Chipcon Products from Texas Instruments

User Manual

Rev. 1.5

CC400DK Development Kit

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Introduction

The CC400 single chip transceiver includes many features and great flexibility which makes the chip suitable for a very large number of applications and system requirements. The CC400 Development Kit is designed to make it very easy for the user to evaluate transceiver performance and in short time develop his own applications.

The Development Kit includes two evaluation boards with a complete CC400 transceiver, voltage regulator and PC interface circuitry. Using the evaluation board connected to a PC running the SmartRF® Studio software, various system parameters can be changed and tested by key-strokes.

Technical features:

- RF power up to 25mW (14dBm) programmable in 1dB steps
- -112 dBm sensitivity for 10^{-3} bit error rate (1.2kbps, 20kHz frequency separation)
- Logic level data input/output (Manchester coded)
- Selectable RF filtering (SAW or LC)
- Selectable IF filtering
- All set-up controlled by PC
- Selectable 3V or 4-10Vunregulated voltage supply inputs

This user manual describes how to get started with the Development Kit. You will also find detailed description of the evaluation board and advice how to develop your own applications. For details on how to use the SmartRF® Studio software please refer to the SmartRF® Studio user manual.

Your SmartRF® CC400DK Development Kit should contain the following items:

Evaluation circuit boards (PCB)	2 ex	
CC400 single chip transceiver	5 ex	
PC parallel port extension cable	2 ex	25-pin D-sub, male-female, 3m
Adapter	4 ex	SMA male-BNC female
Antenna	2 ex	50Ω, λ/4 monopole, SMA male
Quick Start Instructions		
SmartRF® CD-ROM		

The evaluation board includes a significant number of components for great flexibility. However, only a minor part of these components are required in an actual application. Check the datasheet for a typical application circuitry.

Evaluation board

The kit includes an evaluation circuit board (PCB) with the following items:

- CC400
- Necessary external surface mounted devices, SMD, for the chip.
- Voltage regulator 4V-10V to 3V regulated voltage.
- Possibilities to apply a 3V voltage source directly (chosen by switches or connectors at the board).
- Voltage-level interface circuits between the CC400 (3V) and the parallel port of the computer (5V).
- Connector for a PC parallel port cable.
- Connector for antenna and modulation data in/out.
- Edge connector for future use.

This board is designed with great flexibility so that you can evaluate the circuit performance for several circuit configurations, and in development of your own applications. A layout sketch of the evaluation board is shown in chapter 0.

Description

The evaluation circuit board constitutes of three main parts. These are the RF-section, the voltage supply and the PC-interface. The PC-interface contains voltage level shift circuit, which buffers the control lines.

Voltage supply

You can chose between applying a 4-10V non-regulated supply voltage or a 3V regulated supply voltage by setting a switch on the board (SPDT). If a non-regulated supply voltage is applied, an on board regulator generates a regulated 3V supply. A diode prevents damage if wrong polarity is used for the non-regulated input. The connector has five contacts, which is shown below. In addition to the three supply voltage contacts, there are two contacts, which can be used to measure the DC current to the CC400 chip. A short jumper is placed between these two contacts for the circuit to work. If you want to measure the DC current, replace the jumper with an amperemeter (as shown in the figure below). The current range is from 0 to 70 mA.

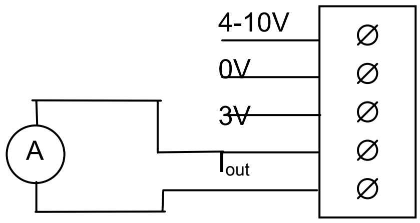


Figure: The power connector with an amperemeter attached.

RF-section

The RF section consists of a CC400 chip with external components. The different components are explained below.

The loop filter

The PLL loop filter contains the components C121-C123 and R121-R123. The software program calculates the component values. Using the calculated component values for the loop filter will give an optimum loop bandwidth for the selected system parameters.

The component values used in the CC400EB is selected for 9.6 kbit/s data rate, but can also be used for evaluation of lower data rates.

The transmitted frequency is FSK modulated, which means that the bits '0' and '1' has different frequencies, see Frequency separation in chapter 4.1.1.5 in SmartRF® Studio user manual.

Note: If you need a shorter switching time between the two frequencies, the PLL settling time has to be shorter. To find the new component values that you need for the loop filter, the software program can be used as a calculator. Using a higher data rate value will give you a larger loop bandwidth, but also an increase in the side-band noise on the carrier. A warning may appear when increasing the data rate. To get around this warning, try to set the X-tal accuracy to zero. Do not update the device when doing this, but use Enter to calculate the values and return to your earlier settings afterwards.

External IF filter

The evaluation board is equipped with an external 455kHz ceramic filter. Input and output impedance to the CC400 is 1.5kΩ, and the bandwidth is approximately 30kHz.

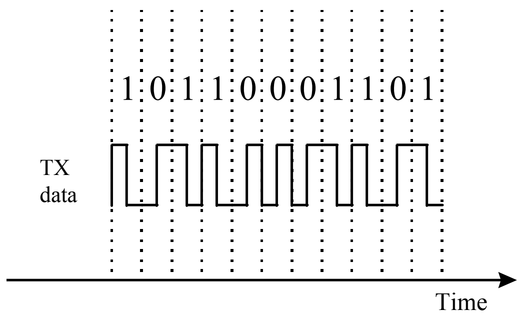
The LOCK signal

A LOCK signal is connected to the parallel port interface to be monitored by the software. The signal tells you if the synthesiser frequency is in lock. It is also available at a test pin, TP2, and is active high.

NOTE: If Power Down mode is selected when the LOCK signal is high, the current consumption will be approximately 23 uA. This is due to the current flowing from the LOCK pin into the external buffer transistor (Q2). This transistor could be replaced with a MOSFET to avoid this trickle current. Without this extra load the CC400 Power Down current is less than 1 uA.

The modulation input/output

The modulation input/output (DIO) is connected to a separate connector. The connector type is SMA female. The data to be sent has to be Manchester encoded (also known as bi-phase-level coding). The Manchester code ensures that the signal has no DC component, which is necessary for the FSK demodulator. The Manchester code is based on transitions; a “0” is encoded as a low-to-high transition, a “1” is encoded as a high-to-low transition. See figure below. Maximum data-rate is 9.6 kbit/s and is chosen in the software. To test your module use a $3V_{pp}$ logic level with 1-10 kHz square wave.



