

Laboratory Report

I C S F O R S E M I C O N D U C T O R S

UAA3201T Demonstration board with single sided component placement

Report No: HAC 95 001

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Abstract

The UAA 3201T is a fully integrated single-chip receiver, primarily intended for use in VHF and UHF systems employing direct return-to-zero (RZ) Amplitude Shift Keying (ASK) modulation. A number of typical application schematics and the corresponding demonstration board is presented which has been designed for single sided component placement and compact size. The demonstration board presented features a receiver supply switch in order to allow intermittent receiver operation for use in applications that target a low average supply current. As a function of the receiver On/Off ratio the average receiver supply current may be as low as 1 mA.

Keywords

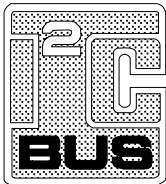
UAA 3201T, Amplitude Shift Keying (ASK), single-chip receiver, SAW resonator, superregenerative receiver, quench frequency, intermittent receiver operation

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Summary:

This Laboratory Note introduces the reader to the fully integrated single-chip receiver UAA 3201T, primarily intended for use in VHF and UHF systems employing direct return-to-zero (RZ) Amplitude Shift Keying (ASK) modulation. The UAA 3201T features a low power and low cost solution for keyless entry, car alarm, remote control, home appliance, security or other telemetry systems. Data rates up to 10 kbps and more are feasible without a significant reduction in sensitivity. The UAA 3201T has a very low radiation and is applicable to fulfil the requirements of FTZ 17 TR 2100. Compared with a superregenerative receiver the UAA 3201T is the superior solution. This note presents a number of application schematics for typical receive frequencies, together with a complete set of diagrams for the corresponding layout and demonstration board. An intermittent receiver operation will be presented that allows to reduce the average receiver supply current.



Purchase of Philips I²C Components conveys a license under the Philips I²C patent to use the components in the I²C-system provided the system conforms to the I²C specification defined by Philips

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1 Introduction

Infrared based remote control systems for keyless entry, e.g. automotive, garage door, etc. are more and more replaced by RF based systems, because RF offers a number of advantages compared to infrared. Some of them are:

- No optical link is required
- Almost independent of direction and weather conditions
- Larger access range

Today's receiver solutions are mostly based on a so called "superregenerative" architecture. This kind of receiver basically consists of an oscillator, running at or close to the desired receive frequency, which is alternated between oscillation and non-oscillation condition by means of a control signal at a low rate, known as the quench frequency. The quench frequency is typically below 50 kHz. Since the antenna signal is fed to the oscillator the oscillator rise time varies as a function of the applied signal strength. The demodulated signal is obtained by simply low pass filtering the oscillator output. Obviously, this receiver is able to detect amplitude modulated carries only.

Depending on the receive frequency and the spurious radiation limits set by the authorities, a regenerative receiver design may consist of 30 discrete and inexpensive components with L/C stabilized oscillator or requires twice the amount of components and a SAW stabilized oscillator. The latter case holds for the UHF range and the stringent radiation limits in Europe.

A receiver design that offers lower component count, better sensitivity, easy application and very low radiation is the UAA 3201 T, manufactured by Philips Semiconductors.

The UAA 3201T is a fully integrated single-chip receiver, primarily intended for use in VHF and UHF systems employing direct return-to-zero (RZ) Amplitude Shift Keying (ASK) modulation. The UAA 3201 T is based on a superhet architecture and requires 25 external low cost components only. Using the same pcb board layout the receiver may be adapted to other receive frequencies by changing values of 7 components. Due to the use of a SAW stabilized local oscillator, which requires no adjustment, very good long term and temperature stability is achieved. The UAA 3201 T may operate with data rates up to some 10 kbit/sec without a significant reduction of sensitivity.

As a result of the high integration level the whole receiver occupies 5 cm^2 (0.8 square inch) of pcb with single side component placement only. The UAA 3201T features a low power and low cost solution for keyless entry, car alarm, remote control, home appliance, security or other telemetry systems.

1.1 Typical system architecture

Like in figure 1, a typical system architecture consists of a ASK modulated transmitter with the data to be send generated by a microcontroller or an encoder ASIC. ASK modulation is preferred compared to FSK due to power consumption reasons, since the transmitter is usually battery powered. In addition ASK is easier to design, providing lower transmitter costs. The carrier is generated by means of an oscillator build around a single transistor. L/C stabilized oscillators are used for VHF and low end applications. SAW stabilized oscillators are used at UHF frequencies or when good frequency stability is required and oscillator alignment has to be avoided. Usually the antenna is part of the oscillator coil in order to minimize component count. Depending on the design some filtering has to be provided in order to suppress harmonics of the carrier frequency. Instead of a discrete solution, a complete ASK transmitter module may be used. Such transmitter modules are available from RFM and include the carrier filtering, e.g. HX 1000. Suitable SAW resonators for a discrete solution are available from RFM, Siemens and others.

It is recommended to use a SAW stabilized transmitter, in order to make use of the relative small system bandwidth of 800 kHz provided by the UAA 3201T on the receive side. Larger or smaller receive bandwidths are feasible when the IF filter design is modified accordingly.

