

Designing with MC33596/MC33696

A Step-by-Step Approach for a Reference Design

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1 Introduction

This document presents a step-by-step approach to designing an optimized RF Module using an MC33696 transceiver or MC33596 receiver. It also describes how to evaluate the RF Module using measurements.

2 Preliminary

Because of the similarities between MC33596 and the receiver components of the MC33696, this application note is based on MC33696. It provides some directions for an MC33596-based design.

Contents

1	Introduction	1
2	Preliminary	1
2.1	MC33696/MC33596 RF Module: Various Versions	2
2.2	MC33696/MC33696 RF Module References	2
2.3	CE-FCC Regulation Compliance	2
3	Introduction to RF Transceivers	2
3.1	RF Transceiver Operation	2
3.2	RF Transceiver Application	3
4	MC33696 Presentation	4
4.1	Main Features	4
4.2	Architecture	5
4.3	Typical Application	7
5	MC33696 RF Module: Reference Design Version	8
5.1	Target of this Design	8
5.2	Reference Design Version of the MC33696 RF Module	9
6	Connector Pin Out	21
7	First Step For Receiver Testing	22
7.1	Test Set Up for OOK and FSK	22
7.2	Registers and Pins Set up	23
8	First Step for Transmitter Testing	24
8.1	Test Set-Up	24
8.2	Registers and Pins Set Up	24
8.3	Measurements	26
9	MC33696/MC33596 RF Module Performances	26
9.1	Performance Variables	26
10	PCB Design	27
10.1	Layout	27
11	Bill of Material	28

2.1 MC33696/MC33596 RF Module: Various Versions

- MC33696MOD092EV evaluation boards are available at various frequencies for RF evaluation.
- MC33696MOD434 reference design is a transceiver reference design optimized for RF performances equipped with a SAW filter, low noise amplifier, and a pin diode switch. This document describes the design of the 434 MHz version. It is not available.
- MC33596MOD434 reference design is a receiver reference design optimized for RF performances equipped with a SAW filter and a low noise amplifier. This document gives some indications for the 434 MHz version. It is not available.

2.2 MC33696/MC33696 RF Module References

Table 1. Module References

Web Ref	Frequency	Type	Status
MC33696MOD315EV	315 MHz	Evaluation tool	available
MC33696MOD434EV	433.92 MHz	Evaluation tool	available
MC33696MOD868EV	868.3 MHz	Evaluation tool	available
MC33696MOD916EV	916.5 MHz	Evaluation tool	not available
MC33696MOD434	433.92 MHz	Reference design	not available
MC33596MOD434	433.92 MHz	Reference design	not available

2.3 CE-FCC Regulation Compliance

For local regulation compliance, RF modules are not provided with an SMA connector. A printed antenna replaces this connector. The study of this antenna is not included in this application note.

3 Introduction to RF Transceivers

3.1 RF Transceiver Operation

A transceiver is essentially a receiver and a transmitter in the same package.

A full-duplex transceiver can transmit and receive simultaneously. You can transmit and receive in RF using different frequencies with a high level of isolation between the transmitter and receiver. This un-economical approach is not used in SRD applications.

A half-duplex transceiver can transmit or receive on the same or different frequencies (if required). This approach is far more economical, as many parts of the transmitter and the receiver can be shared.

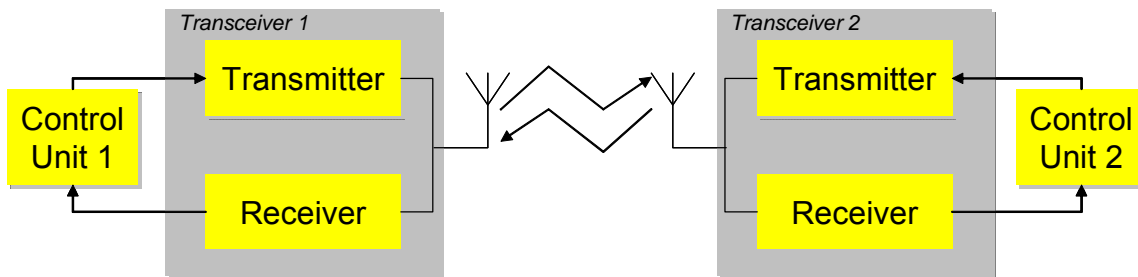


Figure 1. Bidirectional Communication Using Transceivers

An MCU is usually necessary to control the transceiver and send or receive messages according to a defined protocol.

The MCU should have control and status of the following parameters:

- Frequency of operation: to allow frequency change for maximum link reliability in the presence of interferences, for multi-channel operation of several devices
- Modulation used: OOK or FSK
- RSSI value: to verify channel clearance before transmission, to evaluate the distance from the transmitter to the receiver, to allow dynamic RF power management for power saving
- Transmitted power: for power saving where distance between transmitter and receiver is short
- Various digital features such as automatic wake up of the receiver and data processing of the message to reduce MCU load

3.2 RF Transceiver Application

Transceivers are used in many applications in the SRD world, where classic use of a single transmitter and receiver is not possible and additional functionalities are required.

Bidirectional communication improves link performances even if the system functionality doesn't require it. In fact, you can design a protocol that re-transmits a frame when an order is not followed by a feedback indicating that everything is okay, using an RF transceiver.

Automotive:

- Remote keyless entry: The car provides feedback on an LCD screen after a button is pushed (battery voltage, car temperature, tire pressure, fuel level).
- Passive entry: After the driver opens the car door, a special badge he wears activates a bidirectional communication between the badge and the car. After the badge has been authenticated, this signal tells the doors to open.
- Tire pressure monitoring system: A sensor in the wheel transmits temperature and pressure measurements to the car. When the car stops, it transmits information to the sensor to reduce the periodic transmission rate for power saving.

Home automation:

- Garage door opener: After the driver closes the door with the garage door opener and drives off, the car receives confirmation that the door is locked.



- Awnings, screen and shutter control: After pressing the button that closes the house's shutters, the home owner is informed by a feedback that the shutters are locked and not blocked by, for example, a flower pot left on the window sill.
- Light management: Feedback informs you if a lamp is broken.
- Home networking: Information from a remote control or sensor can be transmitted to a receiver several stages up because of networking allowed by transceivers.

Remote metering:

- Fuel level control: The level is transmitted only on demand from a central unit to reduce power consumption and extend the battery life.
- Gas and water metering: The measured quantity is transmitted only on demand from a central unit to reduce power consumption and extend the battery life.

Security:

- Door and window sensors, alarm central unit: All the sensors in an alarm system can be bidirectional to allow power management of the RF power (a sensor close to the central unit needs less transmission power) and to increase battery life.
- Smoke detector: Power management through feedback with a bidirectional link is possible.
- People identification: An authentication sequence can be established between a system controlling the access to a door, a computer, or any other secured equipment and a badge.

4 MC33696 Presentation

Because MC33596 includes the receiver part of MC33696, all comments about MC33696 apply to MC33596 except those concerning the transmitter.

4.1 Main Features

MC33696 is a highly integrated RF transceiver designed for low-voltage applications using half duplex communication in the UHF ISM bands. It includes a programmable PLL for multichannel applications, an RSSI circuit that provides analog and digital results, and a strobe oscillator that periodically wakes up the receiver. A data manager checks the content of incoming message to reduce CPU load and system consumption.

