M2 Integration Circuits Systems

EA2 - Année Scolaire 2017-2018 (S1)

Exam

Durée 1h30 - Authorized documents and calculator

Exercises

Tous les exercices sont indépendants.

Direction de la Formation Initiale
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Exercise 1: From standard DCS1800 to receiver specifications

Frequency bands for DCS1800 standard are the following:

- ✓ uplink (mobile towards base station) : 1710 - 1785 MHz
- ✓ downlink (base station towards mobile) : 1805 – 1880 MHz

The inter channel spacing is 200 kHz. Main specifications are given in Table 1.

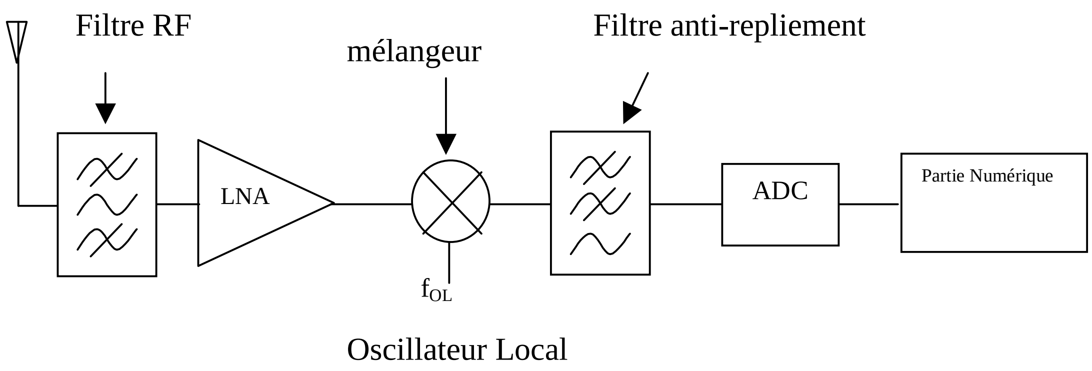
Modulation type	GMSK
Transmit band	1710 – 1785 MHz
Receive band	1805 – 1880 MHz
Channel bandwidth	200 KHz
Reference sensitivity level	-102 dBm
BER	10^{-3} → SNRmin = 7dB

Table I: Main specifications of DCS1800 standard

From these data, determine:

Q1.1 – The thermal noise power, at ambient temperature (T=300K) in the channel at the receiving antenna. (Boltzmann constant k = 1,38 10^{-23} J/K)

Q2.2 – The maximal Noise Figure (NF) allowed for the receiver.



The above schematic shows the receiver architecture. At the antenna, the highest interferer level in the useful band is –26dBm. The technology used for the LNA design limits the LNA maximum output power to –10dBm and leads to a LNA NF of 6 dB.

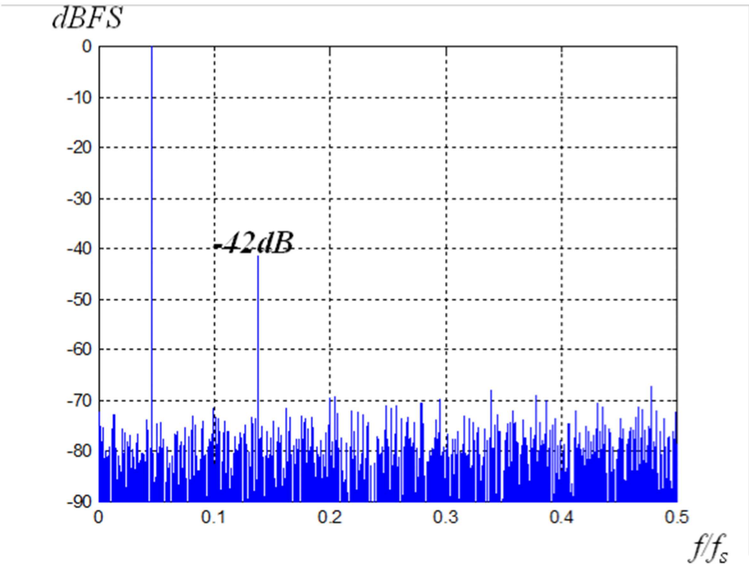
Q2.3 – To avoid saturation of the LNA, what is its gain maximum value?

We assume that the gain is set to this value for the following.

Q2.4 – Assuming RF filter is not degrading NF and after the mixer, the NF degradation is negligible, calculate the maximal NF allowed for the mixer.

Exercise 2: ADC spectral testing

Shown below is a 4096 point FFT of the output of a 9-bit A/D converter for full scale sinusoidal input.



Q2.1 – What is the SFDR of the ADC?

The FFT plot only shows fundamental and 3rd harmonic tones. It is therefore plausible to assume that main source of nonlinearity is 3rd order distortion:

$$v_{out} = a_1 v_{in} + a_3 v_{in}^3$$

Infinite number of ADC bits is assumed in above transfer characteristic for simple calculation. With a single-tone input,

$$v_{in} = 1/2\ V_{FS} \sin(\omega t)$$

Given that the amplitude of the 3rd harmonic is 42dB below that of the fundamental

Q2.2 – Express a_3 in function of a_1 and V_{FS}.

You should use the following formula: $sin3a = 3sina - 4sin^3 a$

And in order to simplify, we will suppose that $a_1 V_{FS}/2 >> 3\, a_3 V_{FS}^3/32$

Q2.3 – Calculate the end points of the out/in transfer function (v_{out} at -$V_{FS}/2$ and at $V_{FS}/2$)

Q2.4 – Calculate the FS linear gain value and conclude that the linearized transfer function is given by the following equation:

$$v'_{out} = 1.032\, a_1\, v_{in}$$

Q2.5 – Compute the $|INL|_{max}$ of the converter in LSBs.

Note that: the definition of INL requires that the offset and gain errors of the ADC are corrected before ie offset = 0 and linear gain = 1. Then find the expression of v_{outcor} before computing $|INL|_{max}$

v_{outcor} (-$V_{FS}/2$) = -$V_{FS}/2$, v_{outcor} (0) = 0, $v_{outcor}(V_{FS}/2)$ = $V_{FS}/2$

For ease of computation, you can assume the transfer function has infinite number of steps.

Q2.6 –Use the rule of thumb expression for SFDR versus INL :

$SFDR = 20\ log\left(\frac{2^B}{INL/_{LSB}}\right)$ where B is the number of bits of the ADC.

Assuming $INL = 3.1LSB$, calculate an approximate value for SFDR, compare the result with the more accurate one you found in Q2.1.

Q2.7 – Calculate the total quantization noise amplitude of a 9-bit ADC in dBFS

Q2.8 – Given 4096 FFT points, quantization noise floor on the spectrum plot should be 33.11 dB lower than quantization noise amplitude (10log10(4096/2) = 33.11). Since this is the spectrum for a real ADC with both quantization noise and circuit generated noise (assume that the actual FFT shows noise floor of about -80dBFS), the difference is then contributed by circuit noise, which can be assumed uncorrelated with quantization noise.

Compute the approximate noise contribution by the circuit in dBFS

Q2.9 – Find the ENOB for this ADC based on SNR only.

Q2.10 – Find the ENOB for this ADC based on SNDR.