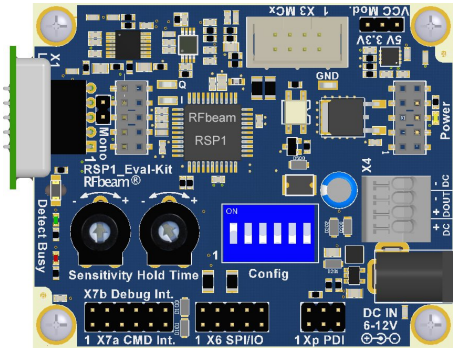
RSP1 Evaluation Kit

User Manual

Features

- Reference design for RFbeam RSP1 processor
- Advanced movement detection system
- High performance signal processing
- More detection range than traditional designs
- Less susceptibility to interferences
- Supports most RFbeam Radar transceivers
- Stand alone or host operated modes
- Analyzing and command software tools included
- Saves time to market and development investments



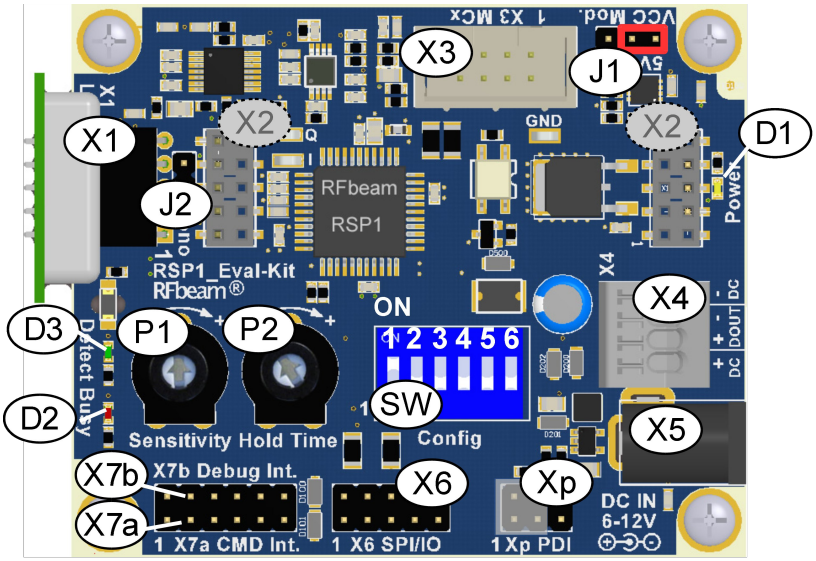
Applications

- Reference design for own developments based on RSP1 processor
- Exploring FFT based Dopppler signal processing
- Optimizing choice of sensor type for different applications

Overview

RSP1 Evaluation Kit is a fully operational movement sensor application using advanced signal processing. It saves an important amount of evaluation and development time and money.
The RSP1 processor offers adaptive noise cancelling and automatic adaptation to different Doppler transceivers.

Functionality can be influenced by manual settings as well as by more than 30 parameters and commands.
The kit can be used as stand alone system or as a server of a host computer or microcontroller.
The kit contains helpful software tools for configuration and signal visualization.



Indicators	
D1	Power LED
D2	Busy LED (start-up)
D3	Detection LED
Connectors	
X1	K-LCx sensor connector
X2	***Backside*** K-LCx connector
X3	K-MCx sensor connector
X4	Digital output connector
X5	DC Supply input 6 .. 12V
X6	Digital I/O (SPI in preparation)
X7a	Serial Command (**RSP_Terminal**)
X7b	Serial Debug (**RSP_Scope**)
Xp	Reserved / Reset
Settings	
P1	Sensitivity pot
P2	Hold time pot
SW	Mode switch
J1	Sensor supply volage
J2	Optional for mono sensor

Fig. 1: Connectors and indicators

Packing List

1. Eval-Kit PCB board
2. RS232 USB cable
3. USB stick containig
   - RSP_Terminal software, RSP_Scope software, RSP_Prog software FTDI USB-Serial drivers
   - Documentation
4. 5 different RFbeam Radar sensors:
   - K-LC1a, K-LC3 (1 channel sensors, also called "mono sensors")
   - K-LC2, K-LC5, K-LC6 (2 channel sensors, also called "stereo sensors", "I/Q sensors")

Getting Started

Preparation

We will begin with using the Evaluation Kit as stand-alone device without any PC software.

Please follow step by step:

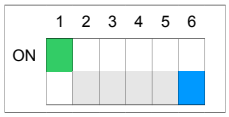
1. Install software from USB stick by starting "Setup_RSP-Tools.exe"
   Different software modules will be installed. If your computer does not already contain the actual LabVIEW runtime engine, you will be asked to accept licenses of National Instruments. Please accept all default storage locations. Several installers are executed by a script. Accept installers until the end of complete installation.

2. If correctly installed, You will find RSP_Terminal and RSP_Scope software under START-PROGRAMS-RFbeam-RSP and the program Icons on your desktop

3. Connect the FTDI USB cable to PC. Leave RSP side connector unplugged!
   FTDI Hardware should be recognized by Windows after some seconds.
   Unplug USB cable from PC again so that power of the kit is off

4. Insert the **K-LC2** sensor in RSP_Evaluation-Kit front connector X1

5. Set 'SW' DIP switch '1' in ON position, all other should be OFF:



6. Set Potentiometer P1 (sensitivity) to maximum (towards +)

7. Set Potentiometer P2 (hold time) to minimum (towards -)

If Windows does not recognize the FTDI USB cable, please uninstall and reinstall the drivers:
1. Uninstall existing driver with `CDMuninstallerGUI.exe`
2. Reinstall driver with `CDM v2.12.00 WHQL Certified.exe`

Always unplug power supply before inserting or unplugging sensors

RFbeam K-LCx radar module are susceptible to electrical discharge . Before plugging the module, please touch first the RSP1 board and then insert the K-LCx device.

Quick Start

No PC software is required yet.

1. Plug in USB cable into X7a (**black wire must be connect to pin '1'**)
2. Plug in USB cable into a USB port of your PC or notebook. This serves as power supply now.
3. Look at the LED indicators
   - D1 power LED is on
   - D2 busy LED turns on for about 5 seconds: RSP1 is learning the sensor and environment.
4. RSP1 is ready, as soon as red D2 is off

RSP1_Eval-Kit can also be used without a PC and USB cable. Use a 12VDC adapter or a 9V battery connected to the X5 power supply connector instead.

Explore!

You have plugged in a K-LC2 "I/Q stereo" sensor. This allows distinguishing between movements towards and backwards from the sensor. (This behavior can be changed by other DIP switch settings).

→ Forward movement;

- Green indicator LED3 turns on only, if there is a forward movement to the sensor. Walk around in some distance from the sensor and check this.

→ Sensitivity potentiometer:

- This affects the maximum detection distance. May be that there is no more reaction near the minimum sensitivity. This behavior depends on the sensor type.

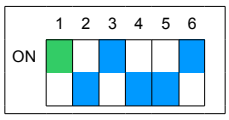
→ Hold time potentiometer.

- Turn it to the center position: hold time will be around 5 seconds. Maximum hold time is around 160 seconds.

