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KESRX01

ASK RECEIVER REFERENCE DESIGN

Application Note

AN4811 - 1.10 August 1998

This Application Note describes the KESRX01 reference designs for use with and without a SAW and 455KHz Ceramic IF Filters to improve the selectivity, sensitivity and image rejection of the receiver.

DEMONSTRATION BOARD SPECIFICATION

- Sensitivity Better than -103dBm in 50Ω system for 1/100 BER
- Complies with ETSI 300-220 and FCC Part 15 regulations
- Demodulated data output provided

REFERENCE DESIGN CONFIGURATION

KESRX01 reference design at 315MHz. (No SAW) and 433.92MHz. are designed with the RF input matched to 50Ω to allow direct interfacing to either a 50Ω signal generator or an antenna via a SMA connector.

Frequency MHz	Saw Filter	Ceramic IF Filter	PCB Marking	Sensitivity @ BER 1/100	Overload @ BER 1/100	Conducted L.O Radiation to 50Ω
315	NO	NO	315/***	-103dBm	-20dBm	-60dBm
434	NO	NO	434/***	-103dBm	-20dBm	-60dBm
434	B3550	NO	434S/***	-100dBm	-20dBm	-60dBm

Note:- 434S/*** PCB Gerber files include the option of a ceramic filter IF, Murata CFU455D2. Ceramic filter to be fitted by the customer

A summary of the actual PCB results for the first 50 samples is illustrated in Figure 1. These results illustrate the receiver performance is well within the above limits.

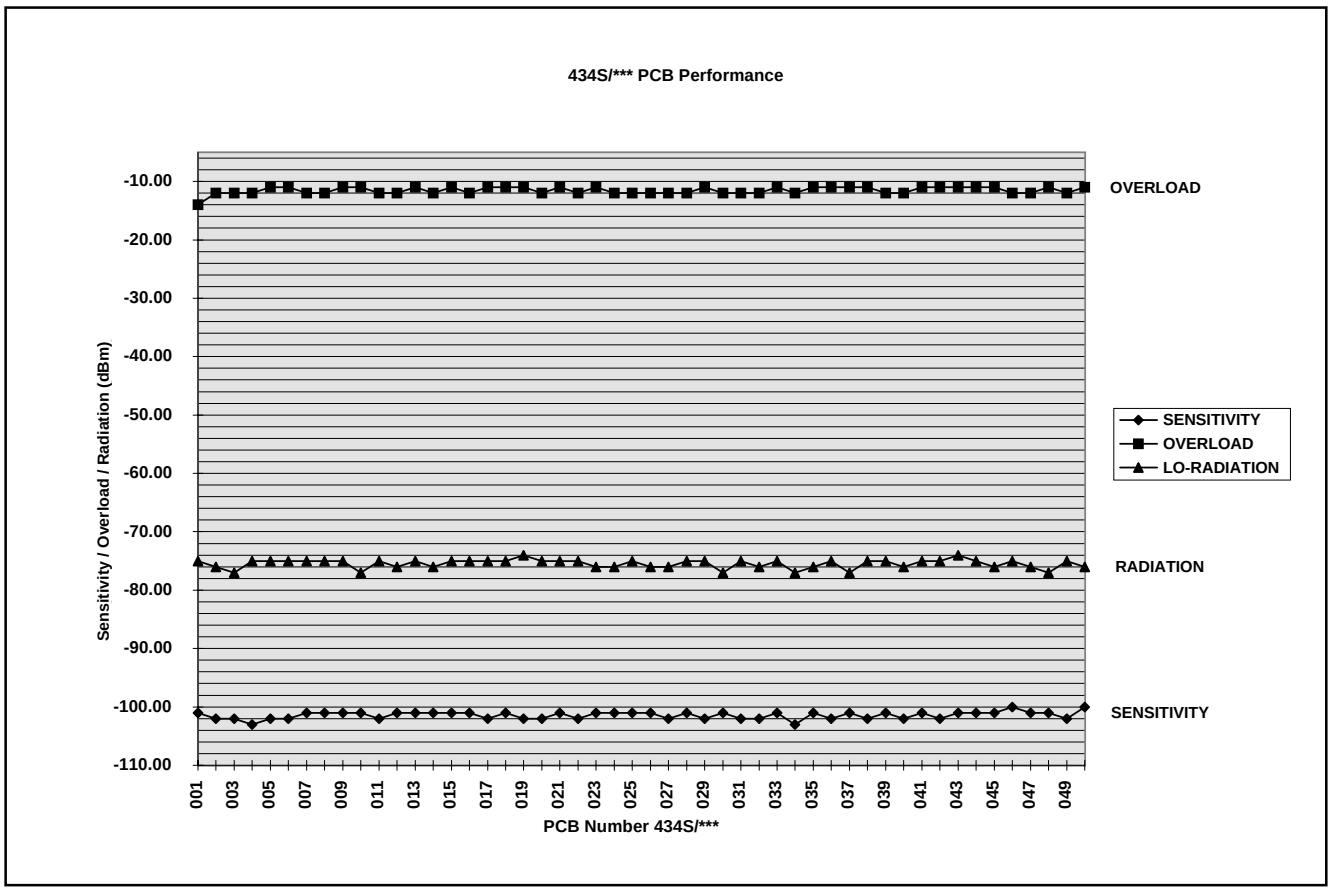


Figure 1- Receiver KESRX01 demonstrator performance @ 434MHz with SAW filter

BOARD CONFIGURATION

The PCB is configured for direct connection to a 5V ± 5% DC power supply, 50Ω signal generator using ON OFF KEY modulation (OOK) and a high impedance (x 10 probe) oscilloscope to monitor the demodulated data output as illustrated below.,