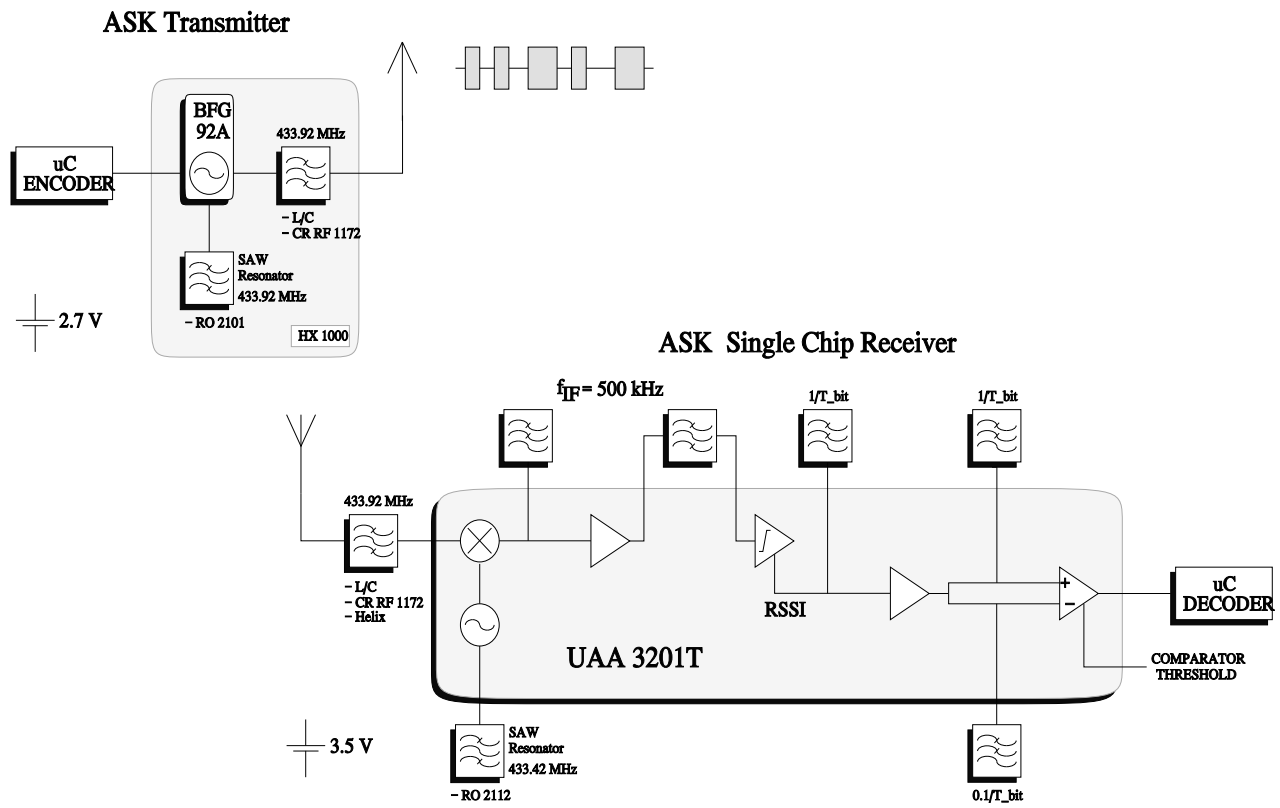


Fig.1 Typical system architecture

On the receive side all necessary functions are provided by means of the UAA 3201T from Philips Semiconductors. The UAA 3201T is based on the superhet architecture and incorporates a local oscillator stabilized by an external SAW resonator (e.g. RFM RO 2112, Siemens R647), thus no alignment is necessary. After filtering the received signal is feed to the mixer and down converted to the IF band. The UAA 3201T uses an IF frequency of 500 kHz which allows to use low cost L and C components for IF filtering. After amplification and filtering the signal is demodulated by a limiter amplifier that rectifies the incoming IF. The RSSI (receive signal strength indicator) derived contains the demodulated data and unwanted frequencies which are removed by low pass filtering in the following. This signal is feed to the positive input of a data slicer (data comparator). The slice reference is derived from the same signal by means of a separate low pass filter. This low pass filter is designed for a long time constant, in order to derive the average RSSI value as an adaptive reference for the data slicer. The adaptive reference enables the receiver to detect a modulated carrier over a input signal dynamic range of more than 75 dB. By means of an external resistor a data slicer threshold may be set, which inhibits noise coming out of the data output, when no RF carrier is present.

Due to the relative low IF frequency of typically 500 kHz and the high receive frequency of up to 434 MHz, the receiver image rejection is limited. With a SAW filter in front of the mixer input (e.g. RFM RF 1172, Siemens B 3530), about 10 dB of image rejection could be obtained. With a simple L/C circuit or a helical filter (e.g. double tuned) almost no image rejection is achieved. However, since the UAA 3201T targets a low cost solution a lack of image rejection can be accepted.

1.2 UAA 3201T Features

- The UAA 3201T incorporates the local oscillator, mixer, IF amplifier, demodulator and data slicer.
- No alignment is necessary due to the use of a SAW stabilized local oscillator.
- Data rates up to 10 kbps and more are feasible with a moderate reduction in sensitivity.
- The sensitivity typically achieved is about -110 dBm for a bit error rate (BER) of 1 % and 512 bps and about -108 dBm for a BER of 1% and 10 kbps (NRZ coding).
- The spurious radiation measured at the RF input port is better than -60 dBm in order to fulfil FTZ 17 TR 2100.
- The on-chip local oscillator allows a receive frequency range from 150 MHz to 450 MHz. When used with an external local oscillator, the receive frequency may be as low as 27 MHz.
- The IF filter bandwidth is typically 800 kHz, but may be modified since it is determined by the application.
- The device operates from 3.5 V to 6.0 V.
- The device operating supply current is 3.7 mA, which may be reduced to an average of 2 mA and less with a proper pulsed receiver operation.
- For a pulsed receiver operation the settling time may be as low as 5 ms.
- The UAA 3201T meets the automotive temperature range from -40 to +85 °C.
- The UAA 3201T requires about 25 external low cost components only.

2 Application examples

The following sections present the schematics diagrams for receiver applications with receive frequencies of 433.92 MHz and 315 MHz. The application examples incorporate a receiver supply switch for intermittent receiver operation in order to reduce the average supply current. In the case a intermittent receiver operation is not required the corresponding components may be omitted.

Please note that the board layout may be used for different receive frequencies by changing a number of components in the oscillator and mixer input section to their appropriate value.

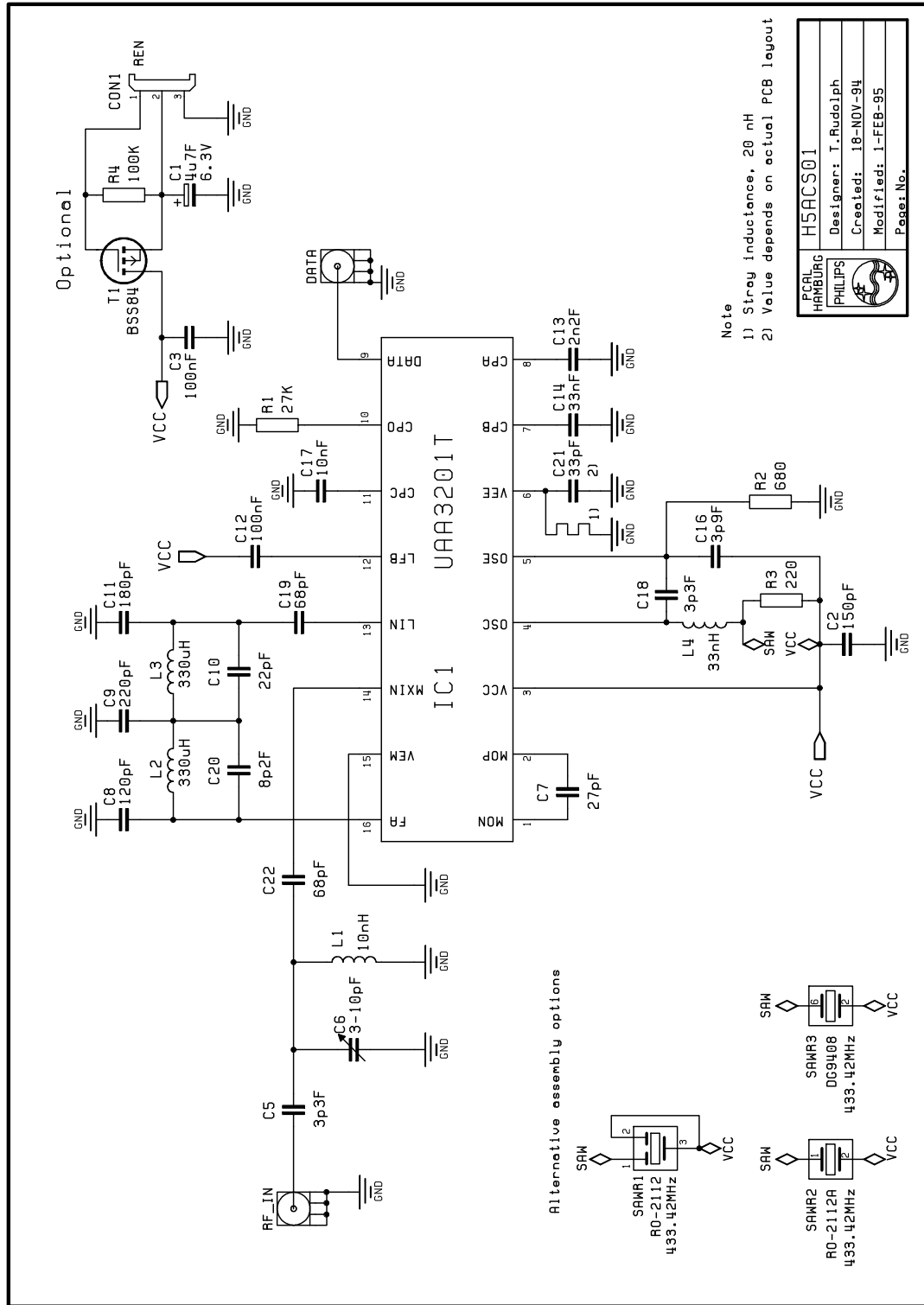
Please note further that the demonstration boards have been designed to fit for a data rate of 512 bps (NRZ coding) resp. 256 bps (RZ or manchester coding). In the case you wish to use a higher data rate, it is mandatory to change the values of C17, C13 and in some cases C14 also.

