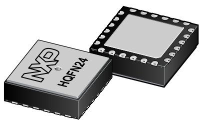


FXTH87EK116

Tire pressure monitor sensor

Rev. 2.1 — 25 June 2021 **Product data sheet**

1 General description

The FXTH87EK116 is a small (7 x 7 mm), fully integrated tire pressure monitoring sensors (TPMS) that provides low transmitting power consumption, large customer memory size and a dual-axis accelerometer architecture. The FXTH87EK116 TPMS solution integrates an 8-bit microcontroller (MCU), a pressure sensor, an XZ-axis accelerometer, and an RF transmitter.

2 Features and benefits

- Long battery service life
- Power optimization software
- Pin-for-pin electrical connections compatible with FXTH87-based customer applications
- Firmware subroutines compatible with FXTH87-based customer software
- Pressure sensor with one of three calibrated pressure ranges
- Temperature sensor
- Dual XZ-axis accelerometer with adjustable offset option
- Voltage reference measured by ADC10
- Six-channel, 10-bit analog-to-digital converter (ADC10) with two external I/O inputs
- 8-bit MCU
  - S08 Core with SIM and interrupt
  - 512 RAM
  - 16 kB FLASH
  - 64-byte, low-power, parameter registers
- Dedicated state machines to sequence routine measurement and transmission processes for reduced power consumption
- Internal 315-/434-MHz RF transmitter
  - External crystal oscillator
  - PLL-based output with fractional-n divider
  - OOK and FSK modulation capability
  - Programmable data rate generator
  - Manchester, Bi-Phase, or NRZ data encoding
  - 256-bit RF data buffer variable length interrupt
  - Direct access to RF transmitter from MCU for unique formats
  - Low-power consumption
- Differential input LF detector/decoder on independent signal pins

- Seven multipurpose GPIO pins
  - Four pins can be connected to optional internal pullups/pulldowns and STOP4 wake-up interrupt
  - Two of seven pins can be connected to a channel on the ADC10
  - Two of seven pins can be connected to a channel on the TPM1
- Real-time Interrupt driven by LFO with interrupt intervals of 2, 4, 8, 16, 32, 64, or 128 ms
- Free-running counter, low-power, wake-up timer and periodic reset driven by LFO
- Watchdog timeout with selectable times and clock sources
- Two-channel general-purpose timer/PWM module (TPM1)
- Internal oscillators
  - MCU bus clock of 0.5, 1, 2, and 4 MHz (1, 2, 4, and 8 MHz HFO)
  - Low frequency, low-power time clock (LFO) with 1 ms period
  - Medium frequency, controller clock (MFO) of 8 μs period
- Low-voltage detection
- Normal temperature restart in hardware (over- or under-temperature detected by software)

3 Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
FXTH87EK116	HQFN24	Plastic thermally enhanced quad flat non-leaded package; 24 terminals; 1.0 mm pitch; 7 mm x 7 mm x 2.2 mm body	SOT1575-1[1]

3.1 Ordering options

Table 2. Ordering information

Part number	Pressure Range	Accelerometer	X-axis Range	Z-axis Range	Code0 Firmware	Code 1 Firmware
FXTH87EK116T1	90 kPa to 1500 kPa	XZ	-80 g to + 90 g	-215 g to +305 g	$24	$BD

4 Block diagram

Figure 1 shows the block diagram for the FXTH87EK116 device. This diagram covers all the main blocks mentioned above and their main signal interactions. In order to keep the block diagram clear and simple, power management controls and bus control signals are not shown.

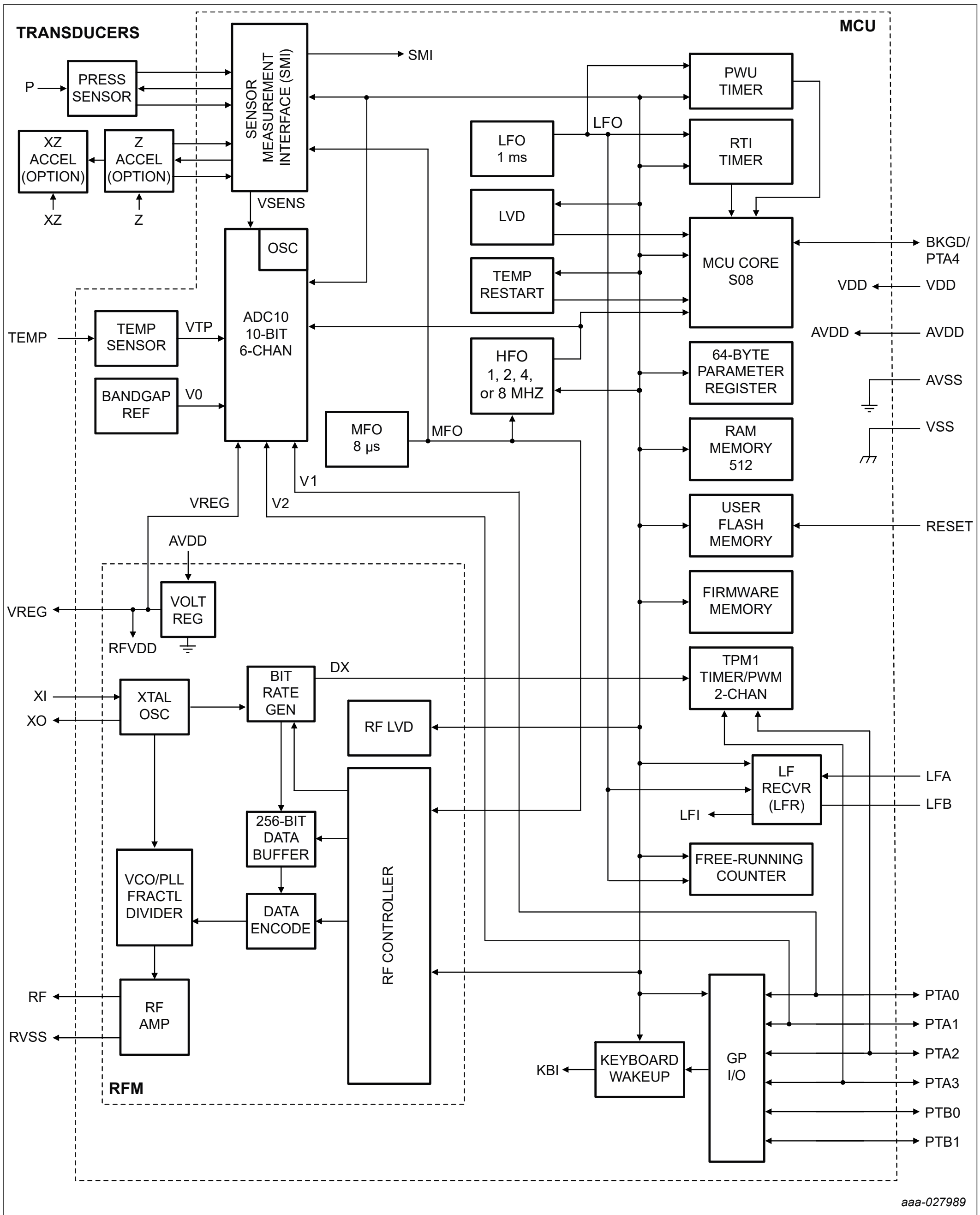


Figure 1. FXTH87EK116 block diagram

5 Pinning information

5.1 Pinning

Figure 2 shows the pinout for the FXTH87EK116 device QFN package with the pressure port side up. Figure 3 shows the orientation of the internal Z-axis accelerometer.

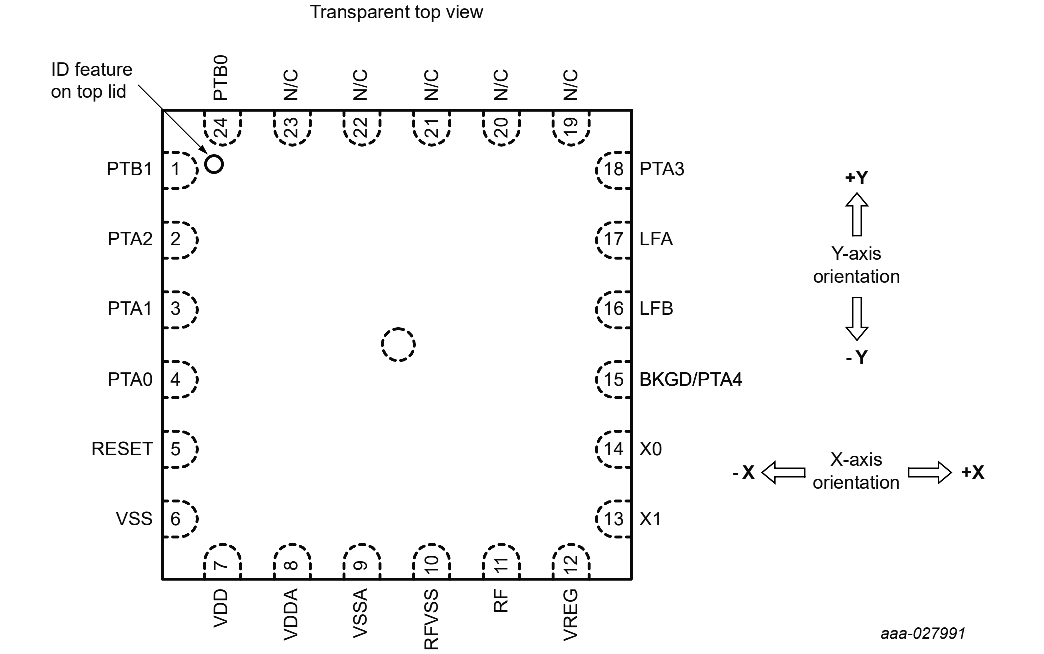


Figure 2. FXTH87EK116 package pinout

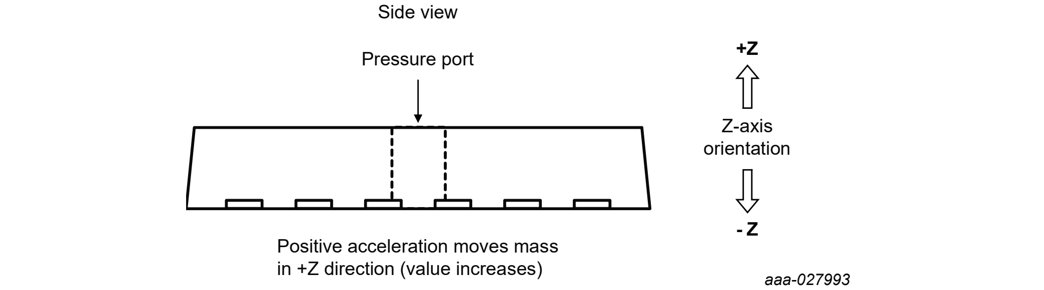


Figure 3. FXTH87EK116 QFN optional Z-axis accelerometer orientation

5.2 Pin description

Table 3. Pin description

Symbol	Pin	Description
PTB1	1	General-purpose I/O
PTA2	2	General-purpose I/O
PTA1	3	General-purpose I/O
PTA0	4	General-purpose I/O
RESET	5	External reset
VSS	6	Digital circuit ground
VDD	7	Digital circuit supply voltage
VDDA	8	Analog circuit supply voltage
VSSA	9	Analog circuit ground
RFVSS	10	RF output amplifier ground
RF	11	RF energy data
VREG	12	External stabilization for analog circuits internal regulator
X1	13	External crystal
X0	14	External crystal
BKGD / PTA4	15	BACKGROUND DEBUG mode enable
LFB	16	LF receiver differential input channel B
LFA	17	LF receiver differential input channel A
PTA3	18	General-purpose I/O
N/C	19, 20, 21, 22, 23	No Connect: Do not connect PCB pads to signal traces, power/ground, or multi-layer via.
PTB0	24	General-purpose I/O

6 Limiting values

Maximum ratings are the extreme limits to which the device can be exposed without permanently damaging it. The device contains circuitry to protect the inputs against damage from high static voltages; however, do not apply voltages higher than those shown in Table 4. Keep V_{IN} and V_{OUT} within the range $V_{SS} \leq (V_{IN}$ or $V_{OUT}) \leq V_{DD}$.