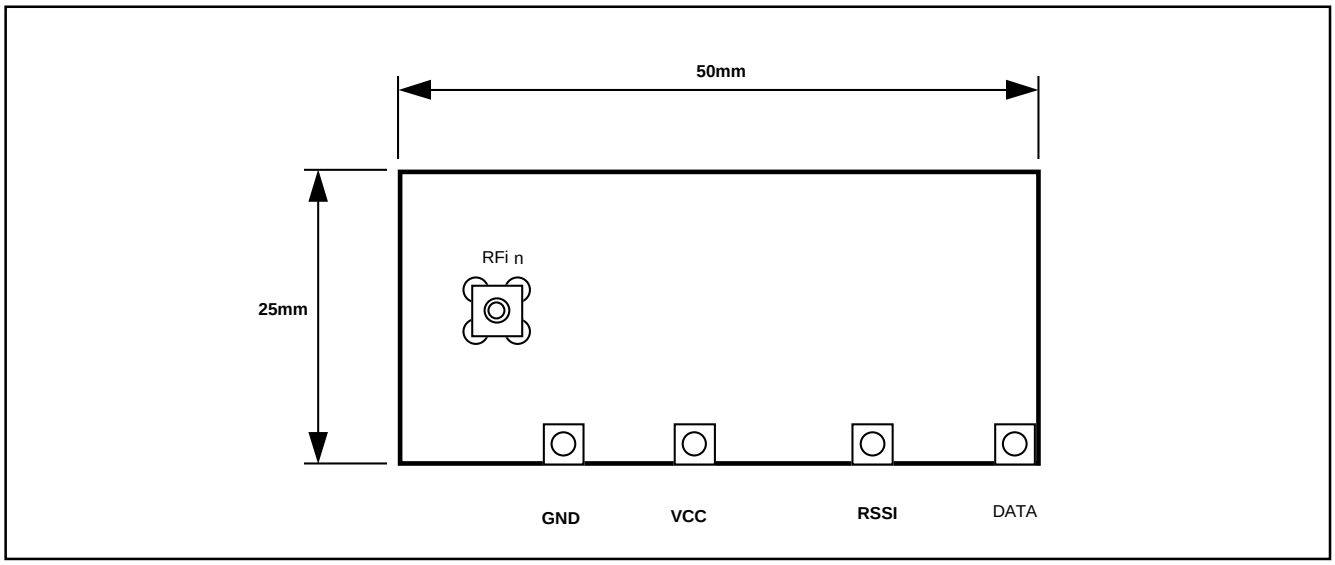


Figure 2 - Board configuration (not to scale)

PCB I/P and O/P	KESRX01 Pin No	Description
RFin	9	SMA Connector, 50Ω matched termination, VSWR <1.5
GND	8, 13	GND connection for DC power supply
VCC	5	Supply connection for 5V ± 5% DC power supply
RSSI	22	Received Signal Strength Indicator, 2.1 to 3.3 volts Monitor using a high impedance probe (x 10 probe)
Data	11	0 to 5 volts (± 0.3V), monitor using a high impedance probe (* 10 probe)

APPLICATION DEPENDENT PARAMETERS

Squelch Operation

The data output is hard wired via R3 to operate in 'averaging' mode for maximum sensitivity, (allowing the data output to toggle "high" and "low" when no signal is received) with the RFin port terminated to 50Ω. To force the data output to squelch "high" when no signal is received the following combination of components need to be changed to operate the receiver in "Peak" mode.

Mode	R3	R6	R5	C21	Data Output
Averaging*	**10KΩ**	**N/C**	**N/C**	**1μF**	**No signal received output status noisy**
Peak	N/C	12 to 27KΩ	1MΩ	<220nF	Adjust R5 for squelch and maximum sensitivity

N/C : Not Connected

* : Original PCB configuration: (Averaging mode)

Data Filter Configuration

The video filter, data filter, bandwidth (BW) is set by components C6 and C5 using the following matrix as a guide. The data filter BW should be between two and five times the minimum pulse width period of transmission. Setting a data filter BW below this figure of merit will cause excessive pulse width variation with applied RF signal power.

e.g. Assuming a 60 / 30% pulse width duty cycle @ 2KHz.
What is the minimum recommended BW for the data filter ?

$$\text{Logic 0} = 30\% = \frac{1 * 30}{2\text{KHz.}*100} = 150\mu\text{S.}$$

$$\text{Data Filter BW} = \frac{2}{150\mu\text{S.}} * = 13.333\text{KHz}$$

Note : The reference design data filter BW has been initially set to 5KHz.

Data Filter BW (KHz)	C5 (pF)	C6 (pF)	Sensitivity dBm (Typ)
2	470	390	-104
5	220	150	-101
10	100	82	-97
20	56	33	-95
40	22	22	-92

Note :

Sensitivity measurements recorded for KESRX01 + SAW (434S PCB). A sensitivity improvement of typically 3dB is obtained without the SAW filter.