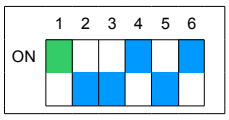
→ Direction settings;

- Set sensitivity to maximum and hold time to minimum again to get best experience.
- Set switches to explore detection modes:

"Mono":
detects movement in both directions



"Backwards":
detects movements away from the sensor only



→ Try other sensors and settings:
Refer to Switch Settings Summary.

Always unplug power supply before inserting or unplugging sensors.

Do not try to connect any device on X2 component side!
Connector X2 is for connecting sensors on the backside of the Evaluation Kit only.

Switch Settings Summary

Settings and around 30 parameters can be set and permanently stored by an ASCII terminal connected via the command interface at X7a. Please refer to the RSP1 data sheet for more information.
For stand alone operation, most important parameters my be set by potentiometers and a DIP switch.

Mode Switch 'SW'

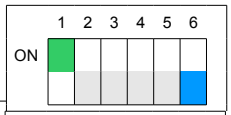
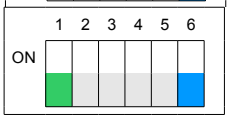
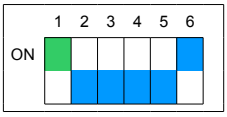
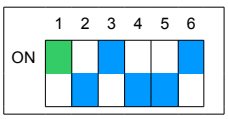
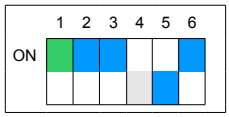
Changes becomes valid only after power up.

Switch #	Function	ON	OFF (default)
1	Sensitivity / Hold Time	Use potentiometers	Use EEPROM Sensitivity/Hold settings
Switches 2 … 5 take only effect, if switch #6 is in ON position			
2	Sensor type	Mono sensor (K-LC1 e.g.)	I/Q sensor (K-LC2 e.g.)
3	Direction mode	Mono (even with I/Q sensor)	Stereo (=Directional)
4	Direction	Backward	Forward
5	Immunity	Higher interference immunity	Low interference immunity
6	Select Setting mode	Use switch 2 … 5 settings	Use EEPROM Mode settings

Typical Settings

These examples assume standard default parameters in EEPROM. For more information on EEPROM parameters refer to the RSP1 datasheet.

Switch #1 defines, if potentiometers for sensitivity and hold time will be active.
Switch #6 enables settings of switches #2 .. #5.
DIP switch is read only after power-on or reset.

Configuration	Switch Setting	Remarks
Use Potentiometers		All parameters from EERPOM except, potentiometers - I/Q stereo sensor (K-LC2, K-LC5, …) - Direction forward
Manual settings inactive		All parameters from EERPOM. Defaults: - I/Q stereo sensor (K-LC2, K-LC5, …) - Direction forward - Minimum hold time - Maximum sensitivity
Typical directional setting		Manual settings: #2: I/Q stereo sensor (K-LC2, K-LC5, …) #3: Direction mode stereo #4: Direction forward #5: Standard interference immunity.
Typical non directional setting I/Q stereo sensor		Manual settings: #2: I/Q stereo sensor (K-LC2, K-LC5, …) #3: Direction mode mono #4: Direction forward #5: Standard interference immunity.
Typical non directional setting mono sensor		Manual settings: #2: Mono sensor (K-LC1, K-LC3) #3: Direction mode mono #4: Don't care #5: Standard interference immunity.

RSP1 Hardware Architecture

Data Acquisition

An internal, programmable differential amplifier allows gains from 1 to 16.
RSP1 works with 2 12Bit ADCs, sampling rate is selectable between 1'200Hz up to 22.5kHz in 10 steps.
This corresponds to maximum speeds from 13km/h to 250km/h.

Data Processing

Processing is based on a complex FFT and on an adaptive noise threshold. Many parameters allow adjusting and optimizing the performance for many different applications.

Advantages of FFT

FFT stands for Fast Fourier Transform, that allows signal processing in the frequency domain (see details on http://en.wikipedia.org/wiki/Fft).
Processing of the Quadrature Doppler signals is performed by a complex FFT. Using FFT results in much better performance than using simple comparator designs or time domain processing.

The RSP1 FFT implementation leads to sophisticated movement and speed detectors:

- Better S/N (21dB with 256pt FFT) → 2 to 3 times larger detection range
- Inherent object speed detection
- Reliable distiction between approaching / receding objects
- Efficient interference suppression through complex FFT (fluorescent light, rain, vibrations …)
- Narrowband filtering of known interference frequencies
- Selective and adaptive noise threshold capability

Hardware

The processor architecture allows data acquisition and processing in parallel. Only a few external components are needed thanks to the high integration level including EEPROM and precision clock generator.

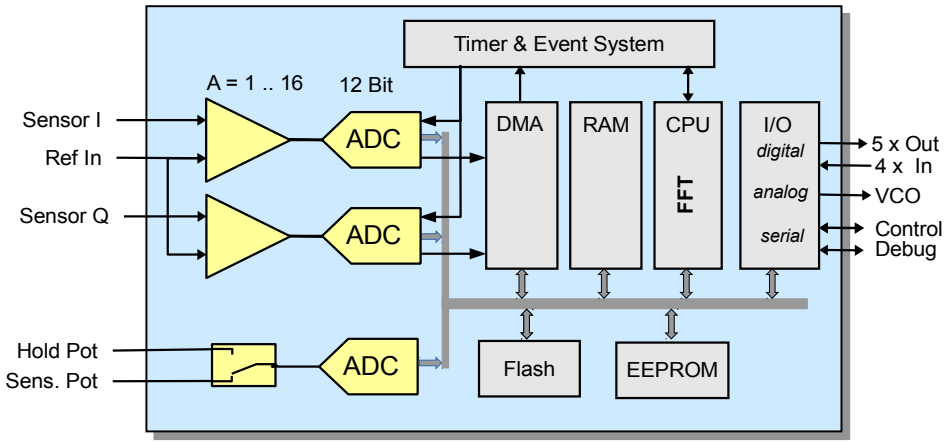


Fig. 2: RSP1 simplified block diagram

Using RSP Software Tools

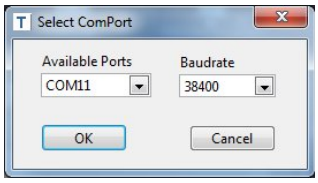
- RSP_Terminal software allows viewing and changing RSP parameters via serial interface on connector X7a. Optionally, it can also be used on connector X7b.
- RSP_Scope software allows viewing internal signals via serial interface on connector X7b.
- RSP_Prog software contains chip update tools as well as parameter handler. Connect to X7b.

Consult the RSP1 datasheet for more detailed explanations on signal processing

RSP1 tools use an FTDI cable virtual com port cable (TTL-232R-3V3) from www.ftdichip.com.
Drivers have been installed automatically together with the RSP1 tools installer.

Locating the Serial Port

Please connect the FTDI cable to a USB port of your computer.
When starting an RSP1 tool, a com port dialog appears:



Normally, the highest COM port number is the right port.

To be sure, please unplug and replug the USB cable during this dialog. The related port number will disapear and apear again.

The RSP tools will remember the selected port.

