Small and very stable RF power generator

Realisation:
Mateusz Szczepaniak
Kraków 27.12.2023

Content Page

1. Introduction

The assumption of the project was to create a small and simple RF generator, with good parameters and high stability. At the very beginning, the generator design based on separate components was eliminated, i.e. separate VCO, PLL, dividers, multiplexers and final stages. Such a design can provide the best stability and noise parameters and be freely and easily modified, but it requires complex design and time-consuming tests. In this straightforward project, reliance is placed on the use of a Wideband Synthesizer with Integrated VCO, which will provide good parameters and in one "silicon" unit will have integrated basic components of the RF generator and the ability to program the output frequencies. Integrated circuits from two manufacturers met the requirements: ADF4350 from Analog Devices and LMX2581 from Texas Instruments. Both solutions have very similar parameters, features and functions, the basic ones are summarized in the table below:

Parameters	ADF4350	LMX2581
Output frequencies	137.5 MHz to 4400 MHz	50 to 3760 MHz
Power consuption	130mA	178mA
VCO range	2,2GHz – 4,4GHz	1,88GHz – 3,76GHz
Phase noice for 10kHz offset		
2,2GHz	-89dBc/Hz	-85,4dBc/Hz
3,3GHz	-86dBc/Hz	-79dBc/Hz

ADF4350 covers the entire assumed frequency range, has better parameters, but is 30% more expensive than LMX2581. The ADF circuit was ordered from free samples on the manufacturer's website, which is another advantage.

An Attiny microcontroller will be used to program the output frequencies due to its simplicity, small size and lack of additional peripherals.

To ensure adequate output power, the PCB will be equipped with an output amplifier, and circuits sensitive to power supply noise will be powered by separate stabilizers to improve parameters.