INTERMEDIATE FREQUENCY (IF) FILTER BANDWIDTH (BW)

The maximum IF BW is restricted to 550 KHz by two internal active low pass Butterworth filters. The IF BW can be reduced by changing the position of the external high pass filter set by C2 or by using a 455KHz ceramic filter. Reducing the BW of the IF strip will lower the noise floor of the receiver and hence produce a corresponding improvement in the sensitivity of the receiver. However, it should be noted that the IF BW must be sufficient to accommodate the sum of the following variations.

- Transmitter frequency drift
- Receiver crystal frequency tolerence
- Data rate

ADJUSTING C2 HIGH FREQUENCY RESPONSE

The cut off frequency of the H.P.F. is set by the following equation, and the difference in frequency between the high frequency and internal low frequency cut-off is the IF BW. To accommodate a SAW resonator based TX with a tolerance of ± 200KHz, C2 has been initially set to 220pF, as illustrated below.

$$\text{High Pass Filter} = \frac{1}{2\pi R*C2} = \frac{1}{753398.22*220E\text{-}12} = 60.2\text{KHz}$$

$R = 12\text{K}\Omega$

IF BW = 550KHz - 60.2KHz = 489.8KHz

USING A 455KHz CERAMIC FILTER

To configure the receiver with a ceramic filter, the output impedance of the mixer and input impedance of the log strip must be matched to the input and output impedance of the ceramic filter. The frequency accuracy of the reference crystal must also be improved to typically less than ± 10ppm over a temperature range of -40 to + 85°C. To successfully match the KESRX01 to a ceramic filter for minimum group delay and overshoot the following circuit configuration should be used.

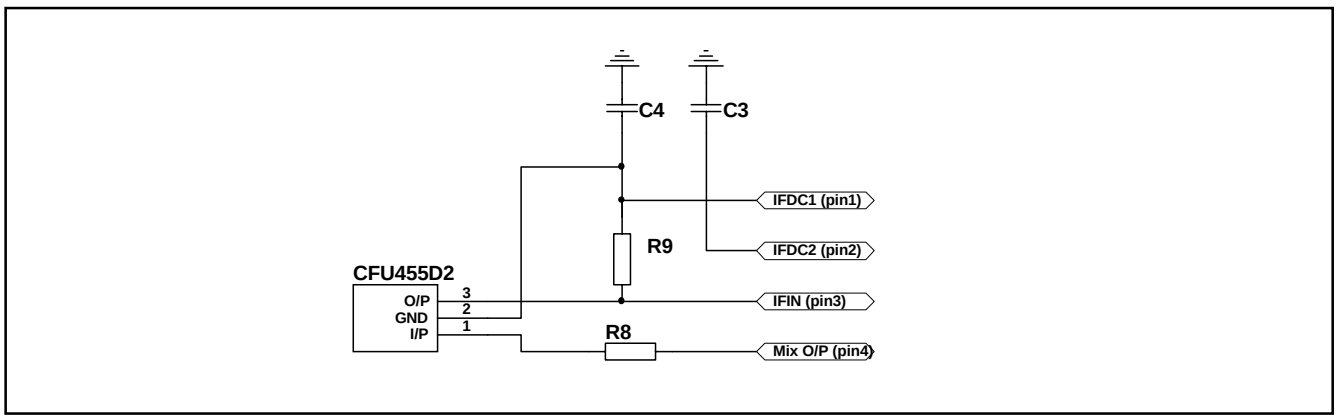


Figure 3 - 455KHz Ceramic filter Schematic

Where:-

$R8 = IPC - MIXout = 1500 - 725 \approx 820\Omega$

$$R9 = \frac{I0C * IFin}{I0C + IFin} = \frac{1500 * 12K}{1500 + 12K} \approx 1.5\text{K}\Omega$$

IPC: Ceramic Filter Input Impedance (CFU4455D2 = 1.5KΩ)

IOC: Ceramic Filter output Impedance (CFU455D2 = 1.5KΩ)

MIXout: Mixer output impedance (725 Ω)

IFin: IFAmplifer Input Impedance (12KΩ)

CRYSTAL SELECTION with a 455KHz CERAMIC FILTER

The BW of commercially available 455KHz ceramic filters is limited to approximately ± 15KHz. This necessitates that the frequency drift of the transmitter and receiver frequency drift with temperature (-40 to + 85°C) should be less than 7.5KHz. Therefore, the maximum tolerance that can be allowed within receiver and transmitter reference crystal is 17.3ppm.

$$XTAL = \frac{IFBW}{2 * N * XTAL_{Freq}} = \frac{15KHz}{2 * 64 * 6.775} \leq 17.3ppm$$

XTAL : Receiver / Transmitter tolerance

IFBW : IF Filter Bandwidth

N : Divider Ratio

$XTAL_{Freq}$: Crystal Frequency (MHz)

For a 20KHz BW filter, the maximum allowable tolerance is 11.5ppm
Thus, the parameters of the crystal should be specified as follows:

Parallel Load Crystal Specification									
IF BW	**IF**	**APPL. Freq**	**C13**	**C14**	**Freq**	**Load Cap**	**ESR**	**Tolerance (ppm) With Temp**	
(KHz)	**Filter**	**(MHz)**	**(pF)**	**(pF)**	**(MHz)**	**(pF)**	**(Ohms)**	**-40°C to + 85°C**	**25°C**
20	CFU455D2	433.92	33	33	6.775	20	<50	10	5
489	C2=220pF	315	18	18	4.918	12	<150	100	50
		433.92	18	18	6.775	12	<150	100	50

Note :

1. For a narrow band 455KHz cramic filter application the parallel resonant load capacitance of the crystal should be increased to 20pF to ensure that parasitic effects on the crystal tolerance are minimised.