LNA/PA matching

The input/output matching network is optimised for 433.92MHz operation. The component values are calculated in the software program, and consist of C51, C61, L51 and L61. Using the specified component values for the input/output match will give an optimum match at the specified operating frequency. Minor tuning of the component values may be necessary to compensate for layout parasitics at other frequencies or other layouts. See appendix A.

The Voltage Controlled Oscillator (VCO)

The VCO tank on the evaluation board is optimised for the 433MHz band, covering approximately 410 – 450MHz. The tank contains the components C91, C92, C93, L91 and the variable capacitance D2.

To operate in other frequency bands, C93 and L91 can be altered. To increase the operation frequency C93 or L91 (or both) should be decreased (use 8.2nH for L91, and 1.5pF or 1.8pF for C93). To decrease the operation frequency C93 or L91 (or both) should be increased (use 12nH for L91, and 2.7pF or 3.3pF for C93).

To find the tuning range for the new VCO tank, set the RF frequency to 300 MHz and 500 MHz in the software, update the device and measure the output frequency. In this way the VCO tank will be tuned to its minimum and maximum operation frequency respectively.

For further details, please contact Chipcon.

The crystal oscillator

Crystal frequency is set to 12.000 MHz, X1. The crystal oscillator circuit has a trimmer capacitor, CT152, which reduces the initial tolerance of the crystal to zero by careful adjustment using a precision frequency counter. The crystal used at this board has ±10 ppm initial tolerance and ±10 ppm drift over the –10 to +70 °C temperature range. The crystal oscillator has an AC coupled (C153) test pin for external clock injection, TP1. Be sure to remove the crystal when an external clock is used. The external clock should have amplitude of 1-3V_{pp}. If using other crystals they should be designed for 12pF load capacitance.

The preselector filter options

There are three preselector filter options: LC-filter, SAW filter, or no filter used. Each of the three filter alternatives is equipped with a female SMA antenna connector. To choose between the three filters there is a zero ohm resistor that can be moved (R61-R63).

Unfiltered antenna output

The unfiltered antenna output has been made with an option. Two components, L71 and C71, can be used to match the antenna if the antenna impedance is different from 50Ω. To select this output the zero ohm resistor must be put in R61, and R62 and R63 shall not be mounted.

LC-filtered antenna output

A LC-filter consisting of L52, C52 and C53 make up a 3dB-equal ripple low-pass filter that prevents harmonics to be emitted from the transmitter. In receive mode the filter removes high frequencies in order to prevent distortion and jamming of in the receiver. The filter is designed for 50Ω termination impedance. The LC-filter is selected by placing the zero ohm resistor in the R62 position. For operation at other frequencies, please use the formulas below.

$$\omega_C \approx \omega_{RF} \cdot \left(\frac{1}{1 - 0.1333} \right), \qquad L = \frac{35.6}{\omega_C}, \qquad C = \frac{0.067}{\omega_C},$$

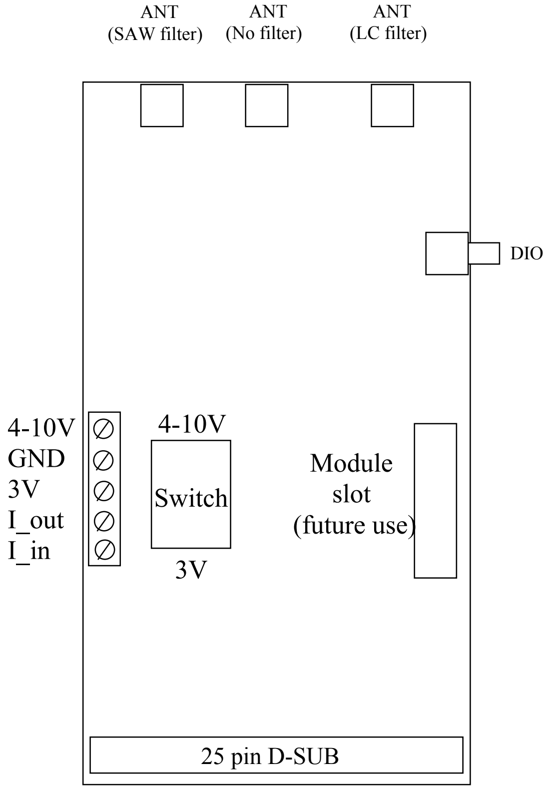
where ω_C is the cut-off frequency and ω_{RF} is the transmitted RF frequency .

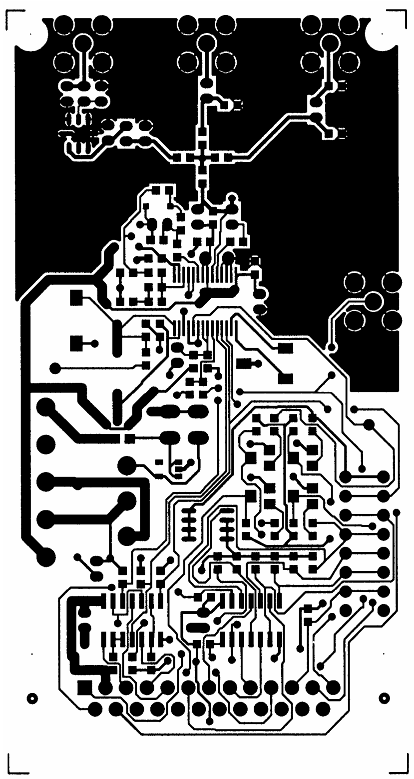
SAW filtered antenna output

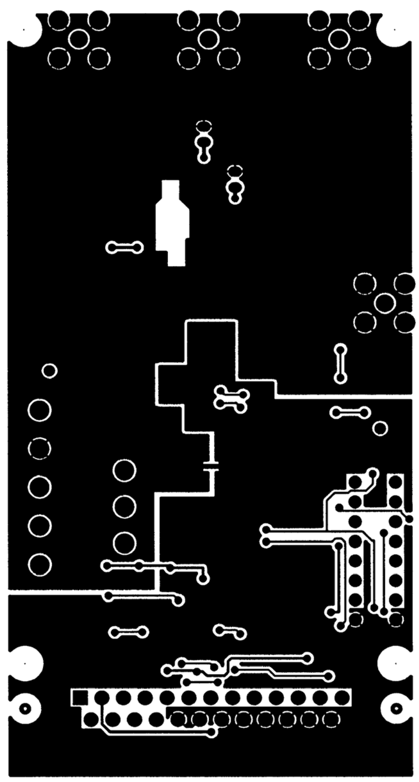
To choose this output the zero ohm resistor must be put in the R63 position. The components around the filter (F2) can be changed to match any SAW filter type. The SAW filter will introduce additional loss, but will increase the selectivity of the receiver. The 3dB bandwidth is approximately 200 kHz. The filter can be replaced with another SAW filter with a 3dB bandwidth of 2 MHz if desirable.

