AN3902

Demonstration Board for the AS3902 433 MHz ISM Band ASK Transmitter

Application Note
Rev. B6, March 2001

1 General Description

The AS3902 demonstration board is designed to demonstrate the functionality of the ASK transmitter. The main functional blocks are:

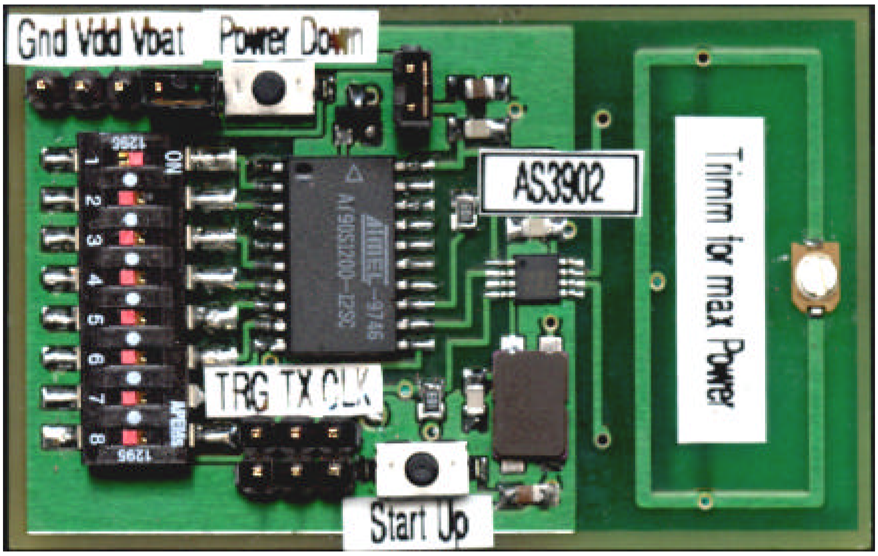
- AS3902 433 MHz ISM band ASK transmitter IC.
- Printed circuit board loop antenna.
- ATMEL AT90S1200 micro controller and interface.Applications

1.1 Key Features

- Supports the European 433 MHz ISM band.
- No frequency pulling by (antenna) load variation due to PLL synthesizer.
- Designed to be conform to EN 300 220-1 requirements.
- Data rate range from 0 to 32 kbit/s.
- Supports clock and reset signals for the external µC.
- Supports total shut down mode without any running XTAL oscillator.
- Only few external components required.
- FSK Operation possible by XTAL pulling.
- Wide supply range between 2.7 V to 5 V.
- Low TX current, typical 8 mA @ transm. „H“, 1 mA @ transm. „L“.
- Wide operating temperature range from -40 to +85 °C.
- Miniature surface mount 8 pin MSOP package.

2 Scope

This application note describes the operation of the AS3902 ASK transmitter demonstration board. This circuit board is a fully operational ASK transmitter including small printed loop antenna and a micro-controller (µC) for data generation. Several test modes, data patterns and data rates can be selected by a DIP switch.



Demonstration board M 2:1 (Original size 55 mm x 33 mm).AS3902
Please refer to the AS3902 Data Sheet for details on operation (Reference list # 1, page 14).

3 Loop Antenna

The AS3902 demonstration board includes a small printed circuit magnetic loop antenna. This type of antenna is especially cost effective and convenient to use in small hand-held transmitters. However, the design of such a small loop antenna requires some care.

A small loop antenna can be modeled by a series connection of an inductor and two resistors, representing the electrical length (< than quarter wavelength) of the loop, the ohmic loss resistor and the radiation resistor. Unfortunately this type of antenna is not very efficient due to the radiation resistor is generally much smaller than the loss resistor.

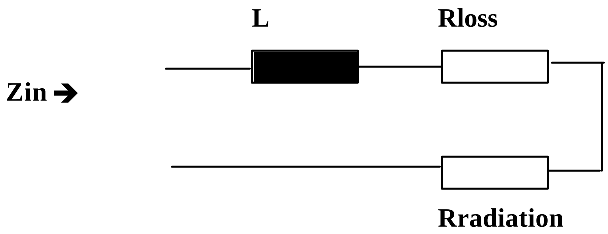


Figure 1: Equivalent circuit of small loop antenna.

For operation, the antenna is typically tuned to parallel resonance at the desired TX frequency by means of a parallel capacitor. In this case the input resistance of the loop antenna will be very high (kΩ). If unusually operated in series resonance with a series compensation capacitor, the impedance will be very low (mΩ).In other words: The small loop antenna is a high Q device but low efficient device.

The AS3902 output stage is a differential open collector output, which delivers an available peak output power of typical 0 dBm into a 2 kΩ load. In order to achieve this desired impedance level an impedance transformation to 2 kΩ is necessary.

