

RF building blocks for the 868 MHz ISM band in XB06 Technology



Objective

The 0.6 μm -BiCMOS-technology XB06 is suitable for the design of radio frequency ASICs for operating frequencies up to 1 GHz. The XB06 design kit (TheKit) contains ad hoc RF passive devices like inductors, varactors and MIM-capacitors and in addition RF optimized bipolar transistors.

To enable the entrance into the design of RF ASICs, a library containing typical RF building blocks was created. The RF building blocks are fully characterized by measurements, so that the accuracy of the simulation models is demonstrated and confirmed.

Customers can then start their own RF developments on a library of reliable, characterized RF building blocks.

Global settings

To allow a broad range of applications, the RF building blocks are functional in a wide supply voltage range from 2.5 V to 5.5 V. They are intended for a temperature range from -40°C up to 85°C . The European ISM band around 868 MHz was chosen as operating frequency range.

Cells:

BIAS

BIAS is a bias cell intended for use with the various RF building blocks. It is based on a bandgap reference and voltage-to-current converters. Current biasing is preferable because of the higher immunity to interferers. Reference currents with different temperature characteristics are available. I_{CONST} is a low-TC current and I_{POLYH} shows a PTAT-like temperature behavior. The I_{POLYH} current results from a voltage-to-current conversion by means of a RPOLYH resistor, which leads to a constant voltage drop in resistor (RPOLYH) loaded CML-circuits.

	V_{BG} [V]	I_{CONST} [μA]	I_{POLYH} [μA]	I_{CC} [mA]	A_{Si} [mm^2]
nominal value	1.25	10	10	0.25	0.14
TC [ppm/ $^{\circ}\text{C}$]	80 ($-40\dots 30^{\circ}\text{C}$) 32 ($30\dots 85^{\circ}\text{C}$)	200 ($-40\dots 85^{\circ}\text{C}$)	3600 ($-40\dots 85^{\circ}\text{C}$)	-	-

Tab. 1: selected parameters of BIAS

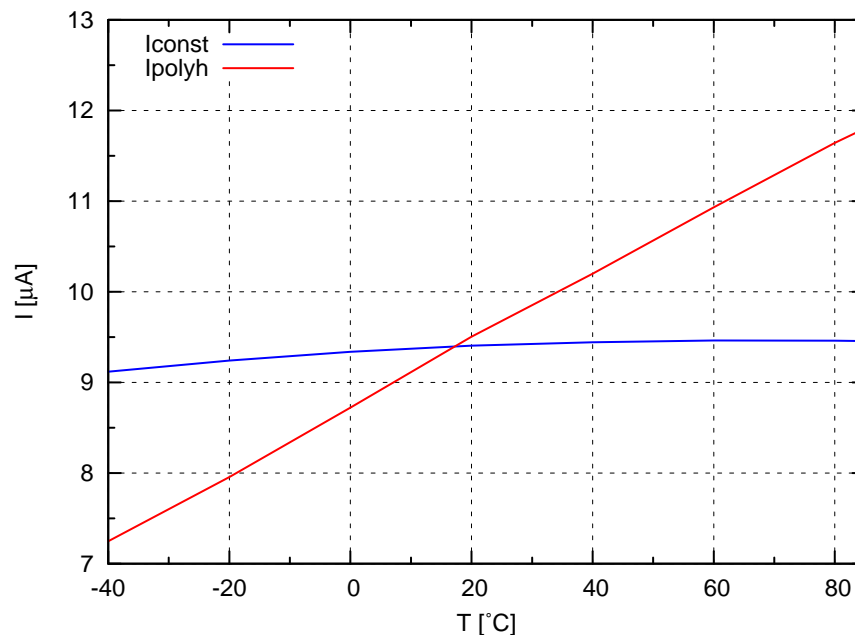


Fig. 1: bias currents vs. temperature available from BIAS

LC-VCOs

Two fully integrated inductor-capacitor-based-VCOs (LC-VCO) are available. Both LC-VCOs are based on a cross-coupled bipolar transistor pair. Additionally LCVCO2 contains AC-coupled varactors and a special circuit technique for maintaining the DC operating point. LCVCO3 contains direct coupled varactors leading to a larger tuning range but with a minimum permitted tuning voltage of 0.5 V.