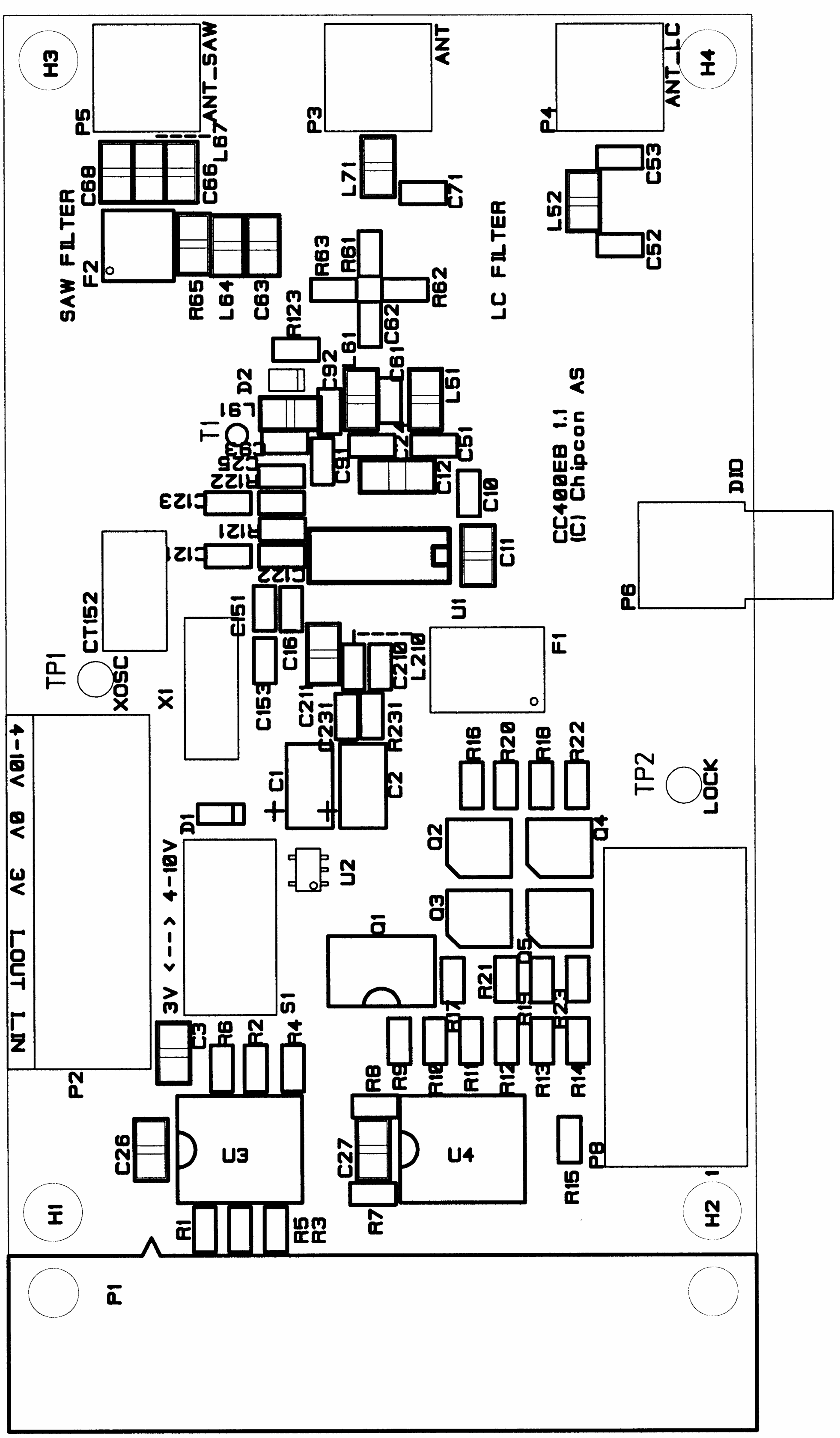
Note: Using the SAW filter, the output power amplifier class should be A or AB and the output power should not exceed 0 dBm. This will give approximately –5 dBm at the antenna output. Using power settings above 0 dBm may cause stability problems.

