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ASK/FSK Single Conversion Receiver

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preliminary



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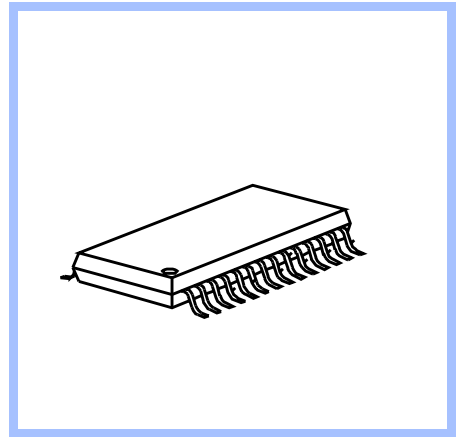
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Product Info

General Description

The IC is a very low power consumption single chip FSK/ASK Superheterodyne Receiver (SHR) for the frequency bands 810 to 870 MHz and 400 to 440 MHz. The IC offers a high level of integration and needs only a few external components. The device contains a low noise amplifier (LNA), a double balanced mixer, a fully integrated VCO, a PLL synthesiser, a crystal oscillator, a limiter with RSSI generator, a PLL FSK demodulator, a data filter, a data comparator (slicer) and a peak detector. Additionally there is a power down feature to save battery life.

Package



Features

- Low supply current (typ. at 868MHz
 $I_s = 5.9\text{mA}$ in FSK mode,
 $I_s = 5.2\text{mA}$ in ASK mode)
- Supply voltage range $5\text{V} \pm 10\%$
- Power down mode with very low supply current (50nA typ)
- FSK and ASK demodulation capability
- Fully integrated VCO and PLL Synthesiser
- ASK sensitivity $< -107\text{dBm}$
- Selectable frequency ranges 810-870 MHz and 400-440 MHz
- Limiter with RSSI generation, operating at 10.7MHz
- Selectable reference frequency
- 2nd order low pass data filter with external capacitors
- Data slicer with self-adjusting threshold
- FSK sensitivity $< -100\text{dBm}$

Application

- Keyless Entry Systems
- Remote Control Systems
- Alarm Systems
- Low Bitrate Communication Systems

Ordering Information

Type	Ordering Code	Package
TDA 5220		P-TSSOP-28-1
samples available on tape and reel		

2 Product Description

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2.1 Overview

The IC is a very low power consumption single chip FSK/ASK Superheterodyne Receiver (SHR) for the frequency bands 810 to 870 MHz and 400 to 440 MHz. The IC offers a high level of integration and needs only a few external components. The device contains a low noise amplifier (LNA), a double balanced mixer, a fully integrated VCO, a PLL synthesiser, a crystal oscillator, a limiter with RSSI generator, a PLL FSK demodulator, a data filter, a data comparator (slicer) and a peak detector. Additionally there is a power down feature to save battery life.

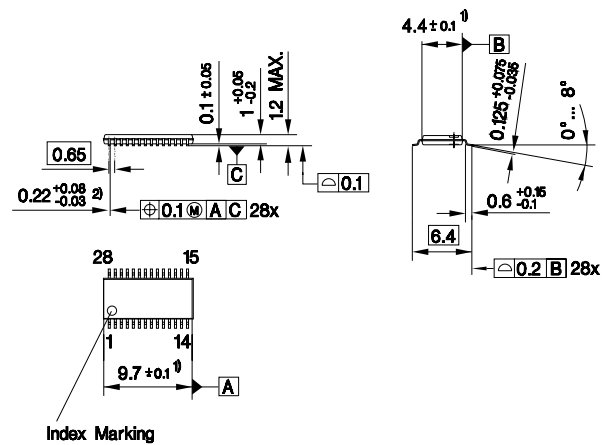
2.2 Application

- Keyless Entry Systems
- Remote Control Systems
- Alarm Systems
- Low Bitrate Communication Systems

2.3 Features

- Low supply current (at 868MHz $I_s = 5.9$ mA typ. FSK mode, 5.2mA typ. ASK mode)
- Supply voltage range 5V $\pm 10\%$
- Power down mode with very low supply current (50nA typ)
- FSK and ASK demodulation capability
- Fully integrated VCO and PLL Synthesiser
- RF input sensitivity ASK < -107 dBm
- RF input sensitivity FSK < -100 dBm
- Selectable frequency ranges 810-870 MHz and 400-440 MHz
- Selectable reference frequency
- Limiter with RSSI generation, operating at 10.7MHz
- 2nd order low pass data filter with external capacitors
- Data slicer with self-adjusting threshold

2.4 Package Outlines



P_TSSOP_28.EPS

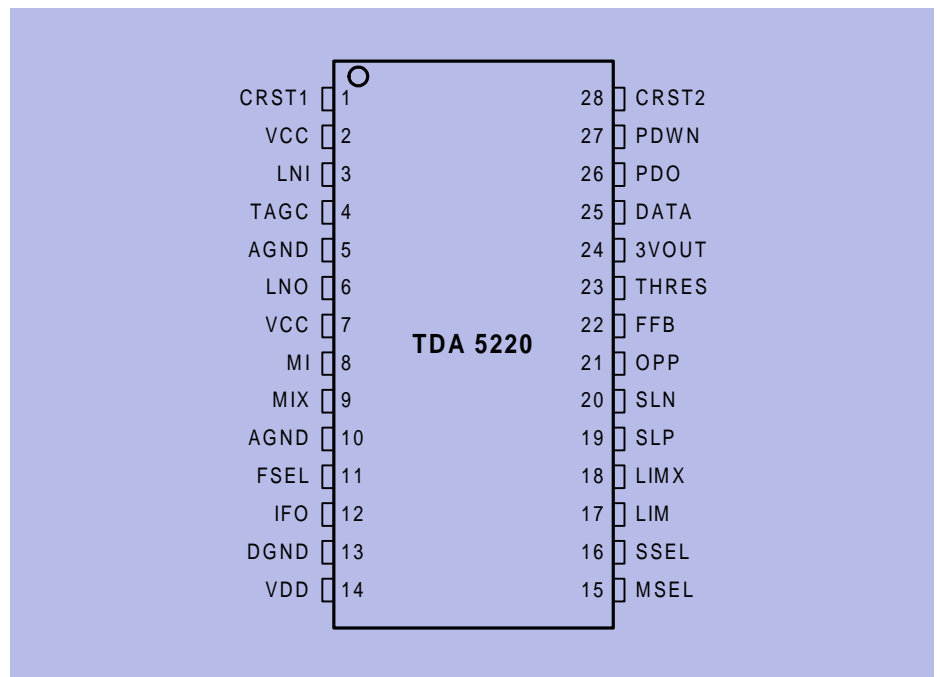
Figure 2-1 P-TSSOP-28-1 package outlines

3 Functional Description

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3.1 Pin Configuration



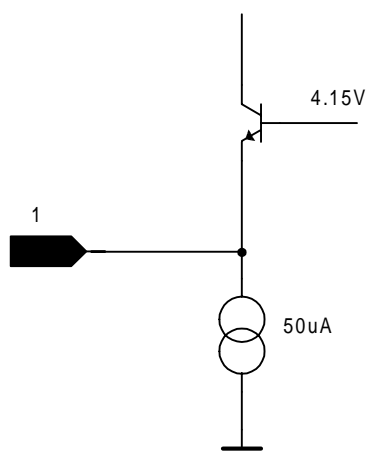
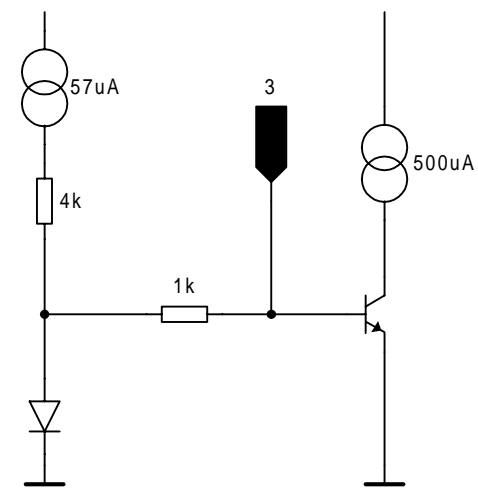
Pin_Configuration_5220.wmf

Figure 3-1 IC Pin Configuration

3.2 Pin Definition and Function

In the subsequent table the internal circuits connected to the pins of the device are shown. ESD-protection circuits are omitted to ease reading.