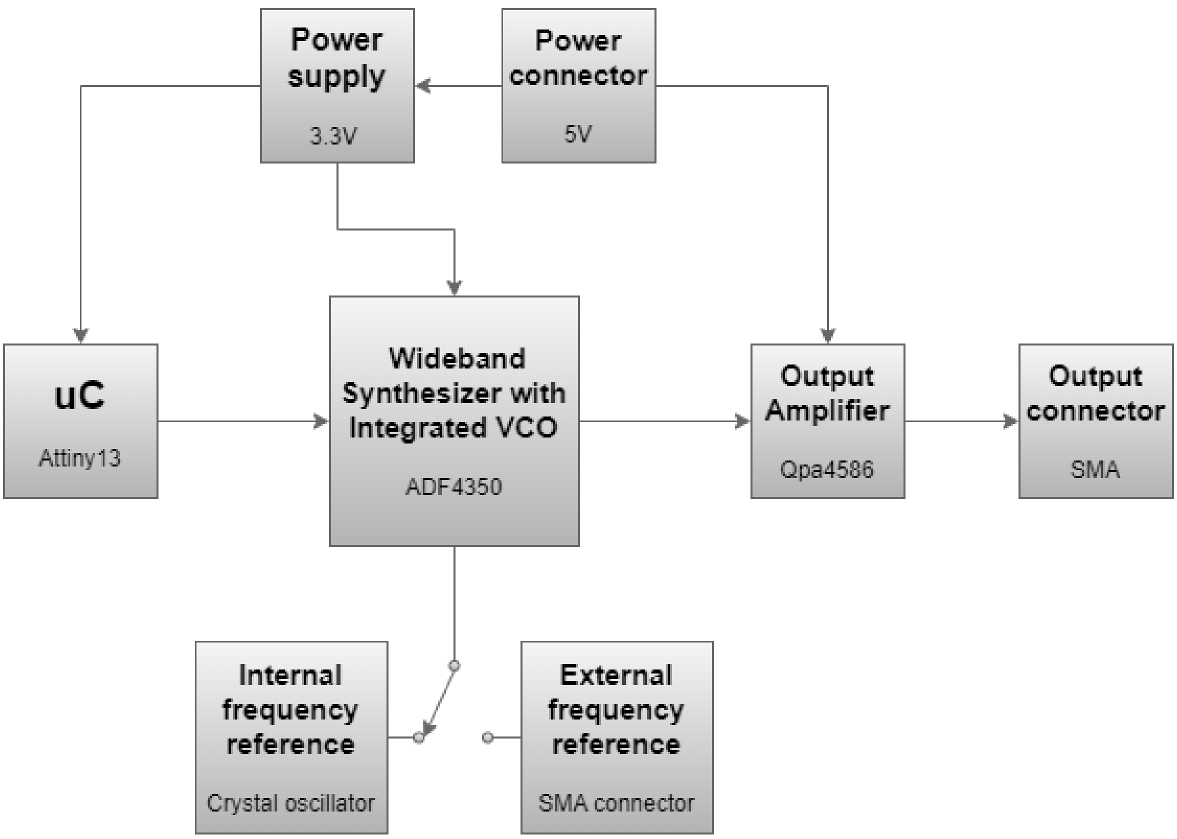
2. Project scope

- Choosing the optimal solution
- Designing a schematic diagram
- Designing a PCB
- Designing a 3D printed housing
- Installation
- Tests and measures

