



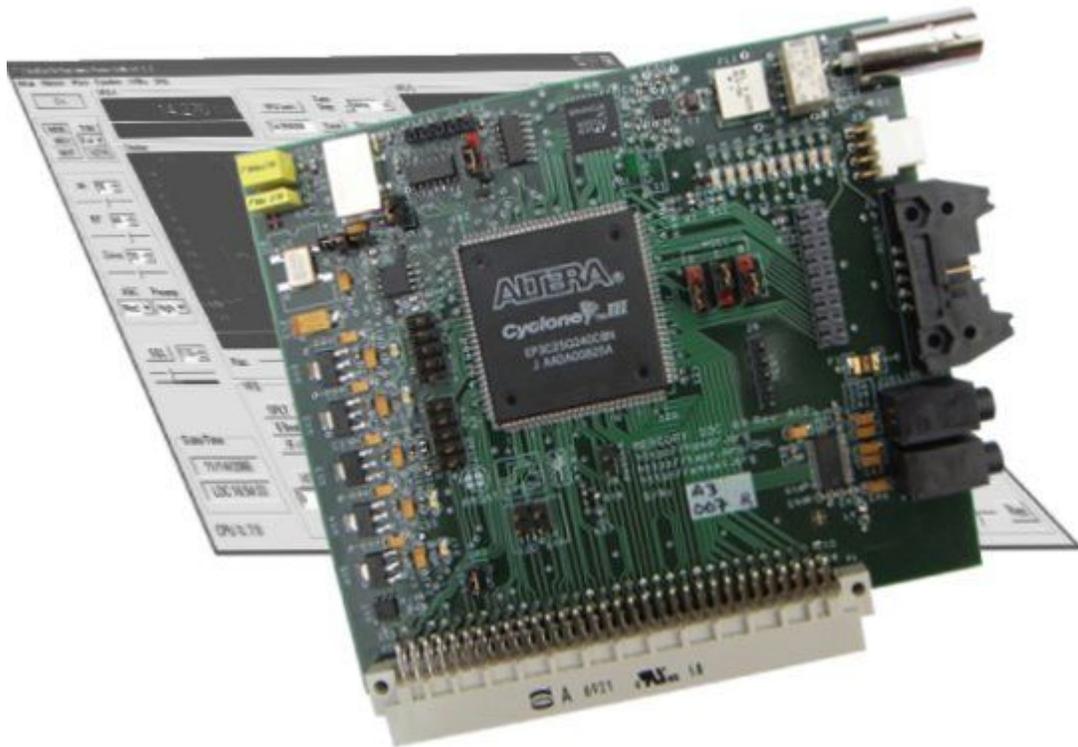
High Performance Software Defined Radio

Open Source Hardware and Software Project

Project Description: <http://hpsdr.org>

Mercury

Operation with PowerSDR™



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Introduction

Mercury is a Digital Down Conversion receiver that covers the frequency range 100kHz to 55MHz¹.

Mercury is designed to be plugged into the HPSDR Atlas bus and be used in conjunction with other HPSDR boards. A minimum configuration to form a high performance receiver requires an HPSDR Atlas bus board and an Ozy computer interface board.

Whilst the minimum configuration will be quite acceptable to many users, for optimum performance Mercury is intended to be used with the Alex RF Preselector² (Alexiaries – see <http://hpsdr.org/wiki/index.php?title=ALEXIARES>) .

Mercury is designed to be used with PowerSDR^{TM3} which provides the necessary demodulation, bandscope etc and control signals. This manual describes the connections to be made between Mercury, Ozy and the PC. Subsequently it describes how to setup PowerSDR to use Mercury for receiving signals.

What you will Need

Table 1 and Table 2 below summarize the hardware and software you will need to use a Mercury board to form an HF receiver.