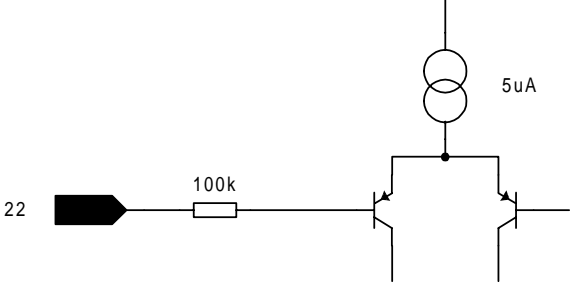
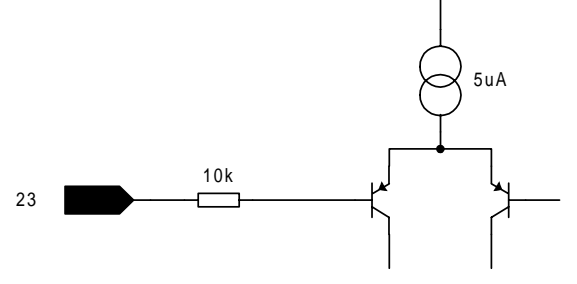
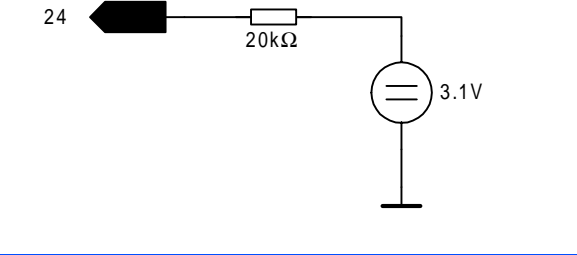
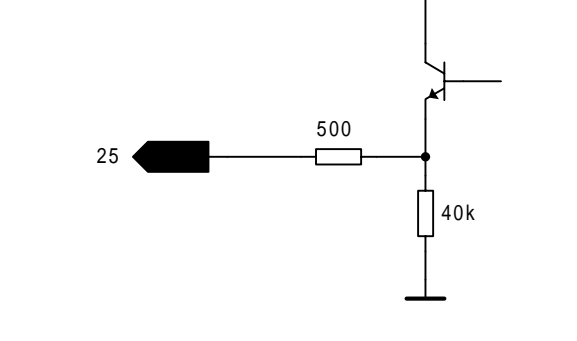
Table 3-1 Pin Definition and Function

Pin No.	Symbol	Equivalent I/O-Schematic	Function
1	CRST1		External Crystal Connector 1
2	VCC		5V Supply
3	LNI		LNA Input

4	TAGC		AGC Time Constant Control
5	AGND		Analogue Ground Return
6	LNO		LNA Output
7	VCC		5V Supply
8	MI		Mixer Input
9	MIX		Complementary Mixer Input
10	AGND		Analogue Ground Return

11	FSEL		868/434 MHz Operating Frequency Selector
12	IFO		10.7 MHz IF Mixer Output
13	DGND		Digital Ground Return
14	VDD		5V Supply (PLL Counter Circuitry)
15	MSEL		ASK/FSK Modulation Format Selector
16	SSEL		Data-Slicer Reference-Level Selector

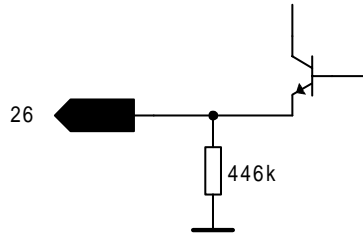
<p>17 18</p>	<p>LIM LIMX</p>		<p>Limiter Input Complementary Limiter Input</p>
<p>19</p>	<p>SLP</p>		<p>Data Slicer Positive Input</p>
<p>20</p>	<p>SLN</p>		<p>Data Slicer Negative Input</p>
<p>21</p>	<p>OPP</p>		<p>OpAmp Noninverting Input</p>

<p>22</p> <p>FFB</p>		<p>Data Filter Feedback Pin</p>
<p>23</p> <p>THRES</p>		<p>AGC Threshold Input</p>
<p>24</p> <p>3VOUT</p>		<p>3V Reference Output</p>
<p>25</p> <p>DATA</p>		<p>Data Output</p>

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PDO

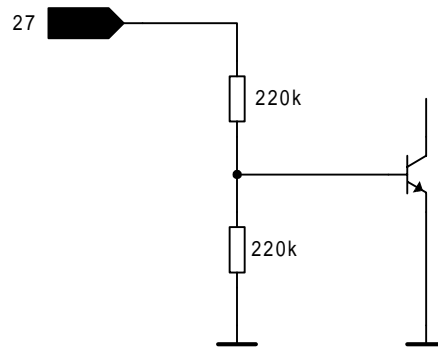
Peak Detector Output



27

PDWN

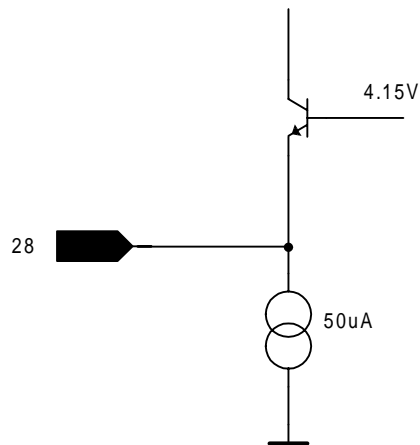
Power Down Input



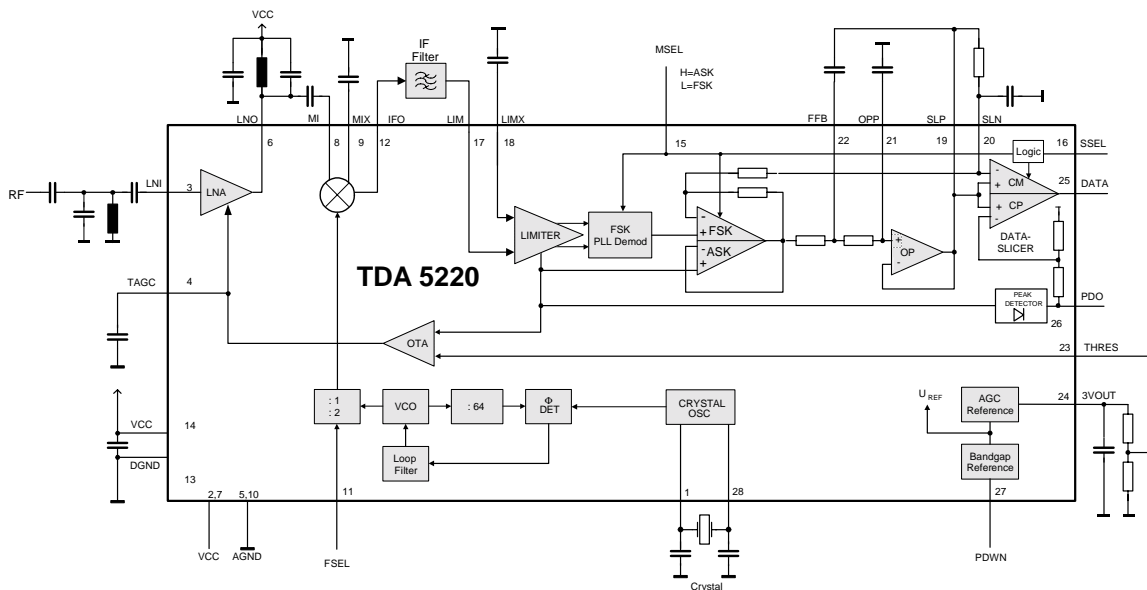
28

CRST2

External Crystal Connector 2



3.3 Functional Block Diagram



Function_5220.wmf

Figure 3-2 Main Block Diagram

3.4 Functional Blocks

3.4.1 Low Noise Amplifier (LNA)

The LNA is an on-chip cascode amplifier with a voltage gain of 15 to 20dB. The gain figure is determined by the external matching networks situated ahead of the LNA and between the LNA output **LNO** (Pin 6) and the Mixer Inputs **MI** and **MIX** (Pins 8 and 9). The noise figure of the LNA is approximately 3dB and the current consumption is 500µA. The gain can be reduced by approximately 18dB. The switching point of this AGC action can be determined externally by applying a threshold voltage at the **THRES** pin (Pin 23). This voltage is compared internally with the received signal (RSSI) level generated by the limiter circuitry. In case that the RSSI level is higher than the threshold voltage the LNA gain is reduced and vice versa. The threshold voltage can be generated by attaching a voltage divider between the **3VOUT** pin (Pin 24) which provides a temperature stable 3V output generated from the internal bandgap voltage and the **THRES** pin as described in Section 4.1. The time constant of the AGC action can be determined by connecting a capacitor to the **TAGC** pin (Pin 4) and should be chosen along with the appropriate threshold voltage according to the

intended operating case and interference scenario to be expected during operation. The optimum choice of AGC time constant and the threshold voltage is described in Section 4.1.

3.4.2 Mixer

The Double Balanced Mixer downconverts the input frequency (RF) in the range of 400-440MHz/810-870MHz to the intermediate frequency (IF) at 10.7MHz with a voltage gain of approximately 21dB by utilising either high- or low-side injection of the local oscillator signal. In case the mixer is interfaced only single-ended, the unused mixer input has to be tied to ground via a capacitor. The mixer is followed by a low pass filter with a corner frequency of 20MHz in order to suppress RF signals to appear at the IF output (**IFO** pin). The IF output is internally consisting of an emitter follower that has a source impedance of approximately 330 Ω to facilitate interfacing the pin directly to a standard 10.7MHz ceramic filter without additional matching circuitry.

3.4.3 PLL Synthesizer

The Phase Locked Loop synthesiser consists of a VCO, an asynchronous divider chain, a phase detector with charge pump and a loop filter and is fully implemented on-chip. The VCO is including on-chip spiral inductors and varactor diodes. It's nominal centre frequency is 840MHz, the operating range guaranteed over the temperature range specified is 820 to 860MHz. Depending on whether high- or low-side injection of the local oscillator is used the receive frequency ranges are 810 to 840 and 840 to 870MHz or 400 to 420 and 420 to 440MHz (see also Section 4.4). No additional external components are necessary.

The oscillator signal is fed both to the synthesiser divider chain and to the down-converting mixer. In case of operation in the 400 to 440 MHz range, the signal is divided by two before it is fed to the mixer. This is controlled by the selection pin **FSEL** (Pin 11) as described in the following table. The overall division ratio of the divider chain is 64. The loop filter is also realised fully on-chip.

Table 3-2 FSEL Pin Operating States	
FSEL	RF Frequency
Open	400-440 MHz
Shorted to ground	810-870 MHz

3.4.4 Crystal Oscillator

The calculation of the value of the necessary quartz load capacitance is shown in Section 4.3, the quartz frequency calculation is explained in Section 4.4.