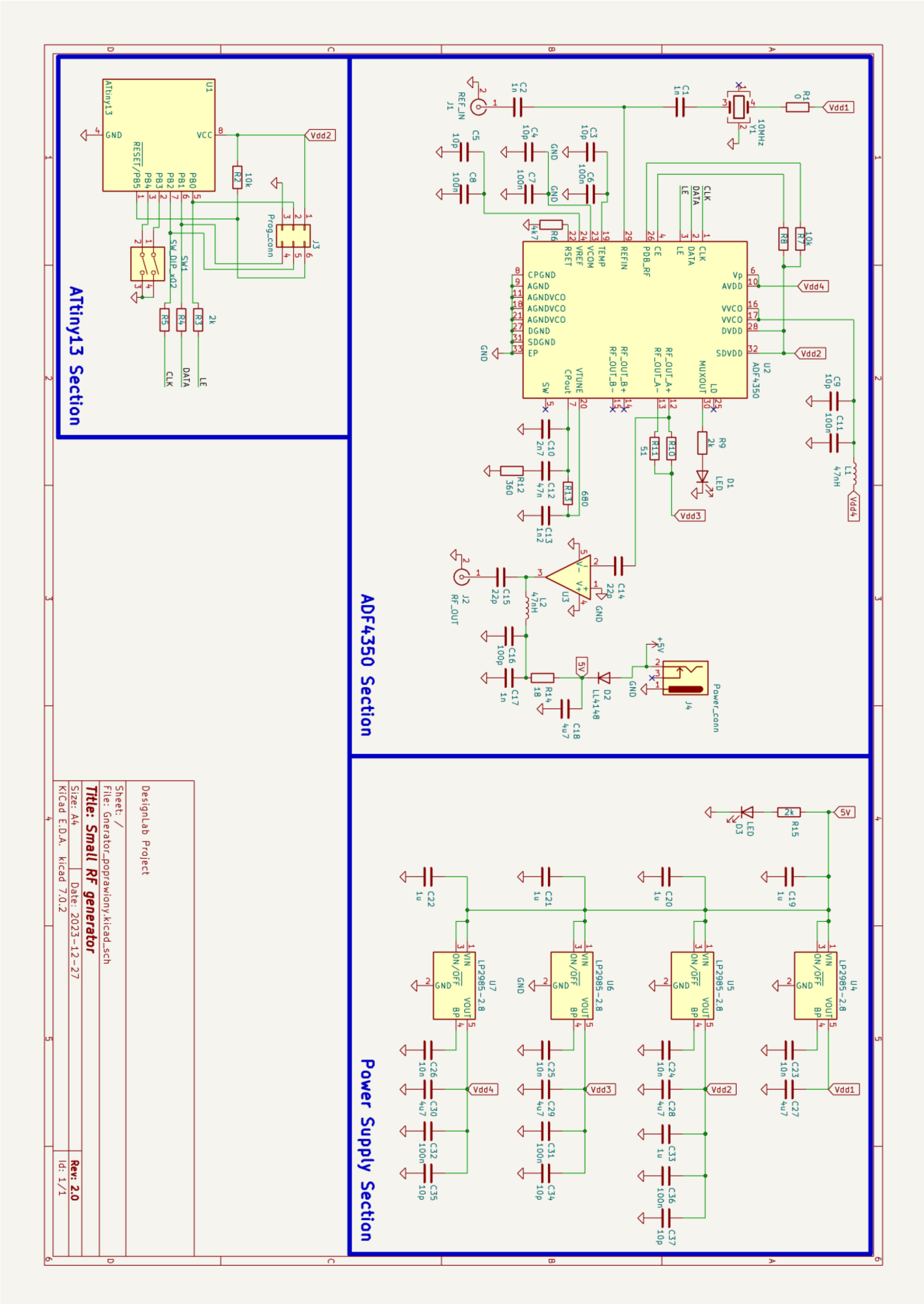
3. Technical Parameters

- Dimensions:
  PCB: 51mm x 46mm,
  Cover: 58mm x 53mm x 27mm
- Power supply: +5V, >200mA
- Output power: 9-15dBm
- Frequency range: 550-4400MHz
- 4 programmable frequency values
- SMA connectors
- Frequency stability: +/- 350 Hz (depends on the frequency)
- Phase noice: (-85) – (-105) dBc/Hz
- Harmonics: -4dB (worst case)

4. Block diagram

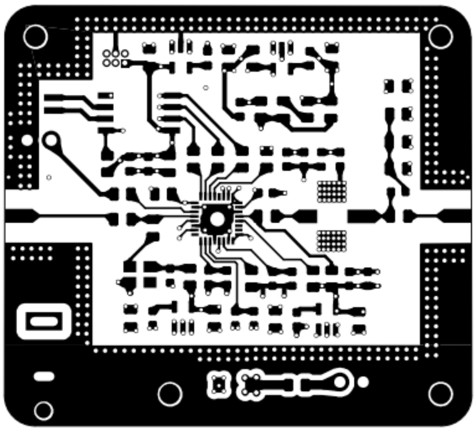


5. Scheme

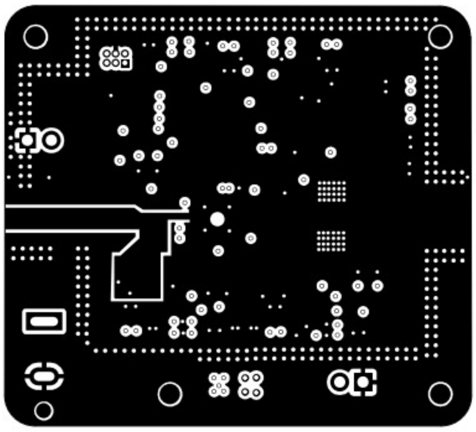

ATtiny13 Section
ADF4350 Section
Power Supply Section
DesignLab Project
Sheet: /
File: Gnerator_poprawiony.kicad_sch
Title: Small RF generator
Size: A4
Date: 2023-12-27
Rev: 2.0
KiCad E.D.A. kicad 7.0.2
Id: 1/1

6. PCB design

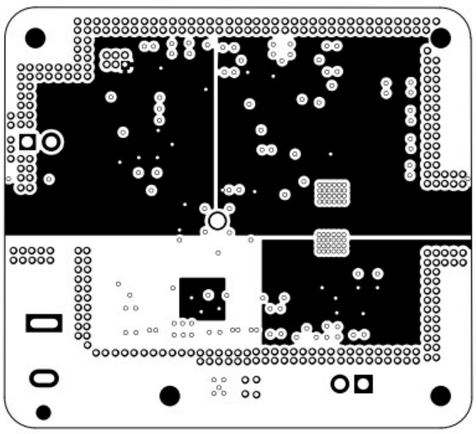
To maintain the intended dimensions and improve RF properties (thinner 50 Ohm paths), the PCB is 4-layer. The design was based on a schematic diagram provided by the manufacturer in the catalog note. To ensure high stability, each voltage pin has its own stabilizer and copper plates. The mass is common, only under the quartz it is cut off. For easier assembly (soldering the ground pad), there is an enlarged hole in the PCB. The mounting holes were placed in convenient places due to the planned use of a 3D printed casing, designed for PCB. An exposed copper ring is used to mount the RF shielding.



