Bruker BioSpin

AVANCE III

NMR Hardware
User Guide

Version 001

NMR Spectroscopy

think forward

This manual was written by

Eamonn Butler

Technical direction was provided by:

Dr. Frank Decker

This manual was edited and desktop published by:

Stanley J. Niles

Rheinstetten, Germany

P/N: Z31839
DWG-Nr.: Z4D10601 - 001

For further technical assistance on the AVANCE III unit, please do not hesitate to contact your nearest BRUKER dealer or contact us directly at:

BRUKER BioSpin GMBH
am Silberstreifen
D-76287 Rheinstetten
Germany

Phone: + 49 721 5161 0
FAX: + 49 721 5171 01
E-mail: service@bruker.de
Internet: www.bruker.com

Contents

Introduction 1

Introduction 1.1

This manual is intended to serve as a single introductory hardware guide to AVANCE III spectrometers. The AVANCE III series is characterized specifically by the presence of an IPSO unit. At this stage it is sufficient to describe the IPSO (Intelligent Pulse Sequence Organizer) as a unit that controls the sequence and precise timing of all pulses which are timing-critical in terms of data acquisition. This manual has been written primarily for operators who wish to have basic information regarding the system components and how they interact with one another. It is not intended as a service guide and is not intended to equip the reader to carry out any service or repairs. However there is an ever increasing desire for users to understand the underlying hardware so they can

- optimize their existing system's performance
- operate the system safely
- choose the most appropriate system for their needs
- make sensible decisions regarding expanding or upgrading current systems

At a more fundamental level there is a widely held belief that as spectrometers become more and more complex the operators have less and less of an understanding of the spectrometer hardware.This manual is intended to help reverse that trend. It is also hoped that the reader will come to appreciate some of the design issues involved in modern spectrometer systems.

Although the days when the spectrometer hardware could be described comprehensively in a single manual are long gone, this manual will attempt to provide the reader with a concise overview of the main components of the system console.

Separate standalone systems such as the VTU and GREAT amplifiers, various accessories such as MAS and Sample Changer as well as probes and magnets are described in other manuals and this information will not be duplicated here.This manual will attempt to explain principally the hardware housed inside the cabinet. There is the danger that attempting to include too much information will simply result in a manual that will gather dust on the shelf. The emphasis in this manual is to provide as much information as possible without overloading the reader with too many technical details. For this reason some of the explanations and descriptions are deliberately presented in a simplified manner hopefully not at the expense of strict technical and scientific correctness. It would also be impossible to provide any realistic comprehensive overview of what is a very extensive system. Where adequate descriptions would be too lengthy or too complicated these areas are simply not included. At the end of each chapter there is however a section entitled 'Further information' should the reader require more details on any particular item.In particular this section will include references to specific manuals on the BASH CD.

This manual is intended to improve the reader's understanding of the console hardware and go someway towards making NMR more rewarding. This manual will not teach you how to operate the system or run basic experiments. For this you are referred to the manual entitled AVANCE AV (SGU Based Frequency Generation) Beginners Guide P/N Z31633e.

With these reservations in mind it is hoped that the reader is sufficiently motivated to read on! If you have any corrections or comments with regard to improving this manual please refer to below.

Contact for Additional Technical Assistance 1.1.1

NMR service and support team

BRUKER BioSpin GMBH
am Silberstreifen
D-76287 Rheinstetten
Germany

Phone: + 49 721 5161 0
FAX: + 49 721 5171 01
E-mail: service@bruker-biospin.de
Internet: www.bruker-biospin.de

Systems to Which This Manual Applies 1.2

This manual is written primarily for the AVANCE III IPSO based spectrometer range though some features are also relevant to earlier systems which were not fitted with the IPSO unit. The preceding spectrometer range (AVANCE II) has been described in a manual entitled NMR Hardware Guide (P/N Z31756) but bear in mind that there is always some overlap between the different configurations. The next few sections serves to differentiate between the various systems and has been included particularly for those more experienced operators that have worked on Bruker systems down through the years. If you are new to Bruker systems you might want to skip down to section ***1.4***.

AVANCE vs. AVANCE II vs. AVANCE III 1.3

New spectrometer hardware is constantly being updated and there is a wide range of available spectrometer configurations. For the purposes of explaining the different hardware generations it is usually helpful to group the various configurations into various categories as outlined in ***Table 1.1.*** below. As mentioned earlier information on earlier systems has been included to ground experienced users. For operators who have recently acquired an IPSO system then column four is most relevant. The development of the IPSO system is by far the most significant recent development and it is the presence of this unit that defines the AVANCE III (column four).

Prior to that, the two most significant advances were the SGU followed by the DRU. The presence or absence of these developments can be clearly seen to differentiate the various systems as outlined in ***Table 1.1.***. In this respect column one is differentiated from two and three on the basis of whether SGUs are fitted or not. More recently a major advance was the new DRU which is also used in the table as a distinguishing feature of the recent AVANCE II series outlined in column three.

In parallel with these 'configuration defining' advances there have been of course many other developments. Among the more recent ones have been the development of

- a BSMS/2 with several new boards
- internal AQS preamplifiers
- a REF unit that ensures synchronization of all timing critical signals throughout the entire spectrometer
- an expanded range of internal amplifiers
- additional Ethernet capability to many units

While much of the details in the table below may appear daunting at this stage (depending of course upon the reader's experience) the information is presented here so that the reader can gain an overview of the various configurations.

One of the difficulties of presenting a single manual to describe different configurations of spectrometer is that the reader can find it difficult to keep sight of their particular system. For this reason ***Table 1.1.*** may also serve as a useful reference as the reader proceeds through this manual.

Table 1.1. Summary of Four Generations of Spectrometer Hardware

AVANCE (without SGU)	**AVANCE (with SGU)**	**AVANCE II (with DRU)**	**AVANCE III (with IPSO)**	**Comment**
AQR/AQX	AQS	AQS or AQS/2	AQS/3	Some early AVANCE III systems may have been fitted with an AQS/2. Two configurations of IPSO are available an AQS version and an external version.
TCU0 or TCU1	TCU3	TCU3	**T-Controller**	Located within the IPSO unit. The IPSO is the distinguishing feature of the AVANCE III
FCU0	FCU3	FCU3 or FCU4	**F-Controller**	Located within the IPSO unit
n/a	n/a	n/a	**R-Controller (optional)**	Located within the IPSO unit
CCU10 or CCU11	CCU10 or CCU11	CCU10 or CCU11	**IPSO Host**	The combination of the host, one T-Controller, one (optional) R-Controller as well as a number of F-Controllers are the main components of the IPSO unit.
ASU + LOT + PTS or Schomandl	**SGU**	SGU	SGU/2	Historically the introduction of SGUs was a most significant development. The latest SGU/2 can deliver RF output at both the RF OUT and AUX OUT connection.

Table 1.1. Summary of Four Generations of Spectrometer Hardware

AVANCE (without SGU)	AVANCE (with SGU)	AVANCE II (with DRU)	AVANCE III (with IPSO)	Comment
ROUTER 3/5	ROUTER 3/5	ROUTER 3/5	1/4 ROUTER	Many standard IPSO systems require no ROUTER, such is the improved switching capability of the SGU/2.
External amplifiers only	External or internal amplifiers	External or internal amplifi-ers	External or internal amplifi-ers	Internal and external amplifiers can not be mixed.
RX22	RX22 or RXBB	RXAD AQS/2 only.	RXAD or RXAD-BB	The BB version is used for sol-ids.
SADC/ HADC/FADC	SADC/ HADC/FADC	RXAD	RXAD or RXAD-BB	The RXAD performs digitizer function
RCU	RCU	**DRU or DRU-E**	DRU or DRU-E	**The DRU is the distinguishing feature of AVANCE II.**
	REF 22 or REF	REF or REF /2	REF or REF /2	Earlier generation spectrome-ters had no direct equivalent of the REF unit.

Units Specific to AVANCE Systems without SGUs 1.3.1

AQX / AQR chassis

FCU0

TCU0 or TCU 1

ASU (Amplitude Setting Unit)

LOT (Local Oscillator Tune)

PTS or Schomandl frequency synthesizer.

Units Specific to AVANCE Systems with SGUs 1.3.2

AQS chassis

FCU3 / FCU4

TCU3

SGU

REF22

Amplifiers can be internal or external.

Additional Units Specific to AVANCE II Systems 1.3.3

DRU

RXAD

AQS/2

REF or REF/2

Additional Units Specific to AVANCE III Systems 1.3.4

IPSO comprising of a host as well as one T-Controller, one (optional) R-Controller as well as a number of F-Controllers.

SGU/2

External amplifiers and Gradient unit with Ethernet interface.

Units Common to all AVANCE Systems 1.3.5

ROUTER (different versions)

External amplifiers (different versions)

HPPR (different versions)

Format of Template Used in This Manual 1.4

With the exception of this introductory chapter each spectrometer unit has been described using a set of standard headings listed below. With such a large range of units this format has been used to help the operator locate the required information speedily and efficiently, even though no single template will suit all units. When in the case of a specific system unit there is no relevant information then this heading is either described as na (not applicable) or simply not included.The headings used in the following chapters are:

- **Introduction:** This will give an overview of the unit and an outline of the role it plays in the overall spectrometer operation. This section often highlights differences to previous generations of the same or similar units.
- **Location and Photograph:** For many operators physically recognizing and locating the various units is an important first step in coming to terms with the hardware.
- **General Information, Configuration and Function:** This is a self explanatory heading. Included in this section will be specifications where applicable as well as an explanation of some signals accessible at the front panel.
- **Switching the Unit On and Off.**
- **Tips ‘n’ Tricks/Basic Troubleshooting**: Bear in mind that this is not a service manual but many operators express an interest in learning about some rudimentary troubleshooting checks.

- **Serial Number / ECL Level / Software Download:** In terms of communicating with Bruker service personnel this information is often very relevant.
- **Other Required Signals/Units:** One of the major issues with troubleshooting modern spectrometers is clearly isolating and identifying the faulty unit if and when a problem arises.
- **Option or Core Item**: This section has been included to help operators understand the various configurations possible.
- **Further Information:** This will usually be a BASH reference so that the reader can research the unit further.

Hardware in the Context of NMR *1.5*

To help put the following chapters into context it is perhaps useful to consider the principal generic features that are required of modern NMR hardware. Much of the system design is aimed at achieving some of the features listed below

The **transmitted** excitation signals should have

- precisely defined pulse lengths with accurately regulated amplitudes, frequency and phase control as well as fast switching of same
- good on/off ratios (maximum suppression of noise etc. outside of signal transmission)
- steep falling and rising edges of rectangular pulses
- shaped pulses with well defined envelopes
- linear and accurate amplification
- high resolution in terms of frequency, phase and amplitude.

The **received** NMR signal should

- be amplified linearly over a large dynamic range and the receiver output should be optimally matched to the ADC input
- be digitized at a high sampling rate to maximize the available sweep width and facilitate oversampling. (‘On the fly’ processing of digitized data to facilitate decimation and digital filtering should also be possible).
- have good resolution (high number of bits assigned to the amplitude of the digitized signal)
- maintain phase coherence over repeated acquisitions.

There should also be complete synchronization between all units with respect to timing and in particular between transmission and receiving. The switching time between transmit and receive must also be optimized. The development of the REF unit has ensured that all timing critical signals used throughout the spectrometer are sourced from one single crystal oscillator. Furthermore the design is such that transmit and receive switching signals used at various locations are generated on the one unit (namely the OBS SGU). Finally, as will be discussed later, the entire IPSO concept ensures that the sequencing of all timing critical events takes places on one single individual electronic chip.

Keeping the above essential features in mind will help the reader understand the various roles performed by many of the individual units described in the following chapters.

Blanking and Gating Signals *1.6*

As the concept will arise in several subsequent chapters it is perhaps informative to explain the role played by these signals at this introductory stage. To generate an RF pulse of a specific duration a continuos RF signal is first generated and subsequently transmitted through an electronic switch which regulates the transmission in that it has two modes, on or off. This on/off switching is referred to as blanking or gating the RF signal. The switches are controlled by blanking or gating signals which are digital (TTL level) operating on active low logic.When the signal is high (5V approx.) the switch is open to prevent transmission, when it goes low (0V approx) the switch is closed to allow transmission.

Important features of rectangular pulses are good on/off ratios as well steep falling and rising edges as mentioned earlier. The on/off ratio can be improved by repeated blanking or gating. Clearly if the blanking/gating is to be repeated at several locations the various controlling signals must be accurately synchronized. The role played by the REF unit along with the SGU in terms of synchronizing the blanking has already been alluded to.

The trend in the latest spectrometer systems is to minimize the requirement for blanking by only generating RF signal during those times when transmission is to occur. Thus the SGU output is switched off outside of transmission (see ***Figure 1.1.***). There is still a need for blanking within the amplifier itself as they will inevitably amplify noise at all times.

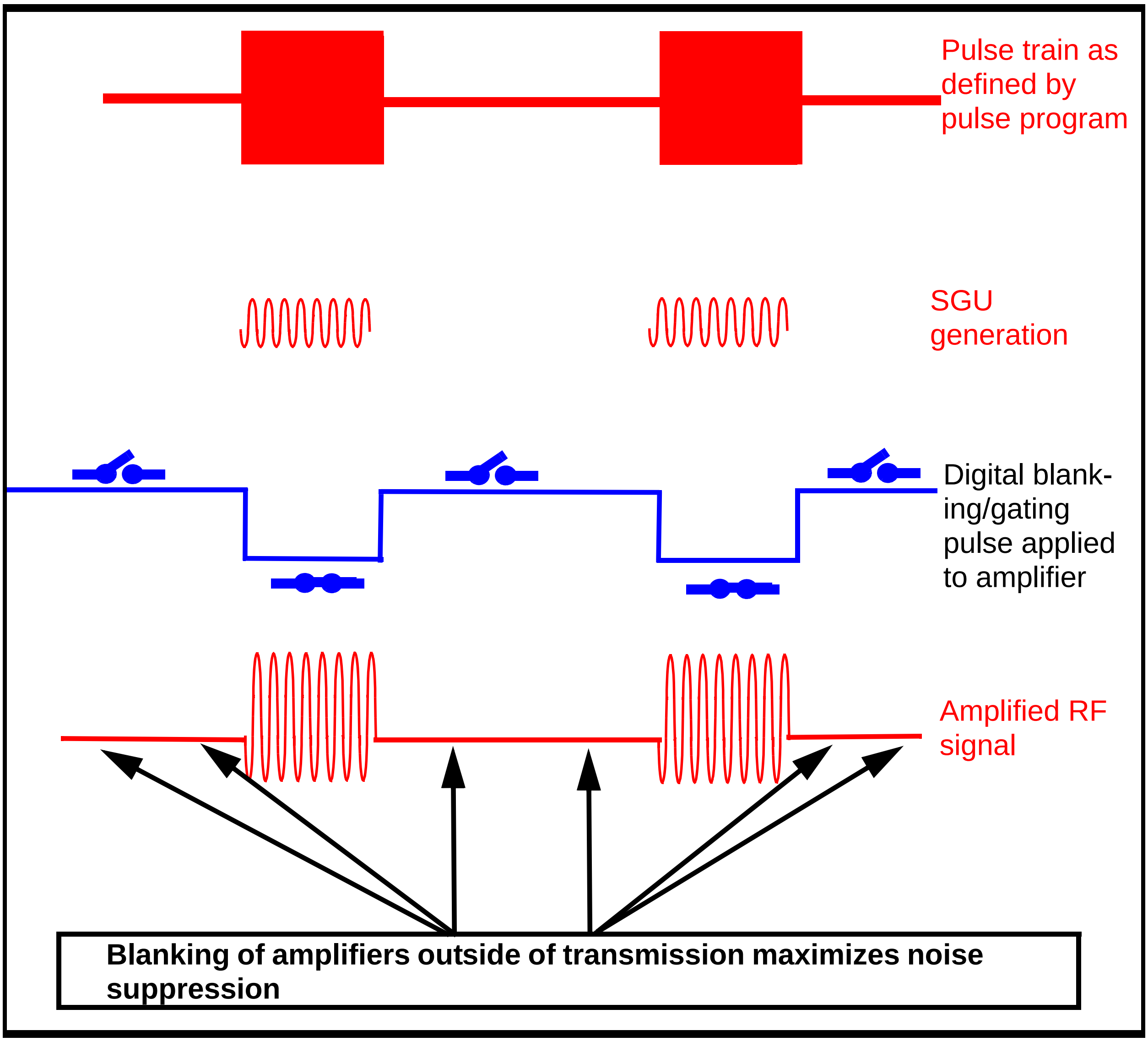


Figure 1.1. Concept of Blanking/Gating in Terms of on/off Switching

Cabinet and System Overview 2

Introduction 2.1

The purpose of the cabinet is to

- house the various spectrometer units in a compact arrangement
- provide shielding to sensitive electronic components
- ease site planning, installation and provision of services.

Shielding of sensitive components such as the receiver from interference arising from electromagnetic radiation from external sources is maximized when all the units are housed within a metal cabinet.The reader should note that they are advised to keep the cabinet doors shut to maximize this shielding. Ventilation fans mounted at the rear of the cabinet cool the various units. As well as providing important electrical internal wiring (via an internal wiring harness) the cabinet is designed to provide the spectrometer pneumatic and mains electrical power connections. With a cabinet arrangement it is easier to provide facilities such as electrical power and compressed air from a single supply.These connections can be seen in ***Figure 2.1.***.

The cabinet can be moved relatively easily (power all units off and disconnect cabling if required) and its position, particularly with respect to the magnet, is an important site planning consideration. In many situations site planning is reduced to providing suitable locations for the cabinet, the operator desk and the magnet. From an operator/customer perspective the only other principal consideration is whether they require a MicroBay, OneBay or TwoBay cabinet and this depends almost entirely on the configuration of the spectrometer (see below for further details).

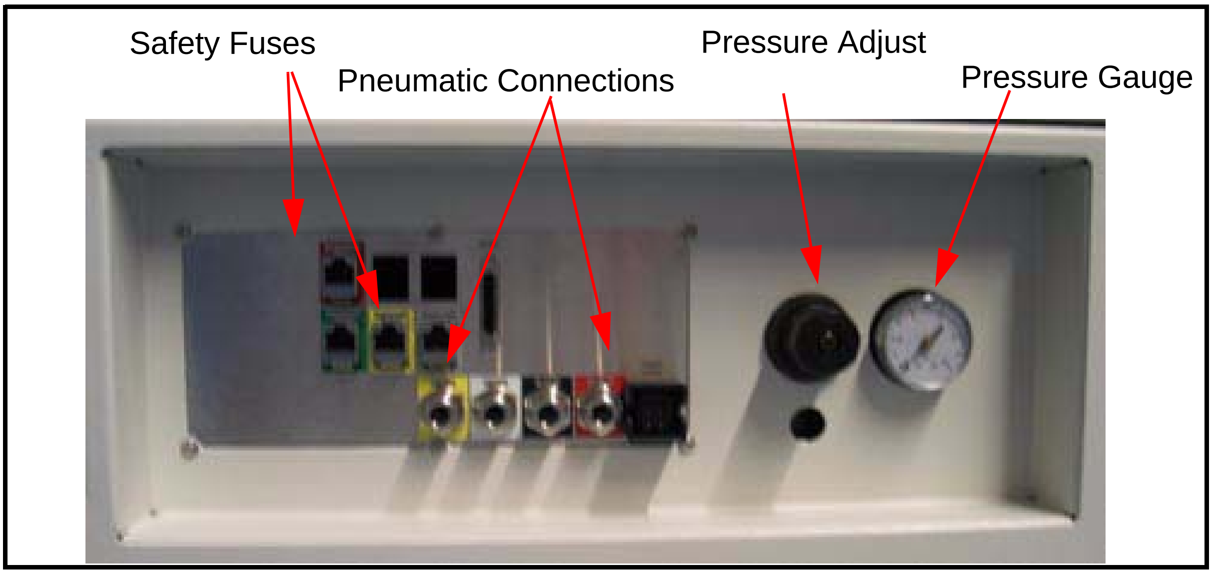


Figure 2.1. Rear View of Base of Cabinet.

Unit Location and Photograph 2.2

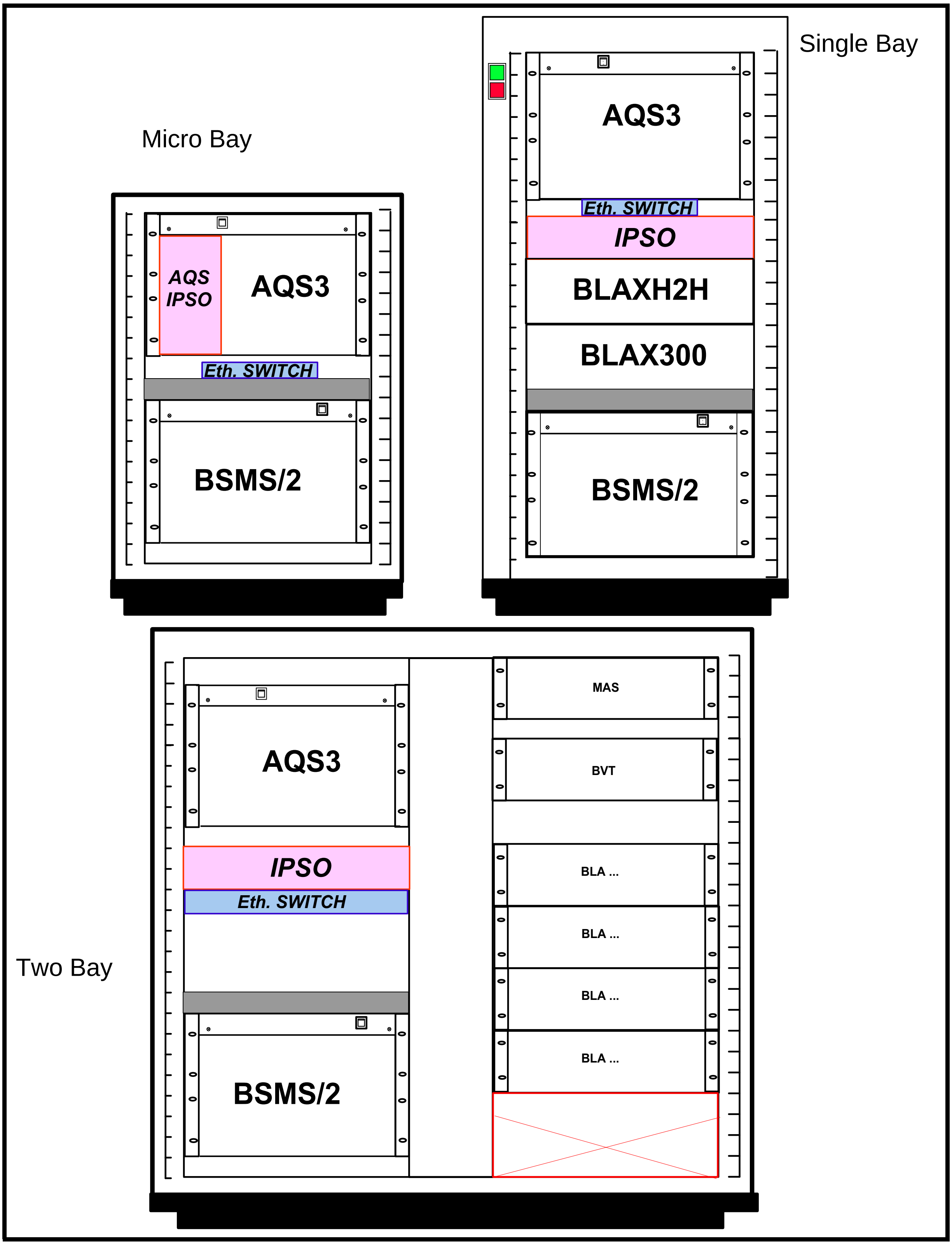


Figure 2.2. Different Cabinet Configurations (not to scale)

General Information, Configuration and Function 2.3

Whether the cabinet is MicroBay, OneBay or TwoBay will depend effectively on the number of channels required.

