HA- RF Expansion Board (HA_RFE) For the HA-SDR Software Defined Radio Project

Requirements and Architecture Spec V0.2

Project:	HA_RFE HA-SDR
Description::	RF Expansion (RFE) Board
Deliverable:	Requirements and Architecture Specification
Version:	v0.2.
Confidentiality:	Public
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Date:	28 June 2009

The newest version is always available at
http://www.brandl.de.tt/AFUNK/HA_SDR_RFE/New_RFE/

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1 Document History

Version	Contributors	Status	Date
V0.01	H.Brandl	Table of content	2009-04-14
V0.1	H.Brandl	Early Draft	2009-06-15
V0.2	H.Brandl	Draft_0, Most errors removed, however missing parts like resulting architecture	2009-06-28

2 Introduction

2.1 Intended Audience

The intended Audience of this document are skilled radio amateurs, engineers and developers who think about building or enhancing their own HA_SDR equipment and especially the RF Expansion Board (RFE) This document was written in parallel to the development of the New_RFE board as an enhancement of the HA_SDR Transceiver.

2.2 Scope and Objectives of New_RFE

The New_RFE contains all functionality which is usually delivered from the RFE board for the SDR-1000 from FlexRadio Systems.

It delivers similar functionality but was adapted to the needs and system requirements of the HA_SDR and especially to the capabilities of amateur radio enthusiasts for self building and enhancing of such a module.

It contains mainly the functionality of :

- 20dB Input attenuator
- Band pass filter bank
- Receiver pre amplifier
- Transmitter pre amplifier
- Low pass flter bank
- Central switching matrix for receive, transmit and external amplifiers and equipment
- Experimental Impulse generator (IMP)

It shall fit to the HA_SDR main board

2.3 Scope and Objectives of Document

Providing a guideline to make architectural design decisions to target aimplementation of the RFE functionality

2.4 Definitions, acronyms, abbreviations and conventions

SDR	Software Defined Radio	
HA_SDR	Public SDR Project	Re engineered SDR-1000 documents from the HA-SDR amateur radio group. More information can be found at the Forum http://hm-sdr-1000.foren-city.de/ Sub_Page for the New_RFE Module at: http://hm-sdr-1000.foren-city.de/topic,17,-zusatz-module.html
O_SDR	Original SDR-1000	The SD-1000 product from Flex Radio Systems
HA_RFE	RFE Board for HA_SDR	RF Expansion Board for the HA_SDR project
RFE	RF Expansion Board	Frontend for the HA-SDR, with main parts BPF, PreAmp, LPF
BPF	Band Pass Filter	Part of the RFE
LPF	Low Pass Filter	Part of the RFE
QSD	Quadrature Sampling Detector	Quadrature Sampling Detector with IQ-Mixer at the HA_SDR mainboard

Table 1 Acronyms and definitions

2.5 References

REF_1	FlexRadio Systems: Operating Manual	FlexRadio Systems: SDR-1000 Operating Manual V1.8 **support.flex-radio.com/Downloads.aspx?id=112**
REF_2	FlexRadio Systems: Installer Instruction 1.4	RF Expansion (RFE) Board Installation Instructions Version1.4 **support.flex-radio.com/Downloads.aspx?id=86**
REF_3	RFE Schematics	**RFE_v1.4a_Schematics.pdf** **http://support.flex-radio.com/Downloads.aspx?id=92**
REF_4	FlexRadio Systems: ECO-001	FlexRadio Systems: Engineering Change Order ECO-001 Protection Diodes for the SDR-RFE-Board -8/17/04 **kb.flex-radio.com/KnowledgebaseArticle50001.aspx**
REF_5	FlexRadio Systems: ECO-025	FlexRadio Systems: Engineering Change Order ECO-025 7/15/2005: To improve 3rd Order dynamic range. RFE Preamplifier Upgrade . **kb.flex-radio.com/KnowledgebaseArticle50008.aspx**
REF_6	Understanding How Ferrites Can Prevent and Eliminate RFI to Audio Systems	Understanding How Ferrites Can Prevent and Eliminate RFI to Audio Systems by Jim, K9YC with the Audio Systems Group, Inc describes in detail how ferrites can be used to mitigate RFI in audio systems. Filesize: 2,007,709 bytes **http://support.flex-radio.com/Downloads.aspx?id=280**
REF_7	PowerSDR Operating Manual, Version 1.8.0	PowerSDR Operating Manual version 1.8.0. for the SDR-1000 only. Filesize: 4,242,978 bytes **http://support.flex-radio.com/Downloads.aspx?id=112**
REF_8	Overview of Flex_Radio SDR-1000 support documents	**http://kb.flex-radio.com/KnowledgebaseCategory30.aspx**