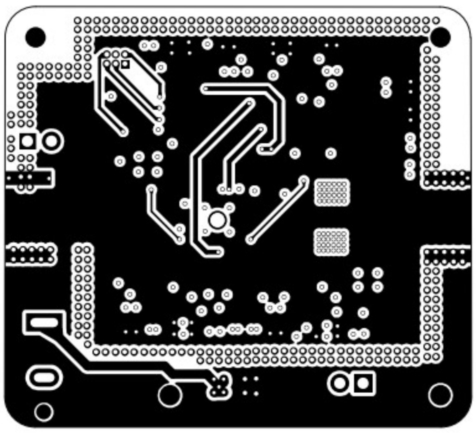
1st layer - signal



2nd layer - ground

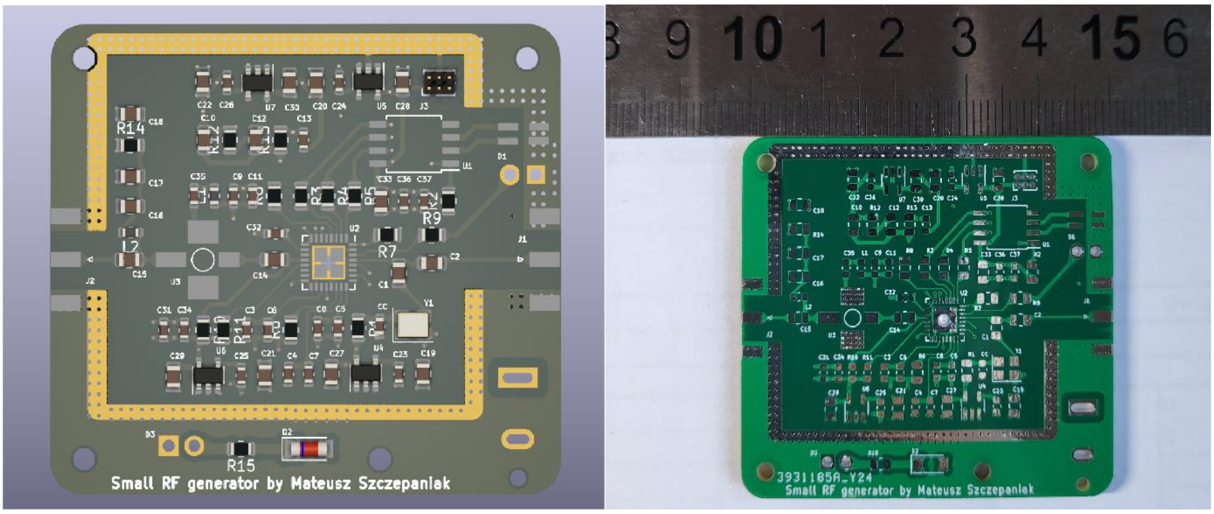


3rd layer - 3,3V distribution



4th layer - 5V distribution

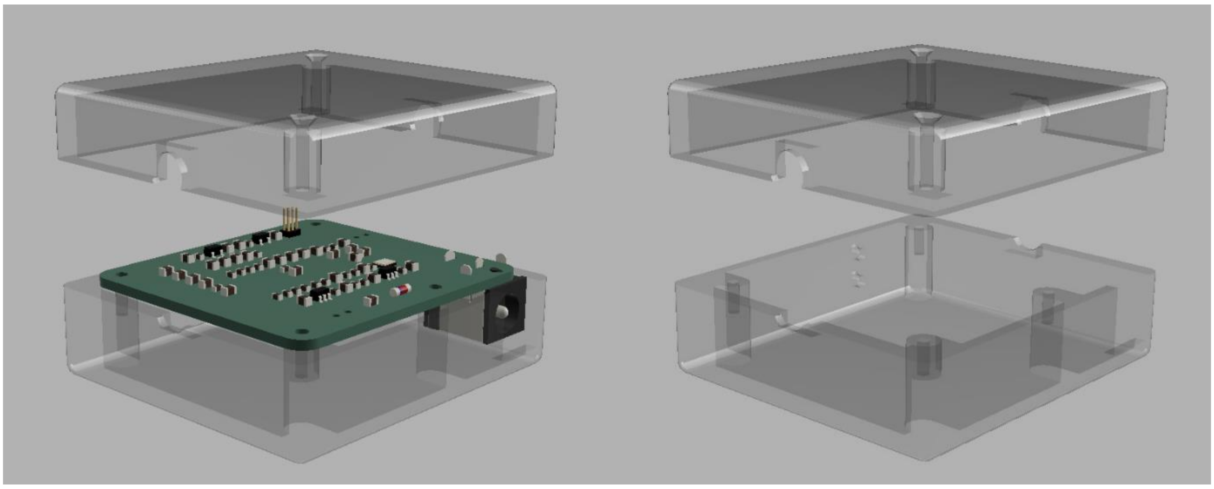
Pic.1. Layers stack



Pic.2 KiCad render and PCB from China

7. Coverdesign

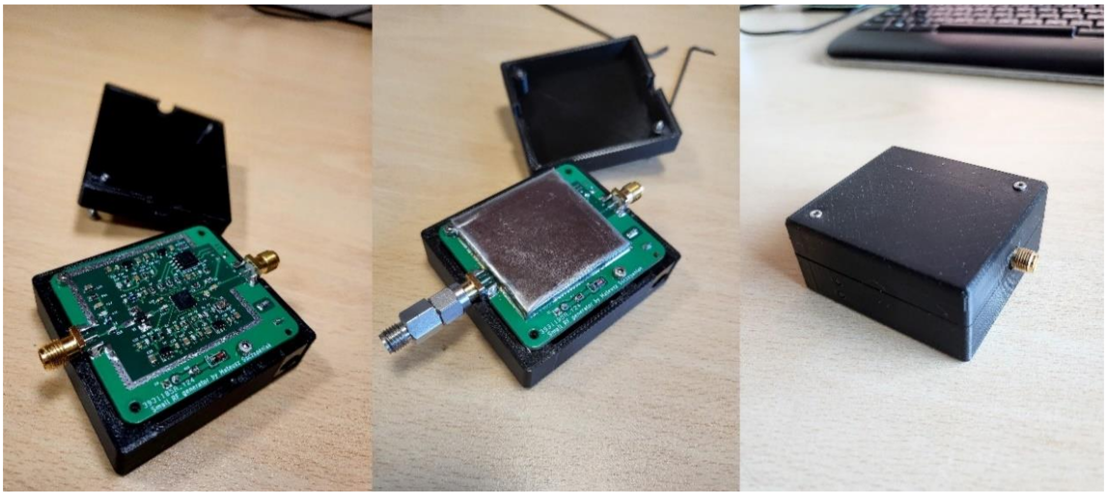
The case was designed in Fusion360 using a PCB model generated in KiCad. 2 screws were used to screw the PCB to the lower part of the cover, another two were used to connect both parts of the case. There are also holes for 2 LEDs, a DC power and SMA connectors. To improve the appearance, the outer layers of the housing were printed using the Hilbert curve on an Ender 3 printer.



Pic.4. Cover render from Fusion360

8. Assembly

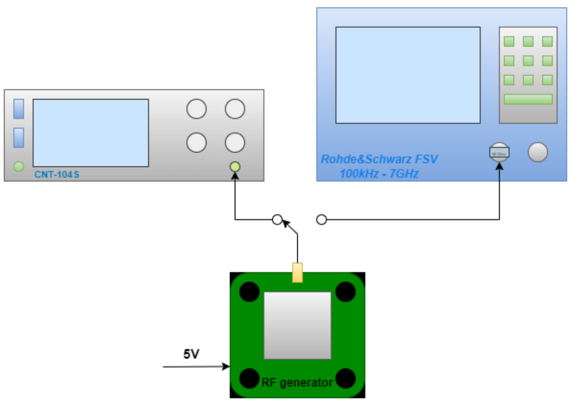
After the boards arrived from China, the soldering stage began, starting from the smallest elements, ending with THT assembly. After checking the correct operation: no short circuits, loading the program and the PLL "catching" the frequency, the RF shielding was installed and the cover was assembled.