Details regarding the UAA 3201T application and design formulas are presented in a separate Application Report.

We hope that you will find no problems during device evaluation and will come quickly to an application that fits perfectly your needs.

For ordering information or in the case of difficulty, please do not hesitate to call your local Philips Semiconductors representative for more help.

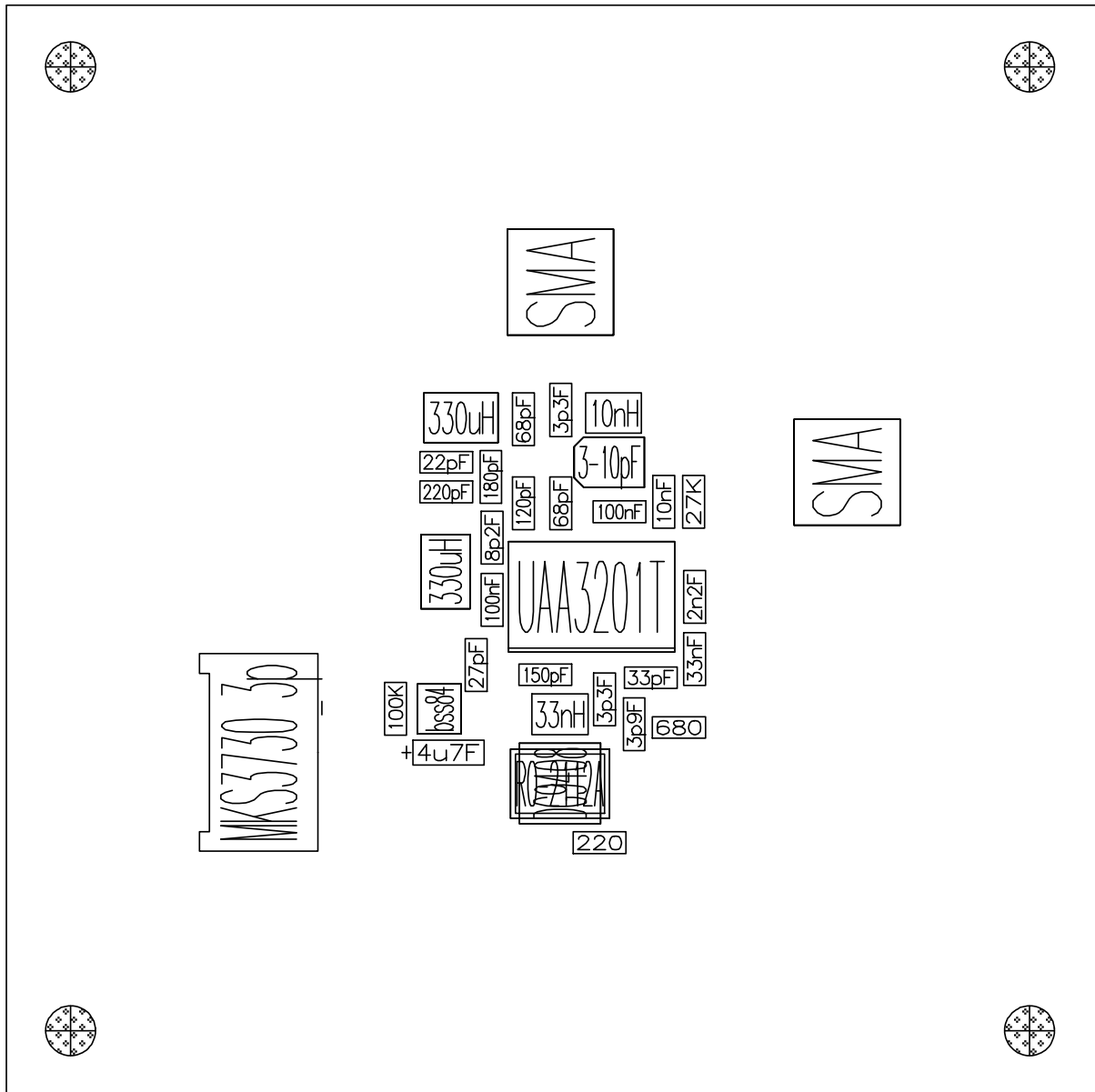
2.1 433.92 MHz ASK Receiver with broad band input