Table 4. Maximum ratings

#	Rating	Symbol	Value	Unit	Notes
100	Supply Voltage (V_{DD}, AV_{DD})	V_{DD}	–0.3 to +3.8	V	C
	Input Voltage				
101	X1	V_{IN}	–0.3 to V_{DD}+0.3	V	C
102	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1	V_{IN}	–0.3 to V_{DD}+0.3	V	C
103	BKGD/PTA4, $\overline{\text{RESET}}$	V_{IN}	–0.3 to V_{DD}+0.3	V	C
104	LFA, LFB	V_{IN}	–0.3 to V_{DD}+0.3	V	C

Table 4. Maximum ratings*...continued*

#	Rating	Symbol	Value	Unit	Notes
	Input Current				
105	X1	I_{IN}	±10	mA	C
106	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1	I_{IN}	±10	mA	C
107	BKGD/PTA4, $\overline{\text{RESET}}$	I_{IN}	±10	mA	C
108	LFA, LFB	I_{IN}	±10	mA	C
	Substrate Current Injection				
	Current from any pin to V_{SS} – 0.3 VDC				
109	XI, PTA0, PTA1, PTA2, PTA3, PTB0, PTB1, BKGD/PTA4, RESET	I_{SUB}	600	µA	C
110	LFA, LFB	I_{SUB}	2	mA	C
	Latchup Current				
111	Current to/from any pin to supply rails + 0.3 VDC	I_{LATCH}	±100	mA	C
	Electrostatic Discharge				
112	Human Body Model (HBM), all pins other than RF	V_{ESD}	±2000	V	C
113	Human Body Model (HBM), RF pin	V_{ESD}	±3000	V	C
114	Charged Device Model (CDM)	V_{ESD}	±500	V	C
115	Maximum Storage Temperature Range	T_{STG}	–50 to +150	°C	C

7 Recommended operating conditions

This section specifies the range of operation in terms of the limits normally expected in the application.

Table 5. Operating range

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Operating Supply Voltage (V_{DD} = AV_{DD})		V_L		V_H		
	Measurements						
200	Pressure, Temperature, Acceleration	V_{DD}	2.3	3.0	3.6	V	B
201	Voltage	V_{DD}	1.8	3.0	3.6	V	B
202	LFR Operation (–20 < T_A < +85 °C)	V_{DD}	2.3	3.0	3.6	V	B
203	RF Transmissions	V_{DD}	1.8	3.0	3.6	V	B
	MCU operation (CPU, ADC10, RAM, TPM1)						
204	FLASH write (–40 °C to +125 °C)	V_{DD}	2.3	3.0	3.6	V	B
205	Content deleted.						
206	FLASH read	V_{DD}	1.8	3.0	3.6	V	B
207	Parameter registers data retention	V_{DD}	1.2	—	—	V	B
	Operating Temperature Range		T_L		T_H		

Table 5. Operating range...*continued*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
208	Continuous Temperature Range	T_A	–40	—	+125	°C	C
209	Temperature Restart mode[1]	T_R	—	—	+150	°C	C

[1] Total of three hours over the life of the device.

8 Characteristics

Tables in the electrical and mechanical specification sections of this data sheet may contain hyperlink note references in the last cell of the row. The hyperlink note references are linked to and defined in Table 6.

Table 6. Electrical and mechanical specification note definition table

Note identifier	Description
A	Parameters tested 100 % at final test.
B	Parameters tested 100 % at unit probe.
C	Verified by characterization, not tested in production.
D	For information only, may be determined by simulation.

8.1 Electrical characteristics

Table 7. Electrical characteristics

$1.8\ V \le V_{DD} \le 3.6\ V$, $T_L \le T_A \le T_H$, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Output High Voltage (I_{Load} = 5 mA)						
300	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1	V_{OH}	V_{DD} – 0.35	—	—	V	B
	Output Low Voltage (I_{Load} = –5 mA)						
301	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1	V_{OL}	—	—	0.35	V	B
	Input High Voltage (2.3 < $V_{DD} \le V_H$)						
302	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1, BKGD/PTA4	V_{IH}	0.7 x V_{DD}	—	—	V	B
	Input High Voltage ($V_L \le V_{DD} \le 2.3$)						
303	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1, BKGD/PTA4	V_{IH}	0.85 x V_{DD}	—	—	V	C
	Input Low Voltage (2.3 < $V_{DD} \le V_H$)						
304	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1, BKGD/PTA4	V_{IL}	V_{SS}	—	0.35 x V_{DD}	V	B
	Input Low Voltage ($V_L \le V_{DD} \le 2.3$)						
305	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1, BKGD/PTA4	V_{IL}	V_{SS}	—	0.28 x V_{DD}	V	C

Table 7. Electrical characteristics...*continued*

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Input High Current (at min V_{IH})						
306	BKGD/PTA4	I_{IH}	–1	—	+1	µA	A
307	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1 (pulldown off)	I_{IH}	–1	—	+1	µA	B
308	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1 (pulldown active)	I_{IH}	0	—	+120	µA	B
	Input Low Current (at max V_{IL})						
309	BKGD/PTA4	I_{IL}	–120	—	0	µA	A
310	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1 (pullup off)	I_{IL}	–1	—	+1	µA	B
311	PTA0, PTA1, PTA2, PTA3, PTB0, PTB1 (pullup active)	I_{IL}	–120	—	0	µA	B
	Pin Capacitance (3 V)						
312	BKGD/PTA4, PTA0, PTA1, PTA2, PTA3, PTB0, PTB1	C	0	—	15	pF	C

8.2 Power consumption (MCU)

Table 8. Power consumption

1.8 V ≤ V_{DD} ≤ 3.6 V, T_A = –40 °C to 125 °C unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Standby Supply Current						
	STOP1 mode, LFR, LVD, and TR all off						
400 401	Content deleted.						
402	T_A = 25 °C, V_{DD} = 1.8 V	I_{STDBY1}	—	—	0.20	µA	C
403	T_A = 25 °C, V_{DD} = 3.0 V	I_{STDBY1}	—	0.18	0.27	µA	B
404	T_A = 25 °C, V_{DD} = 3.6 V	I_{STDBY1}	—	—	0.35	µA	C
405	T_A = 70 °C, V_{DD} = 3.0 V	I_{STDBY1}	—	—	2.2	µA	C
406	T_A = 125 °C, 3.0 V ≤ V_{DD} ≤ 3.6 V	I_{STDBY1}	—	—	12.3	µA	C
407 408 409 410 411 412	Content deleted.						
	Standby Supply Current						
	STOP4 mode, LFR and TR off, LVD or RFLVD on						
413	T_A = –40 °C, V_{DD} = 3.0 V	I_{STDBY4}	—	—	85	µA	C
414	T_A = 0 °C, V_{DD} = 3.0 V	I_{STDBY4}	—	—	89	µA	C

Table 8. Power consumption*...continued*

1.8 V ≤ V_{DD} ≤ 3.6 V, T_A = –40 °C to 125 °C unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
415	T_A = 25 °C, V_{DD} = 1.8 V	I_{STDBY4}	—	—	75	µA	C
416	T_A = 25 °C, V_{DD} ≥ 3.0 V	I_{STDBY4}	—	75	91	µA	B
417	T_A = 70 °C, V_{DD} = 3.0 V	I_{STDBY4}	—	—	91	µA	C
418	T_A = 125 °C, 3.0 V ≤ V_{DD} ≤ 3.6 V	I_{STDBY4}	—	—	125	µA	C
	MCU Operate Current (1.8 ≤ V_{DD} ≤ 3.0 V, –40 °C ≤ T_A ≤ 125 °C)						
	Instruction Speed = 0.333 MIP/f_{BUS}						
419	0.5 MHz f_{BUS}, BUSCLKS[1:0] = 11	I_{DD}	—	0.8	0.94	mA	C
420	1 MHz f_{BUS}, BUSCLKS[1:0] = 10	I_{DD}	—	1.0	1.15	mA	C
421	2 MHz f_{BUS}, BUSCLKS[1:0] = 01	I_{DD}	—	1.42	1.6	mA	C
422	4 MHz f_{BUS}, BUSCLKS[1:0] = 00	I_{DD}	—	2.1	2.4	mA	A
423	Content deleted.						
	Standby Current Adder for Temperature Restart						
424	Content deleted.						
425	1.8 V ≤ V_{DD} ≤ 3.0 V, T_A = 125 °C	ΔI_{DD}	—	10	15	µA	C
	MCU Wake-up Consumption (+25 °C, 3 V)						
426	From STOP1 to first instruction, f_{BUS} = 4 MHz	Q_{WAKE}	0	0.05	0.1	µA-sec	C
	External Battery Model						
427	Series impedance at end-of-life	Z_{EOL}	—	—	60	Ω	D
428	Open circuit voltage at end-of-life	V_{EOL}	2.7	—	—	V	D

8.3 Control timing

Table 9. Control timing

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Internal Clock Frequency						
500	Initial startup frequency, multiplier of f_{MFO}	f_{OSC}	—	64x	—		D
501 502 503	Content deleted.						
504	Complete stabilization time (see Figure 4)		—	300	1000	µsec	C
505	MCU Bus Frequency	f_{BUS}	—	0.5 f_{OSC}	—		D
506	Content deleted.						
	Medium frequency clock (MFO)						
507	Content deleted.						
508	Full temperature range, –40 °C to +125 °C	f_{MFO}	104	125	135	kHz	C

Table 9. Control timing...continued

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Low frequency clock (LFO)						
509	Content deleted.						
510	Full temperature range, –40 °C to +125 °C[1]	f_{LFO}	504	1050	1512	Hz	C
511	LFR clock (derived from LFRO)	f_{LFRO}	118	129	138	kHz	A
	Power-On Reset Response						
512	Supply voltage risetime	t_{VDDR}	—	—	1	sec	C
513	Recovery time below V_{DD} = 0.5 V	t_{VDDOFF}	0	—	70	µsec	C
	MCU Wake-up Time (see Figure 4)						
514	From STOP1 to first instruction, f_{BUS} = 4 MHz	$t_{MCUWAKE}$	—	50	70	µsec	C
515	Content deleted.						
516	From STOP4 to first instruction, f_{BUS} = 4 MHz	$t_{MCUWAKE}$	—	100	200	µsec	C
517	FLASH Data Retention Time	t_{DR}	10	—	—	year	D

[1] The customer application may attain the typical WCLK period of 1 second by calling the firmware routine TPMS_LFOCAL and writing the result into the WDIV register at address $0039 bits 5:0. This process results in an adjustment to the PWU to reach the target typical value of 1 second.