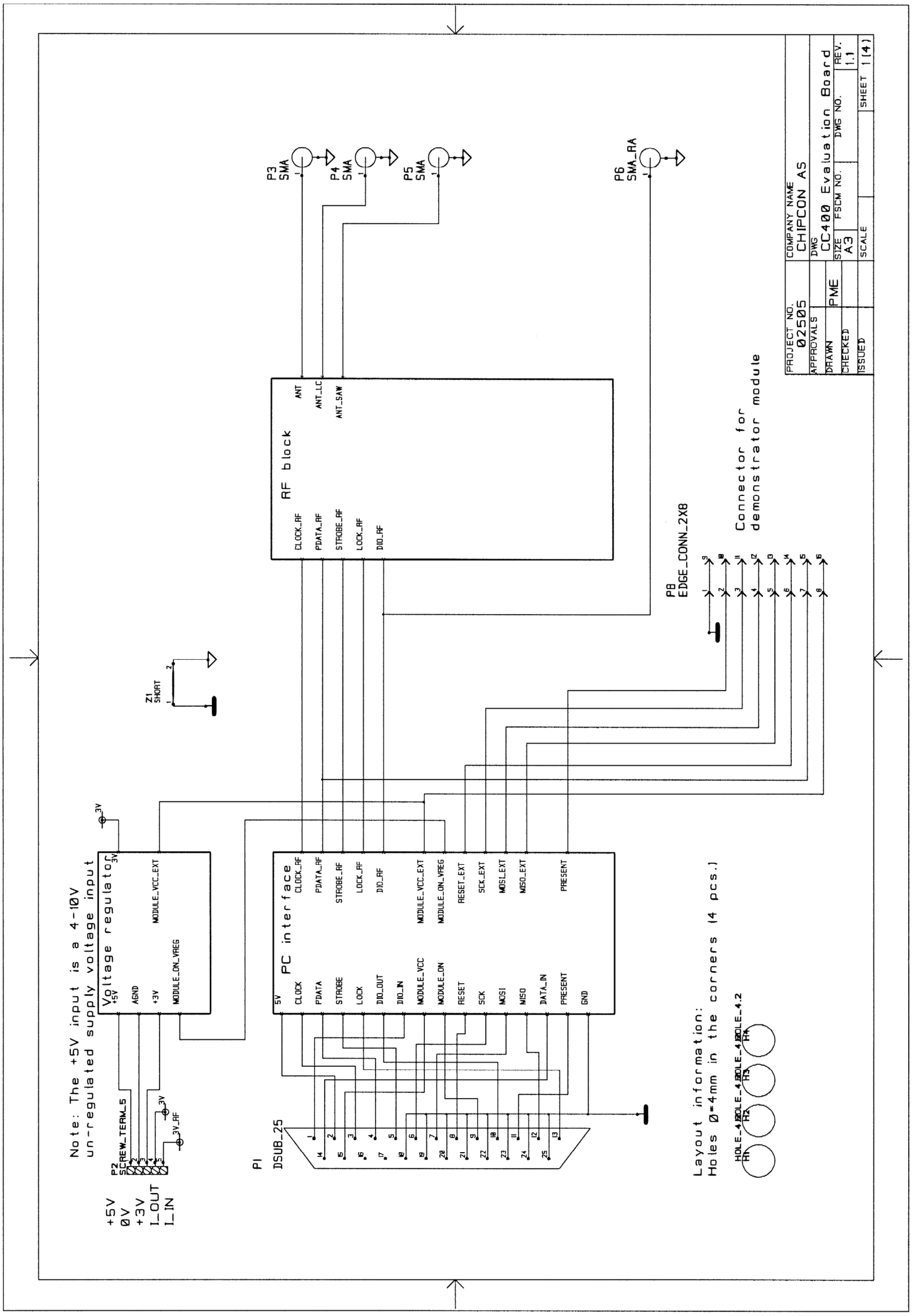
Layout sketches and circuit drawings

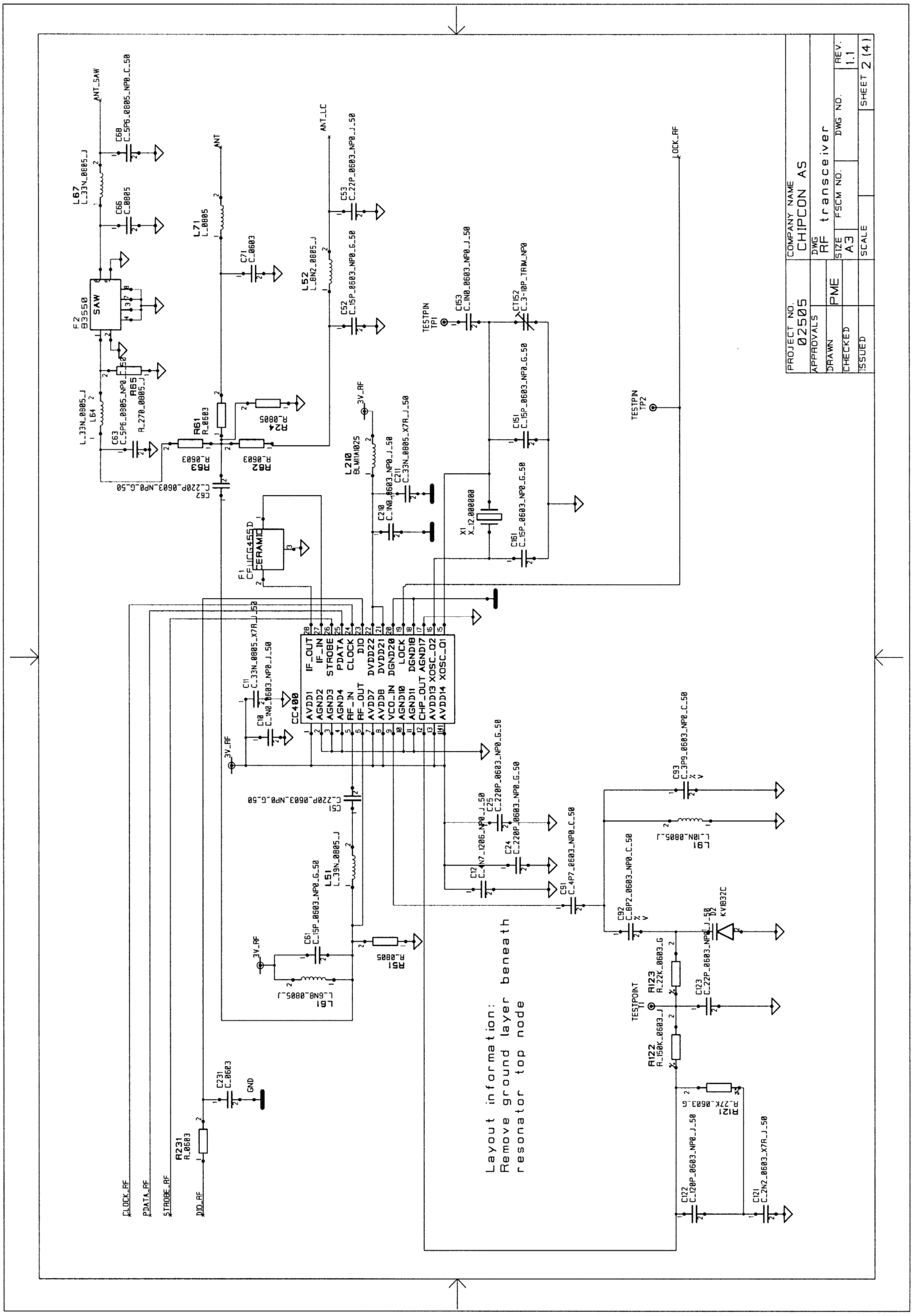


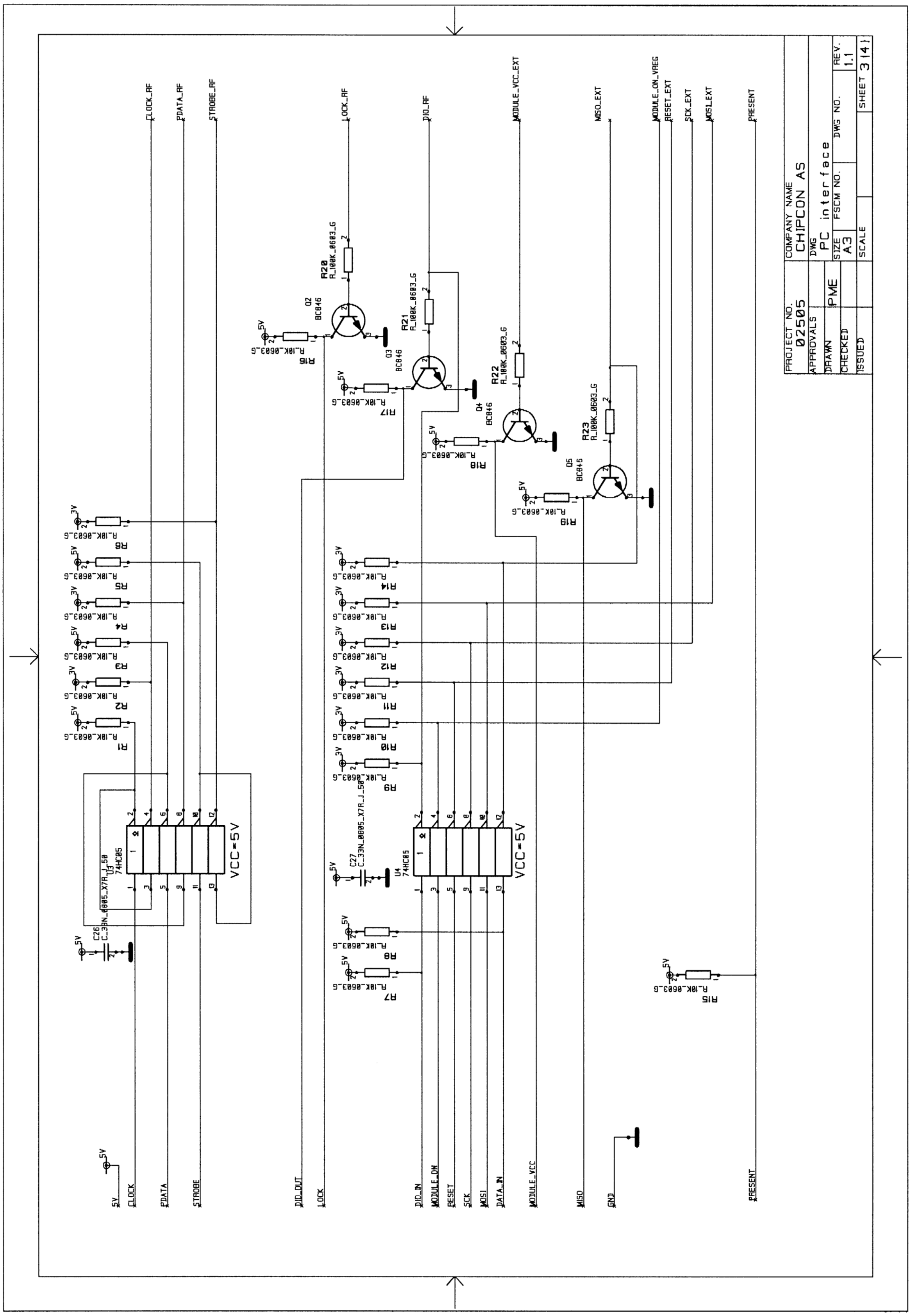


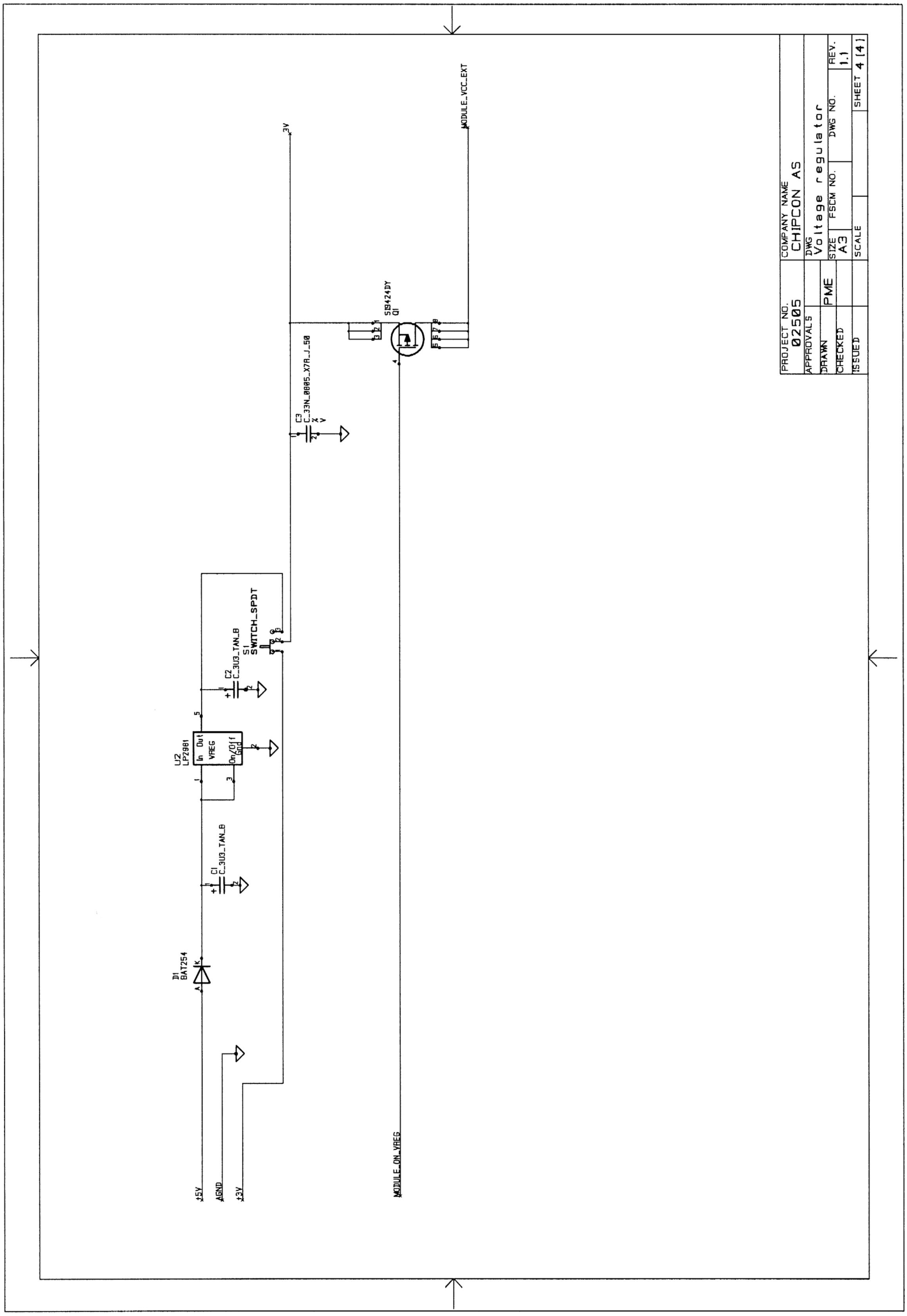



SAW FILTER
LC FILTER
ANT_SAW
ANT
ANT_LC
CC400EB 1.1
(C) Chipcon AS
DIO
XOSC
LOCK
TP1
TP2
4-10V
0V
3V
LOUT
L_IN
3V <--> 4-10V
H1
H2
H3
H4
P1
P2
P3
P4
P5
P6
P8
U1
U2
U3
U4
Q1
Q2
Q3
Q4
S1
D1
D2
T1
X1
F1
F2


Note: The +5V input is a 4-10V un-regulated supply voltage input
Voltage regulator
+5V
AGND
+3V
MODULE_ON_VREG
MODULE_VCC_EXT
3V
P2
SCREW_TERM_5
+5V
0V
+3V
I_OUT
I_IN
3V
3V_RF
Z1
SHORT
P1
DSUB_25
PC interface
5V
CLOCK
PDATA
STROBE
LOCK
DIO_OUT
DIO_IN
MODULE_VCC
MODULE_ON
RESET
SCK
MOSI
MISO
DATA_IN
PRESENT
GND
CLOCK_RF
PDATA_RF
STROBE_RF
LOCK_RF
DIO_RF
MODULE_VCC_EXT
MODULE_ON_VREG
RESET_EXT
SCK_EXT
MOSI_EXT
MISO_EXT
PRESENT
RF block
CLOCK_RF
PDATA_RF
STROBE_RF
LOCK_RF
DIO_RF
ANT
ANT_LC
ANT_SAW
P3
SMA
P4
SMA
P5
SMA
P6
SMA_RA
P8
EDGE_CONN_2X8
Connector for demonstrator module
Layout information:
Holes Ø=4mm in the corners (4 pcs.)
HOLE_4.2
H1
H2
H3
H4
PROJECT NO.
02505
APPROVALS
DRAWN