- A MicroBay cabinet will accommodate up to three independent RF channels.
- A OneBay cabinet will accommodate up to four independent RF channels (reduced to three if internal amplifiers are used).
- A TwoBay cabinet will accommodate up to eight independent RF channels.

Note that there is some scope to place some external units on top of the cabinet, though be aware that such units do not benefit from the cabinet shielding.The principal sub units housed within the cabinet are the AQS (Acquisition Control System), the BSMS (Bruker Smart Magnet System), the VTU (Variable Temperature Unit) as well as various amplifiers (aka transmitters).These principal sub units will now be discussed briefly in the context of a general introduction More details will be provided subsequently.

AQS Rack 2.3.1

AVANCE III are now fitted with the AQS/3 as standard though the principal of operation is the same as with the previous AQS and AQS/2 racks. The various units within the AQS prepare and in some cases amplify the radio frequency pulses used to excite the sample and receive, amplify and digitize the NMR signals emitted by the sample. Once the data is received and digitized, the information is transferred to the host computer for further processing and storage. The data transfer is usually from the DRU (which acts as rack master) to the host computer via the Ethernet switch. The AQS rack greatly reduces the space requirements of the spectrometer. Several buses which run along the backplane make communication between the various units very efficient. Furthermore the combination of so many units into a single rack greatly simplifies the provision of power supply voltages which are also delivered over the backplane to the various units. Depending upon the configuration many of the AQS slots may be vacant but this is inevitable when a single rack is used for multiple configurations.The AQS rack contains a set of slot-in type units as well as the IPSO (where a 19” version is not used). A more detailed description of the AQS is to be found in chapter ***3***.

BSMS 2.3.2

BSMS is an acronym for **B**ruker **S**mart **M**agnet control **S**ystem. Depending upon the configuration the system can be controlled via the

- Commands entered directly from within the TOPSPIN BSMS display
- BSMS shuttle
- BSMS keyboard (optional extra only)

The principal functions of the BSMS are to

- operate the lock system
- control the shim system

- operate the sample lift and spin
- generate gradient pulses (where a GAB/2 unit is fitted).

For an overview of some of the BSMS signals see ***"Simplified Schematic of Principal Signal Paths" on page 30***.The BSMS hardware is comprehensively described in various manuals available on the BASH CD and will not be dealt with in any great detail in this manual with the exception of some recently developed boards such as the new

- ELCB which will be described in chapter ***6***.
- GAB/2 which will be described in chapter ***7***.
- SCB20 which will be described in chapter ***8***.

A summary of the various boards follows and they will be discussed in the order in which they are located (from the left) as in ***Figure 2.3.***

Deuterium Amplifier 2H-Tx: This houses a single 20W amplifier primarily designed to facilitate experiments that require deuterium decoupling.Note that there is also an AQS version with 80W power which is enough to observe deuterium although the 90 degree pulses are relatively long.There is also a BLAXH2H external amplifier which delivers 150W on the deuterium channel (up to 600 MHz systems) and 250W on the deuterium channel (700-900 MHz systems).The BSMS version mentioned above has limited power (20W) due to the current limit of the BSMS power supplies.

Sample and Helium **L**evel **C**ontrol **B**oard SLCB: This board is responsible for all aspects of raising, lowering and spinning the sample as well as monitoring the Helium level. The pneumatic module which controls a supply of compressed air to drive the lift and spin is located at the rear of the BSMS/2.

Gradient **A**mplifier **B**oard GAB/2: This board receives digital data from the G-Controller and converts it into its analogue equivalent in order to perform Z axis gradient spectroscopy. For further details see chapter ***7.***

Shim **C**urrent **B**oard SCB/20.This generates the shim currents for the room temperature shims based on the operator adjustments at the BSMS Keyboard, Shuttle or from within TOPSPIN. Effectively the board is a very sophisticated DAC with high accuracy and resolution.***Figure 2.3.*** shows a BSMS/2 with two of these boards fitted. The actual number of boards fitted (one or two) will depend on the complexity of the shim system. The font panel connections where the currents are accessed are labelled in ***Figure 2.3.***. From here the cabling ports the currents to the rear of the cabinet and then on to the actual shim system located within the magnet bore. The SCB20 will be dealt with in chapter ***8.***

Extended **L**ock **C**ontrol **B**oards ELCB: This new board replaces the old LCB and CPU. In its role as CPU it controls the BSMS and in particular the lock. The main development has been the Ethernet capability. It also incorporates 2 TTY connectors for BACS, VTU, etc.For more details see chapter ***6.***

Lock **R**eceiver Board LRX: Like the Transmitter this board is spectrometer frequency dependent and receives the NMR signal generated by the deuterated solvent. The signal is transmitted from the probe via the 2H module of the HPPR or internal preamp.

Lock **T**ransmitter **B**oard LTX: This board generates the deuterium excitation signal required to maintain the lock and as such is spectrometer frequency dependent. ***Figure 2.3.*** shows a LTX600 signifying that is fitted on a 600 MHz spectrometer. The signal generated by this board is transmitted to the 2H module of the HPPR or internal preamplifier and then to the probe.

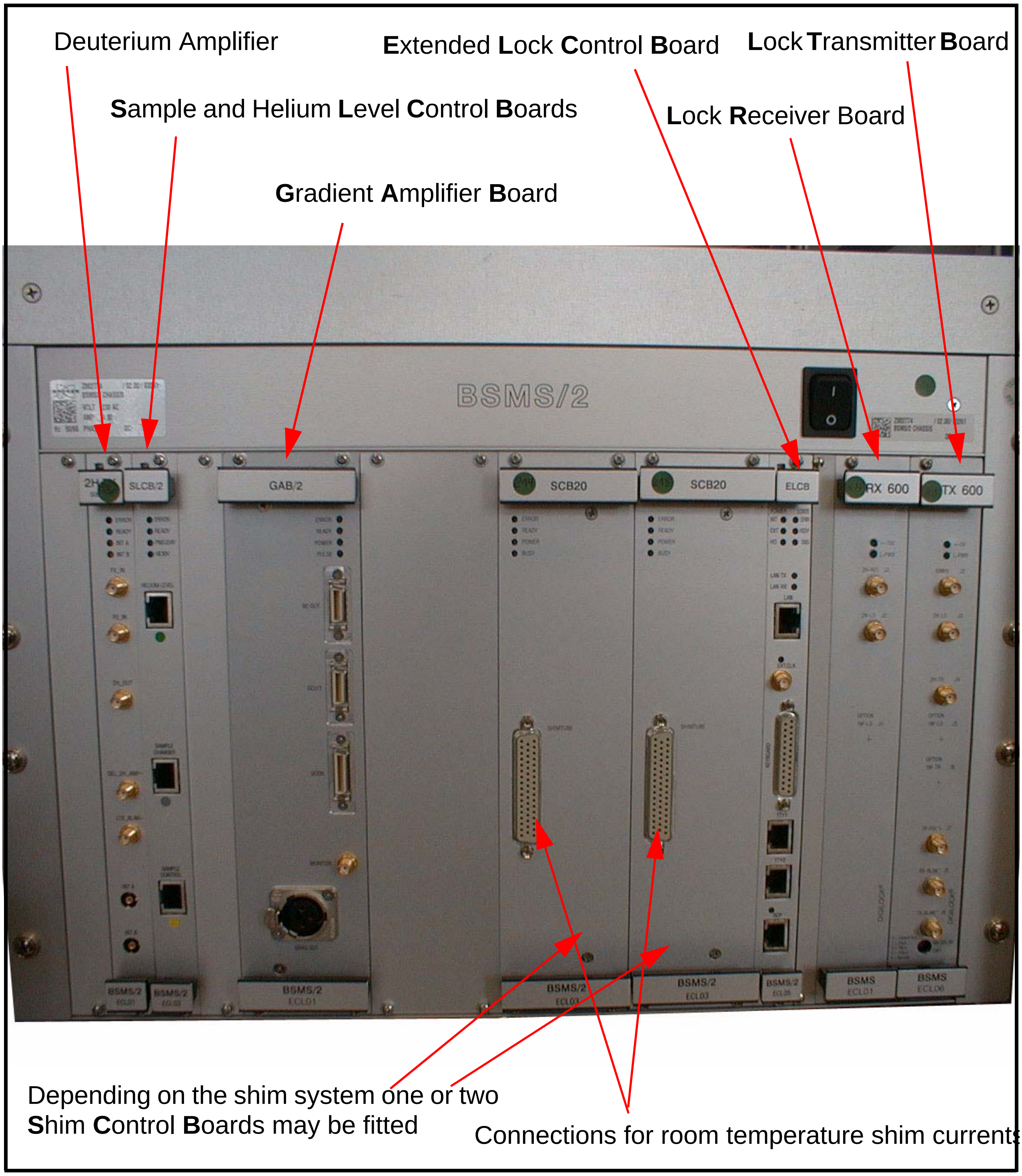


Figure 2.3. Front Panel of BSMS/2

VTU:

Depending on the model the **V**ariable **T**emperature **U**nit may be a separate standalone unit or may be incorporated into the rear of the BSMS. The function of the VTU is to control the sample temperature using a heater in conjunction with an air or nitrogen gas transfer line. A thermocouple serves as a thermometer to constantly monitor the temperature in the vicinity of the sample. All these devices are attached to the base of the probe and are easily accessible.The VTU constantly monitors the thermocouple reading and makes adjustments to the heater power to maintain a regulated temperature. In terms of overall spectrometer hardware the VTU is relatively simple and will not be dealt with in any detail in this manual. However it is worth mentioning the ‘edte’ menu which contains the ‘self-tune’ tab. Using the self-tune routine will optimize the temperature control parameters and these results, which are probe specific, can then be stored on disk in files. In this way it is relatively simple to load the appropriate set of parameters whenever a probe is changed.

Figure 2.4. Typical VTU Unit (BVT3000)

Amplifiers 2.3.3

Also known as transmitters the amplifiers will be dealt with in detail in chapter **10** and chapter **11** but will be introduced here in the context of the overall hardware.

Signals of relatively large amplitude are often required to minimize the 90 degree pulse lengths and optimally excite the NMR sample and hence the need for amplifiers. Amplifiers can be internal (incorporated into the AQS rack) or external (separate standalone units). One other option has been to incorporate a dedicated deuterium amplifier into the BSMS/2 as described in section **2.3.2**. Cables running directly from the amplifier outputs to the hppr/internal preamplifiers carry the RF signal to the sample. Although there is a wide range of available amplifiers (including amplifiers for solid state NMR) the two main categories are:

Selective amplifiers (also known as ^{1}H or proton amplifiers) are specifically designed to amplify the higher frequencies associated with ^{1}H and ^{19}F spectroscopy.

Broadband amplifiers (also known as X amplifiers) designed to amplify a wide range of lower frequencies (excluding ^{1}H and ^{19}F) but including ^{13}C,^{31}P etc.

A third minor category mentioned above are dedicated deuterium amplifiers.

The RF signal enters the amplifier via the SMA type connector usually labelled “RF in” on the front panel (see ***Figure 10.8.*** for an example of different connector types). This is a relatively weak signal with a maximum amplitude of 1Vpp. However the quality of this signal is critical as it defines the frequency, timing, shape and phase of the final signal. Experienced operators sometimes view this signal on an oscilloscope. The function of the amplifier is to take the input signal and apply a fixed gain. Amplitude control and specifically amplitude variation is implemented prior to the amplifier, via the parameters (pl0...pl31) for rectangular pulses and (sp0....sp63) for shaped pulses. The RF signal leaving the amplifier can be of the order of several hundred volts and is not recommended to be viewed on the oscilloscope without adequate attenuation.

Although this manual will deal primarily with the hardware contained **within** the cabinet it is perhaps appropriate to describe (albeit briefly) the remaining principal components of the system such as the magnet, shim system, HPPR, probes and lock system.

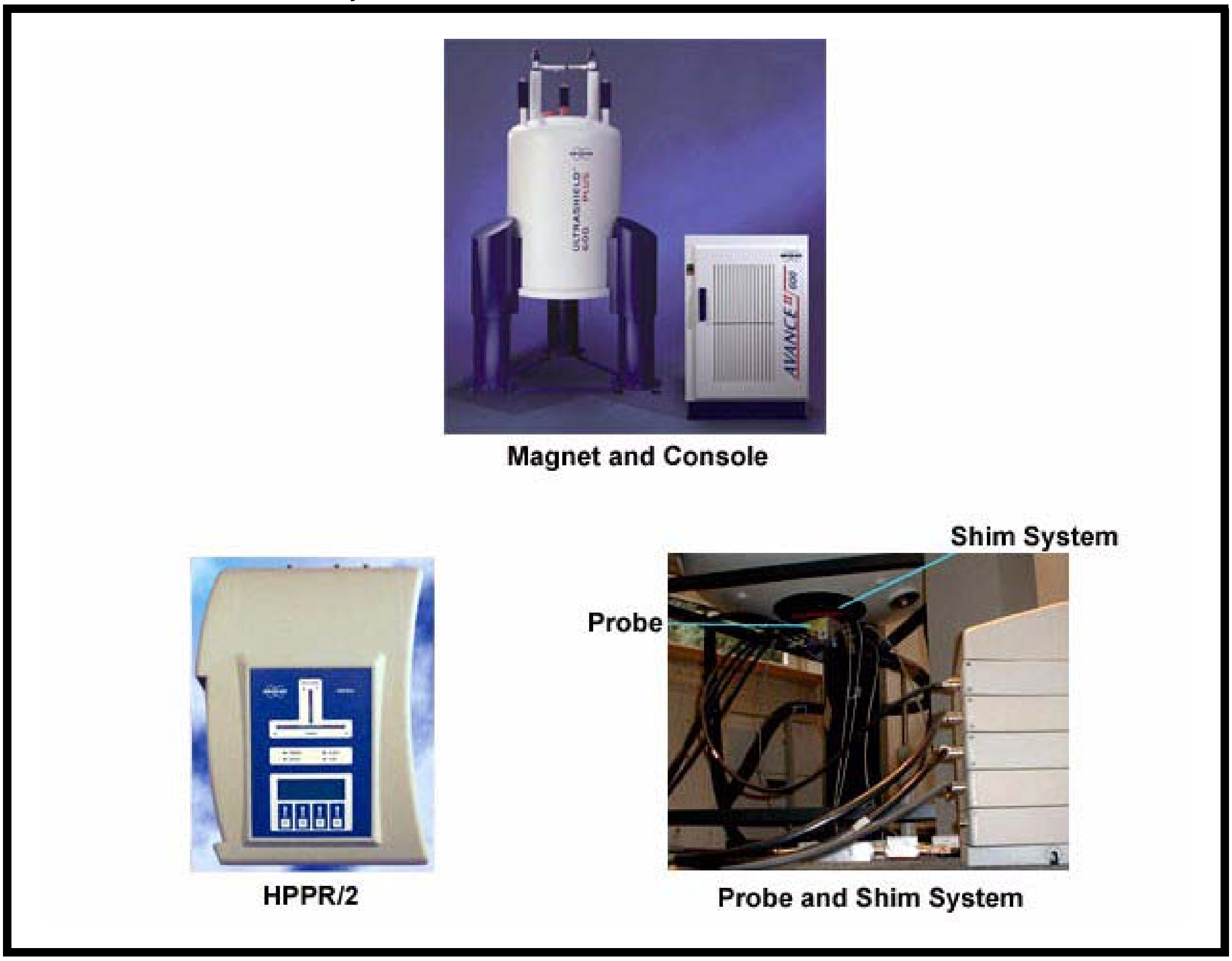


Figure 2.5. Major Components of an NMR System (MIcro-Bay Shown)

Magnet 2.3.4

This generates the magnetic field which in conjunction with the RF excitation signal induces NMR transitions. To maintain a super-conducting system the magnet core is cooled to very low temperatures using liquid nitrogen and helium. The progression to higher strength magnets has been driven by the associated increase in sensitivity. Apart from field strength the main consideration in terms of the 'quality' of the magnet is the homogeneity of the magnetic field and this has a direct bearing on the resolution as determined by the line width of NMR signals. Both sensitivity and line width (or line shape) are fundamental spectrometer specifications. The homogeneity of the magnet field may be adjusted using a procedure known as 'shimming' described below.

Shim System 2.3.5

The room temperature shim system, mounted into the lower end of the magnet, is a set of current carrying coils (known as shims) used to maximize field homogeneity by offsetting any existing inhomogeneities caused by the sample itself, the probe etc. The currents in these room temperature shims (so called as they are not cooled by being immersed in a bath of liquid helium) are controlled by the BSMS and may be adjusted from the BSMS keyboard, BSMS shuttle or from within TOPSPIN to optimize the NMR signal. The process of adjusting the shim currents is called ‘shimming’ and has a major effect on signal resolution and sensitivity. The ‘lock level’ is often used to monitor the progress of the shimming operation.

HPPR/Internal Preamplifiers 2.3.6

Although the HPPR (High Performance Preamplifier) carries the transmitted signal ***to*** the sample it is primarily concerned with magnifying the relatively weak signals emitted ***from*** the sample. The HPPR is located at the base of the magnet to amplify the NMR signal at the earliest possible opportunity and thus minimize losses along the cable. Newer internal preamplifier modules are incorporated in the AQS rack within the cabinet itself and can be seen in ***Figure 3.1.*** Once the signal has been amplified within the HPPR any subsequent losses in cabling are less critical. The HPPR also transmits and receives the deuterium (or fluorine) lock signal and is used in the wobble routine. Up to 8 individual modules (excluding the cover module which is always present) may be configured in the newest versions known as the HPPR/2. All these modules will automatically be displayed in the edsp/edasp window. A very common configuration consisting of three individual modules, a proton, X-BB and ^{2}H along with a cover module, is shown in ***Figure 2.6.*** The ^{2}H module is used to transmit and receive the lock signal. Much of the HPPR technology is concerned with what is known as the Transmit / Receive switching. Effectively the signal going to the probe is transmitted without any action apart from frequency filtering to minimize noise as well as an inevitable insertion loss of typically 1dB. Once this transmit signal has elapsed the signal path within the HPPR is altered so as to amplify the received signal from the probe by typically 30dB. The trick is to make this switch as fast as possible and suppress leakage so that the tail of the transmitted signal does not swamp the start of the received signal.The timing of this switching is controlled by the OBS SGU.

The HPPR hardware is described in detail in manuals available on the BASH CD and will be dealt with briefly in chapter ***13***.

Lock System 2.3.7

The aim of the lock system is to ensure that the strength of the magnetic field surrounding the sample does not change during an experiment or that the effect of any external disturbances is minimized. The operator must be confident that the magnetic field strength is always maintained at precisely the same strength and this is referred to as ‘locking’ onto the sample. The lock system is essentially a separate spectrometer designed to observe deuterium. It should be mentioned that the signals emitted by deuterium are normally far removed from frequencies that are generally of interest in NMR experiments. However if the deuterium frequency is unsuitable then a fluorine (^{19}F) lock may be used. Since it is by far the

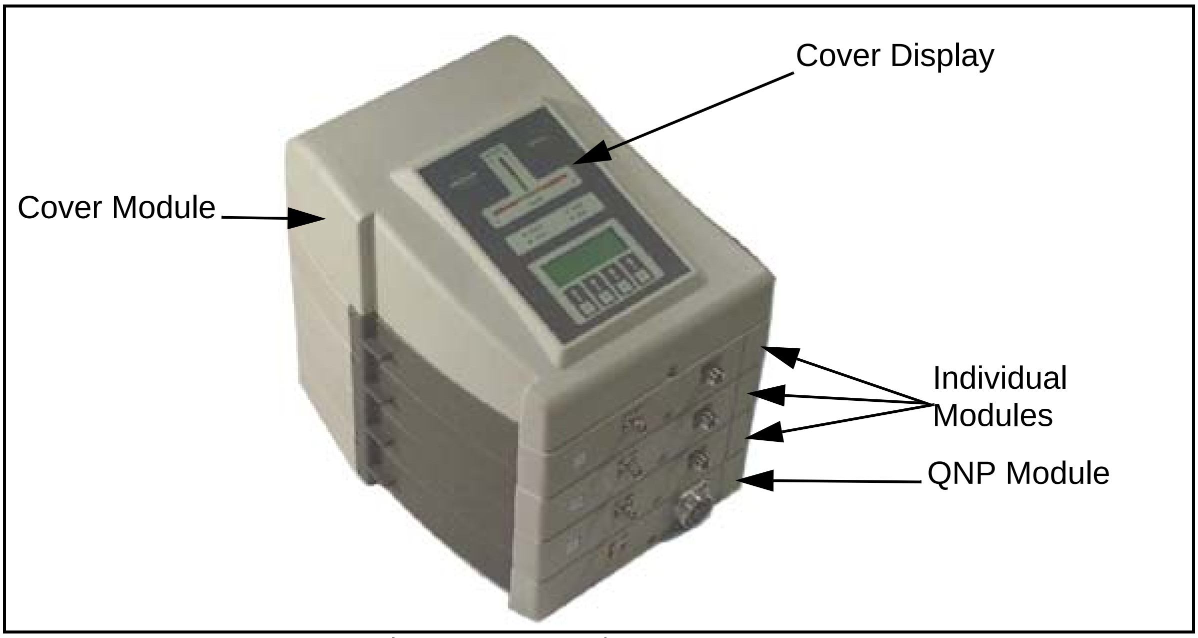


Figure 2.6. HPPR/2

most popular, only the deuterium lock will be dealt with here, but the reader should note that the operating principles of the deuterium and the fluorine lock are identical.

In AVANCE systems the BSMS provides the hardware required to implement the lock and a separate deuterium module in the HPPR or internal preamplifier transmits and receives the lock signals. Some deuterium must of course be introduced into samples that are under analysis. This can most easily be done by dissolving the sample in a deuterated solvent.

The frequency of the signals emitted by deuterium for a particular size of magnet is precisely known. Therefore if the magnetic field strength is correct then any deuterium in the sample for a given type of spin should emit this exact frequency. If the magnet strength varies then so also will the deuterium frequency. The lock system uses a receiver (housed in the BSMS rack) to monitor this deuterium frequency and makes adjustments to the magnetic field strength accordingly.

Probes *2.3.8*

The probe is designed to hold the sample, transmit radio frequency signals which excite the sample and detect the emitted response. The transmission and reception is achieved by using specially designed RF coils.The probe is inserted into the bottom of the magnet and sits inside the room temperature shims. Coaxial cables carry the excitation signals from the HPPR/internal preamplifier to the probe and the NMR signal back from the sample to the HPPR/internal preamplifier. As mentioned in section ***2.3.6*** the preamplifiers are needed to boost the NMR signals which are typically very weak.

Overview of Principal Signal Paths 2.3.9

To help the reader appreciate the overall spectrometer operation before progressing to a description of the individual spectrometer units, it is hopefully informative to give a very brief summary of some of the principal signals in a standard acquisition as in ***Figure 2.7.***. The reader should note that this is a relatively simple example and details will vary depending on the particular spectrometer configuration.In particular the example shown uses the HPPR as opposed to internal preamplifiers as well as an AQS IPSO as opposed to a 19” IPSO.