Receiver:

- Frequency: 304 MHz, 315 MHz, 433 MHz, 868 MHz, and 915 MHz bands
- Sensitivity: -106 dBm to -76 dBm typ in four steps at 4.8 kbps
- Modulation: OOK and FSK
- Data rate: up to 19.2 kbps with data manager
- Data manager with clock recovery for manchester coded signals
- RSSI range: 72 dB digital and 42 dB analog
- Receiver bandwidth: 380 kHz
- Current consumption: 9.2 mA typ

Transmitter:

- Frequency: 315 to 915 MHz
- Output power: +7 dBm to -18 dBm in 4 steps at 434 MHz
- Modulation: OOK and FSK
- Data rate: up to 19.2 kbps
- FSK frequency deviation: programmable
- Current consumption: 12.5 mA typ

Other:

- Package: LQFP32 and LQFN32
- Temperature range: -40 to +85°C
- Supply voltage: 2.1 V-3.6 V and 5 V

4.2 Architecture

MC33696 has a built-in integrated fractional PLL that generates the RF signal for transmission, as well as the local oscillator for the super heterodyne receiver. The tuning range of the PLL enables the receiver and transmitter to be tuned to any frequency $\pm 3\%$ from the central frequency defined by the crystal. This gives about ± 12 MHz at 433 MHz with a tuning step of 6 kHz.

During transmission, the OOK modulation is generated by switching the RF amplifier (also called the power amplifier) on and off. The FSK modulation is generated by switching the divider ratio of the PLL thanks to the small frequency step provided by the fractional divider. During transmission, the output power is software-adjustable so various regulations or application requirements can be fulfilled.

The receiver is a low IF super heterodyne receiver with an image rejection mixer to relax the front end filtering requirements. IF filters with a central frequency of 1.5 MHz and a 380 kHz bandwidth are completely integrated. OOK and FSK modulations are possible.

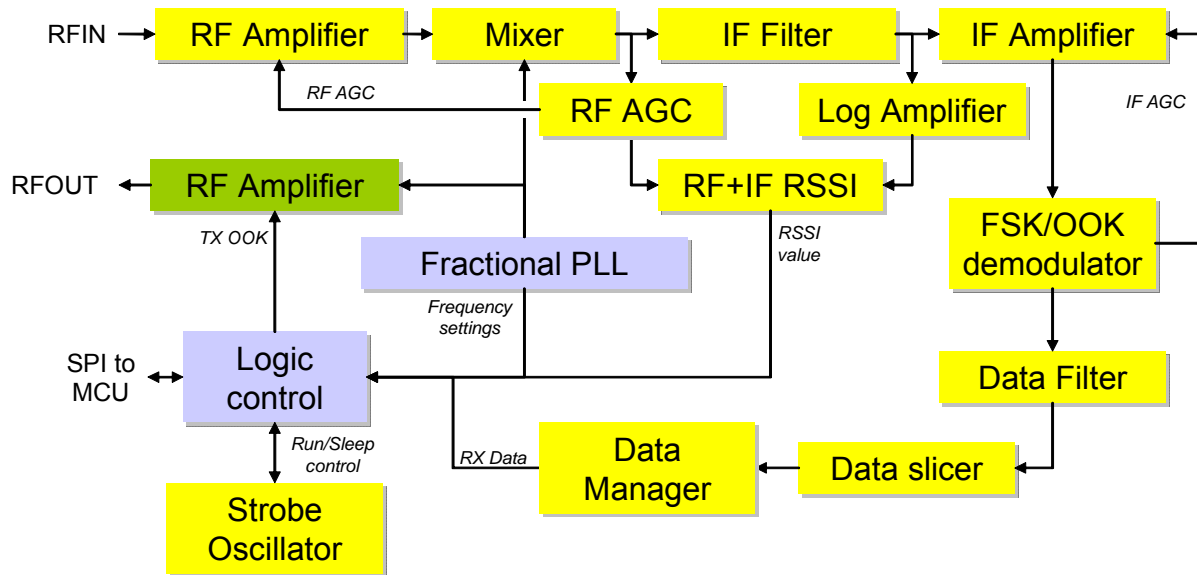


Figure 2. MC33696 Architecture

Two AGC loops regulate the level of the received signal internally. The first loop regulates the level at the output of the mixer to avoid saturation in the active IF filter; it begins this action for RFIN level at about -60 dBm. The second loop regulates the level at the output of the IF amplifier to avoid saturation in this stage.

The OOK demodulator is a peak detector. For FSK operation, the IF amplification is set to maximum to provide a square wave to the FSK demodulator. The FSK demodulator is a frequency-to-voltage converter that uses a low pass filter followed by the OOK demodulator.

Data filters are switched to optimize the signal-to-noise ratio for various data rates. A data slicer converts the analog signal to digital. It compares the signal at the output of the data filter to a reference level that can be fixed or adaptive. When fixed reference level is chosen (useful only in OOK), the slicer reacts very rapidly to incoming signals. Adaptive reference level is generated by averaging the signal. This takes time (this time is programmable), but leads to better sensitivity as less offset error becomes possible. Adaptive reference is mandatory for FSK because the absolute level at the output of the demodulator is unknown. This level depends on the absolute frequency of transmitter and receiver.

An integrated data manager can be selected to avoid the complex task of decoding data with the MCU. This data manager is a powerful logic block, able to recover a clock from a Manchester coded signal and then decode the frame. It can recognize a specific programmable ID in the frame and send on the SPI port the bits that follow. The frame is available on the SPI port with data on the falling edge of the clock that simplifies data reception by the MCU.

A strobe oscillator that wakes up the receiver at a programmable rate automatically is also available. This reduces power consumption because it allows the MCU to sleep as long as the data manager receives no valid data.

All these features are software configurable to fulfill any application specific requirement.

receiver to the matching network. RSSIC controls the state of the RSSI circuit, allowing sampling of the incoming signal RF signal. RSSIOUT is an analog output that provides a voltage that increases with input power.

This schematic is used for the evaluation version of MC33696 RF Module. This simple design is cost effective and requires little power.

However, it does have the following drawbacks:

- Adding a SAW filter to increase EMC performances of the receiver is not recommended because RFIN and RFOUT are connected. SAW in the receiver path causes attenuation on the transmitter path as its impedance is not high when in transmit mode.
- Adding an LNA for the receiver to increase sensitivity or a PA for the transmitter to increase output power is also difficult.

The reference design version of MC33696 RF module should overcome those drawbacks.

5 MC33696 RF Module: Reference Design Version

5.1 Target of this Design

For high performance applications requiring long range transmission with a high level of EMC performance, you may need additional filtering and amplification. Transmission output power can be increased by an additional power amplifier. EMC performance can be improved using a SAW filter that removes all high level out-of-band interferences causing intermodulation distortion or compression. An LNA is then necessary to compensate SAW filter attenuation and to prevent sensitivity loss.

After you do this, you cannot connect the receiver and transmitter path together because they cause attenuation. You must use a switch to disconnect the unused path.

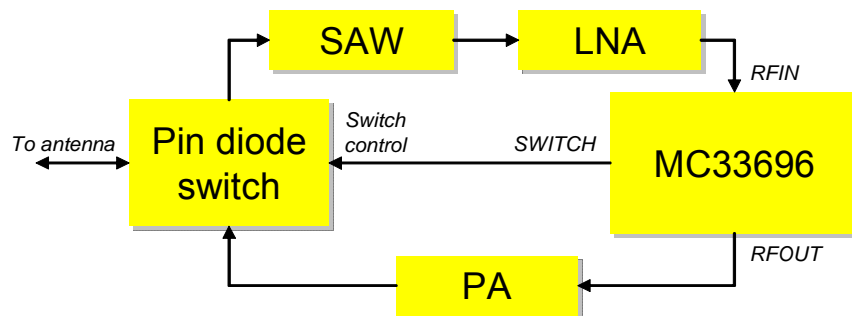


Figure 4. RF Module Architecture

MC33696 can provide the signal to control the state of the switch.