It should be noted that, as in high efficient transmitters usual, the aim of this impedance transformation is not to achieve a conjugate match to the AS3902 output but rather to generate a real load impedance of 2 kΩ optimized for the 0.7 mA_{RMS} collector current 4 V_{PP} differential output swing combination of the AS3902.

As the loop is inherently inductive it can be used as a transformer element by itself. By connecting the output of the AS3902 to an intermediate point of the loop as shown in Figure 2, the desired impedance transformation can be achieved without additional losses and at no additional costs. By proper selection of the tapping point and tuning capacitor a wide range of impedance levels can be achieved.

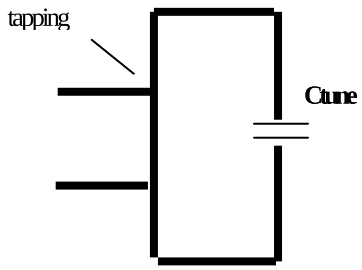


Figure 2: Example of a loop antenna with antenna matching and tuning.

Furthermore this antenna structure allows proper DC biasing of the open collector output.

Any objects within the loop will influence its performance and generally degrade the efficiency. For maximum effective radiated power an empty loop should be used. If this is not possible due to other design restrictions the additional objects should be as small as possible and especially all conductive loops should be avoided.

Further details on small loop antennas can be found in the Reference list, #3, page 14.

2.2 Microcontroller Interface and Power Management

The AS3902 is designed to directly interface to a microcontroller (µC). The µC interface consists of three pins:

1. „Transmit data input“ (TXD).
2. „Active „L“ µC reset output / transmitter power down input“ (NRES/PD).
3. „µC clock output / active „L“ wake-up input“ (CLK/NWUP).

These lines support the µC with the required reset and clock signals and control the AS3902 internal power on/off circuit which wakes up and shuts down the whole transmitter consisting of the AS3902 and the µC. The actual implementation of the interface depends on the µC specifications.

Two cases are considered here:

2.2.1 µC, with Static Power Down in Reset State (Type 1)

Figure 3 shows a typical interfacing of the AS3902 to a µC type 1. Figure 4 presents a related timing for power up and down of the transmitter. A type 1 µC remains in low power standby mode as long as NRESET is „L” and no clock cycles are applied.

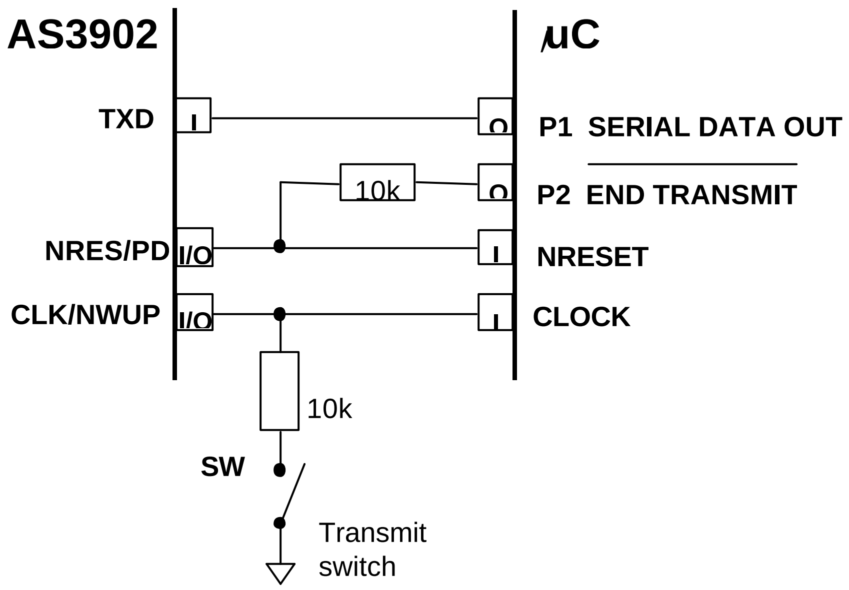


Figure 3: Interfacing the AS3902 to a typical µC.

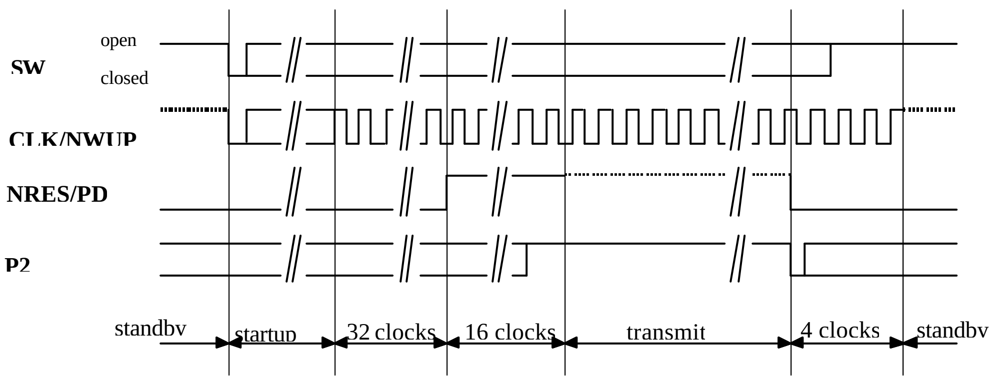


Figure 4: µC interface timing for a transmission cycle.

