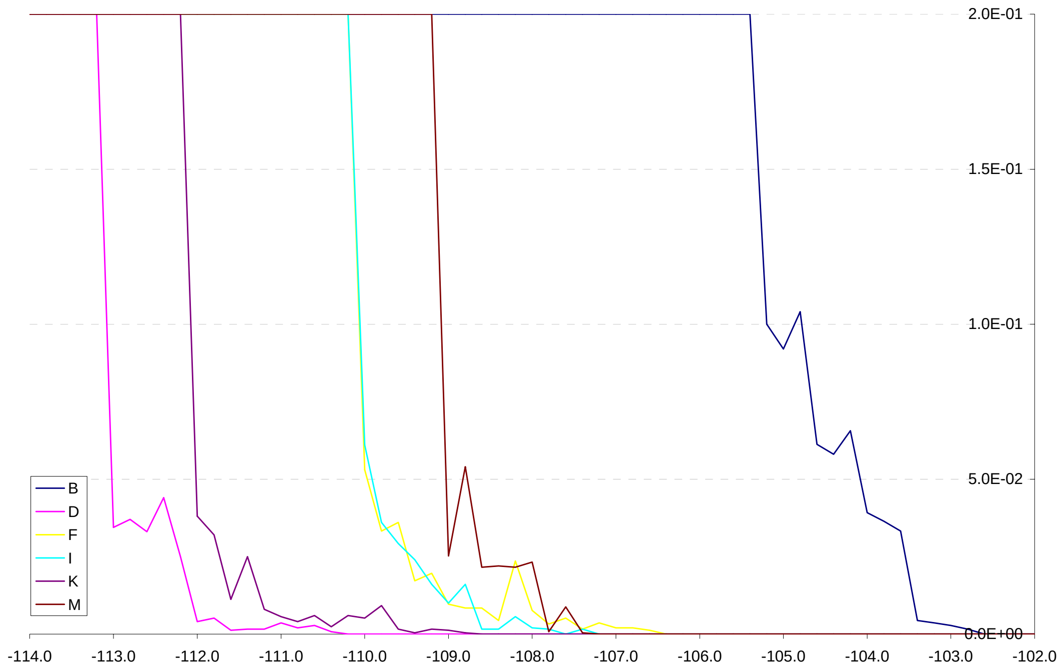
FSK Sensitivity (BER Method)

A data analyzer is used to measure the BER at various RF signal levels. The RF signal is FSK modulated.

Ref :	**1111**	**1110**	**1121**	**1120**	**1131**	**1141**
LNA+SAW :	**no**	**yes**	**no**	**yes**	**no**	**no**
Frequency :	**315MHz**	**315MHz**	**433.92MHz**	**433.92MHz**	**868.3MHz**	**916.5MHz**
Romeo2 ref :	**MC33591**	**MC33591**	**MC33591**	**MC33591**	**MC33593**	**MC33593**
Data rate :	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**	**1.2kbps**
Modulation :	**FSK 100kHz**	**FSK 100kHz**	**FSK 100kHz**	**FSK 100kHz**	**FSK 100kHz**	**FSK 100kHz**
Cagc :	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**	**OFF**
Cdmdat :	**yes**	**yes**	**yes**	**yes**	**yes**	**yes**

	Data Analyzer Setup
Data Rate :	2400 bps NRZ or 1200 bps Manchester
Pattern :	0101 0101 (NRZ)
	Measurements over 2500 bits

Curve :	**B**	**D**	**F**	**I**	**K**	**M**
Sensitivity for 1E-2 BER :	-103.6	-112.2	-108.2	-108.8	-111.4	-108.0



OOK Sensitivity (Functional Method)

The sensitivity is measured using an RF generator modulated by a frame generator. Software decodes the frame and lights an LED if the frame is received correctly.

Ref :	1110	1111	1120	1121	1131	1141
LNA+SAW :	yes	no	yes	no	no	no
Frequency :	315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data rate :	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Modulation :	OOK	OOK	OOK	OOK	OOK	OOK
Cagc :	ON	ON	ON	ON	ON	ON
Data Manager Off	-109.4	-106	-107.6	-105.6	-106.4	-107.2
Data Manager On	-108.6	-106	-105.8	-102.6	-103.6	-105.8

FSK Sensitivity (Functional Method)

The sensitivity is measured using an RF generator modulated by a frame generator. A software decodes the frame and lights an LED if the frame is received correctly.

Ref :	1110	1111	1120	1121	1131	1141
LNA+SAW :	yes	no	yes	no	no	no
Frequency :	315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data rate :	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Modulation :	FSK	FSK	FSK	FSK	FSK	FSK
Cagc :	OFF	OFF	OFF	OFF	OFF	OFF
Data Manager Off	-110.4	-102	-107.6	-107.8	-108	-108.8
Data Manager On	-110	-101.8	-107.2	-106.8	-107	-108

Maximum Demodulated Signal (BER Method)

A data analyzer is used to measure the BER for high RF signal levels.

Ref :	1110	1111	1120	1121	1131	1141
LNA+SAW :	yes	no	yes	no	no	no
Frequency :	315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data rate :	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Modulation :	OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK
Cagc :	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF	ON/OFF
OOK	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm
FSK	10.6dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	0dBm	≥ 19dBm

Maximum Demodulated Signal (Functional Method)

The maximum demodulated level is measured using an RF generator modulated by a frame generator. Software decodes the frame and lights an LED if the frame is received correctly.

Ref :	1110	1111	1120	1121	1131	1141
LNA+SAW :	yes	no	yes	no	no	no
Frequency :	315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data rate :	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Modulation :	OOK	OOK	OOK	OOK	OOK	OOK
Cagc :	ON	ON	ON	ON	ON	ON
Data Manager Off	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	13dBm	14dBm
Data Manager On	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	12.2dBm	11.2dBm

Ref :	1110	1111	1120	1121	1131	1141
LNA+SAW :	yes	no	yes	no	no	no
Frequency :	315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data rate :	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Modulation :	FSK	FSK	FSK	FSK	FSK	FSK
Cagc :	OFF	OFF	OFF	OFF	OFF	OFF
Data Manager Off	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	9.8dBm	15.4dBm
Data Manager On	≥ 19dBm	≥ 19dBm	≥ 19dBm	≥ 19dBm	8.4dBm	14.4dBm