Table 1: Hardware Requirements

Hardware	Comment
Atlas board	Backplane for all HPSDR boards
Ozy board	Control data and digital I/Q streams to/from PC
Mercury board	HF Digital Down Converter
Atlas Power Supply	PC ATX type or equivalent

Table 2: Software Requirements

Software	Comment
Ozy and PowerSDR	See Table 2 in the manual Janus and Ozy operation with PowerSDR

In the following, the set-up of and connection to Mercury will be explained in detail, followed by the PowerSDR settings.

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¹ See Appendix A on page 11 regarding extended frequency operation

² See Appendix B: on page 12 regarding the use of Alex

³ PowerSDR is a trade mark of FlexRadio Systems, Inc.

Mercury Set-up

To use the Mercury board with the Ozy (and other) HPSDR boards six jumpers must be set. These are indicated in light blue and green in Fig 1 below. The jumper marked in green relates to operation of the 10MHz TXCO. Please see Appendix C: on page 13 for information about the use of this jumper.

LEDs that are normally illuminated are marked in red.

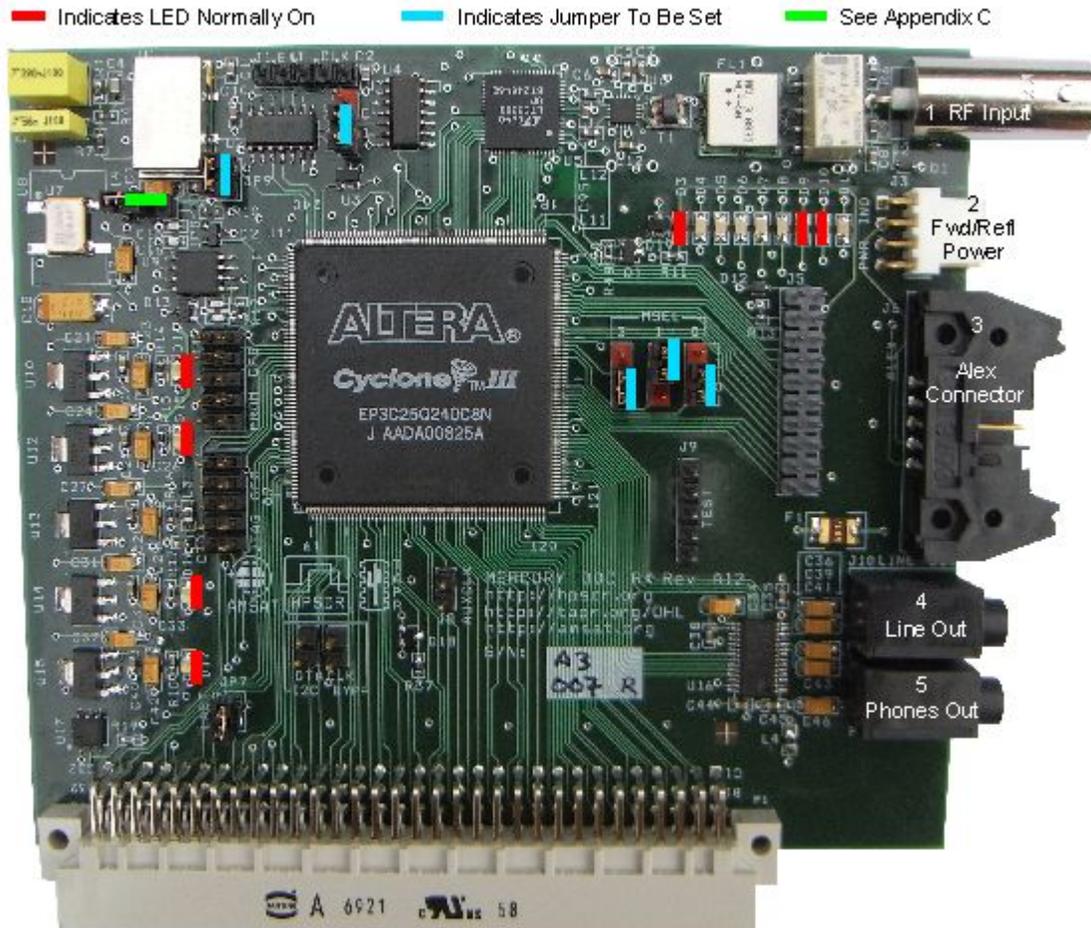


Fig 1: Mercury Board Indicating Jumper Settings, Connections and LEDs

For ease of reference, the I/O jacks in Fig 1 have been enumerated and each will be now dealt with in turn

1 RF Input

This BNC connector is the RF input to Mercury. It may be connected directly to an antenna system or RF Preselector (see Appendix B: on page 12).