3.4.5 Limiter

The Limiter is an AC coupled multistage amplifier with a cumulative gain of approximately 80 dB that has a bandpass-characteristic centred around 10.7 MHz. It has a typical input impedance of 330 Ω to allow for easy interfacing to a 10.7 MHz ceramic IF filter. The limiter circuit also acts as a Receive Signal Strength Indicator (RSSI) generator which produces a DC voltage that is directly proportional to the input signal level as can be seen in Figure 4-2. This signal is used to demodulate ASK-modulated receive signals in the subsequent baseband circuitry. The RSSI output is applied to the modulation format switch, to the Peak Detector input and to the AGC circuitry.

In order to demodulate ASK signals the MSEL pin has to in its 'High'-state as described in the next chapter.

3.4.6 FSK Demodulator

To demodulate frequency shift keyed (FSK) signals a PLL circuit is used that is contained fully on chip. The Limiter output differential signal is fed to the linear phase detector as is the output of the 10.7 MHz center frequency VCO. The demodulator gain is typically 180 μ V/kHz. The passive loop filter output that is comprised fully on chip is fed to both the VCO and the modulation format switch described in more detail below. This signal is representing the demodulated signal with high IF-frequencies applied to the demodulator demodulated to logic ones and low IF-frequencies demodulated to logic zeroes. Please note that due to this behaviour a sign inversion of the data occurs in case of high-side injection of the local oscillator at receive frequencies below 840 or 420MHz, respectively. See also .

The modulation format switch is actually a switchable amplifier with an AC gain of 11 that is controlled by the **MSEL** pin (Pin 15) as shown in the following table. This gain was chosen to facilitate detection in the subsequent circuits. The DC gain is 1 in order not to saturate the subsequent Data Filter with the DC offset produced by the demodulator in case of large frequency offsets of the IF signal. The resulting frequency characteristic and details on the principle of operation of the switch are described in Section 4.6.

MSEL	Modulation Format
High	ASK
Low	FSK

The demodulator circuit is switched off in case of reception of ASK signals.

3.4.7 Data Filter

The data filter comprises an OP-Amp with a bandwidth of 100kHz used as a voltage follower and two 100kΩ on-chip resistors. Along with two external capacitors a 2nd order Sallen-Key low pass filter is formed. The selection of the capacitor values is described in Section 4.2.

3.4.8 Data Slicer

The data slicer is a fast comparator with a bandwidth of 100 kHz. This allows for a maximum receive data rate of up to 100kBaud. The maximum achievable data rate also depends on the IF Filter bandwidth and the local oscillator tolerance values. Both inputs are accessible. The output delivers a digital data signal (CMOS-like levels) for subsequent circuits. A self-adjusting slicer-threshold on pin 20 its generated by a RC-term. In ASK-mode alternatively a scaled value of the voltage at the PDO-output (approx. 87%) can be used as the slicer-threshold. The data slicer threshold generation alternatives are described in more detail in Section 4.5.

3.4.9 Peak Detector

The peak detector generates a DC voltage which is proportional to the peak value of the receive data signal. A capacitor is necessary. The input is connected to the output of the RSSI-output of the Limiter, the output is connected to the **PDO** pin (Pin 26). This output can be used as an indicator for the received signal strength to use in wake-up circuits and as a reference for the data slicer in ASK mode. Note that the RSSI level is also output in case of FSK mode.

3.4.10 Bandgap Reference Circuitry

A Bandgap Reference Circuit provides a temperature stable reference voltage for the device. A power down mode is available to switch off all subcircuits which is controlled by the PWDN pin (Pin 27) as shown in the following table. The supply current drawn in this case is typically 50nA.

Table 3-4 PWDN Pin Operating States	
PWDN	Operating State
Open or tied to ground	Powerdown Mode
Tied to Vs	Receiver On

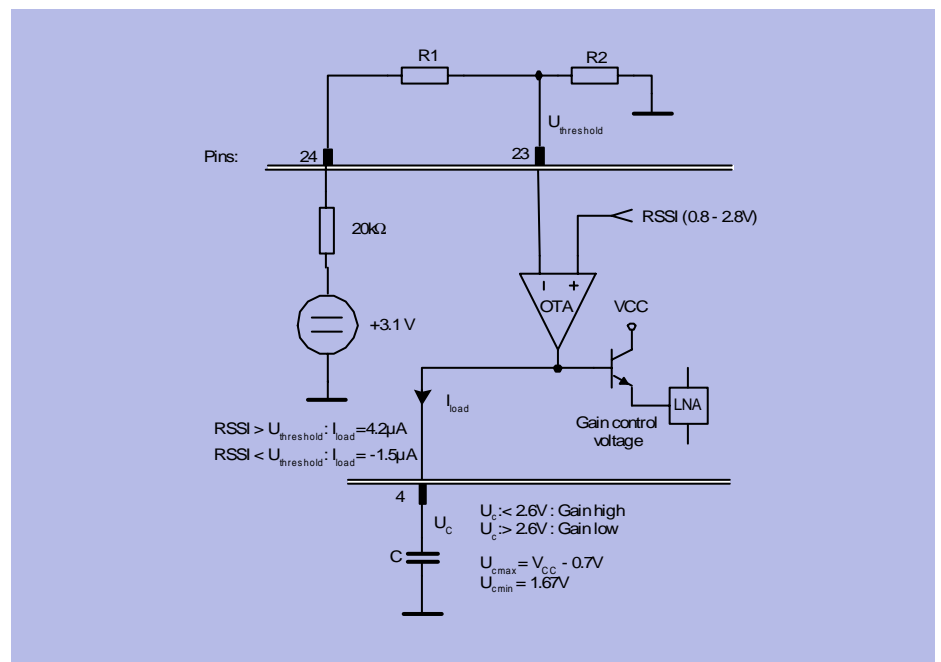
4 Applications

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4.1 Choice of LNA Threshold Voltage and Time Constant

In the following figure the internal circuitry of the LNA automatic gain control is shown.

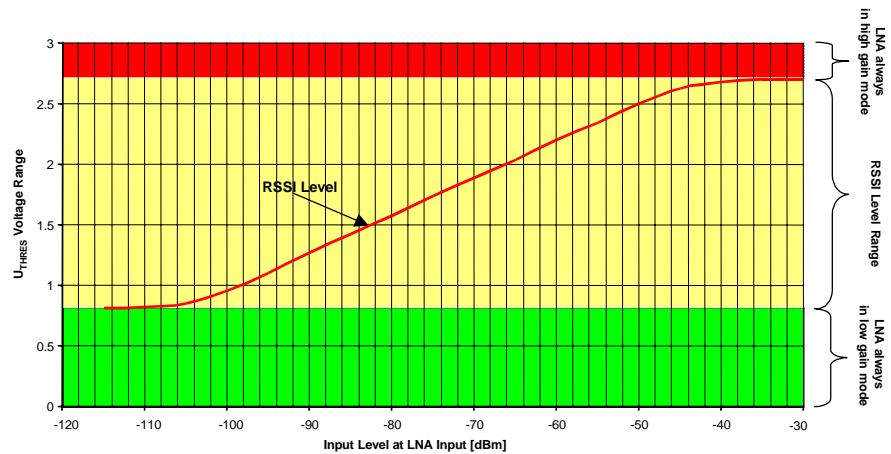


LNA_autom.wmf

Figure 4-1 LNA Automatic Gain Control Circuitry

The LNA automatic gain control circuitry consists of an operational transimpedance amplifier that is used to compare the received signal strength signal (RSSI) generated by the Limiter with an externally provided threshold voltage U_{thres} . As shown in the following figure the threshold voltage can have any value between approximately 0.8 and 2.8V to provide a switching point within the receive signal dynamic range.

This voltage U_{thres} is applied to the **THRES** pin (Pin 23). The threshold voltage can be generated by attaching a voltage divider between the **3VOUT** pin (Pin 24) which provides a temperature stable 3V output generated from the internal bandgap voltage and the **THRES** pin. If the RSSI level generated by the Limiter is higher than U_{thres} , the OTA generates a positive current I_{load} . This yields a voltage rise on the **TAGC** pin (Pin 4). Otherwise, the OTA generates a negative current. These currents do not have the same values in order to achieve a fast-attack and slow-release action of the AGC and are used to charge an external capacitor which finally generates the LNA gain control voltage.



RSSI-AGC.wmf

Figure 4-2 RSSI Level and Permissive AGC Threshold Levels

The switching point should be chosen according to the intended operating scenario. The determination of the optimum point is described in the accompanying Application Note, a threshold voltage level of 1.8V is apparently a viable choice. It should be noted that the output of the **3VOUT** pin is capable of driving up to 50 μ A, but that the **THRES** pin input current is only in the region of 40nA. As the current drawn out of the **3VOUT** pin is directly related to the receiver power consumption, the power divider resistors should have high impedance values. The sum of R1 and R2 has to be 600k Ω in order to yield 3V at the **3VOUT** pin. R1 can thus be chosen as 240k Ω , R2 as 360k Ω to yield an overall **3VOUT** output current of 5 μ A¹ and a threshold voltage of 1.8V

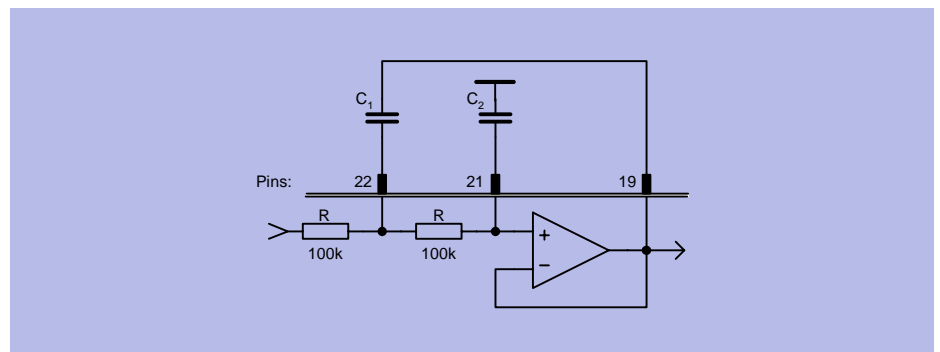
Note: If the LNA gain shall be kept in either high or low gain mode this has to be accomplished by tying the **THRES** pin to a fixed voltage. In order to achieve high gain mode operation, a voltage higher than 2.8V shall be applied to the **THRES** pin, such as a short to the **3VOLT** pin. In order to achieve low gain mode operation a voltage lower than 0.7V shall be applied to the **THRES**, such as a short to ground.