2.1.1 Bill of material for 433.92 MHz application

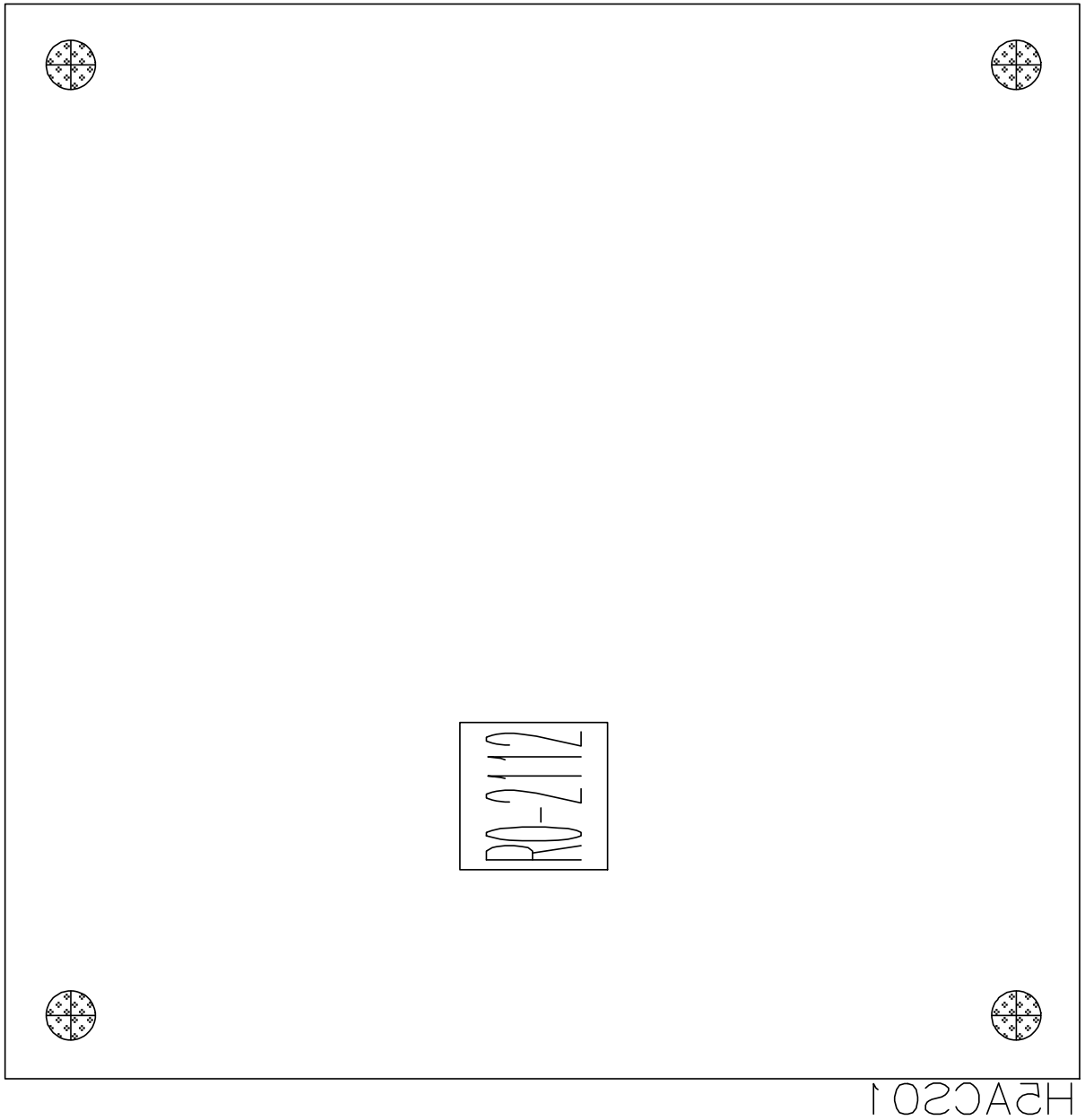
| REF | PART NO. | VALUE | GEOMETRY | DESCRIPTION |
|--------|----------------|-------------|-----------------|--------------------------------|
| C1 | 2222-195-23478 | 4u7F | cts_a | CTS195 |
| C2 | 2222-861-12151 | 150pF | 0805 | C861 |
| C3 | 2222-880-06549 | 100nF | 0805 | C880 |
| C5 | 2222-861-12338 | 3p3F | 0805 | C861 |
| C6 | ECR KN 010 C21 | 3-10pF | tzc03 | Panasonic, ECR K-SERIES |
| C7 | 2222-861-12279 | 27pF | 0805 | C861 |
| C8 | 2222-861-12121 | 120pF | 0805 | C861 |
| C9 | 2222-861-12221 | 220pF | 0805 | C861 |
| C10 | 2222-861-12229 | 22pF | 0805 | C861 |
| C11 | 2222-861-12181 | 180pF | 0805 | C861 |
| C12 | 2222-880-06549 | 100nF | 0805 | C880 |
| C13 | 2222-590-06518 | 2n2F | 0805 | C590 |
| C14 | 2222-590-06534 | 33nF | 0805 | C590 |
| C16 | 2222-861-12398 | 3p9F | 0805 | C861 |
| C17 | 2222-590-06527 | 10nF | 0805 | C590 |
| C18 | 2222-861-12338 | 3p3F | 0805 | C861 |
| C19 | 2222-861-12689 | 68pF | 0805 | C861 |
| C20 | 2222-861-12828 | 8p2F | 0805 | C861 |
| C21 | 2222-861-12339 | 33pF | 0805 | C861 |
| C22 | 2222-861-12689 | 68pF | 0805 | C861 |
| DATA | R-125-426 | SMA | sma | RADIAL |
| IC1 | UAA320IT | UAA320IT | so_16 | |
| L1 | 1008CS100XMBC | 10nH | 11008cs | COILCRAFT, 1008CS-SERIES |
| L2 | 300HS-331-K | 330uH | toko_43fs | TOKO, 43FS-SERIES, SRF > 4 MHz |
| L3 | 300HS-331-K | 330uH | toko_43fs | TOKO, 43FS-SERIES, SRF > 4 MHz |
| L4 | 1008CS330XMBC | 33nH | 11008cs | COILCRAFT, 1008CS-SERIES |
| R1 | 2322-730-60273 | 27k | 0805 | RC-11 |
| R2 | 2322-730-60681 | 680 | 0805 | RC-11 |
| R3 | 2322-730-60221 | 220 | 0805 | RC-11 |
| R4 | 2322-730-60104 | 100k | 0805 | RC-11 |
| RF_IN | R-125-426 | SMA | sma | RADIAL |
| SAWR1 | RO-2112 | RO-2112 | to_39_saw | RFM, 1-PORT, 433.42 MHZ |
| SAWR2 | RO-2112A | RO-2112A | saw_smd_rfm | RFM, 1-PORT, SMD, optional |
| SAWR3 | DG9408 | DG9408 | saw_smd_siemens | Siemens, 1-PORT, SMD, optional |
| SUPPLY | MKS3733-1-0-30 | 3MKS3730_3p | mks3730_3p | STOKO |
| T1 | BSS84 | BSS84 | sot23 | |

2.1.2 Component placement



H5ACS01

Component side (drawing not to scale)



Solder side (drawing not to scale)

2.1.3 Typical performance

Sensitivity

Table 1

| V _{CC} | P _{SENS} ¹ | Condition |
|-----------------|--------------------------------|------------------|
| 3.5 V | -108.5 dBm | R1 = 27 kΩ |
| 5.0 V | -108.5 dBm | R1 = 27 kΩ |
| 3.5 V | -113.5 dBm | R1 not assembled |
| 5.0 V | -113.5 dBm | R1 not assembled |

Spurious radiation

Table 2

| VCC | P _{LO} ³ | P _{2*LO} ² | P _{3*LO} ² | Condition |
|-------|------------------------------|--------------------------------|--------------------------------|-----------|
| 3.5 V | -65 dBm | -75 dBm | -80 dBm | |
| 5.0 V | -65 dBm | -75 dBm | -80 dBm | |

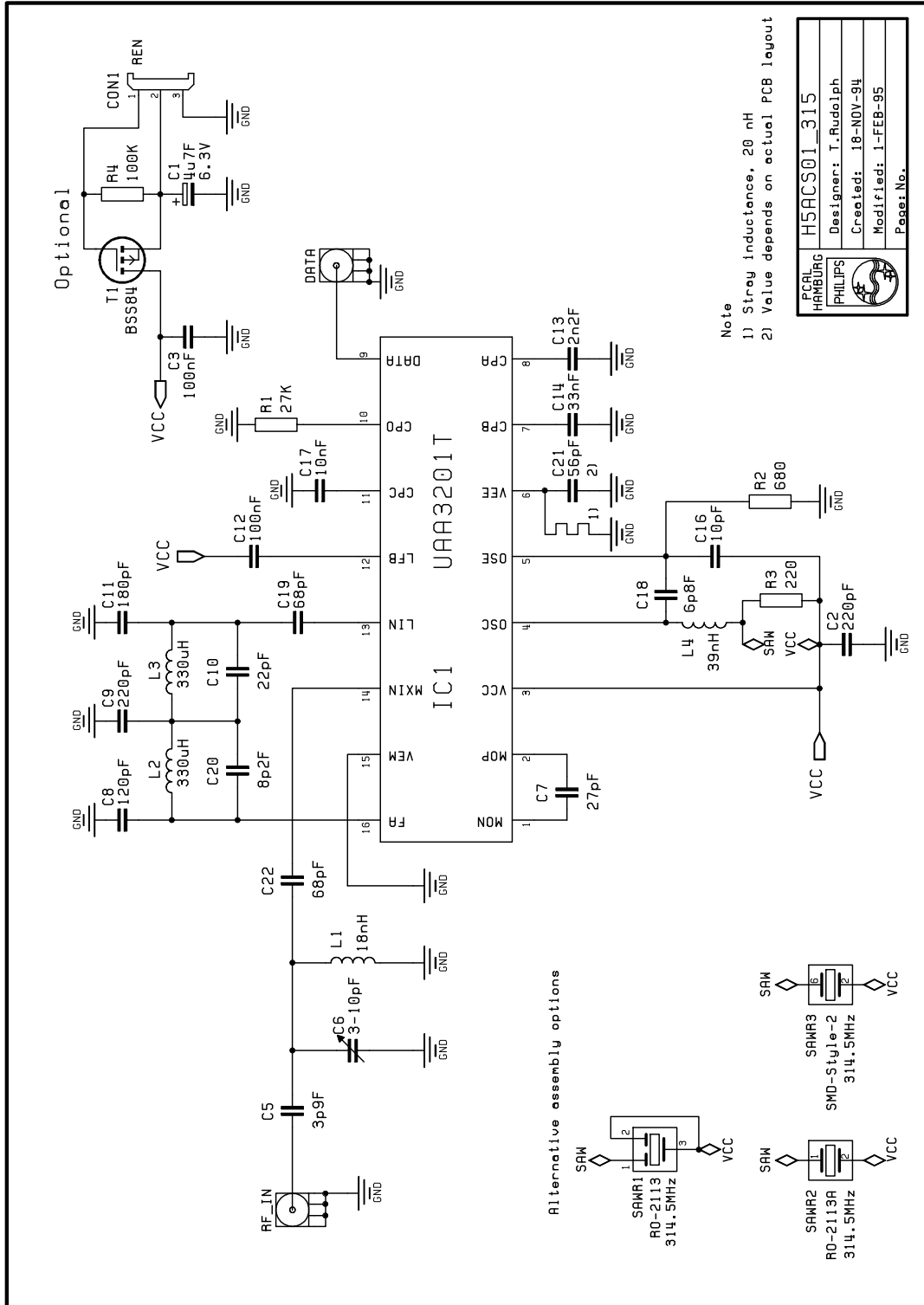
NOTE:

- 1 Measured for a bit error rate (BER) of $1 \cdot 10^{-2}$
- 2 Measured at RF input connector
- 3 Measured at RF input connector. This value depends very much on the PCB layout. More exactly speaking on the value and placement of the capacitor C 21. The closer C 21 is placed to the IC solder pad (pin 6) and the better its connections to the PCB ground plane is provided, the lower the spurious radiation gets. Values of -70 dBm may be achieved with an improved layout. Please refer to the layout of the demonstration boards H4ACS15 and H4ACS21 or to the UAA 320IT Application Report.

General measurement conditions:

TA = 25 °C; RF frequency = 433.92 MHz; AM modulation 256 Hz square wave (512 bps), modulation index 100 % (ASK), REN = LOW

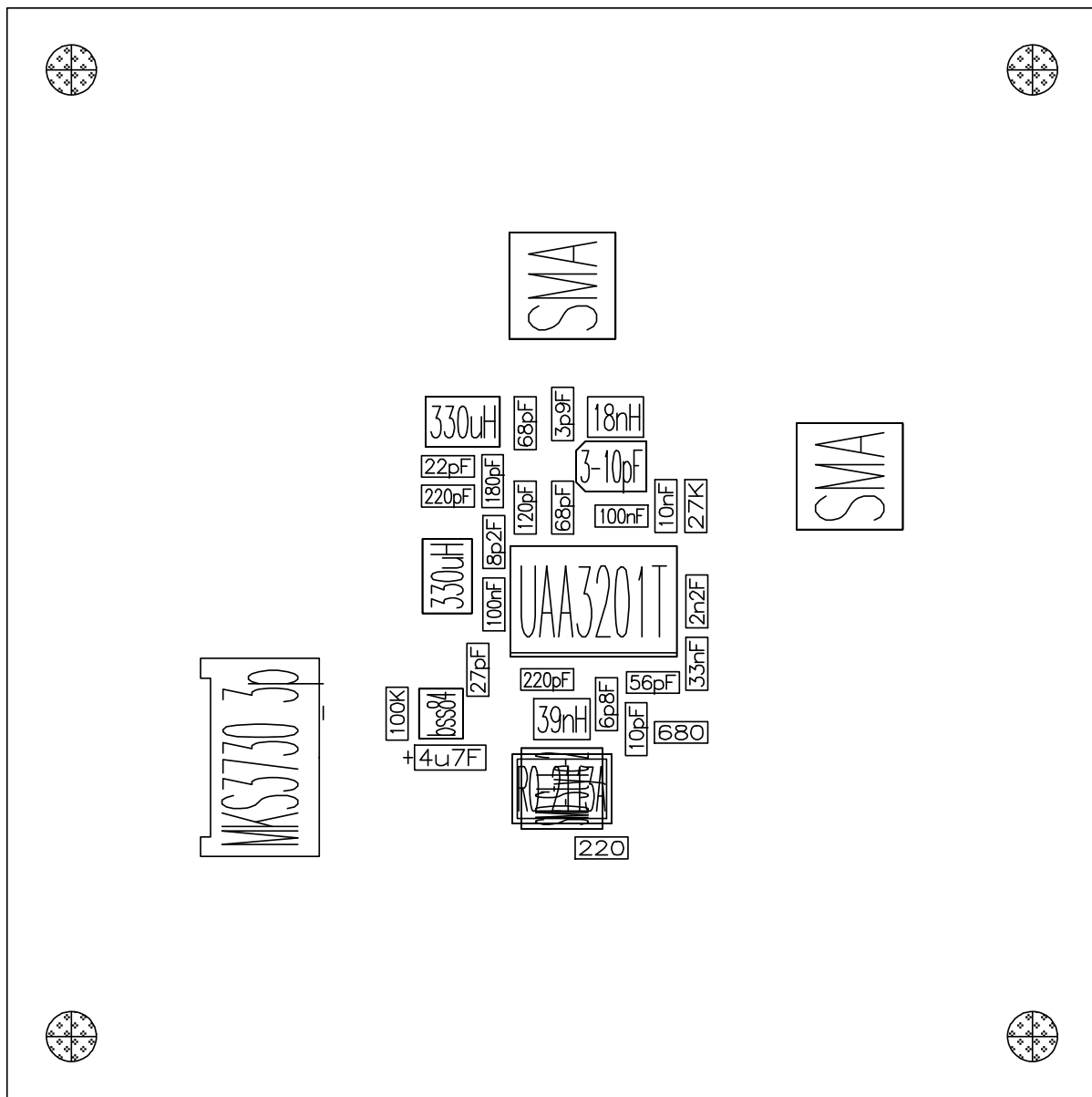
2.2 315 MHz ASK Receiver with broad band input