Transmission of excitation signals: The details of the excitation pulse are prepared and generated by F-Controllers within the IPSO, based on information entered by the operator and transmitted from the workstation via the Ethernet link. This digital information is then transmitted to the SGUs via the LVDS link. After generation on the SGU the analog RF signal (1Vpp max) is connected to an amplifier before transmission to the appropriate HPPR module.

Transmit / Receive switching. The HPPR filters and transmits the excitation signal to the probe and then filters and amplifies the NMR (received) signal. Note that the same cable carries the transmitted signal ***to*** the sample as well as the relatively weak signals emitted ***from*** the sample.

Received NMR signal: The signal is detected and amplified by the RXAD where it is also digitised.The digitized signal is passed to the DRU and finally to the NMR workstation via the Ethernet switch. The acquired signal is then processed and stored.

Lock Signal: The BSMS transmits and receives the Lock signal via the HPPR ^{2}H (or alternatively the ^{19}F) module.

Shim Control: This is achieved using the BSMS.

Both the lock and the shims can be controlled using the BSMS Keyboard, Shuttle or from within TOPSPIN which communicates with the ELCB of the BSMS/2.

Switching the Unit On and Off 2.4

The cabinet and all power supplies are controlled by a red/green switch on the front (see ***Figure 2.8.***). Note in the event of an emergency this switch is the quickest way of removing electrical power from the various spectrometer units.The red/green switch will remove all power immediately whereas individual unit switches on the AQS or BSMS are normally used to power off units within the rack. Standalone items such as the VTU or external amplifiers have separate power switches.

Tips ‘n’ Tricks/Basic Troubleshooting 2.5

- The cabinet should be left permanently closed when operating as this will maximize the shielding and reduce the effect of any electromagnetic disturbances from outside. Care is taken in choosing the material from which the cabinet is constructed to maximize radiation shielding. Keeping the cabinet closed will also reduce any disturbances caused by temperature fluctuations. The cabinet is designed to be sealed from electromagnetic interference (see ***Figure 2.9.***) It is worth noting that steady temperatures in the laboratory itself are always conducive to reliable NMR data.

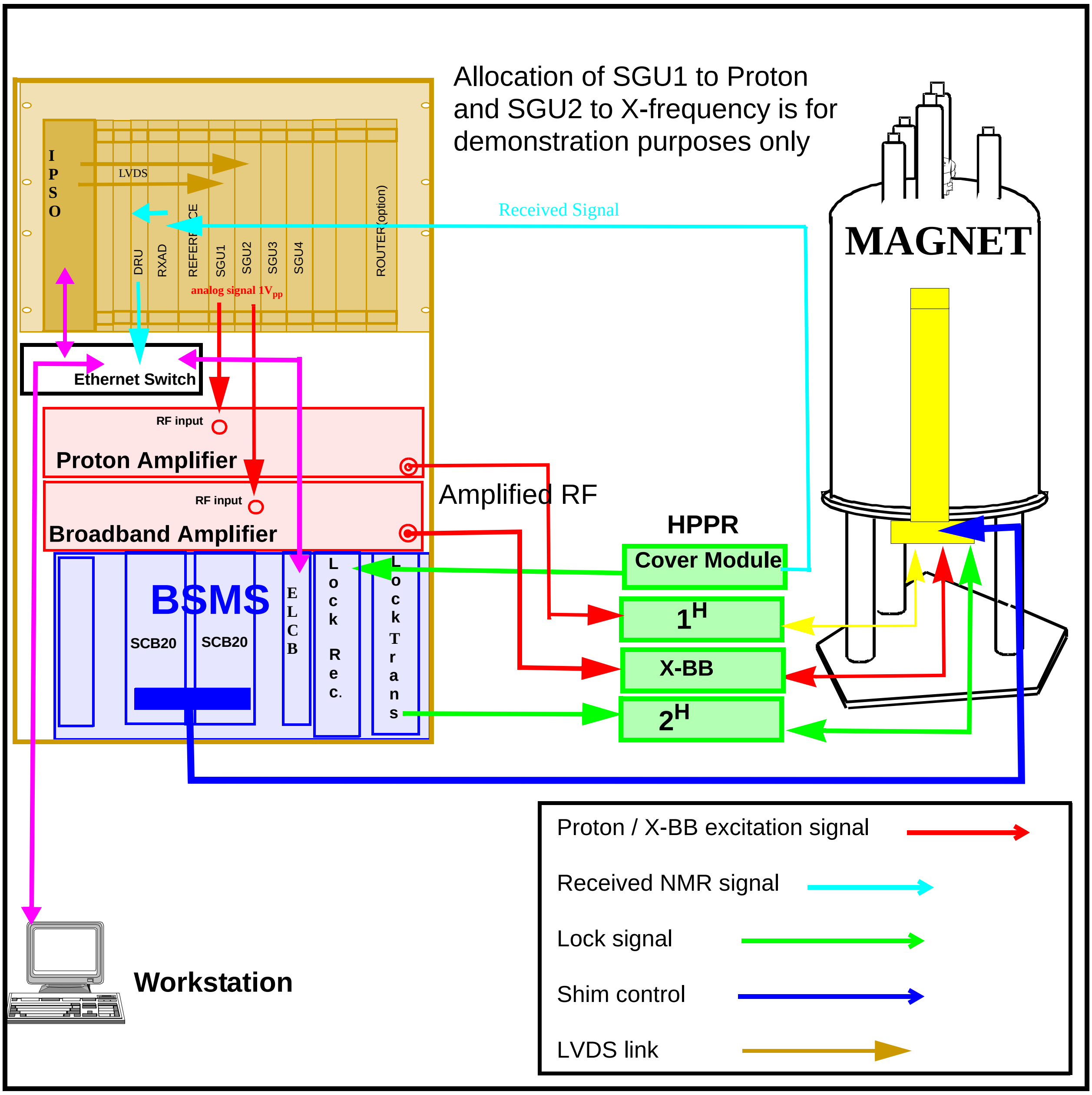


Figure 2.7. Simplified Schematic of Principal Signal Paths

- If a problem is encountered with the pneumatic driven functions such as lift and spin you should check that adequate pressure (see site planning guides for specific requirements) is available at the rear of the cabinet. The pressure gauge and adjustment knob are clearly visible in ***Figure 2.1.***.

Serial Number / ECL Level / Software Download 2.6

The location of the serial number and ECL level of the cabinet is shown ***Figure 2.9.***. While the physical structure of the cabinets is relatively independent of any

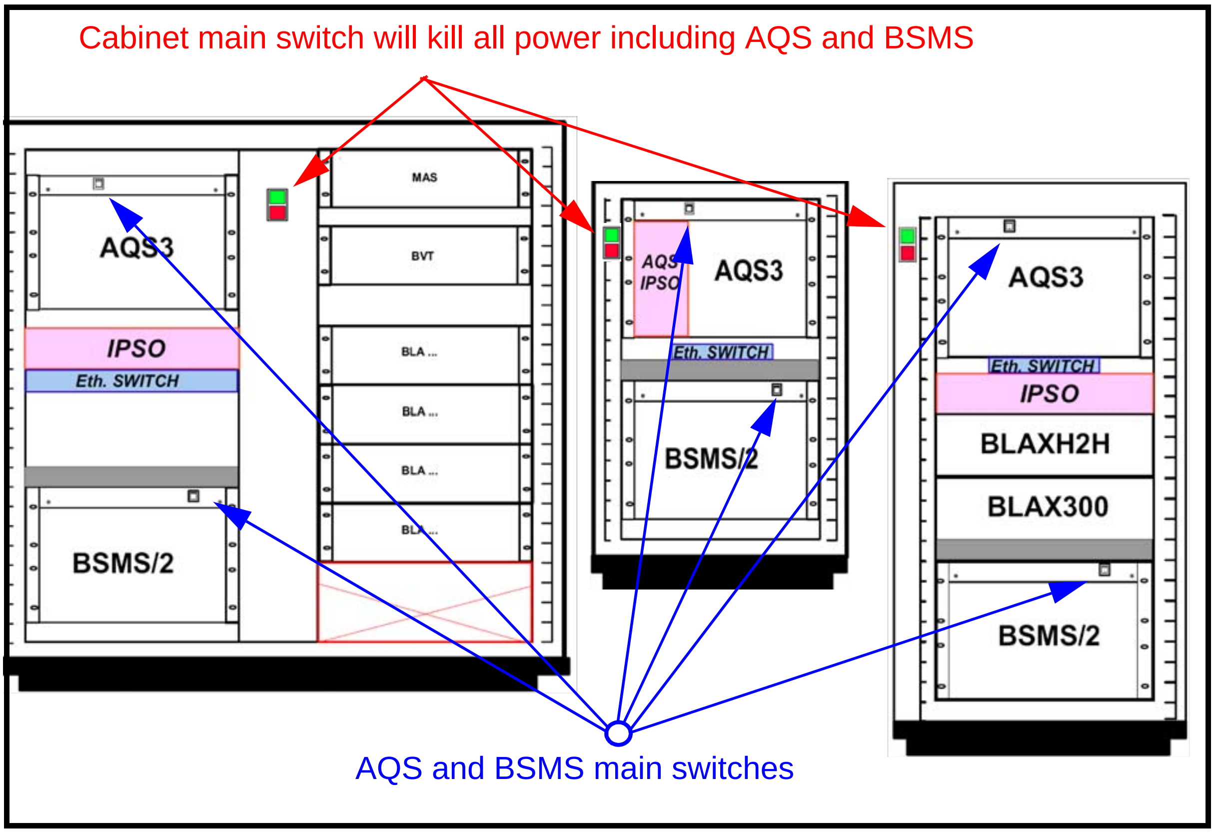


Figure 2.8. Mains Power Switches

engineering changes the internal wiring harness does change with new developments.

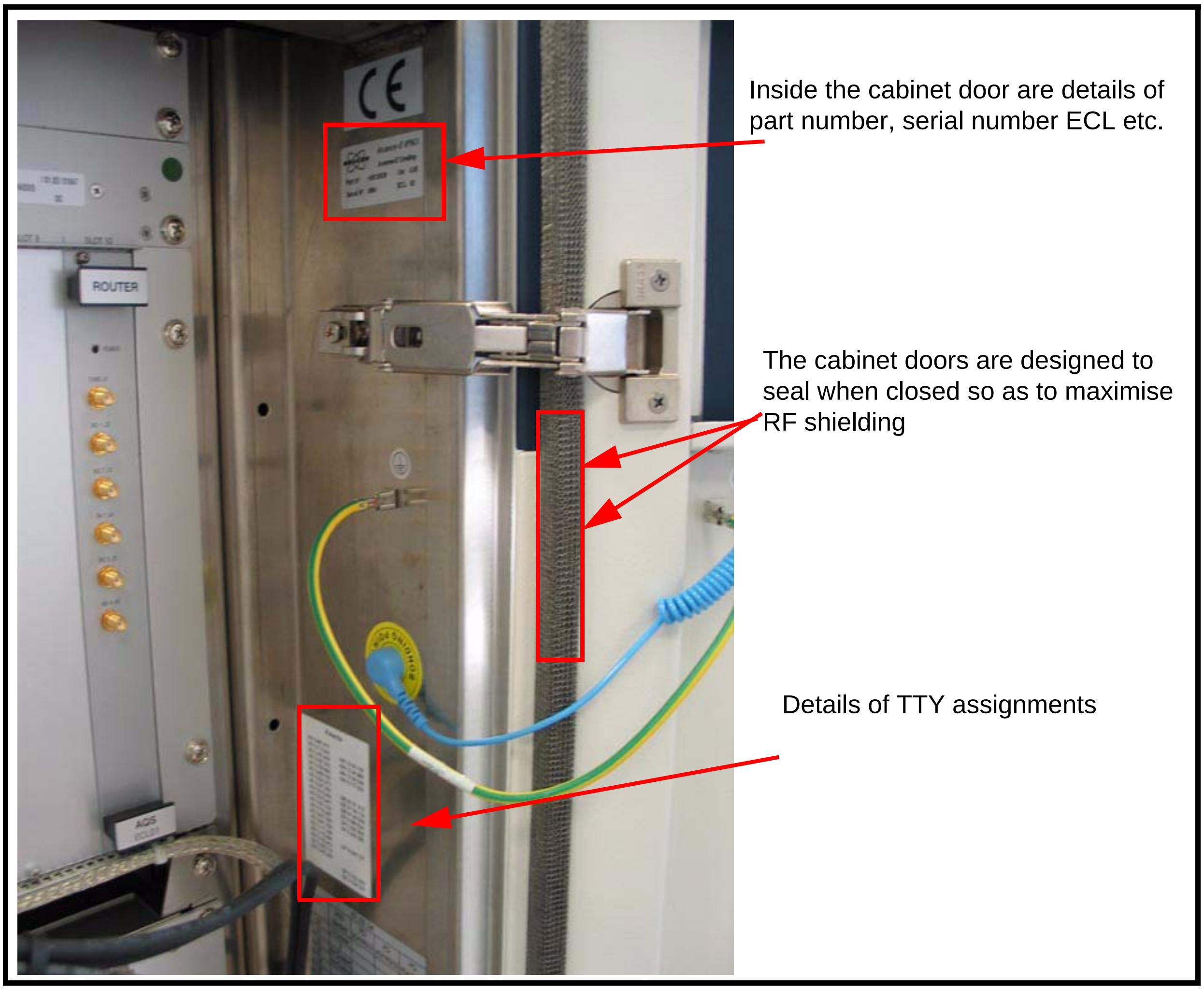


Figure 2.9. Cabinet Production Details

Other Required Signals / Units **2.7**

To operate the cabinet needs

- electrical power
- pneumatic supply

The only other consideration here is that cabinet should always remain the minimum recommended distance from the magnet to avoid magnetic interference with the electronics.The recommended distances will be dependent on the magnet field strength and can be found in the relevant site planning guide.

Option or Core Item 2.8

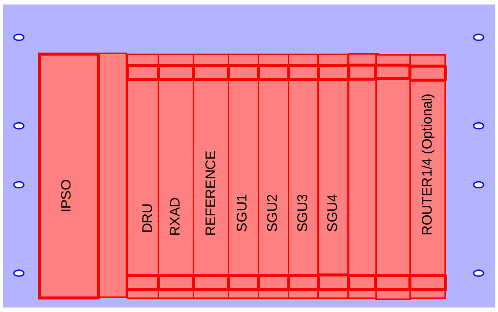
The cabinet be it MicroBay, OneBay or TwoBay is a core item. In particular it is fitted with an internal wiring harness which transmits a range of signals and interconnects many units.

Further Information 2.9

- Site Planning guides available on the BASH CD are useful references particularly with respect to cabinet dimensions, suitable location, electrical and pneumatic requirements etc.
- There are a series of manuals on the various BSMS units not all of which will be described in this manual.For an overview of the various units check out the introductory chapter of BSMS (User Manual) P/N Z31185.
- For an introduction to and overview of temperature control see Variable Temperature Unit (VTU) (User Manual) P/N Z31482.There are also several individual manuals describing the various models.

Acquisition System (AQS/3) 3

Introduction 3.1



The AQS/3 (Acquisition System) rack greatly reduces the space requirements and simplifies the configuration and operation of the spectrometer. Several buses which run along the backplane make communication between the various units very efficient. Furthermore the combination of so many units into a single rack greatly simplifies the provision of power supply voltages which are again delivered over the backplane to the various units.This minimizes the number of front panel cables. While the rack system offers a great space saving the large number of signals that are transmitted over the backplane are inaccessible making troubleshooting in the field very challenging. The rack design is to allow for system flexibility in terms of unit configuration so that standard racks can be used for various spectrometer configurations. The design of the AQS/3 has also had to take account of the fact that it must be compatible with various units that have been developed over time. These units have different physical sizes and use different communication protocols.

Since a single rack must often accommodate a range of configurations, both basic and advanced, it is often the case that many of the slots will be unoccupied for any particular configuration.This is particularly the case when the external IPSO unit is fitted. A second rack can be added to allow a flexible extension for multi-receiving systems.Every slot on the AQS/3 User Bus backplane is hardware coded, so that every unit can be addressed individually via its unique slot address. So also can each individual rack be distinguished from each other using a rack code which can be set with rotary switches on the rear side of the AQS/3 backplane.

At this stage three versions of the AQS have been produced (original AQS, AQS/2 and AQS/3). Although some early systems were fitted with the AQS/2 all AVANCE III systems are now fitted with the AQS/3 and for the purposes of this manual no other rack will be described.

The newest AQS/3 can accommodate the internal IPSO unit as well as having 10 slots for AQS type units.

When combined with an external IPSO the AQS will cater for

6 RF channels (system with external amplifiers)

3 RF channels (system with internal amplifiers)

A second AQS/3 will enable up to 8 RF channels to be installed.

When a AQS IPSO is fitted, the system will cater for 4 RF channels though this is a limitation of the IPSO unit and not the AQS rack.

In the descriptions throughout this manual the term AQS should be read to mean the AQS/3. Where a distinction is to be made this will be specifically stated.

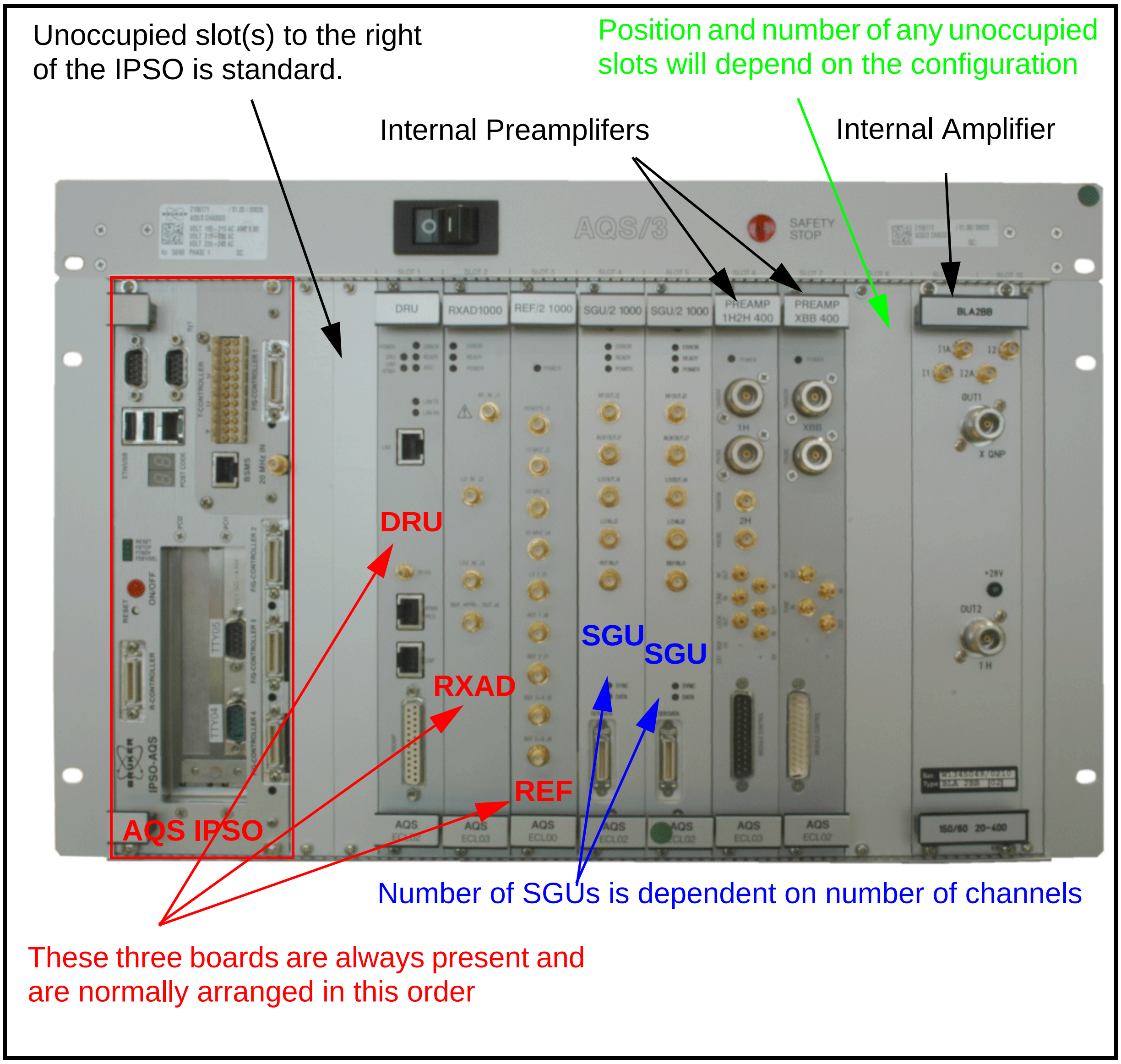


Figure 3.1. Typical AQS/3 rack with AQS IPSO internal preamplifiers and amplifier.

Location and Photograph ***3.2***

The AQS is located inside the main cabinet (see ***Figure 2.2.***)

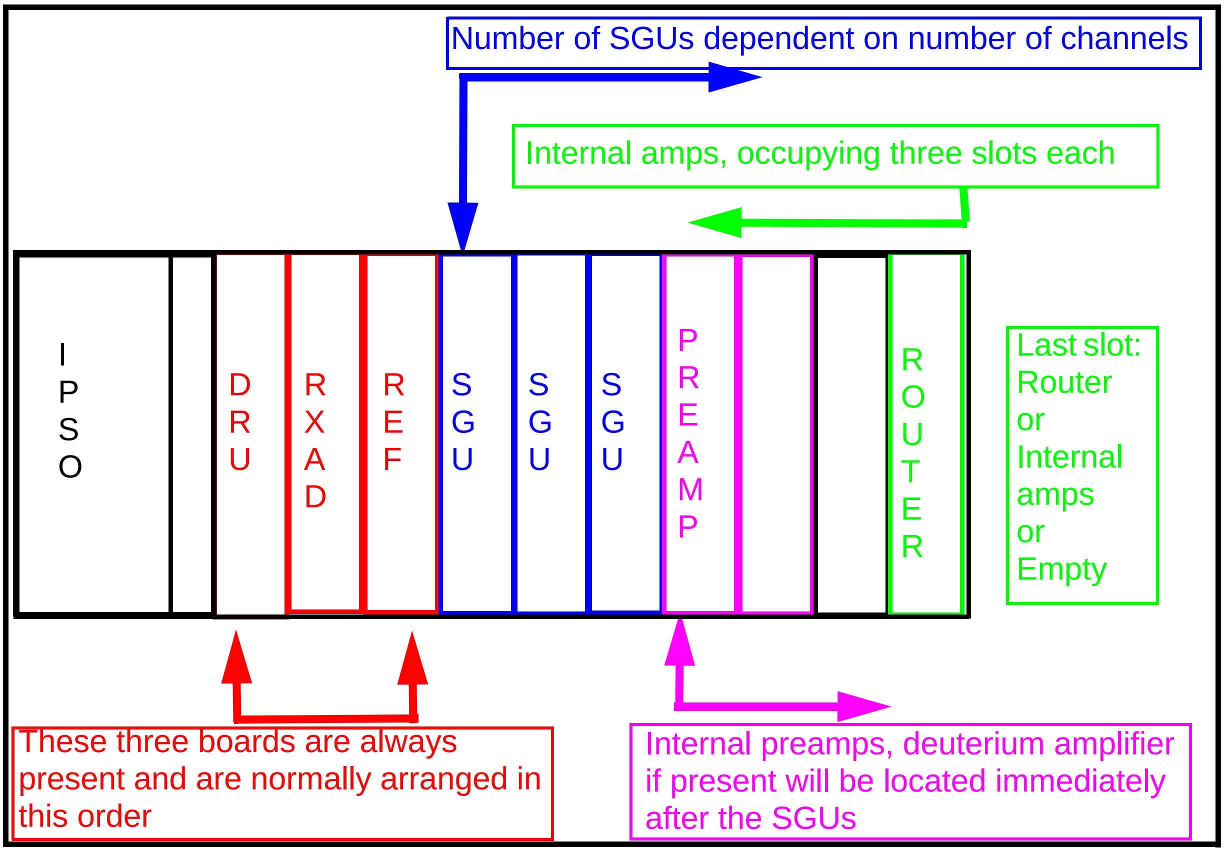


Figure 3.2. General Guidelines Regarding AQS/3 Slot Allocation

The left end of the AQS houses the IPSO unit. All other AQS units, starting with the DRU, occupy what are often referred to as the analog slots.