Local Oscillator Leakage

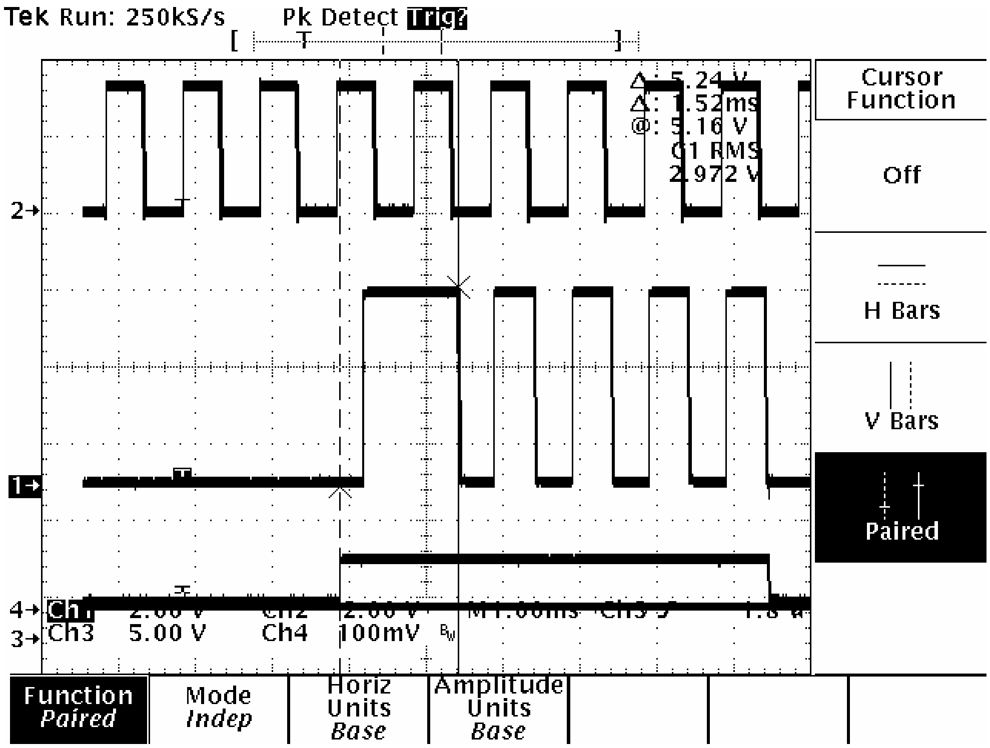
A spectrum analyzer is connected to the RF connector. The level of the local oscillator is measured.

Ref :	**1110**	**1111**	**1120**	**1121**	**1131**	**1141**
LNA+SAW :	**yes**	**no**	**yes**	**no**	**no**	**no**
Frequency :	**315MHz**	**315MHz**	**433.92MHz**	**433.92MHz**	**868.3MHz**	**916.5MHz**
Romeo2 ref :	**MC33591**	**MC33591**	**MC33591**	**MC33591**	**MC33593**	**MC33593**
			Spectrum Analyzer Setup			
RBW (kHz) :	1	1	1	1	1	1
Span (MHz) :	10	10	10	10	10	10
Detector :	Peak	Peak	Peak	Peak	Peak	Peak
Aquisition :	Maxhold	Maxhold	Maxhold	Maxhold	Maxhold	Maxhold
Fc (MHz) :	315	315	433.92	433.92	868.3	916.5
IF (kHz) :	660	660	660	660	660	660
Fc+IF (MHz) :	315.66	315.66	434.58	434.58	868.96	917.16
LO Level (dBm) :	<-113	-95.91	<-113	-96.37	-86.94	-84.99

OOK Wake Up Time

A modulated RF generator is connected to the RF input for various levels. The STROBE pin is connected to a square wave generator. The time between the positive edge on STROBE and the first pulses on MOSI is measured. This measurement is done for various values of Cagc.

Ref :	**1110**			
LNA+SAW :	**yes**			
Frequency :	**315MHz**			
Romeo2 ref :	**MC33591**			
Data rate :	**1.2kbps**			
Modulation :	**OOK**			
Cagc :	**ON/OFF**			
		Wake up time (ms)		
RFin Power Level (dBm) :	-100	-90	-80	-60
CAGC ON	1.52	2.02	1.72	1.8
CAGC OFF	2.08	1.76	1.42	1.6

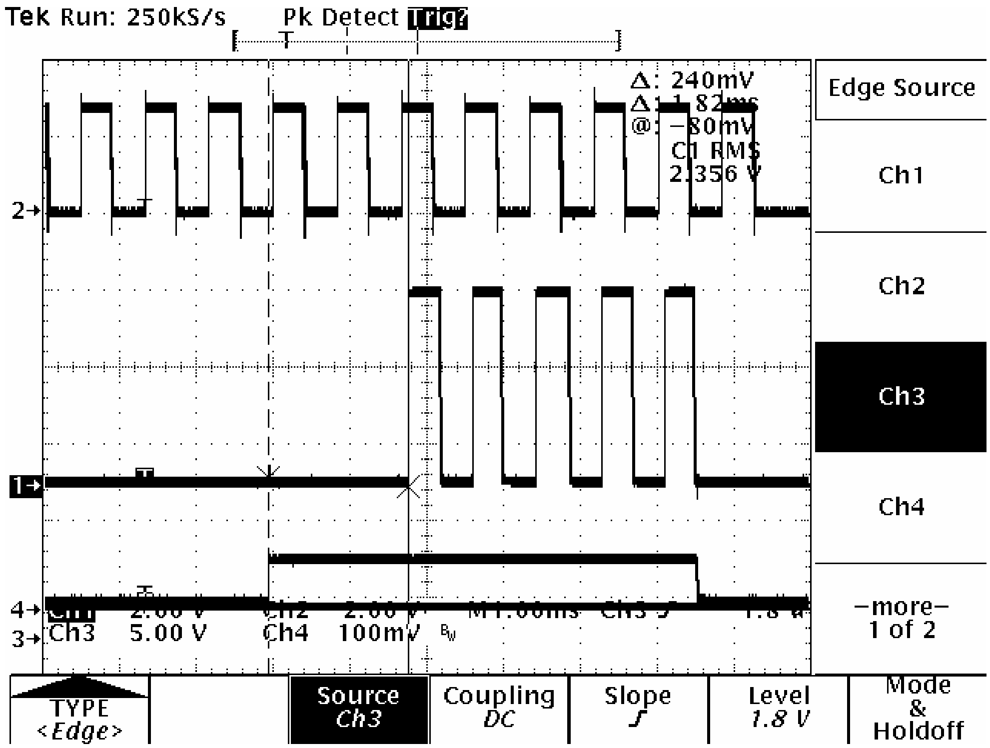


FSK Wake Up Time

A modulated RF generator is connected to the RF input for various levels. The STROBE pin is connected to a square wave generator. The time between the positive edge on STROBE and the first pulses on MOSI is measured. This measurement is done for different values of Cagc.