PME
CHECKED
ISSUED
COMPANY NAME
CHIPCON AS
DWG
CC400 Evaluation Board
SIZE
A3
FSCM NO.
DWG NO.
REV.
1.1
SCALE
SHEET 1(4)


Layout information:
Remove ground layer beneath
resonator top node
CC400
PROJECT NO.
02505
APPROVALS
DRAWN
PME
CHECKED
ISSUED
COMPANY NAME
CHIPCON AS
DWG
RF transceiver
SIZE
A3
FSCM NO.
DWG NO.
REV.
1.1
SCALE
SHEET 2 (4)


COMPANY NAME
CHIPCON AS
DWG
PC interface
PROJECT NO.
02505
APPROVALS
DRAWN
PME
CHECKED
ISSUED
SIZE
A3
FSCM NO.
DWG NO.
REV.
1.1
SCALE
SHEET 3(4)
VCC=5V
74HC05
VCC=5V
74HC05


MODULE_VCC_EXT
3V
SI9424DY
Q1
C3
C_33N_0805_X7R_J_50
SWITCH_SPDT
S1
C2
C_3U3_TAN_B
U2
LP2981
In Out
VREG
On/Off
Gnd
C1
C_3U3_TAN_B
D1
BAT254
+5V
AGND
+3V
MODULE_ON_VREG
PROJECT NO.
02505
APPROVALS
DRAWN
PME
CHECKED
ISSUED
COMPANY NAME
CHIPCON AS
DWG
Voltage regulator
SIZE
A3
FSCM NO.
DWG NO.
REV.
1.1
SCALE
SHEET 4 (4)

Bill of materials

RF part			
Reference	*Description*	*Value*	*Part*
C10	Capacitor 0603	1nF	C_1N0_0603_NP0_J_50
C11	Capacitor 0805	33nF	C_33N_0805_X7R_J_50
C12	Capacitor 1206	4.7nF	C_4N7_1206_NP0_J_50
C24	Capacitor 0603	220pF	C_220P_0603_NP0_G_50