Note 1:The dashed lines indicate weak high or low state when the CLK/NWUP or NRES/PD output of the AS3902 is disabled (in high-resistive Z state) and pulled „H" or „L" by the internal pull-up device or by the µC via a resistor. These weak states can be overridden by the AS3902 if the respective outputs are enabled.

Whenever a line is pulled via an external resistor, however, this should override the internal pull-up devices of the AS3902.

Standby: During standby the XTAL oscillator is turned off and AS3902 holds the µC in a reset state:The AS3902 NRES/PD pin is active and set to „L", holding the µC in reset state. In standby mode the AS3902 internal NRES/PD pull-up is disabled not to drain current from the supply. The AS3902 CLK/NWUP output is disabled, (in high resistive „Z" state) and internally pulled up to „H".

(Re) starting the transmitter: Closing the push button (giving a falling edge on CLK/NWUP - CLOCK line) starts up the AS3902. It turns on its XTAL oscillator and after the oscillator start up phase it turns the CLK/NWUP pin to active (CMOS level) mode and provides a clock to the µC.

After a delay of 32 µC clock cycles the NRES/PD pin of the AS3902 is set to „H" for 16 clock cycles. This rising edge of NRES/PD starts the µC. Now the µC is should program its P2 output to „H“ or disable it (set to high-resistive „Z“ state) within this 16 µC clock periods due to the AS3902 than will disable (set to high-resistive „Z“ state) the NRES/PD output again with its internal pull-up active.

Than the µC can turn on and off the synthesizer and driving amplifier in the rhythm of the data on the TX - P1 (Serial data out) line and transmit ASK data.

Bringing the transmitter to standby: After completing the transmission, the µC may indicate „end of transmission“ by setting P2 (inv. end of transmit) to „L“ and pull the NRES/PD - NRESET line to „L“. Sensing this, 4 clock cycles later the AS3902 will switch back to standby mode, disabling the CLK/NWUP output and turning off the XTAL oscillator.

Repetitive transmission: If the button is still pressed when the µC indicates „end of transmission“ by setting P2 pin to „L“ and pulling the NRES/PD - NRESET line to „L“, 4 µC clock periods later the sequence above is repeated starting from the 32 clock delay period.

Due to the sophisticated tri-state - active / inactive pull-up configuration of the NRES/PD pin the AS3902 does not drain current during its standby periods.

2.2.2 µC with Quasi Active Power Consumption in Reset State (Type 2)

Some µC have a level triggered rather than a edge triggered internal reset generation, some µC have Pull Up resistors on the NRESET input to allow a save Power On Reset (POR) generation. In either case there will be an undesired power consumption in standby mode. In this situation the following interfacing of the AS3902 to the µC will overcome the problem.

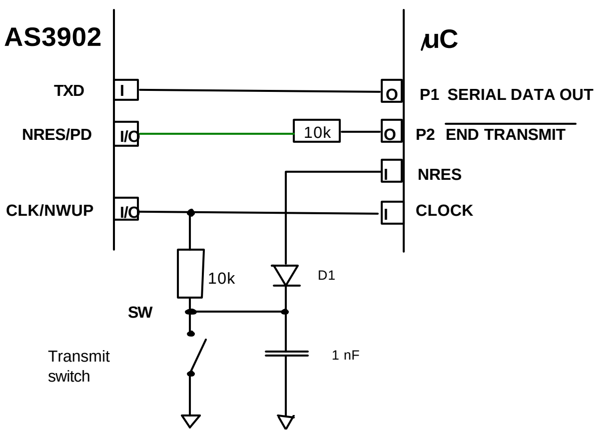
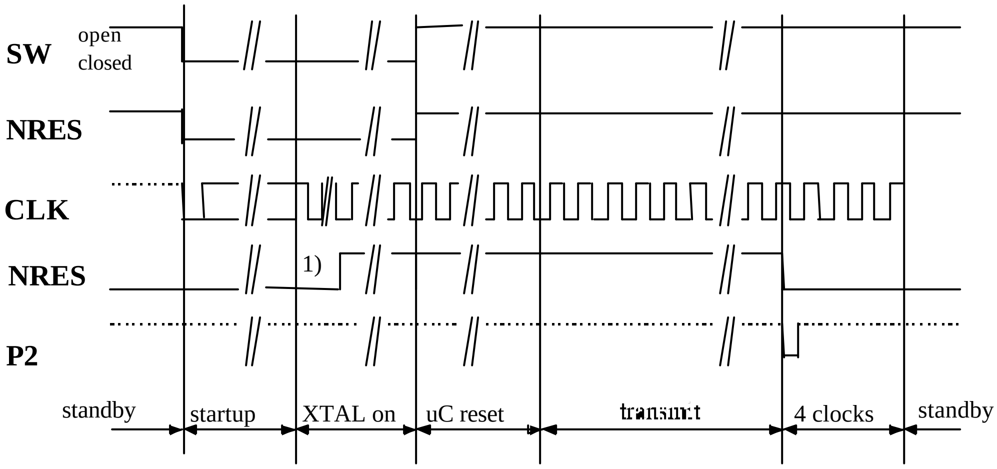