Although many configurations are possible a selection is illustrated below along with ***Table 3.1.*** which is a summary of the max number of channels for various configurations.

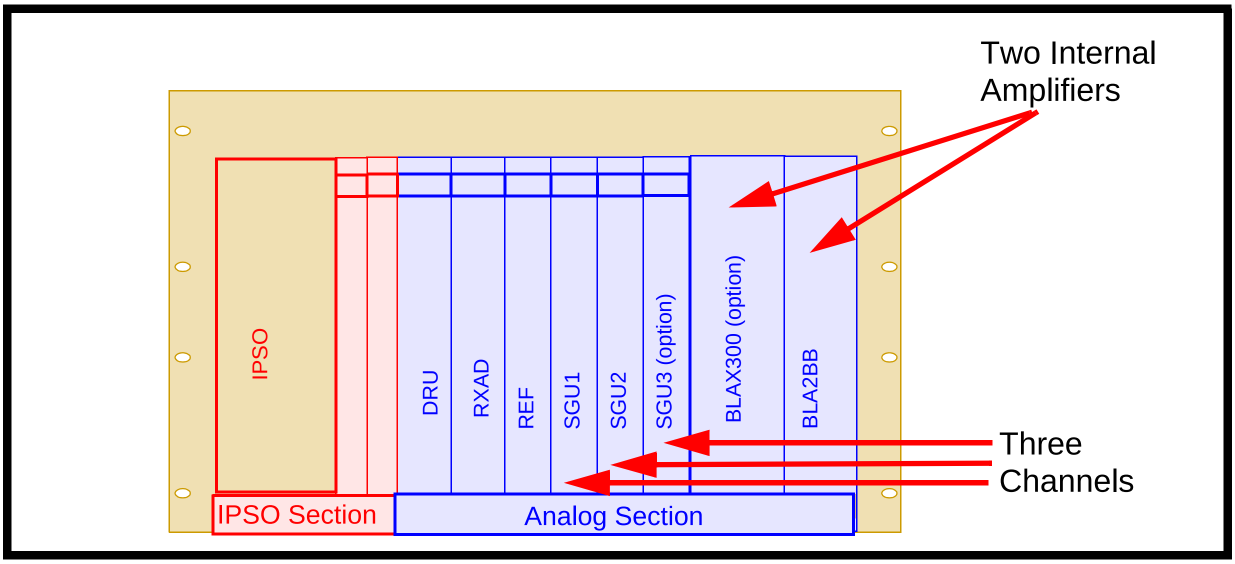


Figure 3.3. AQS/3 with Three Channels and Internal Amplifiers

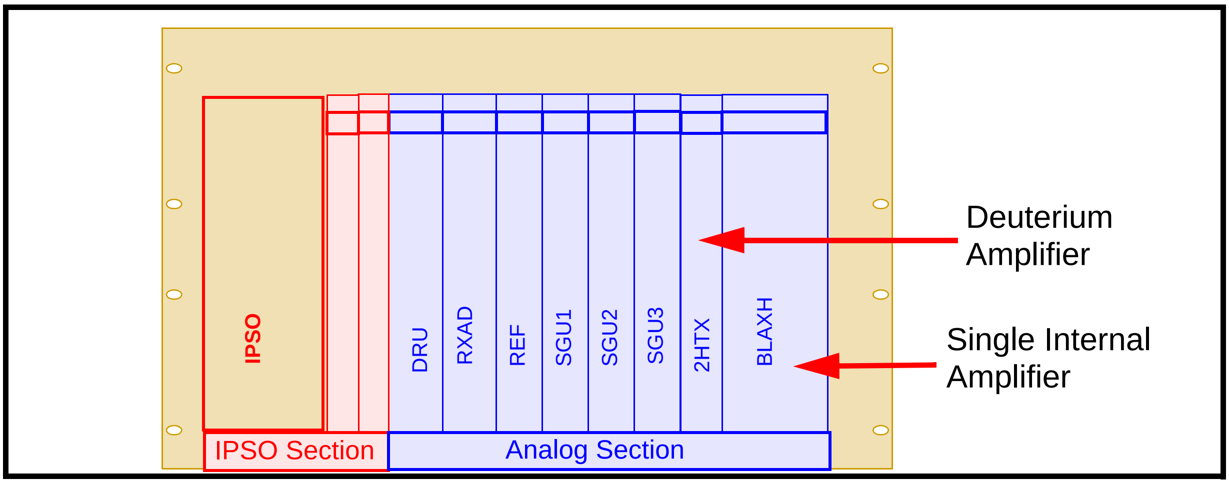


Figure 3.4. AQS/3 with Three Channels 2H-TX and Internal Amplifier

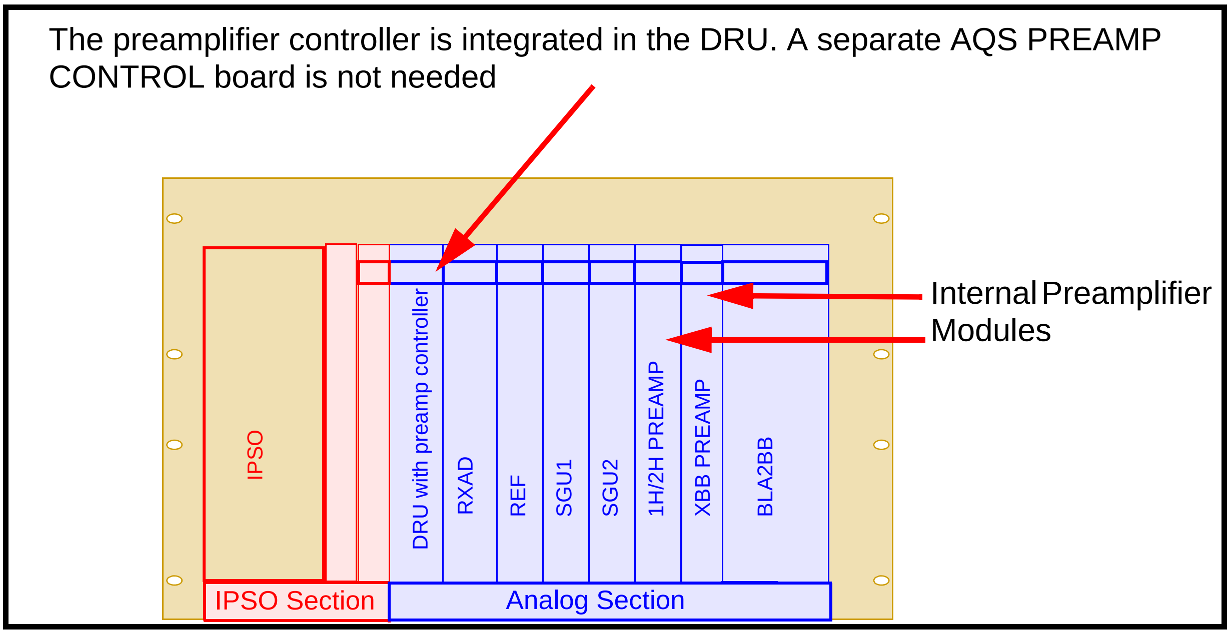


Figure 3.5. AQS/3 with 2 Channels, Internal Preamplifiers and Internal Amplifier

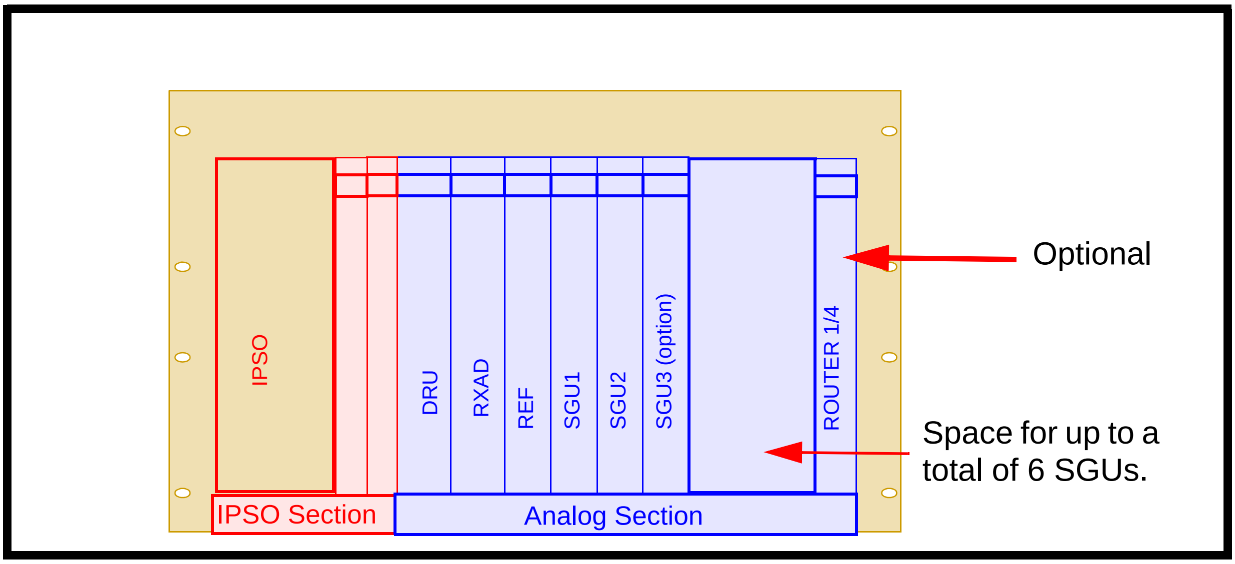


Figure 3.6. AQS/3 with Three Channels and External Amplifiers

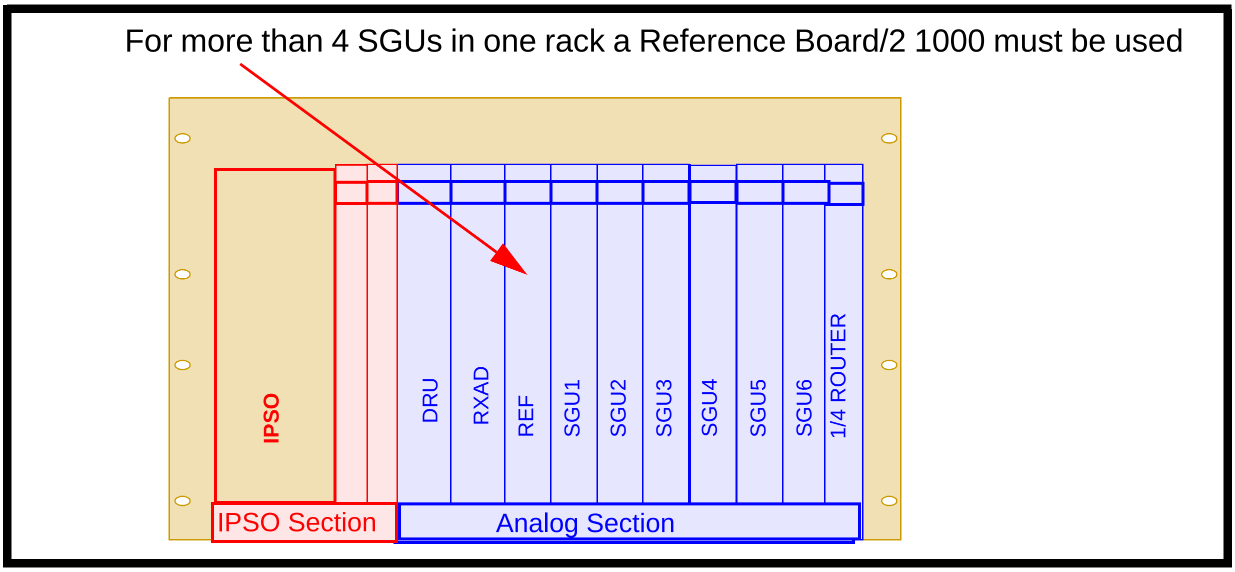


Figure 3.7. AQS/3 with Six Channels and External Amplifiers

Table 3.1. Maximum Number of Channels for Various Configurations

	Transmitters	Preamps	Optional ROUTER	AQS/3	Max channels	Limitation
AQS IPSO	internal	HPPR	no	one	3	Transmitters
	internal	internal	no	one	2	AQS
	external	HPPR	yes/no	one	4/4	IPSO
	external	internal	yes/no	one	4/4	IPSO
External IPSO	internal	HPPR	no	one	3	Transmitters
	internal	internal	no	one	2	AQS
	external	HPPR	yes/no	one	6/7	AQS
	external	internal	yes/no	one	4/5	AQS
	external	HPPR	yes/no	two	8/8	IPSO
	external	internal	yes/no	two	8/8	IPSO

The AQS is designed to house slot-in type units in an integrated rack system and contains much of the electronic hardware associated with the spectrometer. In fact it is often helpful to view an AVANCE spectrometer in terms of the:

- **AQS including IPSO** (performs most acquisition functions)
- **BSMS** system (controls the lock and shim system, sample lift and spin)
- **Amplifiers** (amplify the analog RF signals transmitted to the sample)
- **Preamplifiers** amplify the received signal

- **VTU:** (controls the sample temperature).

The IPSO and various units of the AQS prepare the signal to be transmitted and also receive, amplify and digitize the NMR signal emitted from the sample. Thus in the AQS will be found:

- One DRU, RXAD and REF unit
- A number of SGU/2s
- One Router (optional)
- One deuterium amplifier (optional)
- Internal amplifiers (in the case where there are no external amplifiers)
- Internal preamplifiers (in the case where there is no external HPPR)

Apart from physically housing these units the rear of the AQS rack also provides power supplies to the various units as well as electronic communication channels (aka buses). Once the NMR data is received and digitized, the information is transferred to the host computer for further processing and storage via the Ethernet link from the DRU. For more general communication the principal link with the host computer is via the Ethernet link from the IPSO itself. It is important to emphasize that the Acquisition System has total control over spectrometer operation within the duration of an experiment. This is to ensure uninterrupted operation and so guarantee the integrity of the acquisition.

The analog section of the AQS/3 has nominally 10 rear connectors to the backplane though the number of units that can be installed will depend on their physical width. The backplane connector pin assignment is identical for all ten slots. which means each common signal is accessible on every slot.The DRU acts as rack master to ensure that the transfer of signals and data along the common backplane is coordinated. (Exceptions to the identical pin assignment are the power supply to the internal amplifiers and the data transfer to the DRU via LVDS). Special connectors for the internal amplifiers can be clearly seen in ***Figure 3.9.*** As a result of this identical pin assignment there are various configurations possible depending on the number of racks, whether internal or external amplifiers and preamplifiers are used, whether a ROUTER or internal deuterium amplifier is fitted etc. As a general rule starting from the left the unit order is: DRU, RXAD, REF, bank of SGUs, Internal preamplifiers, internal amplifiers or ROUTER(s) (see ***Figure 3.2.***). Although some of these slot positions are interchangeable it has been decided to follow the general rule as stated above in all installations.

A typical uxnmr.info display is shown in ***Figure 3.8.*** Starting from slot 0 the RXAD, REF, a bank of SGU/2s and a ROUTER are clearly displayed.Note that the DRU which is master of the AQS is listed separately above the other units.

The rear of the rack is primarily designed for power supplies, both digital, analog and specialized power units for internal amplifiers.The rear also houses the PSD3 (Power Supply Distribution) unit.

Switching the Unit On and Off 3.3.1

The AQS is normally left switched on permanently. Integrated fans ensure that the various units are constantly cooled. The on/off switch is located at the upper front

```
DRU1: AQS DRU Z100977/00206 ECL 02.00
- TCP/IP address = 149.236.99.89
- Firmware Version = 60609
- DRU controls AQS-Rack and HPPR/2

AQS-Rack: connected to 149.236.99.89:/dev/tty10
  _Slot_ SBSB _____________________Board_____________________
  Number Addr Type HW-VS FW-VS ID  ECL Name   Description
  ----------------------------------------------------------
     0   0x10 0x42   0x2    AO  R  1.1 REC-1  AQS RXAD600 Z102117/96 ECL 1.1
     1   0x34 0xc0   0x1        X  0.4 REF-1  REF-600 Reference Board for AQS
     2   0x24 0x29   0x8    A$  S  1.0 SGU-1  AQS SGU/2 1000 Z103082/00092 EC
     3   0x25 0x29   0x8    A$  S  0.0 SGU-2  AQS SGU/2 1000 Z103082/00027 EC
     4   0x26 0x29   0x8    A$  S  0.0 SGU-3  AQS SGU/2 1000 Z103082/00024 EC
     5   0x27 0x29   0x8    A$  S  0.0 SGU-4  AQS SGU/2 1000 Z103082/00029 EC
     6   0x3c 0xc5   0x1        Y  0.0 ROUT-1 AQS Router 1/4
     7   0x21 0xcf     0        P  0.0 PSD-1
     8   0x20  0x7     0        B      MASTER AQS Rack Master

Router: 1 AQS Router 1/4
```

Figure 3.8. Extract from uxnmr.info file

left corner of the rack see ***Figure 3.9.***. None of the individual units have separate on/off switches and will automatically be switched on or off by the AQS mains.

In the event of an AC power loss to the spectrometer cabinet, the rack turns itself off and restarts automatically when the power is restored. To prevent a short time power outage an external UPS (uninterruptable power supply) must be fitted as extra.

Safety Stop Indicator

The temperature inside the AQS rack is constantly monitored. Should this temperature exceed the set limit then as a safety precaution the power supply to the rack will be shut off (without warning) and the Safety Stop indicator will light. The operator should establish the cause of the overheating before resetting the switch. A reset can be done by switching the mains off and on. Possible sources of overheating are

- failure of the cooling fans
- too high an ambient room temperature or lack of sufficient air supply to the fans.

The operation of all fans is individually controlled by the AQS controller (the DRU) and the fan status can be checked on the chassis page in the DRU service web (see ***Figure 3.11.***).

Tips 'n' Tricks/Basic Troubleshooting 3.4

The AQS is not suitable for service in the field. Individual units should be removed or swapped by service personnel only. While it is possible to view some front panel signals on an oscilloscope there is little scope for any troubleshooting, particu-

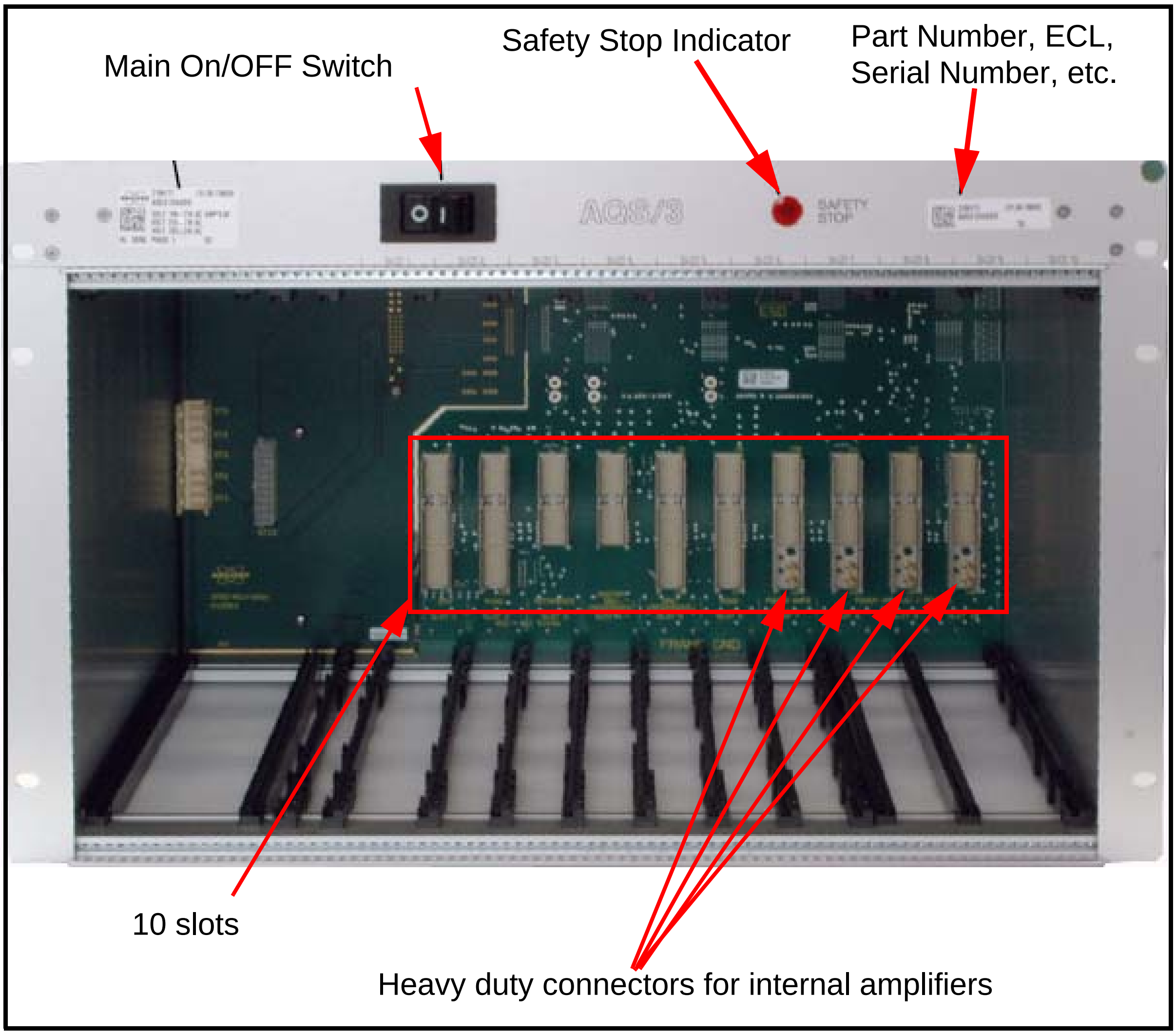


Figure 3.9. AQS/3 Rack. Front View with all Boards Removed

larly with respect to the range of digital signals that use the AQS backplane. In case of error

- Check that the uxnmr.info entries (see ***Figure 3.8.***) correspond to the specific spectrometer configuration.
- Check that cables on the front panels have not become loose or removed.
- Check that 'power on' indicator LEDs on the various front panels are lit.
- If power LEDs on the various front panels are not lit then the LEDs on the power supplies at the rear of the AQS (see ***Figure 3.10.***)should also be checked.
- The length of external cable connections between the various units which carry analog signals are usually kept as short as possible to minimize interference. If a cable is to be replaced it is important to replace it with one of the same length to ensure that no additional phase shifts are introduced.
- As the DRU is the rack master the DRU Service Web is used to access the AQS/3.