2. For wide band IF filter applications, where C2 is used, the parallel resonant load capacitance of the crystal should be de-creased to 12pF to maximise the negative input impedance of the crystal oscillator circuit. This will allow a corresponding increase in ESR value minimising the cost of the crystal,

BOARD DESIGN

The schematic and pcb silk screen information for the reference design are included at the end of this Application Note. The design parts list at 315 and 433.92MHz are listed below.

Freq	315MHz	433.92MHz			Recommended Manufacturer	
ID	No (SAW +Ceramic Filter)		SAW only	SAW + Ceramic	Type	Tolerance
C1	150pF	150pF	150pF	150pF	Murata	COGJ
C2	220pF	220pF	220pF	Not Used	Murata	COGJ
C3, C4	100nF	100nF	100nF	100nF	Murata	X7RK
C5	220pF	220pF	220pF	220pF	Murata	COGJ
C6	150pF	150pF	150pF	150pF	Murata	COGJ
C9	56pF	56pF	56pF	56pF	Murata	COGJ
C11	33pF	33pF	33pF	33pF	Murata	COGJ
C12	1.5nF	1.5nF	1.5nF	1.5nF	Murata	Y5VZ
C13	18pF	18pF	18pF	18pF	Murata	COGJ
C14	18pF	18pF	18pF	18pF	Murata	COGJ
C18	33pF	33pF	33pF	33pF	Murata	COGJ
C21	1µF	1µF	1µF	1µF	Murata	Y5VZ
C26	100pF	100pF	100pF	100pF	Murata	COGJ
C27	1µF	1µF	1µF	1µF	Murata	Y5VZ
C28	1µF	1µF	1µF	1µF	Murata	Y5VZ
C29	100pF	100pF	100pF	100pF	Murata	COGJ
R1	4.7K	4.7K	4.7K	4.7K	N/A	5%
R2	18K	18K	18K	18K	N/A	5%
R3	10K	10K	10K	10K	N/A	5%
R4	4.7K	4.7K	4.7K	4.7K	N/A	5%
R7	100K	100K	100K	100K	N/A	5%
R5	Not used	Not used	Not used	Not used	N/A	5%
R6	Not used	Not used	Not used	Not used	N/A	5%
R8	Not used	Not used	Not used	820	N/A	5%
R9	Not used	Not used	Not used	1.5K	N/A	5%
C16	6pF	5pF	56pF	56pF	Murata	COGC
C19	2pF	2pF	7pF	7pF	Murata	COGC
L1	68nH	47nH	47nH	47nH	Coil Craft	0805CSJ
L2	39nH	18nH	18nH	18nH	Coil Craft	0805CSJ
L3	150nH	68nH	22nH	22nH	Coil Craft	0805CSJ
L4	Not used	Not used	39nH	39nH	Coil Craft	0805CSJ
D1	SMV1104-35	SMV1104-35	SMV1104-35	SMV1104-35	Alpha Ind.	N/A
Saw Filter	Not used	Not used	B3550	B3550	Siemens	N/A
Ceramic Filter	Not used	Not used	Not used	CFU455D2	Murata	N/A
XTAL	4.918MHz	6.775MHz	6.775MHz	6.775MHz	N/A	±100ppm

Note: Reducing the value of C3 and C4 to 10nF will improve the response time of the RSSI from power-up (application of Vcc).

Notes:

To select a different data rate the following component values will require adjustment,

- Data filter C5, C6 (for a 10KBit data rate C5=100pF, C6=82pF).
- For optimisation of slice data level R6, R5, C21 and R3 should be adjusted to optimise the sensitivity of the receiver.
- Adjust R6 for maximum sensitivity in squelch mode, “Peak’’ mode. Setting R6 to 27K will guarantee squelch but at the expense of maximum sensitivity, when compared to the “Average’’ mode configuration. The value of R6 is dependent on background noise level and the value chosen for R5 and C21 to squelch the receiver.
- XTAL a <200ppm crystal, parallel resonant at the given frequency with 12pF load capacitor.
- The value of L2 above is for Alpha Industries varactor SMV 1104-35. To use Siemens BBY53-03W, L2 should be :- changed to

Freq	**315MHz**	**434MHz**
Varactor	BBY53-03W	BBY53-03W
L2	56nH	27nH

C11 and C18 can be used to fine tune the VCO for a centre tuning control voltage of 2.5V.

- C21 maximum value when operating in the peak detector mode should be less than 220nF. Increasing the value of C21 above 220nF may result in spurious noise spikes appearing at the output of DF2. These spurious noise spikes are caused by supply rail generated noise due to interaction between the peak detector output and the sensitive RF sections of KESRX01, limiting the sensitivity of the receiver
- Connect R5, R6 and C21 for peak detector mode.
- Connect R3 and C21 for averaging mode.
- Gerber files for Application Note AN4811 are freely available from Mitel Semiconductor WWW.

BOARD PERFORMANCE SELECTIVITY

The following plots illustrate the selectivity performance @ 433.92MHz for boards configured with a SAW and 455KHz Ceramic IF.

Note:

These measurements were taken with the inband wanted signal set at 3dB above the maximum sensitivity of the receiver.

