

Attendo Carry Transmitter unit Circuit Description

CR2450 is coin type battery for power supply of the whole unit. It's nominal voltage is 3V and capacity is 560mAh.

U1 ATtiny13V is MCU, it control the RF transmitter IC IA4220. the MCU has flash memory and EEPROM internally. The EEPROM can store the ID number of the unit.

IA4220 is the RF transmitter IC, it consists of RF Synthesizer, RF VCO, Controller, RF AMP with gain adjustable and crystal oscillator.

10MHz crystal is for IA4220 and MCU.

The antenna is a PCB loop antenna. It is permanently attached on the RF Module.

IA4220/21 Universal ISM Band FSK Transmitters

DESCRIPTION

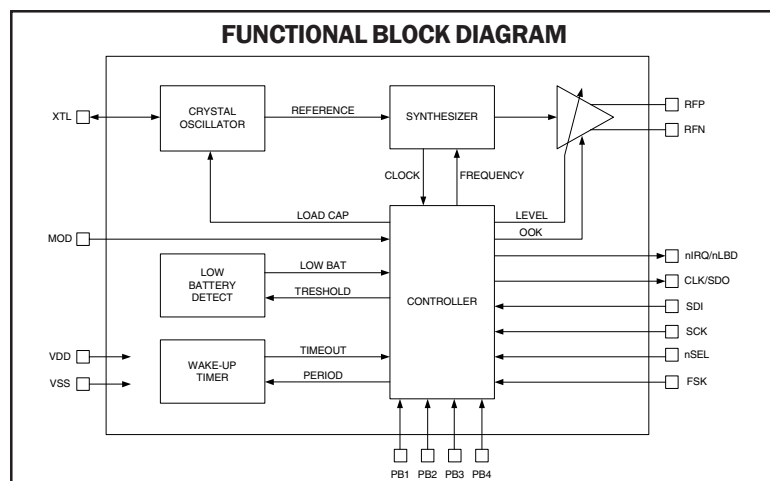
Integration's IA4220 and IA4221 are single chip, low power, multi-channel FSK transmitters designed for use in applications requiring FCC or ETSI conformance for unlicensed use in the 315, 433, 868, and 915 MHz bands. Used in conjunction with IA4320, Integration's FSK receiver, the IA4220/21 transmitters feature EZRadio™ technology, which produces a flexible, low cost, and highly integrated solution that does not require production alignments. All required RF functions are integrated. Only an external crystal and bypass filtering are needed for operation. The IA4221 builds on the features presented by the IA4220 by offering higher output power and an improved phase noise characteristic. The IA4221 shares the same pinout and control command set as the IA4220. The IA4221 offers all of the frequencies as the IA4220, with the exception of the 315 MHz band.

The IA4220/21 feature a completely integrated PLL for easy RF design, and their rapid settling time allows for fast frequency hopping, bypassing multipath fading and interference to achieve robust wireless links. In addition, highly stable and accurate FSK modulation is accomplished by direct closed-loop modulation with bit rates up to 256 kbps. The PLL's high resolution allows the usage of multiple channels in any of the bands.

The integrated power amplifier of the transmitters has an open-collector differential output and can directly drive a loop antenna with programmable output level. No additional matching network is required. An automatic antenna tuning circuit is built in to avoid costly trimming procedures and de-tuning due to the "hand effect".

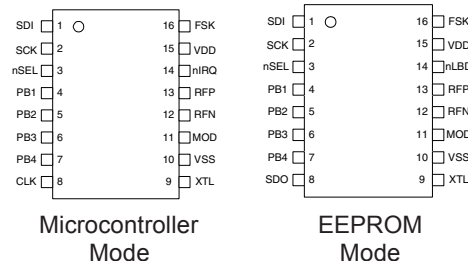
For low-power applications, the device supports automatic activation from sleep mode. Active mode can be initiated by several wake-up events (on-chip timer timeout, low supply voltage detection, or activation of any of the four push-button inputs).

The IA4220/21's on-chip digital interface supports both a microcontroller mode and an EEPROM mode. The latter allows complete data transmitter operation without a microcontroller (both control commands and data are read from the EEPROM). Any wake-up event can start a transmission of the corresponding data stored in the EEPROM.



IA4220/21

PIN ASSIGNMENT



See back page for ordering information.

FEATURES

- Fully integrated (low BOM, easy design-in)
- No alignment required in production
- Fast settling, programmable, high-resolution PLL
- Fast frequency hopping capability
- Stable and accurate FSK modulation with programmable deviation
- High bit rate (up to 256 kbps)
- Direct loop antenna drive
- Automatic antenna tuning circuit
- Programmable output power level
- Alternative OOK support
- EEPROM mode supported
- SPI bus for applications with microcontroller
- Clock output for microcontroller
- Integrated programmable crystal load capacitor
- Power-saving sleep mode
- Multiple event handling options for wake-up activation
- Push-button event handling with switch de-bounce
- Wake-up timer
- Low battery detection
- 2.2 to 5.4 V supply voltage
- Low power consumption
- Low standby current (0.3 μ A)
- Compact 16-pin TSSOP package

TYPICAL APPLICATIONS

- Remote control
- Home security and alarm
- Wireless keyboard/mouse and other PC peripherals
- Toy control
- Remote keyless entry
- Tire pressure monitoring
- Telemetry
- Personal/patient data logging
- Remote automatic meter reading

DETAILED FEATURE-LEVEL DESCRIPTION

The IA4220 FSK transmitter is designed to cover the unlicensed frequency bands at 315, 433, 868, and 915 MHz. The IA4221 is designed to cover the 433, 868, and 915 MHz bands. The devices facilitate compliance with FCC and ETSI requirements.

PLL

The programmable PLL synthesizer determines the operating frequency, while preserving accuracy based on the on-chip crystal-controlled reference oscillator. The PLL's high resolution allows the usage of multiple channels in any of the bands. The FSK deviation is selectable (from 30 to 240 kHz with 30 kHz increments) to accommodate various bandwidth, data rate and crystal tolerance requirements, and it is also highly accurate due to the direct closed-loop modulation of the PLL. The transmitted digital data can be sent asynchronously through the FSK pin or over the control interface using the appropriate command.

The RF VCO in the PLL performs automatic calibration, which requires only a few microseconds. To ensure proper operation in the programmed frequency band, the RF VCO is automatically calibrated upon activation of the synthesizer. If temperature or supply voltage change significantly, VCO recalibration can be invoked easily. Recalibration can be initiated at any time by switching the synthesizer off and back on again.

RF Power Amplifier (PA)

The power amplifier has an open-collector differential output and can directly drive a loop antenna with a programmable output power level. An automatic antenna tuning circuit is built in to avoid costly trimming procedures and the so-called "hand effect."

The transmitters can operate in On-Off Keying (OOK) mode by switching the power amplifier on and off. When the appropriate control bit is set using the *Power Setting Command*, the FSK pin becomes an enable input (active high) for the power amplifier.

Crystal Oscillator

The chip has a single-pin crystal oscillator circuit, which provides a 10 MHz reference signal for the PLL. To reduce external parts and simplify design, the crystal load capacitor is internal and programmable. Guidelines for selecting the appropriate crystal can be found later in this datasheet.

The transmitters can supply the clock signal for the microcontroller, so accurate timing is possible without the need for a second crystal. When the chip receives a *Sleep Command* from the microcontroller and turns itself off, it provides several further clock pulses ("clock tail") for the microcontroller to be able to go to idle or sleep mode. The length of the clock tail is programmable.

Low Battery Voltage Detector

The low battery voltage detector circuit monitors the supply voltage and generates an interrupt if it falls below a programmable threshold

level.

Wake-Up Timer

The wake-up timer has very low current consumption (1.5 uA typical) and can be programmed from 1 ms to several days with an accuracy of $\pm 5\%$.

It calibrates itself to the crystal oscillator at every startup, and then every 30 seconds. When the oscillator is switched off, the calibration circuit switches on the crystal oscillator only long enough for a quick calibration (a few milliseconds) to facilitate accurate wake-up timing.

Event Handling

In order to minimize current consumption, the device supports sleep mode. Active mode can be initiated by several wake-up events: timeout of wake-up timer, detection of low supply voltage, pressing any of the four push-button inputs, or through the serial interface. The push-button inputs can be driven by a logic signal from a microcontroller or controlled directly by normally open switches. Pull-up resistors are integrated.

If any wake-up event occurs, the wake-up logic generates an interrupt, which can be used to wake up the microcontroller, effectively reducing the period the microcontroller has to be active. The cause of the interrupt can be read out from the transmitters by the microcontroller through the nIRQ pin.

Interface

An SPI compatible serial interface lets the user select the operating frequency band and center frequency of the synthesizer, polarity and deviation of FSK modulation, and output power level. Division ratio for the microcontroller clock, wake-up timer period, and low battery detector threshold are also programmable. Any of these auxiliary functions can be disabled when not needed. All parameters are set to default after power-on; the programmed values are retained during sleep mode.

EEPROM Mode

In simple applications, the on-chip digital controller provides the transmitters with direct interface to a serial (SPI) EEPROM. In this case, no external microcontroller is necessary. Wake-up events initiate automatic readout of the assigned command sequence from EEPROM memory. For every event, there is a dedicated starting address available in the EEPROM.

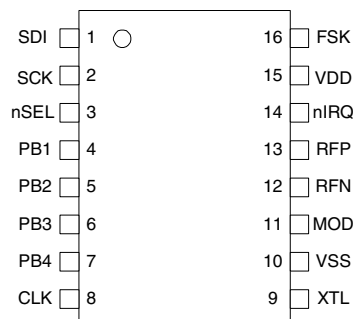
Programming the EEPROM is very simple. Any control command can be programmed in the EEPROM sequentially (same as in microcontroller mode).