2 Power Indicator Through Connector

This 4-pin connector passes the DC signals representing Forward and Reflected Power together with +12VDC from J6, the Alex connector (see next). This is to enable these signals to be passed to Penelope in order that power levels and ALC etc can be measured and applied. The pin connections are shown in Table 3.

Table 3: Pin-Out Power Indicator Through Connector

Pin	Function
1	Ground
2	FWD Power
3	REV Power
4	+12VDC

3 Alex Connector

This 10 pin connector provides the necessary interface signals for the Alex RF Preselector board. The pin connections are shown in Table 4.

Table 4: Alex Connector Pin-Out

Pin	Function
1, 8, 10	Ground
2	+12VDC
3	ALEX SPI SDO
4	ALEX SPI SCK
5	ALEX SPI RX LOAD
6	ALEX SPI TX LOAD
7	FWD Power
9	REV Power

4 Audio Line Out

This 3.5mm tip-ring-sleeve audio socket provides the Mercury receiver audio output suitable for driving a 600 Ohm line. Tip is left audio, ring is right audio and sleeve is ground.

5 Headphones Out

This 3.5mm tip-ring-sleeve audio socket provides the Mercury receiver audio output suitable for driving headphones. Tip is left audio, ring is right audio and sleeve is ground.



Operation

The FPGA on Mercury (or more accurately, a flash memory chip attached to the FPGA) is loaded with the latest version of firmware during manufacture, hence no additional firmware needs to be loaded prior to use. FPGA updates to add new features are expected to be provided in the future. When new firmware is available it can be loaded into Mercury via an Ozy board. A separate manual will be provided that explains how the FPGA firmware on HPSDR boards can be upgraded.

To use Mercury, plug it into an Atlas bus together with an Ozy board. Due to the presence of high frequency clocks on the Ozy board, that may be picked up by Mercury, it is recommended that the two boards not be placed adjacent to each other on the Atlas bus.

We will assume you are familiar with the use of your Ozy board and that you have set up the board and it's associated software as per the user manual [Janus and Ozy Operation with PowerSDR](#).

When powered on, the seven LEDs shown in Fig 1 on page 4 should be illuminated. For the horizontal row of LEDs the left most LED indicates that the FPGA has loaded correctly and the two on the right indicate that the code is running. The rightmost LED lights when the Analog to Digital Converter (ADC) at the input to Mercury is being overloaded. Should this light then turn the preamp off (see Use of Preamp) or otherwise reduce the signal level applied to Mercury.

Configuring PowerSDR Software for use with Mercury

To use Mercury with PowerSDR ensure you are using a KD5TFD Branch version of PowerSDR, specially modified for HPSDR (KD5TFD 30 Dec 2008) or newer.

Install PowerSDR, USB drivers and Microsoft .NET framework versions 1.1 and 2.0-SP1 in accordance with the *Quick Startup Guide* on the HPSDR Wiki at

http://hpsdr.org/wiki/index.php?title=Quick_Startup_Guide

The first time you run PowerSDR after installation, a **PowerSDR Hardware Setup Wizard** will appear. On the **Radio Model** page, select **HPSDR**. On the **HPSDR Hardware** page, select **Mercury** and any other modules listed that you are using. Then proceed to finish.

Once PowerSDR starts, to configure Mercury, click **Setup** on the Front Console to open the **Setup Form**. Click on the **General** tab and then on the **Hardware Config** sub-tab. **HPSDR** should already be selected in the **Radio Model** section (see Fig 2 below). Check that Mercury and the other modules you are using are checked in the **HPSDR Hardware Present** section.