Wanted Signal	Sensitivity	Signal Level	Unwanted	
433.92MHz	-103dBm	-100dBm	100 to 500MHz	-100 to -10dBm

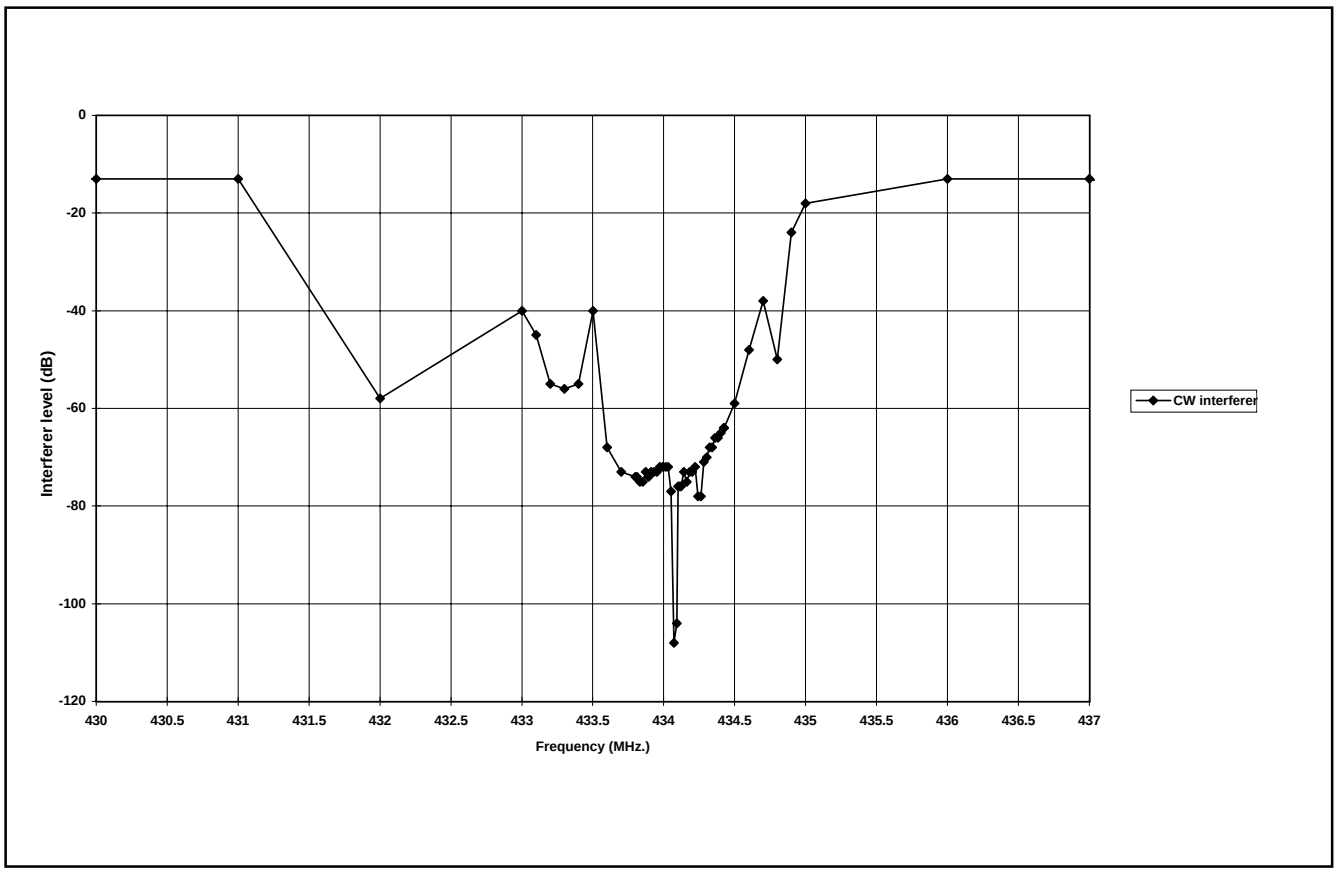


Figure 4 - 434S PCB, (KESRX01 SAW + Ceramic IF)