	f_{VCO} @ $V_{tune}=0.5V$ [MHz]	f_{VCO} @ $V_{tune}=1.5V$ [MHz]	f_{VCO} @ $V_{tune}=2.5V$ [MHz]	Phase noise @ $\Delta f=1MHz$ [dBc/Hz]	I_{CC} [mA]	A_{Si} [mm ²]
LCVCO2	805	865	908	-113	1.27	0.39
LCVCO3	743	882	963	-113	1.10	0.34

Tab. 2: selected parameters of LC-VCOs

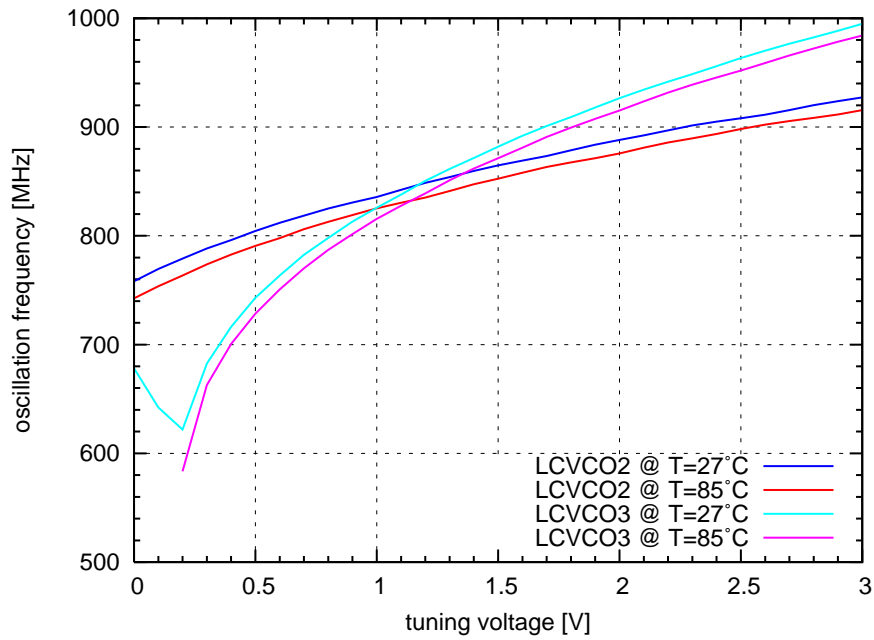


Fig. 2: tuning characteristics of LC-VCOs

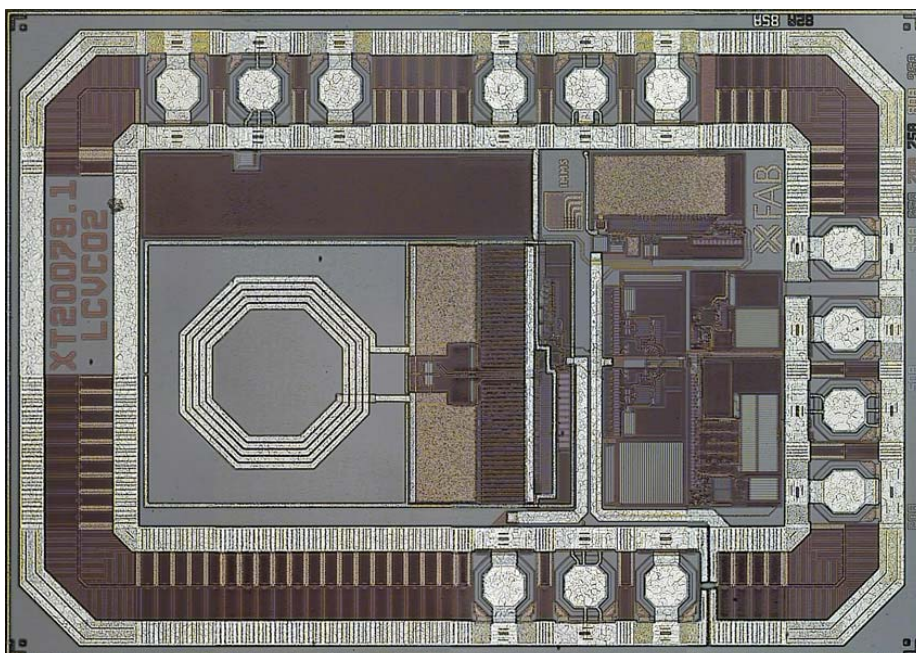


Fig. 3: chip photo of LCVCO2 (test IC)