The internal power-on reset (POR) is a dedicated event, which can be used to program the basic settings of the transmitters. In this case the chip starts to read out the preprogrammed data from the 00h address in EEPROM. Data can be transmitted with the help of the *Data Transmit Command*, which tells the transmitters how many bytes must be transmitted. The whole process finishes with a *Sleep Command*.

PACKAGE PIN DEFINITIONS, MICROCONTROLLER MODE

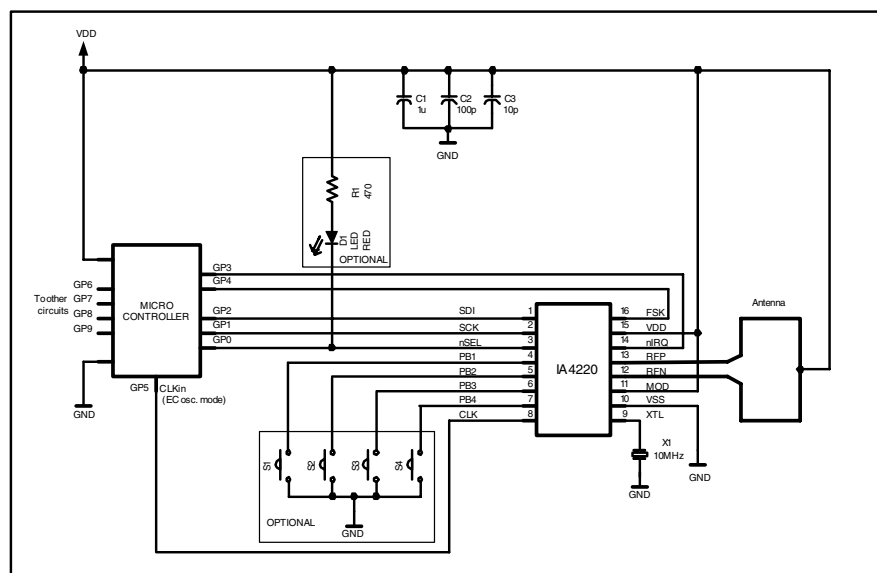
Pin type key: D=digital, A=analog, S=supply, I=input, O=output, IO=input/output

Microcontroller Mode Pin Assignment



Pin	Name	Type	Function
1	SDI	DI	Data input of serial control interface
2	SCK	DI	Clock input of serial control interface
3	nSEL	DI	Chip select input of serial control interface (active low)
4	PB1	DI	Push-button input #1 (active low with internal pull-up resistor)
5	PB2	DI	Push-button input #2 (active low with internal pull-up resistor)
6	PB3	DI	Push-button input #3 (active low with internal pull-up resistor)
7	PB4	DI	Push-button input #4 (active low with internal pull-up resistor)
8	CLK	DO	Microcontroller clock (1 MHz-10 MHz)
9	XTL	AIO	Crystal connection (other terminal of crystal to VSS)
10	VSS	S	Ground reference
11	MOD	DI	Connect to logic high (microcontroller mode)
12	RFN	AO	Power amplifier output (open collector)
13	RFP	AO	Power amplifier output (open collector)
14	nIRQ	DO	Interrupt request output for microcontroller (active low) and status read output
15	VDD	S	Positive supply voltage
16	FSK	DI	Serial data input for FSK modulation

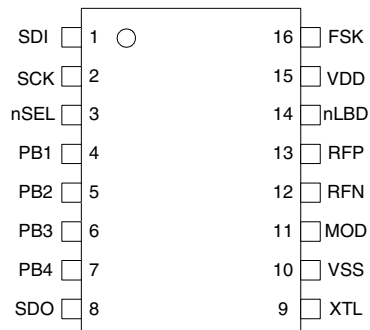
Typical Application, Microcontroller Mode



PACKAGE PIN DEFINITIONS, EEPROM MODE

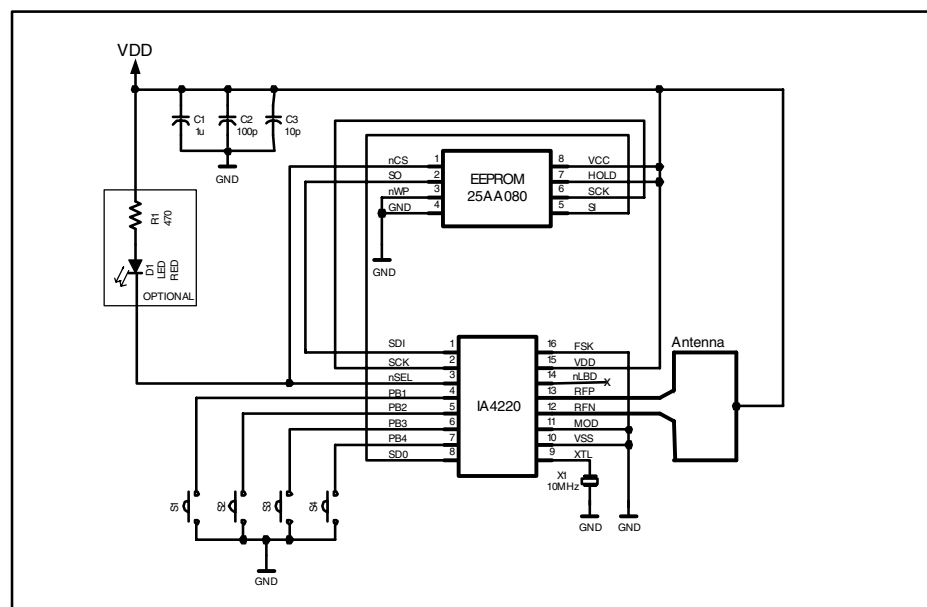
Pin type key: D=digital, A=analog, S=supply, I=input, O=output, IO=input/output

EEPROM Mode Pin Assignment



Pin	Name	Type	Function
1	SDI	DI	Data input of serial control interface
2	SCK	DO	Clock output of serial control interface
3	nSEL	DO	Chip select output of serial control interface (active low)
4	PB1	DI	Push-button input #1 (active low with internal pull-up resistor)
5	PB2	DI	Push-button input #2 (active low with internal pull-up resistor)
6	PB3	DI	Push-button input #3 (active low with internal pull-up resistor)
7	PB4	DI	Push-button input #4 (active low with internal pull-up resistor)
8	SDO	DO	Data output of serial control interface
9	XTL	AIO	Crystal connection (other terminal of crystal to VSS)
10	VSS	S	Ground reference
11	MOD	DI	Connect to logic low (EEPROM mode)
12	RFN	AO	Power amplifier output (open collector)
13	RFP	AO	Power amplifier output (open collector)
14	nLBD	DO	Low battery voltage detector output (active low)
15	VDD	S	Positive supply voltage
16	FSK	DI	Not used, connect to VDD or VSS

Typical Application, EEPROM Mode



GENERAL DEVICE SPECIFICATION

All voltages are referenced to V_{ss} , the potential on the ground reference pin VSS.

Absolute Maximum Ratings (non-operating)

Symbol	Parameter	Min	Max	Units
V_{dd}	Positive supply voltage	-0.5	6.0	V
V_{in}	Voltage on any pin except open collector outputs	-0.5	$V_{dd}+0.5$	V
V_{oc}	Voltage on open collector outputs	-0.5	6.0	V
I_{in}	Input current into any pin except VDD and VSS	-25	25	mA
ESD	Electrostatic discharge with human body model		1000	V
T_{st}	Storage temperature	-55	125	°C
T_{ld}	Lead temperature (soldering, max 10 s)		260	°C

Recommended Operating Range

Symbol	Parameter	Min	Max	Units
V_{dd}	Positive supply voltage	2.2	5.4	V
V_{oc}	Voltage on open collector outputs (Max 6.0 V)	$V_{dd} - 1$	$V_{dd} + 1$	V
T_{op}	Ambient operating temperature	-40	85	°C

ELECTRICAL SPECIFICATION

(Min/max values are valid over the whole recommended operating range, typ conditions: $T_{op} = 27\text{ °C}$; $V_{dd} = V_{oc} = 2.7\text{ V}$)

DC Characteristics

Symbol	Parameter		Conditions/Notes	Min	Typ		Max	Units
					IA4220	IA4221		
$I_{dd_TX_0}$	Supply current (TX mode, $P_{out} = 0\text{ dBm}$)	315 MHz band	Active state with 0 dBm output power		9	n/a		mA
		433 MHz band			10	12		
		868 MHz band			12	14		
		915 MHz band			13	15		
$I_{dd_TX_PMAX}$	Supply current (TX mode, $P_{out} = P_{max}$)	315 MHz band	Active state with maximum output power		11	n/a		mA
		433 MHz band			12	21		
		868 MHz band			14	23		
		915 MHz band			15	24		
I_{pd}	Standby current in sleep mode (Note 1)		All blocks disabled		0.3			µA
I_{wt}	Wake-up timer current consumption				1.5			µA
I_{lb}	Low battery detector current consumption				0.5			µA
I_x	Idle current		Only crystal oscillator is on		1.5			mA
V_{lba}	Low battery detection accuracy				75			mV
V_{lb}	Low battery detector threshold		Programmable in 0.1 V steps	2.2			5.3	V
V_{il}	Digital input low level						$0.3 \cdot V_{dd}$	V
V_{ih}	Digital input high level			$0.7 \cdot V_{dd}$				V
I_{il}	Digital input current		$V_{il} = 0\text{ V}$	-1			1	µA
I_{ih}	Digital input current		$V_{ih} = V_{dd}$, $V_{dd} = 5.4\text{ V}$	-1			1	µA
V_{ol}	Digital output low level		$I_{ol} = 2\text{ mA}$				0.4	V
V_{oh}	Digital output high level		$I_{oh} = -2\text{ mA}$	$V_{dd}-0.4$				V

Note for table above is on page 7.