Ref :	**1110**
LNA+SAW :	**yes**
Frequency :	**315MHz**
Romeo2 ref :	**MC33591**
Data rate :	**1.2kbps**
Modulation :	**FSK 50kHz**
Cagc :	**ON/OFF**

RFin Power Level (dBm) :	-100	-90	-80	-60
CAGC ON	14.6	13.44	14.36	13.8
CAGC OFF	1.82	1.4	2.18	2.58

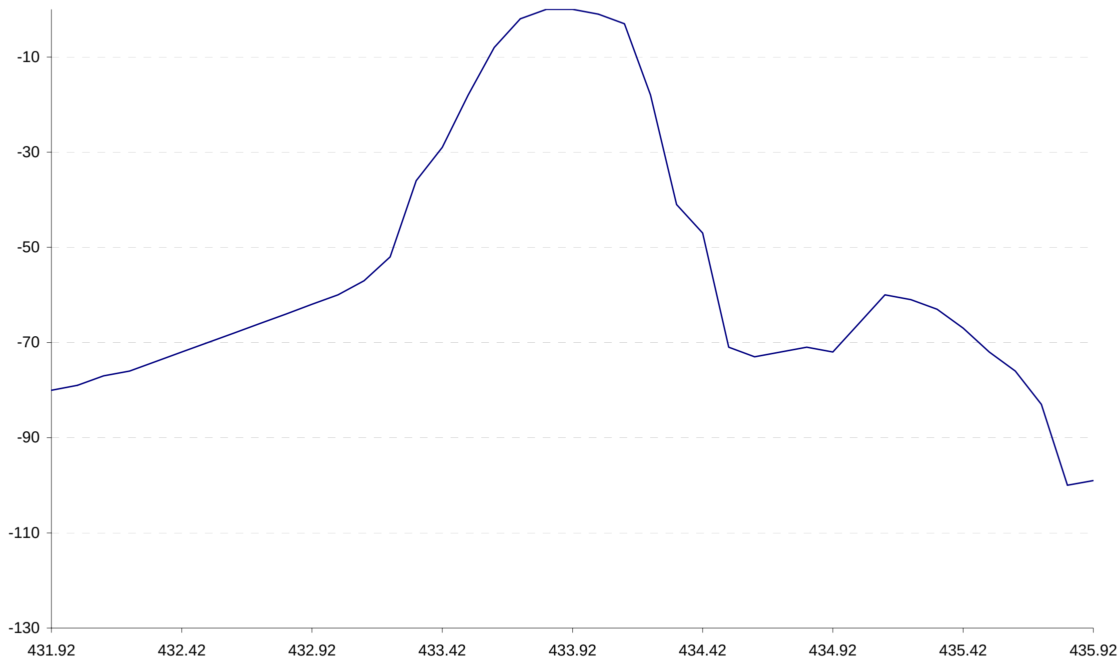


Bandwidth

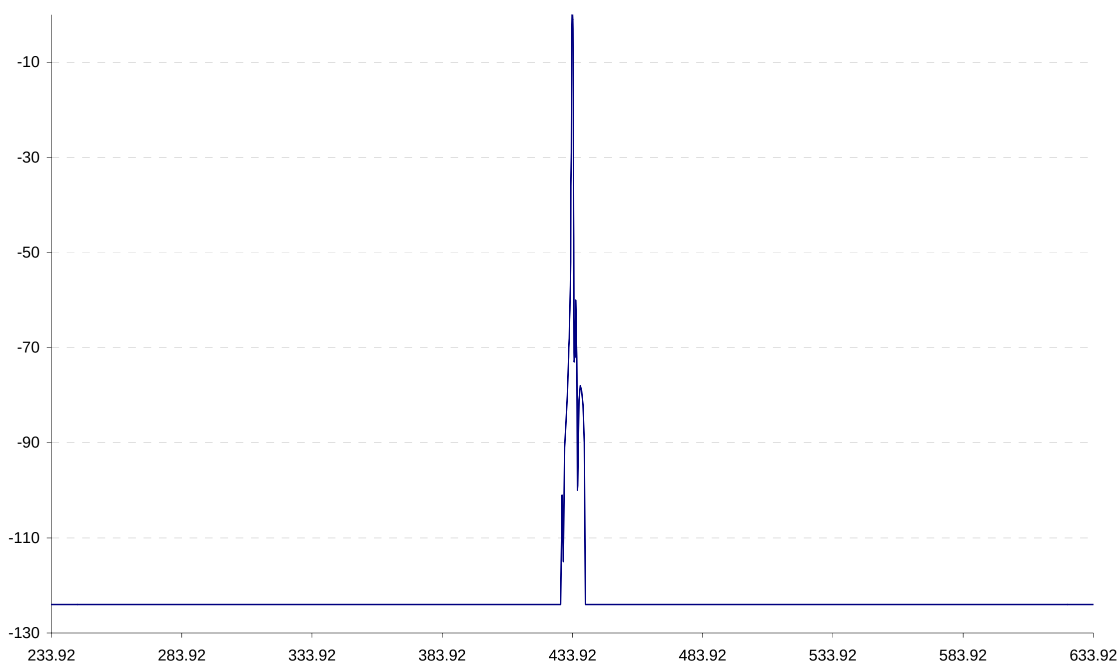
An RF generator is OOK modulated by a frame generator. The level of the RF generator is adjusted to measure the sensitivity of the receiver for various frequencies. The maximum sensitivity is defined as the 0 dB reference.

Ref :	**1120**
LNA+SAW :	**yes**
Frequency :	**433.92MHz**
Romeo2 ref :	**MC33591**
Data rate :	**1.2kbps**
Modulation :	**OOK**
Cagc :	**ON**
Dmdat :	**ON**

2 MHz Span



200 MHz Span



IP3, Blocking and Dynamic Range

A valid signal is applied to the RF input at a level 3dB above the sensitivity level. An interference signal 2 MHz or 10 MHz away is also applied to the RF input using a combiner. The level of the interference signal is increased as long as the demodulation of the valid signal is correct. This gives the blocking level.

For IP3 measurements, two RF generators are used with a combiner, the frequency offsets being -5 MHz and -10 MHz. These have the same level, but one is modulated by a frame generator. The level is increased up to the correct demodulation of the frame. The received signal (in fact, an interference created by the non-linearity of the receiver) has then a level equal to the sensitivity level. IP3 is computed from the sensitivity level and RF generator levels.