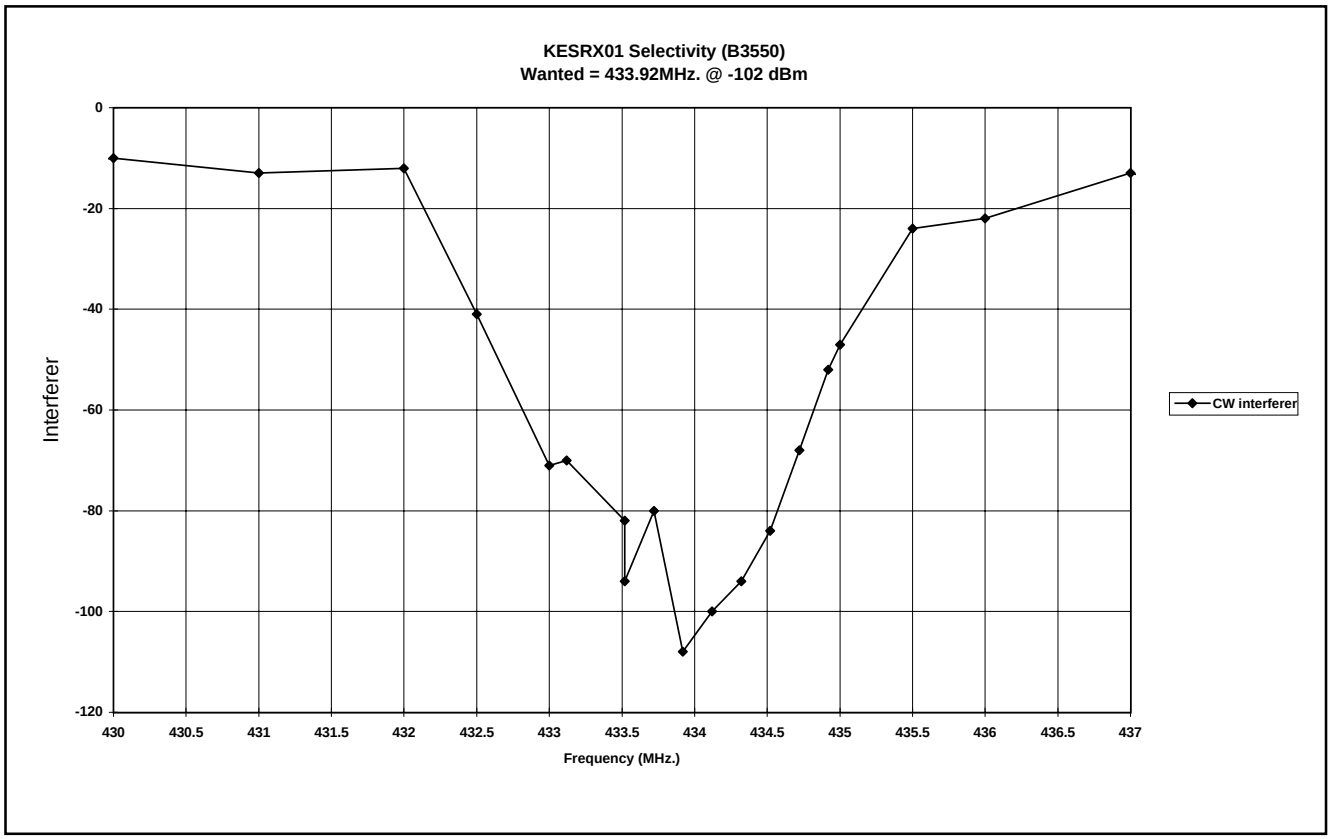


Figure 5 - 434S PCB (KESRX01 + SAW)