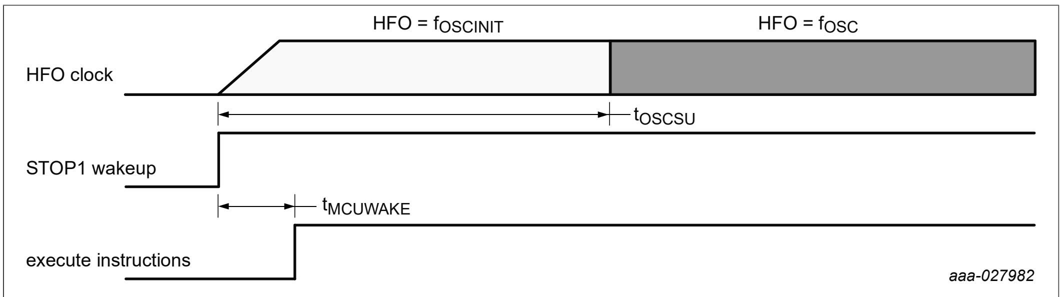


Figure 4. MCU startup delays

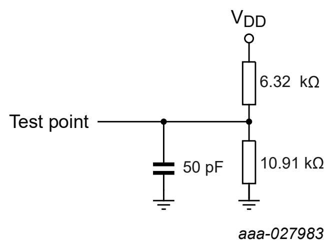


Figure 5. Control timing test load for digital pins

8.4 Voltage measurement characteristics

Table 10. Voltage measurement characteristics

$1.8\ V \leq V_{DD} \leq 3.6\ V$, $T_L \leq T_A \leq T_H$, unless otherwise specified. Transfer Function: $V = (0.01\ V/LSB * V_{CODE}) + 1.22\ V$

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Lower LVD detect threshold[1]						
600	V_{DD} falling	V_{LVDL}	1.84	—	1.96	V	B
601	V_{DD} rising	V_{LVDL}	1.92	—	2.03	V	C
602	Voltage drop detection time[2]	t_{LVDL}	—	—	10	μsec	C
	Higher LVD detect threshold[1]						
603	V_{DD} falling	V_{LVDH}	2.08	—	2.22	V	A
604	V_{DD} rising	V_{LVDH}	2.16	—	2.30	V	C
605	Voltage drop detection time[2]	t_{LVDH}	—	—	10	μsec	C
	Lower LVW detect threshold (LVWV = 0)[1]						
606	V_{DD} falling	V_{LVWL}	2.08	—	2.22	V	A
607	V_{DD} rising	V_{LVWL}	2.16	—	2.30	V	C
608	Voltage drop detection time[2]	t_{LVWL}	—	—	10	μsec	C
	Higher LVW detect threshold (LVWV = 1)[1]						
609	V_{DD} falling	V_{LVWH}	2.32	—	2.52	V	A
610	V_{DD} rising	V_{LVWH}	2.36	—	2.56	V	C
611	Voltage drop detection time[2]	t_{LVWH}	—	—	10	μsec	C
612	RF LVD detect threshold, VDD falling[1]	V_{LVDRF}	1.60	1.88	1.97	V	B
613	Voltage drop detection time[2]	t_{LVDRF}	—	—	10	μsec	C
	Power-On Reset Voltage[1]						
614	Rising Voltage to Recover	V_{PORR}	—	—	2.2	V	D
615	Falling Voltage to Reset	V_{PORF}	0.8	—	—	V	D
616	Sensitivity Tolerance	$\Delta V_{MAX-MIN}$	9	10	12	mV/LSB	C
	V_{DD} Voltage, $0\ °C \leq T_A \leq 50\ °C$						
617	Underflow			0			D
618	= 1.8	V_{MIN}	38	58	78		C
619	= 2.1		68	88	108		C
620	= 2.3		98	108	118		C
621	= 2.8	V_{CODE}	153	158	163	LSB	A
622	= 3.0		173	178	183		C
623	= 3.3		203	208	213		C
624	= 3.6	V_{MAX}	228	238	248		C
625	Overflow			255			D

Table 10. Voltage measurement characteristics*...continued*

*1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified. Transfer Function: V = (0.01 V/LSB * V_{CODE}) + 1.22 V*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
626	Sensitivity Tolerance	$\Delta V_{MAX-MIN}$	9	10	12	mV/LSB	C
	V_{DD} Voltage, 40 °C ≤ T_A ≤ 0 °C, 50 °C ≤ T_A ≤ 125 °C					LSB	
627	Underflow			0		LSB	D
628	= 1.8	V_{MIN}	38	58	78	LSB	C
629	= 2.1		68	88	108	LSB	C
630	= 2.3	V_{CODE}	98	108	118	LSB	C
631	= 2.8	V_{CODE}	148	158	168	LSB	C
632	= 3.0	V_{CODE}	168	178	188	LSB	C
633	= 3.3		198	208	218	LSB	C
634	= 3.6	V_{MAX}	228	238	248	LSB	C
635	Overflow			255		LSB	D
	External Voltage (PTA[1:0], monotonic response, conversion is ratiometric to V_{DD})						
636	Gx_{CODE}, where x = 0, 1 refers to PTA0 or PTA1	n	—	1023 (V_{IN}/ V_{DD})	—	count	D
637	Voltage sensitivity	ΔV_{EXT}	—	V_{DD}/1023	—	V/count	D
638	ADC INL	INL	–1	—	+1	LSB	D
639	ADC DNL	DNL	–1	—	+1	LSB	D
	Voltage Measurement						
	(internal voltage or external pin)						
	Sensor measurement time						
640	Single sample, min delay	t_{VM}	—	0.40	0.64	ms	C
641	Content deleted.						
642	Content deleted.						
643	Peak current [3]	I_V	—	2.85	3.86	mA	C
	Power consumption						
	Raw measurement						
644	10-bit, single sample, min delay	Q_V	—	0.23	0.27	µA-sec	C
645	Content deleted.						
646	Content deleted.						
647	Compensation, 8-bit	Q_V	—	0.44	0.50	µA-sec	C
	Basic compensated reading						
648	8-bit, single sample, max delay	Q_V	—	0.67	0.75	µA-sec	C
	Full compensated reading						
649	8-bit, single sample, min delay	Q_V	—	0.67	0.75	µA-sec	C

Table 10. Voltage measurement characteristics*...continued*

$1.8 V \le V_{DD} \le 3.6 V$, $T_L \le T_A \le T_H$, unless otherwise specified. Transfer Function: $V = (0.01 V/LSB * V_{CODE}) + 1.22 V$

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
650	Content deleted.						
651	Content deleted.						
	Linear "bow-tie" limits between –40 °C and 0 °C and between 50 °C and 125 °C.						

[1] Low voltage detection and warning thresholds defined for voltage change rates less than 20 mV/µs. Hysteresis thresholds may decrease above 85 °C.
[2] Response time to VDD of more than 100 mV below the minimum VDD falling threshold.
[3] Peak currents measured as the current over 10 MCU bus cycles immediately after the ADC wakes up the MCU using the external network shown in Figure 10 with R_{BATT} equal to zero-ohm resistance.

8.5 Temperature measurement characteristics

Table 11. Temperature measurement characteristics

$2.3 V \le V_{DD} \le 3.6 V$, $T_L \le T_A \le T_H$, unless otherwise specified. Transfer Function: $T °C = (1 °C/LSB * T_{CODE}) – 55 °C$

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
700	Sensitivity Accuracy, ±	$\Delta T_{MAX-MIN}$	0.93	1	1.08	°C/LSB	C
	Ambient Temperature, °C					LSB	
701	Underflow			0			D
702	= –50	T_{MIN}	0	5	10		C
703	= –40	$T_{RATE-MIN}$	10	15	20		C
704	= –20	T_{CODE}	32	35	38		A
705	= 0	T_{CODE}	52	55	58		C
706	= 25	T_{CODE}	77	80	83		B
707	= 85	T_{CODE}	136	140	144		A
708	= 125	$T_{RATE-MAX}$	175	180	185		B
709	= 150	T_{MAX}[1]	195	205	215		C
710	Overflow			255			D
711	Temperature measurement stability range[2]	T_{STAB}	—	—	2	count	C
	Thermal Shutdown Recovery (TRE = 1)[3]						
712	High Re-Arming Temperature (TRH = 1)	T_{REARMH}	—	—	125	°C	D
713	High Reset Temperature (TRH = 1)	T_{RESETH}	95	—	—	°C	D
714 715	Content deleted.						
	Temperature Measurement						
	Sensor measurement time						
716	Single sample, min delay	t_{TM}	—	0.55	0.71	ms	C
717 718	Content deleted.						
719	Peak current[4]	I_T	—	3.00	3.80	mA	C

Table 11. Temperature measurement characteristics*...continued*

*2.3 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified. Transfer Function: T °C = (1 °C/LSB * T_{CODE}) – 55 °C*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Power consumption						
	Raw measurement						
720	10-bit, single sample, min delay	Q_T	—	0.21	0.25	µA-sec	C
721 722	Content deleted.						
723	Compensation, 8-bit	Q_T	—	0.24	0.56	µA-sec	C
	Basic compensated reading						
724	8-bit, single sample, max delay	Q_T	—	0.63	0.72	µA-sec	C
	Full compensated reading,						
725	8-bit, single sample, min delay	Q_T	—	0.68	0.77	µA-sec	C
726 727	Content deleted.						

[1] Time at T_{MAX} must not exceed 12 events of 15 minutes duration during the product lifetime.
[2] Total range of variation over 30 consecutive measurements, using compensated output format. Single samples @ max. delay setting on each sample.
[3] Temperature shutdown points trimmed at final test. Limits when TRH ($180F bits 6:4) are a default state of 0x03.
[4] Peak currents measured as the current over 10 MCU bus cycles immediately after the ADC wakes up the MCU using the external network shown in Figure 10 with R_{BATT} equal to zero-ohm resistance.