Table 2 References

3 Introduction

Software Defined Radio (SDR) is a collection of hardware and software technologies that enable reconfigurable system architectures for wireless communications. SDR provides an efficient and comparatively inexpensive solution to the problem of building multi-mode, multi-band, multi-functional communications devices that can be enhanced using software upgrades. As such, SDR can really be considered an enabling technology that is applicable across a wide range of areas within the wireless industry.

SDR-enabled communications devices can be dynamically programmed in software to reconfigure the characteristics of equipment. In other words, the same piece of "hardware" can be modified to perform different functions at different times. This allows the manufacturer to concentrate development efforts on a common hardware platform.

The SDR-1000:

The SDR-1000, from Flexradio.was one of the first SDR equipments targeted for the amateur radio market. It is a complete Software Defined Radio (SDR) transceiver interface to a Personal Computer. It provides everything needed to convert a PC into a high performance, 11KHz-65MHz general coverage receiver with 160M-6M (2M optional) Amateur Radio band transmit capability. The SDR-1000 is described in detail in a four part article series in QEX Magazine. With the new RF Expansion Board (RFE), the SDR-1000 offers world class >90dB third-order IMD dynamic range (depending on sound card quality) and -141dBm MDS in a 500Hz bandwidth. To learn more read the RF Expansion Board data sheet.

After the SDR-1000 production was abandoned by Flexradio systems due to the availability of newer and more advanced radio equipment from them, an Amateur Radio enthusiast group found together (named the HA_SDR group), which is now developing and publishing the drawings of a reengineered version , the HA_SDR.

4 Overall Functionality

SDR and RFE Functionality

4.1 HA_SDR Functionality

The HA_SDR is a complete Software Defined Radio (SDR) designed for Amateur Radio experimentation and use. It offers a true open software interface on a personal computer (PC) for *all* Digital Signal Processing (DSP) and control functions of the radio. General coverage receive operation is provided from DC to 65MHz along with 1W transmit capability on all licensed amateur bands within the coverage range.

The theory behind the HA_SDR is described in detail in a four part *QEX* magazine series entitled, “A Software Defined Radio for the Masses[1].” The articles are available for download from the FlexRadio website at www.Flex-Radio.com. There are also links on the site to other excellent reference materials related to SDR and DSP theory.

The HA_SDR incorporates a novel Quadrature Sampling Detector (QSD) to deliver high dynamic range with minimal components. An Analog Devices AD9854 quadrature DDS and 200MHz, 1ps jitter clock oscillator provides continuous coverage with low phase noise. A power RF op-amp delivers up to 1W RMS into a 50Ω load.

[1] G. Youngblood, “A Software Defined Radio for the Masses: Part 1, Part 2, Part 3, and Part 4,” *QEX*, Jul/Aug 2002, Sep/Oct 2002, Nov/Dec 2002, and Mar/Apr 2003 respectively.

All radio control functions are managed through the PC parallel port including external control for up to seven transverters or other accessories. Use of the parallel port for control eliminates the need for a microcontroller in the radio, thereby removing a source of noise and software complexity. Internal connections are included for controlling up to six filters and TR relay for a user provided linear power amplifier.

4.2 HA_RFE Functionality

The RFE board is designed to sandwich between the SDR-1000 BPF and TRX boards. When installed, the RFE breaks the signal path between those boards to incorporate a low noise preamp, 5th order low pass filters, enhanced 1W PEP amplifier, and transverter control. As a result, the BPF board will provide front end filtering for the low noise preamplifier as well as harmonic suppression for the 1W Tx preamplifier. The block diagram below illustrates the complete radio with RFE and transverter options installed.

