

TH7122 and TH71221 with External PA and LNA

The output power and the sensitivity of TH7122x transceivers for SRD are enough for many applications. They can deliver up to 10dBm output power and have a sensitivity of up to -105dBm in FSK mode.

However, some parameters of the standard TH7122x EVB can be improved. The standard EVB does not have much RF selectivity, so the image rejection of the boards at high frequencies is low. In some cases the leakage from the receiver VCO to the input is also high. For some applications the customer needs a better sensitivity and a higher output power. The aim of this application note is to show how to improve these parameters. One PCB layout has been designed for both TH7122 and TH71221 transceivers. A summary of the measured results is shown below.

Measured Results for 433 MHz

- Power supply range: 3V to 5.5V
- Operating current: 12mA in receive mode and 3.6V power supply
- Operating current: 16mA in receive mode and 5V power supply
- Operating current 77 to 87mA in transmit mode and 3.6V power supply
- Operating current 107 to 112mA in transmit mode and 5V power supply
- Output power +17dBm at 3.6V power supply
- Output power +20dBm at 5V power supply
- Sensitivity: -115dBm at FSK with 180kHz IF filter BW
- Image rejection better than 40dB
- Improved blocking immunity
- Max. Input level: -10 dBm for FSK

Measured Results for 868 MHz

- Power supply range: 3V to 5.5V
- Operating current: 12mA in receive mode and 3.6V power supply
- Operating current: 16mA in receive mode and 5V power supply
- Operating current 77mA in transmit mode and 3.6V power supply
- Operating current 107mA in transmit mode and 5V power supply
- Output power +17dBm at 3.6V power supply
- Output power +20dBm at 5V power supply
- Sensitivity: -115dBm at FSK with 180kHz IF filter BW
- Image rejection better than 25dB
- Blocking immunity is increased
- Max. input level: -10dBm for FSK

Document Content

1	Circuit Description	3
1.1	TX/RX PIN Diode Switch	3
1.2	External Power Amplifier	4
1.3	External LNA and SAW Filter for the Receiver	7
1.4	Software Settings	9
2	Complete Board for the PA, LNA and TX/RX Switch.....	10
2.1	Board Component Values (Fig. 10)	10
2.2	Component Arrangement Top Side	12
2.3	Board Layouts	13
3	References and related documents.....	14

1 Circuit Description

The basic of the schematic is the standard EVB7122x. Three additional blocks: PA, LNA and TX/RX PIN diode switch have been added. All other components from the standard EVB remain the same. The full schematic of the application is shown in Figure 10.

1.1 TX/RX PIN Diode Switch

Since the TH7122x transceivers do not have a dedicated TX/RX control pin we used the voltage on pin PS_PA as the sense signal. This pin is used to set the output power of the transmitter and is connected to ground via resistor RPS. The voltage drop on the resistor RPS is 0 V in receive mode and up to 500mV in transmit mode. The maximum voltage depends on the value of the resistor RPS and the power supply, but the change is enough to use with the voltage comparator, U2. A dual voltage comparator is used also to produce control signals for a PIN diode switch. The PIN diode switch needs complementary signals as is shown in Fig. 1. The first part of U2 works as a voltage comparator and the second part as an inverter. The same control signals can be used to bias the external LNA and the external PA. For a reliable operation of the comparator, the resistors R5 and R6 provide a voltage above 0V and below the voltage on resistor RPS. This voltage is applied to the non-inverting input pin of the comparator U2_1. Thus, during receive mode the output 1 of the comparator is low and the output 7 is high. This switches PIN diode D1 off and the PIN diode D2 on. During transmit mode the control signals are reversed so that D1 is on and D2 is off. The resistors R7, R8 and R9 provide necessary current for proper operation of the PIN diode switches.