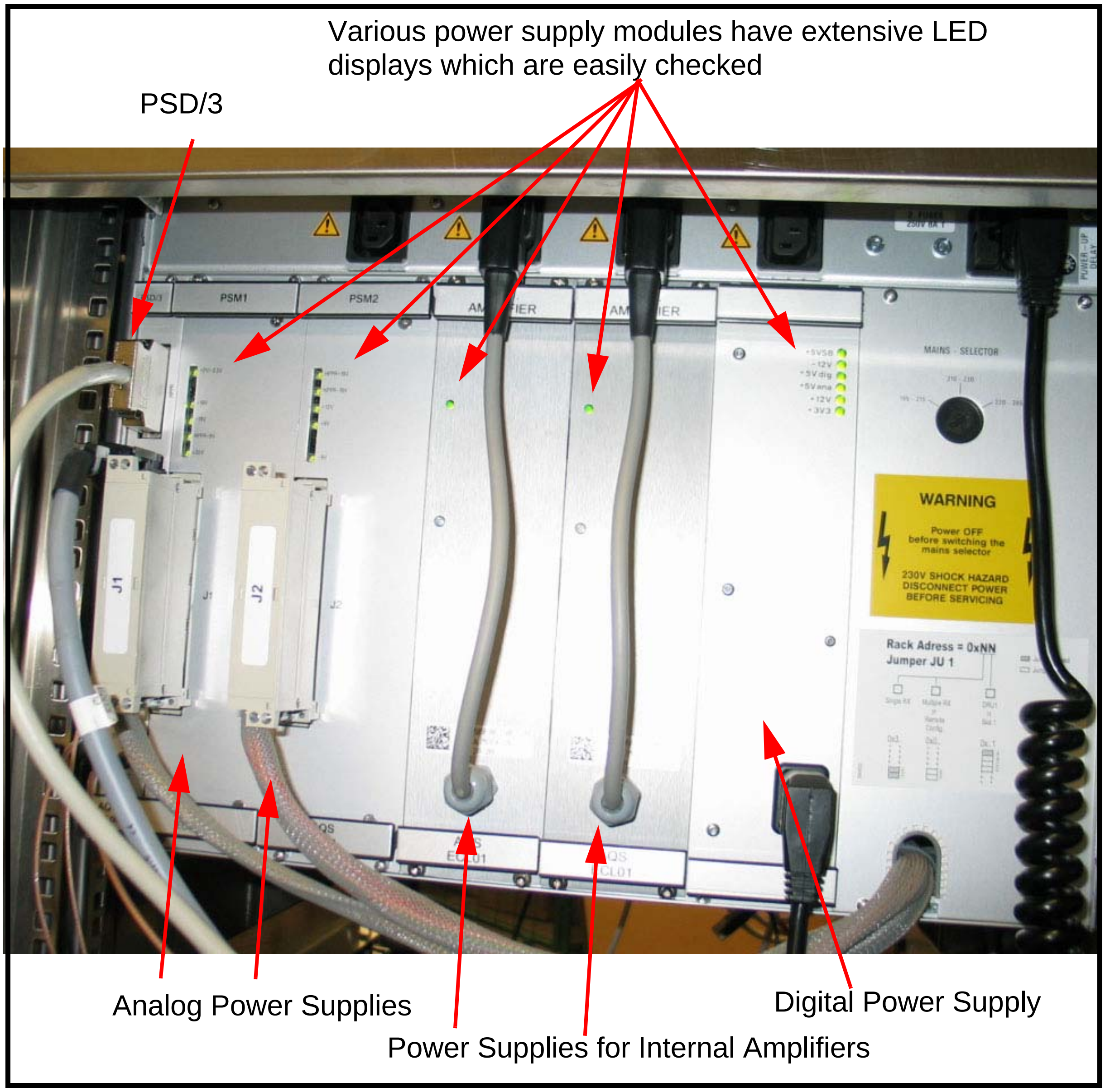


Figure 3.10. Rear View of AQS3

Serial Number / ECL Level / Software Download 3.5

Although individual units within the AQS may require software downloads the AQS rack itself does not. For the location of the ECL level and serial number see ***Figure 3.9.***.

Other Required Signals/Units 3.6

If there is a problem with the AQS there are hardly any spectrometer functions that will be unaffected such is its central role. The AQS rack itself is relatively stan-

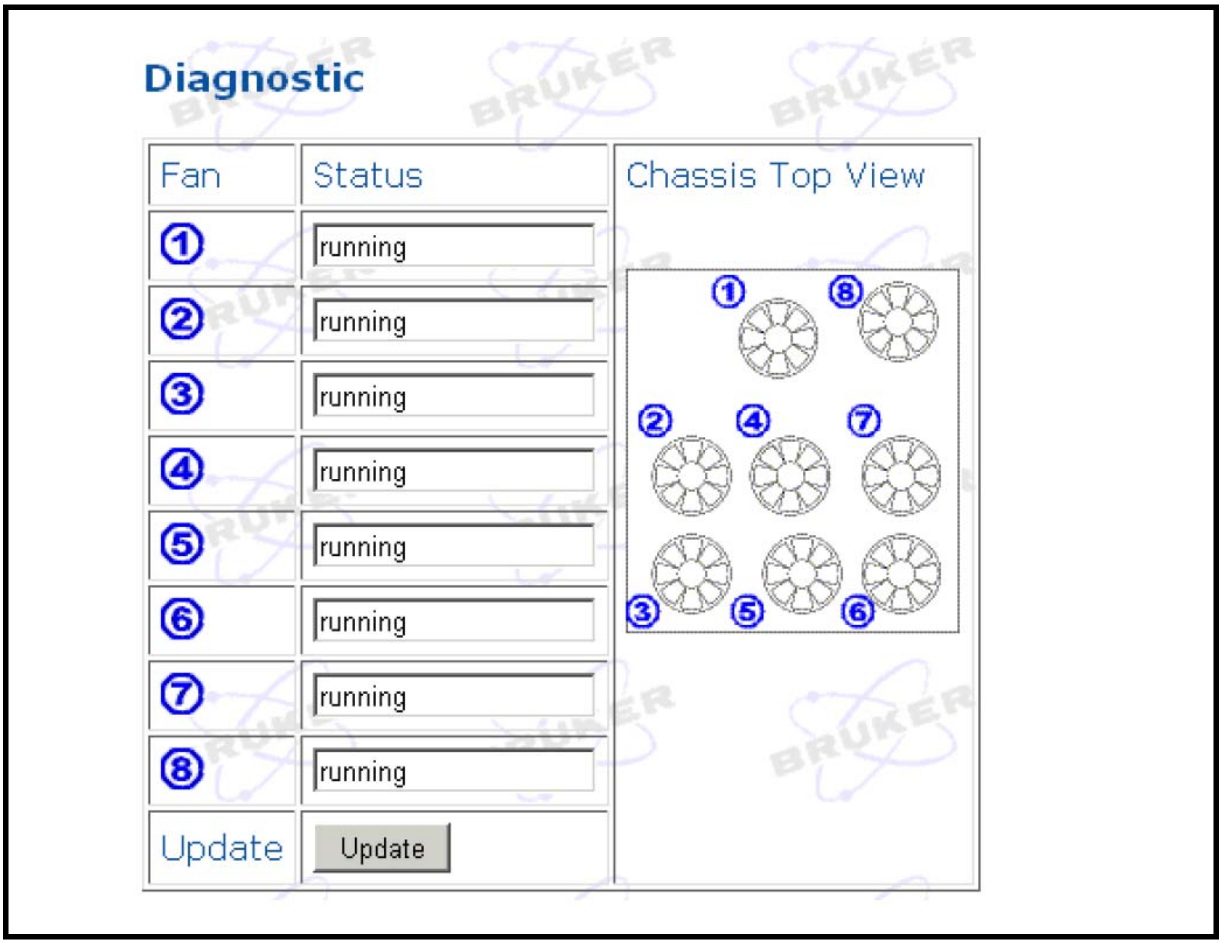


Figure 3.11. Extract from DRU Service Web: AQS Chassis Diagnostic Showing all 8 Fans Running

dalone though the Ethernet connections between the DRU and IPSO to the host workstation must be working for the system to boot.

Option or Core Item 3.7

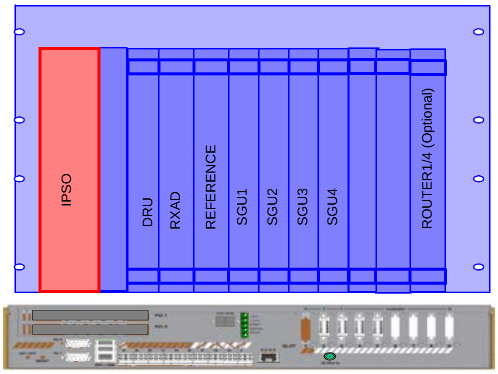
Every system will be fitted with one rack.There is the option to have more than one rack fitted for multi-receiving systems. Each rack will then have its own DRU as master.

Further Information 3.8

For information on the AQS/3 see the manual entitled AQS for IPSO systems (TM) P/N Z31717. Readers should note that this manual also describes some of the newer AQS individual units including the RXAD (Chapter 6) as well as the DRU (Chapter 7).

IPSO 4

Introduction 4.1



Precise timing control has always been a critical feature of NMR spectroscopy, not only in terms of the excitation of the sample but also the receiving of the emitted signals. Here are just a few very simple examples to illustrate where timing control is critical:

- Consider the critical timing in terms of switching off the excitation signal and opening the receiver. If the receiver is opened too early then it may be swamped by the excitation signal. However if it is not opened early enough then sensitivity will be lost.
- Modern excitation sequences involve complicated sequences on multiple channels which must be implemented accurately wrt timing as well as frequency, phase and amplitude. Furthermore the various RF channels must be able to operate independently as well as remaining synchronized with each other.
- Repeatability of experiments can only be guaranteed if timing is accurately controlled and reproducible.
- Digitalization of the received analog signal is carried out in terms of a sample and hold operation whose timing is always at the maximum allowed rate (regardless of the sweep width.) With the advances in oversampling, 'on the fly' processing and digital filtering, the timing is even more critical.

The ability to make **meaningful** real-time decisions on the basis of acquired data processed on the fly can only be supported when the timing control is not only accurate but also can be adjusted almost instantaneously.

All of the above place increasing demands on the processing power capability of the spectrometer.

To improve timing control as well as processing capability, the design philosophy of the IPSO spectrometers has been to implement the control of all timing-critical pulses on a single chip, often referred to as the sequencer. This sequencer lies at the heart of the IPSO in that each IPSO board has immediate access to this chip. (The R-Controller does not normally use the sequencer though it does have access to it.) Furthermore processing capability is enhanced because the implementation of the pulse sequences is much more efficient using the new simplified architecture.

The IPSO (**Intelligent Pulse Sequence Organizer)** unit is a very significant development and is effectively the most distinguishing feature of the newest AVANCE III spectrometer range. The IPSO has replaced almost all digital boards

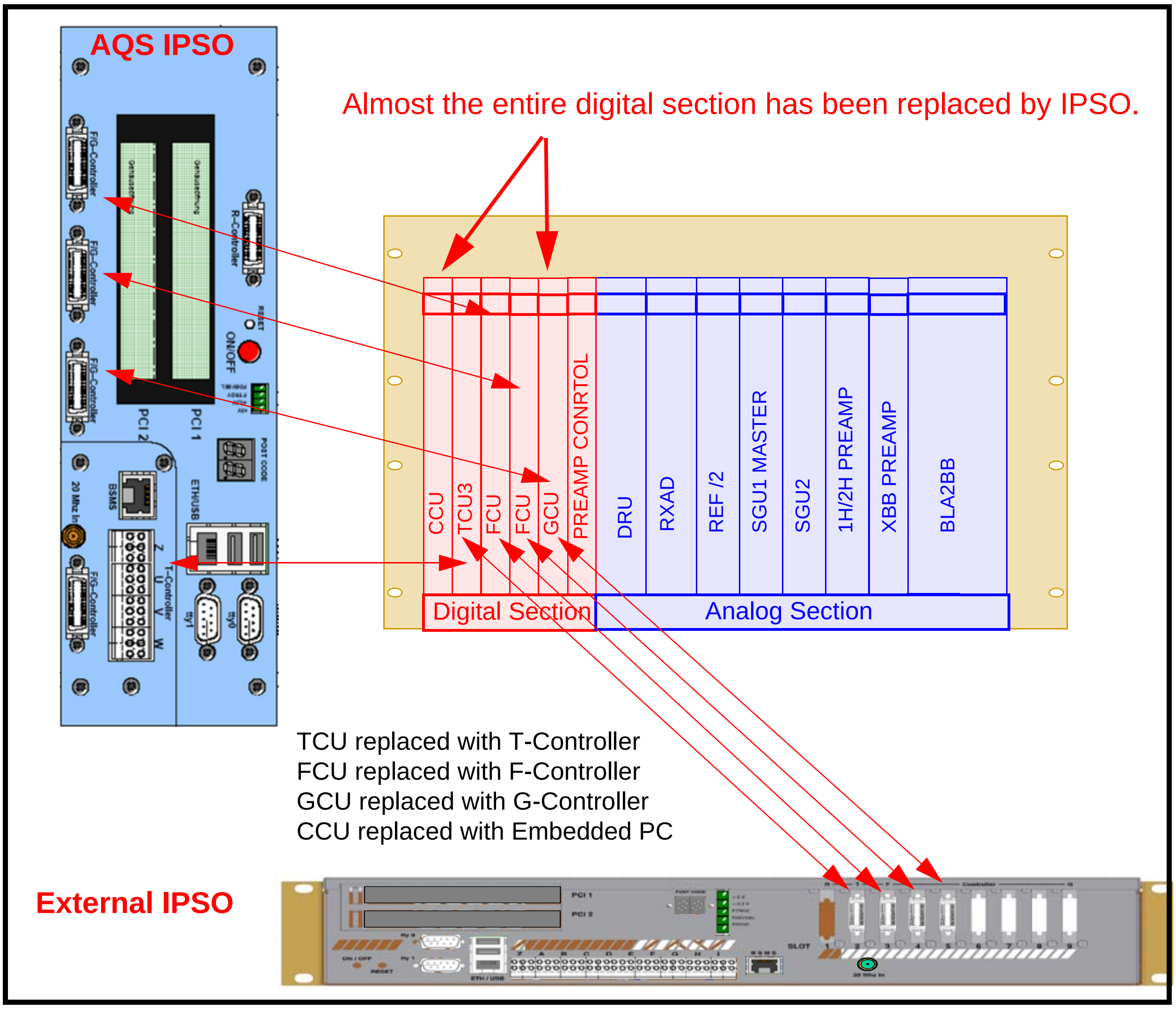
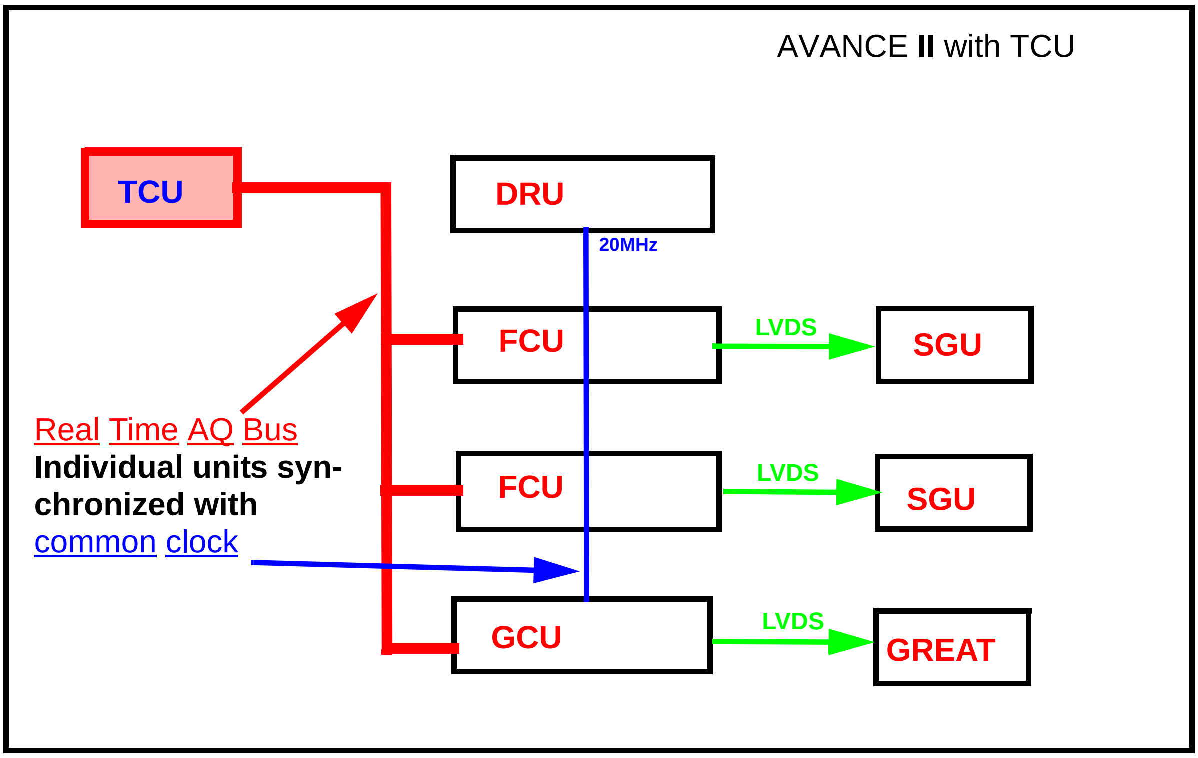


Figure 4.1. Schematic Displaying the Equivalency of Boards in the IPSO to the Previous AQS Generation Boards (not to scale).

in the AQS (see ***Figure 4.1.***) The CCU, TCU, FCU, GCU found in the previous generation of spectrometer have been replaced by a single IPSO unit (albeit in two possible configurations). Although this has obvious benefits in terms of space, as well as cost savings due to uniformity of production, the principal driver has been improved performance. In particular the timing control which was previously carried out principally by the TCU has been improved (details later). Furthermore as customer requirements increase, in terms of evermore exotic pulse sequences, the additional processing power delivered by the IPSO is a significant improvement.

A key aspect of timing control in AVANCE spectrometers is to ensure that up to eight independent RF channels are precisely synchronized. In its simplest form timing control reduces to ensuring that a series of pulses of precise duration is generated in the correct order and delivered to the appropriate destination at the right time.This is often referred to as sequencing. Clearly the correct sequencing of these pulses is critical so that each channel and each unit remain precisely synchronized. Previously this was achieved by assigning timing control to the TCU which was then used to control separate units such as the FCU and GCU. However no matter how well the various units were synchronized there is always the



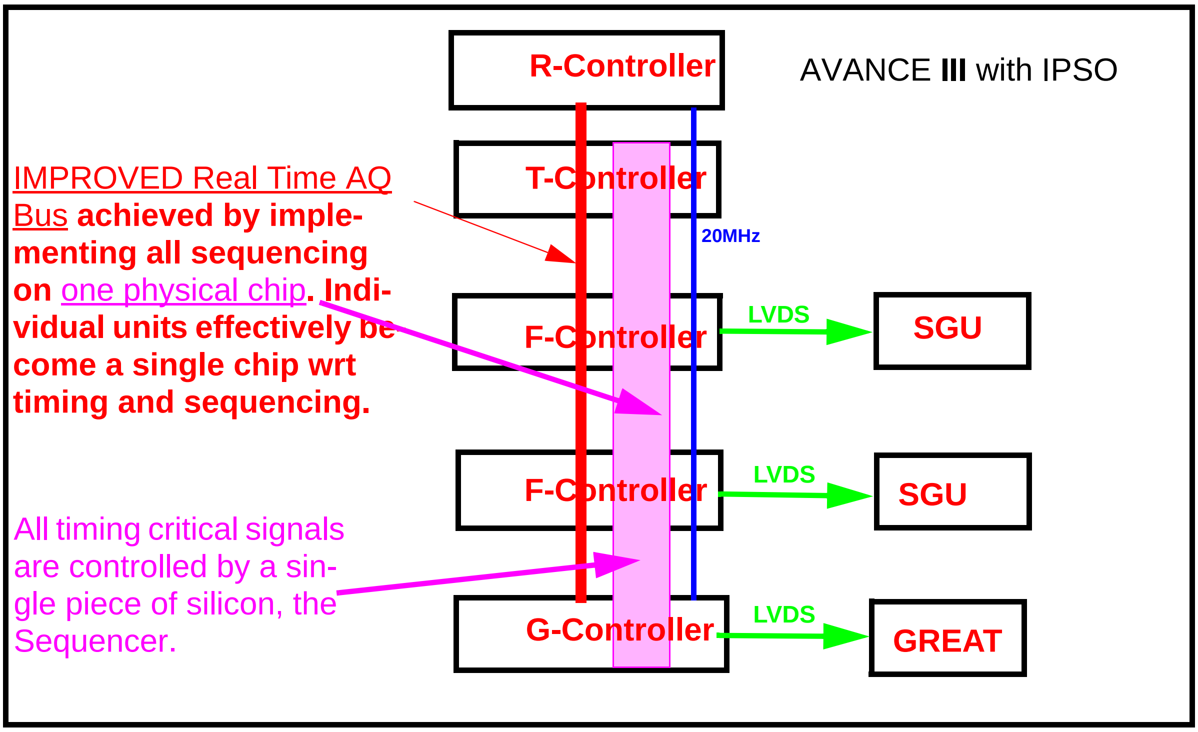


Figure 4.2. Simplified Schematic Comparing Architecture of AVANCE II with TCU and the Newer AVANCE III with IPSO

possibility of drift (however small) between individual units. The IPSO design has enabled all the sequencing to take place on a **single semiconductor chip**. This effectively ensures even more precise timing control since the possibility of drift between two separate units has now been replaced by the much smaller possibility of drift between two different locations on the same chip. To put the timing control into context, the reader should bear in mind that the shortest timing durations possible are now 25ns and so we are in the realm of trying to eliminate incredibly small variations. As mentioned earlier the processing requirements to generate any particular sequence has been reduced with the simplified architecture resulting in enhanced performance in terms of capability and speed. Whereas previously the TCU had to effectively share its processing capability among the various channels, the new simplified architecture means that each channel has dedicated processing space on the chip and the various sequences are enacted with equal efficiency irrespective of whether only one or all eight channels are active at any given moment in time. Put most simply the new IPSO is faster, more precise and has greater capability than previous generations. ***Figure 4.2.*** is an attempt to represent these concepts and in particular the new simplified architecture. Finally even at this introductory stage it is worth emphasizing another aspect of the new approach, namely that the same individual IPSO hardware board can be configured to perform different tasks. Previously there were several **different** hardware units (TCU,FCU,GCU etc.) each designed specifically to perform specialized functions.The IPSO approach uses application software to utilise the same hardware board for different tasks. As shown in ***Figure 4.3.***, depending on the application software, the same hardware board (the Tx-controller) can acts as either a T-Controller, an F-Controller or a G-Controller. This has obvious benefits in terms of unit cost production as well as flexibility in terms of spectrometer configuration.

There are three principal types of boards in the IPSO (see ***Figure 4.3.***).

- **One Embedded PC** which takes care of general (non timing-critical) communication.
- **A number of Tx–Controllers**. Each Tx–Controller is physically identical. The same hardware is configured to perform different functions as described above.