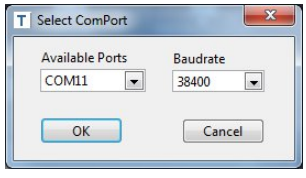
Fig. 3: Connection Dialog

If Windows or RSP Tools do not recognize the FTDI USB cable, please uninstall and reinstall the drivers. Driver software is located on your RSP install media under FTDI:
1. Uninstall existing driver with `CDMuninstallerGUI.exe`
2. Reinstall driver with `CDM v2.12.00 WHQL Certified.exe`

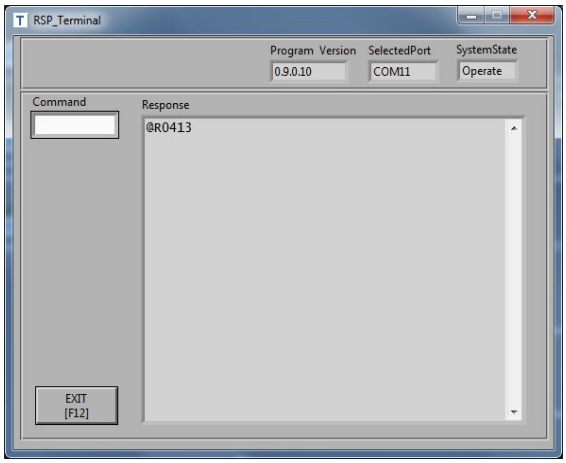
RSP_Terminal

RSP1 processor can be influenced by many parameters. RSP_Terminal allows viewing and setting all parameters. In fact, RSP_Terminal emulates a host computer or microprocessor used in a RSP1 based user hardware.

Establish Connection



Establish connection:
1. Connect serial cable to Eval-Kit connector **X7a**
2. Connect serial cable to USB port of you PC
3. Start RSP_Terminal software
4. Select Port at **baudrate 38400**.
5. Press OK



Check if connection works:

Type command `$R04` ("get RSP1 version")
→ Example Response `@R0418` (Version 1.8)

Type `$L00` ("stream result string")
→ 4 column stream showing
(fwd= forward, bwd=backward)

```
fwd speed;bwd. speed;fwd power; bwd power
fwd speed;bwd. speed;fwd power; bwd power
fwd speed;bwd. speed;fwd power; bwd power
...
```

Type `$L0000` to stop streaming

Entering Commands

RSP1 follows a client-server protocol. RSP1 is the server that executes the client (Host/PC) commands. Some rare exeptions exist when executing loop commands.
All parameters of classes 'A' and 'S' are stored in the permanent EEPROM memory.

Command Syntax

Read parameters: Command `$A02<ENTER>` → Response `@A0209`
Write parameters: Command `$A0203<ENTER>` → Response `@A0203`

Example **read** command	Explanation
`$A02<ENTER>`	$: command identifier A: command class 02: 2 digit hexadecimal parameter number Enter: Enter key (or <CR> or <CR><LF> code)
Example response	
`@A0209<CR><LF>`	@: response identifier A02: command confirmation 09: actual 2 digit value (typically hexadecimal) CRLF: codes for "carriage return-line feed"
Example **write** command	
`$A0203<ENTER>`	$: command identifier A: command class 02: 2 digit parameter number 03: 2 digit new parameter value (typically hexadecimal) Enter: Enter key (or <CR> or <CR><LF> code)
Example response	
`@A0203<CR><LF>`	@: response identifier A02: command confirmation 03: 2 digit value confirmation (typically hexadecimal) CRLF: codes for "carriage return-line feed"
Example **read** command	returns a string
`$R10`	Get firmware version string
Example response	
`@RFbeam RSP1 Version V1.4 Sep 19 2014`	String responses are marked in parameter table with *

You may repeat a command by simply typing $<ENTER>

Most important Parameters and Commands

- For complete parameter list please refer to the RSP1 datasheet
- All values are in **hexadecimal** notation, except values marked with '*'

Param. 1)	default	min	max	Function	Description	R
Class A	(EEPROM)			**Application Parameters**	End-User specific settings in final application	
A01	01	00	09	hold time	09: maximum hold time of detection output	
A02	09	00	09	sensitivity	09: maximum detection sensitivity	
A03	03	00	09	immunity	09: maximum immunity against interference	
A05	00	00	02	direction	00: approaching; 1: receeding; 2: both	
A06 *V1.8*	00	00	7F	low frequency (=speed) limit	00: inactive; >0: Low limit (unit = FFT bin, see Fig. 15)	
A06 *V1.8*	00	00	7F	low frequency (=speed) limit	00: inactive; >0: High limit (unit = FFT bin, see Fig. 15)	
Class S	(EEPROM)			**System Parameters**	Application specific parameters	
S00	00	00	01	sensor type	00: stereo I/Q sensor; 01: mono sensor (1 channel)	x
S01	00	00	01	Use alternate analog port	01: ADC input on pin 2 and 3 instead of pin 44 aqnd pin 1	x
S03	02	01	0A	sampling rate	see Fig. 15	x
S08	01	00	01	bandwidth	01: low bandwidth (digital output used for external filter)	
S09	04	00	04	ADC gain	gain = 2^n: 0 -->1; 1-->2; 2-->4; 3-->8; 4-->16	x
S0C	02	00	FF	Adaptive learn speed	00: maximum; >0: value * 500ms/dB	x
Class R	(immediate)			**Real-Time Read Params**	Read only parameters	
R00	-	00	01	detection active?	01: detection output active (includes hold time)	
R01	-	00	FF	detection speed	00: no peak position (FFT bin #)	
R02		0	FF	noise level mean	arithmetic mean over all FFT bins	
R04	-	00	FF	software version	major.minor version (x.0 are preliminary versions)	
R10	*	--	--	software version string	Full software version and date string, max 40 characters	
R11	*	--	--	result string on serial cmd port	SpeedFW, SpeedBW, MagFW, MagBW<CR>	
Class W	(immediate)			**Real Time Write Params**	Volatile write parameters	
W00	-	00	01	force detection output	01: set digital detection output; 0: normal output operaton	
W01	**-**	**-**	**-**	reset processor	software reset. value has no effect	
W02	**-**	**-**	**-**	**load default parameters**	**load default values for all parameters**	
Class L	(LOOP)			**Continuous output**	Output results continuously until $<CR> is received	
L00	-	-	-	stream result string on serial cmd port	SpeedFW, SpeedBW, MagFW, MagBW<CR> 00: stop streaming	

Notes: Column "R": Reset required
1) Vx.y Parameter added in Version Vx.y

Restore original default parameter values with command ***$W02***

Repeat a command by simply typing $<ENTER>

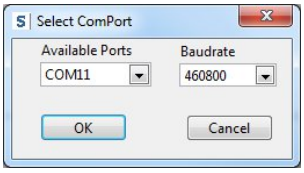
RSP_Scope

This tool is a virtual oscilloscope and shows internal amplitude vs. speed signals. It also shows I and Q time domain signals.
All signals including FFT are processed by RSP1 chip and are sent via high speed serial interface.
RSP_Scope does only scale some values, but does no signal processing.

- RSP_Scope must be connected to connector X7b at 460800 Baud.
- All explanations assume a K-LC2 sensor and RSP default parameters.

Establish Connection

Please refer also to chapter Locating serial PC port.