5.2 Reference Design Version of the MC33696 RF Module

5.2.1 PIN Diode Switch

The pin diode switch connects the transmitter or the receiver path to the antenna.

This switch's specifications include:

- Minimum insertion loss for transmit and receive path
- High isolation between transmit and receive path
- Minimum current consumption when transmitting
- No current consumption when receiving
- Low harmonic distortion for the transmit path
- Low intermodulation distortion for the receive path
- Fast switching time

The pin diode switch uses the properties of the $\lambda/4$ (lambda/4) line with a characteristic impedance of Z_0 :

$$Z_{0\lambda/4} = \sqrt{Z_{in} \times Z_{out}} \quad \text{Eqn. 5-1}$$

or

$$Z_{in} = \frac{Z_{0\lambda/4}^2}{Z_{out}} \quad \text{Eqn. 5-2}$$

The $\lambda/4$ line is an impedance inverter when:

- High impedance input when output is short circuited to ground
- Low impedance input when output is open circuit
- Z_0 impedance input when output is connected to Z_0

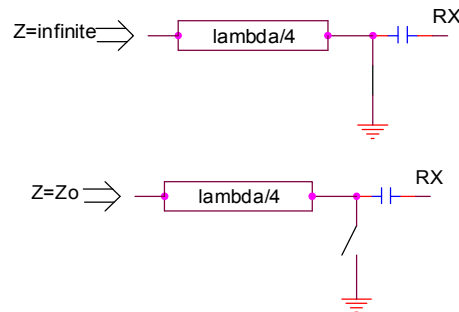


Figure 5. $\lambda/4$ Line Impedance Inversion

The practical design uses that property. D1 is used as a switch; it is forward biased or not according to the voltage presented on T/R pin.

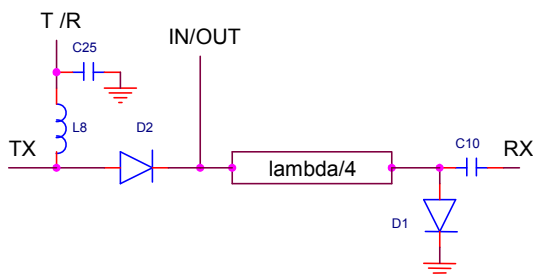


Figure 6. Switch Using Pin Diodes

If T/R is high, a current flows through L8, D2, the $\lambda/4$ line, and D1. Like any pin diode, D1 has a minimum resistance. The impedance presented on the IN/OUT connection is maximum and the receive part is isolated from the IN/OUT connection. D2 is forward-biased and the transmitter part is connected to IN/OUT.

If T/R is low, no current flows and D1 is high impedance. The impedance presented to the $\lambda/4$ line is then defined by the receiver impedance. If this impedance is equal to Z_o , the $\lambda/4$ line reflects Z_o impedance to IN/OUT and is matched. The receiver is then connected to IN/OUT without loss. Because D2 is not biased, it is high impedance and the transmitter path is disconnected from IN/OUT.

The final design uses a slightly different schematic. In fact, the module is supposed to work on various frequencies. Because the $\lambda/4$ line is a printed line on the PCB, you cannot use it for the RF module. Replace the $\lambda/4$ line with its equivalent schematic.

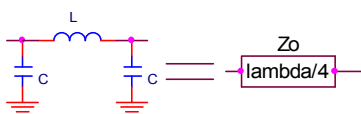


Figure 7. Discrete Component Equivalent To $\lambda/4$ Line

The two circuits are equivalent for the same frequency if:

$$Z_o = |Z_L| = |Z_C| \tag{Eqn. 5-3}$$

with

$$Z_C = \frac{1}{2\pi FC} \tag{Eqn. 5-4}$$

and

$$Z_L = 2\pi FL \tag{Eqn. 5-5}$$

For a given Z_{out} impedance presented at the output, the $\lambda/4$ line reflects at its input a Z_{in} input impedance according to the following relationship:

$$Z_{o_{\lambda/4}} = \sqrt{Z_{in} \times Z_{out}} \tag{Eqn. 5-6}$$

or

$$Z_{in} = \frac{Z_{o_{\lambda/4}}^2}{Z_{out}} \tag{Eqn. 5-7}$$

By changing L and C, you can optimize Z_o and Z_{in} to minimize the loss due to the connection of the receiver path when MC33696 is transmitting.

Diodes used for D1 and D2 are HSMP-3890 from Agilent. They have low impedance even if biased with low current. They also offer very low harmonic distortion for transmitter and do not degrade the overall intermodulation distortion for the receiver.

As D1 can have an ON impedance of about 8Ω when forward biased, it is necessary to have a high Z_o value to obtain a high Z_{in} for proper insulation when transmitting.

The initial design choice for the characteristic impedance of the $\lambda/4$ line was 50Ω Z_o impedance. Then, by short circuiting C14 ($Z_{out}=0$), Z_{in} impedance can be evaluated because it is also dependant on the Q factor of the various components (or losses). The final choice for Z_o is about 300Ω . An additional matching network between C10 and the SAW filter used is required. Exact impedance for the $\lambda/4$ line is not critical.

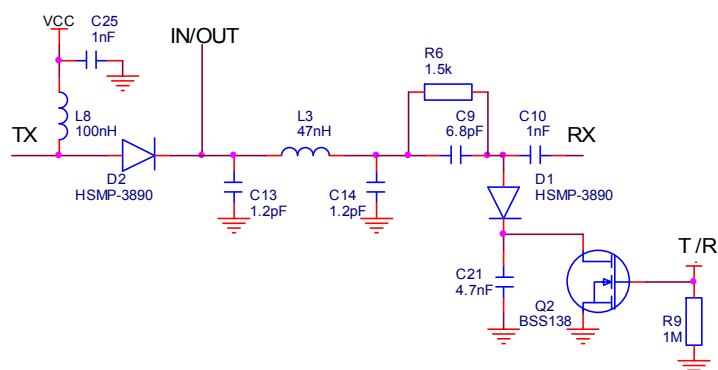


Figure 8. Practical Implementation of the $\lambda/4$ Switch

C9 compensates the inductive part of D1 and associated components that kill the high Z_{in} wanted. By tuning C9, you can have a high pure resistive Z_{in} at the input port.

If T/R equals 1, the switch is in transmit mode:

- Q2 is ON and bypass C21
- D2 is forward bias and connect TX to the IN/OUT port
- D1 is biased with R6 and presents a low Z_{out} impedance to the $\lambda/4$ line output
- The $\lambda/4$ line presents a high impedance to the IN/OUT port
- RX path is then disconnected

If T/R equals 0, the switch is in receive mode:

- Q2 is OFF
- D2 is not biased and TX is isolated from the IN/OUT port
- D1 is not biased and presents an high impedance to the RX port
- RX is connected to the IN/OUT port through the $\lambda/4$ line

The performances of the switch (with matching network to 50 Ω on all ports) are:

- current consumption: 1 mA for 3 V in TX mode
- TX attenuation: -0.8 dB
- RX attenuation: -1 dB
- Isolation TX-RX: 24 dB

5.2.2 Low Noise Amplifier

The low noise amplifier (LNA) should compensate for the losses of the SAW filter. It should improve overall performance and not degrade high level behavior of the receiver.

Specifications for the LNA include:

- Low noise figure
- $+10$ dB power gain
- 1 mA current consumption
- High IP3
- Current consumption that can be switched to 0 mA when not receiving
- SOT23 package, low cost

Some of those specifications are in opposition. High IP3 and high power gain may require a high current. Some compromises must be made. The LNA's design should be optimal for a given current consumption.

The BFT25A represents a compromise for this application. It is used in a common emitter configuration. Biasing is defined by R1 and R8. L1 is a part of output matching network. R7 and C4 can guarantee feedback for unconditional stability. The schematic diagram includes a MOS FET transistor to switch the LNA to ON/OFF.