AC Characteristics

Symbol	Parameter	Conditions/Notes	Min		Typ		Max		Units
			IA4220	IA4221	IA4220	IA4221	IA4220	IA4221	
f_{ref}	PLL reference frequency	Crystal operation mode is parallel (Note 2)	8		10		12		MHz
f_o	Output frequency (programmable)	315 MHz band, 2.5 kHz resolution 433 MHz band, 2.5 kHz resolution 868 MHz band, 5.0 kHz resolution 915 MHz band, 7.5 kHz resolution	310.24				319.75		MHz
			430.24				439.75		
			860.48				879.51		
			900.72				929.27		
t_{lock}	PLL lock time	Frequency error < 10 kHz after 10 MHz step			20				μ s
t_{sp}	PLL startup time	After turning on from idle mode, with crystal oscillator already stable					250		μ s
I_{OUT}	Open collector output current (Note 3)	At all bands	0.1	0.5			2.5	6	mA
P_{max}	Available output power	With opt. antenna impedance (Note 4)			3	8			dBm
P_{out}	Typical output power	Selectable in 3 dB steps (Note3)	$P_{max}-21$				P_{max}		dBm
P_{sp}	Spurious emission	At max power with loop antenna (Note 5)					-50		dBc
C_o	Output capacitance (set by the automatic antenna tuning circuit)	At low bands	1.5		2.3		3.1		pF
		At high bands	1.6		2.2		2.8		
Q_o	Quality factor of the output capacitance		16		18		22		
L_{out}	Output phase noise	100 kHz from carrier 1 MHz from carrier			-75 -85				dBc/Hz
BR_{FSK}	FSK bit rate						256		kbps
BR_{OOK}	OOK bit rate						512		kbps
df_{fsk}	FSK frequency deviation	Programmable in 30 kHz steps	30				240		kHz
C_{xl}	Crystal load capacitance, see crystal sel. guide p19	Programmable in 0.5 pF steps, tolerance +/- 10%	8.5				16		pF
t_{POR}	Internal POR timeout (Note 6)	After V_{dd} has reached 90% of final value					100		ms
t_{sx}	Crystal oscillator startup time	Crystal ESR < 100 Ω					5		ms
t_{PBt}	Wake-up timer clock period	Calibrated every 30 seconds	0.96				1.08		ms
$t_{wake-up}$	Programmable wake-up time		1				$2 \cdot 10^9$		ms
$C_{in,D}$	Digital input capacitance						2		pF
$t_{r,f}$	Digital output rise/fall time	15 pF pure capacitive load					10		ns

All notes for table above are on page 7.

Note 1: Expected battery life is above 2 years with a 60-second wake-up period for sending 100 byte long packets at 19.2 kbps with +3 dBm output power in the 915 MHz band, using a CR2032 battery (225 mAh capacity).

Note 2: Not using 10 MHz crystal is allowed but not recommended because all crystal-referred timing and frequency parameters will change accordingly.

Note 3: Adjustable in 8 steps.

Note 4: Optimal antenna admittance/impedance for the IA4220:

	Yantenna [S]	Zantenna [Ohm]	Lantenna [nH]
315 MHz	9E-4-j4.5E-3	43+j214	112.00
424 MHz	8.4E-4-j6.25E-3	21+j157	59.00
868 MHz	7.6E-4-j1.2E-2	5.3+j83	15.30
915 MHz	7.5E-4-j1.25E-2	4.8+j80	13.90

Optimal antenna admittance/impedance for the IA4221:

	Yantenna [S]	Zantenna [Ohm]	Lantenna [nH]
315 MHz			
424 MHz	1.3E-3-j6.3E-3	31+j152	58.00
868 MHz	1.35E-3-j1.2E-2	9+j82	15.20
915 MHz	1.45E-3-j1.3E-2	8.7+j77	13.60

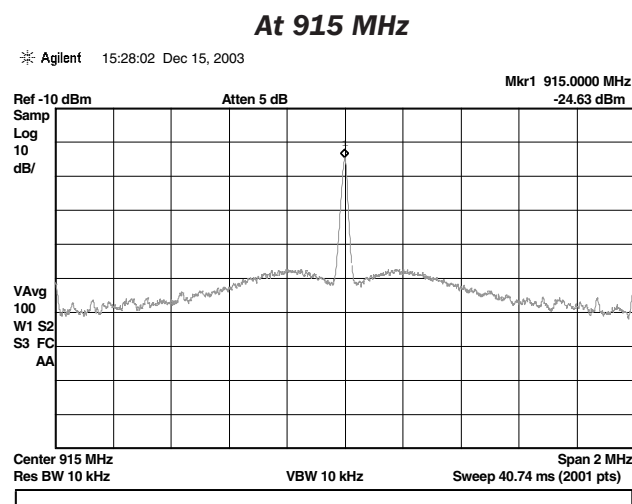
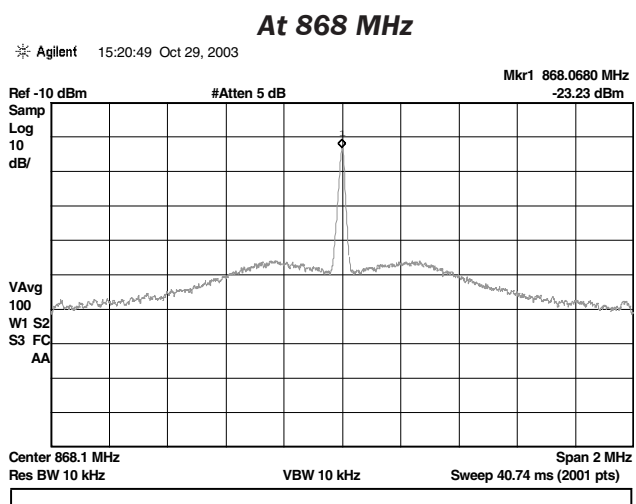
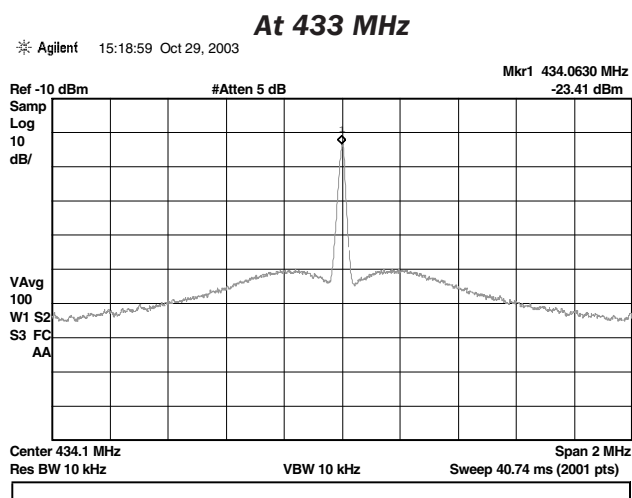
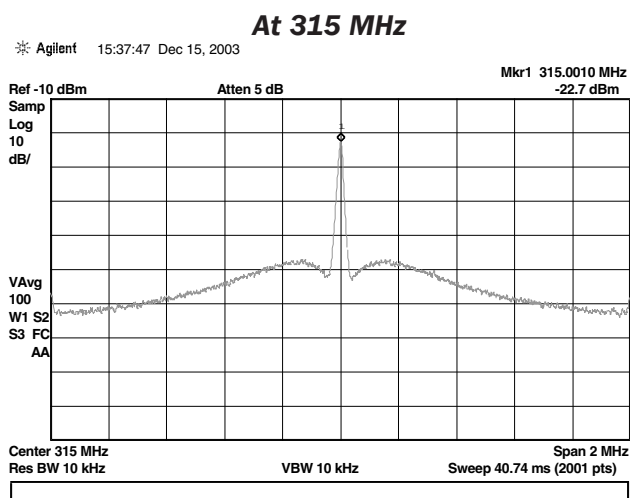
Note 5: With selective resonant antennas (see: Application Notes available from <http://www.integration.com>).

Note 6: During this period, no commands are accepted by the chip.

TYPICAL PERFORMANCE DATA

Unmodulated RF Spectrum

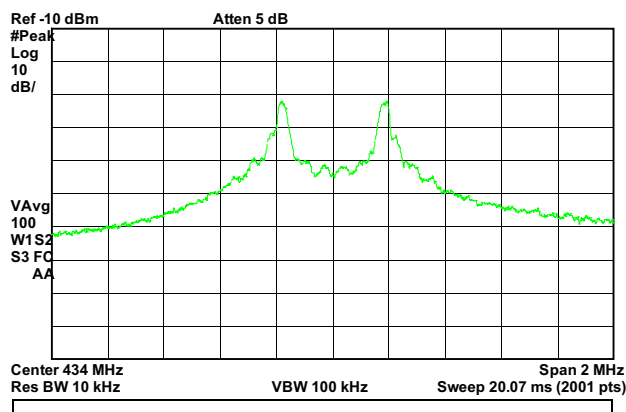
The output spectrum is measured at different frequencies. The output is loaded with 50 Ohms through a matching network.