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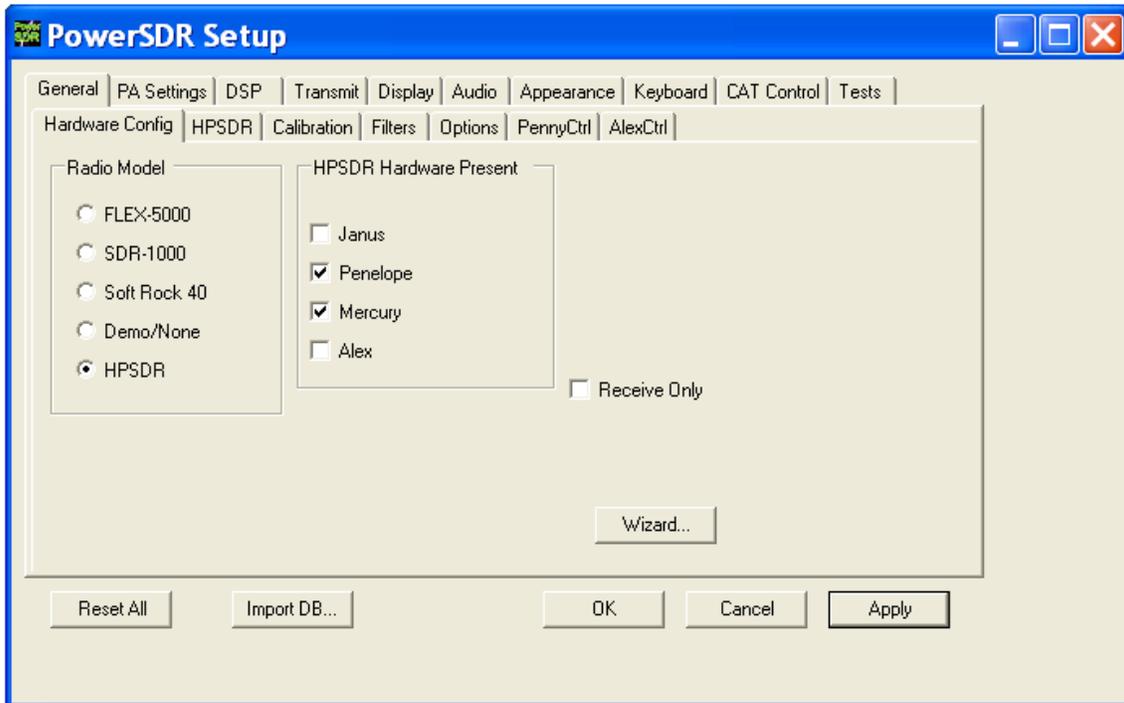


Fig 2: Setup Form, General Tab – Hardware Config Sub-Tab

Next select the **HPSDR** sub-tab (see Fig 3 below).