C25	Capacitor 0603	220pF	C_220P_0603_NP0_G_50
C51	Capacitor 0603	220pF	C_220P_0603_NP0_G_50
C52	Capacitor 0603	15pF	C_15P_0603_NP0_J_50
C53	Capacitor 0603	22pF	C_22P_0603_NP0_J_50
C61	Capacitor 0603	15pF	C_15P_0603_NP0_G_50
C62	Capacitor 0603	220pF	C_220P_0603_NP0_G_50
C63	Capacitor 0805	5.6pF	C_5P6_0805_NP0_C_50
C66	Capacitor 0805		Do Not Mount
C68	Capacitor 0805	5.6pF	C_5P6_0805_NP0_C_50
C71	Capacitor 0603		Do Not Mount
C91	Capacitor 0603	4.7pF	C_4P7_0603_NP0_C_50
C92	Capacitor 0603	8.2pF	C_8P2_0603_NP0_C_50
C93	Capacitor 0603	3.9pF	C_3P9_0603_NP0_C_50
C121	Capacitor 0603	2.2nF	C_2N2_0603_X7R_J_50
C122	Capacitor 0603	120pF	C_120P_0603_NP0_J_50
C123	Capacitor 0603	22pF	C_22P_0603_NP0_J_50
C151	Capacitor 0603	15pF	C_15P_0603_NP0_G_50
C153	Capacitor 0603	1nF	C_1N0_0603_NP0_J_50
C161	Capacitor 0603	15pF	C_15P_0603_NP0_G_50
C210	Capacitor 0603	1nF	C_1N0_0603_NP0_J_50
C211	Capacitor 0805	33nF	C_33N_0805_X7R_J_50
C231	Capacitor 0603		Do Not Mount
CT152	Trimmer Capacitor		C_3-10P_TRIM_NP0
D2	Varactor diode		KV1832C, Toko
F1	Ceramic filter, 455kHz		CFUCG455D, Murata
F2	SAW filter, 433.92MHz		B3550, Siemens