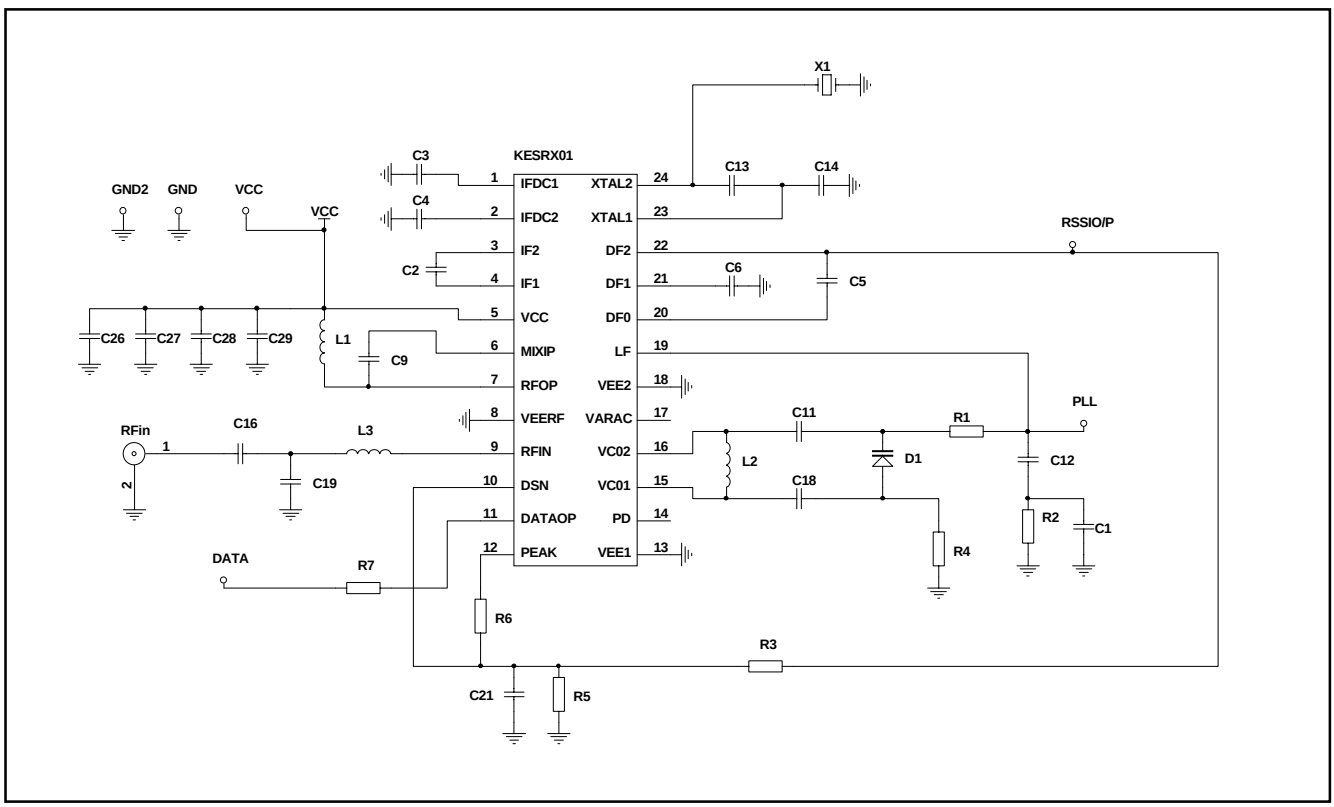


Figure 6 - KESRX01 434 and 315MHz (No SAW) Schematic

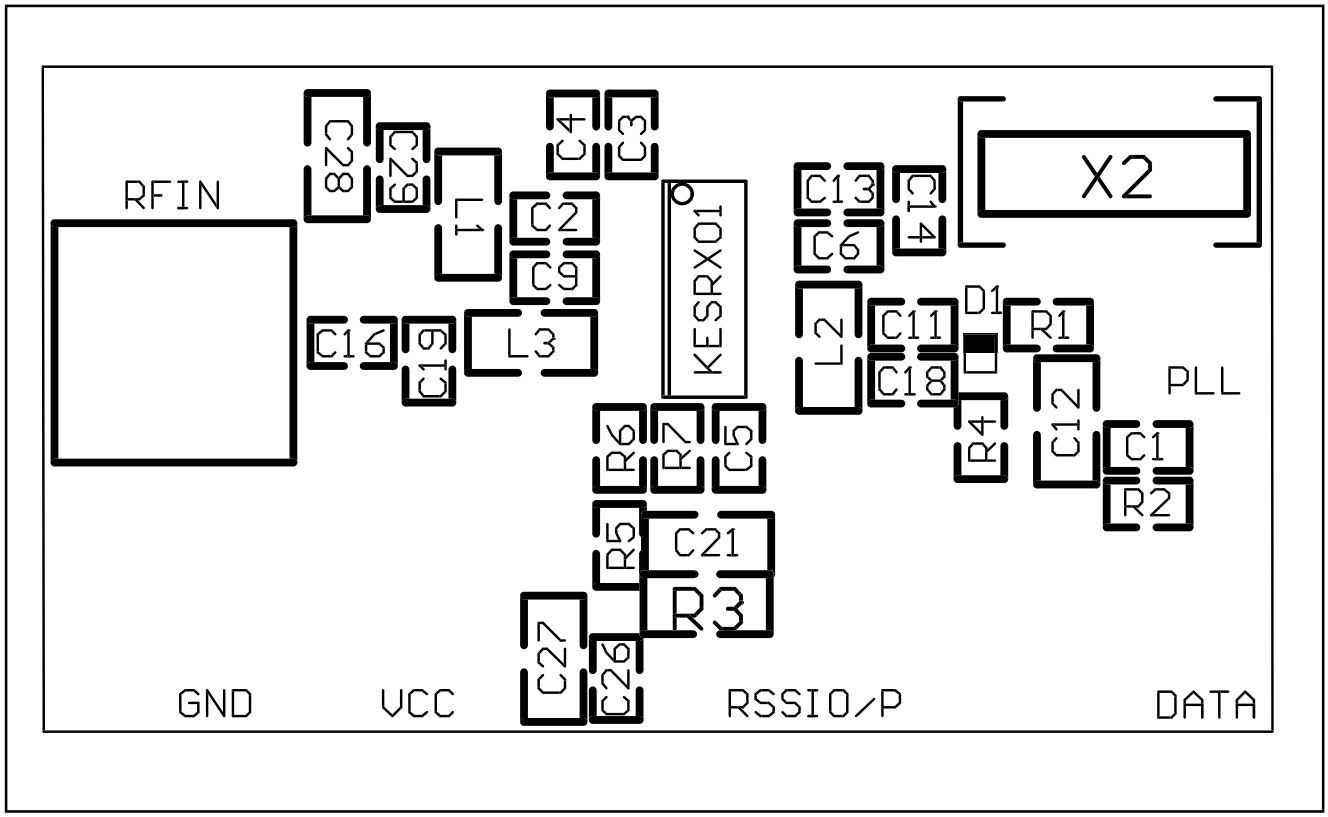


Figure 7- KESRX01 434 and 315MHz PCB layout