8.6 Pressure measurement characteristics

8.6.1 Pressure measurement characteristic (90 kPa to 1500 kPa range)

Table 12. Pressure measurement characteristic (90 kPa to 1500 kPa range)

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Transfer Function: P kPa = (2.80 kPa/LSB * P_{CODE}) + 87.20 kPa*

#	Characteristic		Symbol	Min	Typ	Max	Units	Notes
900	Sensitivity –40 °C ≤ T_A ≤ 85		$\Delta P_{MAX\text{-}MIN}$	2.70	2.80	2.90	kPa/LSB	C
901	Underflow				0		LSB	D
	Proof pressure, kPa -40 °C ≤ T_A ≤ 85 °C	90	P_{MIN}		1	7		
902		327	P_{CODE}	80	86	92		C
903		564		164	170	176		A
904		801		249	255	261		C
905		1038		334	340	346		C
906		1275		418	424	430		C
		1512	P_{MAX}	503	509			
907	Overflow				511			D
908	Sensitivity T_A = 125 °C		$\Delta P_{MAX–MIN}$	2.65	2.80	2.97	kPa/LSB	C
909	Underflow				0		LSB	D

Table 12. Pressure measurement characteristic (90 kPa to 1500 kPa range)*...continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Transfer Function: P kPa = (2.80 kPa/LSB * P_{CODE}) + 87.20 kPa*

#	Characteristic		Symbol	Min	Typ	Max	Units	Notes
		90	P_{MIN}		1	14		
910		327		80	86	99		C
911		564		164	170	183		C
912	Proof pressure, kPa T_A = 125 °C	801	P_{CODE}	249	255	268		C
913		1038		334	340	353		C
914		1275		418	424	437		C
		1512	P_{MAX}	503	509			
915	Overflow				511			D
916	Pressure measurement stability range		P_{STAB}			6		C
	Interpolated limits between 85 °C and 125 °C							
917	0 g to 500 g		P_{ACC}	0	—	0	Pa/g	C
918	> 500 g		P_{ACC}	–6.5	–4.5	–2	Pa/g	C
919	0 to –500 g		P_{ACC}	0	—	0	Pa/g	C
920	> –500 g		P_{ACC}	2	4.5	6.5	Pa/g	C
	Pressure Measurement							
	Sensor measurement time							
921	Single sample, min delay		t_{PM}	—	0.68	0.85	ms	C
922	Single sample, max delay		t_{PM}	—	3.00	3.80	ms	C
923	Content deleted.							
924	Peak current[1]		I_P	—	2.8	3.15	mA	C
	Power consumption							
	Raw measurement							
925	10-bit, single sample, min delay		Q_P	—	1.10	2.70	µA-sec	C
926	10-bit, single sample, max delay		Q_P	—	2.35	3.60	µA-sec	C
928	Compensation, 9-bit		Q_P	—	2.00	2.27	µA-sec	C
	Basic compensated reading							
927	9-bit, single sample, min delay		Q_P	—	3.10	3.60	µA-sec	C
929	9-bit, single sample, max delay		Q_P	—	4.35	5.00	µA-sec	C
	Full compensated reading							

Table 12. Pressure measurement characteristic (90 kPa to 1500 kPa range)...*continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Transfer Function: P kPa = (2.80 kPa/LSB * P_{CODE}) + 87.20 kPa*

#	Characteristic		Symbol	Min	Typ	Max	Units	Notes
930	9-bit, single sample, min delay		Q_P	—	3.50	4.40	μA-sec	C
931	9-bit, single sample, max delay		Q_P	—	4.75	5.80	μA-sec	C
932	Content deleted.							
	Linear "bow-tie" limits between –40 °C and 0 °C and between 70 °C and 125 °C. Interpolated limits between 85 °C and 125 °C.							

[1] Peak currents measured as the current over 10 MCU bus cycles immediately after the ADC wakes up the MCU using the external network shown in Figure 10 with R_{BATT} equal to zero-ohm resistance.

8.7 Optional acceleration sensor characteristics

8.7.1 Example Z-axis acceleration sensor calculations (similar for X-axis)

As an example, assume that the dynamic firmware routine has returned STEP = 6 indicating offset step 6, and A_{xCODE} = 256. Refer to Table 13 near line 1064 to retrieve the step number 6 Proof Inertia values for A_{xCODE} = 509 and for A_{xCODE} = 1. Then apply Equation (1) to calculate the sensitivity for offset step 6:

$$\begin{aligned} \Delta A_{Z6} &= \frac{(\text{Proof Inertia} @ A_{\text{RATE-MAX}} - \text{Proof Inertia} @ A_{\text{RATE-MIN}})}{(\text{LSB} @ A_{\text{RATE-MAX}} - \text{LSB} @ A_{\text{RATE-MIN}})} \\ &= \frac{(51-(-51))}{(509-1)} \\ &= 0.2\ g\ \text{per}\ \text{A}_{xCODE}\ \text{integer} \end{aligned} \quad (1)$$

Once the sensitivity $\Delta A_{Z\text{-}6}$ has been calculated, the acceleration A_Z can be calculated with the transfer function shown in Equation (2):

$$\begin{aligned} A_Z &= \Delta A_{Z6} \times (A_{xCODE} - \text{LSB}\ @\ A_{\text{RATE-MIN}}) + A_{\text{RATE-MIN}} \\ &= (0.20 \times (256 - 1)) + (-51) \\ &= 0\ g \end{aligned} \quad (2)$$

Another example where STEP has been returned as 15 and A_{xCODE} has been returned as 256:

$$\begin{aligned} \Delta A_{Z15} &= \frac{(\text{Proof Inertia} @ A_{\text{RATE-MAX}} - \text{Proof Inertia} @ A_{\text{RATE-MIN}})}{(\text{LSB} @ A_{\text{RATE-MAX}} - \text{LSB} @ A_{\text{RATE-MIN}})} \\ &= \frac{(402-301)}{(509-1)} \\ &= 0.2\ g\ \text{per}\ \text{A}_{xCODE}\ \text{integer} \end{aligned} \quad (3)$$

Then:

$$\begin{aligned} A_Z &= \Delta A_{Z15} \times (A_{xCODE} - \mathrm{LSB}\ @\ A_{\mathrm{RATE\text{-}MIN}}) + A_{\mathrm{RATE\text{-}MIN}} \\ &= (0.20 \times (256 - 1)) + (301) \\ &= 352\ g \end{aligned} \tag{4}$$

8.7.2 Acceleration measurement characteristics (X-axis, –80 g to +90 g range option)

Table 13. Acceleration measurement characteristics (X-axis –80 g to +90 g range option)

*2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified. Offset Step 7 Transfer Function: A g's = (0.056 g/LSB * A_{CODE}) – 14.2 g*

#1	Characteristic	Symbol	Min	Typ	Max	Units	Notes
1090	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX\text{-}MIN}$	—	0.056	—	g/LSB	D
	Proof Inertia, g, Offset Step 0, –20 °C ≤ T_A ≤ 85 °C					LSB	
1091	Underflow			0			D
	= –84	A_{MIN}		1			
1092	= –77			128			C
1093	= –70	A_{CODE0}	88	255	422		C
1094	= –63			382			C
	= –56	A_{MAX}		509			
1095	Overflow			511			D
	Proof Inertia, g, Offset Step 1, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –74	A_{MIN}		1			
	= –67			128			
	= –60	A_{CODE1}	105	255	405		D
	= –53			382			
	= –46	A_{MAX}		509			
	Proof Inertia, g, Offset Step 2, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –64	A_{MIN}		1			
	= –57			128			
	= –50	A_{CODE2}	123	255	387		D
	= –43			382			
	= –36	A_{MAX}		509			
	Proof Inertia, g, Offset Step 3, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –54	A_{MIN}		1			
	= –47			128			
	= –40	A_{CODE3}	140	255	370		D
	= –33			382			
	= –26	A_{MAX}		509			

Table 13. Acceleration measurement characteristics (X-axis –80 g to +90 g range option)*...continued*

*2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified. Offset Step 7 Transfer Function: A g's = (0.056 g/LSB * A_{CODE}) – 14.2 g*

#1	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Proof Inertia, g, Offset Step 4, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –44	A_{MIN}		1			
	= –37			128			
	= –30	A_{CODE4}	158	255	352		D
	= –23			382			
	= –16	A_{MAX}		509			
	Proof Inertia, g, Offset Step 5, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –34	A_{MIN}		1			
	= –27			128			
	= –20	A_{CODE5}	175	255	335		D
	= –13			382			
	= –6	A_{MAX}		509			
	Proof Inertia, g, Offset Step 6, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –24.2	A_{MIN}		1			
	= –17			128			
	= –10	A_{CODE6}	193	255	317		D
	= –3			382			
	= 4.2	A_{MAX}		509			
1102	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX-MIN}$	0.04	0.056	0.10	g/LSB	C
	Proof Inertia, g, Offset Step 7, –20 °C ≤ T_A ≤ 85 °C					LSB	
1103	Underflow			0			D
	= –14	A_{MIN}		1	71		C
1104	= –7		71	128	185		C
1105	= 0	A_{CODE7}	210	255	300		A
1106	= 7		325	382	439		C
	= 14	A_{MAX}	439	509			C
1107	Overflow			511			D

Table 13. Acceleration measurement characteristics (X-axis –80 g to +90 g range option)*...continued*

*2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified. Offset Step 7 Transfer Function: A g's = (0.056 g/LSB * A_{CODE}) – 14.2 g*

#1	Characteristic	Symbol	Min	Typ	Max	Units	Notes
1108	Sensitivity Tolerance, T_A = –40 °C and 125 °C	$\Delta A_{MAX-MIN}$	0.04	0.056	0.12	g/LSB	D
	Proof Inertia, g, Offset Step 7, –40 °C and 125 °C					LSB	
1109	Underflow			0			D
	= –14	A_{MIN}		1	85		D
1110	= –7		59	128	197		D
1111	= 0	A_{CODE7}	201	255	309		D
1112	= 7		313	392	451		D
	= 14	A_{MAX}	425	509			D
1113	Overflow			511			D
	Proof Inertia, g, Offset Step 8, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –4	A_{MIN}		1			
	= 3			128			
	= 10	A_{CODE8}	193	255	317		D
	= 17			382			
	= 24	A_{MAX}		509			
	Proof Inertia, g, Offset Step 9, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 6	A_{MIN}		1			
	= 13			128			
	= 20	A_{CODE9}	175	255	335		D
	= 27			382			
	= 34	A_{MAX}		509			
	Proof Inertia, g, Offset Step 10, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 16	A_{MIN}		1			
	= 23			128			
	= 30	A_{CODE10}	158	255	352		D
	= 37			382			
	= 44	A_{MAX}		509			
	Proof Inertia, g, Offset Step 11, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 26	A_{MIN}		1			
	= 33			128			
	= 40	A_{CODE11}	140	255	370		D
	= 47			382			
	= 54	A_{MAX}		509			