RINGVCO1

RINGVCO1 is a fully integrated VCO that consists of a ring-oscillator that is tuned by switching the delay chain between 2 and 4 delay stages. The transition in this range is continuous.

	f_{VCO} @ $V_{tune}=0.5V$ [MHz]	f_{VCO} @ $V_{tune}=1.4V$ [MHz]	f_{VCO} @ $V_{tune}=2.5V$ [MHz]	Phase noise @ $\Delta f=1MHz$ [dBc/Hz]	I_{CC} [mA]	A_{Si} [mm ²]
RINGVCO1	636	841	1146	-90	1.74	0.08

Tab. 3: selected parameters of RINGVCO1

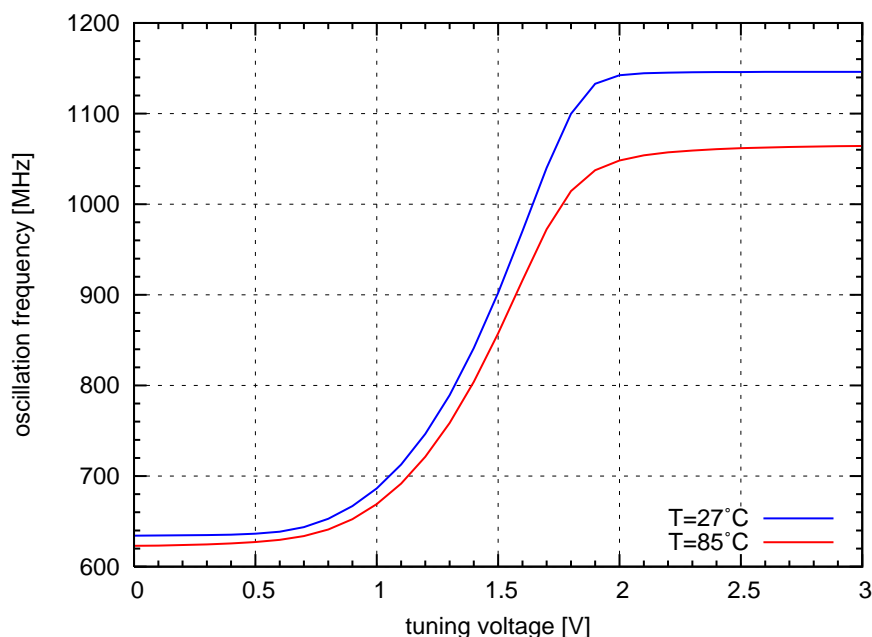


Fig. 4: tuning characteristic of RINGVCO1

DIV32

DIV32 is a Prescaler with a fixed divider ratio of 32. It consists of asynchronous connected D-Flip-flops realized in bipolar CML-Logic.

	N (divider ratio)	f_{max} (max. divisible input frequency) [MHz]	I_{CC} [mA]	A_{Si} [mm ²]
DIV32	32	1700	1.0	0.04

Tab. 4: selected parameters of DIV32

LNAs

Three Low-Noise-Amplifiers (LNAs) are available.

LNA1 is a fully integrated LNA based on an emitter stage with feedback resistor between base and collector to achieve both input and output matching. If mounted in a package with reasonably short leads and bond wires, LNA1 is already quite good matched to 50 Ω at both input and output and does not need any external matching circuitry.

LNA2 is based on a bipolar cascode configuration with an on-chip load resistor of 50 Ω . Thus, the output is quite good matched to 50 Ω , but the input needs external components for better matching.

LNA3 is also based on a bipolar cascode configuration with an on-chip LC-tank to compensate for the parasitic capacitors at the output node. This allows a higher gain compared to resistively loaded LNAs with additionally reduced current consumption. The output is quite good matched to 50 Ω but only in the vicinity of 868 MHz. For good input matching external components are required.