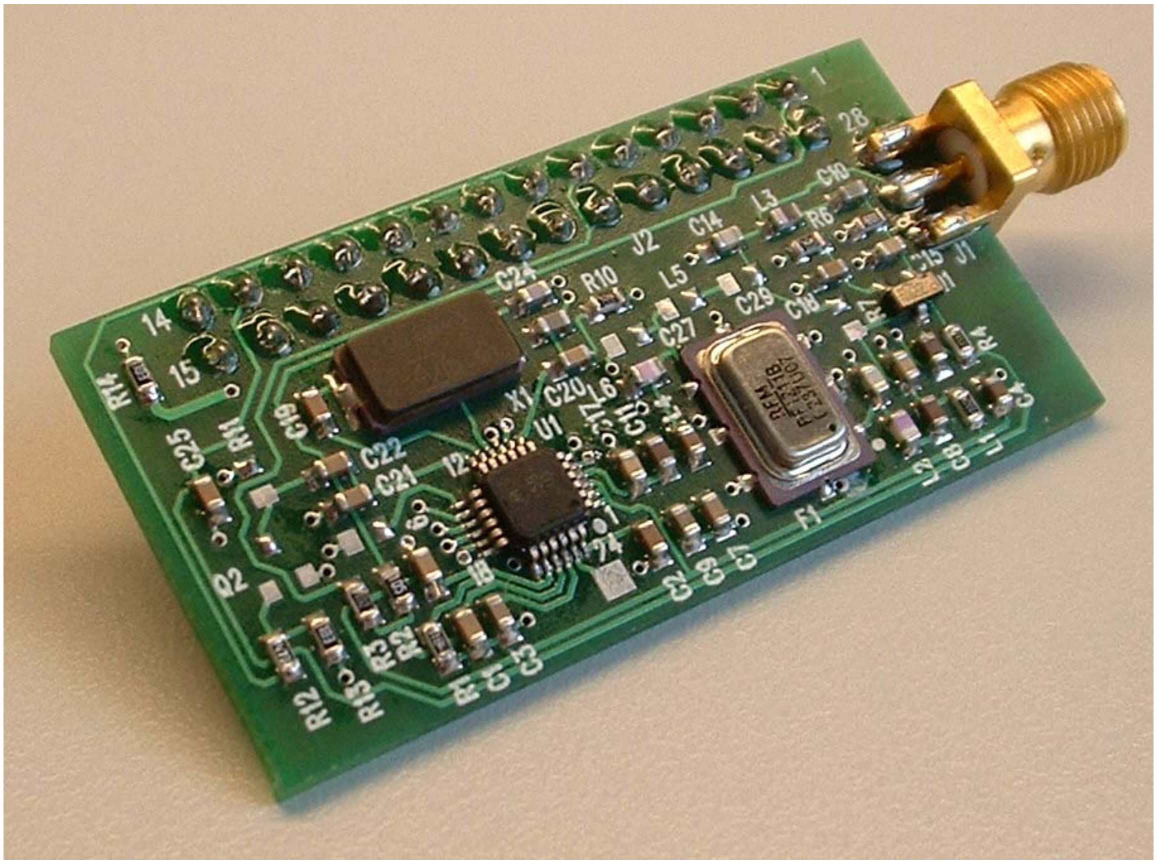
$IP3 = (3*SL-GL)/3$

Where SL = sensitivity level and GL = generator level.

The dynamic range is then defined as the difference between the sensitivity level and IP3.

Ref :	1111	1110	1121	1120	1131	1141
LNA+SAW :	no	yes	no	yes	no	no
Frequency :	315MHz	315MHz	433.92MHZ	433.92MHz	868.3MHz	916.5MHz
Romeo2 ref :	MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
Data Manager :	on	on	on	on	on	on
Modulation :	OOK	OOK	OOK	OOK	OOK	OOK
Cagc :	on	on	on	on	on	on
Sensitivity :	-108.6	-106.0	-105.8	-102.6	-103.6	-105.8
Sensitivity+3dB :	-105.6	-103.0	-102.8	-99.6	-100.6	-102.8
Interference Frequency 1 :	305.00	305.00	423.92	423.92	858.30	906.50
Interference Frequency 2 :	310.00	310.00	428.92	428.92	863.30	911.50
Interference level :	-49.5	-34.9	-48.0	-34.6	-48.7	-50.3
Interference IM3 level :	-108.6	-38.3	-50.4	-34.6	-51.3	-52.6
OOK Blocking level (10MHz) :	-53.2	-22.2	-49.7	-32.7	-54.6	-51.2
FSK Blocking level (10MHz) :	-48.4	-18.4	-48.6	-19.6	-52.4	-51.6
OOK Blocking level (2MHz) :	-63.2	-45.2	-64.7	-48.7	-76.6	-70.2
FSK Blocking level (2MHz) :	-61.4	-43.4	-62.6	-33.6	-65.4	-82.6
IP3 :	-20.0	0.7	-19.1	-0.6	-21.3	-22.6
Dynamic Range :	88.6	106.7	86.7	102.0	82.3	83.2

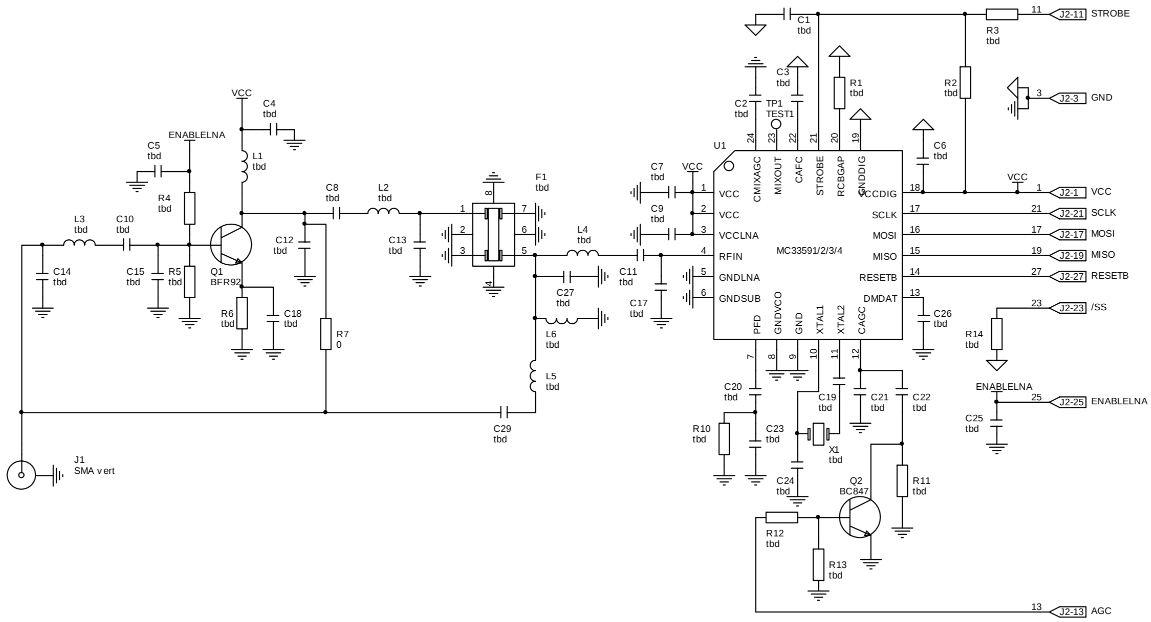
CAD Files



Generic schematics

The following schematic diagram is a generic one that can be adapted for many configurations.