L51	Inductor 0805	39nH	L_39N_0805_J
L52	Inductor 0805	8.2nH	L_8N2_0805_J
L61	Inductor 0805	6.8nH	L_6N8_0805_J
L64	Inductor 0805	33nH	L_33N_0805_J
L67	Inductor 0805	33nH	L_39N_0805_J
L71	Resistor 0805	0Ω	R_0R_0805
L91	Inductor 0805	10nH	L_10N_0805_J LQN21A, Murata
L210	EMI filter bead		BLM11A102S, Murata
R24	Resistor 0805		Do Not Mount
R51	Resistor 0805		Do Not Mount
R61	Resistor 0603	0Ω	R_0R_0603
R62	Resistor 0603		Do Not Mount
R63	Resistor 0603		Do Not Mount
R65	Resistor 0805	270Ω	R_270_0805_J
R121	Resistor 0603	27kΩ	R_27K_0603_G
R122	Resistor 0603	150kΩ	R_150K_0603_J
R123	Resistor 0603	22kΩ	R_22K_0603_G
R231	Resistor 0603	0Ω	R_0R_0603
TP1	Testpoint		TESTPIN
TP2	Testpoint		TESTPIN
U1	Single chip transceiver		CC400
X1	Crystal, HC-49-SMD		X_12.000000 MHz, 12pF load

Voltage regulator			
Reference	*Description*	*Value*	*Part*
C1	Capacitor, tantal	3.3μF	C_3U3_TAN_B
C2	Capacitor, tantal	3.3μF	C_3U3_TAN_B
C3	Capacitor 0805	33nF	C_33N_0805_X7R_J_50
D1	Diode, Si		BAT254
Q1	MOSFET, P ch.		SI9424DY, Siliconix
S1	SPDT switch		SWITCH_SPDT
U2	Voltage regulator		LP2981, 3V, National

PC interface			
Reference	*Description*	*Value*	*Part*
C26	Capacitor 0805	33nF	C_33N_0805_X7R_J_50
C27	Capacitor 0805	33nF	C_33N_0805_X7R_J_50
Q2	BJT, Si, NPN, small signal		BC846
Q3	BJT, Si, NPN, small signal		BC846
Q4	BJT, Si, NPN, small signal		BC846
Q5	BJT, Si, NPN, small signal		BC846
R1	Resistor 0603	10kΩ	R_10K_0603_G
R2	Resistor 0603	10kΩ	R_10K_0603_G
R3	Resistor 0603	10kΩ	R_10K_0603_G
R4	Resistor 0603	10kΩ	R_10K_0603_G
R5	Resistor 0603	10kΩ	R_10K_0603_G
R6	Resistor 0603	10kΩ	R_10K_0603_G
R7	Resistor 0603	10kΩ	R_10K_0603_G
R8	Resistor 0603	10kΩ	R_10K_0603_G
R9	Resistor 0603	10kΩ	R_10K_0603_G
R10	Resistor 0603	10kΩ	R_10K_0603_G
R11	Resistor 0603	10kΩ	R_10K_0603_G
R12	Resistor 0603	10kΩ	R_10K_0603_G
R13	Resistor 0603	10kΩ	R_10K_0603_G
R14	Resistor 0603	10kΩ	R_10K_0603_G
R15	Resistor 0603	10kΩ	R_10K_0603_G
R16	Resistor 0603	10kΩ	R_10K_0603_G
R17	Resistor 0603	10kΩ	R_10K_0603_G
R18	Resistor 0603	10kΩ	R_10K_0603_G
R19	Resistor 0603	10kΩ	R_10K_0603_G
R20	Resistor 0603	100kΩ	R_100K_0603_G
R21	Resistor 0603	100kΩ	R_100K_0603_G
R22	Resistor 0603	100kΩ	R_100K_0603_G
R23	Resistor 0603	100kΩ	R_100K_0603_G
U3	Hex inverter, oc		74HC05
U4	Hex inverter, oc		74HC05

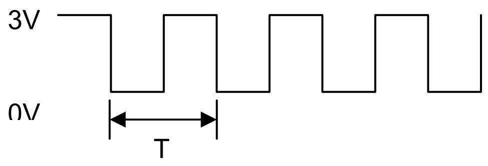
Evaluation board			
Reference	*Description*	*Value*	*Part*
H1	Circuit Board Support		Distance 12.5mm
H2	Circuit Board Support		Distance 12.5mm
H3	Circuit Board Support		Distance 12.5mm
H4	Circuit Board Support		Distance 12.5mm
P1	D-Sub, 25 pin		DSUB_25
P2	5 pin terminal, screw		SCREW_TERM_5
P3	SMA connector		SMA (Straight)
P4	SMA connector		SMA (Straight)
P5	SMA connector		SMA (Straight)
P6	SMA connector		SMA_RA (Right angle)
P8	Edge connector, 2 x 8 pin		EDGE_CONN_2X8

Using the Development Kit

The purpose of the Development Kit is to give users of the integrated transceiver CC400 hands-on experience with the chip. A typical set-up of the evaluation board is shown below. Each of the evaluation boards is connected to a PC to be programmed by the software.

- How to set up a transmitter.

The data signal that you want to send in transmit mode must be Manchester coded. If you don't have Manchester coded signals available, a square wave from a function generator can be used instead. The signal source shall be connected to the Data I/O port (DIO) at the evaluation board. The signal must be a square wave from 0 to 3V as shown. Do not apply a 5V signal because it can damage the CC400 chip. The signal from the function generator will represent either zeroes or ones, and the bit rate will be 1/T, where T is the period time. For example, when 1.2 kbit/s is used, set the function generator frequency to 1.2 kHz as this will give a 1.2kbit/s Manchester coded bit stream.



The transmitted signal can be studied on a spectrum analyser, sent out on the antenna (see note below) or sent to the receiver via a cable with an attenuator attached.