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	NF [dB]	G _P [dB]	ICP _{1dB} [dBm]	IIP ₃ [dBm]	I _{CC} [mA]	A _{Si} [mm ²]
LNA1	3.1	12	-17	-3	4.6	0.05
LNA2	2.3	14	-19	-5	7.9	0.08
LNA3	2.2	15	-19	-5	2.5	0.25

Tab. 5: selected parameters of LNAs

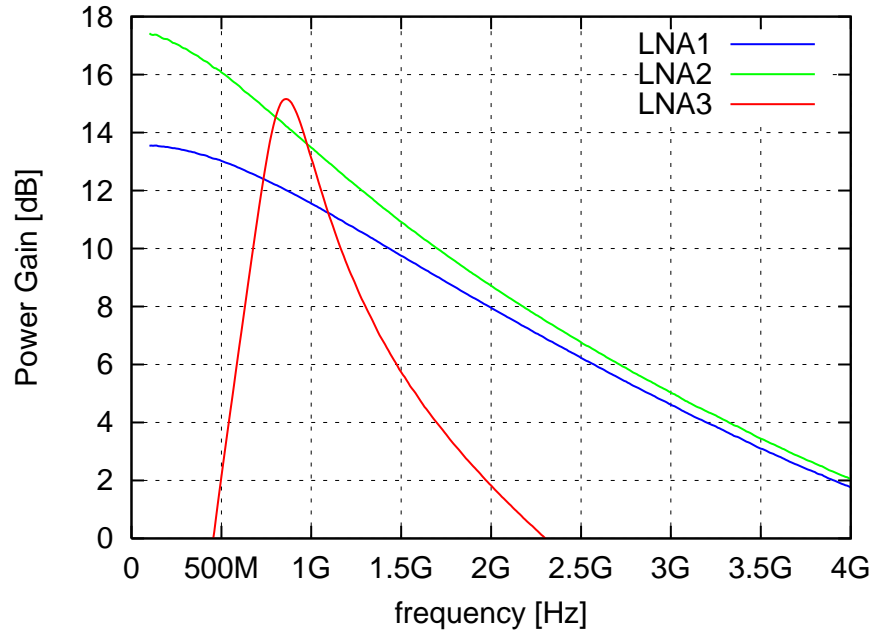


Fig. 5: Power Gain vs. frequency of LNAs

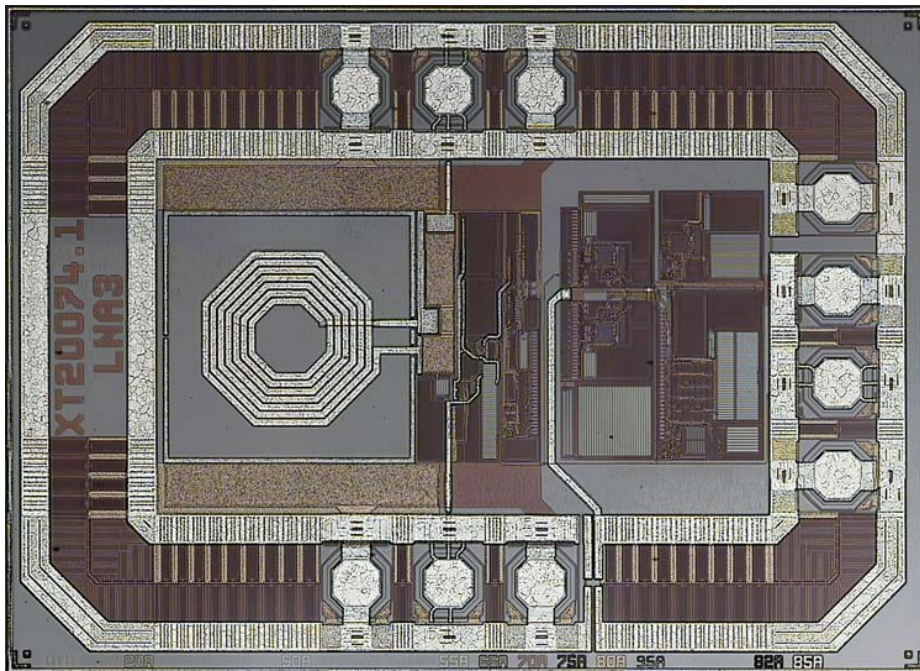


Fig. 6: chip photo of LNA3 (test IC)