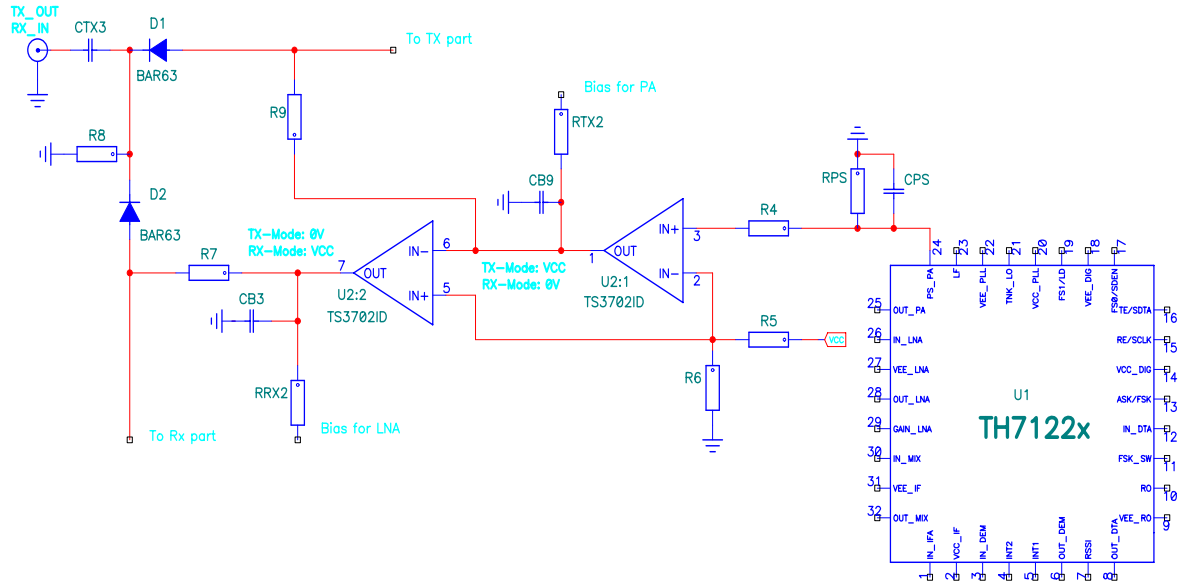


Fig. 1: Schematic of the PIN diode switch

1.2 External Power Amplifier

The output power of the standard TH7122x EVB is up to 10dBm with a 3V power supply. It is enough for SRD and low power devices. If more output power is desired, an external power amplifier can be used. The transistor amplifier operates together with the PIN diode TX/RX switch. The schematic of the external PA and the TX/RX switch is shown in Fig. 2. A low cost transistor BFP450 is used. The base of the transistor Q1 is biased from the TX/RX switch through the resistor RTX2 in transmit mode only. In receive mode the transistor is off. The collector bias is provided via resistor RTX1 and inductor LTX2. The load for the collector is the output matching network. The output matching network is a low pass filter which suppresses all harmonics about 35-40dB. The output power is about 20dBm with a 5V power supply and 17dBm with a 3.6V power supply for the both 433 and 868MHz bands.

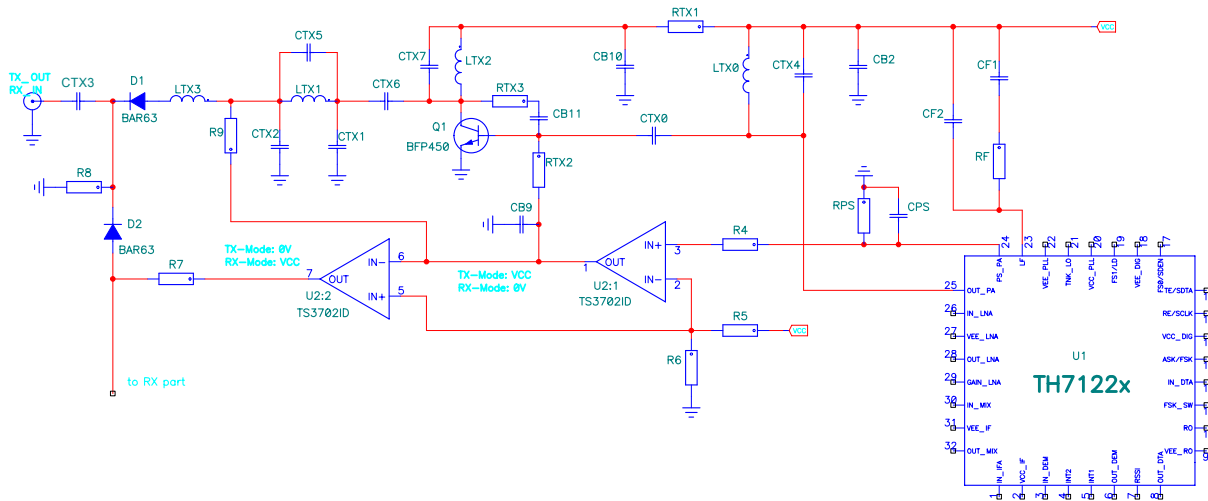


Fig. 2: Schematic of the external PA with TX/RX switch

Some spectrum plots are shown below. The plots have been taken for the 433 and 868MHz bands. Fig. 3 to 5 show the spectrum plots for 433MHz and 5V power supply. Fig. 6 to 8 show the same parameters for the 868MHz application.

The harmonic emissions for 433MHz are better than -35dBc while for 868MHz values of about -42dBc can be achieved. Note that these measurements are made conductive, into the 50Ω load of a spectrum analyzer. Harmonic emissions can be further suppressed by using an antenna.