2.2.1 Bill of material for 315 MHz application

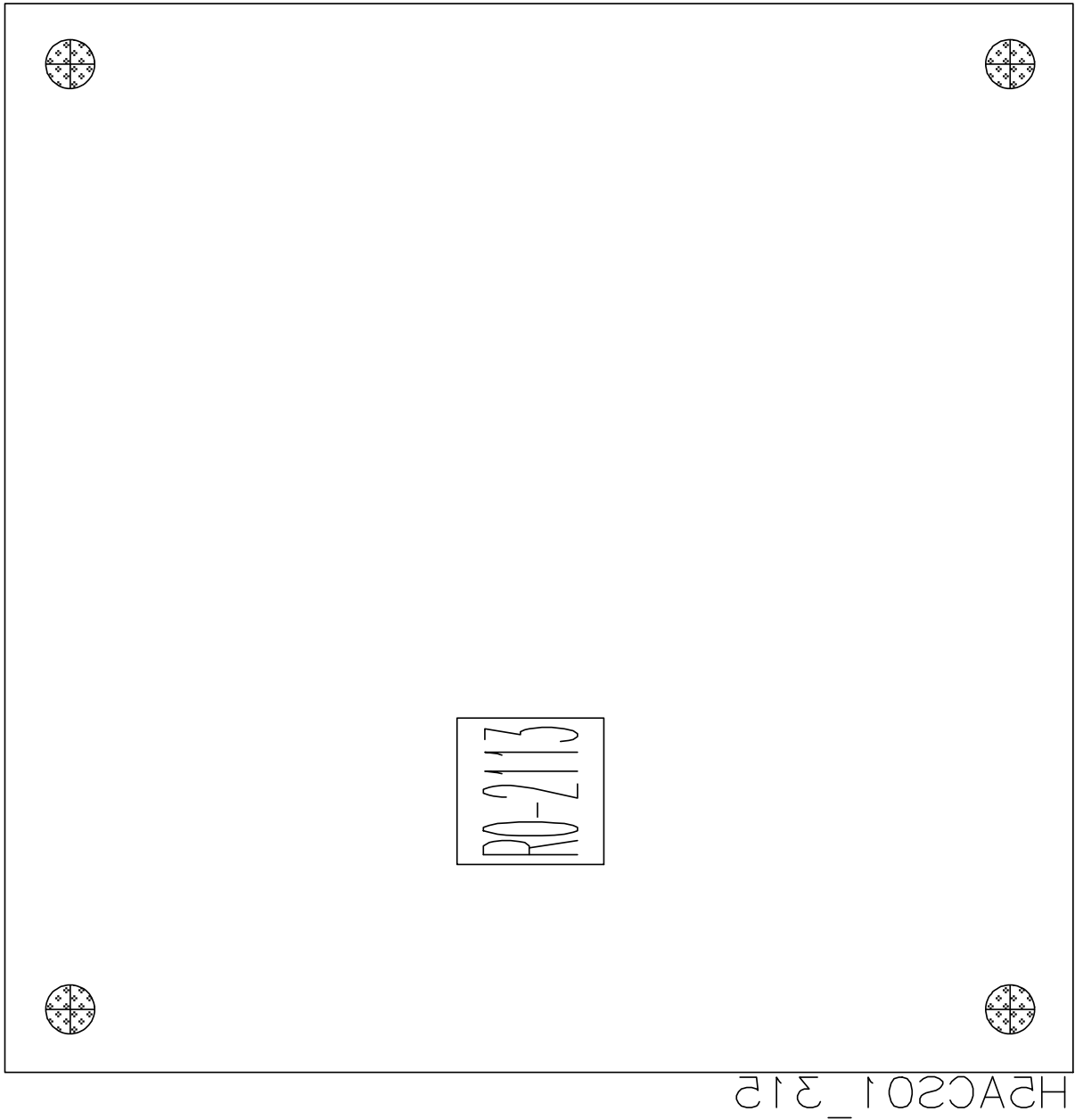
| REF | PART NO. | VALUE | GEOMETRY | DESCRIPTION |
|--------|-----------------|------------|-----------------|--------------------------------|
| C1 | 2222-195-23478 | 4u7F | cts_a | CTS195 |
| C2 | 2222-861-12221 | 220pF | 0805 | C861 |
| C3 | 2222-880-06549 | 100nF | 0805 | C880 |
| C5 | 2222-861-12398 | 3p9F | 0805 | C861 |
| C6 | ECR KN 010 C21 | 3-10pF | tzc03 | Panasonic, ECR K-SERIES |
| C7 | 2222-861-12279 | 27pF | 0805 | C861 |
| C8 | 2222-861-12121 | 120pF | 0805 | C861 |
| C9 | 2222-861-12221 | 220pF | 0805 | C861 |
| C10 | 2222-861-12229 | 22pF | 0805 | C861 |
| C11 | 2222-590-06504 | 180pF | 0805 | C590 |
| C12 | 2222-880-06549 | 100nF | 0805 | C880 |
| C13 | 2222-590-06518 | 2n2F | 0805 | C590 |
| C14 | 2222-590-06534 | 33nF | 0805 | C590 |
| C15 | 2222-861-12221 | 220pF | 0805 | C861 |
| C16 | 2222-861-12109 | 10pF | 0805 | C861 |
| C17 | 2222-590-06527 | 10nF | 0805 | C590 |
| C18 | 2222-861-12688 | 6p8F | 0805 | C861 |
| C19 | 2222-861-12689 | 68pF | 0805 | C861 |
| C20 | 2222-861-12828 | 8p2F | 0805 | C861 |
| C21 | 2222-861-12569 | 56pF | 0805 | C861 |
| C22 | 2222-861-12689 | 68pF | 0805 | C861 |
| DATA | R-125-426 | SMA | sma | RADIAL |
| IC1 | UAA320IT | UAA320IT | so_16 | |
| L1 | 1008CS180-XK. | 18nH | 11008cs | COILCRAFT, 1008CS-SERIES |
| L2 | 300HS-331-K | 330uH | toko_43fs | TOKO, 43FS-SERIES, SRF > 4 MHz |
| L3 | 300HS-331-K | 330uH | toko_43fs | TOKO, 43FS-SERIES, SRF > 4 MHz |
| L4 | 1008CS390-XK. | 39nH | 11008cs | COILCRAFT, 1008CS-SERIES |
| R1 | 2322-730-60273 | 27K | 0805 | RC-11 |
| R2 | 2322-730-60681 | 680 | 0805 | RC-11 |
| R3 | 2322-730-60221 | 220 | 0805 | RC-11 |
| R4 | 2322-730-60104 | 100k | 0805 | RC-11 |
| RF_IN | R-125-426 | SMA | sma | RADIAL |
| SAWR1 | RO-2113 | RO-2113 | to_39_saw | RFM, 1-PORT, 314.5 MHZ |
| SAWR2 | RO-2113A | RO-2113A | saw_smd_rfm | RFM, 1-PORT, SMD, optional |
| SAWR3 | tbf | tbf | saw_smd_siemens | Siemens, 1-PORT, SMD, optional |
| SUPPLY | MKS3733-1-0-303 | MKS3730_3p | mks3730_3p | STOKO |
| T1 | BSS 84 | BSS 84 | sot23 | |

2.2.2 Component placement



H5ACS01_315

Component side (drawing not to scale)



Solder side (drawing not to scale)

2.2.3 Typical performance

Sensitivity

| VCC | PSENS ¹ | Condition |
|-------|--------------------|-------------------------|
| 3.5 V | -111 dBm | R1 = 27 kΩ |
| 5.0 V | -111 dBm | R1 = 27 kΩ |
| 3.5 V | -114 dBm | R1 not assembled |
| 5.0 V | -114 dBm | R1 not assembled |

Spurious radiation

| VCC | PLO ³ | P2*LO ² | P3*LO ² | Condition |
|-------|------------------|--------------------|--------------------|-----------|
| 3.5 V | -70 dBm | -75 dBm | -80 dBm | |
| 5.0 V | -70 dBm | -75 dBm | -80 dBm | |

NOTE:

- 1 Measured for a bit error rate (BER) of $1 \cdot 10^{-2}$
- 2 Measured at RF input connector
- 3 Measured at RF input connector. This value depends very much on the PCB layout. More exactly speaking on the value and placement of the capacitor C 21. The closer C 21 is placed to the IC solder pad (pin 6) and the better its connections to the PCB ground plane is provided, the lower the spurious radiation gets. Please refer to the layout of the demonstration boards H4ACS15 and H4ACS21 or the UAA 320IT Application Report.

General measurement conditions:

$T_A = 25 \text{ }^\circ\text{C}$; RF frequency = 315 MHz; AM modulation 256 Hz square wave (512 bps), modulation index 100 % (ASK), REN = LOW

3 Supply current reduction by intermittent receiver operation

The typical operating supply current for the UAA 320IT is about 3.7 mA. However, various receiver applications target an average receiver supply current of 2 mA and less. If an intermittent receiver operation is allowed the average supply current may easily be reduced to less than 2 mA. For an intermittent receiver operation a number of parameter need to be considered, like receiver settling time, receiver On/Off duration and system response time.

Although the data sheet UAA 320IT specifies a receiver settling time of 10 ms, one can reduce the receiver settling time to 5 ms and less by proper application. As a result the designer is almost free to choose the system response time and receiver On/Off duration according to his needs in order to meet his average supply current requirements.