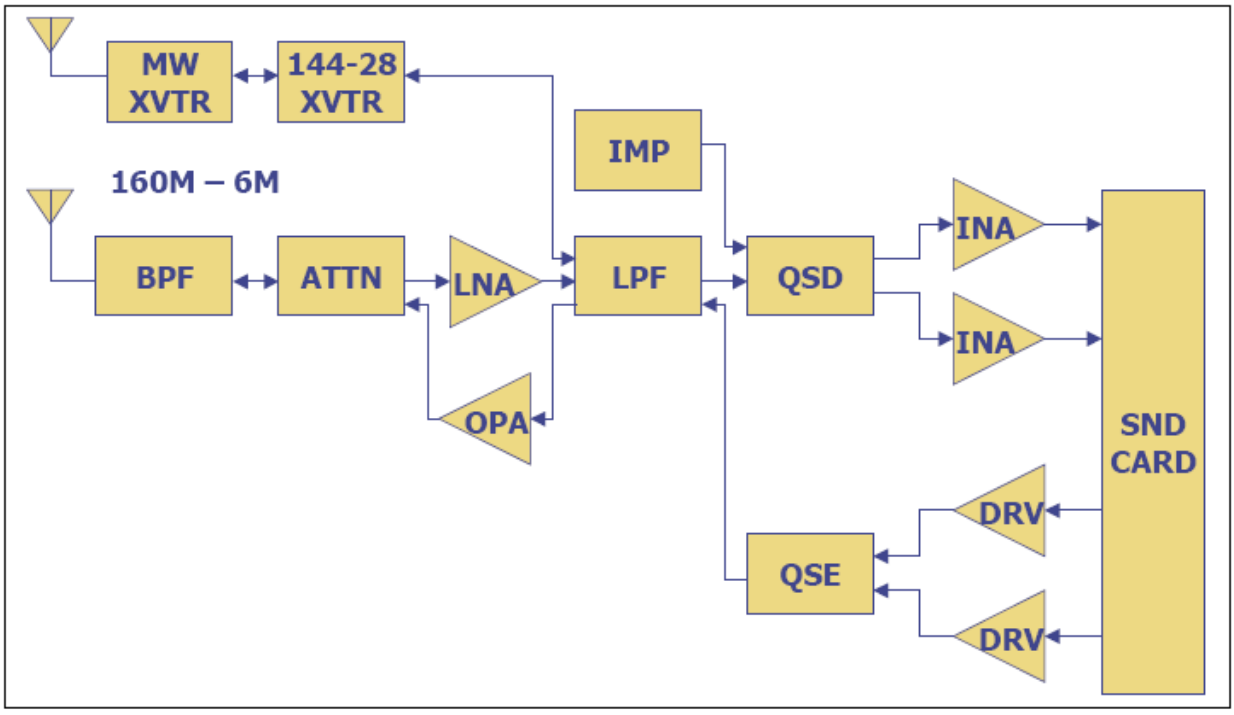

Fig. 1: Original FlexRadio RFE Architecture

5 Requirements for the new HA_RFE Board

REQ_5.0.1:

- Components should be selected for easy procurement and low price. If special or proprietary components are required, delivery sources should be referred.
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5.1 20dB Input attenuator (ATT)

REQ_5.1.1:
HA_RFE shall contain the controllable 20dB Input attenuator like in OSDR

5.2 Band pass filter bank

REQ_5.2.1:

- Bandpassfilter (BPF) design should be extended to degree n=4 (in original SDR-1000 n=3) with serial port directed to antenna.
  Reason:
  Currently the antenna connector is feed to the parallel port of the filter. Out of EMI design and development it is known that undefined impedances on unmatched complex inputs can produce voltage or current peaks which can overload nonlinear devices like inductors, capacitors and semiconductors. This can severly reduce intermodulation characteristics like at contest operations. A serial circuit at the filters input will at least reduce current resonance peaks and connect the antenna only at the selected receiving frequency. A BPF device parameter set should be available for this extended (n=4) filter.
- Also the standard OSDR (SDR-1000) filter components should be available as an own parameter set for original filter assembly

- Signal Power and Intermodulation characteristics:
  - The bandpassfilter (BPF) has to be able to transfer transmit signals of about 30dm+ without noticeable saturation and distortion effects. The BPF filter components should withstand such levels without additional intermodulation. It is assumed that the standard SDR-1000 filter parameter set with inductor components like Amidon T37 toroid cores will fullfill these requirements.
  .

5.3 Receiver pre amplifier (RX PreAmp)

REQ_5.3.1:
HA_RFE shall include the Rx-Preamplifier as described in ECO-25[REF_5]:

- Gain about 15 dB
- P1db (at saturation) > 20dBm.
- Noise figure < 4db.
  According to ITU environmental and space noise guideline, the environmental noise in the shortwave bands is in the range of up to 20dB NF.. Much lower noise figures of the receiver have therefore no real advantage as the external noise signal from environment via a standard antenna is always higher than a receiver NF in the shortwave bands around e.g. 10dB.