Modulated RF Spectrum

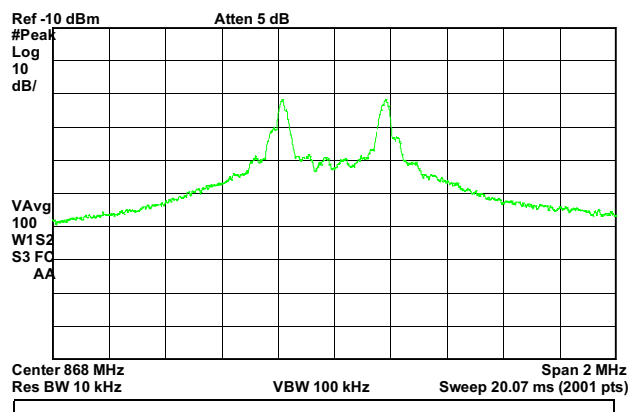
At 433 MHz with 180 kHz Deviation at 64 kbps

Agilent 15:46:09 Oct 29, 2003



At 868 MHz with 180 kHz Deviation at 64 kbps

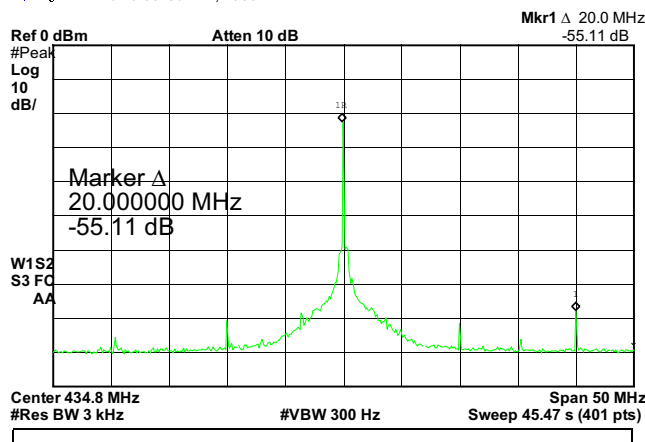
Agilent 15:43:45 Oct 29, 2003



Other Important Characteristics

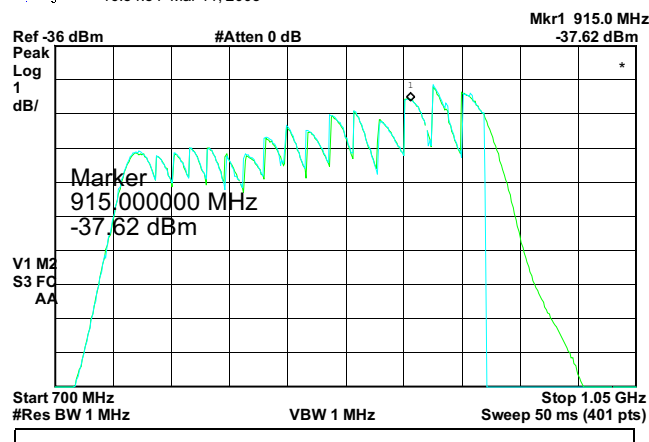
Spurious RF Spectrum with 10 MHz CLK Output Enabled at 433 MHz

Agilent 16:29:03 Jun 17, 2003



Antenna Tuning Characteristics 750–970 MHz

Agilent 16:54:54 Mar 11, 2003



The antenna tuning characteristics was recorded in “max-hold” state of the spectrum analyzer. During the measurement, the transmitters were forced to change frequencies by forcing an external reference signal to the XTL pin. While the carrier was changing the antenna tuning circuit switched through all the available states of the tuning circuit. The graph clearly demonstrates that while the complete output circuit had about a 40 MHz bandwidth, the tuning allows operating in a 220 MHz band. In other words the tuning circuit can compensate for 25% variation in the resonant frequency due to any process or manufacturing spread.

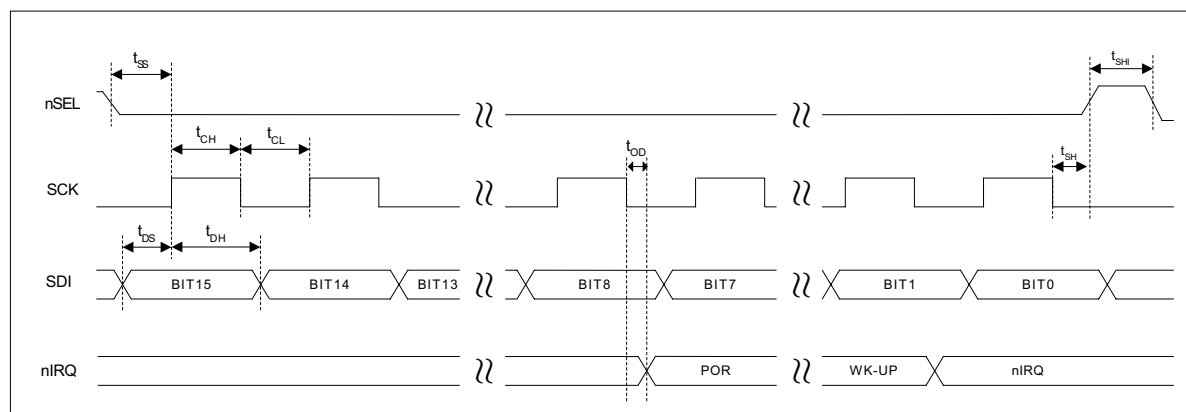
CONTROL INTERFACE

Commands to the transmitters are sent serially. Data bits on pin SDI are shifted into the device upon the rising edge of the clock on pin SCK whenever the chip select pin nSEL is low. When the nSEL signal is high, it initializes the serial interface. The number of bits sent is an integer multiple of 8. All commands consist of a command code, followed by a varying number of parameter or data bits. All data are sent MSB first (e.g. bit 15 for a 16-bit command). Bits having no influence (don't care) are indicated with X. The Power On Reset (POR) circuit sets default values in all control and command registers.

Timing Specification

Symbol	Parameter	Minimum Value [ns]
t_{CH}	Clock high time	25
t_{CL}	Clock low time	25
t_{SS}	Select setup time (nSEL falling edge to SCK rising edge)	10
t_{SH}	Select hold time (SCK falling edge to nSEL rising edge)	10
t_{SHI}	Select high time	25
t_{DS}	Data setup time (SDI transition to SCK rising edge)	5
t_{DH}	Data hold time (SCK rising edge to SDI transition)	5
t_{OD}	Data delay time	10
t_{BL}	Push-button input low time	25

Timing Diagram



Control Commands

Control Command		Related Parameters/Functions
1	Configuration Setting Command	Frequency band, microcontroller clock output, crystal load capacitance, frequency deviation
2	Power Management Command	Crystal oscillator, synthesizer, power amplifier, low battery detector, wake-up timer, clock output buffer
3	Frequency Setting Command	Carrier frequency
4	Data Rate Command	Bit rate (at EEPROM mode only)
5	Power Setting Command	Nominal output power, OOK mode
6	Low Battery Detector Command	Low battery threshold limit
7	Sleep Command	Length of the clock tail after power down
8	Push-Button Command	Push-button related functions
9	Wake-Up Timer Command	Wake-up time period
10	Data Transmit Command	Data transmission
11	Status Register Command	Transmitter status read

Note: In the following tables the POR column shows the default values of the command registers after power-on.

1. Configuration Setting Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	0	0	b1	b0	d2	d1	d0	x3	x2	x1	x0	ms	m2	m1	m0	8080h

b1	b0	Frequency Band [MHz]
0	0	315
0	1	433
1	0	868
1	1	915

d2	d1	d0	Clock Output Frequency [MHz]
0	0	0	1
0	0	1	1.25
0	1	0	1.66
0	1	1	2
1	0	0	2.5
1	0	1	3.33
1	1	0	5
1	1	1	10

x3	x2	x1	x0	Crystal Load Capacitance [pF]
0	0	0	0	8.5
0	0	0	1	9.0
0	0	1	0	9.5
0	0	1	1	10.0
.....				
1	1	1	0	15.5
1	1	1	1	16.0

The resulting output frequency can be calculated as:

$$f_{out} = f_0 - (-1)^{SIGN} * (M + 1) * (30\text{kHz})$$

where:

f_0 is the channel center frequency (see the next command)

M is the three bit binary number <m2 : m0>

SIGN = (ms) XOR (FSK input)

2. Power Management Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	0	0	0	0	a1	a0	ex	es	ea	eb	et	dc	C000h

Bits 5-0, enable the corresponding block of the transmitters, i.e. the crystal oscillator is enabled by the ex bit, the synthesizer by es, the power amplifier by ea and the low battery detector by eb, while the wake-up timer by et. The bit dc disables the clock output buffer.

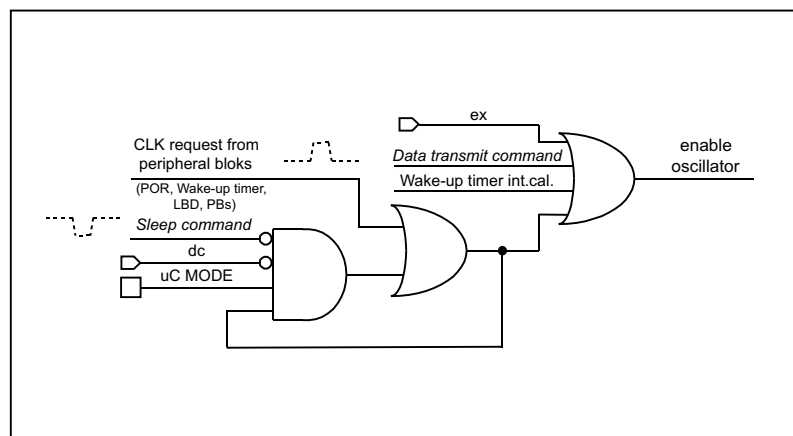
When receiving the *Data Transmit Command*, the chip supports automatic on/off control over the crystal oscillator, the PLL and the PA.