Establish connection:

1. Connect serial cable to Eval-Kit connector **X7b**
2. Connect serial cable to USB port of you PC
3. Start RSP_Scope software
4. Select Port at baudrate **460800**
5. Press OK

Example: moving person approaching and reseeding from K-LC2 sensor

Fig. 4: Initial RSP_Scope screen showing noise (top) and movement history (bottom)

Virtual scope (upper screen) has logarithmic Y-axis showing signal level. Therefore, noise looks very high. Refer to the RSP datasheet for more explanations.

Interpreting Virtual Scope Display

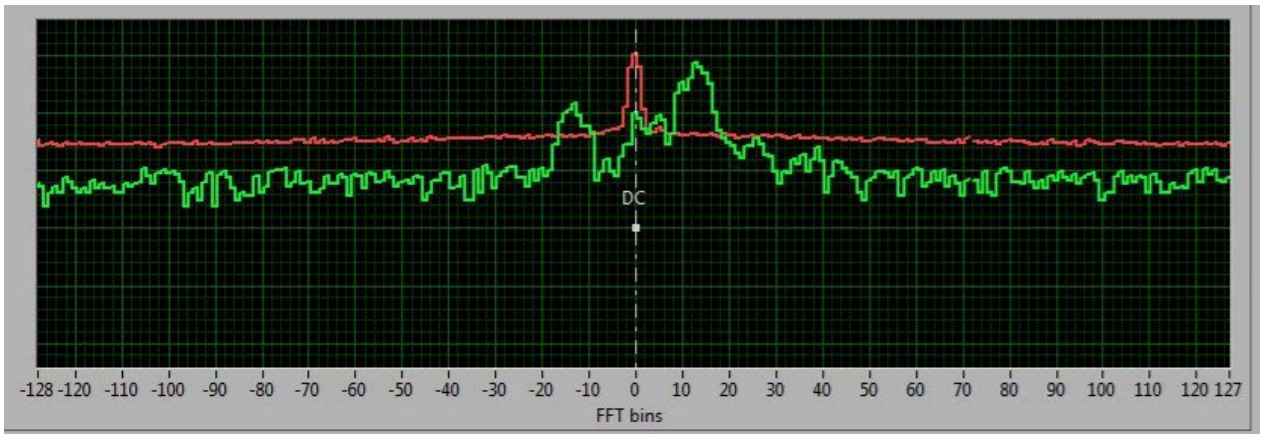


Fig. 5: Person walking towards a two channel I/Q "stereo" sensor

Highest peak on right side shows speed of a person walking towards the sensor.
(Peak on the left side is due to the sensor I/Q inbalance and phase error)

Speed scale (X-axis) is related to the 256 point FFT signal processing algorithm and represents the doppler frequency. Positive frequency represents approaching, negative frequency receeding object. Please find more details on speed interpretation in chapter Background Information.

Y-axis represents the signal level (FFT magnitude) in a logarithmic form. The higher the reflectivity of the object, the higher the level.
→ Level depends on:

- Size of moving object
- Material of moving object
- Distance of moving object

RSP1 sets detection output, if peak exceeds the red threshold (sensitivity) and if direction corresponds th the setting of parameter ***A05*** or DIP-switches 3 and 4.

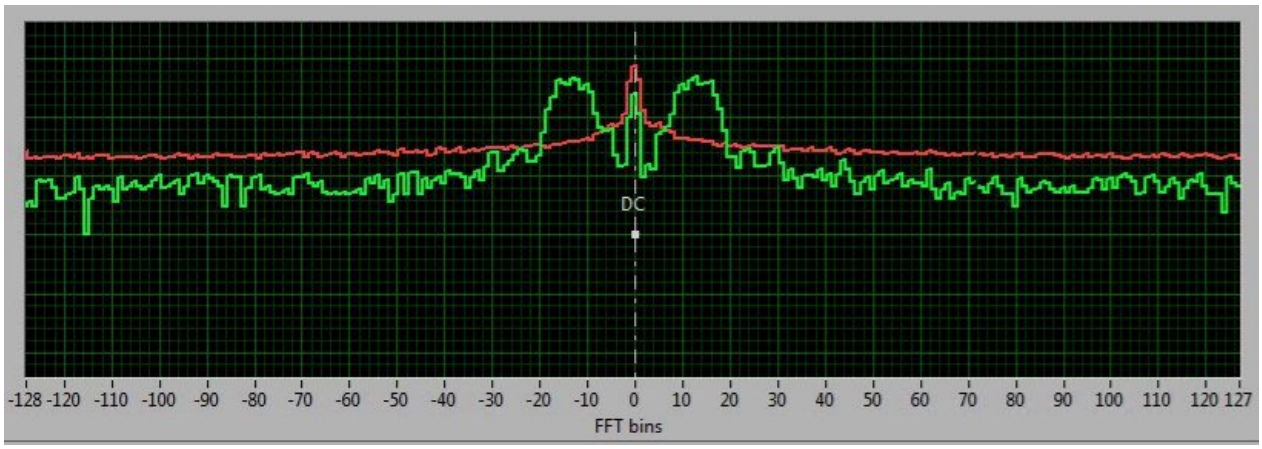


Fig. 6: Person walking towards a single channel "mono" sensor

Single channel sensors like K-LC1 or K-LC3 produce two similar peaks and therefore do not allow to detect movement directions.

Horiztontal cursors may be activated on order to measure signal to noise ratio in dB.

Adding IQ Signal Display

I/Q signal display appears at Channel switch position 4.
IQ display display directly the sensor's output signals that are captured by the RSP AD converter.
Please refer to chapter Doppler Signal Basics for more details on IQ signals.

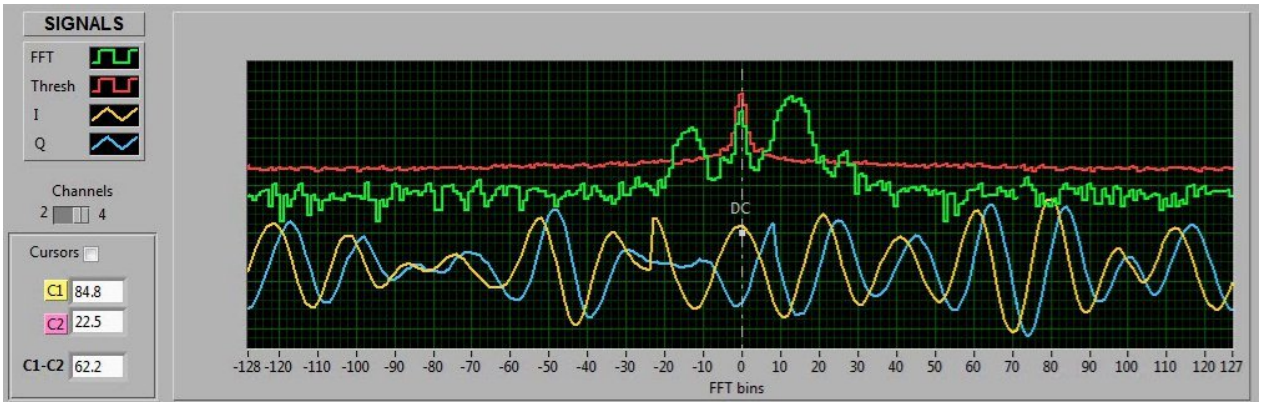


Fig. 7: Frequency and Time signal of moving person towards sensor

Using the Command Feature

You may read and set parameters in the command section while RSP_Scope is running. Example: check influence of parameter ***$A02*** on the red theshold level. Use same syntax as for RSP_Terminal.