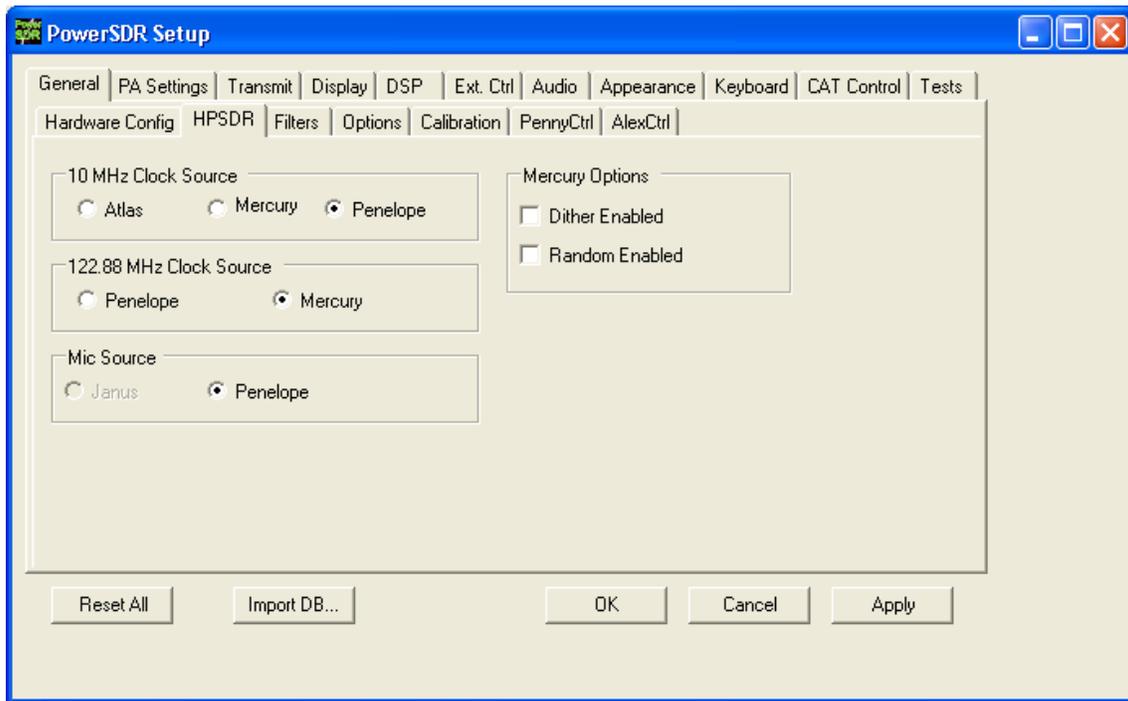


Fig 3: Setup Form, General Tab – HPSDR Sub-Tab



MERCURY OPERATION WITH POWERSDR

In the section marked **10MHz Clock Source** you may select either the 10MHz TCXO fitted to the **Mercury** board, **Penelope** board or an external 10MHz reference connected to the **Atlas** bus on bus line C16. The selected 10MHz source will be used to phase lock the various HPSDR clocks.

If you are using **Mercury** with **Penelope** then select the 10MHz clock from **Penelope** and remove the jumper JP8 marked in green in Fig 1. See Appendix C: on page 13 for further information regarding the 10MHz reference options.

IMPORTANT: DO NOT SELECT BOARDS OR CLOCKS THAT ARE NOT ACTUALLY PRESENT SINCE DOING SO MAY CAUSE POWERSDR TO HANG AND MAY REQUIRE A RE-BOOT OF THE PC IN ORDER TO RECOVER.

NOTE: UNLESS A JANUS BOARD IS FITTED IT IS NORMAL FOR LED 0 TO FLASH UNTIL **POWERSDR** IS STARTED. THIS LEAD MEANS THAT THE 12.288 MHz CLOCK IS MISSING.

In the section marked **122.88 MHz Clock Source**, select **Mercury**, or **Penelope**, if present. Either is acceptable.

In the section marked **Mic Source**, select the input location for Mic audio. Make sure the microphone source, bias, and PTT jumpers are properly set at that location. Refer to the documentation for that module.

In the section marked **Mercury Options**, there are two analog to digital data converter options that are normally "OFF." These functions are associated with the LTC2208 analog to digital data converter for improving low level linearity and reducing spurs. In the event that you are encountering internally generated spurs (signals that don't move when the antenna input is removed), you may wish to experiment with these settings. Either or both may be turned on. **Dither** will raise the noise floor everywhere by a dB or so, in exchange for reducing spurs generated in the A to D converter. **Random** will eliminate a different class of spurs. (Refer to the data sheet on the Linear Technologies LTC2208, sections *Internal Dither* and *Digital Output Randomizer* for further information.)

Level and S-Meter Calibration

Click on the **Calibration** sub-tab to calibrate the S-Meter and bandscope as per the PowerSDR user instructions for the SDR-1000™⁴. See the section **Level Calibration – Spectrum & S-Meter** on page 35 of the **SDR-1000 Operating Manual, version 1.8.0**.