If bit a1 is set, the crystal oscillator and the synthesizer are controlled automatically. *Data Transmit Command* starts up the crystal oscillator and as soon as a stable reference frequency is available the synthesizer starts. After a subsequent delay to allow locking of the PLL, if a0 is set the power amplifier is turned on as well.

Note:

- To enable the automatic internal control of the crystal oscillator, the synthesizer and the power amplifier, the corresponding bits (ex, es, ea) must be zero in the *Power Management Command*.
- In EEPROM operation mode after an identified *Data Transmit Command* the internal logic switches on the synthesizer and PA. At the end of *Data Transmit Command* header if necessary the current clock cycle is automatically extended to ensure the PLL stabilization and RF power ramp-up.
- In EEPROM operation mode the internal logic switches off the PA when the given number of bytes is transmitted. (See: *Data Transmit Command* in EEPROM operation.)
- When the chip is controlled by a microcontroller, the *Sleep Command* can be used to indicate the end of the data transmission process, because in microcontroller mode the *Data Transmit Command* does not contain the length of the TX data.
- For processing the events caused by the peripheral blocks (POR, LBD, wake-up timer, push-buttons) the chip requires operation of the crystal oscillator. This operation is fully controlled internally, independently from the status of the ex bit, but if the dc bit is zero, the oscillator remains active until *Sleep Command* is issued. (This command can be considered as an event controller reset.)

Oscillator control logic



3. Frequency Setting Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	0	1	0	f11	f10	f9	f8	f7	f6	f5	f4	f3	f2	f1	f0	A7D0h

The 12-bit parameter of the *Frequency Setting Command* <f11 : f0> has the value F. The value F should be in the range of 96 and 3903. When F is out of range, the previous value is kept. The synthesizer center frequency f_o can be calculated as:

$$f_o = 10 \text{ MHz} * C1 * (C2 + F/4000)$$

The constants C1 and C2 are determined by the selected band as:

Band [MHz]	C1	C2
315	1	31
433	1	43
868	2	43
915	3	30

Note:

- For correct operation of the frequency synthesizer, the frequency and band of operation need to be programmed **before** the synthesizer is started. Directly after activation of the synthesizer, the RF VCO is calibrated to ensure proper operation in the programmed frequency band.
- When coding for the IA4220/21, it is suggested that recalibration routines be added to compensate for significant changes in temperature and supply voltages.

4. Data Rate Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	1	0	0	0	r7	r6	r5	r4	r3	r2	r1	r0	C800h

In EEPROM mode the transmitted bit rate is determined by the 8-bit value R (bits <r7 : r0>) as:

$$BR = 10 \text{ MHz} / 29 / (R+1)$$

Apart from setting custom values, the standard bit rates from 2.4 to 115.2 kbps can be approximated with minimal error. The commands are read out with a different fixed bit rate:

$$F_{\text{sc}} = 10\text{MHz} / 29 / 3 [\sim 115.2 \text{ kHz}]$$

5. Power Setting Command

bit	7	6	5	4	3	2	1	0	POR
	1	0	1	1	ook	p2	p1	p0	B0h

The bit *ook* enables the OOK mode for the PA, in this case the data to be transmitted are received through the FSK pin.

p2	p1	p0	Output Power [dB]
0	0	0	0
0	0	1	-3
0	1	0	-6
0	1	1	-9
1	0	0	-12
1	0	1	-15
1	1	0	-18
1	1	1	-21

The output power is given in the table as relative to the maximum available power, which depends on the actual antenna impedance. (See: Antenna Application Note available from <http://www.integration.com>).

6. Low Battery Detector Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	0	0	1	0	X	X	X	t4	t3	t2	t1	t0	C200h

The 5-bit value T of <t4 : t0> determines the threshold voltage V_{lb} of the detector:

$$V_{lb} = 2.2 \text{ V} + T * 0.1 \text{ V}$$

7. Sleep Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	0	1	0	0	s7	s6	s5	s4	s3	s2	s1	s0	C400h

The effect of this command depends on the *Power Management Command*. It immediately disables the power amplifier (if $a0=1$ and $ea=0$) and the synthesizer (if $a1=1$ and $es=0$). Stops the crystal oscillator after S periods of the microcontroller clock (if $a1=1$ and $ex=0$) to enable the microcontroller to execute all necessary commands before entering sleep mode itself. The 8-bit value S is determined by bits <s7 : s0>.

8. Push-Button Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	1	0	1	0	p4	d1	d0	b4	b3	b2	b1	bc	CA00h

If the corresponding bit was set (b1-b4) the event remains active while the button is pressed. In EEPROM mode, the chip is continuously performing the routine assigned to the push-button while it is pressed. In microcontroller mode, the chip continuously generates interrupts on nIRQ until the push-button is released. Weak pull-up currents are switched off when bc is high.

The d0, d1 bits set the de-bouncing time period:

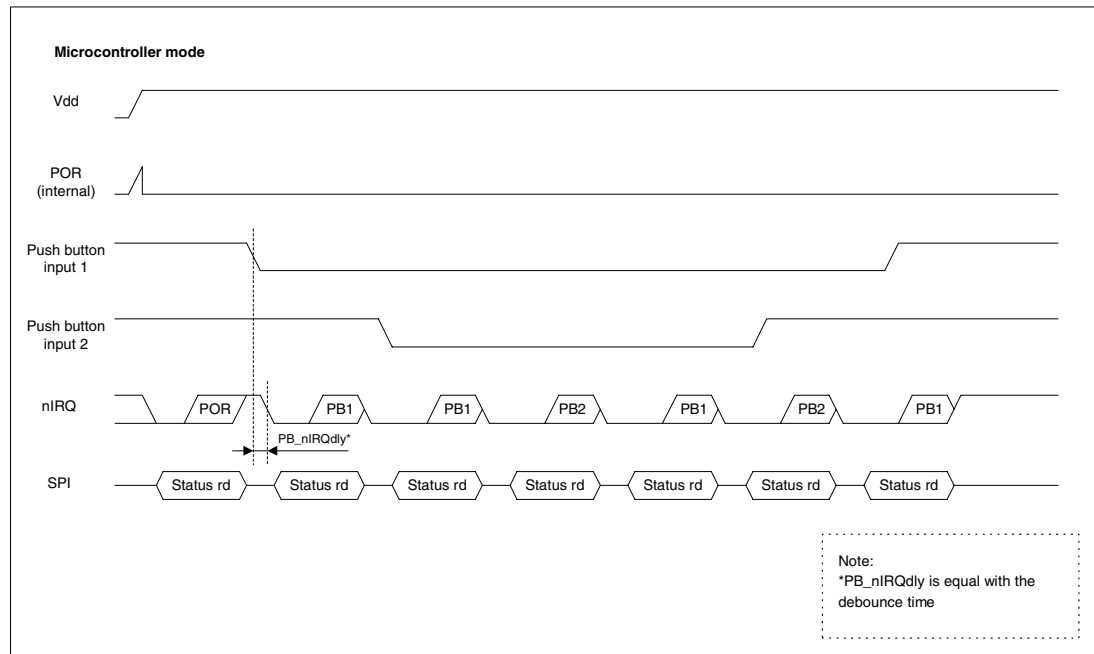
d1	d0	De-Bouncing Time [ms]
0	0	160
0	1	40
1	0	10
1	1	0 (Bypassed)

Note: Until the de-bouncing time has expired, the crystal oscillator remains switched on, independent of the status of the ex bit in the *Power Management Command*. (Because the circuit uses the crystal oscillator signal for timing.)

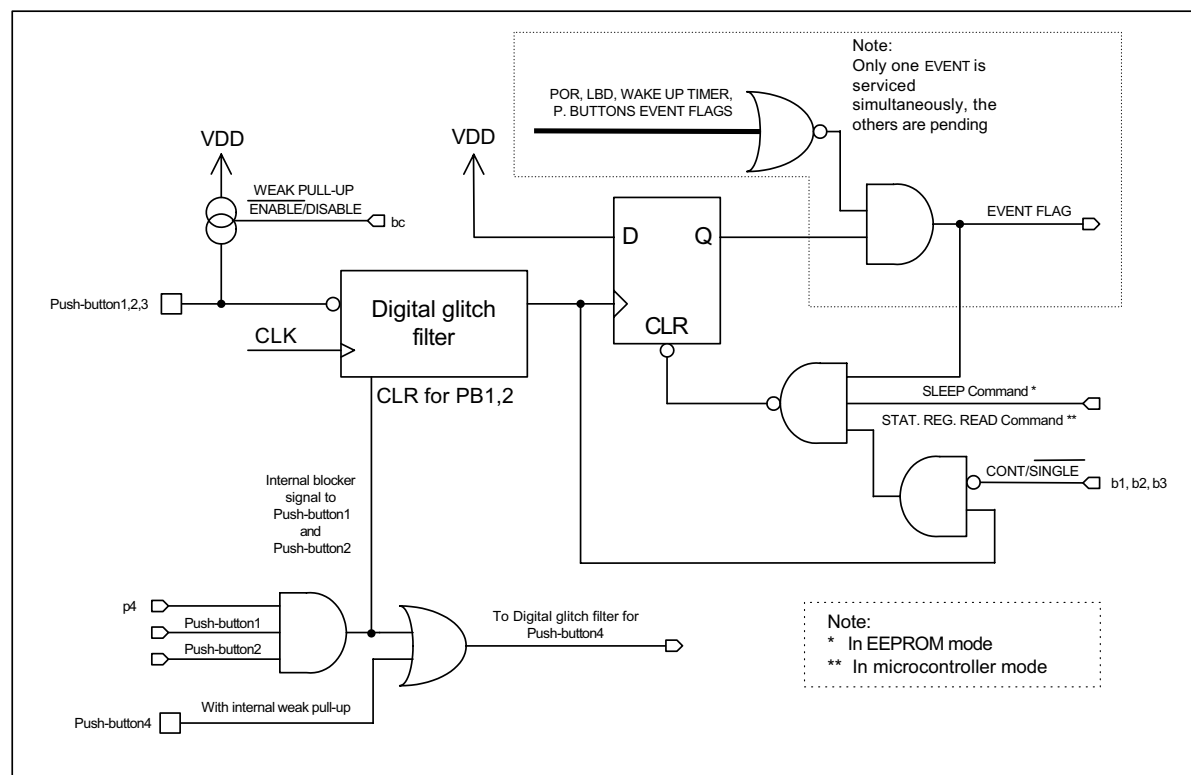
If the p4 bit is set, the controller performs the routine assigned to the fourth button when PB1 and PB2 are pressed down simultaneously. With the addition of this feature, there is a way to build a device that uses 3 buttons, but performs 4 functions.