- With or without LNA
- With or without SAW filter
- Different frequencies
- Different AGC and DMDAT filtering optimizations

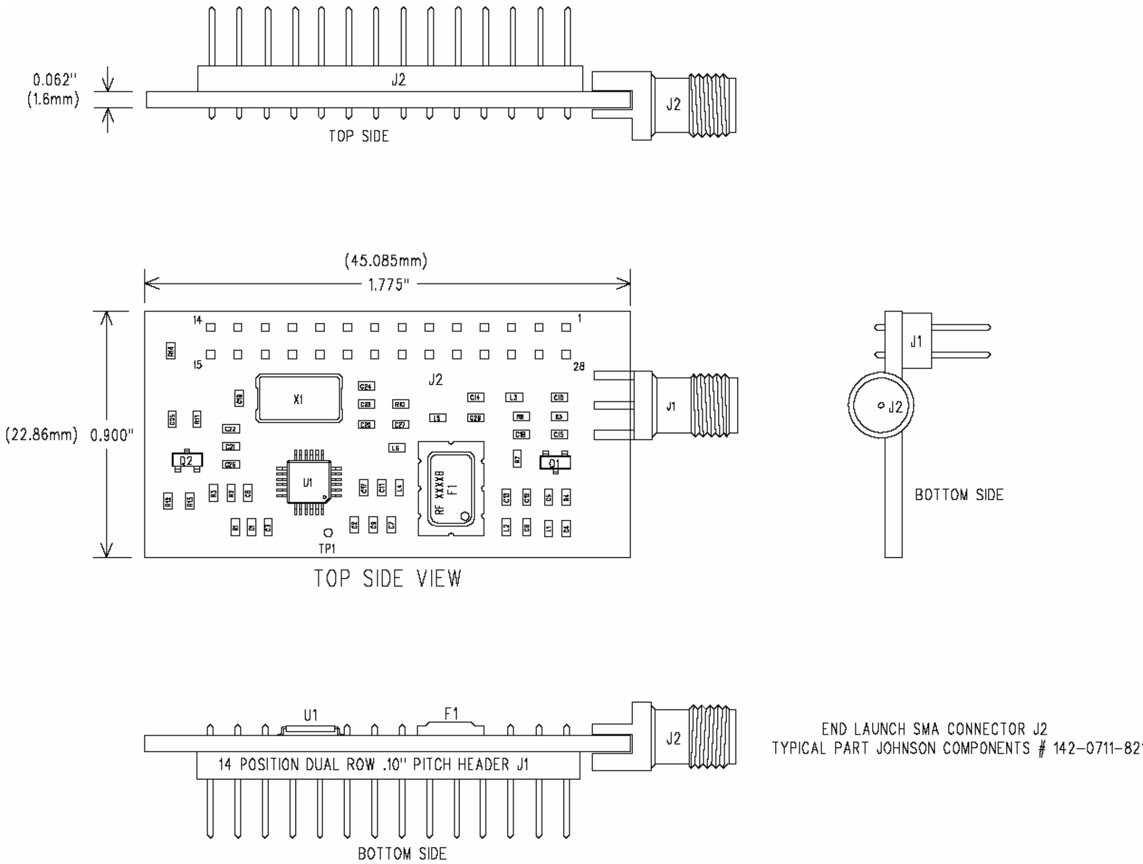


Bill of Materials

Module reference		1110	1111	1120	1121	1131	1141
Frequency		315MHz	315MHz	433.92MHz	433.92MHz	868.3MHz	916.5MHz
Equipment		LNA+SAW	Basic	LNA+SAW	Basic	Basic	Basic
Modulation		OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK	OOK/FSK
Minimum Baud Rate		1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps	1.2kbps
Reference	**Package**						
R1	0603	180k 1%	180k 1%	180k 1%	180k 1%	180k 1%	180k 1%
R2	0603	1M 1%	1M 1%	1M 1%	1M 1%	1M 1%	1M 1%
R3	0603	1k	1k	1k	1k	1k	1k
R4	0603	15k	not equiped	15k	not equiped	not equiped	not equiped
R5	0603	10k	not equiped	10k	not equiped	not equiped	not equiped
R6	0603	1k	not equiped	1k	not equiped	not equiped	not equiped
R7	0603	not equiped	not equiped	not equiped	not equiped	not equiped	not equiped
R9 (may replace L1)	0603	1k	not equiped	1k	not equiped	not equiped	not equiped
R10	0603	1k	1k	1k	1k	1k	1k
R11	0603	not equiped	not equiped	not equiped	not equiped	not equiped	not equiped
R12	0603	47k	47k	47k	47k	47k	47k
R13	0603	10k	10k	10k	10k	10k	10k
R14	0603	10k	not equiped	10k	not equiped	not equiped	not equiped
R20 (may replace L4)	0603	not equiped	0R	not equiped	0R	0R	0R
C1	0603	100nF	100nF	100nF	100nF	100nF	100nF
C2	0603	10nF	10nF	10nF	10nF	10nF	10nF
C3	0603	100pF	100pF	100pF	100pF	100pF	100pF
C4	0603	100pF	not equiped	100pF	not equiped	not equiped	not equiped
C5	0603	100pF	not equiped	100pF	not equiped	not equiped	not equiped
C6	0603	100nF	100nF	100nF	100nF	100nF	100nF
C7	0603	100nF	100nF	100nF	100nF	100nF	100nF
C8	0603	100pF	not equiped	27pF	not equiped	not equiped	not equiped
C9	0603	100pF	100pF	100pF	100pF	100pF	100pF
C10	0603	100pF	not equiped	100pF	not equiped	not equiped	not equiped
C11	0603	100pF	100pF	100pF	100pF	100pF	100pF
C12	0603	4.7pF	not equiped	3.9pF	not equiped	not equiped	not equiped
C13	0603	3.3pF	not equiped	1.5pF	not equiped	not equiped	not equiped
C14	0603	1.5pF	not equiped	1pF	6.8pF	3.3pF	6.8pF
C15	0603	4.7pF	not equiped	1.8pF	not equiped	not equiped	not equiped
C16 (may replace L4)	0603	22pF	not equiped	8.2pF	not equiped	not equiped	not equiped
C17	0603	2.7pF	not equiped	8.2pF	not equiped	not equiped	not equiped
C18	0603	10nF	not equiped	10nF	not equiped	not equiped	not equiped
C19	0603	10nF	10nF	10nF	10nF	10nF	10nF
C20	0603	4.7nF	4.7nF	4.7nF	4.7nF	4.7nF	4.7nF
C21	0603	100nF	100nF	100nF	100nF	100nF	100nF
C22	0603	470nF	470nF	470nF	470nF	470nF	470nF
C23	0603	390pF	390pF	390pF	390pF	390pF	390pF
C24	0603	10pF	10pF	10pF	10pF	10pF	10pF
C25	0603	10nF	10nF	10nF	10nF	10nF	10nF
C26	0603	not equiped	not equiped	not equiped	not equiped	not equiped	not equiped
C27	0603	not equiped	not equiped	not equiped	not equiped	not equiped	not equiped
C29	0603	not equiped	33pF	not equiped	27pF	27pF	68pF
L1	0603	replaced by R9	not equiped	replaced by R9	not equiped	not equiped	not equiped
L2	0603	68nH	not equiped	56nH	not equiped	not equiped	not equiped
L3	0603	22nH	not equiped	18nH	not equiped	not equiped	not equiped
L4	0603	replaced by C16	not equiped	replaced by C16	not equiped	not equiped	not equiped
L5	0603	not equiped	82nH	not equiped	56nH	10nH	1.5nH
L6	0603	33nH	not equiped	15nH	not equiped	not equiped	not equiped
Q1	SOT23	BFR92	not equiped	BFR92	not equiped	not equiped	not equiped
Q2	SOT23	BC847	BC847	BC847	BC847	BC847	BC847
F1		RF1211B	not equiped	RF1172B	not equiped	not equiped	not equiped
U1		MC33591	MC33591	MC33591	MC33591	MC33593	MC33593
X1		9.864375MHz	9.864375MHz	13.580625MHz	13.580625MHz	13.577491MHz	14.331195MHz
J1		SMA	SMA	SMA	SMA	SMA	SMA
J2		28 pins	28 pins	28 pins	28 pins	28 pins	28 pins