MIXER

MIXER is a down conversion mixer based on a Gilbert cell topology. It has a single-ended 50 Ω small signal input impedance to allow the connection to a preceding LNA with 50 Ω output impedance. The MIXER output is also single-ended and can be easily matched to a standard 10.7 MHz-IF-filter for example, but the IF can also be somewhat between 1 and 70 MHz. The input frequency can be in the range of 800 MHz and 1 GHz.

	f_{IF} [MHz]	NF [dB]	VCG [dB]	ICP_{1dB} [dBm]	IIP_3 [dBm]	I_{CC} [mA]	A_{Si} [mm ²]
MIXER	1..70	14.8	11.0	-23.3	-15.1	2.2	0.06

Tab. 6: selected parameters of MIXER

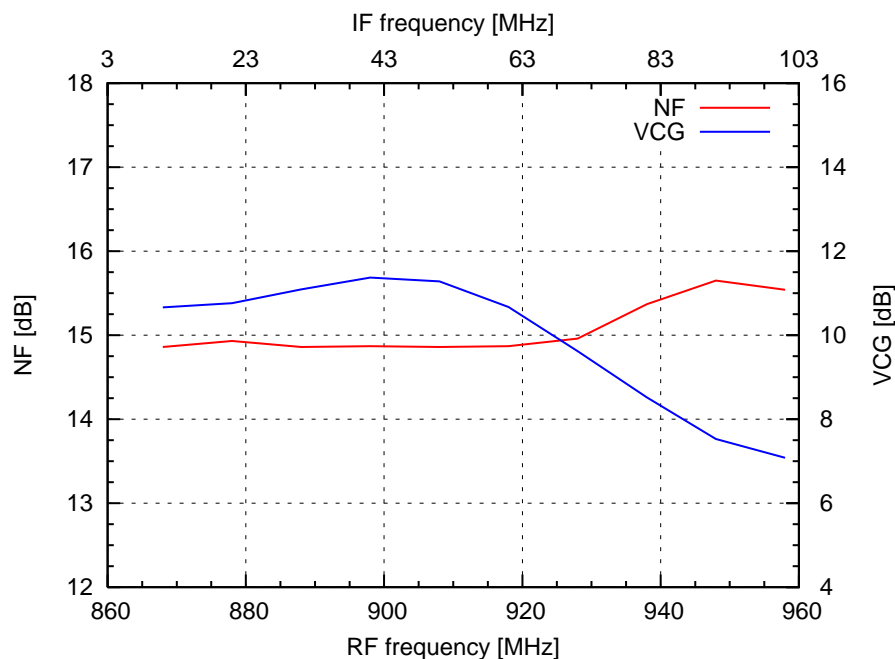


Fig. 7: Noise Figure and Voltage Conversion Gain of MIXER ($V_{CC}=3$ V, $T=27^{\circ}C$, $f_{LO}=853$ MHz)

PA

PA is a non-linear Power Amplifier that is intended for the transmission of ASK and FSK signals. Its output power level can be digitally controlled in 4 steps. The input frequency can be in the range of 800 MHz and 1 GHz.

	f_{RF} [MHz]	Power step	P_{out} [dBm]	I_{CC} [mA]	A_{Si} [mm ²]
PA	800..1000	1	-7.9	2.3	0.16
		2	-1.8	3.9	
		3	4.4	7.5	
		4	11.6	19.8	