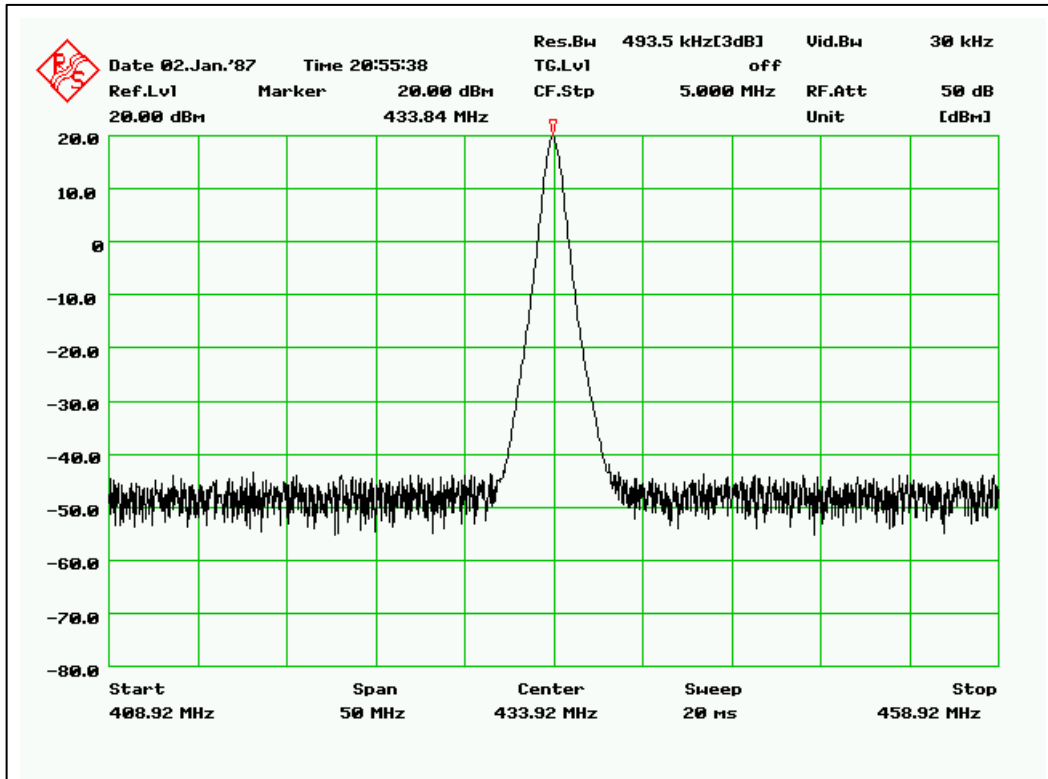


Fig. 3: TX output signal at 433MHz, CW mode

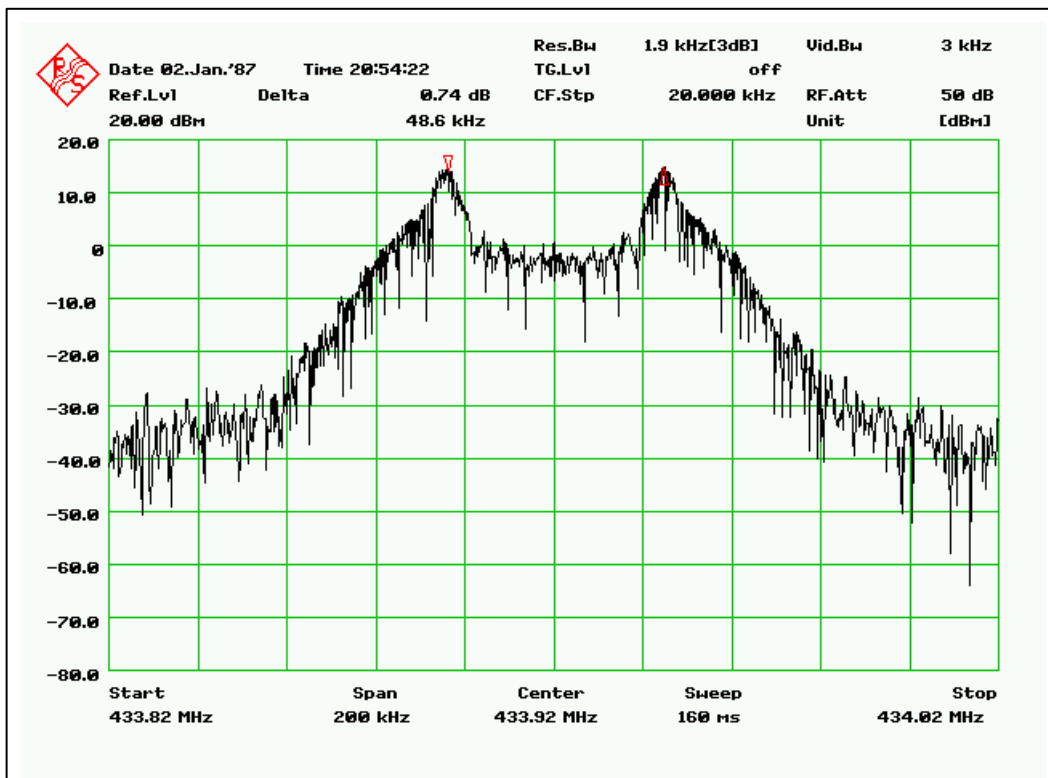


Fig. 4: TX output signal at 433MHz, FSK modulation

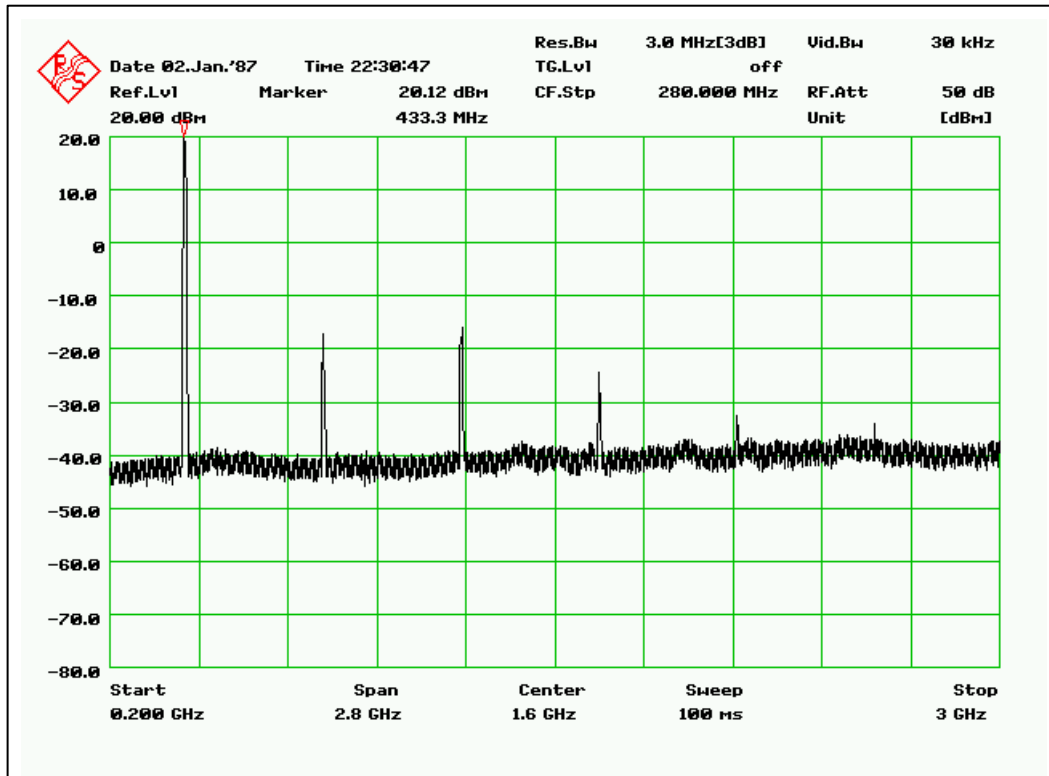


Fig. 5: TX output signal and spurious emissions, CW mode at 433MHz

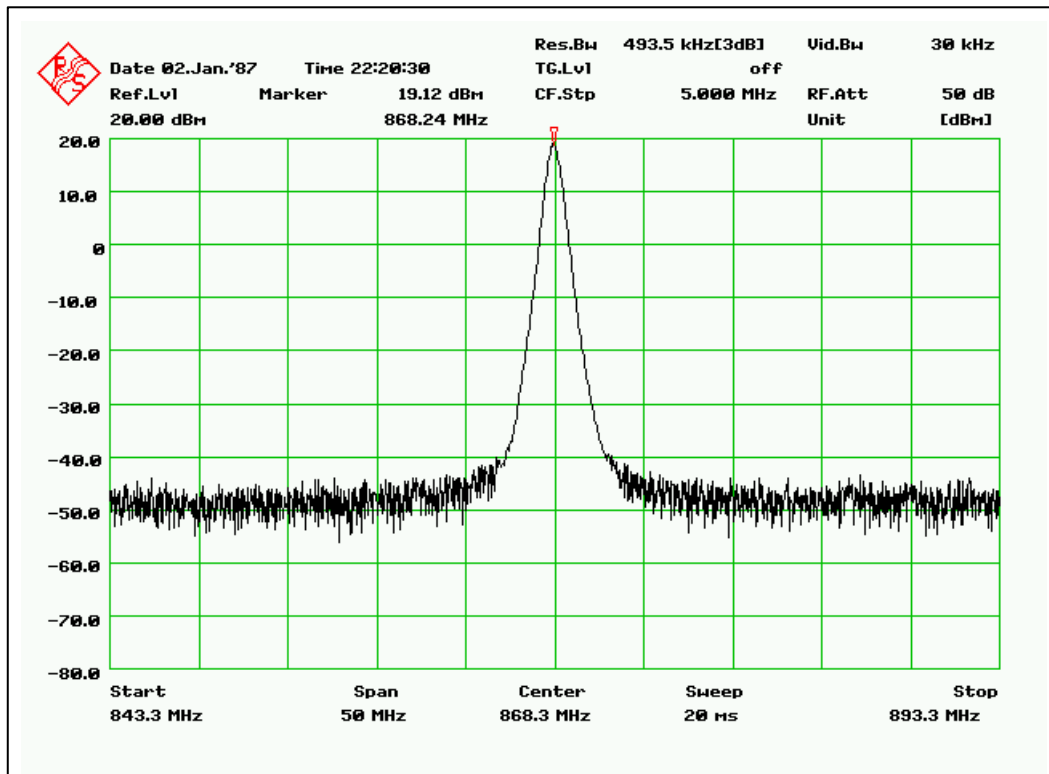


Fig. 6: TX output signal at 868MHz, CW mode

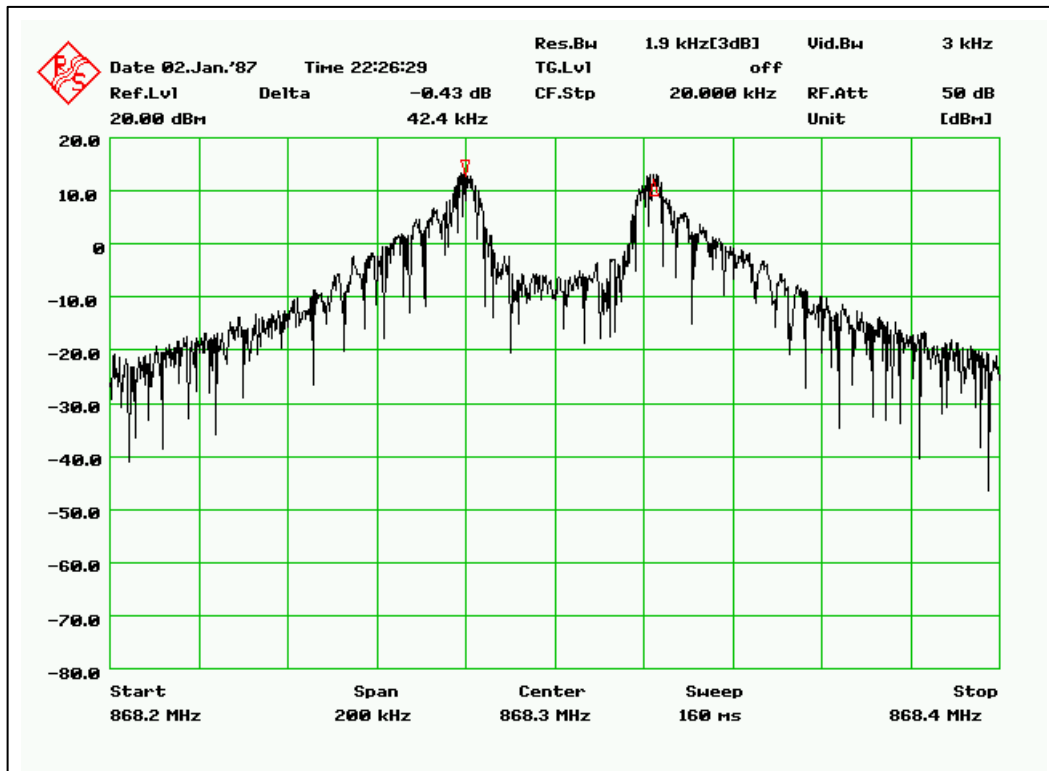


Fig. 7: TX output signal at 868MHz, FSK modulation

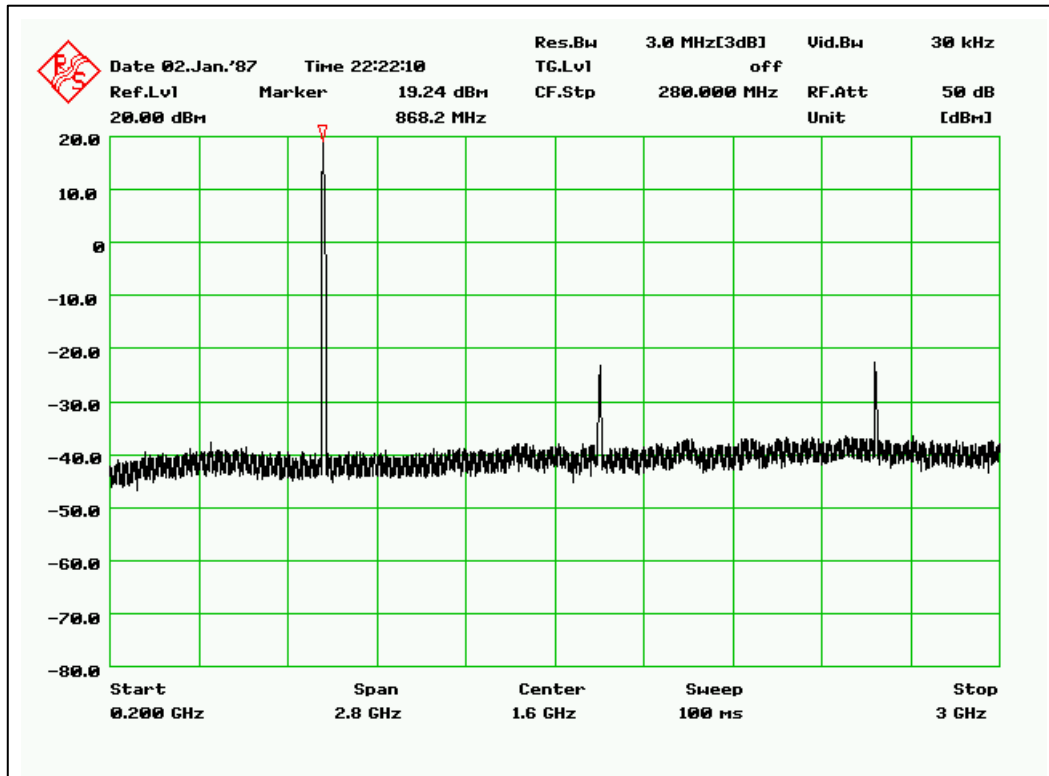


Fig. 8: TX output signal and spurious emissions, CW mode at 868MHz

1.3 External LNA and SAW Filter for the Receiver

When the receiver requirements call for better image rejection and sensitivity, an external LNA with SAW filter can be used to significantly improve the performance. The TH7122x transceivers are a single conversion super-heterodyne with no inherent suppression