Interpreting Speed Chart Display

Chart displays object speed as a function of time. If IQ sensors are used, direction can be discriminated.
X-axis: Time (256* sampling time)
Y-axis: Speed (FFT bin)

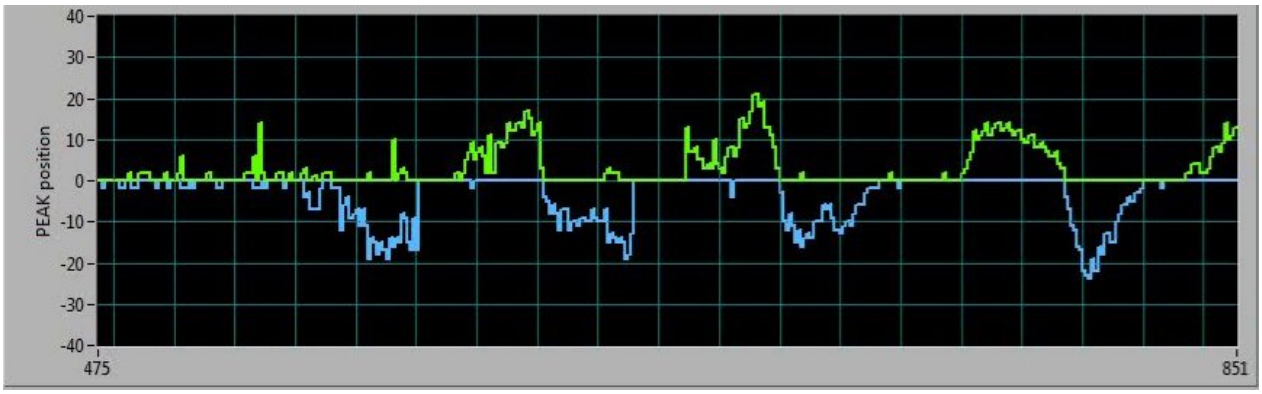


Fig. 8: Speed of person moving forwards (green) and (blue) backwards

In future versions of RSP_Scope, Axis will be scaled in physical time and speed units.

RSP_Prog Tool

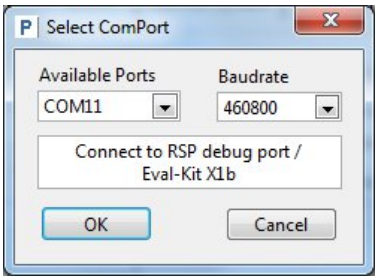
This tool allows updating RSP1 firmware as well as exchanging RSP1 user parameters.

Do not interrupt power or communication while uploading updates to RSP1.
Data or program in RSP1 may be lost.

- RSP_Prog must be connected to connector X7b at 460800 Baud.

Establish Connection

Please refer also to chapter Locating serial PC port.



Establish connection:

1. Connect serial cable to Eval-Kit connector **X7b**
2. Connect serial cable to USB port of you PC
3. Start RSP_Prog software
4. Select Port at baudrate **460800**
5. Press OK

Following screen should appear:

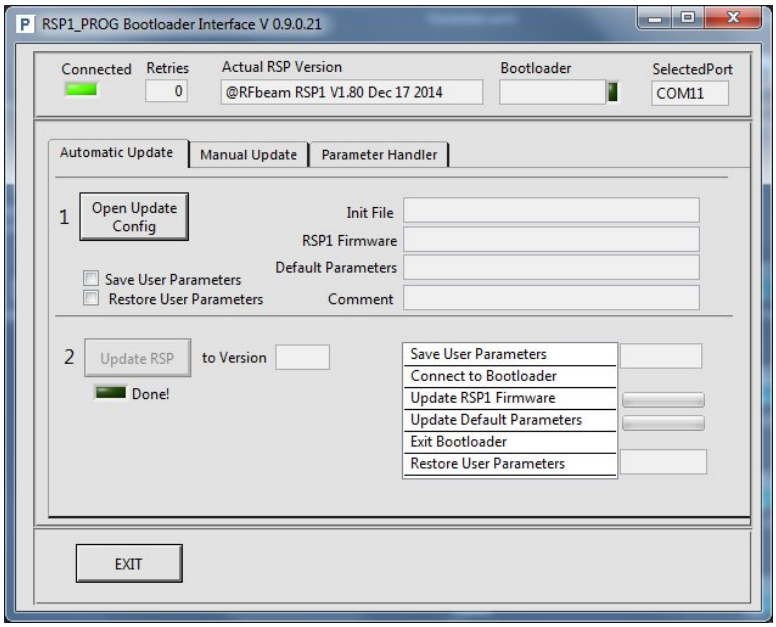


Fig. 9: RSP1:PROG initial screen

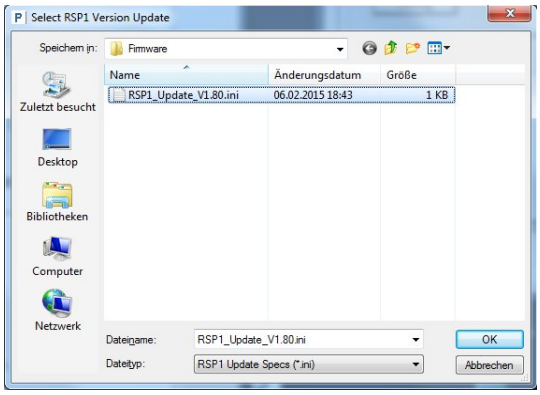
Programming Modes

Automatic RSP1 Firmware Update

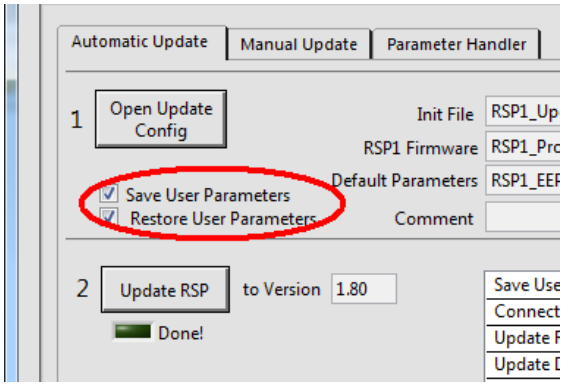
In this mode, RSP1 chip may be updated on new firmware versions. Updating needs 2 or 3 files.
The files are automatically selected when opening the information file.