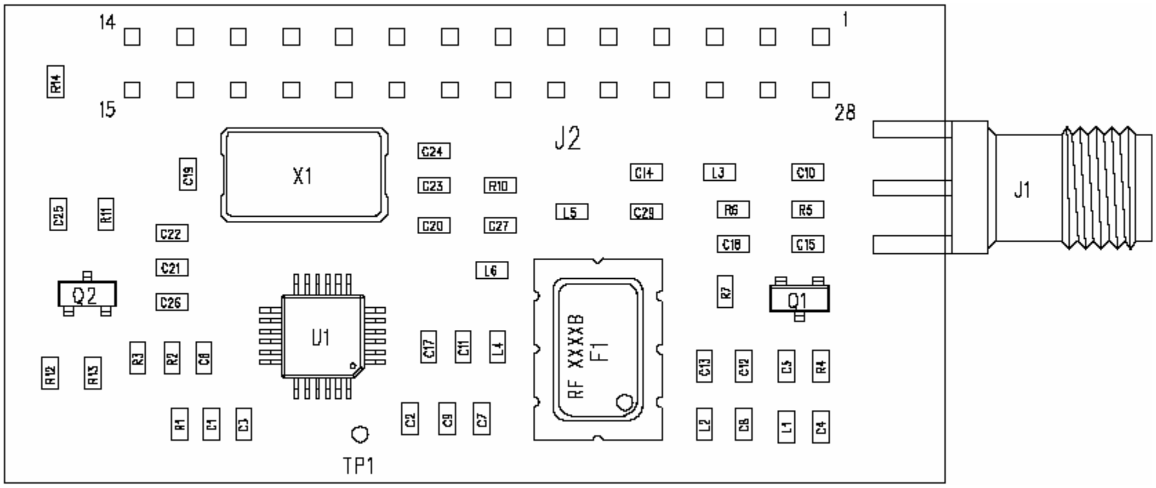
Nota : for all modules, C26=4.7nF if max data rate=1200bps. for general use, C26 is not equiped

Board Geometry



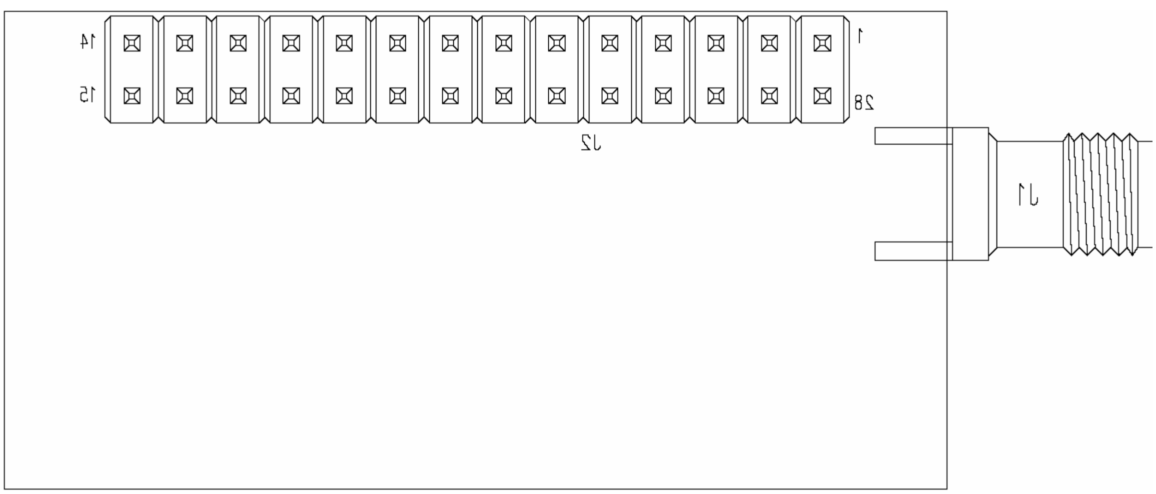
Refer to the updated pinout described in “How to use the Romeo2 RF Module” on page 14.