Table 13. Acceleration measurement characteristics (X-axis –80 g to +90 g range option)...*continued*

*2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified. Offset Step 7 Transfer Function: A g's = (0.056 g/LSB * A_{CODE}) – 14.2 g*

#1	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Proof Inertia, g, Offset Step 12, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 36	A_{MIN}		1			
	= 43			128			
	= 50	A_{CODE12}	123	255	387		D
	= 57			382			
	= 64	A_{MAX}		509			
	Proof Inertia, g, Offset Step 13, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 46	A_{MIN}		1			
	= 53			128			
	= 60	A_{CODE13}	105	255	405		D
	= 67			382			
	= 74	A_{MAX}		509			
	Proof Inertia, g, Offset Step 14, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 56	A_{MIN}		1			
	= 63			128			
	= 70	A_{CODE14}	88	255	422		D
	= 77			382			
	= 84	A_{MAX}		509			
1114	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX-MIN}$	—	0.056	—	g/LSB	C
	Proof Inertia, g, Offset Step 15, –20 °C ≤ T_A ≤ 85 °C					LSB	
1115	Underflow			0			D
	= 66	A_{MIN}					
1116	= 73			128			C
1117	= 80	A_{CODE15}	70	255	440		C
1118	= 87			382			C
	= 94	A_{MAX}		509			
1119	Overflow			511			D
	Linear "bow-tie" limits between –40 °C and –20 °C and between 85 °C and 125 °C. Interpolated limits between –40 °C to –20 °C and between 85 °C to 125 °C.						

8.7.3 Acceleration measurement characteristics (Z-axis, –215 g to +305 g range option)

Table 14. Acceleration measurement characteristics (Z-axis, –215 g to +305 g range option)

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Offset Step 6 Transfer Function: A g's = (0.144 g/LSB * A_{CODE}) – 36.5 g*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
1050	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX\text{-}MIN}$	—	0.144	—	g/LSB	C
	Proof Inertia, g, Offset Step 0, –20 °C ≤ T_A ≤ 85 °C					LSB	
1051	Underflow			0			D
	= –217	A_{MIN}		1			
1052	= –198			128			C
1053	= –180	A_{CODE0}	115	255	395		C
1054	= –162			382			C
	= –143	A_{MAX}		509			
1055	Overflow			511			D
	Proof Inertia, g Offset Step 1, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –187	A_{MIN}		1			
	= –168			128			
	= –150	A_{CODE1}	136	255	374		D
	= –132			382			
	= –113	A_{MAX}		509			
	Proof Inertia, g Offset Step 2, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –157	A_{MIN}		1			
	= –138			128			
	= –120	A_{CODE2}	156	255	354		D
	= –102			382			
	= –83	A_{MAX}		509			
	Proof Inertia, g Offset Step 3, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –127	A_{MIN}		1			
	= –108			128			
	= –90	A_{CODE3}	176	255	334		D
	= –72			382			
	= –53	A_{MAX}		509			

Table 14. Acceleration measurement characteristics (Z-axis, –215 g to +305 g range option)*...continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Offset Step 6 Transfer Function: A g's = (0.144 g/LSB * A_{CODE}) – 36.5 g*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Proof Inertia, g Offset Step 4, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –97	A_{MIN}		1			
	= –78			128			
	= –60	A_{CODE4}	197	255	313		D
	= –42			382			
	= –23	A_{MAX}		509			
	Proof Inertia, g Offset Step 5, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –67	A_{MIN}		1			
	= –48			128			
	= –30	A_{CODE5}	217	255	293		D
	= –12			382			
	= 7	A_{MAX}		509			
1062	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX-MIN}$	0.12	0.144	0.17	g/LSB	C
	Proof Inertia, g, Offset Step 6, –20 °C ≤ T_A ≤ 85 °C					LSB	
1063	Underflow			0			D
	= –37	A_{MIN}		1	43		C
1064	= –18		98	128	158		C
1065	= 0	A_{CODE6}	238	255	272		A
1066	= 18		352	382	412		C
	= 37	A_{MAX}	467	509			C
1067	Overflow			511			D
1068	Sensitivity Tolerance, T_A = –40 °C and 125 °C	$\Delta A_{MAX-MIN}$	0.11	0.144	0.18	g/LSB	D
	Proof Inertia, g, Offset Step 6, –40 °C and 125 °C					LSB	
1069	Underflow			0			D
	= –37	A_{MIN}		1	52		D
1070	= –18		92	128	164		D
1071	= 0	A_{CODE6}	234	255	276		D
1072	= 18		346	382	418		D
	= 37	A_{MAX}	458	509			D
1073	Overflow			511			D

Table 14. Acceleration measurement characteristics (Z-axis, –215 g to +305 g range option)*...continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Offset Step 6 Transfer Function: A g's = (0.144 g/LSB * A_{CODE}) – 36.5 g*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Proof Inertia, g Offset Step 7, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= –7	A_{MIN}		1			
	= 12			128			
	= 30	A_{CODE7}	217	255	293		D
	= 48			382			
	= 67	A_{MAX}		509			
	Proof Inertia, g Offset Step 8, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 23	A_{MIN}		1			
	= 42			128			
	= 60	A_{CODE8}	197	255	313		D
	= 78			382			
	= 97	A_{MAX}		509			
	Proof Inertia, g Offset Step 9, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 53	A_{MIN}		1			
	= 72			128			
	= 90	A_{CODE9}	176	255	334		D
	= 108			382			
	= 127	A_{MAX}		509			
	Proof Inertia, g Offset Step 10, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 83	A_{MIN}		1			
	= 102			128			
	= 120	A_{CODE10}	156	255	354		D
	= 138			382			
	= 157	A_{MAX}		509			
	Proof Inertia, g Offset Step 11, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 113	A_{MIN}		1			
	= 132			128			
	= 150	A_{CODE11}	136	255	374		D
	= 168			382			
	= 187	A_{MAX}		509			

Table 14. Acceleration measurement characteristics (Z-axis, –215 g to +305 g range option)*...continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, unless otherwise specified.

*Offset Step 6 Transfer Function: A g's = (0.144 g/LSB * A_{CODE}) – 36.5 g*

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Proof Inertia, g Offset Step 12, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 143	A_{MIN}		1			
	= 162			128			
	= 180	A_{CODE12}	115	255	395		D
	= 198			382			
	= 217	A_{MAX}		509			
	Proof Inertia, g Offset Step 13, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 173	A_{MIN}		1			
	= 192			128			
	= 210	A_{CODE13}	95	255	415		D
	= 228			382			
	= 247	A_{MAX}		509			
	Proof Inertia, g Offset Step 14, –20 °C ≤ T_A ≤ 85 °C					LSB	
	= 203	A_{MIN}		1			
	= 222			128			
	= 240	A_{CODE14}	74	255	436		D
	= 258			382			
	= 277	A_{MAX}		509			
1074	Sensitivity Tolerance, –20 °C ≤ T_A ≤ 85 °C	$\Delta A_{MAX\text{-}MIN}$	—	0.14	—	g/LSB	C
	Proof Inertia, g, Offset Step 15, –20 °C ≤ T_A ≤ 85 °C					LSB	
1075	Underflow			0			D
	= 233	A_{MIN}		1			
1076	= 252			128			C
1077	= 270	A_{CODE15}	54	255	456		C
1078	= 288			382			C
	= 307	A_{MAX}		509			
1079	Overflow			511			D
	Linear "bow-tie" limits between –40 °C and –20 °C and between 85 °C and 125 °C. Interpolated limits between –40 °C to –20 °C and between 85 °C to 125 °C.						

8.7.4 Accelerometer measurements

Table 15. Accelerometer measurements

2.3 V ≤ V_{DD} ≤ 3.6 V, –20 °C ≤ T_A ≤ 85 °C, unless otherwise specified.

#	Characteristic[1]	Symbol	Min	Typ	Max	Units	Notes
	Accelerometer Measurement (X- or Z-axis)						
	Sensor measurement time						
1150	Single sample, min delay	t_{AM}	—	0.68	0.85	ms	C
1151	Single sample, max delay	t_{AM}	—	3.00	3.80	ms	C
1152	Content deleted.						
1153	Peak current[2]	I_A	—	2.80	3.15	mA	C
	Power consumption						
	Raw measurement						
1154	10-bit, single sample, min delay	Q_A	—	1.10	2.70	μA-sec	C
1155	10-bit, single sample, max delay	Q_A	—	2.35	3.60	μA-sec	C
1157	Compensation, 9-bit	Q_A	—	2.00	2.27	μA-sec	C
	Basic compensated reading						
1156	9-bit, single sample, min delay	Q_A	—	3.10	3.60	μA-sec	C
1158	9-bit, single sample, max delay	Q_A	—	4.35	5.00	μA-sec	C
	Full compensated reading						
1159	9-bit, single sample, min delay	Q_A	—	3.50	4.40	μA-sec	C
1160	9-bit, single sample, max delay	Q_A	—	4.75	5.80	μA-sec	C
1161	Content deleted.						
1162	Acceleration measurement stability range[3]	A_{STAB}	—	—	4	LSB	C
1163	Acceleration cross-axis sensitivity	A_{CROSS}	-5	—	5	%	D
1164	Acceleration sensitivity variation	$\Delta\Delta A$	-15	0	15	%	D

[1] The content of Table 15 are applicable to Table 13 and Table 14.
[2] Peak currents measured as the current over 10 MCU bus cycles immediately after the ADC wakes up the MCU using the external network shown in Figure 10 with R_{BATT} equal to zero-ohm resistance.
[3] Total range of variation over 30 consecutive measurements, using compensated output format. Single samples @ max. delay setting on each sample.

8.8 LFR sensitivity

LFR detection is tested to assure > 90 % message success rate. LFR no detection is tested to assure < 10 % message success rate. In carrier detect mode, the applied input pulse is at least 2x the LFCDTM selected. In all cases, the envelope of the input waveform must have an RC time constant less than 15.3 μs. LF sensitivity limits are measured while the device is in the STOP1 mode, which is characterized as a worst-case condition; sensitivity in the other modes are improved versus the STOP1 modes. LFR sensitivity detection/no detection uses firmware release 2A (Z-axis) or 24 (XZ-axis) or higher.