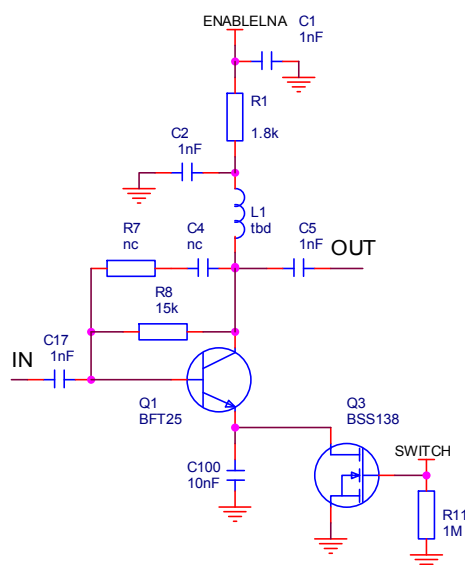


Figure 9. LNA Schematic

S-Parameters are available for $V_{ce}=1$ V and $I_c=1$ mA. This is the bias currently in use.

5.2.2.1 Design Using S-Parameters

You can design an LNA using S-Parameters. If the LNA is unconditionally stable, you can define the maximum power gain and the terminal impedances to obtain stability and amplification. If the device chosen is not unconditionally stable at any frequency, a feedback can be applied to modify the LNA S-Parameters.

For the study of this LNA, an Excel sheet has been created to evaluate over a wide frequency band:

- The stability criteria (to know if a device is unconditionally stable or not)
- The maximum available gain
- The conjugate match impedances (impedance to present to have maximum gain)
- The impedance to present for a given gain
- The location and radius of the stability circles (location on the Smith chart of the impedances to present to have stability)
- The location and radius of the NF circles (location on the Smith chart of the impedances to present to have a given noise factor)
- The resulting S-parameters for a device with an RLC feedback

This Excel sheet gives the computations using the transistor S-Parameters:

$$S = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix}$$

Figure 10. S-Parameters Matrix

5.2.2.1.1 Stability

Rollet stability factor (K) computation shows a device is unconditionally stable or not:

$$K = \frac{1 + |D_S|^2 - |S_{11}|^2 - |S_{22}|^2}{2 \times |S_{21}| \times |S_{12}|} \quad \text{Eqn. 5-8}$$

with

$$D_S = S_{11} \times S_{22} - S_{12} \times S_{21} \quad \text{Eqn. 5-9}$$

If K is greater than 1, the device is unconditionally stable. It is stable for any combination of source and load impedances.

If K is less than 1, the transistor is conditionally stable for some combinations of source and load impedances. In this case, choose another transistor for your application, another bias point, or compute the source and load impedances that can be used in a stable configuration.

5.2.2.1.2 Maximum Available Gain (MAG)

The MAG is the maximum available gain that can be obtained from a device if its input and output reflection coefficients fulfill some conditions (See [Section 5.2.2.1.3, “Simultaneous Conjugate Match”](#)).

Eqn. 5-10

$$MAG_{dB} = 10 \times \log \frac{|S_{21}|}{|S_{12}|} + 10 \times \log \left| K + \left(\text{signof}(B_1) \times \sqrt{K^2 - 1} \right) \right|$$

with:

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |Ds|^2$$

Eqn. 5-11

$$Ds = S_{11} \times S_{22} - S_{12} \times S_{21}$$

Eqn. 5-12

K is the Rollet Stability Factor

NOTE

The MAG is defined only for unconditional stable transistors because K has to be greater than 1.

5.2.2.1.3 Simultaneous Conjugate Match

The MAG is obtained by applying the impedances representing the conjugate matching that matches input and output to the device ports.

The output load coefficient is defined by:

Module:

Eqn. 5-13

$$|\Gamma_L| = \frac{B_2 - \left(\text{signof}(B_2) \times \sqrt{B_2^2 - 4 \times |C_2|^2} \right)}{2 \times |C_2|}$$

Argument:

$$\angle \Gamma_L = -\angle C_2$$

Eqn. 5-14

with

$$B_2 = 1 + |S_{22}|^2 - |S_{11}|^2 - |Ds|^2$$

Eqn. 5-15

$$Ds = S_{11} \times S_{22} - S_{12} \times S_{21}$$

Eqn. 5-16

$$C_2 = S_{22} - Ds(S_{11})^*$$

Eqn. 5-17

The input load coefficient is defined by:

Eqn. 5-18

$$\Gamma_S = \left[S_{11} + \frac{S_{12} \times S_{21} \times \Gamma_L}{1 - (\Gamma_L \times S_{22})} \right]^*$$

5.2.2.1.4 Practical Design

The Excel paper sheet has been used to compute the input and output matching network for a given gain. The results have been simulated with a Smith chart program. You can also evaluate the bandwidth of the various matching networks and the sensitivity of the various components on the results.

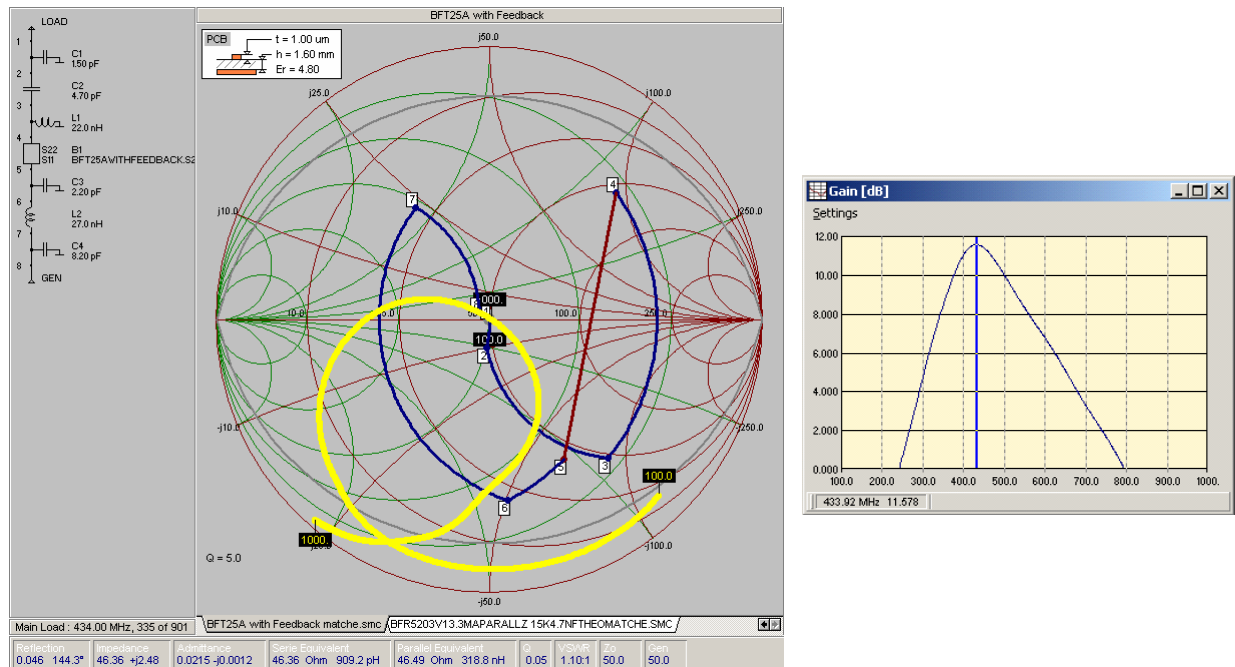


Figure 11. Simulated Results

Computation and simulation shows the LNA should have an RLC feedback to have unconditional stability (1.2 K+4.7 nF).