As stated above the capacitor connected to the **TAGC** pin is generating the gain control voltage of the LNA due to the charging and discharging currents of the OTA and thus is also responsible for the AGC time constant. As the charging and discharging currents are not equal two different time constants will result. The time constant corresponding to the charging process of the capacitor shall be chosen according to the data rate. According to measurements performed at Infineon the capacitor value should be greater than 47nF.

1. note the 20k Ω resistor in series with the 3.1V internal voltage source

4.2 Data Filter Design

Utilising the on-board voltage follower and the two 100kΩ on-chip resistors a 2nd order Sallen-Key low pass data filter can be constructed by adding 2 external capacitors between pins 19 (SLP) and 22 (FFB) and to pin 21 (OPP) as depicted in the following figure and described in the following formulas¹.



Filter_Design.wmf

Figure 4-3 Data Filter Design

(1)(2)

$$C_1 = \frac{2Q\sqrt{b}}{R2\Pi f_{3dB}} \quad C_2 = \frac{\sqrt{b}}{4QR\Pi f_{3dB}}$$

with

$$Q = \frac{\sqrt{b}}{a} \quad (3)\text{the quality factor of the poles}$$

where

in case of a Bessel filter $a = 1.3617$, $b = 0.618$

and thus $Q = 0.577$

and in case of a Butterworth filter $a = 1.414$, $b = 1$

and thus $Q = 0.71$

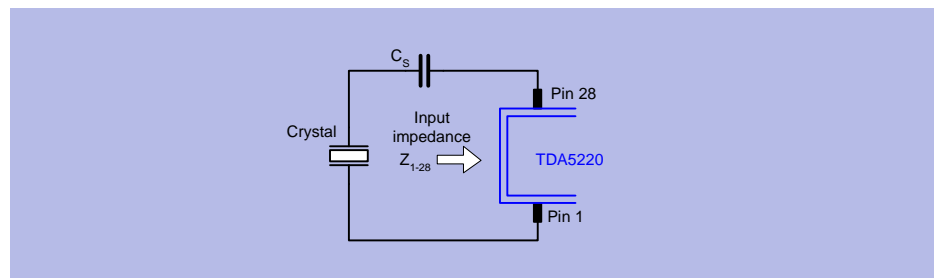
Example: Butterworth filter with $f_{3dB} = 5\text{kHz}$ and $R = 100\text{k}\Omega$:

$$C_1 = 450\text{pF}, C_2 = 225\text{pF}$$

1. taken from Tietze/Schenk: Halbleiterschaltungstechnik, Springer Berlin, 1999

4.3 Quartz Load Capacitance Calculation

The value of the capacitor necessary to achieve that the quartz oscillator is operating at the intended frequency is determined by the reactive part of the negative resistance of the oscillator circuit as shown in Section 5.1.3 and by the quartz specifications given by the quartz manufacturer.



Quartz_load.wmf

Figure 4-4 Determination of Series Capacitance Value for the Quartz Oscillator

Crystal specified with load capacitance

$$C_s = \frac{1}{\frac{1}{C_l} + 2\pi f X_L}$$

with C_l the load capacitance (refer to the quartz crystal specification).

Example:

13.4 MHz: $C_L = 12 \text{ pF}$, $X_L = 1010 \text{ } \Omega$, $C_S = 5.9 \text{ pF}$

This value may be obtained in high accuracy by putting two capacitors in series to the quartz, such as 22pF and 8.2pF for 13.4MHz.

4.4 Quartz Frequency Calculation

As described in Section 3.4.3 the operating range of the on-chip VCO is 820 to 860 MHz with a nominal center frequency of 840MHz. This signal is divided by 2 before applied to the mixer in case of operation at 434 MHz. This local oscillator signal can be used to downconvert the RF signals both with high- or low-side injection at the mixer. The resulting receive frequency ranges then extend between 810 and 870MHz or between 400 and 440MHz. Low-side injection of the local oscillator has to be used for receive frequencies between 840 and 870MHz as well as high-side injection for receive frequencies below 840MHz. Corresponding to that in the 400MHz region low-side injection is applicable for receive frequencies above 420MHz, high-side injection below this frequency. Therefore for operation both in the 868 and the 434 MHz ISM bands low-side injection of the local oscillator has to be used. Then the local oscillator frequency is calculated by subtracting the IF frequency (10.7 MHz) from the RF frequency (434 or 868 MHz). Please note that no sign-inversion occurs in case of reception and demodulation of FSK-modulated signals.

The overall division ratios in the PLL is 64 in case of operation at 868 MHz or 32 in case of operation at 434 MHz. The quartz frequency in case of low-side injection may be calculated by using the following formula:

$$f_{QU} = (f_{RF} - 10.7) / r$$

with f_{RF} receive frequency

f_{LO} local oscillator (PLL) frequency ($f_{RF} - 10.7$)

f_{QU} quartz oscillator frequency

r ratio of local oscillator (PLL) frequency and quartz frequency as shown in the subsequent table

Table 4-1 Dependence of PLL Overall Division Ratio on FSEL

FSEL	Ratio r = (f_{LO}/f_{QU})
open	32
GND	64

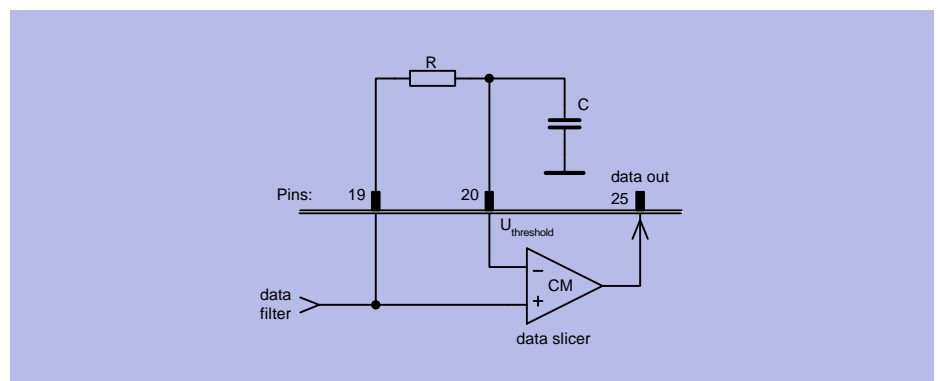
:

$$f_{QU} = (868.4MHz - 10.7MHz) / 64 = 13.40156MHz$$

$$f_{QU} = (434.2MHz - 10.7MHz) / 32 = 13.23437MHz$$

4.5 Data Slicer Threshold Generation

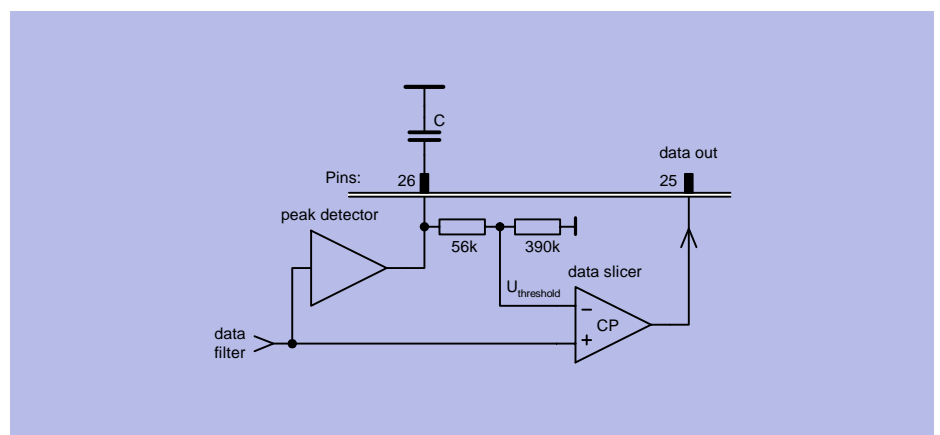
The threshold of the data slicer can be generated using an external R-C integrator as shown in Figure 4-5. The cut-off frequency of the R-C integrator has to be lower than the lowest frequency appearing in the data signal. In order to keep distortion low, the minimum value for R is 20kΩ.



Data_slice1.wmf

Figure 4-5 Data Slicer Threshold Generation with External R-C Integrator

In case of ASK operation another possibility for threshold generation is to use the peak detector in connection with an internal resistive divider and one capacitor as shown in the following figure. The component values are depending on the coding scheme and the protocol used.