Usage:

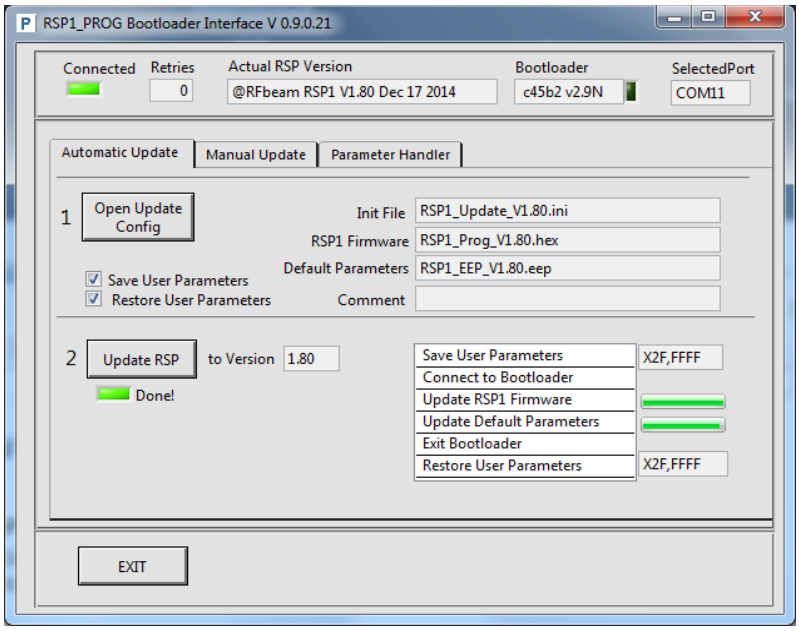
1. [Open Update Config] and select version



Option: save and restore previous user parameters



2. [Update RSP]



*.ini file contains Items to be updated

Updating takes some seconds.

Table shows progress depending on the updatable items

Manual Update Mode

This mode is for experienced users.
Firmware and default parameters may be individually programmed.
Please refer to chapter RSP1_Prog File and Directory Organization.

Firmware and parameter versions MUST match: _Vx.y must be identical.
Matching example: RSP1_EEP_**V1.8**2 and RSP_Prog_**V1.8**0 are OK

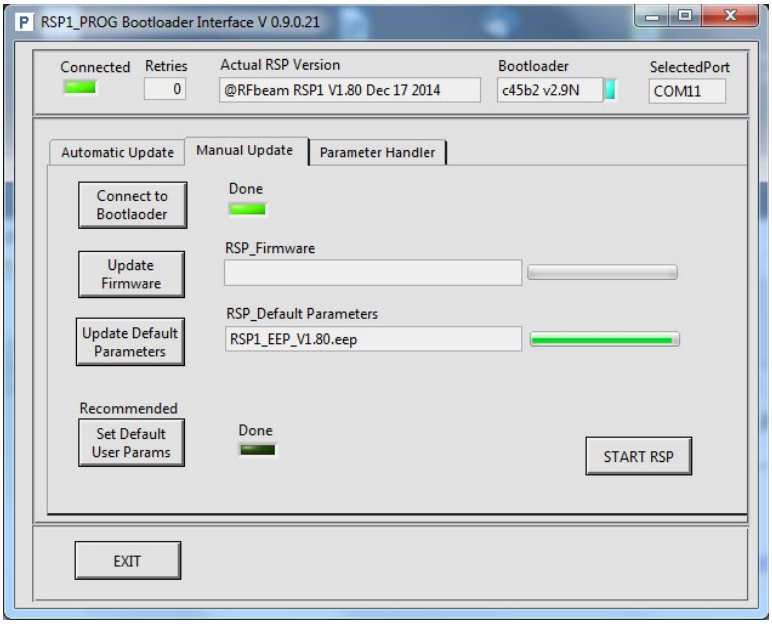


Fig. 10: Example: Program default parameters only

Copy default parameters to user area by clicking
[Set Default User Params].

Exit Bootloader by [START RSP]

Parameter Handler

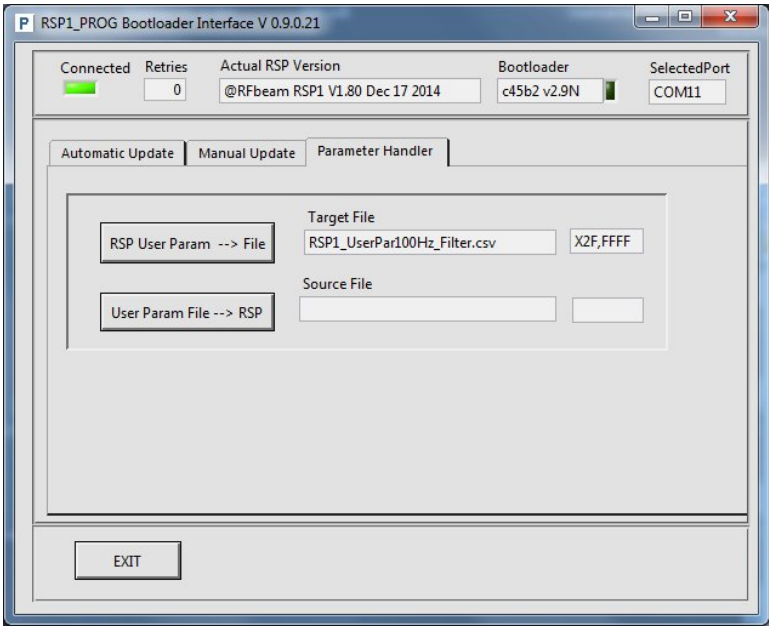


Fig. 11: Example: Program default parameters only

This mode allows saving and restoring user parameters.

You may use it for saving application specific parameters.
For mass production, restore your predefined parameter files.

RSP1 Memory Organization

RSP1 contains 4 storage sections

Storage item	Storage location	Purpose	Programmable by	
			RSP1_Prog	Serial interfaces
User Parameters	EEPROM	Initially a copy of default parameters. Changable by ***$S*** and ***$X*** parameters	YES	YES
Default parameters	EEPROM	Factory default values	YES	NO
Firmware	Flash	RSP1 functionality	YES	NO
Bootloader	Flash	Used for programming flash and default parameters	NO	NO

Table 1: RSP1 storage sections

RSP1_Prog File and Directory Organization

RSP_Prog uses different folders for different types of data.
During installation of RSP1_Prog software, a set of 3 update files will be copied to the PC harddisk.
The files contain the latest RSP1 version available at the time of the RSP1_Prog software release.

RSP1 firmware must only be programmed with the RFbeam RSP1_Prog tool. Using other tools or programmers will result in permanent loss of RSP1 program. RFbeam does not replace eased or illegaly programmed chips.

RSP1 Firmware update files

The update files must not be renamed or changed.

Update file locations
Assuming C:\ as system drive.

Windows 7 and later:
`C:\ProgramData\RFbeam\RSP1\Firmware\`

Windows XP:
`C:\Documents and Settings\All Users\Application Data\RFbeam\RSP1\Firmware`

There are 3 update files for each RSP1 version:

Information file	`RSP1_Update_Vx.yy.ini`	This file contains internal settings and information for automatic update. **Do not alter this file.**
RSP1 firmware	`RSP1_Prog_Vx.yy.hex`	RSP functionality. This is a scrambled file
Default parameters	`RSP1_EEP_Vx.yy.eep`	These parameters do not automatically overwrite user parameters. Refer to chapter RSP1 parameters files

Table 2: Update files

RSP1 User parameter files

Default location of user parameter files:
Assuming C:\ as system drive. User may select other locations. New location will be remembered by the program.