of the image frequency. An RF front-end filter, usually a SAW filter, is required for good image rejection. Another advantage of a SAW filter is the improvement of the blocking immunity of the receiver, but the disadvantage is that filter has some insertion loss which decreases the sensitivity of the receiver. An external LNA can compensate the loss of the filter and improve the sensitivity of the receiver because of its lower noise figure. The sensitivity of the standard EVB is about -105dBm, and it becomes about -115dBm for both 433 and 868MHz bands with the external LNA. The schematic is shown in Fig. 9. For the LNA a BFP405 transistor is chosen. It is used as a common emitter amplifier. At low frequencies, an emitter resistor is important for stability, but at high frequencies, a bypass capacitor in parallel with emitter resistor can produce oscillation and make the amplifier unstable for some frequencies. Furthermore, a non-bypassed emitter resistor can degrade the performance of the amplifier. Therefore, in this design the emitter of the transistor is grounded. The components CRX0, CRX1, LRX2 and LRX4 are input/output matching networks for different types of SAW filters. For the 50 ohms Murata filters the inductor LRX2 is not in place. The external LNA works together with the TX/RX switch and the TX/RX control unit. The base of the transistor Q2 is biased at receive mode via resistor RRX2. In the transmit mode the transistor is off. The capacitor CRX2 and the inductor LRX5 represent the input matching network for the LNA transistor. The image rejection is between 25dB and 50dB for different frequency bands. The blocking immunity in this application is increased significantly. Also the VCO leakage in receive mode is further decreased in this circuit.