See: *http://www.arrl.org/announce/regulatory/et03-104/reply-comments-exhibit-c.html*

5.4 Transmitter pre amplifier (Tx PreAmp)

REQ_5.4.1:
HA_RFE shall include the Tx-Preamplifier (about 20 db amplification) as described in the RFE schematics [REF_3].

5.5 Low pass flter bank

REQ_5.5.1:

- Low Pass Filter (LPF) should be fully compatible with original SDR-1000 as this filter is a part of the Preamplifier/RFE Filter combination and currently no better combination is known of from practical reasons.[RFE02]
- Signal Power and Intermodulation characteristics:
- The SDR backend can deliver 10mW for transmit and it is expected that receiving signals can reach similar levels. The LPF filter components should withstand such levels without excesessive additional intermodulation contribution . It is assumed that using Amidon T30 toroid kernels for the filters inductors fullfills these load requirements.
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5.6 Experimental Impulse Generator (IMP)

REQ 5.4.1.:

The HA_RFE shall contain the Experimental Impulse Generator know from the OSDR description.

It creates 4.5nsec pulses for equalization of the OSD and sound card quadrature path.

It can only be used with the appropriate DSP software which should calculate the impulse response of the circuit and automatically correct for phase and amplitude imbalance between the channels. This should provide dynamic opposite sideband rejection optimization

5.7 Central switching matrix for receive, transmit and connection of external equipment

REQ_5.7.1:

For flexibility of use and cooperation with other external devices (like application a central relay switching matrix should be able to activate and switch into the signal path:

- Direct connection of antenna port to the internal filter and mixer
- Transmit preamplifier for delivering an output TX signal of 30dBm at the antenna connector of the HA_RFE
- Receive preamplifier for rising weak antenna signals
- External cannectors for making the internal Rx input as well as the internal Tx output (level about 10dBm) available to external devices. This could be used for connecting to external transmit PA with low level inputs and also to transverters with a rx an tx power level high enough.
- Transverter (XVTR) interface with a 5Volt switching voltage for remote control.

All these signal paths should be selectable individually by using rx or tx control signals selected via plug in jumpers.

5.8 System Interfacing capabilities

REQ_5.8.1:

- All connectors should have the same logical and physical interface as known from the original SDR-1000 system to ensure for interoperability and controlability with existing and future control software like PowerSDR [REF_7] . Exceptions are possible if connectors and cabling can be easily adapted and will fit
- All known and relevant ECO (RFE04, RFE05] of the OSDR should be incorporated into HA_RFE design
- Connectors which feed RF signals should be of RF type. SMA, SMB, SMC and MX types should be possible for individual selection. The footprint on the board should allow to mount all these connectors by selection of the builder.

5.9 Filter Configuration and Parameters

REQ_5.9.1:

- Signal Power and Intermodulation characteristics:
  - The SDR backend can deliver +10dBm for transmit and it is expected that receiving signals after the preamplifier can reach 15dBm levels. The LPF filter components should withstand such levels without additional intermodulation. It is assumed that Amidon T30 toroid cores fullfill these requirements.
  - The band pass filter (BPF) has to be able to transfer transmit signals of about 30dm+ without noticeable saturation and distortion effects. It is assumed that with the standard SDR-1000 filter parameter set and components value Amidon Toroids T37 will be sufficient.
  - At developing own filter parameter and components values the maximum magnetic field and current limitations (for preventing nonlinear distortions) also inside the filter nodes have to be taken care.
- For limited power requirements (like RX only) also components
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5.10 Physical Dimensions

REQ_5.!0.1:

The New_RFE should fit physically to the already existing HA_SDR board

- Size of the board should fit to existing HA_SDR :
  - HA_SDR size is 102mm*192 mm and contains no regular mounting holes
  - For HA_RFE it should be possible to be mounted on Top of HA_SDR board, as a consequence mounting holes of the HA_RFE should be positioned at locations with empty space at HA_SDR
- Connectors (at least TRX_ BOARD, POWER_SUPPLY and RF IN/OUT) should be located for easy interfacing with the HA_SDR Connectors and board.
- Connectors should be physical as well as logical interoperable with the original SDR-1000 and also with HA_SDR. If there are discrepancies lines schould be selectable by soldered jumpers
- Height of Board profile should be a minimum for easy housing fit and selection and limited interface cabling efforts. Components should be selected accordingly.
-

The new HA_RFE board design and layout should be prepared for an easy redesign capability (by a professional CAD board design equipment) into a format smaller than 100mm* 160mm for a potential future new HA_SDR which should fit in a small extruded shift in profile (typically space for 100mm broad board).