The receiver settling time depends on a number of application parameter:

- The power supply slew rate
- The receiver On/Off duration
- The data filter design
- The RF input power

From the above the most important one is the power supply slew rate. It is important to note that the power On as well as the power Off slew rate need to be considered. In order to minimize the receiver settling time the receiver power supply should be switched Off and On very fast providing a very steep voltage step at the UAA 3201T VCC terminals. This avoids a complete discharge of the capacitor external to the UAA 3201T and as a result a fast recovery from receiver Off is achieved.

In order to provide a steep change at the VCC terminals, it is mandatory to place the large electrolyte by-pass capacitor right before the supply switch, see figure 2.

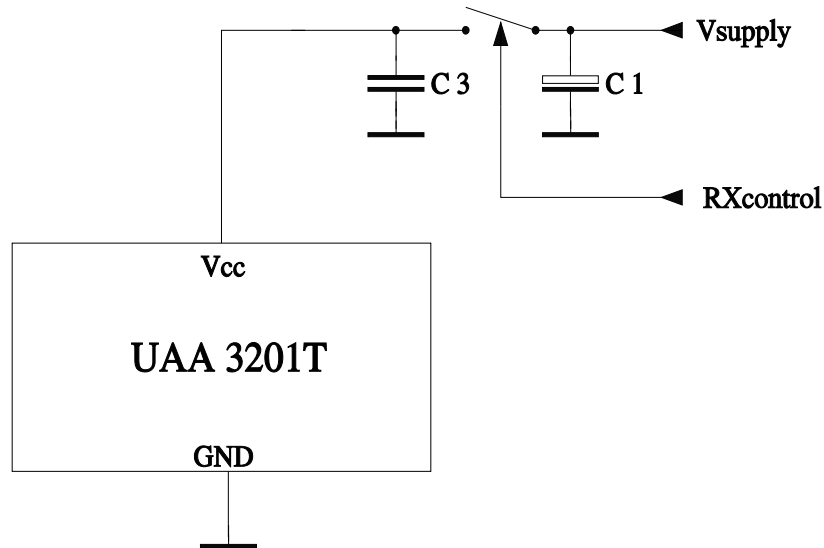


Fig.2 Power supply concept for intermittent receiver operation

The IC supply now drops more or less instantly when the switch is opened, avoiding discharge of the external capacitors as much as possible. As a result the settling time achieved is about 10 ms when the receiver is switched On and Off periodically. Please note that the initial settling time, when the receiver is Off for a very long time, will increase to a couple of 10 ms, depending on the capacitor values external to the UAA 3201. However, the initial settling time is of minor interest usually.

The receiver settling time may be reduced to about 5 ms and less when an additional discharge resistor is incorporated. The resistor shall accelerates the discharge of the small VCC by-pass capacitor (C3), see Figure 3

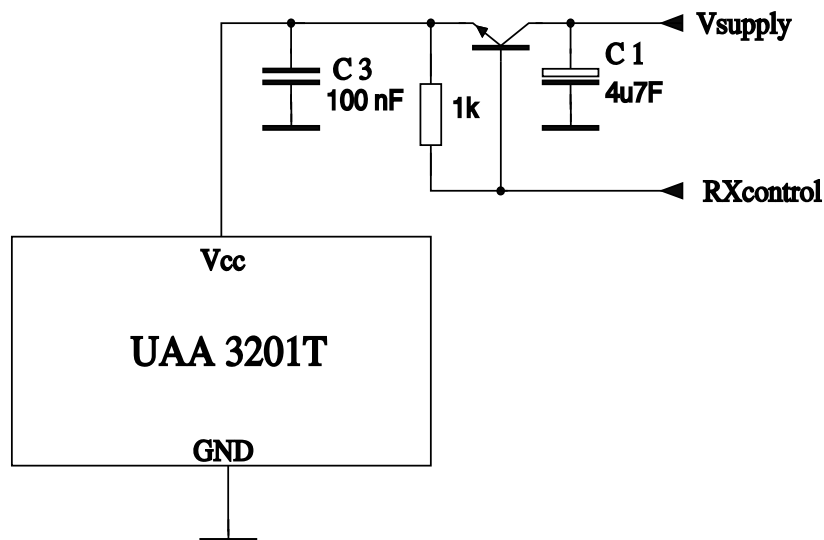


Fig.3 Power supply concept for intermittent receiver operation with fast recovery

Care has to be taken during selection of the receiver On time. For a proper intermittent receiver operation it is recommended to select a receiver On time of at least 20 ms for the application given above. Shorter receiver On times may be used when the value of capacitor C 14 is reduced.

Since the value of C14 is fixed during the design of the data filter it is recommended to make use of a data coding scheme that allows C14 to become relatively small. More exactly speaking, it is recommended to use Bi-Phase coding rather than Pulse-Width coding, when a fast receiver settling is desired.

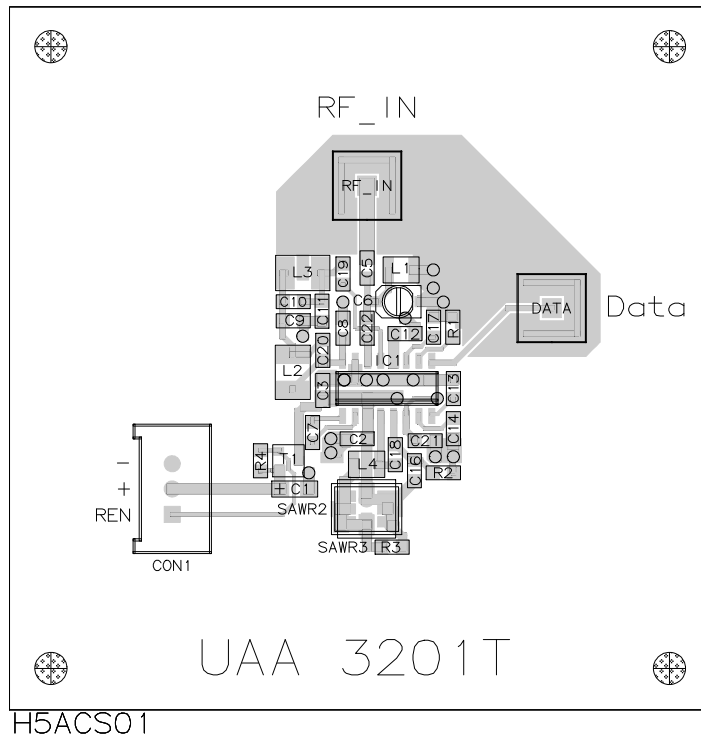
Please note that the receiver settling time values mentioned so far have been measured at the threshold of sensitivity. When the receiver RF input power is increased the settling time reduces at the same time. The lowest settling time that could be expected is about 1 ms with a RF input power of approx. 10 dB above the threshold of sensitivity or higher.

Almost any average supply current can be achieved by proper selection of the duty cycle, while having control over the system response time by means of the repetition rate used. For a more detailed discussion of an intermittent receiver operation please referred to the UAA 320IT Application Report.