Table 16. LFR sensitivity

2.3 V ≤ V_{DD} ≤ 3.6 V, –20 °C ≤ T_A ≤ 85 °C, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	LFR Input Sensitivity in carrier mode, 125 kHz carrier,						
	LFCDTM = 256 µs UOS,						
	Very Low Sensitivity, SENS(1:0) = 00, CHK125 = 00						
1180	Detect level, LFA:B	S_{DET_VL}	—	—	60	mV p-p	D
1181	No detect level, LFA:B	S_{NODET_VL}	24	—	—	mV p-p	D
	Low Sensitivity, SENS(1:0) = 01, CHK125 = 00						
1182	Detect level, LFA:B	S_{DET_L}	—	—	14	mV p-p	D
1183	No detect level, LFA:B	S_{NODET_L}	2	—	—	mV p-p	D
	High Sensitivity, SENS[1:0] = 10, CHK125 = 10						
1184	Detect level, LFA:B	S_{DET_H}	—	—	3.0	mV p-p	B
1185	No detect level, LFA:B	S_{NODET_H}	0.5	—	—	mV p-p	B
	Sensitivity Shift in High Sensitivity,						
	SENS[1:0] = 10, CHK125 = 10						
1186	Detect level, LFA:B, (typical difference observed between CHK125 = 00 and 10	S_{DET_H}	—	–0.12	—	mV p-p	C
1187	No detect level, LFA:B, No detect level, LFA:B (typical difference observed between CHK125 = 00 and 10)	S_{NODET_H}	—	–0.12	—	mV p-p	C
	LFR Input Sensitivity in data mode						
	125 kHz carrier, LFCDTM = 64 µsec						
	Valid reception of 10 consecutive frames of 16-bit						
	Manchester bit preamble + 9T SYNC +16-bit ID + 4 bytes of data. Continuously ON						
	High Sensitivity, SENS[1:0] = 10, CHK125 = 10						
1188	Data detect level	S_{PER_H}	—	—	2.5	mV p-p	B
1189	Data no detect level	S_{NOPER_H}	0.25	—	—	mV p-p	B
	LFR Input Sensitivity in data mode						
	125 kHz carrier, LFCDTM = 64 µsec						
	Valid reception of 10 consecutive frames of 16-bit						
	Manchester bit preamble + 9T SYNC +16-bit ID + 4 bytes of data. Continuously ON						
	Low Sensitivity, SENS[1:0] = 01, CHK125 = 00						
1190	Data detect level	S_{PER_L}	—	—	14	mV p-p	C
1191	Data no detect level	S_{NOPER_L}	2	—	—	mV p-p	C

8.9 LFR characteristics

Table 17. LFR characteristics

2.3 V ≤ V_{DD} ≤ 3.6 V, –20 °C ≤ T_A ≤ 85 °C, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	LF Input Signal Characteristics						
	Relative to High Sensitivity Data Mode Always Detect, S_{PER_H}						
1200	Dynamic Range, DEQEN = 0	V_{IN}	56	—	—	dB	C
	LFR Input Signal Characteristics						
	(Manchester Data Mode)						
1201	Modulation Depth (Data 1 to Data 0)/Data 1	M_R	70	—	100	%	C
1202	Data bit time	t_{DATA}	248	256	264	μsec	C
1203	Bit Duty Cycle	M_{DC}	45	—	55	%	C
	LFR Differential Input (LFA to LFB, Figure 6)						
1204	Differential Resistance	R_{LFDF}	0.8	—	4	MΩ	C
1205	Differential Capacitance (C_3)	C_{LFDF}	2	3.8	6	pF	C
	LFR Carrier Frequency Range						
	VALEN = 1, LFCDTM = 256 μsec						
1206	Always accepted carrier	f_{LFC}	121.25	—	128.75	kHz	C
1207	Always rejected carrier, rejected frequencies upper limit	f_{LFCH}	—	—	80	kHz	C
1208	Always rejected carrier, rejected frequencies lower limit	f_{LFCL}	210	—	—	kHz	C
	VALEN = 0, LFCDTM = 256 ms						
1209	High Cutoff Freq, 5 mV p-p input, SENS[1:0] = 00	f_{LFCO}	—	350	—	kHz	D
1210	LFR Detector Power Up Settling Time (2 LFO cycles)	t_{PU}	1.4	2.0	2.6	ms	D
	LFR Preamble Decoder Settling Time						
	Data Mode Only, LFCDTM plus t_{DEC}						
1211	LPSM = 0	t_{DEC}	—	—	200	μsec	D
1212	LPSM = 1	t_{DEC}	—	—	400	μsec	D

8.10 LFR power consumption

Table 18. LFR power consumption

2.3 V ≤ V_{DD} ≤ 3.6 V, –20 °C ≤ T_A ≤ 85 °C, unless otherwise specified. All parameters based on DEQEN = 0 setting.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	LFR Supply Current, Carrier Detect Mode						
	Monitor for carrier with VALEN = 0, LPSM = 1						
1300	Content deleted.						
1301	T_A = –40 °C to 125 °C	I_{LFR}	—	4.8	7.0	μA	C

Table 18. LFR power consumption*...continued*

2.3 V ≤ V_{DD} ≤ 3.6 V, –20 °C ≤ T_A ≤ 85 °C, unless otherwise specified. All parameters based on DEQEN = 0 setting.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Frequency validation with						
	VALEN = 1, LPSM = 1 and CHK125 = 00						
1302	Content deleted.						
1303	T_A = –40 °C to 125 °C	I_{LFR}	—	6.0	7.7	μA	C
	Frequency validation with						
	VALEN = 1, LPSM = 1 and CHK125 = 10						
1304	Content deleted.						
1305	T_A = –40 °C to 125 °C	I_{LFR}	—	6.4	8.1	μA	A
	LFR Supply Current, Manchester Data Mode						
	Decoding of data stream after carrier detected						
1306	Content deleted.						
1307	T_A = –40 °C to 125 °C	I_{LFR}	—	11.3	14.3	μA	C

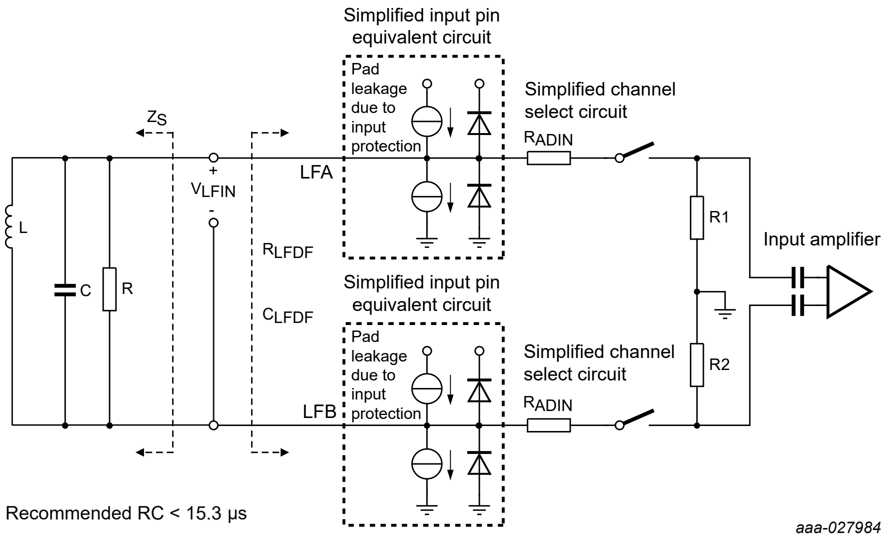


Figure 6. LFR detector input equivalent circuit

8.11 RF output stage

Power output based on using Dynamic RF Power Correction firmware routine.

Output load of 50 Ω resistance as shown in Figure 9 unless otherwise specified.

MCU in STOP1 mode during all RF tests.

RF output terminates when the total RF IDD causes VDD to fall below 1.8 V (VDD = VBATT − IBATT × RBATT). See Figure 10.

8.12 Power consumption RF transmissions

Table 19. RF output stage

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	Nominal Output Power with 50 Ω matching network[1]						
1400	315 MHz, T_A = 25 °C, V_{DD} = 3 V, PWR[4:0] = 01100	P_{RF}	4.4	5.0	7.2	dBm	A
1401	434 MHz, T_A = 25 °C, V_{DD} = 3 V, PWR[4:0] = 01110	P_{RF}	3.8	5.0	7.0	dBm	A
	Nominal Output Power with 50 Ω matching network at maximum power step, PWR[4:0] = 10100.						
1402[2]	Temperature and voltage range defined by Figure 7 and Figure 8.	P_{RF}	3	—	—	dBm	C
	Programmable Power Adjustment						
	PWR[4:0] = 00000 through 11111						
1403	Low-power mode (PWR[4:0] = 00000)	P_{LPM}	—	–10	—	dBm	C
1404	Range (nominal, (PWR[4:0] > 00000)	P_{RF}	–3.5	—	9.1	dBm	C
1405	Adjustment step (–1.5 dBm to +8 dBm)	P_{ADJ}	—	0.4	—	dBm	C
	Programmable Frequency Steps						
	Carrier and FSK Deviation						
1406	(AFREQ[12:0] and BFREQ[12:0])	f_{STEP}	—	3.174	—	kHz	C
1407	External Crystal Frequency[3]	f_{XTAL}	—	26.000	—	MHz	C
1408	Fixed portion of RF start process	$t_{S\text{-}RCTS}$	—	—	300	µsec	C
1409	Variable portion of RF start process	Bits	—	3	—	bit times	D
1410	Total RF transmit start time from write of SEND bit to start of RF @ 2,000 bit/s $t_{RF} = t_{S\text{-}RCTS}$ + (Bits * bit/s^{-1})	t_{RF2}	—	—	1.8	ms	C
1411	Total RF transmit start time from write of SEND bit to start of RF @ 9,600 bit/s $t_{RF} = t_{S\text{-}RCTS}$ + (Bits * bit/s^{-1})	$t_{RF9.6}$	—	—	613	µsec	C
1412	Total RF transmit start time from write of SEND bit to start of RF @ 20,000 bit/s $t_{RF} = t_{S\text{-}RCTS}$ + (Bits * bit/s^{-1})	t_{RF20}	—	—	450	µsec	C
1413	OOK Modulation Depth	M_{OOK}	50	—	—	dBc	C
	Manchester Encoding Data Rate						
1414	Bit Rate Dependent on accuracy of MFO.[4]	DR	—	—	±5	%	C
1415	Modulation Duty cycle (OOK and FSK)	DC	45	50	55	%	C
1416	XTAL Oscillator Margin (over 26 MHz)[5]	ML	600	—	—	Ω	D
	Harmonic 2 Level (315 MHz and 434 MHz bands, with matching reference network)						
1417	Content deleted.						
1418	1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H, power step adjusted to reach the targeted power in each domain	H2	—	–40	–19	dBc	C
	Harmonic 4 Level and above (315 MHz and 434 MHz bands, with matching reference network)						
1419	V_{DD} = 3 V, T_A = 25 °C, PWR[4:0] = 01110	H4	—	–50	–50	dBc	C