A Tx–Controller configured to provide RCP outputs is referred to as a T-Controller

A Tx–Controller configured to control an SGU is referred to as an F-Controller

A Tx–Controller configured to control a gradient amplifier is referred to as a G-Controller

- **One (optional) R-Controller** which receives data from the DRU.

Note that the R-Controller, though not identical, is very similar to a Tx–Controller with the LVDS transmitter replaced by an LVDS receiver

Location and Photograph 4.2

The IPSO has two configurations.

The AQS IPSO occupies the left hand (digital) section of the AQS/3 as in ***Figure 3.1.***.

The external IPSO is located beneath the AQS as in ***Figure 2.2.***.

General Information, Configuration and Function 4.3

The next section will discuss the various boards within the IPSO unit. As you read this It may help the reader to refer to ***Table 4.1.*** which is a summary of the various

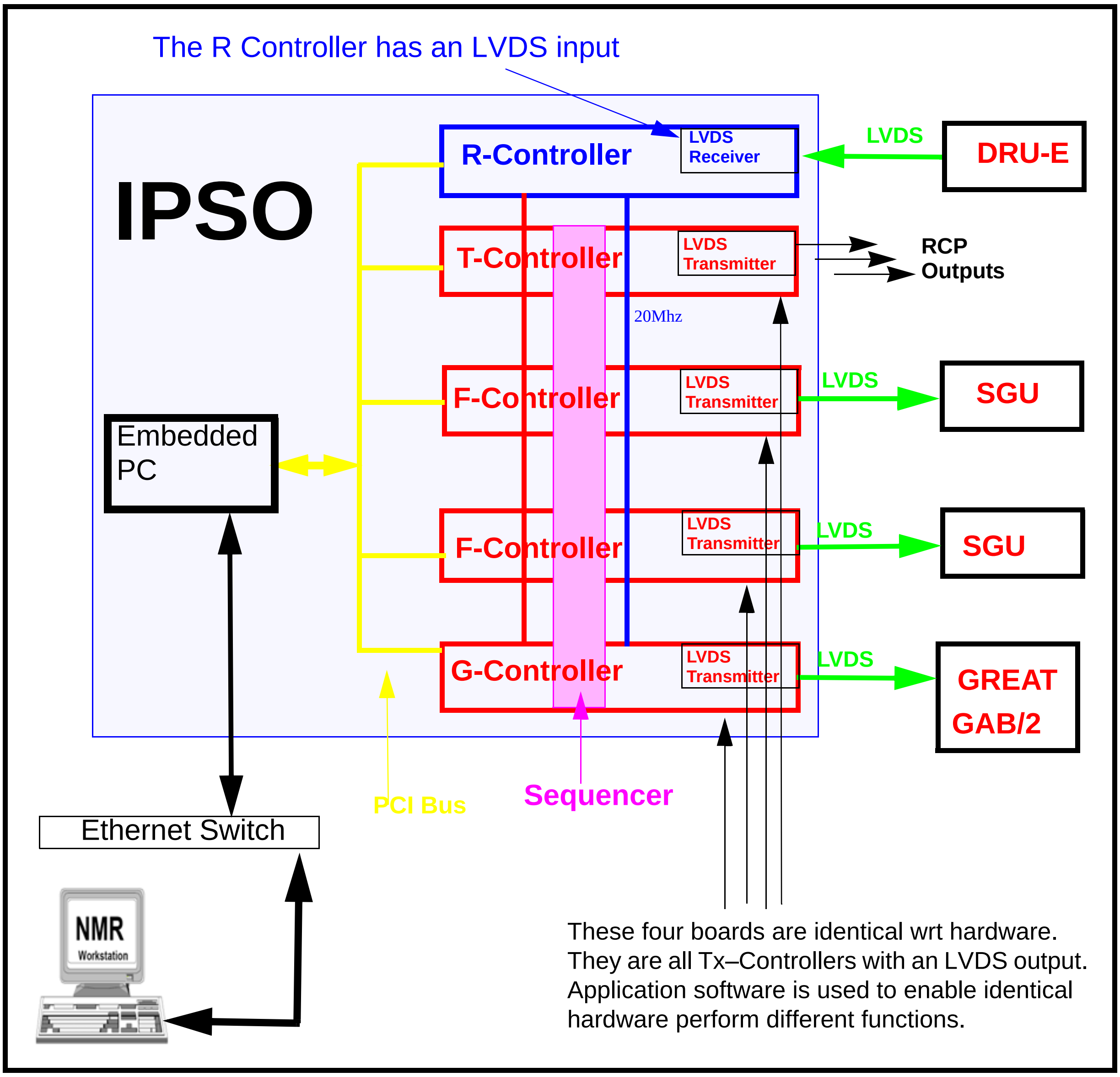


Figure 4.3. Overview of Principal IPSO Units.

boards.The boards to be discussed will be the Embedded PC, T-Controller, F-Controller, G-Controller and R-Controller.

Table 4.1. Summary of IPSO Boards

Board	Number	Board Type	Replaces	Principal function
Embedded PC	One per system	Unique	CCU	General communication
T-Controller	One per system	Tx-Controller	TCU	Generates RCP outputs
F-Controller	One per SGU/2	Tx-Controller	FCU	Controls SGU
G-Controller	One per gradient unit	Tx-Controller	GCU	Controls gradient unit
R-Controller	One per system. Optional extra	Unique (Modified Tx-Controller)		Facilitates real time ‘on the fly’ processing of acquired data.

Embedded PC 4.3.1

The function of the Embedded (IBM compatible) PC is to provide general communication between the various IPSO units as well as with the host workstation (via the Ethernet switch). Communication internal to the IPSO is achieved over a standard PCI bus which is used for **non** timing-critical signals. (The Embedded PC has no connection with the sequencer).

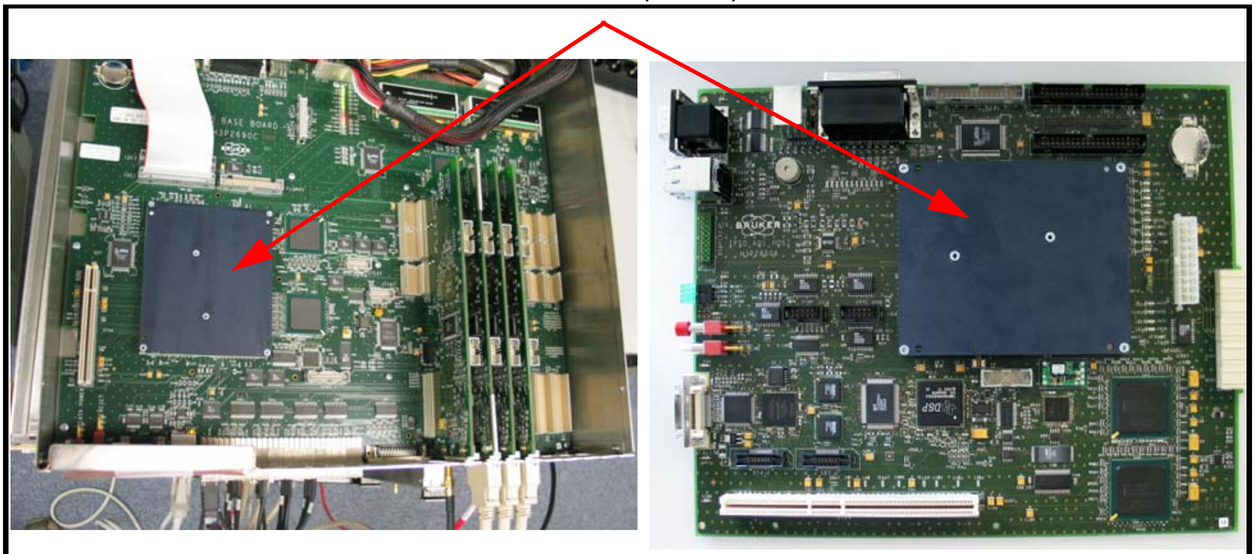


Figure 4.4. Internal View of 19” IPSO (left) and AQS IPSO (right). The Embedded PCs are clearly marked

The Embedded PC is used to transfer information that is required **prior to the start of the acquisition** via the PCI bus. Once an acquisition has started however, the sequencer bus would be used for timing-critical data. As an example, timing-critical data on the transmission side, such as the transfer of sequences in real-time from the F-Controller to the SGU via the LVDS is still controlled ultimately by the Sequencer. On the receiving side timing critical operations such as ‘on the fly’ processing of acquired data is controlled by the R-Controller or DRU.

Typical functions of the Embedded PC are:

- **Internal** communication with the various IPSO boards via the standard PCI bus.This link is shown in yellow in ***Figure 4.5.*** One typical example would be to establish the type and number of IPSO boards installed using the ‘cf’ routine. Note also that this bus is also used to configure each board as either a T, F, G or R controller upon initial spectrometer startup.
- **External** communication via the Ethernet link to the workstation. This link is effectively the means by which the commands entered at the operator desk are transmitted to the IPSO. All acquisition parameters as well as pulse program information are transmitted via the Ethernet link to the Embedded PC and then to the DSP chip on the various controllers via the PCI bus. The physical link is achieved by means of the Ethernet cable entering the IPSO front panel from the Ethernet switch.
- Control of 2 x RS232 links. These two links are labelled tty00 and tty01on the front panel. tty00 is a dedicated link to the NMR workstation and tty01 is used to communicate with external units such as the temperature unit (VTU), pneumatic unit etc. This enables these units to be operated from the operator desk.

- Control of 2 x USB links. These are typically unused in current configurations.
- Control of 2 x PCI slots.To physically increase the space use can be made of an RS232 extension unit for controlling additional external units. Alternatively the PCI slot can house a DPP unit which is used to calculate the digital pre emphasis for either a GREAT (gradient amplifier) or a GAB/2

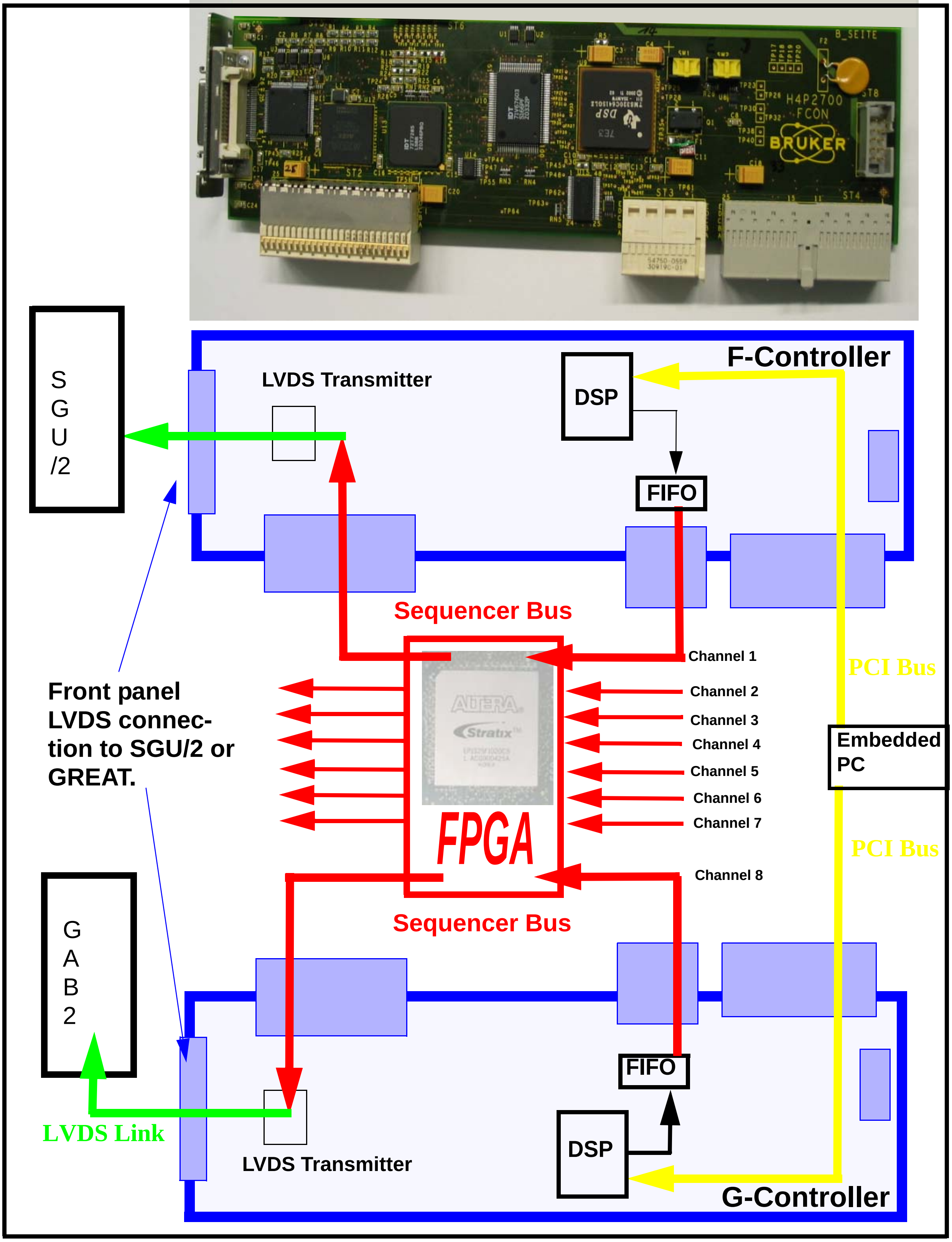


Figure 4.5. *Schematic of principal IPSO board signal paths showing two channels in detail. Top shows photo of board to same scale as schematic. Note that the entire timing control or 8 channels is achieved on the FPGA which is a single chip.*

The Embedded PC performs no on-board data manipulation processing or computation. Although it has an Ethernet link to the NMR workstation it is bypassed when acquisition data is to be transmitted to the workstation. This data is transferred directly from the DRU via its own dedicated Ethernet link.

The Embedded PC boots from the TOPSPIN–PC via the Ethernet link. Powering on or resetting the IPSO will automatically cause it to boot. In terms of equivalent units in earlier generation spectrometers the Embedded PC is most like the CCU.

Tips 'n' Tricks/Basic Troubleshooting the Embedded PC *4.3.2*

If the Embedded PC hangs then it may be necessary to initiate a reset. A reset can be effected in several ways. Hardware resets can be implemented

1. by pressing the red (on/off) button on the front panel
2. by hitting the reset button on the front panel

Software resets can be implemented by

1. activating Linux commands such as 'power off', 'reboot' and 'halt' from within a kermit shell
2. rebooting from within the IPSO service web page

The re-booting after a reset can be most easily observed by clicking on the Hyperterminal icon (Windows systems) or use the 'CU' command (Linux systems). Note that the re-booting can only be observed if the tty00 connection is present.

Other Required Signals / Units *4.3.3*

The Embedded PC plays such an important role in spectrometer operation that should it fail most other functions will crash.

The unit itself requires power from the internal IPSO power supply as well as a functioning Ethernet link to the host workstation in order to boot.

T –Controller *4.3.4*

A T-Controller (Timing Controller) is effectively a Tx-Controller with specific application software.

- There is one and only one T-Controller in each IPSO spectrometer.
- A single T-Controller is designed to provide the required signals for a spectrometer with up to 7 RF channels. (assuming an R-Controller is fitted)
- The board position (see ***Figure 4.9.***) is fixed regardless of the individual spectrometer configuration, number of channels etc. Indeed it is the board position that designates a Tx-Controller as a T-Controller.
- There is no distinction in hardware between the T-Controller board of a AQS IPSO and the T-Controller board of an external IPSO

Put most simply the T-Controller delivers a series of synchronous timing pulse sequences with very high resolution and accuracy which are used throughout the spectrometer to control various functions and a wide range of units. These signal are referred to as RCP (Real-time Clock Pulse) outputs. All the T-Controller RCP outputs are TTL active low signals.

The introduction to this chapter described the importance of accurately controlling the timing of signals in NMR and how the IPSO spectrometer design achieves this using a single sequencer chip.The T-Controller is responsible for generating a series of precisely controlled signals and relaying these to the sequencer. ***Figure 4.5.*** shows this principle except that it is drawn for to the F-Controller and G-Controller. The operating principle is the same for the T-Controller except that instead of a single destination such as an SGU or GAB the T-Controller delivers signals to a number of destinations.

To understand the role played by the T-Controller it is perhaps useful to view the spectrometer operation as follows:

- The F-Controller delivers the pulse sequences required by the SGUs.
- The G-Controller delivers the pulse sequences required by the Gradient units.
- The OBS SGU (under the control of the F-Controller) delivers the pulses required by the RXAD and DRU.
- The T-Controller delivers almost all other timing critical signals and in particular those required for controlling many external devices through the RCP outputs.

It is worth repeating that the T-Controller has identical hardware to an F-Controller or G-Controller, it is simple configured differently using the appropriate application software. Thus in terms of performance, which will now be discussed, all controllers have identical capabilities.

Generally the performance of the T-Controller can be viewed in terms of how precisely it can control the timing of various events (timing resolution) as well as how many events it can control (number of outputs). Needless to say synchronization requires that all other interacting units are clocked with a common signal. In the case of the AVANCE III system this is achieved using a single 20 MHz signal originating on the REF unit. The connection of the signal can be clearly seen on the front panels (see ***Figure 4.12.*** and ***Figure 4.14.*** where it is labelled REF signal input).

Based on information received from the Embedded PC (which in turn depends on commands entered by the operator) the T-Controller interprets the pulse program requirements and converts them into a set of RCP outputs which control (in particular) various external devices.

RCP outputs External IPSO. Connectors Z/A/B/C/D/E/F/G/H/I 4.3.5

In total there are 60 signals (10 connectors x 6 pins) accessible at the front panel (see ***Figure 4.12.***) of the external IPSO unit as well as a further 19 which are connected internally within the IPSO unit itself. Depending upon the spectrometer configuration many of the front panel outputs may be unconnected.The RCP signals are generated on the T-Controller (slot 2 only) and ported to connectors Z and connectors A to I on the IPSO front panel. One of the 10 connectors (connector Z) is reserved for emergency signals a well as a status line.You will notice that the LVDS connector of the T-Controller in slot 2 is blanked off to prevent the operator attaching the standard LVDS cable. This is because when a T-xController is configured as a T-Controller signals are not designed to be accessed at the LVDS connector.

The T-Controller signals can be subdivided as follows:

- RCP signals used to control devices such as external amplifiers, QNP Pneumatic Unit, BSMS etc. This type of output make up the bulk of the RCP signals.
- A further set of RCP outputs have no preassigned function and are thus user defined. The user can use these signals for whatever purpose they wish bearing in mind that they must be physically connected to the appropriate unit.(see ***4.3.7*** for information on how to program these outputs)
- Several reserved output RCP signals. These are typically reserved for future developments.
- Trigger inputs, of which there are four. These inputs are designed with specific external sources such as the MAS or BSMS units in mind. Typically they are used to synchronise an acquisition with externally generated pulses.
- Various stop/suspend inputs and outputs which are designed to halt an acquisition. These signals all use connector Z as mentioned earlier. This group also include the emergency stop signal which can be both an input or output. Typical use might be the generation of an emergency stop output which will halt all transmission by the SGU/2 and preamplifiers when for example a fault (such as excessive power) is detected.

While the RCP signals are generated by the T-Controller, they are all ported through the sequencer chip to ensure synchronization with all other IPSO boards. The sequencer can make adjustments as required.The digital signals are then retransmitted back through the T-Controller for transmission to the front panel connectors (see ***Figure 4.5.*** and simply substitute T-Controller for F-Controller and G-Controller).

RCP Outputs AQS IPSO. Connectors Z/U/V/W — *4.3.6*

The T-Controller of the AQS IPSO delivers a reduced set of RCP signals In total there are 24 signals (4 connectors x 6 pins) accessible at the front panel of the unit as well as a further 3 which are connected internally within the IPSO unit itself. One of the four connectors (connector Z) is reserved for emergency signals as well as a status line The programming, specifications etc. of the T-Controller of the AQS IPSO is identical to the T-Controller of the external IPSO unit, the only difference is the number of signals available. The AQS IPSO has a max of 4 channels and hence fewer RCP outputs are required.

RCP Output Specifications and Programming — *4.3.7*

As mentioned earlier the T-Controller outputs are TTL (active low) and one critical specification is the pulse rise and fall times.

TTL Pulse Rise Times: 5ns

TTL Pulse Fall Times: 4ns.

The reader is reminded that pulse lengths in modern NMR spectroscopy are normally of the order of microseconds whereas the IPSO performance is specified in terms of nanoseconds.

Minimum Duration: 25ns

This effectively means that bits (i.e signals) can be set high or low for a minimum duration of 25ns.

Timing Resolution: 12.5ns.

This resolution is set by the 80 MHz clocking frequency This clock is derived from the quadrupling of the REF 20 MHz (see ***Figure 16.2.***). Bits can thus be set high or low for durations of 25,37.5,50, 62.5, 75,87.5ns etc.

Table 4.2. contains a summary of some of the key specifications of the T-Controller compared with the TCU (Timing Control Unit) of previous spectrometer generations.

Table 4.2. Comparison of the T-Controller Specifications with TCU3

Parameter	AVANCE II with TCU3	AVANCE III with IPSO
Set any or all parameters (phase, amplitude, frequency)	phase 50ns, amplitude 50ns frequency 100ns all parameters 200ns	phase 25ns, amplitude 25ns frequency 25ns all parameters 25ns
LVDS Data format	28 bit words at a clock rate of 20 MHz. per word	48 bit words at a clock rate of 80 MHz. per word
Total number of RCP outputs: (available at front panel.	67	60 (external IPSO) 24 (AQS IPSO)
Minimum Duration:	50ns	25ns
Timing Resolution:	12.5ns	12.5ns
TTL Pulse Rise Times:	5ns	5ns
TTL Pulse Fall Times:	4ns	4ns

A detailed description of the full set of RCP signals is beyond the scope of this manual but a few typical examples of some of the more common signals that will hopefully have some meaning for the reader are given in the ***Table 4.3.*** The pin assignments have not been listed. It should also be noted that some of these signals will not be required (depending on the configuration) and so will be unconnected at the front panel.

The signals are normally set automatically from either the ‘edsp’, ‘edasp’ or ‘eda’ tables or from the pulse program itself. In this way they are not transparent to the operator. The T-Controller does however allow for the possibility of the operator programming various outputs and using them as precisely controlled switching signals. The operator is effectively free to use any free outputs for any customized purpose, but will need to write the commands explicitly into the pulse program for any non-standard functions.

Historically the signals are divided into NMRWords 0, 3 and 4. To explicitly program the various outputs the following syntax can be used within a pulse program

d11 setnmr4^3 = set NMRword 4 bit 3 high (inactive).

d11 setnmr4|3 = set NMRWord 4 bit 3 low (active)**.**

d11 is the switching time and can be set as low as 25ns (the minimum duration.)

.

Table 4.3. Example of Some typical RCP Signals.