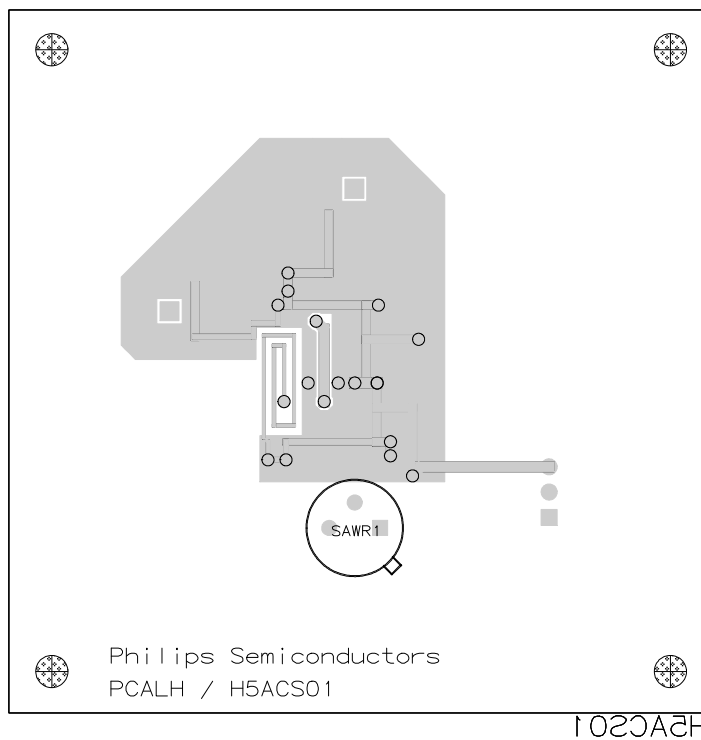
APPENDIX

A H5ACS01 demonstration board drawings

A.1 H5ACS01 board assembly

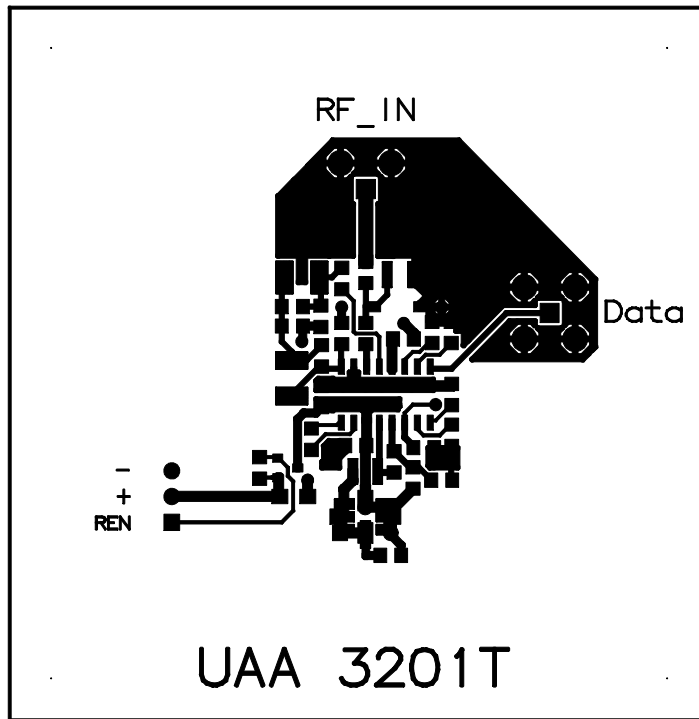


Component side (drawing not to scale, original size is 70 mm x 70 mm)



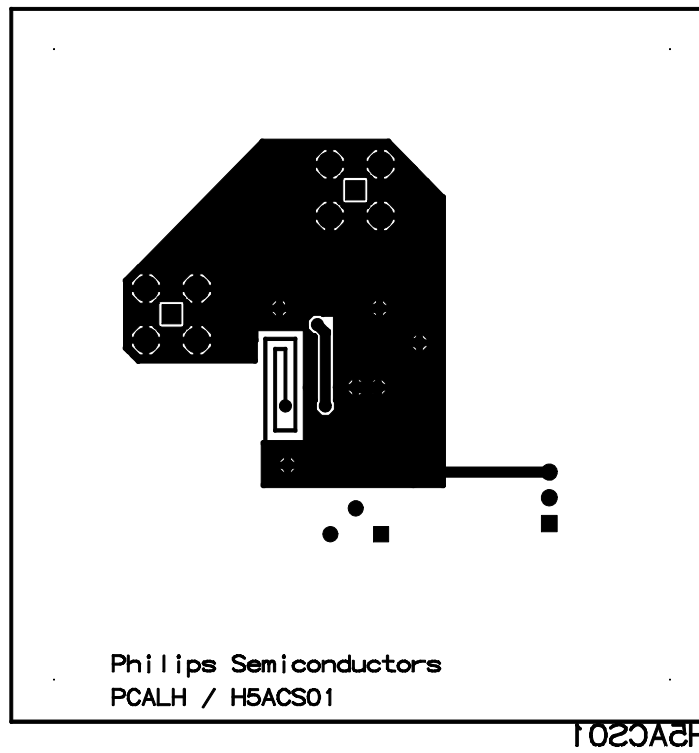
Solder side (drawing not to scale, original size is 70 mm x 70 mm)

A.2 H5ACS01 artwork



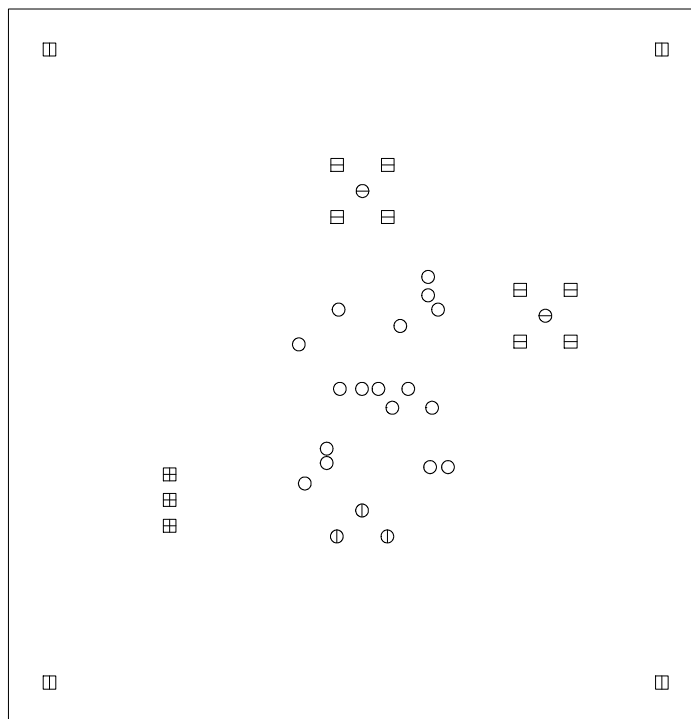
H5ACS01

Component side (drawing not to scale, original size is 70 mm x 70 mm)



Solder side (drawing not to scale, original size is 70 mm x 70 mm)

A.3 H5ACS01 board drill holes



H5ACS01

BOARD's HOLE SCHEDULE

| HOLE SYMBOL | HOLE SIZE | COUNT | PLATED | TOLERANCE |
|-------------|-----------|-------|--------|-----------|
| ○ | 0.600000 | 17 | YES | --- |
| ▣ | 1.000000 | 3 | YES | --- |
| ⊙ | 0.900000 | 3 | YES | --- |
| ▤ | 1.600000 | 8 | YES | --- |
| ⊖ | 1.300000 | 2 | YES | --- |
| ▣ | 3.200000 | 4 | NO | --- |

B Product overview SAW devices from RFM

The following information on SAW devices is courtesy of RF Monolithics. Philips Semiconductors assumes no responsibility for errors or omissions.

The information is presented to provide the reader with a reference and some technical data.

Please note that the demonstration board H5ACS01 has been designed for SAW resonators of the 1-Port type. SAW resonators of the 2-Port type could also be used in principle, however, the connection to the SAW terminals differs from a 1-Port application. The designer is asked to contact the SAW supplier for the appropriate configuration.

C Device specification for the SAW components used

The following information on SAW devices is courtesy of RFM. Philips Semiconductors assumes no responsibility for errors or omissions.

The information is presented to provide the reader with a reference and some technical data.