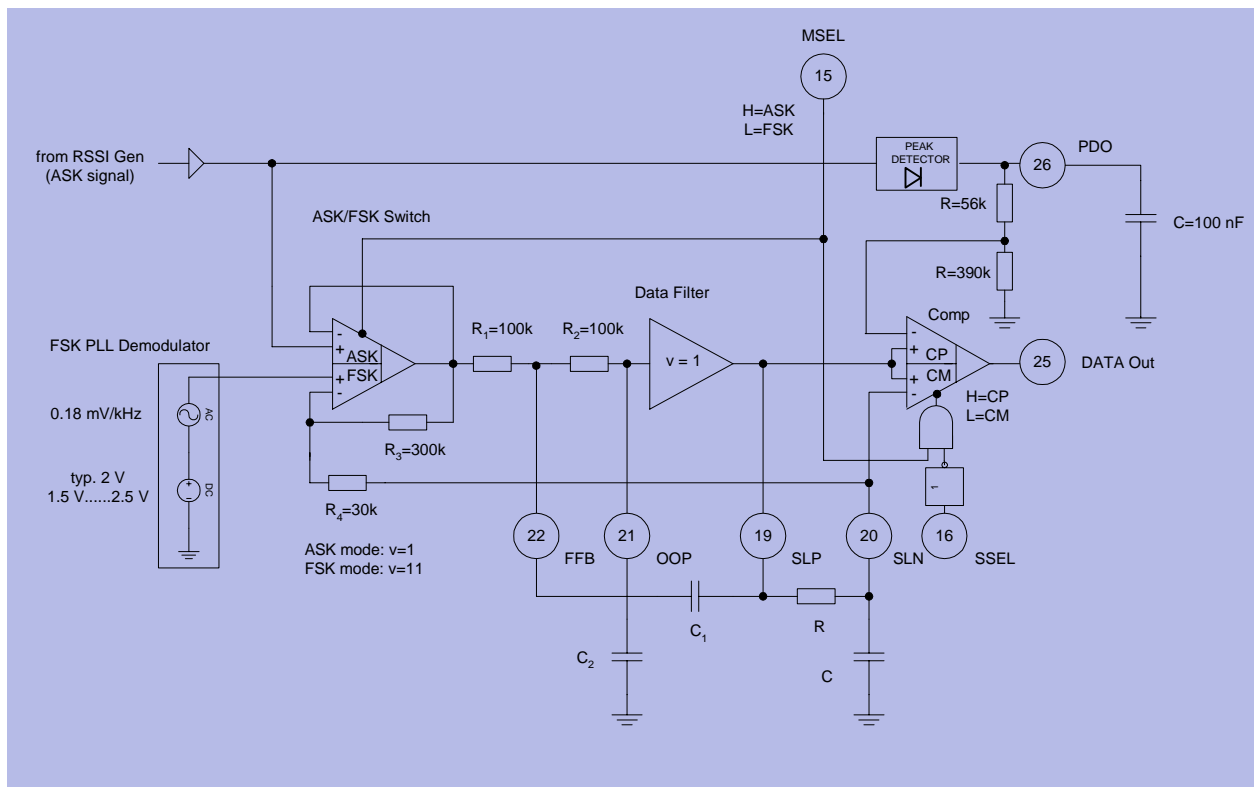
Data_slice2.wmf

Figure 4-6 Data Slicer Threshold Generation Utilising the Peak Detector

4.6 ASK/FSK Switch Functional Description

The TDA5220 is containing an ASK/FSK switch which can be controlled via Pin 15 (MSEL). This switch is actually consisting of 2 operational amplifiers that are having a gain of 1 in case of the ASK amplifier and a gain of 11 in case of the FSK amplifier in order to achieve an appropriate demodulation gain characteristic. In order to compensate for the DC-offset generated especially in case of the FSK PLL demodulator there is a feedback connection between the threshold voltage of the bit slicer comparator (Pin 20) to the negative input of the FSK switch amplifier.

In ASK-mode alternatively to the voltage at Pin 20 (SLN) a value of approx. 87% of the peak-detector output-voltage at Pin 26 (PDO) can be used as the slicer-reference level. The selection between these modes is controlled by Pin 16 (SSEL). This is shown in the following figure.



ask_tsk_datapath.VMMF

Figure 4-7 ASK/FSK mode datapath

4.6.1 FSK Mode

The FSK datapath has a bandpass characteristic due to the feedback shown above (highpass) and the data filter (lowpass). The lower cutoff frequency f_2 is determined by the external RC-combination. The upper cutoff frequency f_3 is determined by the data filter bandwidth.

The demodulation gain of the FSK PLL demodulator is $180\mu\text{V}/\text{kHz}$. This gain is increased by the gain v of the FSK switch, which is 11. Therefore the resulting dynamic gain of this circuit is $2\text{mV}/\text{kHz}$ within the bandpass. The gain for the DC content of FSK signal remains at $180\mu\text{V}/\text{kHz}$. The cutoff frequencies of the bandpass have to be chosen such that the spectrum of the data signal is influenced in an acceptable amount.

In case that the user data is containing long sequences of logical zeroes the effect of the drift-off of the bit slicer threshold voltage can be lowered if the offset voltage inherent at the negative input of the slicer comparator (Pin20) is used. The comparator has no hysteresis built in.

This offset voltage is generated by the bias current of the negative input of the comparator (i.e. 20nA) running over the external resistor R . This voltage raises the voltage appearing at pin 20 (e.g. 1mV with $R = 100\text{k}\Omega$). In order to obtain benefit of this asymmetrical offset for the demodulation of long zeros the lower of the two FSK frequencies should be chosen in the transmitter as the zero-symbol frequency.

In the following figure the shape of the above mentioned bandpass is shown.

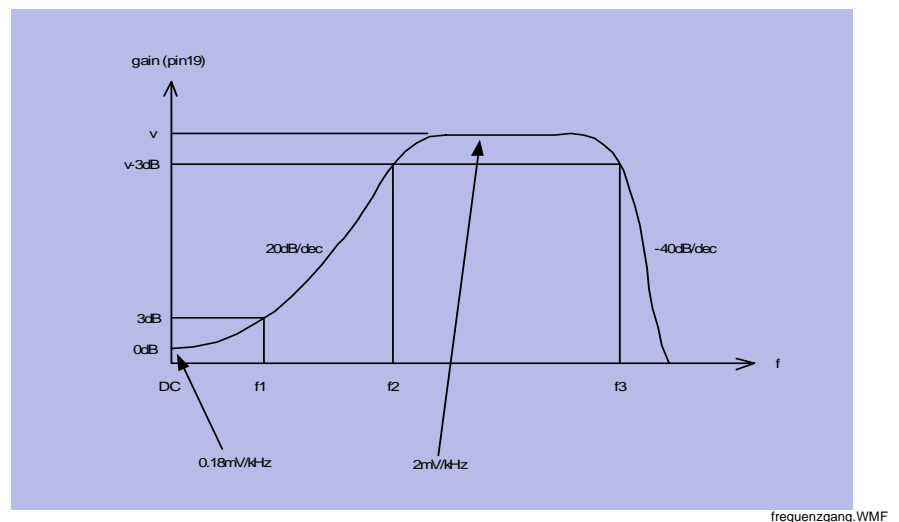


Figure 4-8 Frequency characteristic in case of FSK mode

The cutoff frequencies are calculated with the following formulas:

$$f_1 = \frac{1}{2\pi \frac{R \cdot 330\text{k}\Omega}{R + 330\text{k}\Omega} \cdot C}$$

$$f_2 = v \cdot f_1 = 11 \cdot f_1$$

$$f_3 = f_{3dB}$$

f_3 is the 3dB cutoff frequency of the data filter - see Section 4.2.

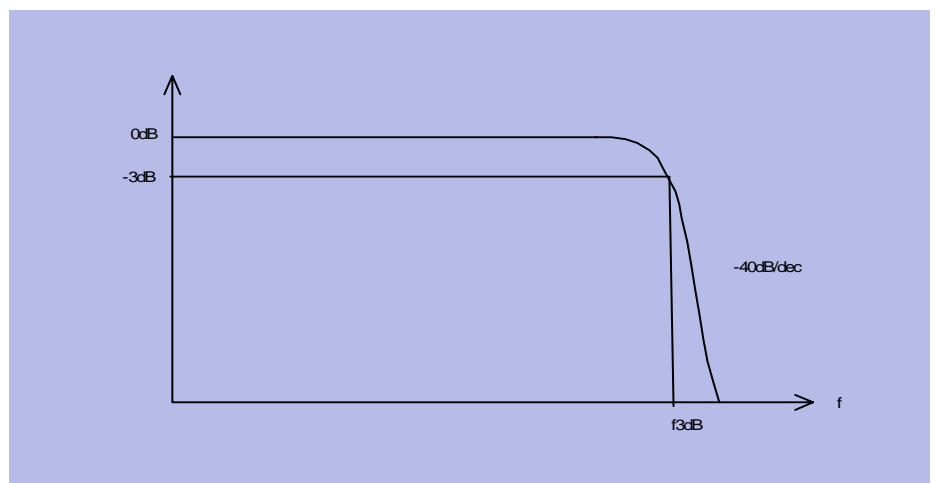
Example:

$R = 100k\Omega$, $C = 47nF$

This leads to $f_1 = 44Hz$ and $f_2 = 485Hz$

4.6.2 ASK Mode

In case the receiver is operated in ASK mode the datapath frequency characteristic is dominated by the data filter alone, thus it is lowpass shaped. The cutoff frequency is determined by the external capacitors C12 and C14 and the internal 100k resistors as described in Section 4.2



freq_ask.WMF

Figure 4-9 Frequency characteristic in case of ASK mode

4.7 Principle of the Precharge Circuit

In case the data slicer threshold shall be generated with an external RC network as described in Section 4.5 it is necessary to use large values for the capacitor C attached to the **SLN** pin (pin 20) in order to achieve long time constants. This results also from the fact that the choice of the value for R connected between the **SLP** and **SLN** pins (pins 19 and 20) is limited by the 330kΩ resistor appearing in parallel to R as can be seen in Figure 4-7. Apart from this a resistor value of 100kΩ leads to a voltage offset of 1mV at the comparator input as described in Section 4.6.1. The resulting startup time constant τ_1 can be calculated with:

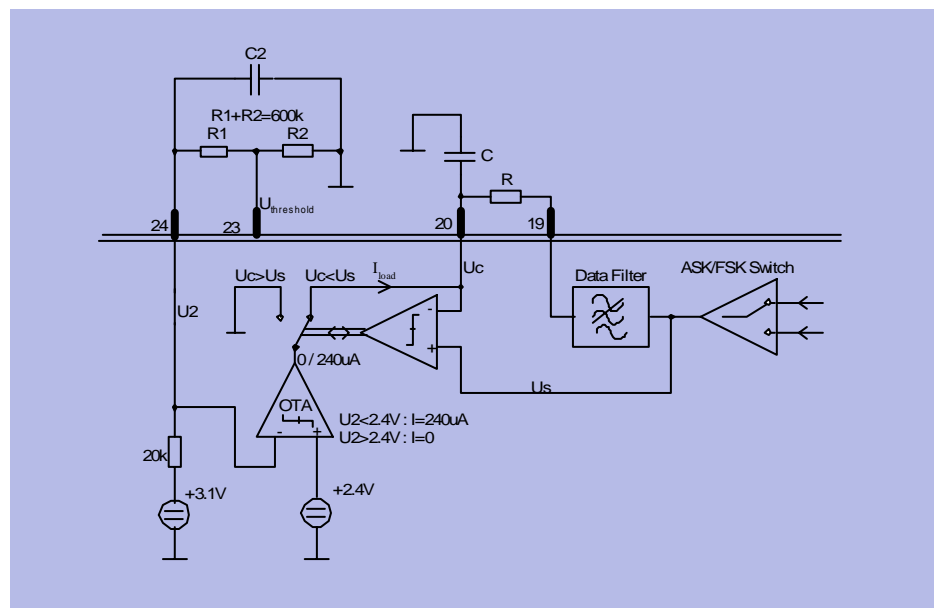
$$\tau_1 = (R // 330k\Omega) \cdot C$$

In case R is chosen to be 100kΩ and C is chosen as 47nF this leads to

$$\tau_1 = (100k\Omega // 330k\Omega) \cdot 47nF = 77k\Omega \cdot 47nF = 3.6ms$$

When the device is turned on this time constant dominates the time necessary for the device to be able to demodulate data properly. In the powerdown mode the capacitor is only discharged by leakage currents.

In order to reduce the turn-on time in the presence of large values of C a precharge circuit was included in the TDA5220 as shown in the following figure.



precharge.WMF

Figure 4-10 Principle of the precharge circuit

This circuit charges the capacitor C with an inrush current I_{load} of typically $220\mu A$ for a duration of T_2 until the voltage U_c appearing on the capacitor is equal to the voltage U_s at the input of the data filter. This voltage is limited to $2.5V$. As soon as these voltages are equal or the duration T_2 is exceeded the precharge circuit is disabled.

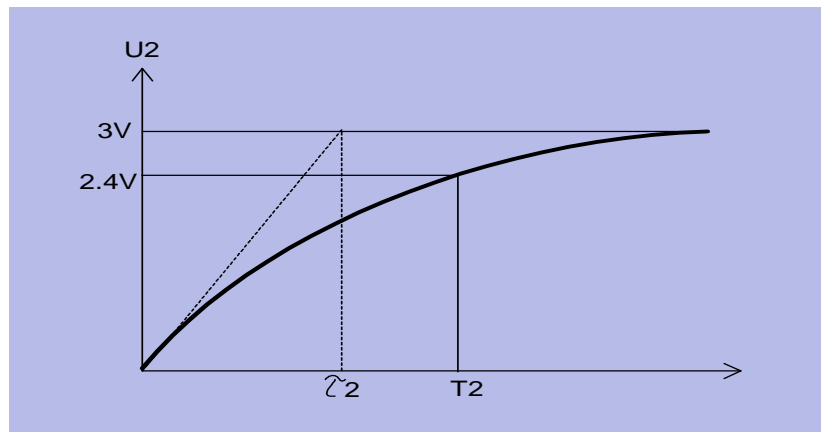
τ_2 is the time constant of the charging process of C which can be calculated as

$$\tau_2 \approx 20k\Omega \cdot C2$$

as the sum of R1 and R2 is sufficiently large and thus can be neglected. T_2 can then be calculated according to the following formula:

$$T_2 = \tau_2 \ln \left(\frac{1}{1 - \frac{2.4V}{3V}} \right) \approx \tau_2 \cdot 1.6$$

The voltage transient during the charging of C2 is shown in the following figure:

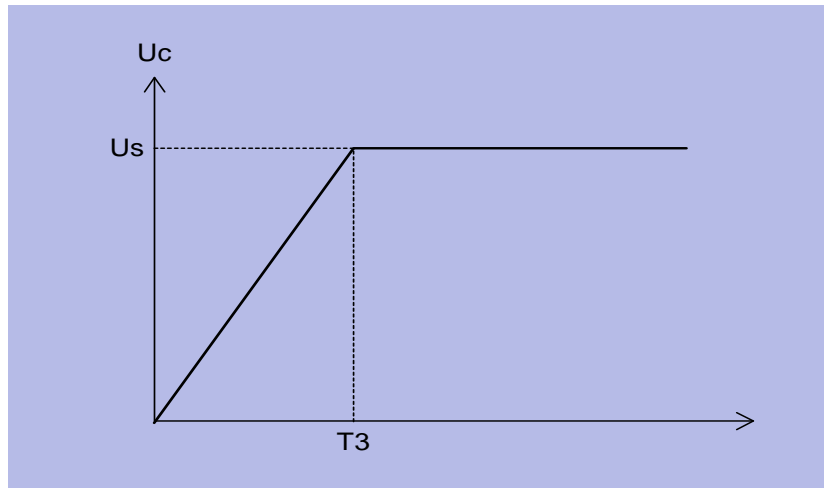


e-ikt1.WMF

Figure 4-11 Voltage appearing on C2 during precharging process

The voltage appearing on the capacitor C connected to pin 20 is shown in the following figure. It can be seen that due to the fact that it is charged by a constant current source it exhibits a linear increase in voltage which is limited to $U_{Smax} = 2.5V$ which is also the approximate operating point of the data filter input. The time constant appearing in this case can be denoted as $T3$, which can be calculated with

$$T3 = \frac{U_{Smax} \cdot C}{220\mu A} = \frac{2,5V}{220\mu A} \cdot C$$



e-Fkt2.WMF

Figure 4-12 Voltage transient on capacitor C attached to pin 20

As an example the choice of $C_2 = 22\text{nF}$ and $C = 47\text{nF}$ yields

$$\tau_2 = 0.44\text{ms}$$

$$T_2 = 0.71\text{ms}$$

$$T_3 = 0.53\text{ms}$$

This means that in this case the inrush current could flow for a duration of 0.64ms but stops already after 0.49ms when the $U_{S_{\max}}$ limit has been reached. T_3 should always be chosen to be shorter than T_2 .

It has to be noted finally that during the turn-on duration T_2 the overall device power consumption is increased by the 220 μA needed to charge C.

The precharge circuit may be disabled if C_2 is not equipped. This yields a T_2 close to zero. Note that the sum of R_4 and R_5 has to be 600k Ω in order to produce 3V at the THRES pin as this voltage is internally used also as the reference for the FSK demodulator.

5 Reference

Contents of this Chapter

5.1	Electrical Data.....	5-2
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5.1 Electrical Data

5.1.1 Absolute Maximum Ratings



WARNING

The maximum ratings may not be exceeded under any circumstances, not even momentarily and individually, as permanent damage to the IC will result.

Table 5-1 Absolute Maximum Ratings, Ambient temperature $T_{AMB} = -40^{\circ}\text{C} \dots +105^{\circ}\text{C}$

#	Parameter	Symbol	Limit Values		Unit	Remarks
			min	max		
1	Supply Voltage	V_s	-0.3	5.5	V	
2	Junction Temperature	T_j	-40	+150	$^{\circ}\text{C}$	
3	Storage Temperature	T_s	-40	+125	$^{\circ}\text{C}$	
4	Thermal Resistance	R_{thJA}		114	K/W	
5	ESD integrity, all pins excl. Pins 1,3, 6, 28 ESD integrity Pins 1,3,6,28	V_{ESD}		+2 +1.5	kV kV	HBM according to MIL STD 883D, method 3015.7

5.1.2 Operating Range

Within the operational range the IC operates as explained in the circuit description. The AC/DC characteristic limits are not guaranteed. Currents flowing into the device are denoted as positive currents and v.v.