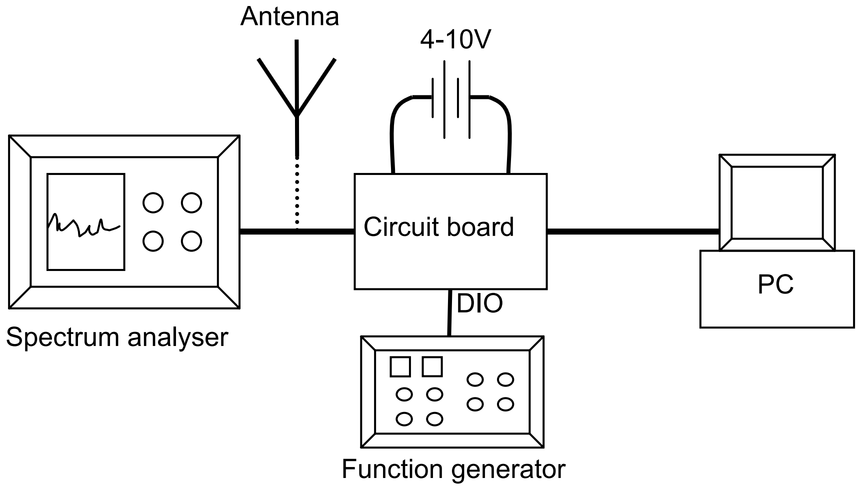


Figure: Equipment set-up in transmit mode.

- How to set up a receiver

In receive mode a RF generator can be connected to the antenna input to give an ideal RF signal to the circuit board for testing the receiver. Use FSK modulation with appropriate deviation and modulation rate. If you don't have the equipment to send FSK modulation, you can use a RF generator with FM modulation and use an external function generator to modulate the signal with a square wave. The RF signal can also come from the transmitter via the antenna. An oscilloscope is used to see the Manchester coded signal that is being received.

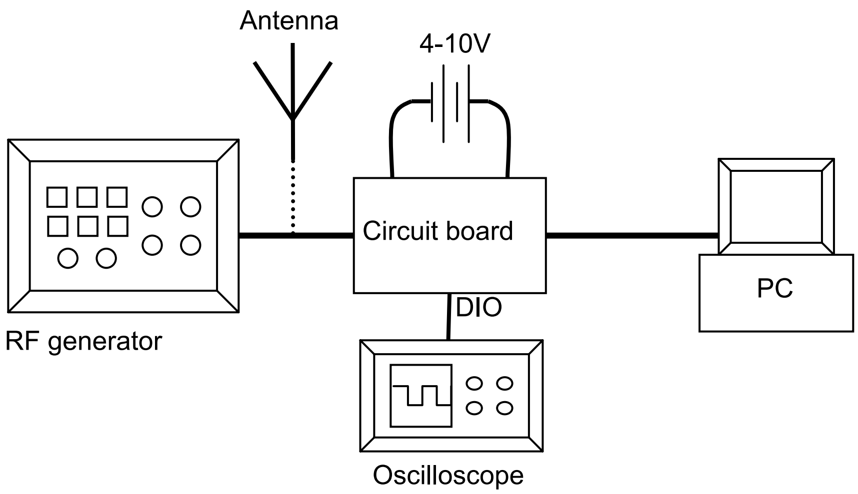


Figure: Equipment set-up in receive mode.

Important: The use of radio transceivers is regulated by international and national rules. Before transmitting a RF signal out on the antenna, please contact your local telecommunication authorities to check if you are licensed to operate the transceiver.

Appendix A

The component values to the input/output matching network are calculated in the software program, and consist of C51, C61, L51 and L61. Using the specified component values for the input/output match will give an optimum match at the specified operating frequency. Minor tuning of the component values may be necessary to compensate for layout parasitics at other frequencies or other layouts.

A.1 Fine tuning procedure of LNA/PA matching network

Follow the procedure below to fine-tune the matching network. Use the components that the software program calculates as initial values. Set the bits F5:F3 = 000 in the Register configuration window and update the device.

1) Receiver tuning

Connect a Network Analyser to the unfiltered antenna output as shown in the figure, and measure the impedance at the output.

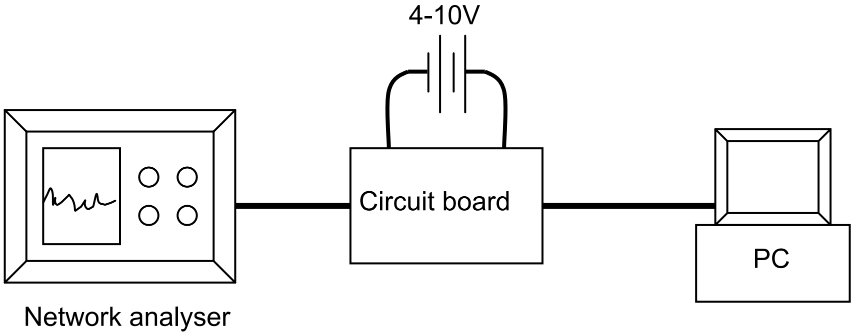


Figure: Equipment set-up.

Set the CC400 transceiver in RX mode with the software program and adjust L51 and C61 until you measure approximately 50Ω impedance at the antenna output.

2) Transmitter tuning

Connect a Spectrum Analyser to the unfiltered antenna output in the same way as you did for the RX tuning and measure output power. Set the CC400 transceiver in TX mode and adjust C61 until you measure the highest output power.

3) Setting the Register bits

Choose the Register configuration window in the software.

1) If the optimum value of C61 found in RX mode is larger than C61 found in TX mode:

Set bit F2 to 0 and increase bits F5 to F3 by an amount following the formula below and update the device.

$$F5:F3 = round\left(\frac{C61_{RX} - C61_{TX}}{1.25pF}\right)$$

Choose the value of C61 that you got from the TX tuning ($C61_{TX}$).

Example: If $C61_{TX}$ = 12pF and $C61_{RX}$ = 15pF the bits F5:F3 = 010.

2) If the optimum value of C61 found in TX mode is larger than C61 found in RX mode:

Set bit F2 to 1 and increase bits F5 to F3 by an amount following the formula below and update the device.

$$F5 : F3 = round\left(\frac{C61_{TX} - C61_{RX}}{1.25pF}\right)$$

Choose the value of C61 that you got from the RX tuning ($C61_{RX}$).

General Information