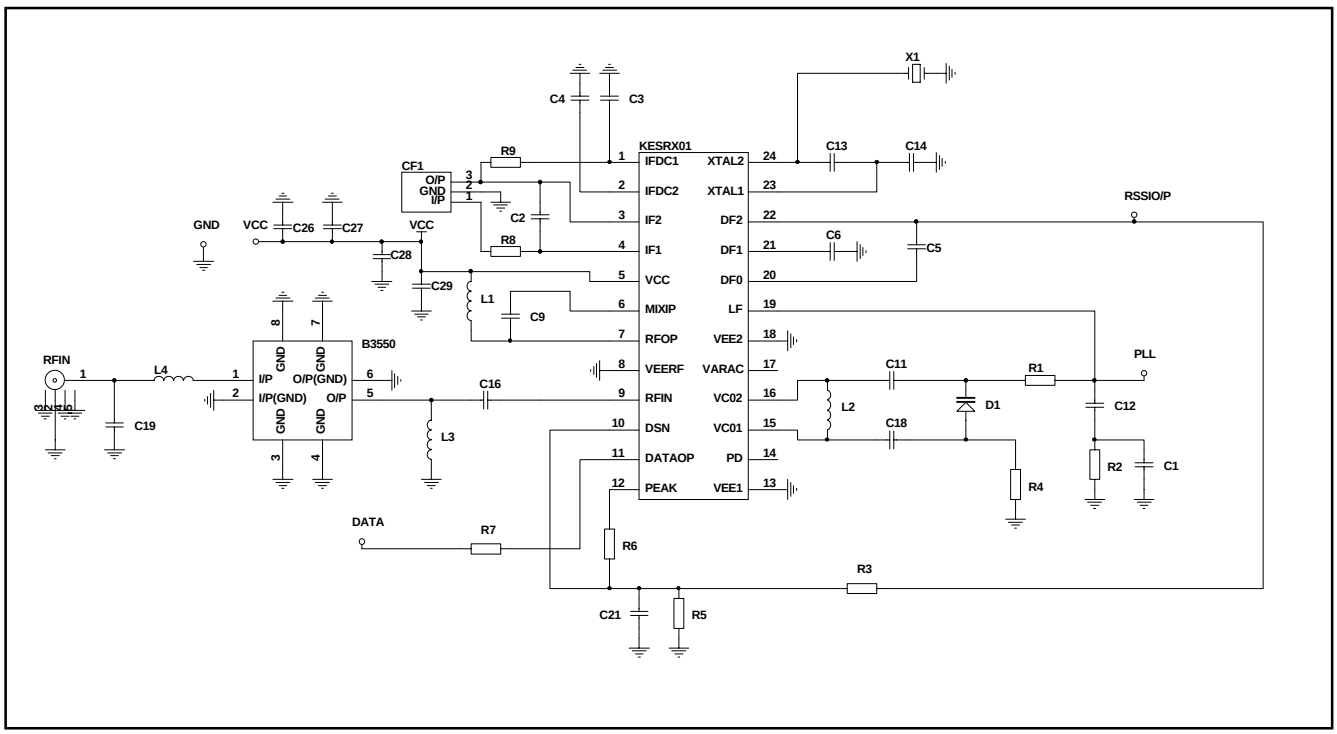
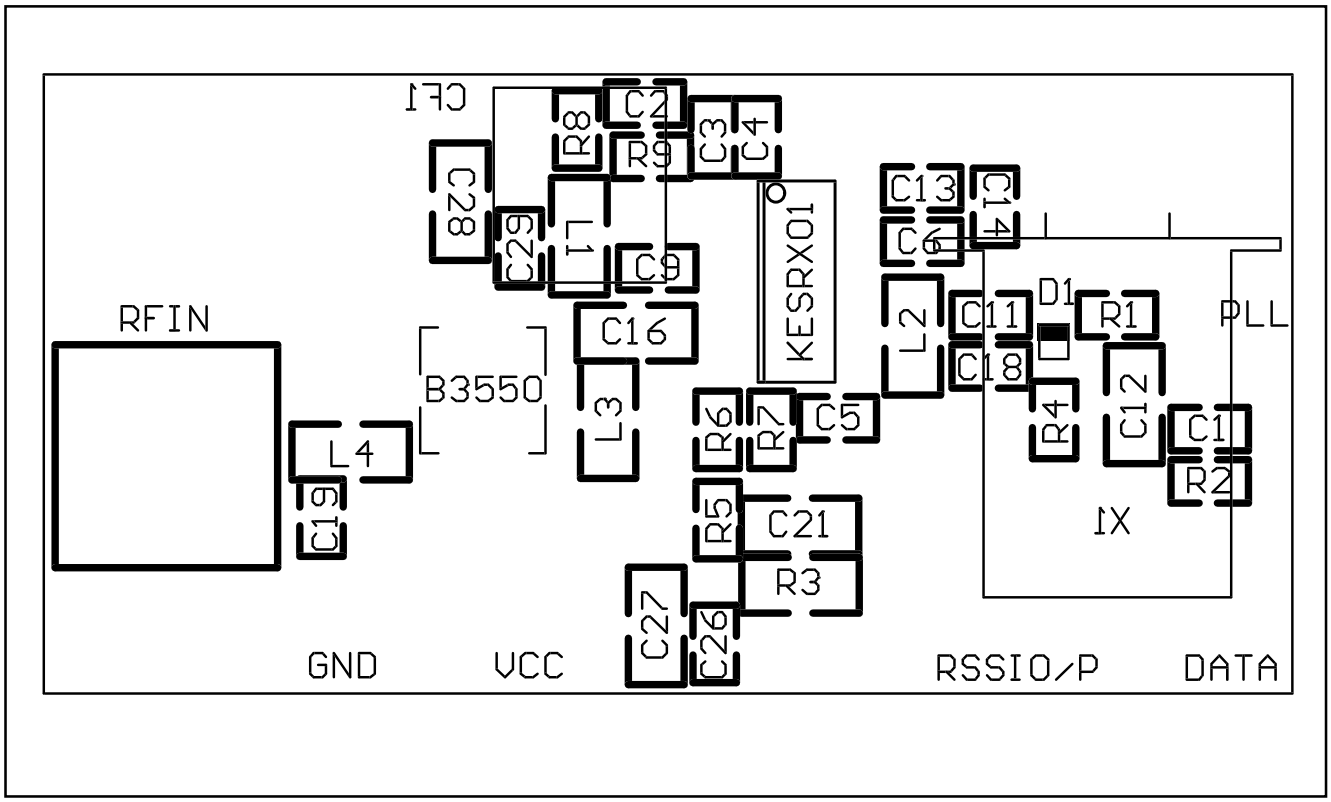


Figure 8 - KESRX01 434MHz (with SAW)



Figure, 9 - KESRX01 434MHz (with SAW)

KESRX01

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