Bruker name	Function	input/ output	Destination	NMRword/bit
SEL_! X/F	This signal controls the external switchbox accessory	output	1H/19F Amplifier	NMRword3/bit2
FXA, FXB	Two signal FXA and FXB allow up to 4 different QNP preamplifiers be chosen.	output	QNP	NMRword3/bit 8 and 9
Relay_1, Relay_2, Relay_3 and Relay_4	Three signals used to switch between high power and low power in high power amplifiers	output	High Power amplifiers	NMRword4/bit 7, 8, 9 and10
Lockhold	This temporarily suspends the lock system while gradient pulses are being applied.	output	BSMS	NMRword3/bit0
BLK_GRAD_X BLK_GRAD_Y BLK_GRAD_Z	Three signals used to blank gradient amplifiers. The amplifiers can only transmit while the blank pulse is low.	output	Gradient amplifier	NMRword0/bit 32,33 and 34

Tips 'n' Tricks/Basic Troubleshooting of the T-Controller 4.3.8

- Check the various tests on the IPSO service webpage see sec. ***4.5***
- To check that the T-Controller has been correctly identified use the 'ha' command and follow the procedure schematically represented in ***Figure 4.15.***. The presence of a T-Controller entry can be clearly seen. If there is no corresponding entry reconfigure the instrument. The same check can also be carried out using the TOPSPIN display 'uxnmr.info' which is shown during the 'cf' routine. see ***Figure 4.11.***
- Check the presence of the 20 MHz signal (1Vpp at 50 Ohms) from the REF unit.
- LVDS interfaces can be tested with the IPSOTEST if they are connected to an Rx–Controller. (service personnel only)
- Since the T-Controller is simply a Tx-Controller with specific application software if it is suspected that a T-Controller hardware is faulty then the board can be swapped using the following procedure.

1. Switch off the IPSO unit.
2. Remove the T-Controller and replace it with the board from the last occupied slot. (Rightmost on external IPSO, lowermost on AQS IPSO)
3. Switch on and reconfigure.
4. Check that the new board has been recognized with the 'ha' command.

The main function of the Frequency Controller (F-Controller) is to generate and transmit digital pulse sequences to be used by the SGU/2 to generate the RF signals that will ultimately be transmitted to the NMR sample. The signal delivered to the SGU/2 from the F-Controller contains all the required information with respect to frequency, amplitude, phase etc. As well as rectangular pulses the details of shaped pulses, CPD sequences, phase programs etc. must also be defined. The F-Controller output is in effect the digital version of the analog RF signal and the SGU/2 can in that respect be viewed as an extremely sophisticated DAC. Needless to say the digital sequences must not only possess the right information, they must also be delivered at precisely the correct time. This is ensured by the F-Controller having direct access to the sequencer chip. Although the F-Controller prepares the sequence based on information received from the Embedded PC, the information is ported through the sequencer where ultimate control of synchronization resides. The digital sequence is then retransmitted back through the F-Controller for transmission to the SGU/2. This data chain is depicted in ***Figure 4.6.***.

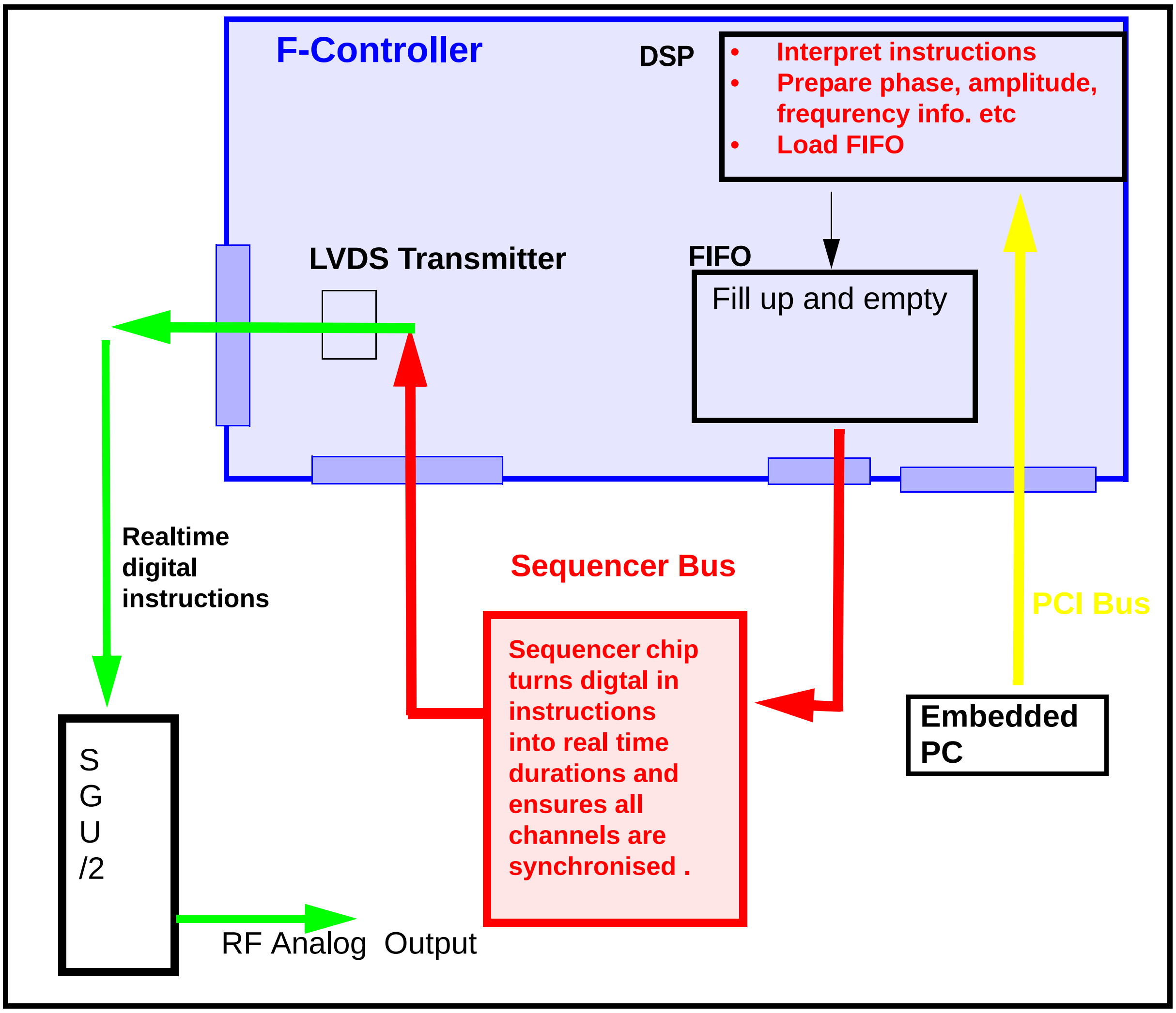


Figure 4.6. Schematic of Principal Data Flow in F-Controller Operation.

Each F-Controller will control one SGU/2.The standard configuration is that the number of F-Controllers will equal the number of SGU/2s. This is in contrast to earlier spectrometers where a single FCU would cater for multiple SGUs. As already described the application software loaded onto a Tx-Controller during start-up of the spectrometer determines the specific use of the board as T-, F- or G-Controller. In the case of the F-Controller detection of the right application firmware is achieved by detecting the presence of the LVDS connection to an SGU/2. Switching an LVDS cable from an SGU/2 to a GREAT, for example, will transform the respective F-Controller into a G-Controller after the next IPSO reset.

The number of F-Controllers present in a particular system is automatically made known to the software during the 'cf' routine and can easily be checked in the edsp/edasp window where each channel is individually displayed (see ***Figure 4.7.***). It can also be checked using the "ha" command from within TOPSPIN. see ***Figure 4.15.*** The same check can also be carried out using the TOPSPIN window ('uxnmr.info') which is displayed during the 'cf' routine. see ***Figure 4.11.***

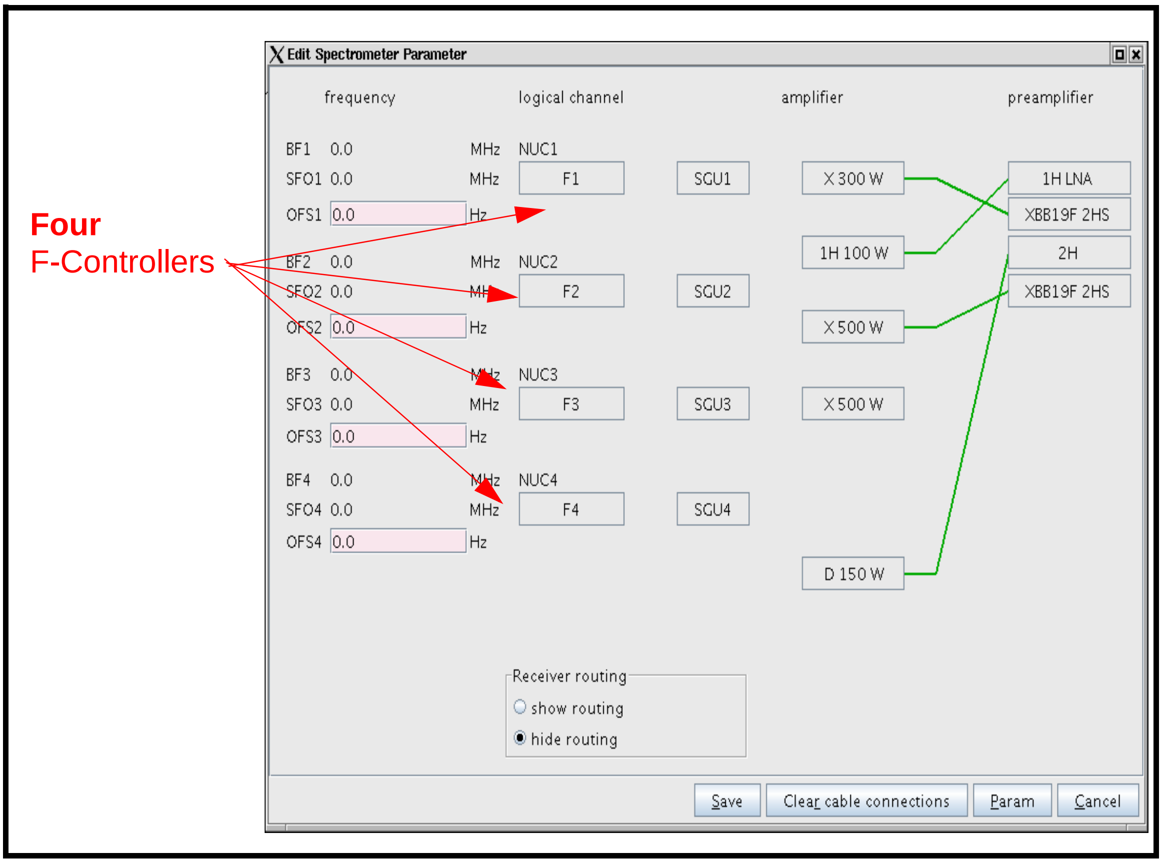


Figure 4.7. EDSP/EDASP Window will clearly show all Recognized F-Controllers

All F-Controllers are physically and electronically identical and must be inserted into slot # 3-9 of the external IPSO.

- The external IPSO can accommodate a max. of 7 F-Controllers.
- The AQS IPSO can accommodate a max. of 4 F-Controllers.

Some sample configurations are shown in ***Figure 4.8.*** and ***Figure 4.9.***. Note that every AQS IPSO will be fitted with 4 Tx-Controllers as standard. The type and number of channels will depend on whether each board is connected and whether it is connected to an SGU/2 (F-Controller) or gradient unit (G-Controller) see ***Figure 4.8.***

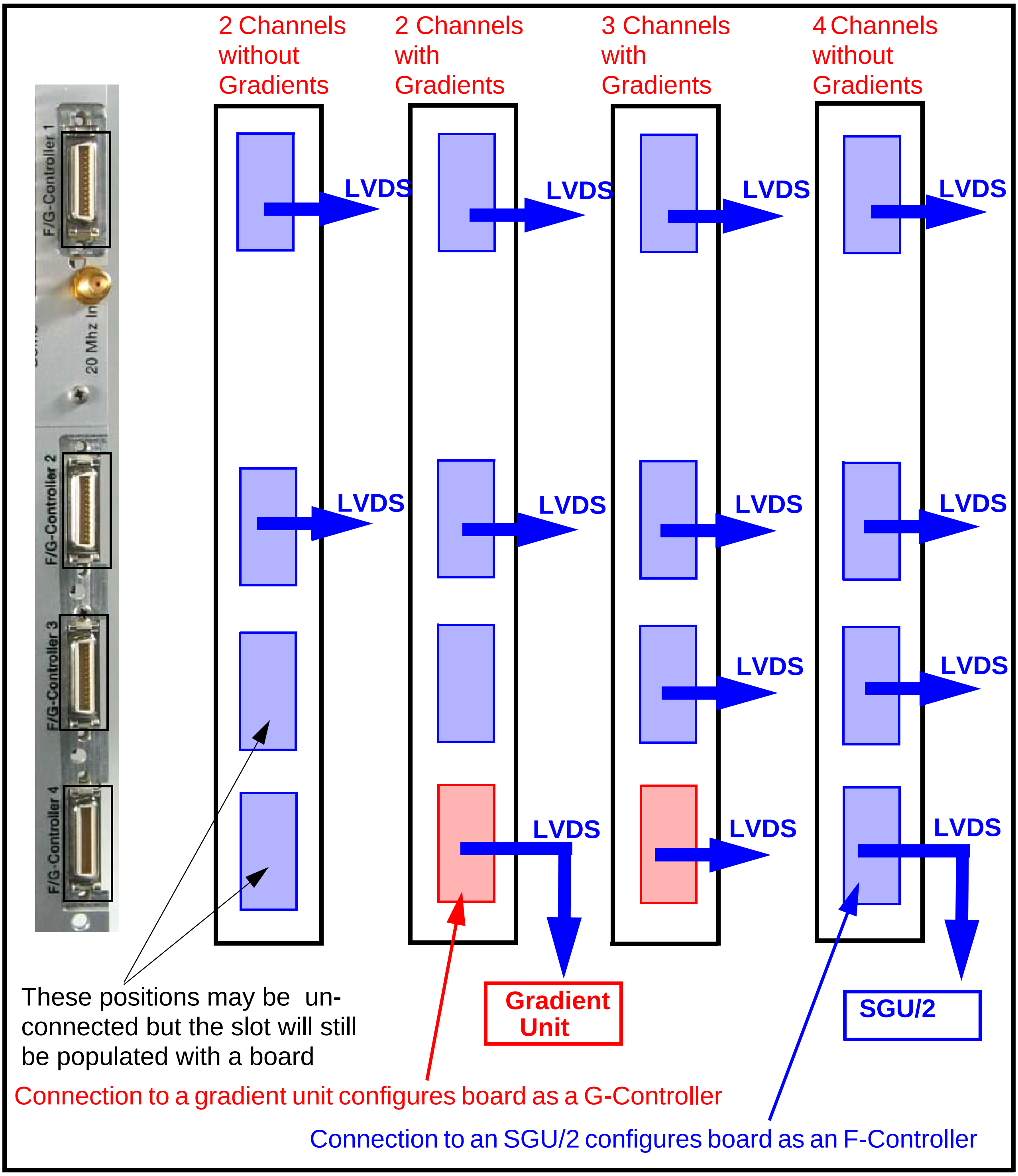


Figure 4.8. Four Sample Configurations of the AQS IPSO

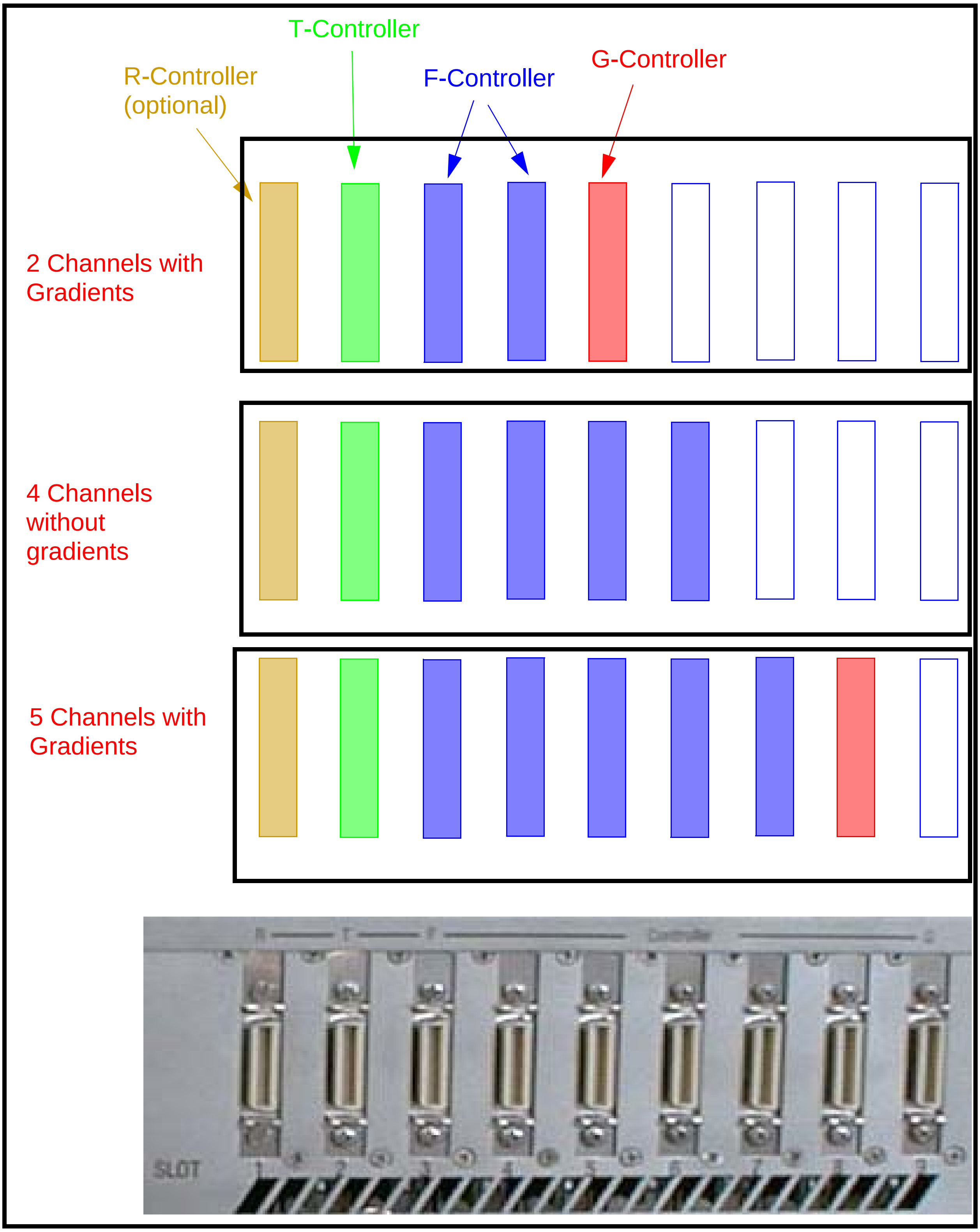


Figure 4.9. Three Sample Configurations of the 19” IPSO

Tips 'n' Tricks/Basic Troubleshooting of F-Controllers 4.3.10

- No vacant slots should ever be left between individual F-Controllers.
- Make sure that all F-Controllers are connected to the corresponding SGU/2
- Check that the LED below the LVDS connector is green signifying an F-Controller (as opposed to yellow for a G-Controller).

Possible solutions to potential problems are

- From within edsp/edasp perform the same experiment over a different channel
- Check that all F-Controllers have been correctly identified using the ha' command
- Run IPSOTEST from within the IPSO service web page.
- Check the presence of the 20 MHz signal from the REF unit.
- Since the F-Controller is simply a Tx-Controller with specific application software if it is suspected that a F-Controller hardware is faulty then the board can be swapped using the following procedure.

1. Switch off the IPSO unit.
2. Remove the F-Controller and replace it with the board from the last occupied slot.
3. Switch on and reconfigure.
4. Check that the new board has been recognized with the 'ha' command.

Specifications 4.3.11

Since the various units (F-Controller, T-Controller and SGU/2s are so inextricably liked in terms of operation it is perhaps most meaningful to consider specifications in terms of overall performance and several of the most relevant parameters have already been detailed in ***Table 4.2.*** In the context of F-Controllers the reader should note the improved performance in terms of phase, amplitude and frequency setting times compared with previous generation spectrometers. There is a also an improved specification in the LVDS data transmission rate. Each Tx–Controller outputs a stream of 48–bit words at a clock rate of 80 MHz per word. To describe a complete set of parameters such as Frequency, Phase, Amplitude requires two words. The 80 MHz clock delivers a timing resolution of 12.5 ns but the requirement for two words results in a parameter setting time of 25 ns.

G –Controller 4.3.12

As the name suggests that G-Controller (Gradient Controller) provides the digital signals (gradient packets) for gradient amplifiers. The digital information is transmitted via the standard LVDS link. The G-Controller output is in effect the digital version of the analog signal that will be generated by the gradient amplifier. In effect the G-Controller is to a gradient unit what an F-Controller is to an SGU.

The G-Controller can service either a GREAT, GAB/2 or DPP (Digital Pre-emphasis) unit. Since the LVDS link is a dedicated link it can only serve one i.e one G-Controller is required per gradient amplifier.

As mentioned in earlier sections the G-Controller is a Tx-Controller with specific application software. Only the Tx-Controller which is connected to a Gradient Amplifier will be configured as a G–Controller and its LED below the LVDS connector will change from green to yellow.

In terms of slot position the G-Controller can be inserted into any slot from position three to nine (slot #3-9) but must also be in the last physically occupied slot.

Connecting more than one Controller to a Gradient Amplifier is not supported by TOPSPIN.

The principle of operation of the G-Controller is very similar to the F-Controller which is hardly surprising given that the hardware is the same. Referring to ***Figure 4.6.***, to visualize the operation of the G-Controller simply replace the SGU with a GAB/2 or GREAT or pre emphasis unit.

Tips ‘n’ Tricks/Basic Troubleshooting the G-Controller — *4.3.13*

- Ensure that an LVDS cable connects the G-Controller to either a GREAT, GAB/2 or DPP. All the cables are identical.
- Check that the LED below the LVDS connector is yellow signifying a G-Controller (as opposed to green for an F-Controller).
- Run IPSOTEST from within the IPSO service web page.
- The easiest way to check if the system has recognized the presence of a G-Controller is to enter the ”ha” command from within TOPSPSIN and follow the routine outlined in ***Figure 4.15.*** where the presence of a G-Controller is clearly shown.The same check can also be carried out using the TOPSPIN window ‘uxnmr.info’ which is displayed during the ‘cf’ routine. see ***Figure 4.11.***

Since the G-Controller is simply a Tx-Controller with specific application software, if it is suspected that a G-Controller hardware is faulty then the board can be removed and its function performed by an F-Controller.The last F-Controller must be used as it is not permitted to have any gaps between occupied slots in the IPSO. Use the following procedure to swap the board.

1. Switch off the IPSO unit.
2. Remove the faulty G-Controller from its slot
3. Connect the rightmost F-Controller (external IPSO) or lowermost F-Controller (AQS IPSO) to the Gradient unit using the standard LVDS link. This will (after a successful ‘cf’) effectively convert the F-Controller to a G-Controller).
4. Switch on and reconfigure.
5. Check that the new board has been recognized with the ‘ha’ command.