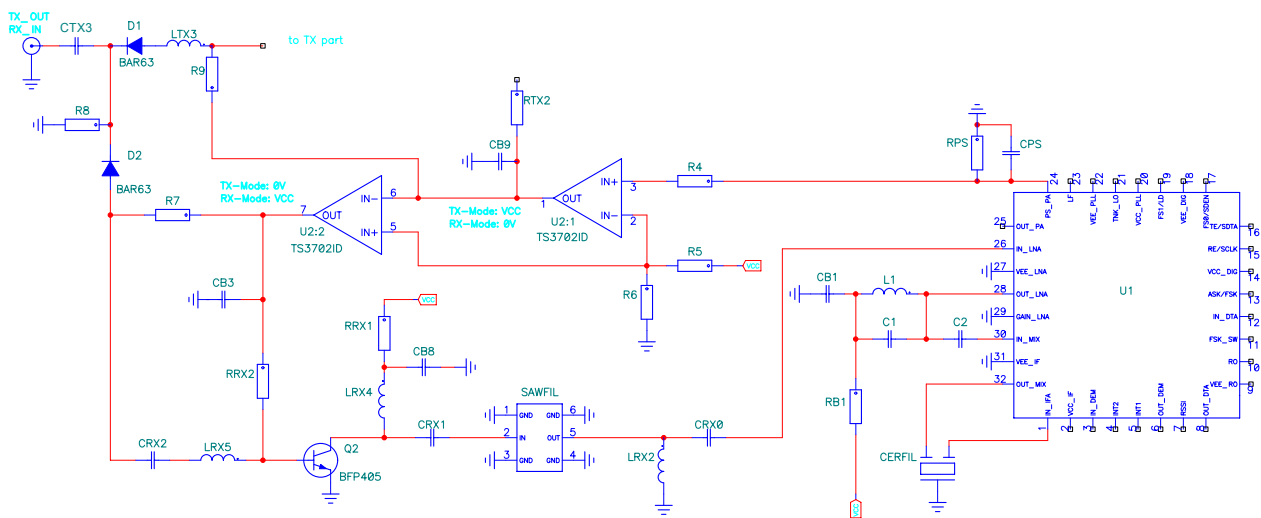


Fig. 9: External LNA with TX/RX switch

1.4 Software Settings

Channel frequency	$f_{RO} = 7.1505\text{MHz}$				CPCUR		VCOCUR	
	RR	NR	RT	NT	RX	TX	RX	TX
433.92 MHz	32	1894	32	1942	260 μA	260 μA	500 μA	500 μA
868.3 MHz	16	1919	16	1943	260 μA	260 μA	900 μA	900 μA