Figure 5: Interfacing the AS3902 to a Type 2 µC.



1) NRES is set to "H" after 32 Clock Cycles

Figure 6: Interface timing for a transmission cycle with Type 2 µC (see Note 1, Page 4).

Standby: During standby the XTAL oscillator is turned off and AS3902 holds the µC in a reset state:

The AS3902 NRES/PD pin is active and set to „L".
The AS3902 CLK/NWUP output is disabled, (in high resistive „Z" state) and internally pulled up to „H".

(Re) starting the transmitter: Closing the push button (giving a falling edge on CLK/NWUP - CLOCK line) starts up the AS3902. It turns on its XTAL oscillator and after the oscillator start up phase it turns the CLK/NWUP pin to active (CMOS level) mode and provides a clock to the µC. As long as the push button is pressed the µC is reset. Once the push button is released the XTAL oscillator has already started up and the initialization phase of the µC begins. The AS3902 is kept awake by the internal pull up on NRES. Therefore the µC needs to output either a logic "H" or a high resistive „Z" state signal at P2 pin.

Then the µC can turn on and off the synthesizer and driving amplifier in the rhythm of the data on the TX - P1 (Serial data out) line and transmit ASK data.

Bringing the transmitter to standby: After completing the transmission, the µC may indicate „end of transmission" by setting P2 (inv. end of transmit) to „L" and pull the NRES/PD line to „L". Sensing this, 4 clock cycles later the AS3902 will switch back to standby mode, disabling the CLK/NWUP output and turning off the XTAL oscillator. The µC needs to be programmed to enter a power down / sleep mode during this 4 clock cycles.

3 Application Schematic and PCB

Note 2: Inductor L1 can be omitted if the DC feed of the loop antenna is connected to an AC ground. Such an AC ground is e.g. the symmetric point of the loop used on the demonstration board.