It is possible to detect multiple pressed push-buttons, in both modes. In EEPROM mode the controller executes sequentially all the routines belonging to the pressed buttons.

Simultaneously Pressed Push-Button Detect By Microcontroller



Simplified Block Diagram of Push-Button 1-4 Inputs



9. Wake-Up Timer Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	1	r4	r3	r2	r1	r0	m7	m6	m5	m4	m3	m2	m1	m0	E000h

The wake-up time period can be calculated as:

$$T_{\text{wake-up}} = M * 2^R \text{ [ms]},$$

where M is defined by the <m7 : m0> digital value and R is defined by the <r4 : r0> digital value

10. Data Transmit Command

This command is not needed if the transmitters' power management bits (ex, es, ea) are fully controlled by the microcontroller and TX data comes through the FSK pin.

In EEPROM operation mode:

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	0	1	1	0	n7	n6	n5	n4	n3	n2	n1	n0	- -

In microcontroller slave mode:

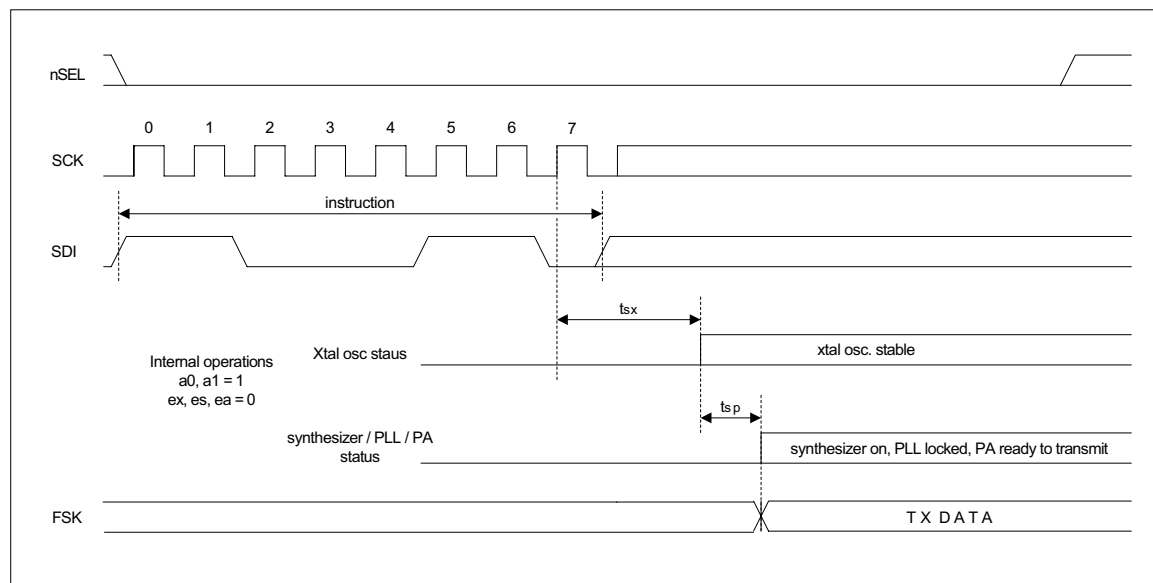
bit	7	6	5	4	3	2	1	0
	1	1	0	0	0	1	1	0

This command indicates that the following bitstream coming in via the serial interface is to be transmitted. In EEPROM mode, the 8-bit value N of bits <n7 : n0> contains the number of data bytes to follow.

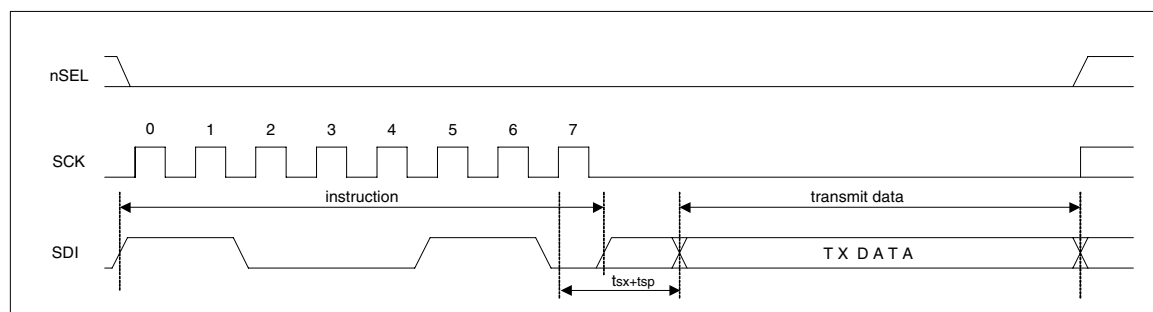
Note:

- If the crystal oscillator was formerly switched off (ex=0), the internal oscillator needs t_{sx} time, to switch on. The actual value depends on the type of quartz crystal used.
- If the synthesizer was formerly switched off (es=0), the internal PLL needs t_{sp} startup time. Valid data can be transmitted only when the internal locking process is finished.
- In EEPROM mode, before issuing the *Data Transmit Command*, the power amplifier must be enabled, with the ea or a0 bit in the *Power Management Command*.
- In EEPROM mode, when N bytes have been read and transmitted the controller continues reading the EEPROM and processing the data as control commands. This process stops after *Sleep Command* has been read from the EEPROM.

Data Transmit Sequence Through the FSK Pin



Data Transmit Sequence Through the SDI Pin



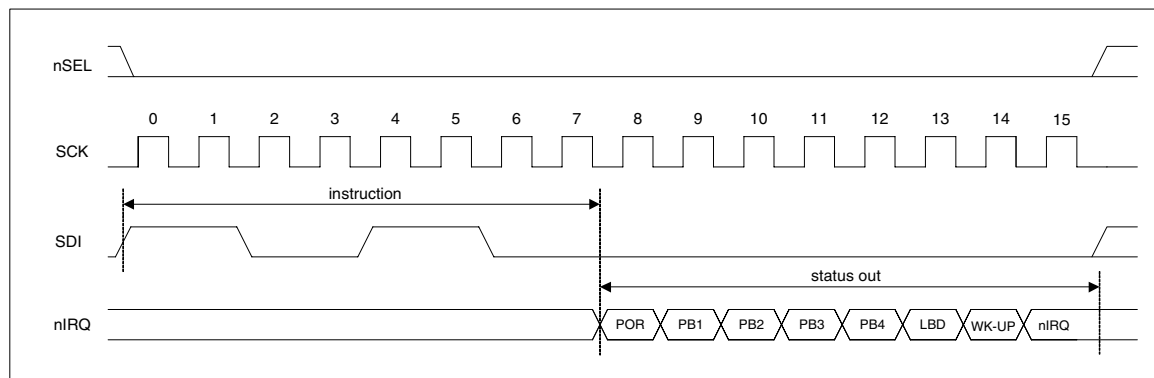
- Note:**
1. Do not send CLK pulses with the TX data bits, otherwise they will be interpreted as commands.
 2. This mode is not SPI compatible, therefore it is not recommended in microcontroller mode.
 3. If the crystal oscillator and the PLL are running, the tsx+tsp delay is not needed.

11. Status Register Read Command

bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	POR
	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	--

With this command, it is possible to read the chip's status register through the nIRQ pin. This command clears the last serviced interrupt and processing the next pending one will start (if there is any).

Status Register Read Sequence



EEPROM MODE

In this mode, the transmitters can operate with a standard at least 1 kbyte serial EEPROM with an SPI interface, and no microcontroller is necessary. The following events cause wake-up of the device:

Event Number N	EEPROM entry point	Description
0	0000h	power-on
1	0080h	low level on input PB1
2	0100h	low level on input PB2
3	0180h	low level on input PB3
4	0200h	low level on input PB4
5	0280h	low supply voltage level
6	0300h	wake-up timer timeout

After any of these events, the crystal oscillator turns on and the device starts to read bytes from the EEPROM continuously (block read) starting from address $N * 128$ (decimal) and executes them as commands as described in the previous section.

Note: Zero bytes can be put in the EEPROM for timing purposes. Never put more than 31 consecutive zero bytes into the EEPROM's active region (between the actual entry point and the closing *Sleep Command*).