A prototype matched to input and output to 50 Ω was then built and measured on a network analyzer.

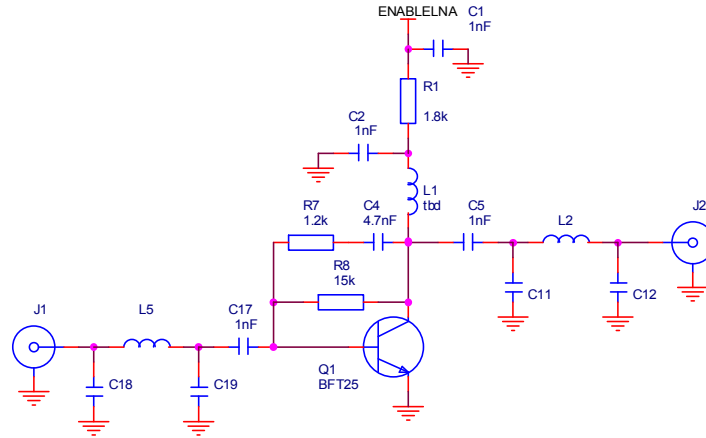


Figure 12. LNA Prototype

This prototype showed the following performances:

- 9.9 dB gain (for 11.57 dB by simulation)
- 1 mA current consumption
- NF not measured

Later, the LNA on the final PCB presented different characteristics as tracks and ground connections of emitter changes the LNA S-parameters. As a result, RLC feedback was no longer needed.

5.2.3 Power Amplifier

The power amplifier (PA) should increase the output power of the transmitter with minimum current consumption and distortion.

We can define some specifications for the PA:

- +5 dB to +10 dB gain
- +10 dBm output power
- Less than 15 mA current consumption
- Low distortion
- Current consumption may be switched to 0 mA when not transmitting
- SOT23 package, low cost

The BFR520 is indicated for this kind of application. To minimize distortion, a feedback network is used.

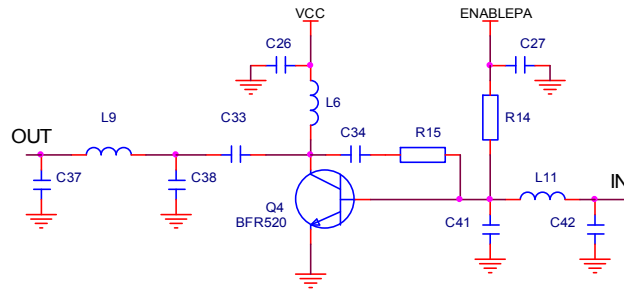


Figure 13. PA Prototype

The design of a PA cannot be used with low-level parameters like S-Parameters. You may need to use hot S-Parameters (S-Parameter characterization using high level signals) or deal with an intensive RF simulation or lab test.

One prototype that provides +8.8 dBm for 15 mA power consumption and reasonable distortion exists.

But because the latest version of MC33696 silicon provides about +7 dBm at low frequency, demand for an external PA is too low to justify the additional current consumption.

Even with some provisions for the PA on the printed circuit board, it is not equipped with components.

5.2.4 Schematic Diagram of MC33696/MC33596 RF Module

The schematics presented here show only the 433.92 MHz versions. For information on other frequencies, see [Section 11, “Bill of Material.”](#)

5.2.4.1 MC33696 Reference Design at 433.92MHz

[Figure 5-13](#) shows the version developed in this application note. MC33696 is surrounded by an LNA, a SAW filter, and a PIN diode Switch. This version is not available as an evaluation tool.

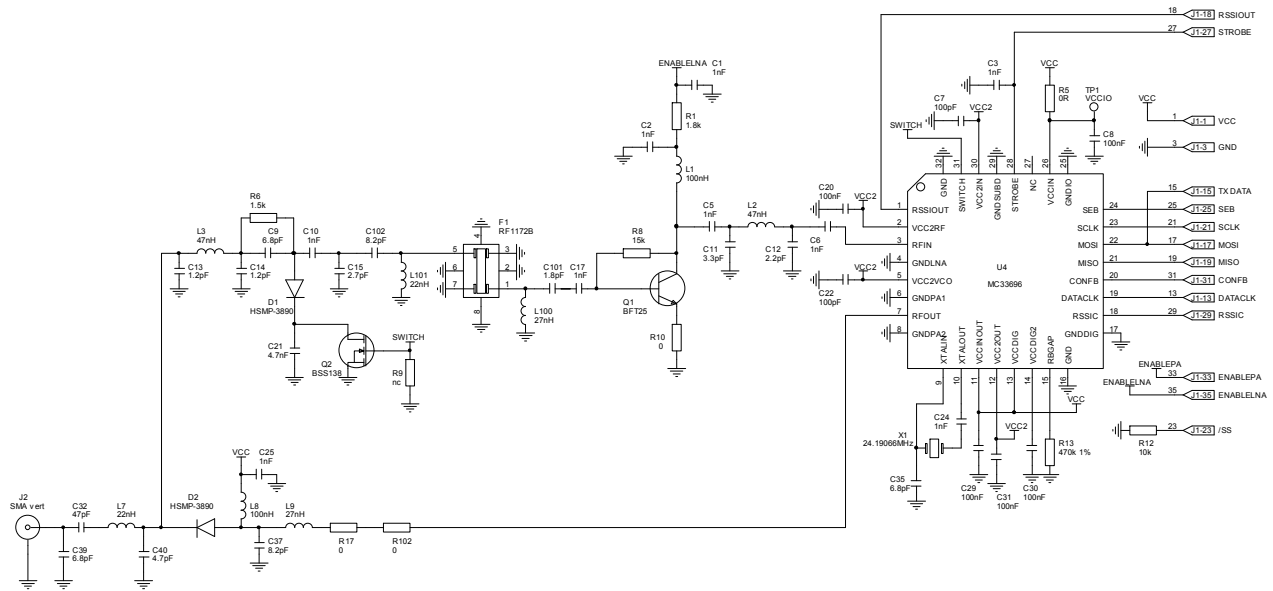


Figure 14. MC33696 Reference Design Schematic Diagram

5.2.4.2 MC33596 Reference Design at 433.92MHz

Figure 15 shows MC33596 surrounded by an LNA and a SAW filter. This version is not available as an evaluation tool.