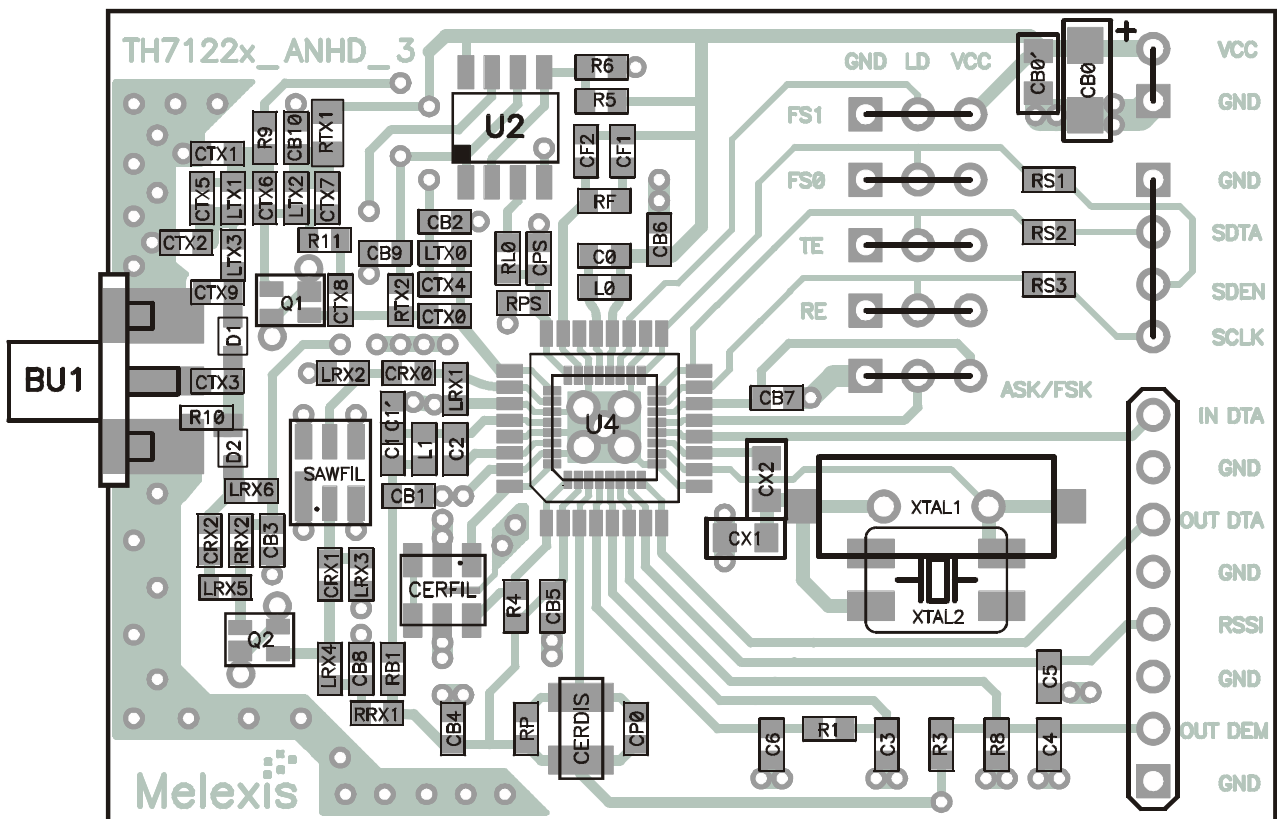
Part	Size	Value @ 433 MHz	Value @ 868 MHz	Description
CB5	0603	100 nF	100 nF	de-coupling capacitor
CB6	0603	100 pF	100 pF	de-coupling capacitor
CB7	0603	100 nF	100 nF	de-coupling capacitor
CB8	0603	100 pF	100 pF	de-coupling capacitor
CB9	0603	100 pF	100 pF	de-coupling capacitor
CB10	0603	100 pF	100 pF	de-coupling capacitor
CF1	0603	1 nF	1 nF	loop filter capacitor
CF2	0603	100 pF	100 pF	loop filter capacitor
CP0	0603	NIP	NIP	CERDIS loading capacitor
CPS	0603	NIP	NIP	power select capacitor
CX1	0805	12 pF	12 pF	RO capacitor for FSK
CX2	0805	82 pF	56 pF	RO capacitor for FSK
CRX0	0603	100 pF	100 pF	RX coupling capacitor
CRX1	0603	100 pF	100 pF	RX coupling capacitor
CRX2	0603	100 pF	100 pF	RX coupling capacitor
CTX0	0603	100 pF	100 pF	TX coupling capacitor
CTX1	0603	6.8 pF	3.3 pF	TX impedance matching capacitor
CTX2	0603	4.7 pF	3.3 pF	TX impedance matching capacitor
CTX3	0603	100 pF	100 pF	output coupling capacitor
CTX4	0603	4.7 pF	2.2 pF	TX impedance matching capacitor
CTX5	0603	2.7 pF	2.7 pF	TX impedance matching capacitor
CTX6	0603	100 pF	100 pF	TX coupling capacitor
CTX7	0603	NIP	NIP	TX impedance matching capacitor
CTX8	0603	470 pF	470 pF	PA feedback capacitor
L0	0603	33 nH	4.7 nH	VCO tank inductor
L1	0603	15 nH	4.7 nH	LNA output tank inductor
LTX0	0603	15 nH	3.9 nH	TX impedance matching inductor
LTX1	0603	33 nH	10 nH	TX impedance matching inductor
LTX2	0603	10 nH	6.8 nH	TX impedance matching inductor
LTX3	0603	39 nH	10 nH	TX impedance matching inductor
LRX4	0603	82 nH	82 nH	RX impedance matching inductor
LRX5	0603	22 nH	10 nH	RX impedance matching inductor
RB1	0603	150	150	protection resistor
RF	0603	33 k	33 k	loop filter resistor
RP	0603	NIP	NIP	CERDIS loading resistor
RL0	0603	NIP	NIP	CERFIL loading resistor, optionally
RPS	0603	47 k	47 k	power select resistor
RS1	0603	10 k	10 k	protection resistor
RS2	0603	10 k	10 k	protection resistor
RS3	0603	10 k	10 k	protection resistor
RRX1	0603	100	100	protection resistor
RRX2	0603	82 k	82 k	LNA bias resistor
RTX1	0603	6	6	protection resistor
RTX2	0603	3.9 k	5.1 k	PA bias resistor
RTX3	0603	560	560	Negative feedback resistor
R1	0603	NIP	NIP	PKDET resistor
R3	0603	NIP	NIP	demodulator output loading resistor
R4	0603	100 k	100 k	voltage comparator input resistor
R5	0603	100 k	100 k	voltage comparator divider resistor
R6	0603	4.7 k	4.7 k	voltage comparator divider resistor
R7	0603	1.2 k	1.2 k	PIN diode bias resistor

Part	Size	Value @ 433 MHz	Value @ 868 MHz	Description
R8	0603	1.2 k	1.2 k	PIN diode bias resistor
R9	0603	1.2 k	1.2 k	PIN diode bias resistor
R10	0603	NIP	NIP	demodulator output loading resistor
CERFIL	SMD 3.45x3.1	SFECF10M7HA00	SFECF10M7HA00	ceramic filter from Murata, or equivalent part
CERDIS	SMD type	CDSCB10M7GA136	CDSCB10M7GA136	ceramic discriminator, from Murata, or equivalent part
SAWFIL	SMD 3x3	SAFCC433MBL0X00 (f ₀ = 433.92 MHz)	SAFCC868MSL0X00 (f ₀ = 868.3 MHz)	low-loss SAW filter from Murata, or equivalent part
XTAL	HC49 SMD	7.1505 MHz ±20ppm calibration, ±20ppm temperature		fundamental-mode crystal, C _{load} = 10 pF to 15pF, C _{0,max} = 7 pF, R _{m,max} = 70 Ω