Example EEPROM Hexa Content

Power-On Reset:

```

00000000  C0  C4  CA  1E  C8  23  C4  00  00  00  00  00  00  00  00  00
00000010  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000020  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000030  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000040  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000050  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000060  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00
00000070  00  00  00  00  00  00  00  00  00  00  00  00  00  00  00

```

Short Explanation:

Data in *Address*, *Command*, and *Parameter* fields are hexadecimal values.

For the detailed description of the control command bits, see previous section.

Address	Command	Parameter	Related Control Command	Remarks
00-01	C0	C4	Power Management	Crystal- Synthesizer – Power Amplifier auto on/off mode enable
02-03	CA	1E	Push-Button	Continuous execution for all push buttons
04-05	C8	23	Bit Rate	BR=10M/29/(35+1)~9600 bps
06-07	C4	00	Sleep	Power down

Push-button 1:

00000080	88	72	A6	10	C6	60	55	55	55	55	55	55	55	55	55	55
00000090	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
000000A0	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
000000B0	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
000000C0	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
000000D0	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
000000E0	55	55	55	55	55	55	C4	00	00	00	00	00	00	00	00	00
000000F0	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00	00

Short Explanation:

Address	Command	Parameter	Related Control Command	Remarks
80–81	8	872	Configuration Control	433MHz band, Crystal $C_L=12\text{pF}$ $df_{fsk}=90\text{kHz}$
82–83	A	610	Frequency	$f_c=(43+1552/4000)*10\text{MHz}$
84–85	C6	60	Data Transmit	Transmit the next 96 bytes
86–E5		60x55		Data
E6–E7	C4	00	Sleep	Power down, go to address 80 (Note 1)

Note 1: This routine is repeatedly executed while PB1 is pressed, because continuous execution was selected at POR (CA1E code issued in the power-on reset section before).

CRYSTAL SELECTION GUIDELINES

The crystal oscillator of the IA4220/21 requires a 10 MHz parallel mode crystal. The circuit contains an integrated load capacitor in order to minimize the external component count. The internal load capacitance value is programmable from 8.5 pF to 16 pF in 0.5 pF steps. With appropriate PCB layout, the total load capacitance value can be 10 pF to 20 pF so a variety of crystal types can be used.

When the total load capacitance is not more than 20 pF and a worst case 7 pF shunt capacitance (C_o) value is expected for the crystal, the oscillator is able to start up with any crystal having less than 300 ohms ESR (equivalent series loss resistance). However, lower C_o and ESR values guarantee faster oscillator startup.

The crystal frequency is used as the reference of the PLL, which generates the RF carrier frequency (f_c). Therefore f_c is directly proportional to the crystal frequency. The accuracy requirements for production tolerance, temperature drift and aging can thus be determined from the maximum allowable carrier frequency error.

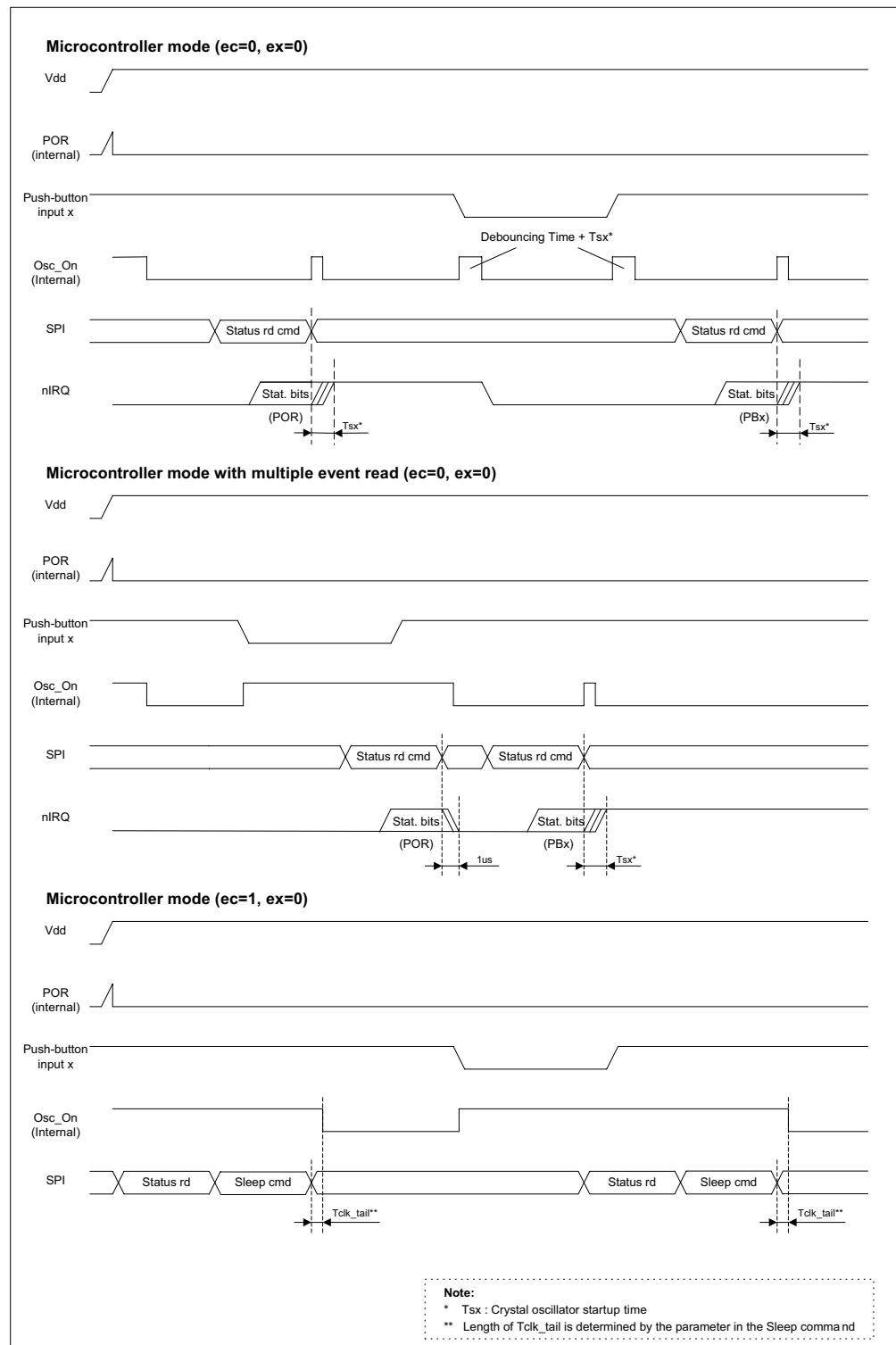
Whenever a low frequency error is essential for the application, it is possible to “pull” the crystal to the accurate frequency by changing the load capacitor value. The widest pulling range can be achieved if the nominal required load capacitance of the crystal is in the “midrange”, for example 16 pF. The “pull-ability” of the crystal is defined by its motional capacitance and C_o .

SIMPLIFIED INTERNAL CONTROL AND TIMING

The internal controller uses the clock generated by the crystal oscillator to sequentially process the various events and to de-bounce the push-button (PB) inputs. If the oscillator is not running, internal logic automatically turns it on temporarily and then off again. Such events are: any wake-up event (POR, PB press, wake-up timer timeout, low supply voltage detection), PB release and status read request by the microcontroller.

If two wake-up events occur in succession, the crystal oscillator stays on until the next status read (acknowledgment of the first event).

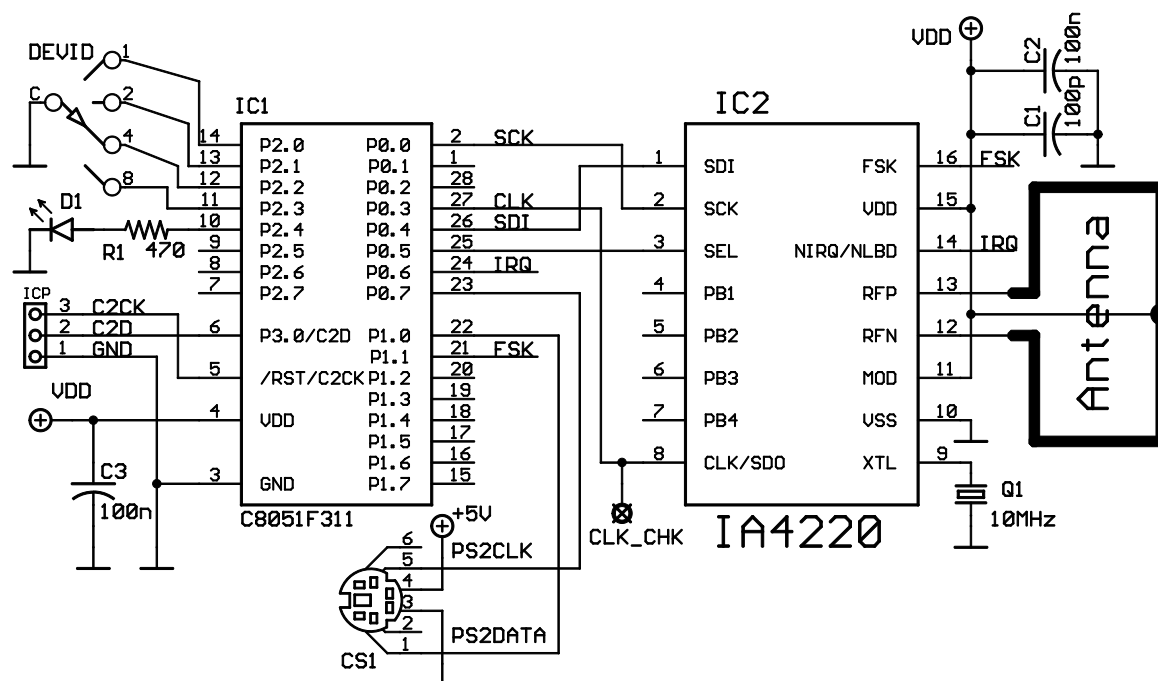
Simplified Internal Control and Timing Diagrams