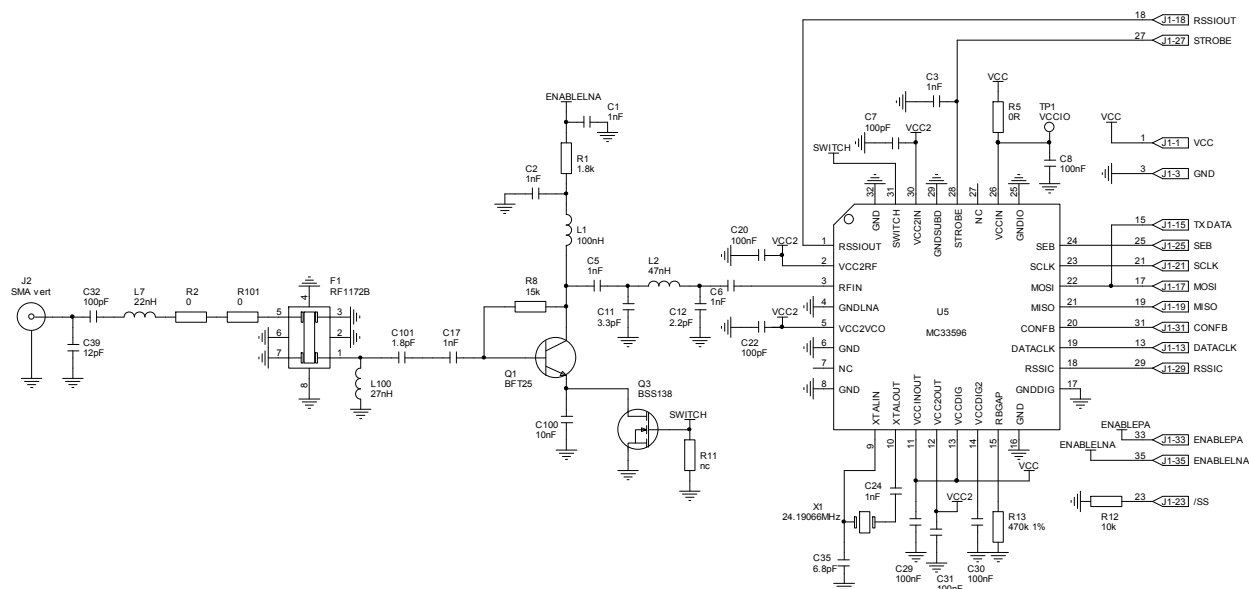


Figure 15. MC33596 Reference Design Schematic Diagram

5.2.4.3 MC33696 Evaluation Version at 433.92MHz

This version of the RF Module shown in Figure 16 is the simplest one. It has been developed to allow lab evaluation of MC33696. Only 50Ω matching networks are added to MC33696. This version is available at various frequencies for evaluation.

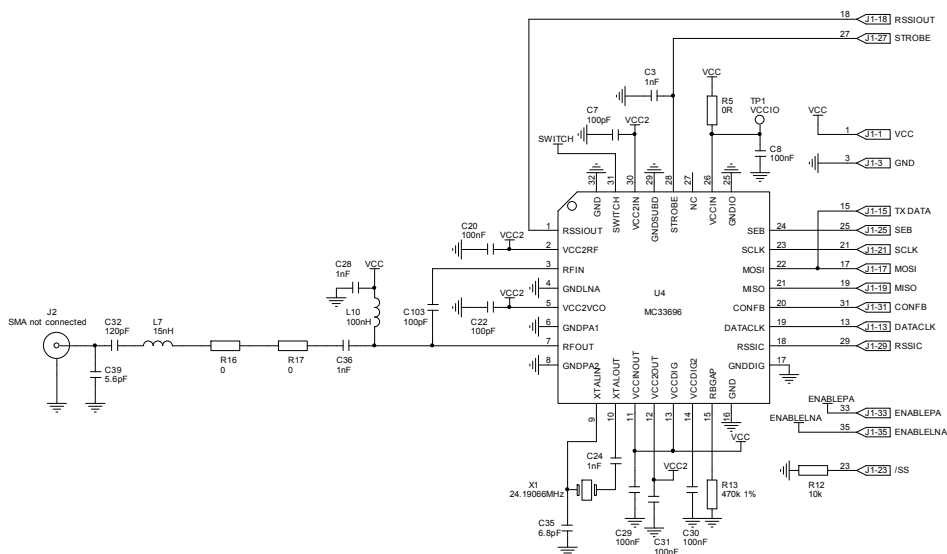


Figure 16. MC33696 Reference Design Schematic Diagram

5.2.4.4 Schematic Diagram Common to MC33696/MC33596 RF Modules Versions

The schematic shown in [Figure 17](#) is used to allow the CAD generation of different versions of MC33696 RF Modules. It is possible to obtain various schematics by adding or removing components:

- MC33696 Evaluation Version:
 - MC33696
 - 50Ω Matching network
- MC33696 Reference Design Version:
 - MC33696
 - LNA
 - SAW Filter
 - Power Amplifier (not developed)
 - Pin Diode Switch
 - 50Ω Matching network

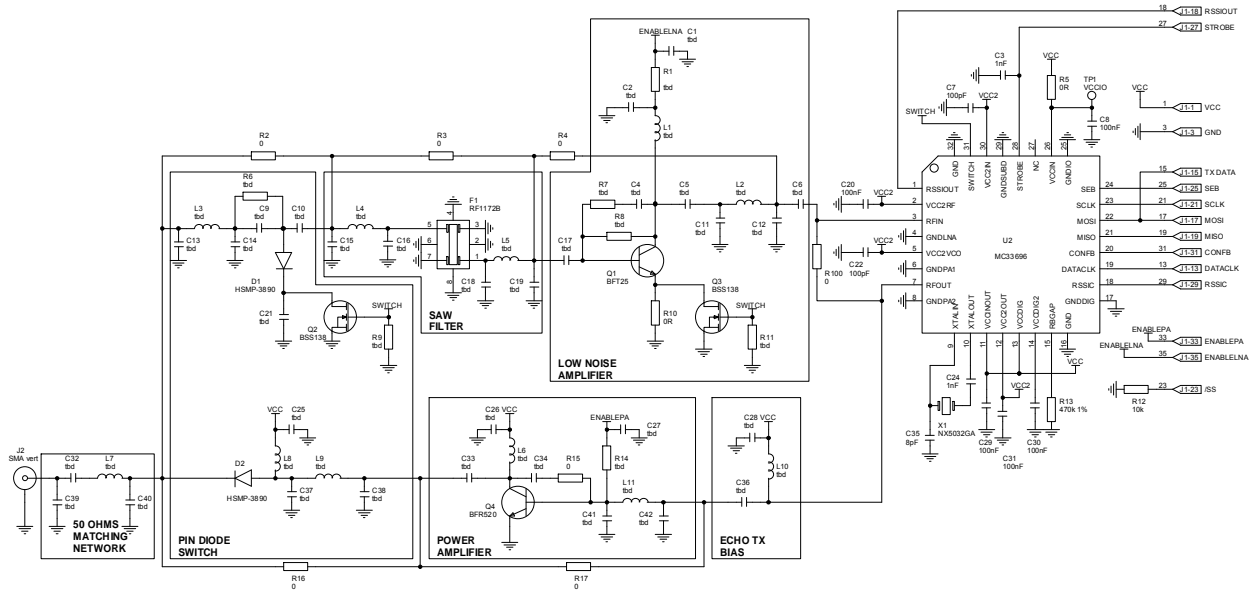


Figure 17. Complete Schematic Diagram Used for CAD Design

6 Connector Pin Out

All the logic level signals available on J1 are referred to as VDD and GND. Do not apply any signal higher than VDD or lower than GND to the module.

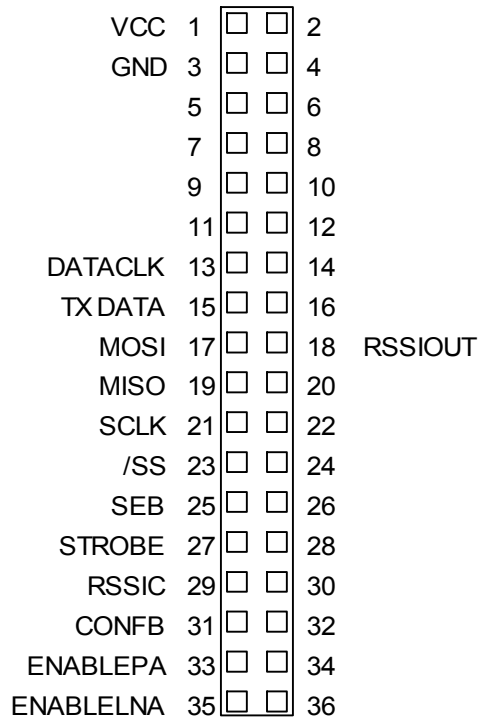


Figure 18. Connector Pin Out

Table 2.