Note: NIP – not in place, may be used optionally

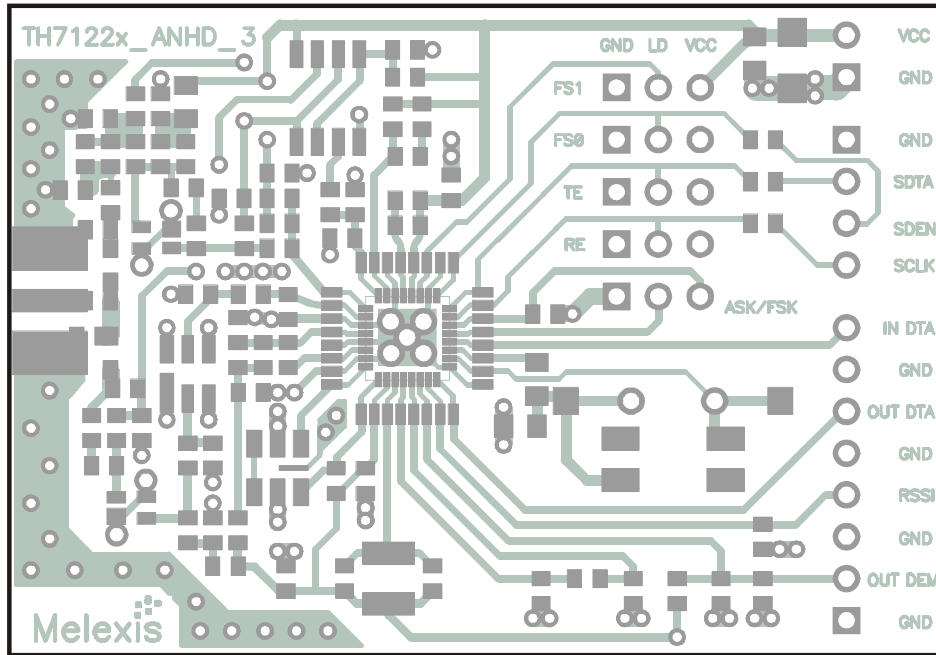
2.2 Component Arrangement Top Side

Board size is 58.5mm x 39.4mm

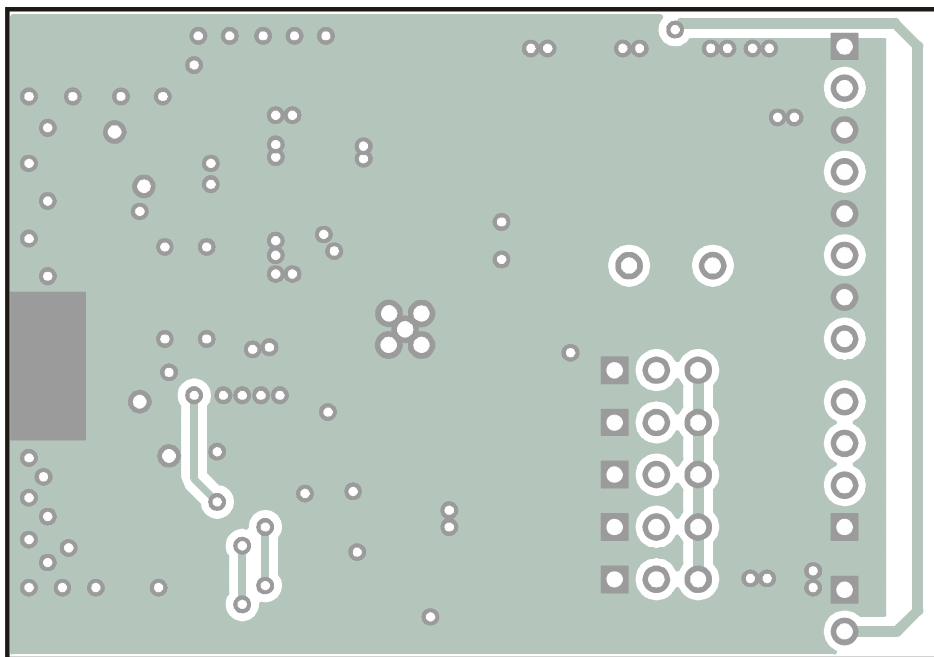


2.3 Board Layouts

- Board layout data in Gerber format is available, board size is 58.5mm x 39.4mm.



PCB top view



PCB bottom view

3 References and related documents

- TH7122 data sheet
- TH71221 data sheet
- Evaluation Board for TH7122
- Evaluation Board for TH71221
- Guillermo Gonzalez: "Microwave Transistor Amplifier Analysis and Design"

For the latest version of this document, go to our website at:

www.melexis.com

Or for additional information contact Melexis Direct:

Europe and Japan:	All other locations:
Phone: +32 1367 0495	Phone: +1 603 223 2362
E-mail: sales_europe@melexis.com	E-mail: sales_usa@melexis.com

ISO/TS16949 and ISO14001 Certified