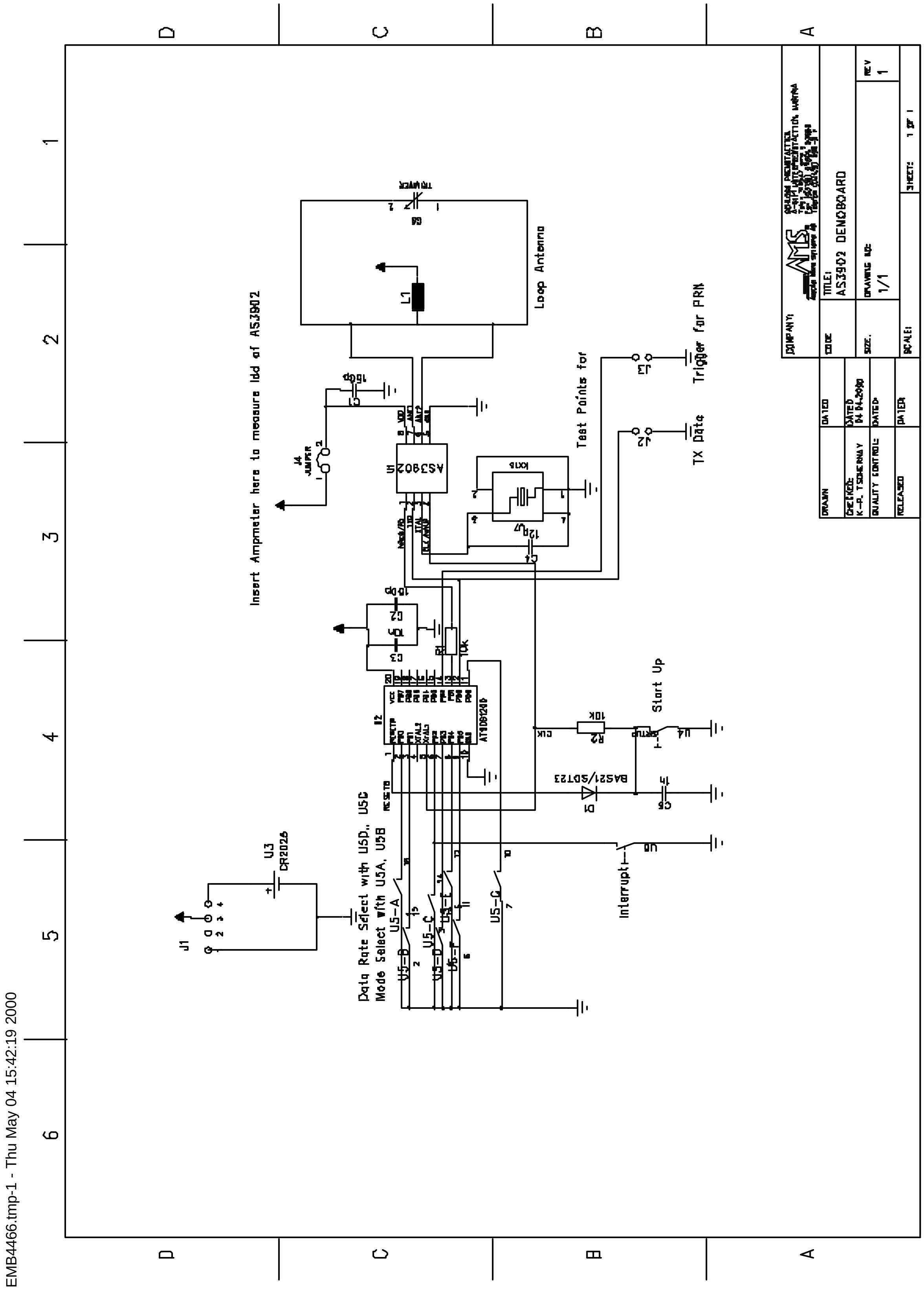


Figure 7: Application board schematic.

Board Layout

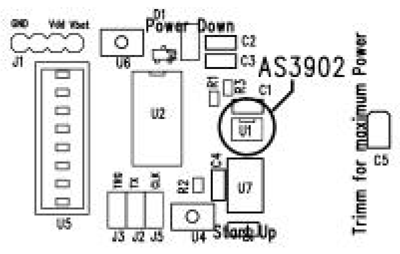


Figure 8: Component arrangement top side.

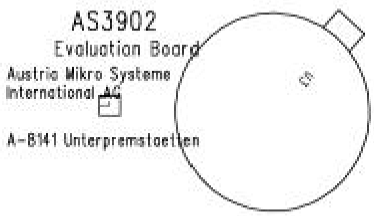


Figure 9: Component arrangement bottom side.

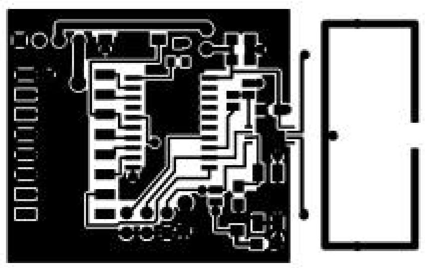


Figure 10: Top layer (component side).

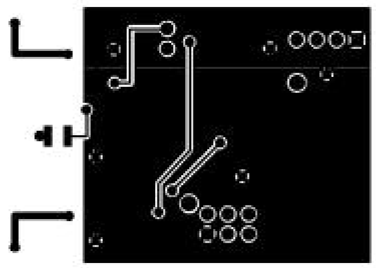


Figure 11: Bottom layer.

List of Components

Number	Component	Value	Purpose
Transmitter			
U1	AS3902		ASK transmitter IC
U7	XTAL	13.56 MHz, 50 ppm	Frequency reference
C1	Capacitor	150 pF	Supply decoupling
C4	Capacitor	12 pF	XTAL pulling
C5	Capacitor	1.4 to 3 pF	Antenna tuning
L1	Inductor	390 nH	RF isolation (optional)
Processor			
U2	AT90S1200		µC
R1,R2	Resistor	10 kOhm	For wired OR function
C2	Capacitor	150 pF	Supply decoupling
C3	Capacitor	10 nF	Supply decoupling
C6	Capacitor	1 nF	Clock filter
D1	Diode	BAS21	For wired OR function
U5	DIP switch		For mode select
U4,U6	Push button		Start / stop of operation
U3	Battery	3 V	Power supply

Table 1: List of components

µC Program

The µC generates test signals for several test modes and data rates. These modes are selected by a DIP - switch. Please refer to Table 2 for.mode selection:

DIP -1	DIP –2	Mode
ON	ON	Continuous series of …0101…, interrupted by pushing power down switch
OFF	ON	PRN9 single shot: System enters sleep mode after end of TX cycle.
ON	OFF	PRN9 continuous series, interrupted by pushing power down switch
OFF	OFF	Continuous wave transmission, interrupted by pushing power down switch

Table 2: Available test modes.