Component Placement Side 1



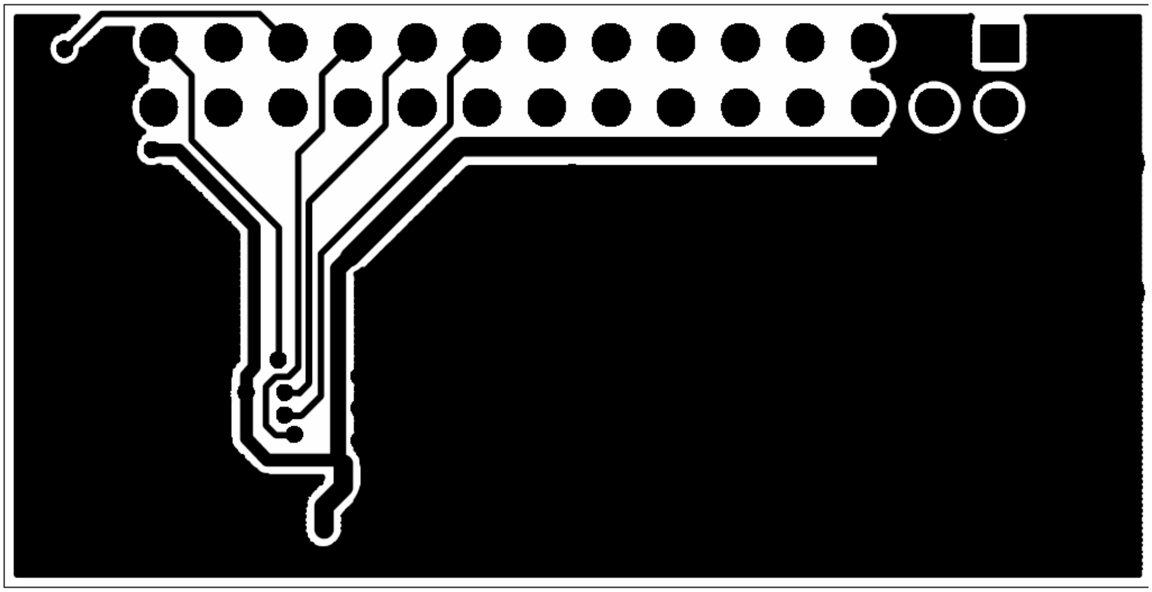
Refer to the updated pinout described in “How to use the Romeo2 RF Module” on page 14.

Component Placement Side 2

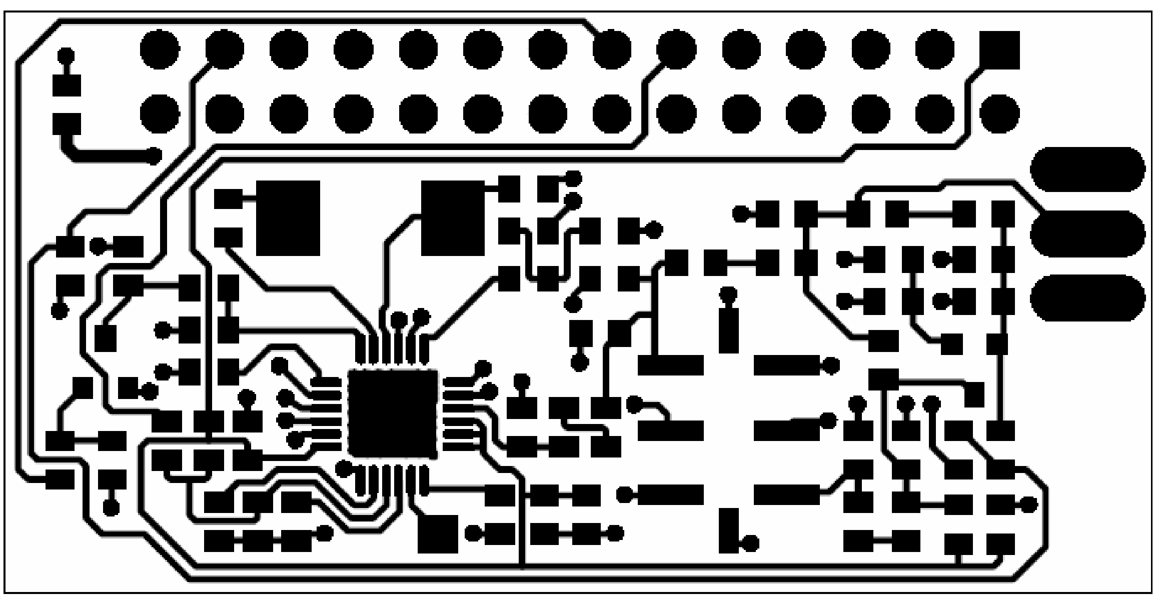


Refer to the updated pinout described in “How to use the Romeo2 RF Module” on page 14.