6 Architecture

6.1 Sub 5

6.2 Sub 5

NOT yet finalized

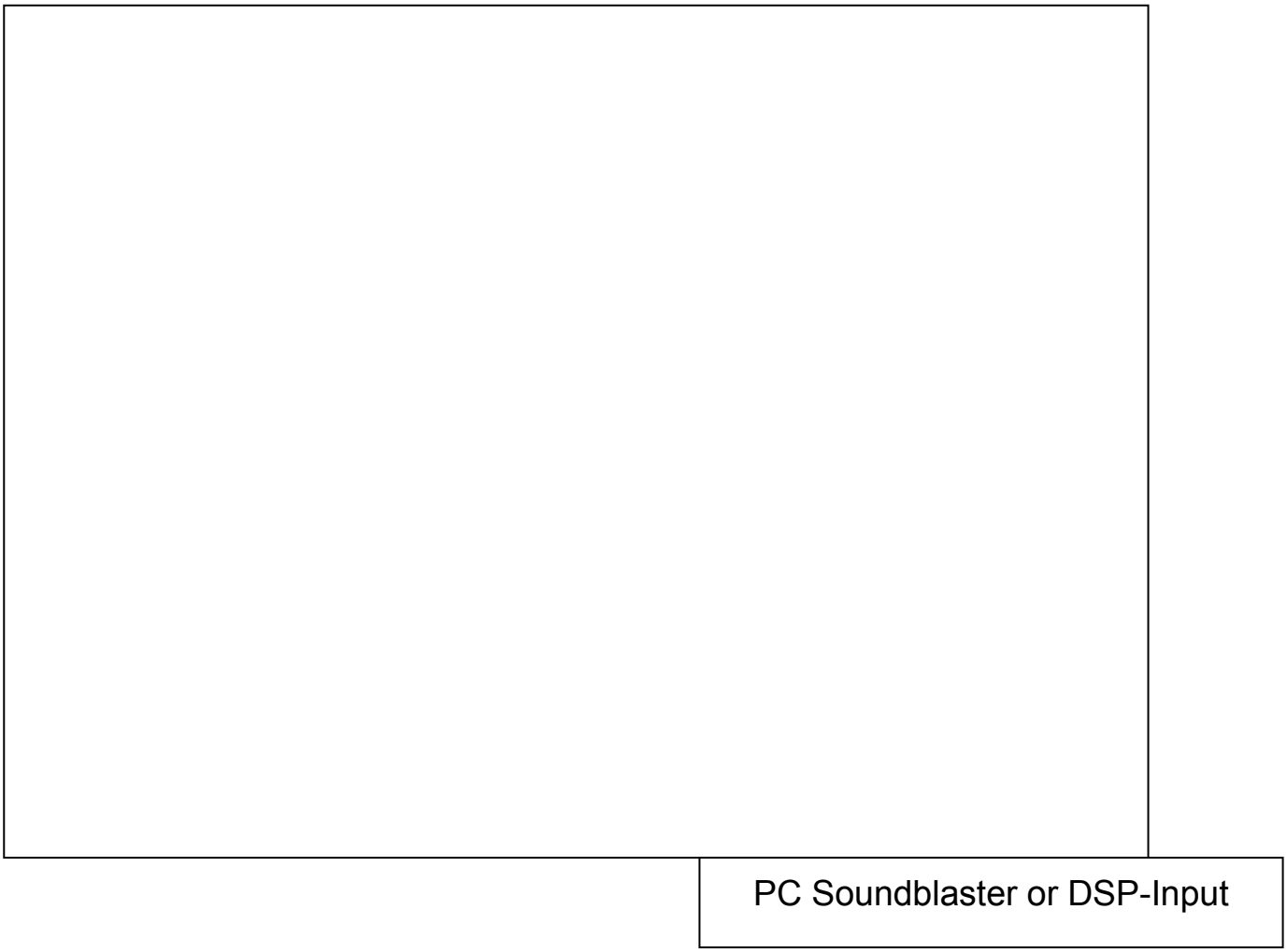

Fig. 2 : HA_RFE Architecture

PC Soundblaster or DSP-Input

PC Soundblaster or DSP-Input

Fig. 2Fig. 3