PRN9 is a pseudo random noise signal, generated with the shift register method. The length of the shift register is 9 bit.In case of PRN9 single sequence a trigger signal is output to J3 at the beginning of the PRN9 series to ease analysis of the transmitted signal.A wider range of data rates can be selected with DIP switches 4 to 7. Please refer to Table 3 on details of available data rates. Different data rates are achieved by adding an appropriate number of NOP cycles to the program flow.

DIP - 7	DIP - 6	DIP - 5	DIP - 4	app. Data Rate [kBit/s]
OFF	OFF	OFF	OFF	32
OFF	OFF	OFF	ON	28
OFF	OFF	ON	OFF	24.5
OFF	OFF	ON	ON	16
OFF	ON	OFF	OFF	14
OFF	ON	OFF	ON	12
OFF	ON	ON	OFF	10
OFF	ON	ON	ON	8
ON	OFF	OFF	OFF	7
ON	OFF	OFF	ON	6
ON	OFF	ON	OFF	5
ON	OFF	ON	ON	4
ON	ON	OFF	OFF	3
ON	ON	OFF	ON	2
ON	ON	ON	OFF	1
ON	ON	ON	ON	0.57

Table 3: Data rates.

Note 3: Due to programming restrictions the given data rates are only approximate numbers and differ slightly from 01010 series to PRN9 series.

All used inputs to the µC are programmed to have internal pull ups to keep external component count low. However, these pull ups will force current if the corresponding DIP switch is closed. Therefore Idd power down measurements for the whole transmitter board should be performed in the default state with all DIP switches OFF.An external interrupt is triggered by pushing push button U6. The interrupt routine outputs a low to P2 (end transmit signal) to put the AS3902 into standby mode and brings the µC to power down mode.In this state the current consumption of the entire transmitter demonstration board is less that 1 µA. (Under the condition that all DIP switches are in OFF state.

4 Operation Instructions

The demonstration board is equipped with a 3V lithium cell for full standalone operation. Put a jumper across the amperemeter connector J4 and an additional jumper across pins Vdd and Vbat on J1 to start operation. Transmission starts immediately in the mode selected by the DIP switch setting. This is because both AS3902 and the µC perform a POR entering the active state.
Any transmission can be interrupted at any time by operating push button U6 which triggers an interrupt for the µC.
A new transmission cycle starts when the push button U4 is pressed. During an initialization phase the µC reads in mode and data rate settings given by the DIP switch and finally enters the desired mode.
Please note that changes made to the DIP switch setting are only effective after a Power Down / Power Up sequence.

5 Typical Measurements

The following gives some typical measured spectra radiated by the AS3902 demonstration board. These measurements have been performed in a general laboratory environment not specifically suited for calibrated radiation measurement. However, care has been taken to keep the transmission path during a specific measurement as constant as possible.
Therefore all given measurement examples do not claim to give absolute power levels. The intention is rather to give a relative measure of the spectral distribution of the radiated energy. Actual power levels depend strongly on the characteristic of the application specific antenna design.

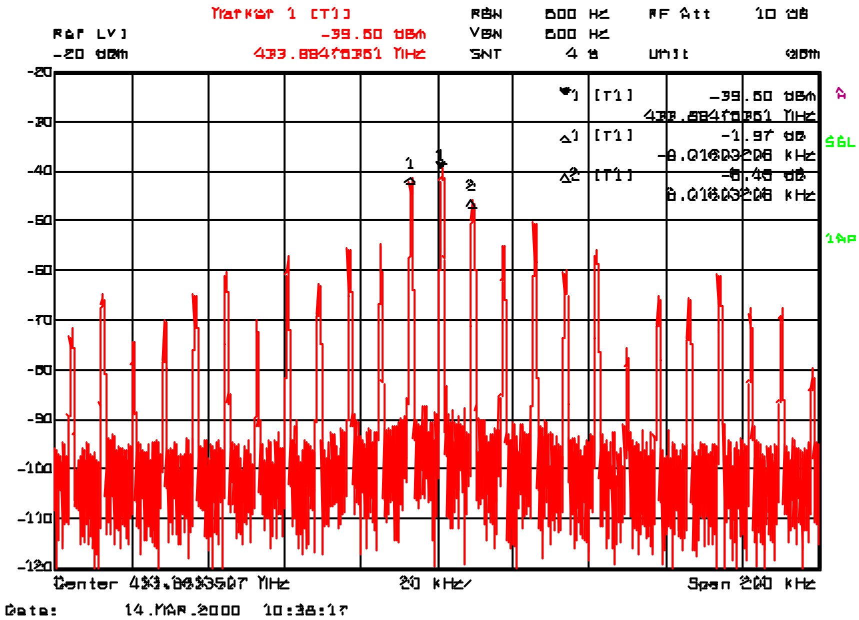


Figure 12: Narrow band output spectrum of the AS3902 modulated with a 101…-data pattern at 16 kbit/s.