Supply voltage: VCC = 4.5V .. 5.5V

Table 5-2 Operating Range, Ambient temperature $T_{AMB} = -40^{\circ}\text{C} \dots +105^{\circ}\text{C}$

#	Parameter	Symbol	Limit Values		Unit	Test Conditions	L	Item
			min	max				
1	Supply Current	$I_{SF\ 868}$	t.b.d.	t.b.d.	mA	$f_{RF} = 868\text{MHz}$, FSK Mode		
		$I_{SF\ 434}$	t.b.d.	t.b.d.	mA	$f_{RF} = 434\text{MHz}$, FSK Mode		
		$I_{SA\ 868}$	t.b.d.	t.b.d.	mA	$f_{RF} = 868\text{MHz}$, ASK Mode		
		$I_{SA\ 434}$	t.b.d.	t.b.d.	mA	$f_{RF} = 434\text{MHz}$, ASK Mode		
2	Receiver Input Level ASK FSK, frequ. dev. $\pm 50\text{kHz}$	RF_{in}	-106	-13	dBm	@ source impedance 50Ω , BER 2E-3, average power level, Manchester encoded datarate 4kBit, 280kHz IF Bandwidth	■	
			-100	-13	dBm			
3	LNI Input Frequency	f_{RF}	400/ 810	440/ 870	MHz			
4	MI/MIX Input Frequency	f_{MI}	400/ 810	440/ 870	MHz			
5	3dB IF Frequency Range ASK FSK	$f_{IF\ -3dB}$	5	23	MHz		■	
			10.4	11				

■ This value is guaranteed by design.

5.1.3 AC/DC Characteristics at $T_{AMB} = 25^{\circ}\text{C}$

AC/DC characteristics involve the spread of values guaranteed within the specified voltage and ambient temperature range. Typical characteristics are the median of the production. Currents flowing into the device are denoted as positive currents and vice versa.

Table 5-3 AC/DC Characteristics with $T_A = 25^{\circ}\text{C}$, $V_{VCC} = 4.5 \dots 5.5 \text{ V}$

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
Supply									
Supply Current									
1	Supply current, standby mode	$I_{S\ PDWN}$		50	t.b.d.	nA	Pin 27 (PDWN) open or tied to 0 V		
2	Supply current, device operating in 868 MHz range, FSK mode	$I_{SF\ 868}$	t.b.d.	5.9	t.b.d.	mA	Pin 11 (FSEL) tied to GND, Pin 15 (MSEL) tied to GND		
3	Supply current, device operating in 434 MHz range, FSK mode	$I_{SF\ 434}$	t.b.d.	5.7	t.b.d.	mA	Pin 11 (FSEL) open, Pin 15 (MSEL) tied to GND		
4	Supply current, device operating in 868 MHz range, ASK mode	$I_{SA\ 868}$	t.b.d.	5.2	t.b.d.	mA	Pin 11 (FSEL) tied to GND, Pin 15 (MSEL) open		
5	Supply current, device operating in 434 MHz range, ASK mode	$I_{SA\ 434}$	t.b.d.	5	t.b.d.	mA	Pin 11 (FSEL) open, Pin 15 (MSEL) open		
LNA									
Signal Input LNI (PIN 3), $V_{THRES} > 2.8\text{V}$, high gain mode									
1	Average Power Level at BER = 2E-3 (Sensitivity) ASK	RF_{in}		-110		dBm	Manchester encoded datarate 4kBit, 280kHz IF Bandwidth	■	
2	Average Power Level at BER = 2E-3 (Sensitivity) FSK	RF_{in}		-103		dBm	Manchester enc. datarate 4kBit, 280kHz IF Bandw., $\pm 50\text{kHz}$ pk. dev.	■	
3	Input impedance, $f_{RF}=434 \text{ MHz}$	$S_{11\ LNA}$	0.873 / -34.7 deg					■	
4	Input impedance, $f_{RF}=869 \text{ MHz}$	$S_{11\ LNA}$	0.738 / -73.5 deg					■	
5	Input level @ 1dB compression	$P_{1dB\ LNA}$		-15		dBm		■	
6	Input 3 rd order intercept point $f_{RF}=434 \text{ MHz}$	$IIP3_{LNA}$		-10		dBm	matched input	■	
7	Input 3 rd order intercept point $f_{RF}=869 \text{ MHz}$	$IIP3_{LNA}$		-14		dBm	matched input	■	

Table 5-3 AC/DC Characteristics with T_A 25 °C, $V_{VCC} = 4.5 \dots 5.5$ V (continued)

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
8	LO signal feedthrough at antenna port	LO_{LNI}			-73	dBm		■	
Signal Output LNO (PIN 6), $V_{THRES} > 2.8V$, high gain mode									
1	Gain $f_{RF}=434$ MHz	S_{21} LNA	1.509 / 138.2 deg					■	
2	Gain $f_{RF}=869$ MHz	S_{21} LNA	1.419 / 101.7 deg					■	
3	Output impedance, $f_{RF}=434$ MHz	S_{22} LNA	0.886 / -12.9 deg					■	
4	Output impedance, $f_{RF}=869$ MHz	S_{22} LNA	0.866 / -24.2 deg					■	
5	Voltage Gain Antenna to IFO $f_{RF}=434$ MHz	G_{AntMI}		42		dB			
6	Voltage Gain Antenna to IFO $f_{RF}=869$ MHz	G_{AntMI}		40		dB			
Signal Input LNI, $V_{THRES} = GND$, low gain mode									
1	Input impedance, $f_{RF}=434$ MHz	S_{11} LNA	0.873 / -34.7 deg					■	
2	Input impedance, $f_{RF}=869$ MHz	S_{11} LNA	0.738 / -73.5 deg					■	
3	Input level @ 1dB C. P $f_{RF} = 434$ MHz	$P1dB_{LNA}$		-18		dBm	matched input	■	
4	Input level @ 1dB C. P $f_{RF} = 869$ MHz	$P1dB_{LNA}$		-6		dBm	matched input	■	
5	Input 3 rd order intercept point $f_{RF}=434$ MHz	$IIP3_{LNA}$		-10		dBm	matched input	■	
6	Input 3 rd order intercept point $f_{RF}=869$ MHz	$IIP3_{LNA}$		-5		dBm	matched input	■	
Signal Output LNO, $V_{THRES} = GND$, low gain mode									
1	Gain $f_{RF}=434$ MHz	S_{21} LNA	0.183 / 140.6 deg					■	
2	Gain $f_{RF}=869$ MHz	S_{21} LNA	0.179 / 109.1deg					■	
3	Output impedance, $f_{RF}=434$ MHz	S_{22} LNA	0.897 / -13.6 deg					■	
4	Output impedance, $f_{RF}=869$ MHz	S_{22} LNA	0.868 / -26.3 deg					■	
5	Voltage Gain Antenna to MI $f_{RF}=434$ MHz	G_{AntMI}		22		dB			
6	Voltage Gain Antenna to MI $f_{RF}=869$ MHz	G_{AntMI}		19		dB			

Table 5-3 AC/DC Characteristics with T_A 25 °C, $V_{VCC} = 4.5 \dots 5.5$ V (continued)

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
Signal 3VOUT (PIN 24)									
1	Output voltage	V_{3VOUT}	2.9	3.1	3.3	V	3VOUT Pin open		
2	Current out	I_{3VOUT}	-3	-5	-10	μ A	see Section 4.1		
Signal THRES (PIN 23)									
1	Input Voltage range	V_{THRES}	0		$V_S - 1V$	V	see Section 4.1		
2	LNA low gain mode	V_{THRES}	0			V			
3	LNA high gain mode	V_{THRES}	2.8	3	V_S	V	or shorted to Pin 24		
4	Current in	I_{THRES_in}		5		nA			
Signal TAGC (PIN 4)									
1	Current out, LNA low gain state	I_{TAGC_out}	-3.6	-4.2	-5	μ A	$RSSI > V_{THRES}$		
2	Current in, LNA high gain state	V_{TAGC_in}	1	1.6	2.2	μ A	$RSSI > V_{THRES}$		
MIXER									
Signal Input MI/MIX (PINS 8/9)									
1	Input impedance, $f_{RF}=434$ MHz	$S_{11\ MIX}$	0.942 / -14.4 deg					■	
2	Input impedance, $f_{RF}=869$ MHz	$S_{11\ MIX}$	0.918 / -28.1 deg					■	
3	Input 3 rd order intercept point $f_{RF}=434$ MHz	$IIP3_{MIX}$		-28		dBm		■	
4	Input 3 rd order intercept point $f_{RF}=869$ MHz	$IIP3_{MIX}$		-26		dBm		■	
Signal Output IFO (PIN 12)									
1	Output impedance	Z_{IFO}		330		Ω		■	
2	Conversion Voltage Gain $f_{RF}=434$ MHz	G_{MIX}		+19		dB			
3	Conversion Voltage Gain $f_{RF}=869$ MHz	G_{MIX}		+18		dB			
LIMITER									
Signal Input LIM/LIMX (PINS 17/18)									
1	Input Impedance	Z_{LIM}	264	330	396	Ω		■	
2	RSSI dynamic range	DR_{RSSI}	60		80	dB			
3	RSSI linearity	LIN_{RSSI}		± 1		dB		■	
4	Operating frequency (3dB points)	f_{LIM}	5	10.7	23	MHz		■	

Table 5-3 AC/DC Characteristics with T_A 25 °C, $V_{VCC} = 4.5 \dots 5.5$ V (continued)