Sampling Rate

Provided that Mercury is running firmware version 2.2 or later, the sampling rate may be selected to be 192 khz, 96 kHz or 48 kHz. The sampling rate is selected on the **Setup Form, Audio** tab – **Primary** sub-tab.

We first note that a higher Sampling Rate will give you a wider frequency span in the panoramic display, but simultaneously increase your CPU loading. A smaller Audio Buffer Size will also increase your CPU loading. If you hear audio artifacts such as drop-outs or pops, you need to reduce your CPU loading by either reducing Sampling Rate, or increasing Audio Buffer Size or both.

However, Sampling Rate and Audio Buffer Size also effect latency and minimum filter width/filter

⁴ SDR-1000 is a trademark of FlexRadio Systems, Inc.



slope as does DSP Buffer Size (**Setup Form, DSP** tab – **Options** sub-tab) as follows:

- Minimum filter width and filter slope are proportional to $[\text{Sampling Rate}]/[\text{DSP Buffer Size}]$, or phrased differently: a higher Sampling Rate and/or smaller DSP Buffer Size will lead to a wider minimum filter width and filter skirts that are less brick-wall and more roll-off, and vice versa.
- Latency is proportional to $(\text{MAX}[\text{Audio Buffer Size}, \text{DSP Buffer Size}])/[\text{Sampling Rate}]$, or phrased differently: a larger Buffer Size and/or lower Sampling Rate will lead to a higher latency.

The above shows that steeper, narrower filters result in higher latencies and vice versa. We also see that where only the DSP Buffer Size effects the filter, the larger of Audio and DSP Buffer Sizes effects latency. We therefore recommend the following:

- Given a Sampling Rate, set your Audio Buffer Size as small as you can get away with in your computer system. This will give you the highest range of adjustment for the DSP Buffer Size.
- For a given mode of operation, adjust Sampling Rate and DSP Buffer Size accordingly. E.g. For CW you may find you need narrower/steeper filters and adjust accordingly, until you reach a limit due to increasing latency. For SSB you may find you don't need such steep filters and prefer a wider frequency span in the panoramic display.

More information and illustrative examples can be found in Appendix A of the FLEX-5000™⁵ Owners Manual, available from FlexRadio Systems at <http://www.flex-radio.com/>.

Use of Preamp

The input of Mercury is fitted with an input protection circuit, Low Pass Filter, 20dB switchable attenuator and preamplifier. While we refer to a “preamp switch” in fact the preamp is left in circuit permanently and the 20dB attenuator switched in or out of circuit.

When the 20dB attenuator is bypassed, the PowerSDR **Preamp** control indicates **On**. When the 20dB attenuator is active, the **Preamp** control indicates **Off**. See Fig 4 below.

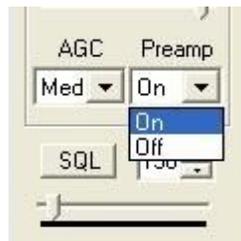


Fig 4: Preamp Control

The last setting of the **Preamp** is stored for each band. Normally the **Preamp** will be **Off** for frequencies below 14 MHz and **On** for frequencies above 14 MHz. Users with high performance 20m antennas may also find the **Preamp** can be left **Off** on this band.

⁵ FLEX-5000 is a trademark of FlexRadio Systems, Inc.



MERCURY OPERATION WITH POWERSDR

As a general rule-of-thumb, for any given band, if the baseline noise on the bandscope increases by 10dB or more when the antenna is connected with the **Preamp Off**, then the **Preamp** can remain **Off** for this band. Keeping the **Preamp On** lowers the overload point of the Mercury ADC: the ADC overload point has been measured as -12 dBm with the **Preamp On** and +8 dBm with the **Preamp Off**.

Image Rejection

Since the I & Q signals are generated digitally in Mercury there is no receiver image that needs to be rejected. Hence there is no need to apply Receiver Phase and Gain correction. On the **Setup Form, DSP Tab, Image Reject Sub-Tab** both controls will automatically be set to zero once Mercury is selected.