Copper Side 1



Copper Side 2



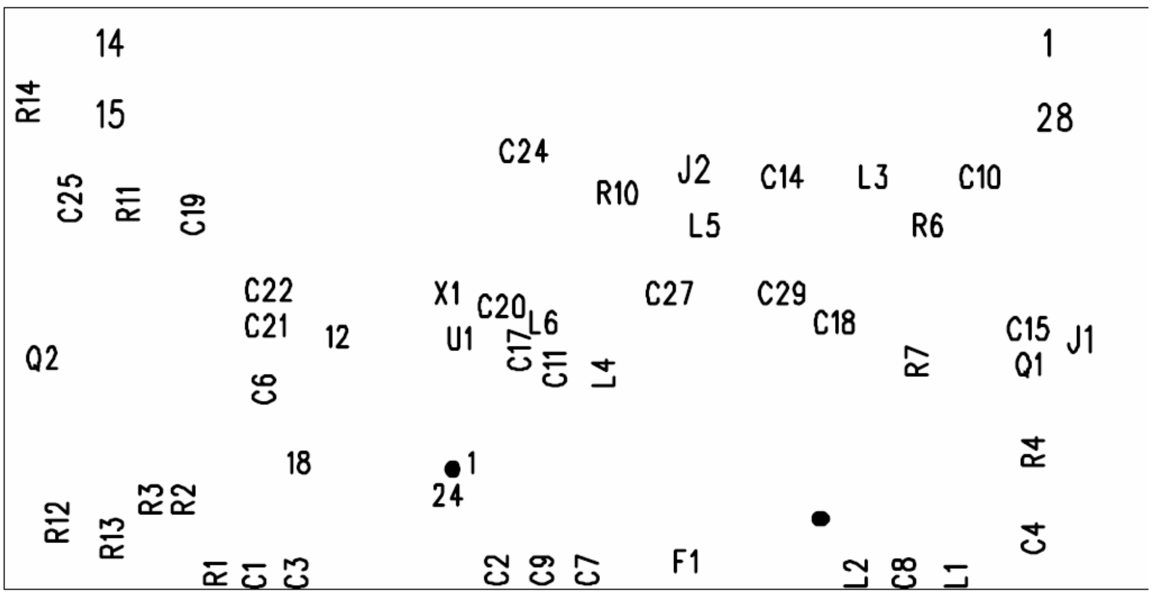
Varnish Side 1

Not available

Varnish Side 2

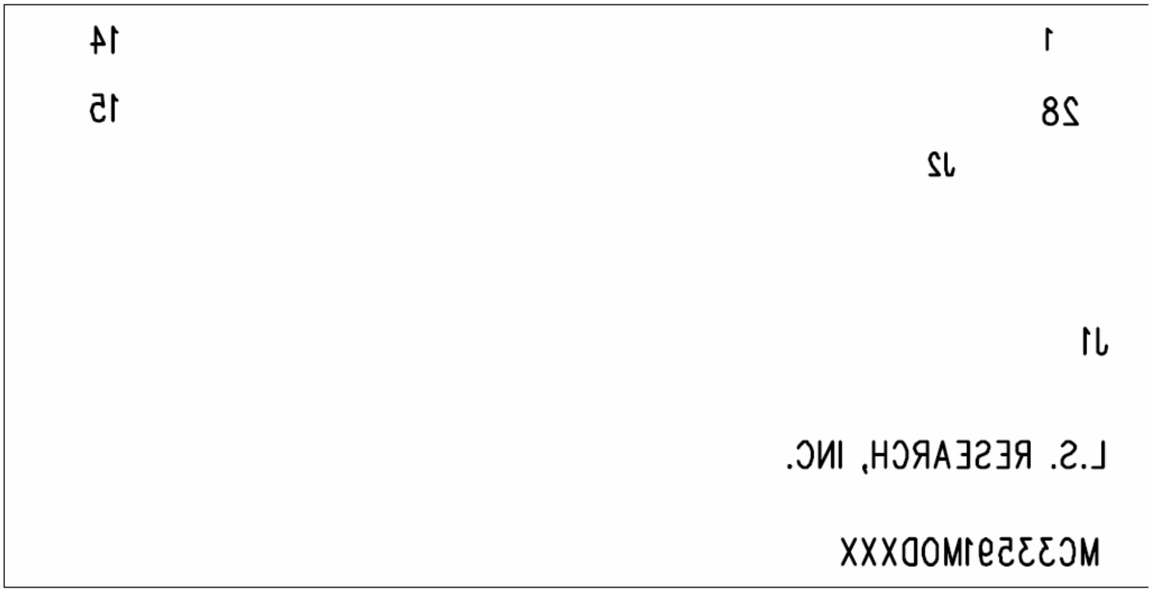
Not available

Silkscreen Side 1



Refer to the updated pinout described in "How to use the Romeo2 RF Module" on page 14.

Silkscreen Side 2

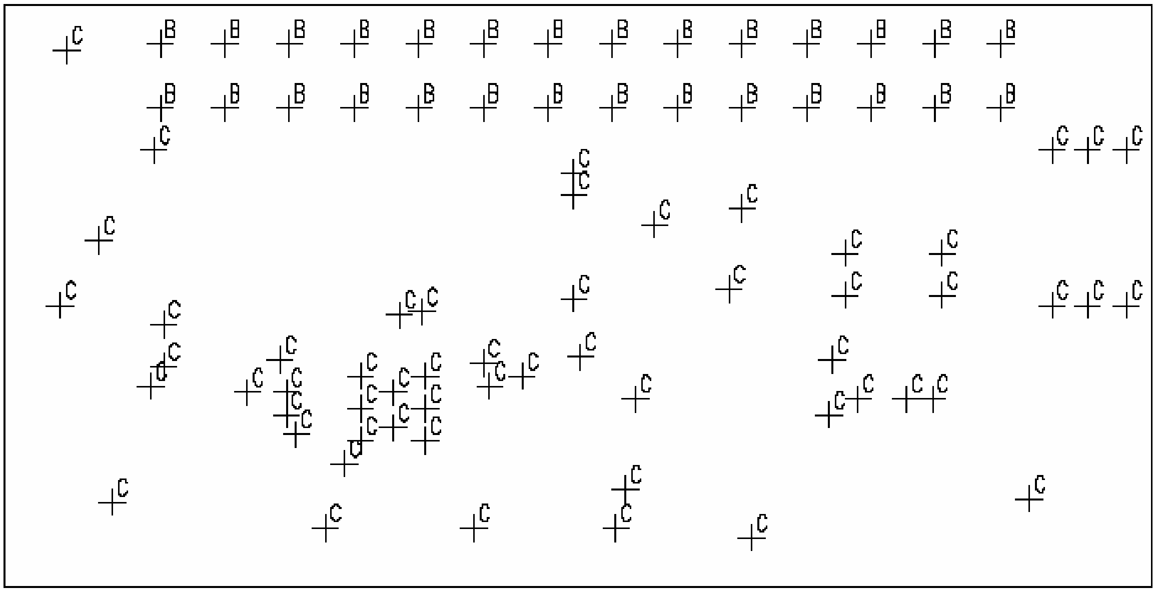


Refer to the updated pinout described in “How to use the Romeo2 RF Module” on page 14.

Drilling and Sizes

FABRICATION NOTES:

1. ALL BOARD DIMENSIONS IN INCHES. TOLERANCE = +/−0.005" UNLESS NOTED OTHERWISE.
2. BOARD MATERIAL – FR−4 GRADE GLASS EPOXY, 0.062" +/− .005" THICKNESS MEASURED OVER SOLDERMASK
   MINIMUM FLAMMABILITY RATING UL 94V−0
3. OUTER LAYER COPPER THICKNESS 0.0014" (1 OZ).
4. SOLDER MASK OVER BARE COPPER, LPI, CLASS 2 GEN. INDUSTRIAL REGISTRATION +/−0.004", GREEN.
   NO COVERAGE ON SOLDER PADS PERMITTED.
5. FINISH−TIN/LEAD REFLOWED OR HOT AIR SOLDER LEVELED−0.0002" TO 0.002" PLATING THICKNESS.
   NO EXPOSED BARE COPPER PERMITTED
6. WHITE SILKSCREEN LEGEND OVER GREEN SOLDERMASK – TOP SIDE
7. HOLE SIZE TOLERANCE = +/− 0.002" UNLESS NOTED OTHERWISE.
   HOLE CENTERS AND PAD CENTERS TO BE CONCENTRIC WITHIN 0.004"



SIZE	QTY	SYM	PLTD
35	28	B	PLTD
14	56	C	PLTD

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