Number	Name	Type	Function
1	VDD	Power supply	3 V for MC33696 and LNA.
3	GND	Power supply	To be connected to a large ground plane
13	DATACLK	Output	Clock for MCU timer
15	DATA	Input	Transmitter input
17	MOSI	Input/Output	Serial data for the SPI port
18	RSSIOUT	Output	Analog RSSI output
19	MISO	Output	Serial data for the SPI port
21	SCLK	Input/Output	Serial clock for the SPI port
25	SEB	Input	Serial Bus Enable. Connect to 1 to enable SPI bus
27	STROBE	Input	Strobe oscillator control 0: strobe oscillator is stopped and MC33696 sleeps 1: strobe oscillator is stopped and MC33696 runs high: strobe oscillator is running

Table 2.

Number	Name	Type	Function
29	RSSIC	Input	RSSI control 0: RSSI sampled on falling edge 1: RSSI continuously updated
31	CONFB	Input	Configuration mode/normal mode control for the SPI port
33	ENABLEPA	Input	PA bias control 0: PA is OFF 1: PA is ON. Normal mode during transmission
35	ENELELNA	Input	LNA bias control 0: LNA is OFF. 1: LNA is ON. Normal mode during reception

7 First Step For Receiver Testing

The following set-up allows measurement of the sensitivity of MC33696's receiver:

- 433.92 MHz
- 4800 bps
- No data manager
- OOK or FSK

To test the receiver in other configurations, refer to the registers description in the MC33696 datasheet to modify the settings properly.

For other frequencies, additional script files are provided in the CD attached to the MC33696 RF Module.

7.1 Test Set Up for OOK and FSK

- Plug the RF module into the MCU board
- Connect the MCU board to the PC with an RS232 cable
- Connect an RF generator to the SMA connector
 - OOK configuration:
 - Frequency: 433.92 MHz
 - Modulation: pulse (or 100% AM square wave), 4.8 kHz
 - RF level: -70 dBm
 - FSK configuration:
 - Frequency: 433.92 MHz
 - Modulation: FSK ± 50 kHz, 4.8 kHz
 - RF level: -70 dBm
- Connect an oscilloscope probe on MOSI (pin 17 of connector)
 - 1 V/div, 20 μ s/div

- Connect a voltmeter or a oscilloscope probe on RSSIOUT (pin 17 of connector)
- Apply 9 V power supply to the MCU board

7.2 Registers and Pins Set up

Use scripts to avoid manual setting (see files in RF modules kit CD ROM). Use the control software to set up registers and pins as given in the following sections.

7.2.1 RX OOK 433.92 MHz

- STROBE 1
- SEB 0
- CONFIG1 50
- CONFIG2 cD
- CONFIG3 00
- COMMAND 19
- F 07F5
- FT 7096F7
- ID 00
- HEADER 00
- DATA Z
- PA 0
- LNA 1
- RSSIC 1

7.2.2 RX FSK 433.92 MHz

- STROBE 1
- SEB 0
- CONFIG1 50
- CONFIG2 ED
- CONFIG3 00
- COMMAND 19
- F 07F5
- FT 7096F7
- ID 00
- HEADER 00
- DATA Z
- PA 0
- LNA 1

- RSSIC 1

7.2.3 Measurements

The oscilloscope shows the demodulated signal. Decrease RF signal levels and control the quality of the demodulated signal to evaluate sensitivity.

The voltmeter measures RSSI analog voltage. Change the RF signal level to check influence.

8 First Step for Transmitter Testing

The following set up allows you to measure the output power and spectral purity of MC33696's transmitter:

- 433.92 MHz
- Continuous wave or modulated
- OOK or FSK

To test the transmitter in other configurations, refer to the registers description in MC33696 datasheet to modify settings properly.

For other frequencies, additional script files are provided in CD attached to the MC33696 RF Module.

8.1 Test Set-Up

- Plug the RF module onto the MCU board
- Connect the MCU board to the PC with an RS232 cable
- Connect a spectrum analyzer to the SMA connector
 - Center frequency: 433.92 MHz
 - Span: 1 MHz
 - Reference level: 15 dBm
 - RBW: auto or 10 kHz
- Apply 9 V power supply to the MCU board

8.2 Registers and Pins Set Up

Use scripts to avoid manual setting (see files in RF Modules kit CD ROM). Use the control software to set up registers and pins as given in the following sections.

8.2.1 TX OOK 433.92 MHz

- CONFB 1
- STROBE 1
- SEB 0
- CONFIG1 50
- CONFIG2 CD
- CONFIG3 00
- COMMAND 39
- F 07F5
- FT 7006F7
- DATA 1
- PA 1
- LNA 0
- RSSIC 0

8.2.2 TX FSK 433.92 MHz

- CONFB 1
- STROBE 1
- SEB 0
- CONFIG1 50
- CONFIG2 ED
- CONFIG3 00
- COMMAND 39
- F 07F5
- FT 7086F7
- DATA 1
- PA 1
- LNA 0
- RSSIC 0

8.3 Measurements

The spectrum analyzer displays the RF spectrum and allows peak power measurement.

To make measurements using modulated waves, use the following command:

- TXSQUARE 208

This modulates the signal with a square wave at 4800 bps or 208 μ s period.

Stop modulation by striking the return key.

To allow another transmission in CW mode:

- MODE 1
- DATA 1

9 MC33696/MC33596 RF Module Performances

9.1 Performance Variables

Table 3 shows measurements done with the conditions:

- RX: OOK 4.8 kbps, sensitivity measured for BER = 10⁻³
- TX: continuous wave, peak power measurement

Table 3. Measurements

Ref	Frequency	RX Sensitivity	TX Power	RX current	TX current
MC33696MOD315EV	315 MHz	-105 dBm	+8 dBm	8.8 mA	12 mA
MC33696MOD434EV	433.92 MHz	-104 dBm	+7.5 dBm	9 mA	13 mA
MC33696MOD868EV	868.3 MHz	-103 dBm	+4 dBm	9.2 mA	13 mA
MC33696MOD916EV	916.5 MHz	-103 dBm	+3.5 dBm	9 mA	12.5 mA
MC33696MOD434	433.92 MHz	-106 dBm	+7 dBm	10.2 mA	13.5 mA
MC33596MOD434	433.92 MHz	-106 dBm	na	10.2 mA	na

10 PCB Design

10.1 Layout

Be careful with the layout of the PCB by using a double-sided PCB.

MC33696/MC33596:

- Use a large ground plane on the opposite layer
- Connect each ground pin to the ground plane using a separate via for each signal. Do not use a common via
- Place each decoupling capacitor as close as possible (no more than 2-3 mm) to the corresponding VDD pin
- VCCDIG2 decoupling capacitor (C30) should be placed directly between VCCDIG2 (pin 14) and GND (pin 16)
- Crystal X1 and associated capacitors C24 and C36 should be close to U1. Avoid loops due to the component size and tracks. Avoid digital signal routing in this area.

SAW filter:

- Connect each ground return directly to the ground plane. Avoid common via to guarantee maximum out of band rejection
- The associated matching network should have separate ground connections

LNA:

- The connection of the Q1 emitter should be very short to ground to minimize track inductance and maintain stability
- Feedback components (R5, R6, C4) should be connected directly between base and collector
- The C2 decoupling capacitor should be connected directly between L1 and ground

Other:

- Minimize any track routing RF signal
- Use high frequency coils with high Q values for the frequency of operation (min 15). Any change of coil source should be validated
- Avoid proximity of any input and output of a block to maintain stability (LNA) or maximum rejection (SAW filter)
- If the ground plane has to be cut on the opposite layer to route on a signal, maintain the continuity with another ground plane on the opposite layer and a lot of via to have minimum parasitic inductance
- If you can afford a multilayer PCB, use an internal layer for the ground plane. Route the power supply and digital signals on the last layer. RF components are placed on the first layer.