Table 19. RF output stage*...continued*

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
1420	1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H, power step adjusted to reach the targeted power in each domain	H4	—	–50	–50	dBc	C
	Harmonic 3 Level (315 MHz and 434 MHz bands, with matching reference network)						
1421	Content deleted.						
1422	1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H, power step adjusted to reach the targeted power in each domain	H3	—	–40	–31	dBc	C
	Noise for BOOST = 0						
	Phase Noise (315 MHz)						
1423	f_{RF} ± 10 kHz	N_{PH}	—	–86	–78	dBc/Hz	C
1424	f_{RF} ± 100 kHz	N_{PH}	—	–94	–88	dBc/Hz	C
1425	f_{RF} ± 1 MHz	N_{PH}	—	–84	–82	dBc/Hz	C
	Phase Noise (434 MHz)						
1426	f_{RF} ± 10 kHz	N_{PH}	—	–90	–85	dBc/Hz	C
1427	f_{RF} ± 100 kHz	N_{PH}	—	–89	–83	dBc/Hz	C
1428	f_{RF} ± 1 MHz	N_{PH}	—	–82	–80	dBc/Hz	C
	Spurious Noise (315 MHz MHz and 434 MHz bands)						
1429	f_{RF} ± f_{REF}	N_{SPUR}	—	–45	–40	dBc	C
	Occupied Bandwidth (Korea, MIC 2007-63)						
1430	For FSK up to ±35 kHz and 19.2 kbit/s and For OOK up to 9600 bit/sec Analyzed setup: RBW = VBW up to 10 kHz, Span up to 1.25 MHz, and MaxHold PA slope @ 3 μs	OBW_K	—	—	200	kHz	C
	Noise for BOOST = 1 Phase Noise (315 MHz)						
1431	f_{RF} ± 10 kHz	N_{PH}	—	–75	–67	dBc/Hz	C
1432	f_{RF} ± 100 kHz	N_{PH}	—	–80	–76	dBc/Hz	C
1433	f_{RF} ± 1 MHz	N_{PH}	—	–95	–93	dBc/Hz	C
	Spurious Noise (315 MHz bands)						
1434	f_{RF} ± f_{REF}	N_{SPUR}	—	–45	–40	dBc	C
	Occupied Bandwidth (Japan, ARIB STD-T93)						
1435	For FSK up to ±45 kHz and 38.4k bit/s PA slope @ 3 μs	OBW_J	—	—	400	kHz	C
1436	For OOK up to 38.4k bit/s Analyzed setup: RBW = VBW up to 30 kHz, Span up to 3.5 MHz, and MaxHold PA slope @ 3 μs	OBW_J	—	—	700	kHz	C

Table 19. RF output stage...*continued*

1.8 V ≤ V_{DD} ≤ 3.6 V, T_L ≤ T_A ≤ T_H, unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
1437	RF Oscillator Frequency Accuracy, XCO[1] excluding external crystal and component variations	f_{XCO}	—	—	±4	ppm	C

[1] Actual final test value degraded by losses in the tester. Correlation study done as characterization to infer actual value. Does not include variances due to application-specific external crystal choice. NDK NX3225SA used during characterizations.
[2] NXP D-FMEA class 306.
[3] Suggested crystal is NDK NX3225SA, 26.000 MHz.
[4] Accuracy of the RF data rate when using the data buffer is dependent on the overall oscillator function (for example, including external crystal and internal circuit tolerances).
[5] Crystal oscillator margin is the value of the total series resistance including the XTAL ESR, that can be applied before the XCO does not start up. This definition does not define any specific start up time.

Table 20. Power consumption RF transmissions

1.8 V ≤ V_{DD} ≤ 3.6 V, T_A = 25 °C unless otherwise specified.

#	Characteristic	Symbol	Min	Typ	Max	Units	Notes
	RF Supply Transmission Current						
	V_{DD} = 3.0 V, PWR[4:0] set for nominal 5 dBm						
1500	315 MHZ Power delta for BOOST = 1	ΔI_{DD}	—	—	0.55	mA	B
	315 MHZ Carrier Frequency, BOOST = 0						
1501	Data 1, FSK, or OOK	I_{DD}	—	5.7	6.3	mA	A
	434 MHZ Carrier Frequency, BOOST = 0						
1502	Data 1, FSK, or OOK	I_{DD}	—	6.5	7.1	mA	A
1503	Content deleted.						
1504	Interframe period, IFPD = 0, 1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H	I_{DD}	—	525	715	µA	C
1505	Interframe period, IFPD = 1, DRLPEN = 1, 1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H	I_{DD}	—	17.5	38.5	µA	C
1506	Content deleted.						
1507	Interframe period, IFPD = 1, DRLPEN = 0, 1.8 ≤ V_{DD} ≤ 3.6, T_L ≤ T_A ≤ T_H	I_{DD}	—	72	125	µA	C

Using the TPMS_RF_DYNAMIC_POWER firmware routine (refer to the FXTH87xx11 and FXTH87xx12 embedded firmware user guide), allows adjusting the power steps in order to compensate for variations of output power versus temperature and voltage. This routine is associated with a part-to-part trimming that initially adjusts the power step to compensate for process variations.

The trim and look-up tables provide typical guaranteed-by-characterization values for power consumption as presented below (average values among 100 parts plus improvements predicted from the design).

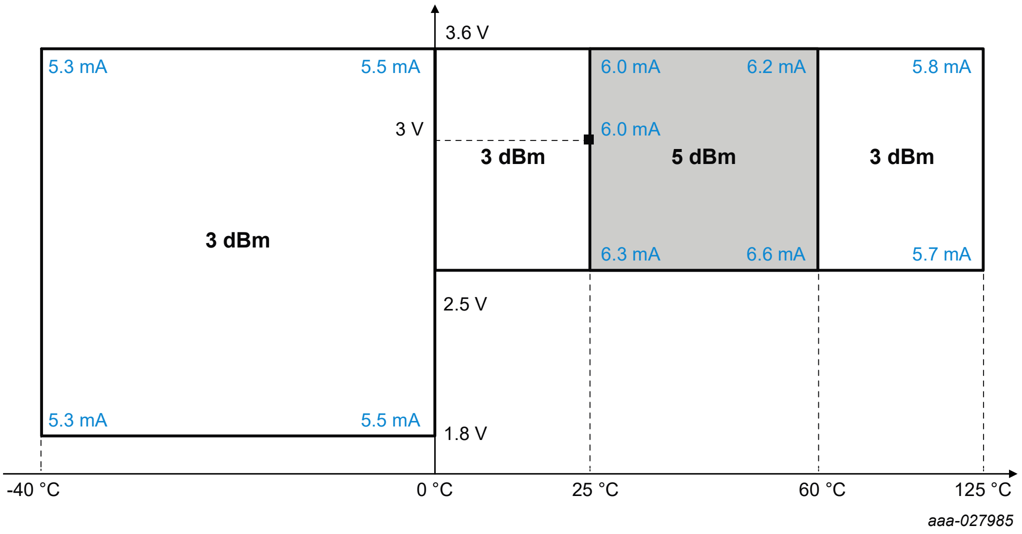


Figure 7. Dynamic power adjustment — 315 MHz

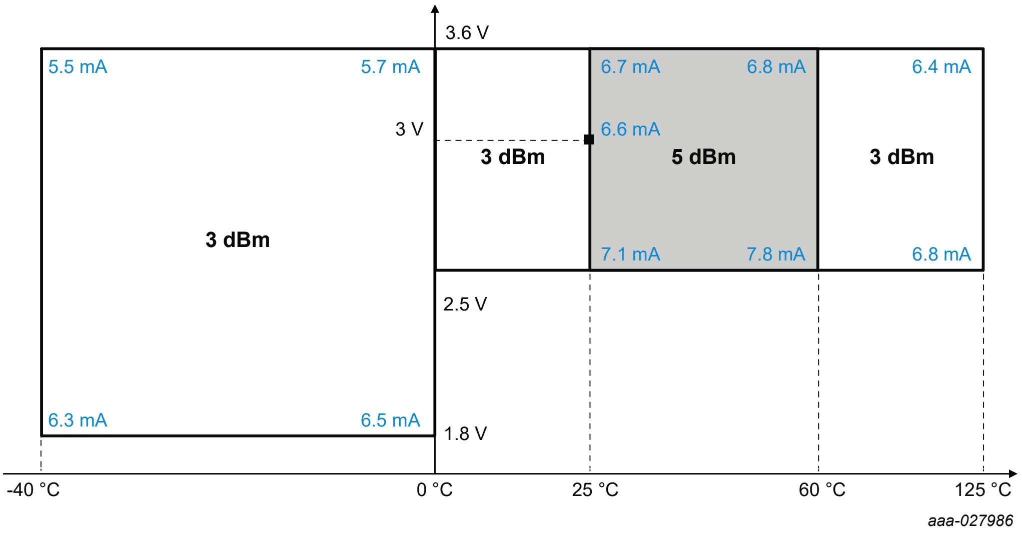


Figure 8. Dynamic power adjustment — 434 MHz

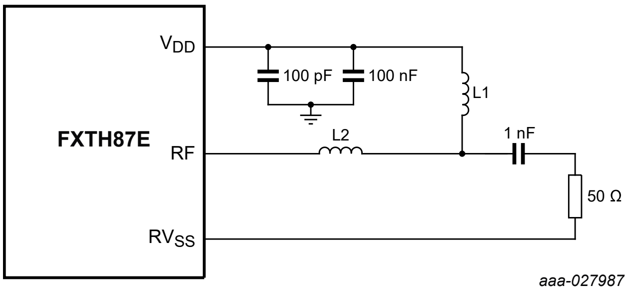


Figure 9. RF output power measurement configuration

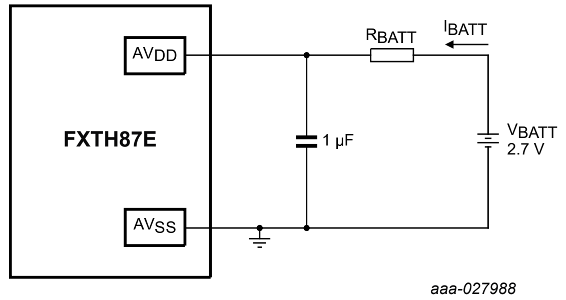


Figure 10. Battery performance test configuration

8.13 Mechanical characteristics

8.13.1 Limiting values (mechanical)

Limiting value ratings are the extreme limits to which the device can be exposed without permanently damaging it. The device contains circuitry to protect the inputs against damage from high static voltages; however, do not apply voltages higher than those shown in the table below. Keep V_{IN} and V_{OUT} within the range $V_{SS} \leq (V_{IN} \text{ or } V_{OUT}) \leq V_{DD}$.