There is also no need to run any automatic receiver image rejection process.

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Appendix A: Extended Frequency Operation

As supplied Mercury is intended to operate over the frequency range of 100kHz to 55MHz. Experienced users may extend the frequency range by using the alias responses of the Analog to Digital Converter (ADC) used in Mercury.

The system clock used by Mercury is at 122.88MHz. Hence signals above $122.88/2 = 61.44$ MHz will alias back into the receiver passband and appear within the range 100kHz to 55MHz.

For example a signal at 96.1MHz will appear at 28.264MHz whilst a signal at 147.6MHz will appear at 24.72MHz. Normally such signals will be attenuated by the filter at the input to Mercury. Experienced users may wish to either bypass or remove the input filter (marked FL1 on the schematic) to enable reception of VHF and UHF bands. Whilst the ADC is specified to 750MHz no Mercury performance specifications are available for use outside the 100kHz to 55MHz frequency range.

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Appendix B: Use with Alex RF Preselector

The Analog to Digital Converter (ADC) used in Mercury has an input bandwidth of some 750MHz. The ADC will therefore have alias responses over the VHF and UHF ranges. In order to minimize the effect of alias responses a Low Pass Filter (LPF) is fitted to the input of Mercury. The LPF passes frequencies from 100kHz to ~55MHz and attenuates higher frequencies.

Whilst the performance of the LPF is expected to be adequate for the majority of users there may be circumstances where the user is located in the vicinity of VHF/UHF transmitters that are of such strength that the LPF attenuation at these frequencies is insufficient. In which case the fitting of an external filter, for example Alex will be required (see Alexiars - <http://hpsdr.org/wiki/index.php?title=ALEXIARES>). Alternatively, in many cases the station transmitter LPF will provide sufficient additional VHF/UHF attenuation.

The input LPF on Mercury passes all signals in the range 100kHz to 55MHz. Whilst there are numerous advantages to a broadband input it is possible that very strong signals in this range could cause the ADC to overload. For example, signal strengths in Europe in the 49m band have been reported to reach as high as 0dBm. Local Medium Wave broadcast stations can also produce very high signal levels.

Alternatively, should Mercury be used in, for example, a contest station with nearby transmitters then high signal levels could be present. In which case the use of the Alex RF Preselector, which contains band switched high pass filters, will significantly attenuate signals appropriately removed from the current operating frequency. In addition, Alex contains a very high performance, narrow band, 6m preamp which users of this band will find beneficial.

Extensive testing of prototype Mercury receivers has indicated that in most instances the inherent frequency response of the user's station equipment e.g. antenna, ATU, transmitter LPF etc. will provide sufficient out of band rejection of unwanted signals.

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Appendix C: Use of 10MHz TCXO

Mercury is fitted with an on board 10MHz Temperature Compensated Crystal Oscillator (TCXO). The internal master clock at 122.88MHz can be phase locked to the TCXO in order to reduce thermal drift when operating Mercury over an extended temperature range.

The TCXO has been chosen for high temperature stability rather than high frequency accuracy. An external 10MHz reference, connected to the Atlas bus, is recommended where high frequency accuracy is required (see Gibraltar – <http://hpsdr.org/wiki/index.php?title=GIBRALTAR>).

When the Mercury 10MHz TCXO is not required, such as when Penelope is present and selected, or a 10 Mhz reference frequency is being injected via the Atlas bus, the jumper JP8 marked in Green in Fig 1 should be REMOVED to reduce 10MHz spurious signal levels in the receiver.

In this case the 122.88MHz clocks on Mercury and Penelope will be phase locked to the same 10MHz source enabling transceiver operation with no frequency error between transmit and receive.

It should be noted that the use of the 10MHz TCXO on Mercury will introduce a few low level spurs, mostly on 15m. For most users these will be below the band noise and will only be detected with the antenna removed.

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Table of Revisions

Table 5: Revisions to this Document

Revision	Date	Comment
Rev 1.0	Jan 2009	Initial Publication

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