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
DATA FILTER									
1	Useable bandwidth	$BW_{BB\ FILT}$			100	kHz		■	
2	RSSI Level at Data Filter Output SLP, $RF_{IN} = -103$ dBm	$RSSI_{low}$	0.3		1	V	LNA in high gain mode		
3	RSSI Level at Data Filter Output SLP, $RF_{IN} = -30$ dBm	$RSSI_{high}$	1.8		3	V	LNA in high gain mode		
Slicer, Signal Output DATA (PIN 25)									
1	Maximum Datarate	DR_{max}			100	kBps	NRZ, 20pF capacitive loading	■	
2	LOW output voltage	V_{SLIC_L}	0		0.1	V			
3	HIGH output voltage	V_{SLIC_H}	$V_S - 1.3$ V	$V_S - 1$ V	$V_S - 0.7$ V	V			
Slicer, Negative Input (PIN 20)									
1	Precharge Current Out	I_{PCH_SLN}	-100	-220	-300	μA	see Section 4.7		
PEAK DETECTOR									
Signal Output PDO (PIN 26)									
1	Load current	I_{load}	-600	-950	-1300	μA			
2	Internal resistive load	R	t.b.d.	446	t.b.d.	kΩ			
CRYSTAL OSCILLATOR									
Signals CRSTL1, CRSTL 2, (PINS 1/28)									
1	Operating frequency	f_{CRSTL}	t.b.d.		14	MHz	fundamental mode, series resonance		
2	Input Impedance @ ~13MHz	Z_{1-28}		-600 +j1010		Ω		■	
3	Serial Capacity @ ~13MHz	$C_{S13} = C1$		5.9		pF			
ASK/FSK Signal Switch									
Signal MSEL (PIN 15)									
1	ASK Mode	V_{MSEL}	1.4		4	V	or open		
2	FSK Mode	V_{MSEL}	0		0.2	V			
3	Input bias current MSEL	I_{MSEL}	t.b.d.	-11	t.b.d.	μA	MSEL tied to GND		

Table 5-3 AC/DC Characteristics with T_A 25 °C, $V_{VCC} = 4.5 \dots 5.5$ V (continued)

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
FSK DEMODULATOR									
1	Demodulation Gain	G_{FMDEM}	85	180	225	$\mu\text{V}/\text{kHz}$			
2	Useable IF Bandwidth	BW_{IFPLL}	10.2	10.7	11.2	MHz			
POWER DOWN MODE									
Signal PDWN (PIN 27)									
1	Powerdown Mode On	$PWDN_{ON}$	0		0.8	V			
2	Powerdown Mode Off	$PWDN_{Off}$	2.8		V_S	V			
3	Input bias current PDWN	I_{PDWN}		19		μA	Power On Mode		
4	Start-up Time until valid signal is detected at IF	T_{SU}			1	ms			
VCO MULTIPLEXER									
Signal FSEL (PIN 11)									
1	f_{RF} range 434 MHz	V_{FSEL}	1.4		4	V	or open		
2	f_{RF} range 869 MHz	V_{FSEL}	0		0.2	V			
3	Input bias current FSEL	I_{FSEL}	-160	-200	-240	μA	FSEL tied to GND		
DATA-SLICER REFERENCE-LEVEL									
Signal SSEL (PIN 16), ASK-Mode									
1	Slicer-Reference is voltage at Pin 20 (SLN)	V_{SSEL}	1.4		4	V	or open		
2	Slicer-Reference is approx. 87% of the voltage at Pin 26 (PDO)	V_{SSEL}	0		0.2	V			
3	Input bias current SSEL	I_{SSEL}	-3	-5	-7	μA	SSEL tied to GND		

■ Measured only in lab.

5.1.4 AC/DC Characteristics at $T_{AMB} = -40$ to 105°C

Currents flowing into the device are denoted as positive currents and vice versa

Table 5-4 AC/DC Characteristics with $T_{AMB} = -40^{\circ}\text{C} \dots +105^{\circ}\text{C}$, $V_{VCC} = 4.5 \dots 5.5 \text{ V}$

Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
		min	typ	max				
Supply								
Supply Current								
1	Supply current, standby mode	$I_{S\ PDWN}$		50	t.b.d.	nA	Pin 27 (PDWN) open or tied to 0 V	
2	Supply current, device operating in 868 MHz range, FSK mode	$I_{SF\ 868}$	t.b.d.	5.9	t.b.d.	mA	Pin 11 (FSEL) tied to GND, Pin 15 (MSEL) tied to GND	
3	Supply current, device operating in 434 MHz range, FSK mode	$I_{SF\ 434}$	t.b.d.	5.7	t.b.d.	mA	Pin 11 (FSEL) open, Pin 15 (MSEL) tied to GND	
4	Supply current, device operating in 868 MHz range, ASK mode	$I_{SA\ 868}$	t.b.d.	5.2	t.b.d.	mA	Pin 11 (FSEL) tied to GND, Pin 15 (MSEL) open	
5	Supply current, device operating in 434 MHz range, ASK mode	$I_{SA\ 434}$	t.b.d.	5	t.b.d.	mA	Pin 11 (FSEL) open, Pin 15 (MSEL) open	
Signal 3VOUT (PIN 24)								
1	Output voltage	V_{3VOUT}	2.9	3.1	3.3	V	3VOUT Pin open	
2	Current out	I_{3VOUT}	-3	-5	-10	μA	see Section 4.1	
Signal THRES (PIN 23)								
1	Input Voltage range	V_{THRES}	0		$V_S - 1\text{V}$	V	see Section 4.1	
2	LNA low gain mode	V_{THRES}	0		0.3	V		
3	LNA high gain mode	V_{THRES}	3		V_S	V	or shorted to Pin 24	
4	Current in	I_{THRES_in}		5		nA		
Signal TAGC (PIN 4)								
1	Current out, LNA low gain state	I_{TAGC_out}	-1	-4.2	-8	μA	$RSSI > V_{THRES}$	
2	Current in, LNA high gain state	V_{TAGC_in}	0.5	1.5	5	μA	$RSSI > V_{THRES}$	
MIXER								
1	Conversion Voltage Gain $f_{RF}=434 \text{ MHz}$	G_{MIX}		+19		dB		
2	Conversion Voltage Gain $f_{RF}=869 \text{ MHz}$	G_{MIX}		+18		dB		
LIMITER								
Signal Input LIM/LIMX (PINS 17/18)								
1	RSSI dynamic range	DR_{RSSI}	60		80	dB		

Table 5-4 AC/DC Characteristics with $T_{AMB} = -40^{\circ}\text{C} \dots +105^{\circ}\text{C}$, $V_{VCC} = 4.5 \dots 5.5\text{ V}$

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
DATA FILTER									
2	RSSI Level at Data Filter Output SLP, $RF_{IN} = -103\text{dBm}$	$RSSI_{low}$	0.3		1	V	LNA in high gain mode		
3	RSSI Level at Data Filter Output SLP, $RF_{IN} = -30\text{dBm}$	$RSSI_{high}$	1.8		3	V	LNA in high gain mode		
Slicer, Signal Output DATA (PIN 25)									
1	Maximum Datarate	DR_{max}			100	kBps	NRZ, 20pF capacitive loading	■	
2	LOW output voltage	V_{SLIC_L}	0		0.1	V			
3	HIGH output voltage	V_{SLIC_H}	$V_S - 1.5\text{V}$	$V_S - 1\text{V}$	$V_S - 0.5\text{V}$	V			
Slicer, Negative Input (PIN 20)									
1	Precharge Current Out	I_{PCH_SLN}	-100	-220	-300	μA	see Section 4.7		
PEAK DETECTOR									
Signal Output PDO (PIN 26)									
1	Load current	I_{load}	-400	-850	-1400	μA			
2	Internal resistive load	R	t.b.d.	446	t.b.d.	$\text{k}\Omega$			
CRYSTAL OSCILLATOR									
Signals CRSTL1, CRSTL 2, (PINS 1/28)									
1	Operating frequency	f_{CRSTL}	t.b.d.		14	MHz	fundamental mode, series resonance		
ASK/FSK Signal Switch									
Signal MSEL (PIN 15)									
1	ASK Mode	V_{MSEL}	1.4		4	V	or open		
2	FSK Mode	V_{MSEL}	0		0.2	V			
3	Input bias current MSEL	I_{MSEL}	t.b.d.	-11	t.b.d.	μA	MSEL tied to GND		
FSK DEMODULATOR									
1	Demodulation Gain	G_{FMDEM}	105	180	245	$\mu\text{V}/\text{kHz}$			
2	Useable IF Bandwidth	BW_{IFPLL}	10.2	10.7	11.2	MHz			
POWER DOWN MODE									
Signal PDWN (PIN 27)									
1	Powerdown Mode On	$PWDN_{ON}$	0		0.8	V			
2	Powerdown Mode Off	$PWDN_{Off}$	2.8		V_S	V			

Table 5-4 AC/DC Characteristics with $T_{AMB} = -40^{\circ}\text{C} \dots +105^{\circ}\text{C}$, $V_{VCC} = 4.5 \dots 5.5 \text{ V}$

	Parameter	Symbol	Limit Values			Unit	Test Conditions	L	Item
			min	typ	max				
3	Start-up Time until valid signal is detected at IF	T_{SU}			1	ms			

VCO MULTIPLEXER

Signal FSEL (PIN 11)

1	f_{RF} range 434 MHz	V_{FSEL}	1.4		4	V	or open		
2	f_{RF} range 869 MHz	V_{FSEL}	0		0.2	V			
3	Input bias current FSEL	I_{FSEL}	-110	-200	-340	μA	FSEL tied to GND		

DATA-SLICER REFERENCE-LEVEL

Signal SSEL (PIN 16), ASK-Mode

1	Slicer-Reference is voltage at Pin 20 (SLN)	V_{SSEL}	1.4		4	V	or open		
2	Slicer-Reference is approx. 87% of the voltage at Pin 26 (PDO)	V_{SSEL}	0		0.2	V			
3	Input bias current SSEL	I_{SSEL}	t.b.d.	-11	t.b.d.	μA	SSEL tied to GND		