Windows XP
`C:\Documents and Settings\<user name>\my documents\RFbeam\RSP1\`

Windows 7 and later
`C:\Users\<user name>\Documents\RFbeam\RSP1\`

User parameter files an be stored or read by using Parameter Handler mode.

File format (may be opened with spreadsheet programs like Microsoft Excel or LibreOffice Calc)

Be careful when manually changing the content of the files! Header number of lines must not be changed! First line must not be changed!

```
StartLine,6
Content,User Parameters
FW Version,@RFbeam RSP1 V1.80 Dec 17 2014
Write date,2015_02_25  16:15:58
Comment,
Param,Value
A00,00
A01,01
A02,09
A03,03
A04,01
A05,00
A06,00
…
```

RSP1_Eval-Kit Hardware

Complete schematics are provided with the Evaluation Kit.
Additional information can be found in the RSP1 chip data sheet.

Power Supply

Stable and low noise power supply is essential for optimal sensor results.
For details, please refer to the Evaluation Kit circuit schematics and to the RSP1 data sheet.

RSP1_Eval-Kit may be powered bay different sources. Most convenient way is using the USB 5V power from Personal Computer. USB power is very noisy. The evaluation kit uses a switched step-up regulator, followed by a linear power supply resulting in a very clean power supply.

Eval-Kit provides 3 independent and decoupled power inputs:
- 5V USB power at X7a
- 5V USB power at X7b
- 6 .. 12VDC external supply at X4 and X5

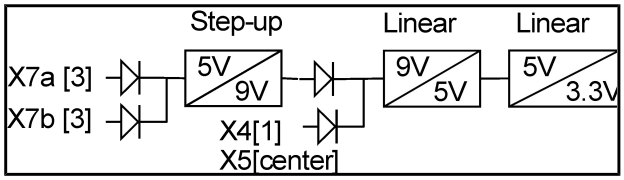


Fig. 12: Evaluation Kit low noise supply concept

Digital Output

RSP1_Eval-Kit provides an optically isolated digital output with a maximum 28VDC, nominal 20mA driving capability. The output is completely floating for maximum flexibility.

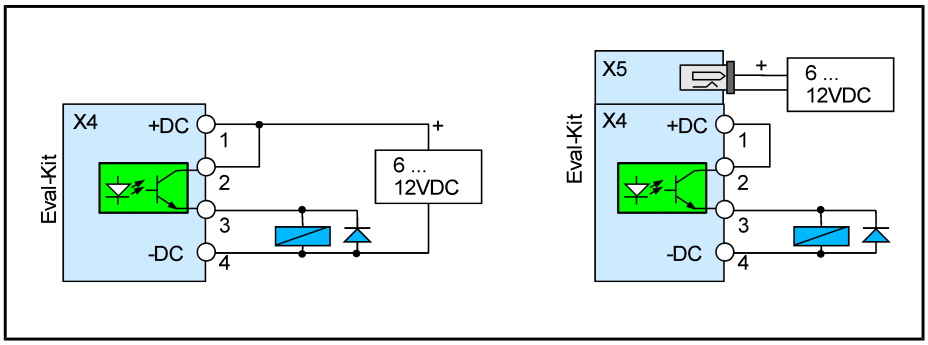
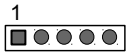


Fig. 13: Output wiring examples using external supply for output and system power

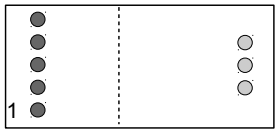
Connector Pins

X1 K-LCx connector

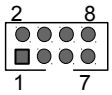
Pin	Signal	Description	Connector top view
1	IF Q	Doppler Signal (“Quadrature”)	
2	Vcc	Sensor Power 5V or 3.3V, depending on Jumper J1 position	
3	IF I	Doppler Signal (“In Phase”)	
4	GND	Sensor Ground	
5	VCO	FM output, not used	

X2 K-LCx connector

Located on backside of the Eval-Kit

Pin	Signal	Description	Sensor mount on PCB backside
1	IF Q	Doppler Signal (“Quadrature”)	
2	Vcc	Sensor Power 5V or 3.3V, depending on Jumper J1 position	
3	IF I	Doppler Signal (“In Phase”)	
4	GND	Sensor Ground	
5	VCO	FM output, not used	

X3 K-MCx connector (alternate sensor)

Pin	Signal	Description	Connector top view
1	GND	Sensor /enable	
2	Vcc	Sensor Power 5V or 3.3V, depending on Jumper J1 position	
3	GND	Sensor Ground	
4	IF Q	Doppler Signal (“Quadrature”)	
5	IF I	Doppler Signal (“In Phase”)	
6	VCO	Not connected	
7	IF Q DC	Not connected	
8	IF I DC	Not connected	

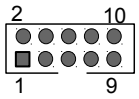
X4 Digital output and power connector

Pin	Signal	Description	Connector top view
1	+DC	+6 .. 12V power supply input (in parallel to X5 center pin)	
2	+DOUT	Opto isolated detection out plus side	
3	-DOUT	Opto isolated detection out minus side	
4	GND	Ground power supply input (in parallel to X5 outer contact)	

X5 power supply input

Pin	Signal	Description	Connector top view
1	+DC	+6 .. 12V power supply input (in parallel to X4 pin 1)	
2	GND	Ground power supply input (in parallel to X4 pin 4)	

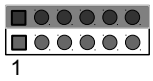
X6 Digital I/O and SPI

Pin	Signal	Description	Connector top view
1	NC		
2	GND	Signal Ground	
3	NC		
4	Detect out	digital processor output: high at detection + hold time	
5	*MISO*	*SPI Master-In-Slave-Out*	
6	*CMD Tx Enable*	*Enable signal for RS-485 drivers*	
7	*SCK*	*SPI Serial clock*	
8	*MOSI*	*SPI Master-Out-Slave-In*	
9	*nSS*	*SPI slave select*	
10	GND	Signal Ground	

Grey signals: reserved for future implementation

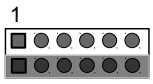
X7a Serial Command Interface

Outer row of X7: 38400Baud 3.3V command interface.
FTDI compatible pin layout.

Pin	Signal	Description	Connector top view
1	GND	Power GND FTDI cable black wire	
2	NC	Not connected	
3	+5V	Power supply input	
4	RXD	serial UARTdata input	
5	TXD	serial UART data output	
6	NC	Not connected	

X7b Serial Debug Interface

1Inner row of X7: 38400Baud 3.3V command interface
FTDI compatible pin layout.

Pin	Signal	Description	Connector top view
1	GND	Power GND FTDI cable black wire	
2	NC	Not connected	
3	+5V	Power supply input	
4	RXD	serial UARTdata input	
5	TXD	serial UART data output	
6	NC	Not connected	

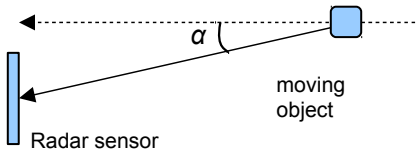
 Serial Debug Interface is also used for updating RSP1 firmware

Background Information

Doppler Signal Basics

A moving object in range of a Radar sensor (often called “transceiver “) generates a low frequency output signal. Frequency depends on the object speed. Amplitude depends on distance, reflectivity and size of the object. Doppler frequency f_d is proportional to the object speed v:

$$f_d = v \cdot \frac{44\,Hz}{km/h} \cdot \cos\alpha \qquad v = \frac{f_d}{44\,Hz \cdot \cos\alpha} km/h$$



Note that the angle of the moving object reduces Doppler frequency.