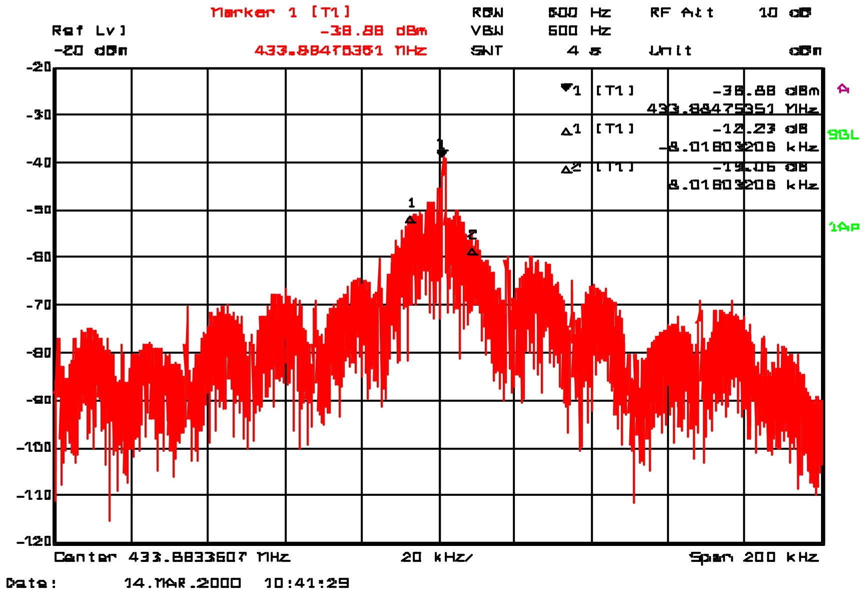


Figure 13: Narrow band output spectrum of the AS3902 modulated with pseudo random data at 16 kbit/s.

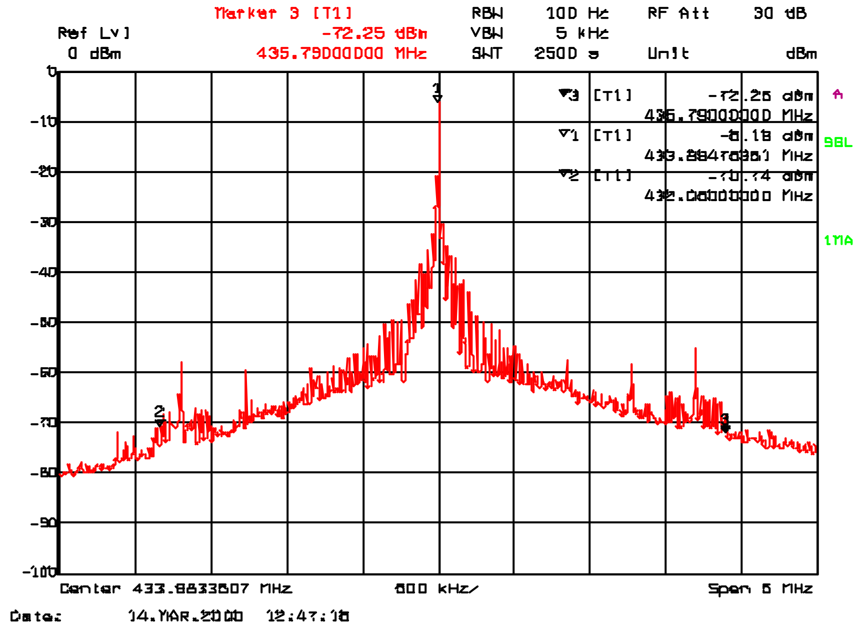


Figure 14: Modulation bandwidth of the AS3902 at 16 kbit/s measured close to the ETSI EN 300 220-1 recommendation for wide-band equipment, clause 8.6.(Only difference: 5kHz VBW was used instead of 10 kHz). From EN 300 220-1 the modulation bandwidth is defined to be the frequency difference between the points wherein the power level is above -36 dBm. Therefore the bandwidth value is dependent on the E.I.R.P. and should be within the ISM band limits. The marker settings correspond to the limits of the 433 MHz ISM band.