NOTE

Matching networks should be retuned if any change has been made to PCB (track width, length or place, PCB thickness, component value). Never use a matching network designed for another PCB.

11 Bill of Material

Table 4. Bill of Materials

		WEB Module reference	MC33696MOD315EV	MC33696MOD434EV	MC33696MOD868EV	MC33696MOD434	MC33596MOD434
		BOM version	V2.0	V2.0	V2.0	V2.0	V1.0
		Frequency	315 MHz	433.92 MHz	868.3 MHz	433.92 MHz	433.92 MHz
		Equipment	Evaluation	Evaluation	Evaluation	Ref Design	Ref Design
Reference	Package	Supplier					
C1	0603	any	not equipped	not equipped	not equipped	1 nF	1 nF
C10	0603	any	not equipped	not equipped	not equipped	1 nF	not equipped
C100 (may replace R10)	0603	any	not equipped	not equipped	not equipped	not equipped	10 nF
C101 (may replace L5)	0603	any	not equipped	not equipped	not equipped	1.8 pF	1.8 pF
C102 (may replace L4)	0603	any	not equipped	not equipped	not equipped	8.2 pF	not equipped
C103 (may replace R100)	0603	any	100 pF	100 pF	100 pF	8.2 pF	not equipped
C11	0603	any	not equipped	not equipped	not equipped	3.3 pF	3.3 pF
C12	0603	any	not equipped	not equipped	not equipped	2.2 pF	2.2 pF
C13	0603	any	not equipped	not equipped	not equipped	1.2 pF	not equipped
C14	0603	any	not equipped	not equipped	not equipped	1.2 pF	not equipped
C15	0603	any	not equipped	not equipped	not equipped	2.7 pF	not equipped
C16	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C17	0603	any	not equipped	not equipped	not equipped	1 nF	1 nF
C18	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C19	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C2	0603	any	not equipped	not equipped	not equipped	1 nF	1 nF

Table 4. Bill of Materials

		WEB Module reference	MC33696MOD315EV	MC33696MOD434EV	MC33696MOD868EV	MC33696MOD434	MC33596MOD434
C20	0603	any	100 nF	100 nF	100 nF	100 nF	100 nF
C21	0603	any	not equipped	not equipped	not equipped	4.7 nF	not equipped
C22	0603	any	100 pF	100 pF	100 pF	100 pF	100 pF
C24	0603	any	1 nF	1 nF	1 nF	1 nF	1 nF
C25	0603	any	not equipped	not equipped	not equipped	1 nF	not equipped
C26	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C27	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C28	0603	any	1 nF	1 nF	1 nF	not equipped	not equipped
C29	0603	any	1 nF	1 nF	1 nF	100 nF	1 nF
C3	0603	any	1 nF	1 nF	1 nF	1 nF	1 nF
C30	0603	any	10 nF	10 nF	10 nF	100 nF	10 nF
C31	0603	any	10 nF	10 nF	10 nF	100 nF	10 nF
C32	0603	any	82 pF	120 pF	27 pF	47 pF	100 pF
C33	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C34	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C35	0603	any	6.8 pF	6.8 pF	6.8 pF	6.8 pF	6.8 pF
C36	0603	any	1 nF	1 nF	1 nF	not equipped	not equipped
C37	0603	any	not equipped	not equipped	not equipped	8.2 pF	not equipped
C38	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C39	0603	any	3.9 pF	5.6 pF	0.47 pF	6.8 pF	12 pF
C4	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C40	0603	any	not equipped	not equipped	not equipped	4.7 pF	not equipped
C41	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C42	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
C5	0603	any	not equipped	not equipped	not equipped	1 nF	1 nF
C6	0603	any	not equipped	not equipped	not equipped	1 nF	1 nF

Table 4. Bill of Materials

		WEB Module reference	MC33696MOD315EV	MC33696MOD434EV	MC33696MOD868EV	MC33696MOD434	MC33596MOD434
C7	0603	any	100 pF	100 pF	100 pF	100 pF	100 pF
C8	0603	any	100 nF	100 nF	100 nF	100 nF	100 nF
C9	0603	any	not equipped	not equipped	not equipped	6.8 pF	not equipped
D1	SOT23	Agilent	not equipped	not equipped	not equipped	HSMP-3890	not equipped
D2	SOT23	Agilent	not equipped	not equipped	not equipped	HSMP-3890	not equipped
F1	SM8558-8	RFM	not equipped	not equipped	not equipped	RF1172B	RF1172B
J1	DIL2x18	Pin length 8mm MIN	DIL 2x18-2.54 mm	DIL 2x18-2.54 mm	DIL 2x18-2.54 mm	DIL 2x18-2.54 mm	DIL 2x18-2.54 mm
J2	SMA	Johnson Components	replaced by ANT315	replaced by ANT434	replaced by ANT868	replaced by ANT434	replaced by ANT434
L1	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	100 nH	100 nH
L10	0603	TDK (MLG1608)	100 nH	100 nH	47 nH	not equipped	not equipped
L100 (may replace C18)	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	27 nH	27 nH
L101 (may replace C16)	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	22 nH	not equipped
L11	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	not equipped	not equipped
L2	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	47 nH	47 nH
L3	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	47 nH	not equipped
L4	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	not equipped	not equipped
L5	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	not equipped	not equipped
L6	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	not equipped	not equipped
L7	0603	TDK (MLG1608)	47 nH	15 nH	47 nH	22 nH	22 nH
L8	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	100 nH	not equipped
L9	0603	TDK (MLG1608)	not equipped	not equipped	not equipped	27 nH	not equipped
Q1	SOT23	Philips	not equipped	not equipped	not equipped	BFT25	BFT25

Table 4. Bill of Materials

		WEB Module reference	MC33696MOD315EV	MC33696MOD434EV	MC33696MOD868EV	MC33696MOD434	MC33596MOD434
Q2	SOT23	Fairchild	not equipped	not equipped	not equipped	BSS138	not equipped
Q3	SOT23	Fairchild	not equipped	not equipped	not equipped	not equipped	BSS138
Q4	SOT23	Philips	not equipped	not equipped	not equipped	not equipped	not equipped
R1	0603	any	not equipped	not equipped	not equipped	1.8 k	1.8 k
R11	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R10	0603	any	not equipped	not equipped	not equipped	0R	not equipped
R100	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R101 (may replace L4)	0603	any	not equipped	not equipped	not equipped	not equipped	0R
R102 (may replace C36)	0603	any	not equipped	not equipped	not equipped	0R	not equipped
R12	0603	any	10 k	10 k	10 k	10 k	10 k
R13	0603	any	470 k 1%	470 k 1%	470 k 1%	470 k 1%	470 k 1%
R14	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R15	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R16	0603	any	0R	0R	0R	not equipped	not equipped
R17	0603	any	0R	0R	0R	0R	not equipped
R2	0603	any	not equipped	not equipped	not equipped	not equipped	0R
R3	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R4	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
R5	0603	any	0R	0R	0R	0R	0R
R6	0603	any	not equipped	not equipped	not equipped	1.5 k	not equipped
R7	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped

Table 4. Bill of Materials

		WEB Module reference	MC33696MOD315EV	MC33696MOD434EV	MC33696MOD868EV	MC33696MOD434	MC33596MOD434
R8	0603	any	not equipped	not equipped	not equipped	15 k	15 k
R9	0603	any	not equipped	not equipped	not equipped	not equipped	not equipped
U1	LQFP32 5x5	Freescale	MC33696	MC33696	MC33696	MC33696	MC33596
X1	NX5032 GA	NDK	17.5814 MHz	24.19066 MHz	24.16139 MHz	24.19066 MHz	24.19066 MHz

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