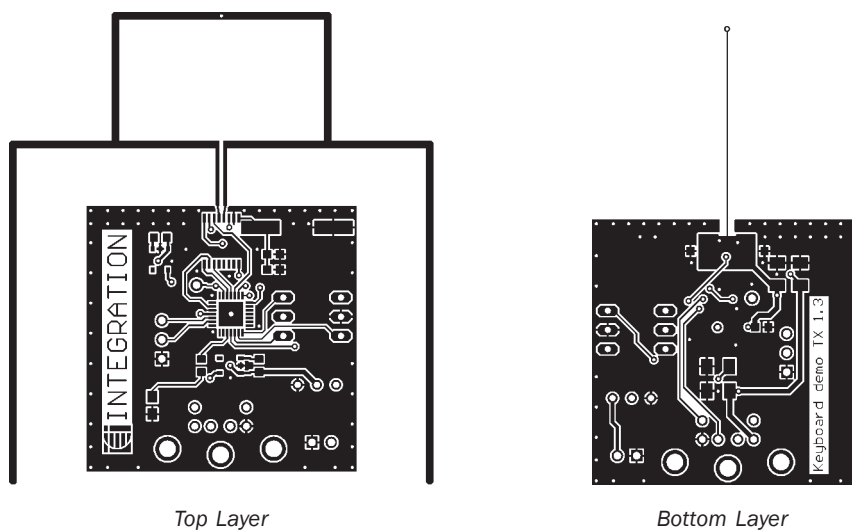
EXAMPLE APPLICATIONS

For Microcontroller Mode

Schematic

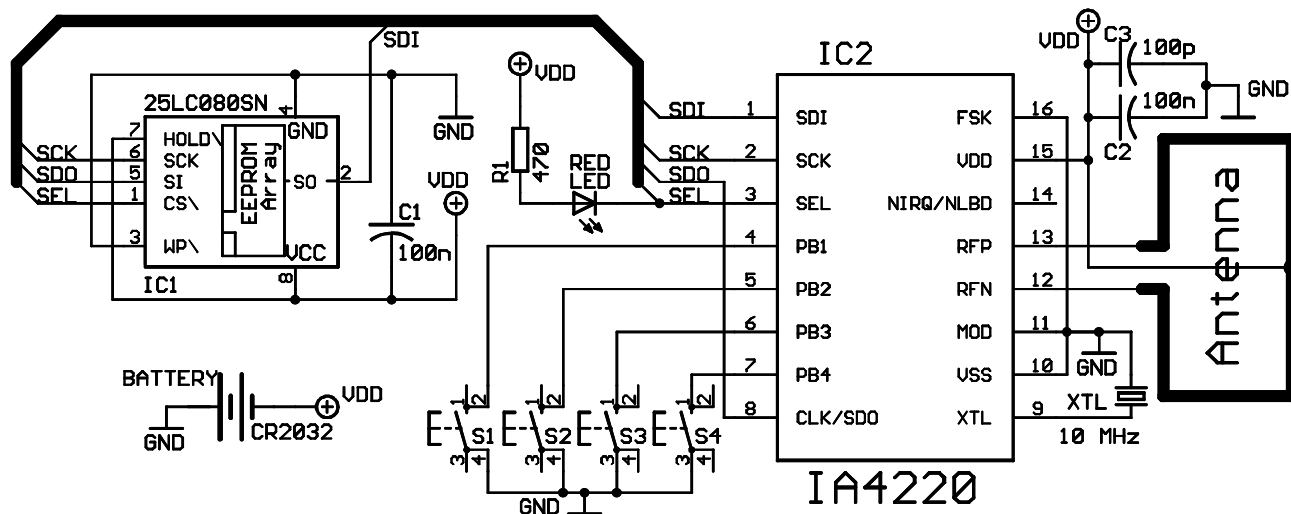


PCB Layout of Keyboard Transmitter Demo Circuit Using Microcontroller Mode (operating in the 915 MHz band)

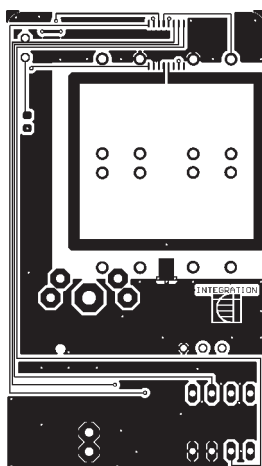


For EEPROM Mode

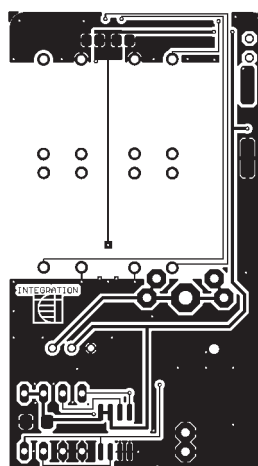
Schematic



PCB Layout of Push-Button Transmitter Demo Circuit Using EEPROM Mode (operating in the 434 MHz band)



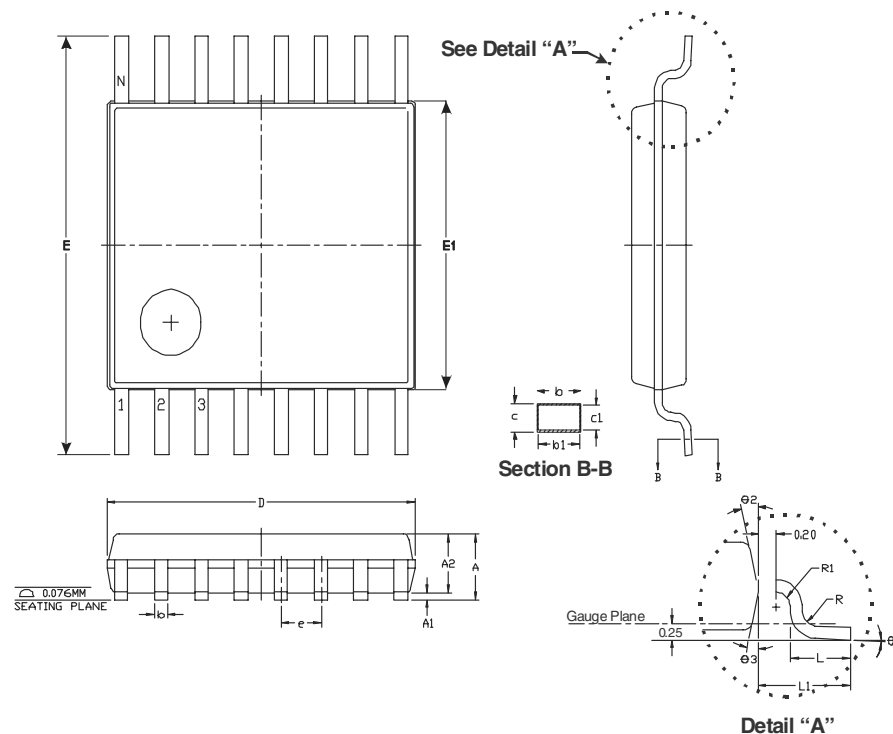
Top Layer



Bottom Layer

PACKAGE INFORMATION

16-pin TSSOP



Symbol	Dimensions in mm			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A			1,20			0,047
A1	0,05		0,15	0,002		0,006
A2	0,80	0,90	1,05	0,031	0,035	0,041
b	0,19		0,30	0,007		0,012
b1	0,19	0,22	0,25	0,007	0,009	0,010
c	0,09		0,20	0,004		0,008
c1	0,09		0,16	0,004		0,006
D	4,90	5,00	5,10	0,193	0,197	0,201
e	0.65 BSC.			0.026 BSC.		
E	6.40 BSC.			0.252 BSC.		
E1	4,30	4,40	4,50	0,169	0,173	0,177
L	0,50	0,60	0,75	0,020	0,024	0,030
L1	1.00 REF.			0.39 REF.		
R	0,09			0,004		
R1	0,09			0,004		
θ1	0		8	0		8
θ2	12 REF.			12 REF.		
θ3	12 REF.			12 REF.		

RELATED PRODUCTS AND DOCUMENTS

IA4220/21 Universal ISM Band FSK Transmitters

DESCRIPTION	ORDERING NUMBER	
IA4220 16-pin TSSOP	IA4220-IC CC16	Revision #
IA4221 16-pin TSSOP	IA4221-IC CC16	Revision #
die	see Integration Associates	

Demo Boards and Development Kits

DESCRIPTION	ORDERING NUMBER
Development Kit	IA ISM – DK
Wireless Keyboard Demo	IA ISM – DA WK
RF Link Analysis Board	IA ISM – DA RF Link
Remote Temp. Monitoring Station	IA ISM – DA TempDemo

Related Resources

DESCRIPTION	ORDERING NUMBER
Antenna Selection Guide	IA ISM – AN1
Antenna Development Guide	IA ISM – AN2
IA4320 Universal ISM Band FSK Receiver	see http://www.integration.com for details

Note: Volume orders must include chip revision to be accepted.

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