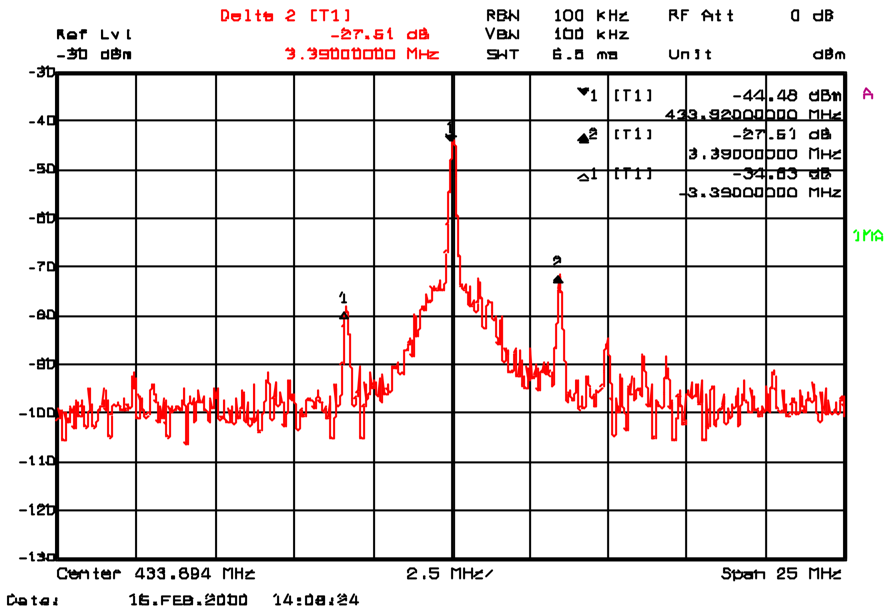


Figure 15: Spurious emissions of the AS3902 measured close to the ETSI EN 300 220-1 recommendation for wide-band equipment, clause 8.7, without modulation, transmitting a constant “H“. (Only difference: 100 kHz RBW was used instead of 120 kHz). The highest spurious emissions are generated at a carrier distance of 3.39 MHz (mC clock frequency).

The EN 300 220-1 specifies an absolute level of -36 dBm E.I.R.P. for spurious emissions. This limits the maximum E.I.R.P. for a transmitter using the AS3902 to about -11 dBm.

Measurement was performed over a free-space link using R&S HL040 antenna for reception.

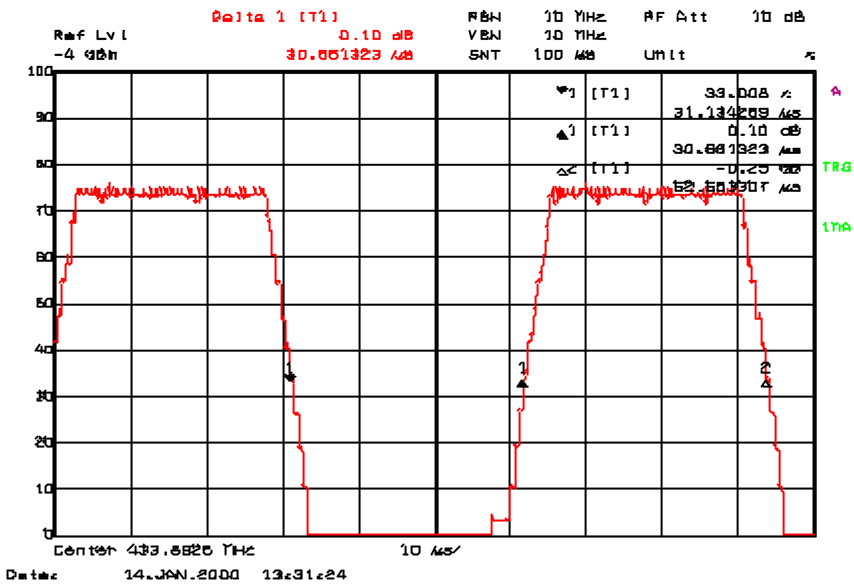


Figure 16: Demodulated RF wave for 101…- data pattern at 32kbit/s (linear scale).

Related Standards and References

1. AS3902 433MHz ISM band ASK transmitter data sheet.

2. EN 300 220-1 “Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Technical characteristics and test methods for radio equipment to be used in the 25 MHz to 1000 MHz frequency range with power levels ranging up to 500 mW; Part 1: Parameters intended for regulatory purposes.

3. Fujimoto, K.; et. al: “Small Antennas”, 1987, JOHN WILEY & SONS INC., ISBN 0 471 91413 4.

Michael MICU-BUDISTEANU
Application Engineer
Schloss Premstaetten
A-8141 Unterpremstaetten
AUSTRIA
Tel: +43-(0)3136-500-364
FAX: +43-(0)3136-500-693
E-Mail: michael.micu-budisteanu@amsint.com