Table 21. Maximum ratings

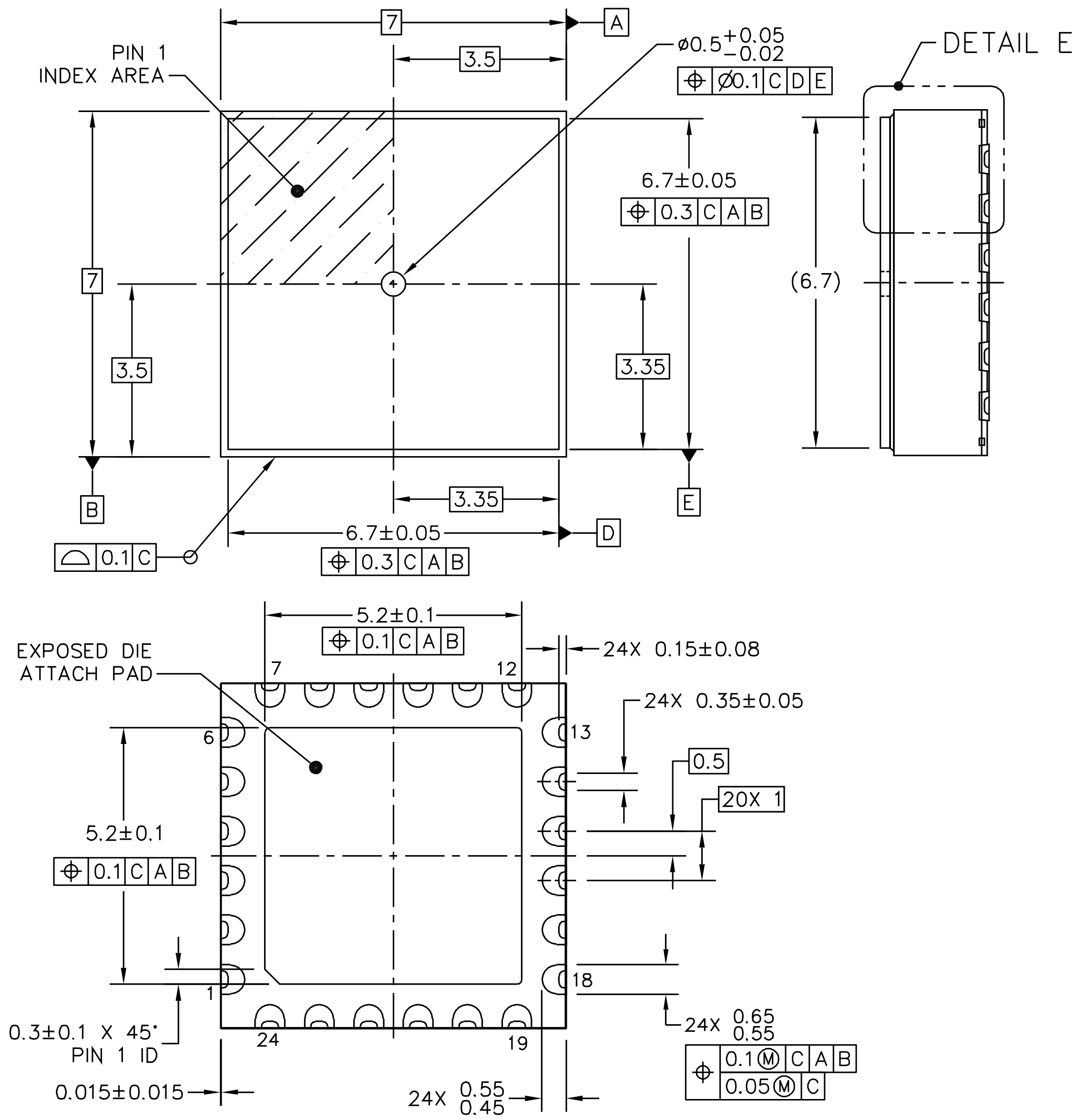
#	Rating	Symbol	Value	Unit	Notes
	Maximum Pressure (absolute)		up to 1500 kPa		
1800	Continuous	p_{max}	2000	kPa	C
1801	Pulsed, 5 seconds, 25 °C	p_{max}	2500	kPa	C
	Centrifugal Force Effects (Z-axis)				
1802	Sustained acceleration (Z-axis)	g_{CENT}	2600	g	C
1803	Powered Shock (peak, 0.1 ms, half-sine, 6-axis)	g_{shock}	6000	g	C
1804	Drop Test (onto concrete, unpowered)	h_{DROP}	1.2	m	C
	Pressure Sensor Resonance				
1805	Resonant frequency	f_{P0}	5.5	MHz	D
1806	Damping Ratio	Q_P	1		D
	Optional X-axis Accelerometer Sensor Resonance				
1807	Resonant frequency (no-peak, over-damped)	f_{X0}	12.5	kHz	D
1808	Damping Ratio	Q_X	0.1		D
1809	Maximum acceleration before limit stops are reached	g_{MAX}	180	g	D
	Z-axis Accelerometer Sensor Resonance				
1810	Resonant frequency (no-peak, over-damped)	f_{Z0}	10.5	kHz	D
1811	Damping Ratio	Q_Z	5		D
1812	Maximum acceleration before limit stops are reached	g_{MAX}	800	g	D
1813	Package Weight	w	0.30	gm	C

8.13.2 Media compatibility

Media compatibility is based on the media and test methods described in NXP specification NXPOMS-999116894-4501[2]. Consult your sales representative for more details and specific requirements.

9 Package outline

Consult the most recently issued package drawing[1] before initiating or completing a design. .



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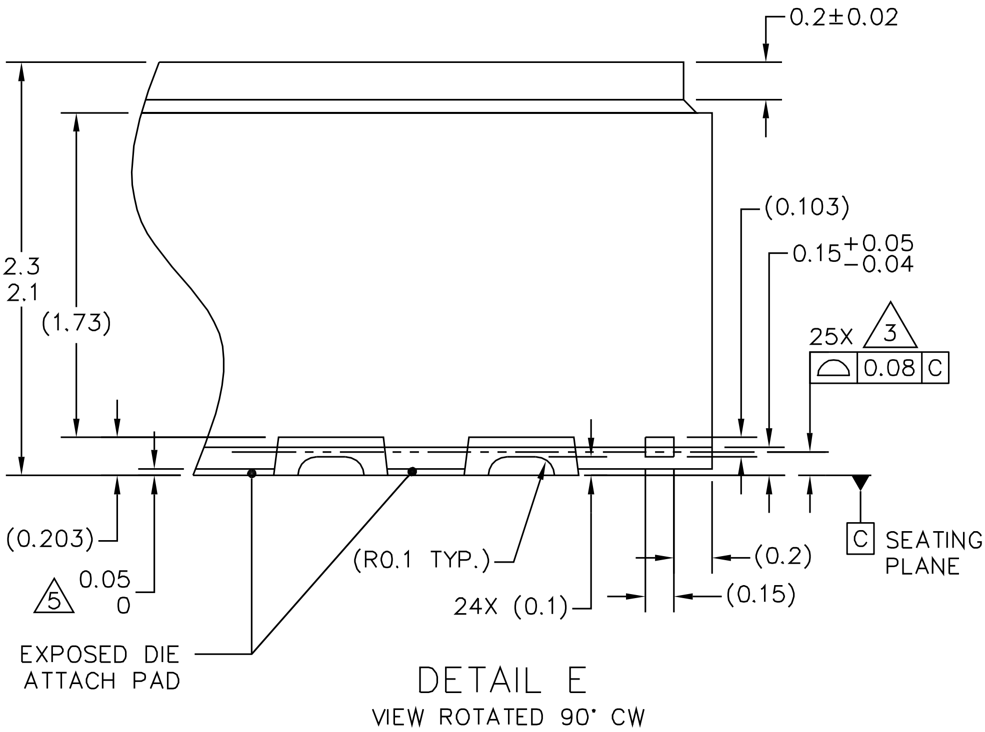
	STANDARD: NON−JEDEC	
	SOT1575−1	08 JAN 2016

Figure 11. Package outline HQFN24 (SOT1575-1)



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	STANDARD: NON−JEDEC	
	SOT1575−1 08 JAN 2016	

Figure 12. Package outline detail HQFN24 (SOT1575-1)

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.

2. INTERPRET DIMENSIONS AND TOLERANCES PER ASME Y14.5M–1994.

3. COPLANARITY APPLIES TO LEADS, AND DIE ATTACH PAD.

4. MIN METAL GAP SHOULD BE 0.2MM.

5. THIS DIMENSION APPLIES ONLY FOR TERMINALS.

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	STANDARD: NON–JEDEC	
	SOT1575–1	08 JAN 2016

Figure 13. Package outline notes HQFN24 (SOT1575-1)

10 Mounting recommendations

The package should be mounted with the pressure port pointing away from the axis of tire rotation so that centrifugal force propels any contaminants out of the pressure port. In cases where the application must orient the pressure port pointing inward, care must be taken to assure that no contaminants accumulate inside the pressure port.

A plugged port exhibits no change in pressure and can be cross-checked in the user's software using the method described in the *FXTH87E Hardware Reference Manual*[3].

Refer to application note AN1902[4] for proper printed circuit board attributes and recommendations.

11 References

The features and operations of the FXTH87EK116 are described in various reference manuals, user guides, and application notes. To find the most-current versions of these documents:

1. Go to the FXTH87E Tire Pressure Sensor Monitors (TPMS) Family page on NXP.com.
2. Select the documentation tab and review the related documentation.

Contact NXP sales representatives for performance attributes such as electrical, mechanical, and time-based characteristics.

[1] SOT1575-1 — https://www.nxp.com/docs/en/package-information/SOT1575-1.pdf

[2] NXPOMS-999116894-4501 — Media Test for TPMS MCM Automotive Pressure Sensors

[3] FXTH87E, Family of Tire Pressure Monitor Sensors - Reference Manual
FXTH87E Tire Pressure Monitor Sensors Reference manual

[4] AN1902 — Assembly guidelines for QFN (quad flat no-lead) and SON (small outline no-lead) packages
https://www.nxp.com/docs/en/application-note/AN1902.pdf

[5] FXTH87E Tire Pressure Monitor Sensor (TPMS) Family webpage
FXTH87E Tire Pressure Monitor Sensor (TPMS) Family

12 Revision history

Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
FXTH87EK116 v.2.1	20210625	Product data sheet	—	FXTH87EK116 v.2
Modifications	• Section 3.1, Table 2, corrected typo in part number from "FXTH87E116T1" to "FXTH87EK116T1".			
FXTH87EK116 v.2	20210420	Product data sheet	—	FXTH87EK116 v.1.5
FXTH87EK116 v.1.5	20201030	Objective data sheet	—	—

13 Legal information

13.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

13.2 Definitions

Draft — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

Short data sheet — A short data sheet is an extract from a full data sheet with the same product type number(s) and title. A short data sheet is intended for quick reference only and should not be relied upon to contain detailed and full information. For detailed and full information see the relevant full data sheet, which is available on request via the local NXP Semiconductors sales office. In case of any inconsistency or conflict with the short data sheet, the full data sheet shall prevail.

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Date of release: 25 June 2021
Document identifier: FXTH87EK116