Pic.5. Assembled device

9. Tests and measurements

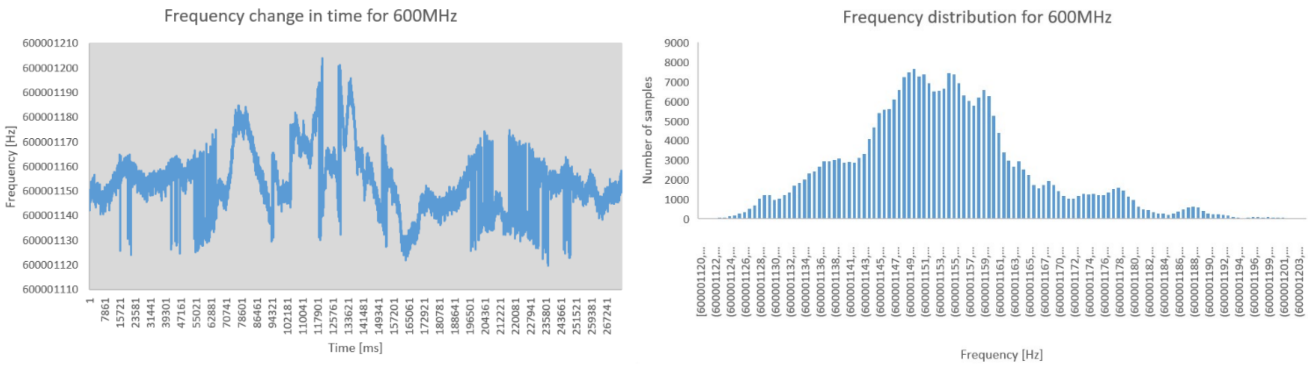
Measurements were made according to the connections shown in the diagram below. For this purpose, a Rohde&Schwarz FSV spectrum analyzer and a pendulum frequency counter, model CNT-104S, were used. The generator was powered by a laboratory power supply. All devices were turned on for at least 1 hour before the measurement to stabilize the temperature and achieve stable measurement conditions. The frequency stability measurement took 4 hours, after which the generator was switched to the input of the spectrum analyzer and after waiting 30 minutes, measurements of harmonics, signal power and phase noise were made. The procedure was repeated for 3 frequencies from different operating ranges of the ADF4350 synthesizer: 600MHz, 1380MHz and 2400MHz.



Pic.6. Measurement scheme

Measurement results for the 600MHz frequency:

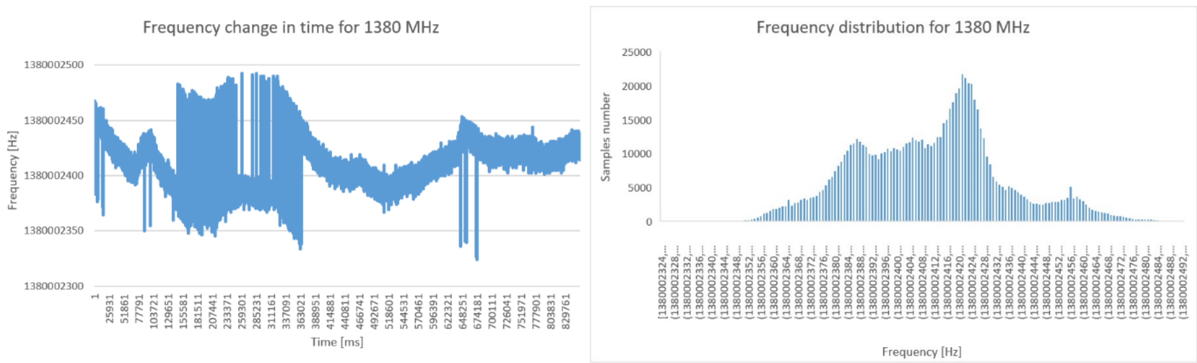
- Output frequency (exact): 600001200 Hz
- Frequency stability: +/-150Hz
- Power consumption: 0,79mW
- Output power: 14,34 dBm
- Phase noice (10kHz): -103,1dBc/Hz
- Harmonics: 2nd: -9dB, 3rd: -20dB, 4th: -25dB



Pic.7. 600MHz measurement charts

Measurement results for the 1380MHz frequency:

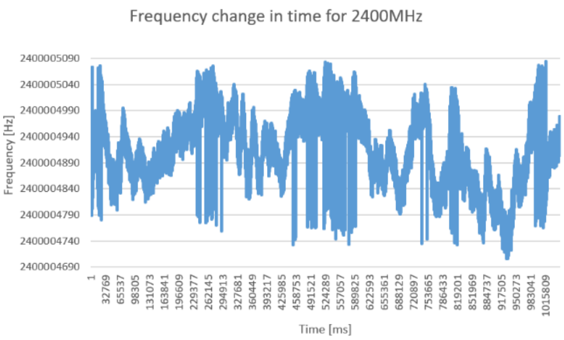
- Output frequency (exact): 1380002470 Hz
- Frequency stability: +/-300 Hz
- Power consumption: 0,73 mW
- Output power: 9,1 dBm
- Phase noice (10 kHz): -90,25 dBc/Hz
- Harmonics: 2nd: -16dB, 3rd: -4dB, 4th: -25dB