I/Q Doppler Signals

I/Q sensors like K-LC2, K-LC5, K-LC6 and others produce 2 output signals, that are phase shifted by 90°. Main advantages:

- Forward / Backward movement differentiation
- Efficient interference suppression
- Vibration suppression

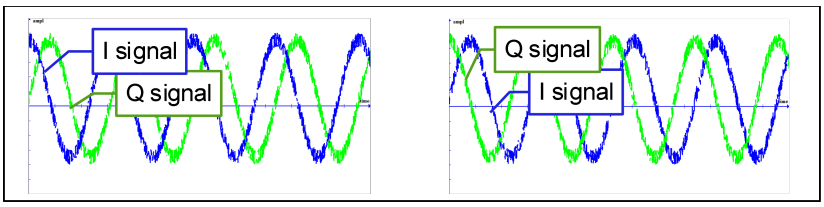


Fig. 14: I/Q signals left: approaching; right receding movement

FFT Fast Fourier Transform

Explanations go beyond the scope of this document. Please refer to literature (e.g. http://en.wikipedia.org/wiki/Fast_Fourier_transform and to the RSP1 datasheet.
Fortunately, RSP1, the user does not have to care about the details on FFT.

FFT represents in fact many narrowband filters that reduce noise amplitude. RSP1 uses 256 point FFT resulting in 128 bins (filters) for each forward and backward movements.
This kind of detection results in a much better sensitivity than simple comparator solutions. Theoretical gain in S/N ratio by using a 256pt (2 8) FFT is 10 * log(8) = 24dB. In reality, more than double detection distances can be reached compared to comparator solution.

RSP1 debug port and RSP_Scope help understanding using FFT in movement and speed sensors.

Sampling Rate and Bandwidth

Chosing optimal sampling rate is crucial for best detection results.
There are close relationships and dependencies between

- size of FFT (RSP1 uses 256pt Fast Fourier Transform)
- sampling rate
- detectable speed range
- speed resolution
- amplifier bandwidth
- system sensitivity (signal to noise ratio SNR)

Minimum Sampling Rate

Sampling rate *fs* must be at least twice the highest Doppler frequency appearing in the application.

$f_s > 2 \cdot f_d$ (Nyquist criteria)

However, the higher the sampling rate, the lower the frequency resolution:

$d_f > FFTn / f_s$ (In RSP1: FFTn = 256)

Maximum Amplifier Bandwidth

Amplifier bandwidth must be significantly lower than the maximum frequency mentioned in Fig. 15. 2nd order lowpass filter is recommended. Otherwise, aliasing effects will occur. (Wikipedia http://en.wikipedia.org/wiki/Nyquist%E2%80%93Shannon_sampling_theorem).

Sampling Rate Table

Sampling rate can be set by parameter ***S03.***

Parameter ***S03***	sample rate Hz	resolution Hz	max. frequency Hz	resolution km/h	max speed km/h	response time ms [1)]
01	1'280	5	640	0.11	14.5	200
02	2'560	10	1'280	0.23	29.1	100
03	3'840	15	1920	0.34	43.6	67
04	5'120	20	2"560	0.45	58.2	50
05	6'400	25	3'200	0.57	72.7	40
06	7'680	30	3'840	0.68	87.3	33
07	8'960	35	4'480	0.80	101.8	29
08	10'240	40	5'120	0.91	116.4	25
09	11'264	44	5'632	1.00	128.0	23
0A	22'530	88	11'265	2.00	256.0	12

Note 1): response time on host interface. Digital output depends also on params $A03 and $S02

Fig. 15: Detectable speed depend on parameter S03

Rule of Thumb for your application:
Use lowest possible amplifier bandwidth at highest possible sampling rate

Using Serial Interfaces in parallel

RSP_Scope connected to Debug Interface X7b) and RSP_Terminal (connected to Command Interface X7a) may be used in parallel. A 2nd FTDI cable is required for this.
This RSP1 feature becomes important for debugging applications with a host CPU connected to the RSP1 Command Interface with the RSP_Scope connected to the debug port.

General Radar Installation Tips

Radar for movement detection is a very reliable and robust technology. It is insensitive to heat, wind, dust, sunlight and other influences.

However, there are some important issues to take into consideration:

- Sensitivity to fluorescent light (→ use IQ modules and/or RSP1 FFT Filter features)
- Material and thickness of cover
- Sensitivity to vibrations (→ use I/Q modules)

The following application notes should help to optimize your application.

Cover

Every cover has some influence on the shape of detection field and the achievable maximum distance. Radar can „view“ through plastic and glass of any color. This makes a high degree of design freedom. Nevertheless, some rules should be considered.

- Cover must not be metallic.
- Plastic coating with colors NOT containing metallic or carbon particles.
- Distance between cover and front of Radar sensor > 1cm
- Best cover material is Polycarbonat or ABS
- Best cover thickness is 3-4mm
- Vibrations of sensor module relatively to the cover should be avoided, because this generates signals that can trigger the output

Interference Factors

RSP1 designs are much more robust against interference factors than traditional Radar based designs. Nevertheless, take care on the following tips.

Fluorescence Light

- Do not mount Radar modules directly facing to fluorescent lamps
- Use sensors at the lowest possible sensitivity for your certain application

Radar is susceptible to fluorescent lamps, even if controlled by electronic ballasts. These lamps produce a 100Hz (50Hz mains, Europe) or 120Hz (60Hz mains, USA) Radar signal that is similar to the signals produced by a person walking at about 2km/h.
RSP1 features adaptive filters, intelligent suppression algorithms and selective programmable FFT filters. Refer to RSP1 datasheet.

Rain

- Prevent cover to get wet
- The lager the distance to rainy environment, the smaller the rain effect.

Raindrops can be interpreted by Radar as moving objects and may trigger the output.

Vibrations, Ventilators etc.

- Radar based sensor and its cover should be mounted stable to prevent vibrations
- Try to prevent objects like ventilators in the sight of the detection field

Sensitivity and Maximum Range

Sensitivity defines the necessary signal strength at the Radar sensor to trigger the output.
RSP1 allows adjusting sensitivity by potentiometer and/or by parameters.

Trigger distance at same sensitivity setting can vary depending on

- Type of moving object (person, car etc.).
- Moving direction of the object

Further Reading

- **RSP1 datasheet** contains important information on signal processing and hardware design.
- Schematics of the RSP1 Evaluation Kit are included on the installation media.
- Application note AN-04 contains amplifier examples.
  http://www.rfbeam.ch/fileadmin/downloads/appnotes/AN-04%20TypicalSignalAmp.pdf
- Application Note AN-03 contains tips for cover ("Radome") and housings
  http://www.rfbeam.ch/fileadmin/downloads/appnotes/AN-03-Radome.pdf

Revision History

Version 0.2	Sept 21, 2014	Preliminary release
Version 0.3	Nov 01, 2014	Preliminary release
Version 1.0	April 13, 2015	Valid from RSP1 firmware V1.8