Tab. 7: selected parameters of PA

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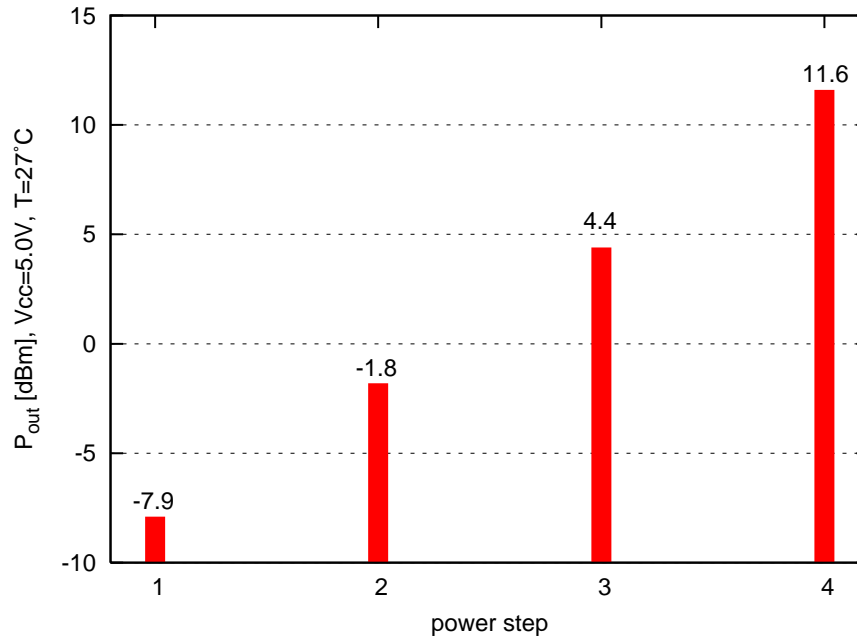


Fig. 8: Output power of PA at different power steps ($V_{CC}=5$ V, $T=27^{\circ}\text{C}$, $f_{RF}=868$ MHz)

Application notes

general:

- The single cells do not contain power rails, hence the Pins VCC and VEE shall be connected at the intended locations respectively. Power nets should be adopted in a star routing topology.
- The supply nets should be adequately buffered with on-chip capacitors to suppress distortions injected to the supply nets, that can finally degrade the performance of sensible RF circuits.
- Supply nets shall also have an impedance as low as possible to avoid unwanted voltage drops.
- RF inputs and outputs should be connected as close as possible to the intended pads in order to avoid large parasitic capacitors and inductances.
- The usage of X-FAB's own RF-PAD library is recommended.
- RF suitable packages have to be used solely. This means that the packages shall have short leads and bond wires.
- Concerning the application of RF circuits on PCBs, a careful board layout is always necessary. Impedance controlled PCBs should be used that have an extra ground layer. The applied external elements should have reasonably high Q-factors to guaranty good RF behavior of the complete circuit.

regarding VCOs:

- The tuning input is very sensitive regarding the phase noise performance of a VCO. Therefore, this input should be carefully connected to the PLL loop filter circuitry. When an external loop filter is used, the tuning input should be located as close as possible to its pad. Other disturbing signals should not cross or placed in the vicinity of the tuning input signal path.

regarding LNAs:

- When implementing a RF circuit containing a LNA, it is very important to have enough internal buffer capacitance, at least 200pF. This is important to prevent degradation of the noise performance by supply injected interferences.

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regarding MIXER:

- The RF input of the Mixer is internal biased to exhibit a small signal input impedance of approx. 50Ω . This input has to be AC-coupled to the output of the previous LNA. If the connection between LNA output and MIXER RF input is completely located on-chip, it should be as short as possible to minimize effects of parasitic RLC elements and substrate coupling. If an external filter is used between LNA output and MIXER RF input, the connections to the corresponding pads should also be as short as possible with additional shielding mechanism used.

regarding PA:

- The output circuitry of the PA works as a current sink. So an external tank connected between the output pin of the PA and the positive supply voltage V_{CC} (on application board) is needed to generate the RF amplitude. A preferred tank circuit configuration would be the tapped capacitor configuration that allows for two important aspects:
 - AC-coupling of the output signal from the tank towards the antenna
 - transformation of the antenna impedance to the optimum load impedance for the PA outputAdditional low-pass filter function should be implemented to further attenuate spurious harmonics of the PA. This is important to achieve the required transmit specification in the European ISM band at 868 MHz for instance.
- The values of the external elements strongly depend on the used package and application board, because package and board parasitics influence the output impedance of the PA.