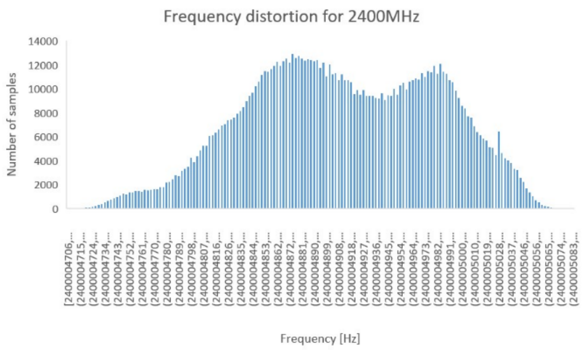


Pic.8. 1380MHz measurement charts

Measurement results for the 2400MHz frequency:

- Output frequency (exact): 2400004910 Hz
- Frequency stability: +/-350Hz
- Power consumption: 0,72 mW
- Output power: 11,45 dBm
- Phase noice (10kHz): -87,57 dBc/Hz
- Harmonics: 2nd: -15dB, 3rd: out of range FSV





Pic.7. 2400MHz measurement charts

	Frequency	Stability	Power consumtion	Output power	Phase noise	Harmonics
550-1100 MHZ	**600001200 Hz**	**+/-150Hz**	**0,79mW**	**14,34 dBm**	**-103,1 dBc/Hz**	**2nd: -9dB, 3rd: -20dB, 4th: -25dB**
1100-2200 MHz	**1380002470 Hz**	**+/-300 Hz**	**0,73mW**	**9,1 dBm**	**-90,25 dBc/Hz**	**2nd: -16dB, 3rd: -4dB, 4th: -25dB**
2200-4400 MHZ	**2400004910 Hz**	**+/-350Hz**	**0,72mW**	**11,45 dBm**	**-87,57 dBc/Hz**	**2nd: -15dB**

10. Bill of materials

Part	Package	Quantity	Value
D2	D_MiniMELF	1	LL4148
C20,C22,C21,C19,C33	C0805	5	1uF
C27,C18,C28,C29,C30	C0805	5	4u7F
R6	R0805	1	4k7F
C5,C35,C34,C37,C9,C4,C3	C0603	7	10pF
R7,R8,R2	R0805	3	10kΩ
C16	C0805	1	100pF
R12	R0805	1	360Ω
R11,R10	R0805	2	51Ω
R5,R3,R4,R9,R15	R0805	5	2kΩ
C14,C15	C0805	2	22pF
C17,C1,C2	C0805	3	1nF
L1,L2	L0603	2	47nH
C25,C26,C23,C24	C0603	4	10nF
R13	R0805	1	680Ω
R14	R0805	1	18Ω
U2	LFCSP-32-1EP	1	ADF4350
C31,C6,C8,C32,C11,C36,C7	C0603	7	100nF
R1	R0805	1	0
U4,U7,U5,U6	SOT-23-5	4	LP2985
C10	C0805	1	2n7F
CC	C0603	1	
C13	C0603	1	1n2F
J2	SMA_AmphenolEdgeMount	1	RF_OUT
C12	C0805	1	47nF
U1	SOIC-8W	1	ATtiny13
Y1	Crystal_SMD_3225-4Pin	1	10MHz
D1,D3	D_DO-15_P2.54mm	2	LED
U3	TO-50-4	1	
J1	SMA_AmphenolEdgeMount	1	REF_IN
J3	PinHeader_2x03_P1.00mm	1	Prog_conn
J4	BarrelJack	1	Power_conn

11. Literature

1. VHFdesign: LO PLL ADF4350 project: https://vhfdesign.com/plls/lo-pll-adf4350.html
2. Zdzisław Bieńkowski „Poradnik ultrakrólkofalowca” 1988.
3. https://www.analog.com/media/en/technical-documentation/data-sheets/adf4350.pdf