R–Controller — *4.3.14*

The R-controller is a (hardware) modified T-X Controller with the LVDS transmitter chip replaced by an LVDS receiver (see ***Figure 4.3.***). The LVDS link is used as a fast data link from the receiver channel (specifically the DRU-E) to the IPSO, bypassing the Ethernet link to the TOPSPIN PC (which is the normal pathway for acquired data.)The purpose of this link is to enable the user observe the progress and results of an acquisition ‘on-the-fly’ and make adjustments as appropriate. The DSP capability of the R-Controller enables the acquired data to be processed in real-time. As a result real-time decisions based on the progress of the acquisition can be made and the results transmitted to other IPSO boards via the standard PCI bus. Historically this feature has been particularly useful for imaging experiments but it is likely to become a more important feature of high resolution NMR experiments. Note that without the R-Controller the acquisition can only be viewed by porting and processing the information via the TOPSPIN PC which of course is not real-time. The R-Controller has no direct link to the sequencer chip and hence any adjustments are ported through the PCI bus.These features are illustrated in ***Figure 4.10.***

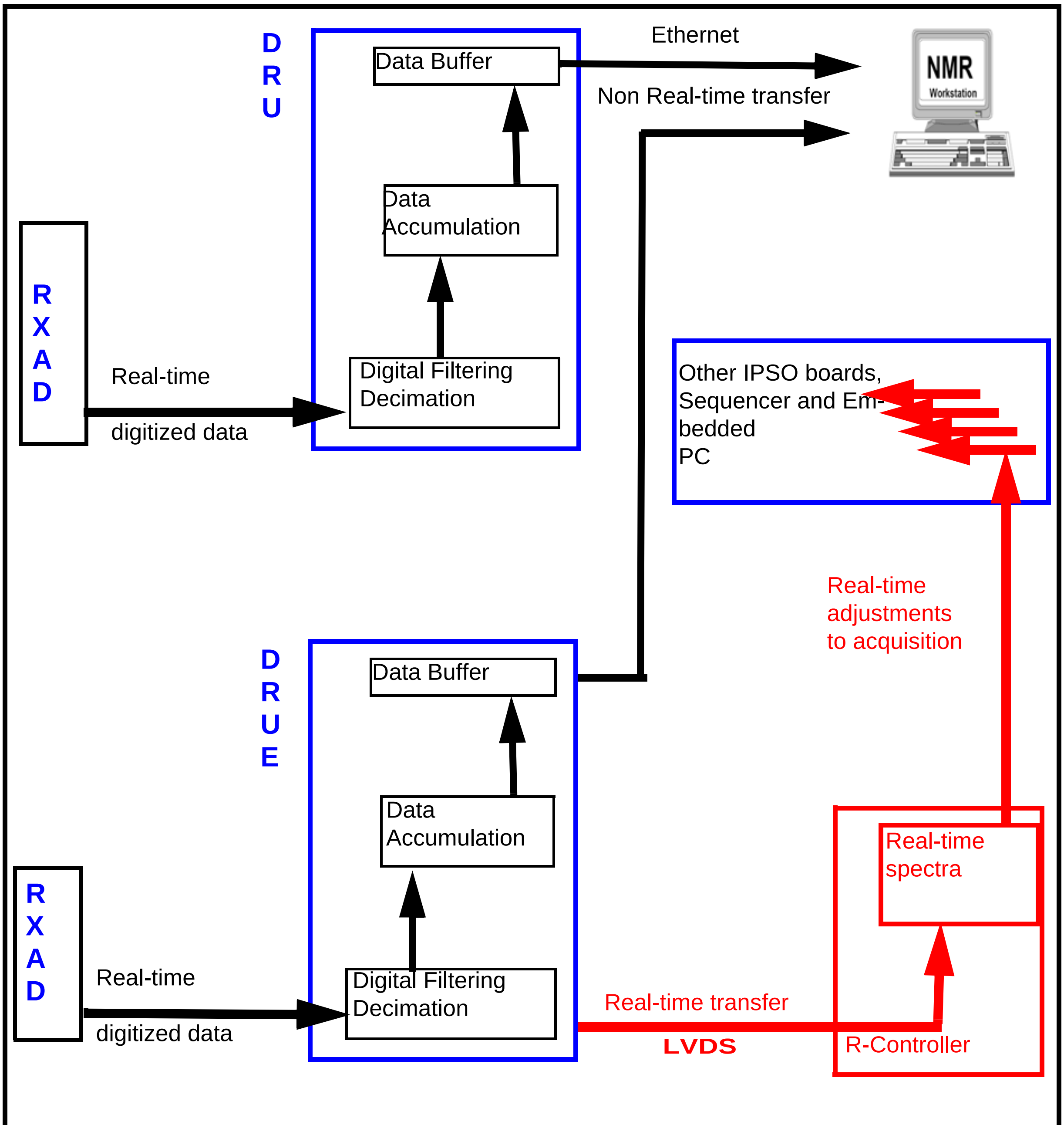


Figure 4.10. Schematic Comparing Operation of an R-Controller and DRU-E with Operation of a Standard DRU.

The R-Controller features are most likely to be used by the high end user and can only be accommodated when used in conjunction with a DRU-E. The DRU has no high speed port for LVDS type data. An R-Controller is an optional extra since the DRU or DRU-E can handle the acquired data via the standard Ethernet link to the NMR workstation as shown in ***Figure 4.10.***.

- The R-Controller is an option.
- There is usually one per system though more can be installed to facilitate multiple receiver systems.
- It will function in any slot of the IPSO but should be inserted in slot 1.

Troubleshooting the R-Controller *4.3.15*

- Unlike other T-Controller boards the R-Controller is unique (due to LVDS receiver as opposed to LVDS transmitter) and can not be simply swapped. It can only be replaced by another R-Controller.
- Where a system has been fitted with an R-Controller its presence can be checked with the TOPSPIN window 'uxnmr.info' which is displayed during the 'cf' routine. see ***Figure 4.11.***

The R-Controller is designed to have the digitized data from the DRU-E as input via the LVDS link. This data can be replaced by the LVDS output from any other IPSO board. It is thus a very useful troubleshooting tool.

```
System        : Avance II+ NMR spectrometer
1H-frequency  : 600.13 MHz
Hardware info: detected by hardware itself

IPSO: connected to spectrometer subnet
- TCP/IP address = 149.236.99.248
- Tctrl  : 1
- Fctrls: 4
- Gctrl  : without digital preemphasis
- Rctrl  : 1

DRU1: AQS DRU Z100977/00206 ECL 02.00
- TCP/IP address = 149.236.99.89
- Firmware Version = 60609
- DRU controls AQS-Rack and HPPR/2
```

Figure 4.11. Extract from the 'uxnmr.info' window displaying the presence of a T-Controller, a G-Controller , 4 F-Controllers and a R-Controller

Overview of Slot Allocation *4.3.16*

Slot 1: Intended to be used by the R–Controller only.

Slot 2 to **Slot 9** are designed for Tx–Controllers

Slot 2: Only this slot provides access to the acquisition global functions such as START, STOP and so on, as well as to the RCP outputs. Therefore the Tx– Controller in this slot is automatically configured as a T–Controller. It controls the RCP outputs instead of its LVDS output. Do not connect a cable to this LVDS connector. The LED below this connector is always off.

Slot 3 to Slot 9: Tx–Controllers in these slots can work as F–Controllers (default) or as a G–Controller. The LED below the LVDS connector lights green for an F–Controller and yellow for a G–Controller. The channel numbering of the F–Controller begins at the leftmost one and counts to the right. There must not be any gap between occupied slots.

Review *4.3.17*

Having gone through the individual units it is perhaps timely to discuss a typical order of events (see ***Figure 4.5.***) to carry out an acquisition.

The operator enters the acquisition details at the NMR workstation.

The information (pulse program, power levels, pulse length, delays etc.) is transmitted to the Embedded PC via the Ethernet link.

The Embedded PC transmits this info to the various DSPs on the individual controllers via the standard PCI Bus.

The DSP operating on a 720 MHz clock (soon be increased to 1GHz) performs the required calculations, compiles the pulse programs etc. The DSP then loads its FIFO with the appropriate data.

The sequencer reads the data from each FIFO, and transmits the appropriate signals back to the individual controllers.The sequencer generates real time durations from the timing information and as mentioned earlier the entire sequence of events is controlled on and by a single chip.Once the acquisition has started the DSP must simply ensure that its FIFO gets new data at the input as it is emptied at the output by the sequencer. The LVDS transmitter sends the info to the SGU/2 or gradient amplifier as appropriate.The SGU/2 then transmits the excitation signal as well as generating.

- blanking signals for the amplifiers
- gating signals for the receiver and ADC
- gating signals for the preamplifiers.

These SGU signals will be discussed in the next chapter.

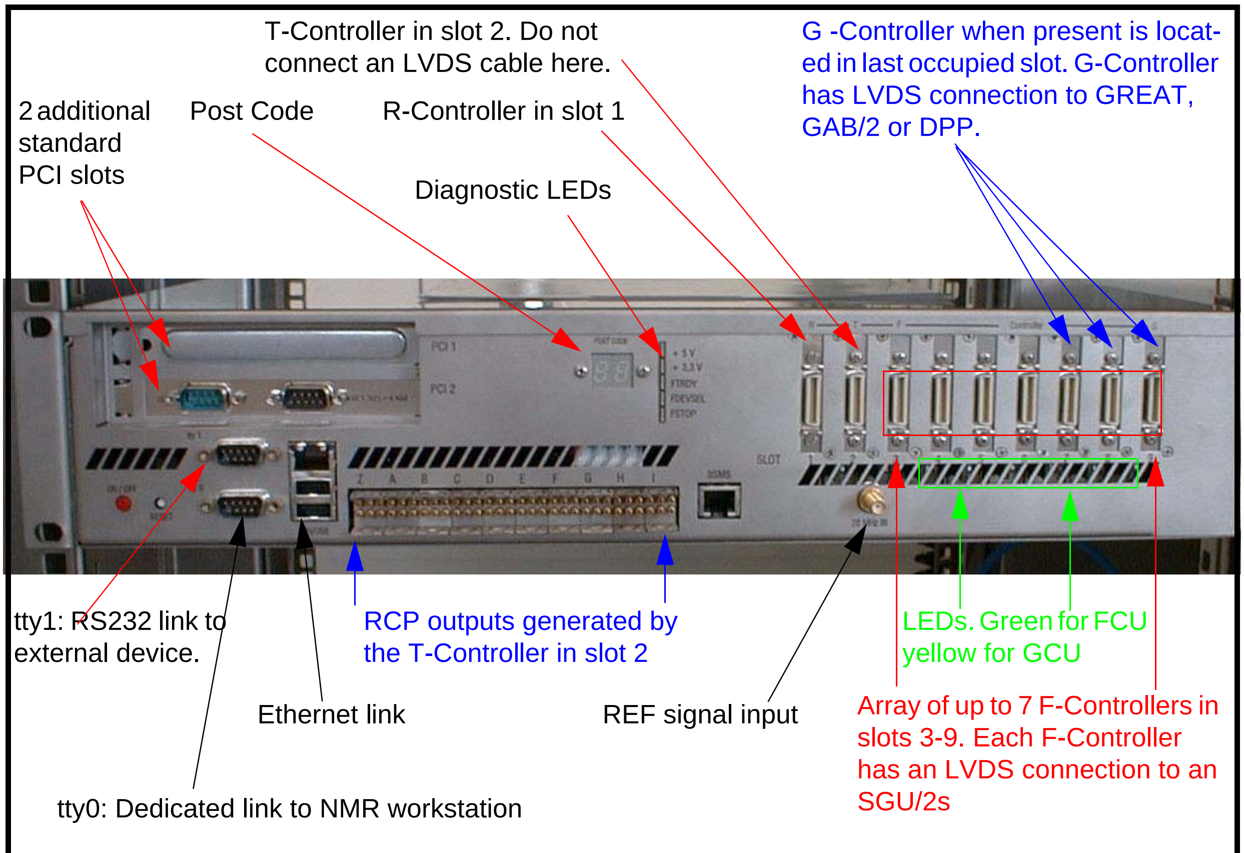


Figure 4.12. IPSO19'" Front Panel. Note that above example has all IPSO slots occupied.

Power ON/OFF Button

To be effective this button needs to be pressed for about 2 seconds to switch the system on and 6 seconds to switch it off.

Reset Button

This button resets the Embedded PC and restarts the boot process. It leads therefore to the same result as the ON/OFF button without actually powering off.

PCI1 and PCI2

These two slots may or may not be occupied. They allow for the possibility of additional connections such as

- Additional TTY connections for controlling external devices. ***Figure 4.12.*** shows a standard set of two TTY connectors occupying PCI2. PCI-RS cards are available that cater for 2,4 or 8 TTY ports.
- Additional LVDS ports for GREAT amplifiers that require pre-emphasis.

tty0 tty1

tty00 is a dedicated link to the NMR workstation and enables the operator to 'log onto spect'.

tty01 is used to communicate with external units such as the temperature unit (VTU), pneumatic unit etc. (see ***Figure 4.13.***. This enables these units to be controlled from the operator desk.

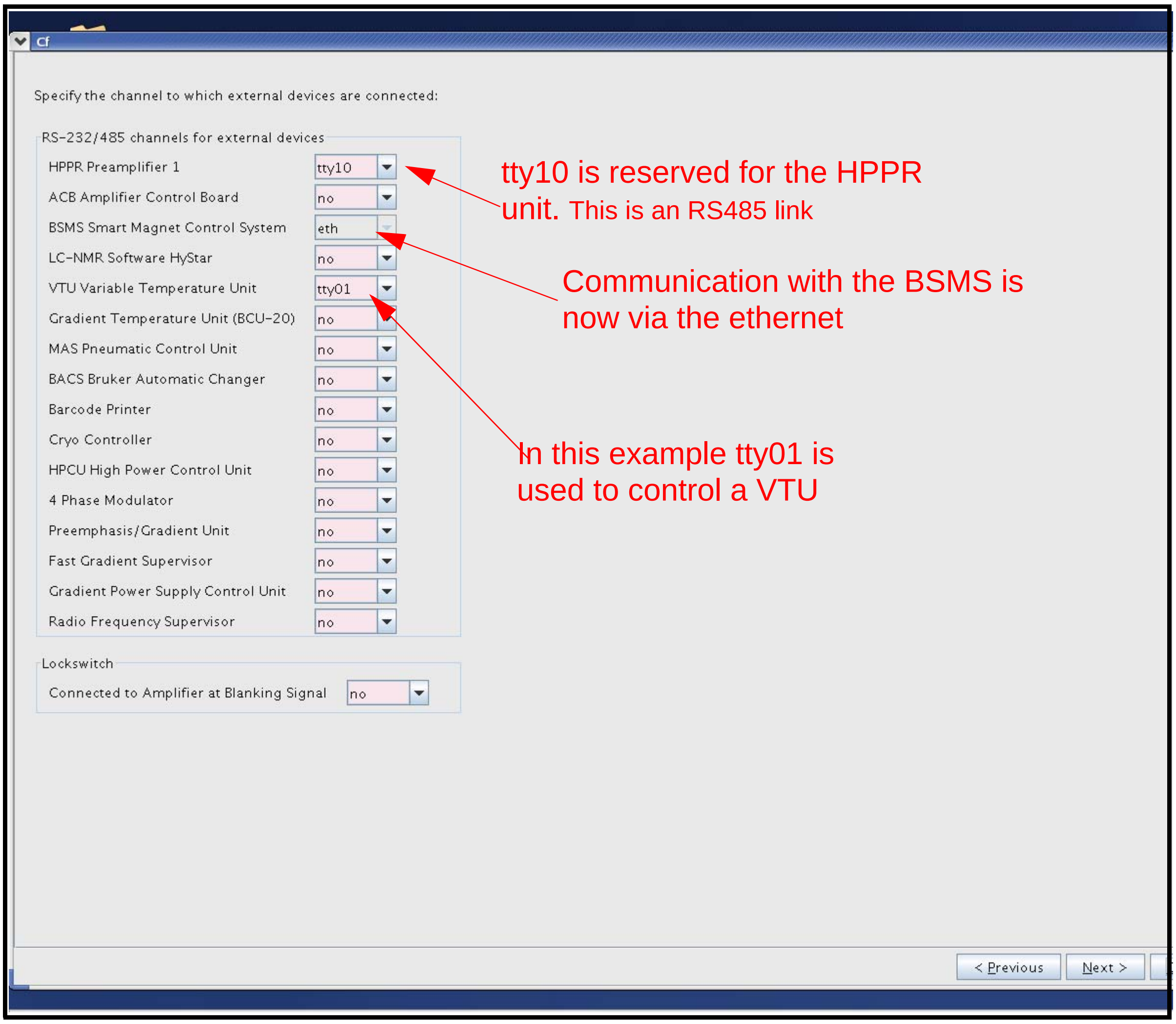


Figure 4.13.During the ‘cf’ Routine the tty Assignments are Displayed.

ETH/USB

The Ethernet link is connected to the Ethernet switch which in turn is connected to the NMR workstation. Note that this is the means by which the Embedded PC communicates with the NMR workstation. The two USB ports are likely to be unoccupied as Bruker devices prefer to use linux when running USB ports and this will use temporary IP addresses. However Bruker devices need permanent addresses, although this can be solved using the DHCP server.

RCP outputs external unit.

Connectors Z/A/B/C/D/E/F/G/H/I

See section ***4.3.5***.

Post Code

After a successful boot the post code display should show "94" with a "93" or "95" appearing every 5 seconds.

Diagnostic LEDs

The presence of the required power supply voltages (+5V and -3.3V)can be easily verified with the upper two LEDs.The lighting sequences of the three lower LEDs has significance but in reality they flicker too fast to allow for meaningful interpretation by the operator.

20 MHz in

This is a synchronizing clock signal generated by the REF unit. It is distributed to all IPSO boards ensuring that all IPSO units are synchronized with the various AQS units. The same signal is used to clock all other AQS units.

BSMS

This link is to the ELCB of the BSMS/2. It carries RCP signals such as Lockhold and Homospoil.

During a gradient pulse the field is (deliberately) distorted and the LOCKHOLD command temporarily turns off the lock.

The Homospoil signal provides a low current gradient in the Z axis by making an adjustment to the Z shim. It is sometimes viewed as a poor mans gradient.

LVDS connections

The LVDS protocol is the preferred transmission method for digital data words between the Tx– and the Rx–Controllers respectively and peripheral devices such as the SGU/2s, Gradient Amplifier (GAB/2 or GREAT), DPP and DRUE.

The abbreviation LVDS means “low voltage differential signal”. The voltage switching range of the data lines is between 1.0V and 1.4V. This is in contrast to 0 and 5 Volts associated with TTL signals. The data protocol uses 48–bit data words at a clock rate of 80 MHz (100 MHz between DRU and Rx–Controller respectively).

Besides the data and clock lines the LVDS cable includes 2 status lines. From the status lines the type of connected device can be established. Possible states are unconnected, SGU connected, Gradient Amplifier (GAB/2 or GREAT) connected, DPP connected etc. This feature is used during the ‘cf’ routine to establish which boards are present and consequently which application software should be loaded.

Front Panel Connections: AQS IPSO *4.3.19*

There are many obvious similarities to the front panel description already given for the external IPSO in section ***4.3.18*** and there is little point in reproducing this. The reader should refer to this description now. The section below will simply highlight the differences between the two front panels.

T-Controller: Connectors Z, U, V, W

There is a reduced set of RCP signals available, since the AQS IPSO has a max of 3 channels (excluding the T-Controller).

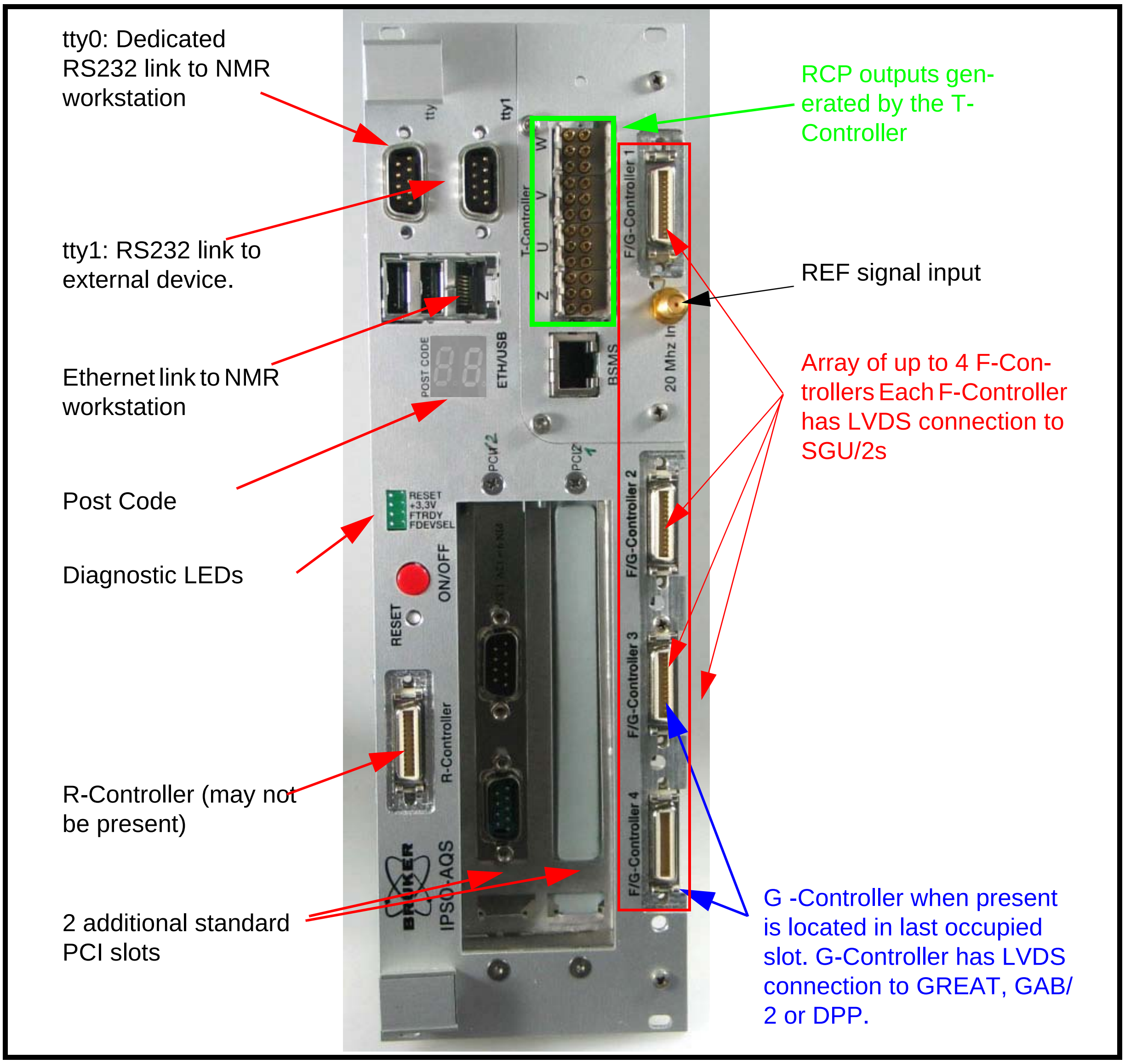


Figure 4.14. AQS IPSO Front Panel

Switching the Unit On and Off 4.4

Power ON/OFF Button

To be effective this button needs to be pressed for about 2 seconds to switch the system on and 6 seconds to switch it off.The IPSO (i.e Embedded PC) automatically boots up (powers down) every time the IPSO is switched on (off).

The reboot can also achieved using Ethernet via the IPSO Service page/Administrative Tools/Reboot.

After rebooting the IPSO it is customary to ‘log onto spect’. This is physically logging onto the Embedded PC and is usually done with the RS232 connection to tty00. The window interface is called up by clicking on the CCU Hyperterminal icon of the host workstation graphics monitor or alternatively use the ‘CU’ command (Linux systems).

Note that you can also use ‘telnet spect’ to gain access via the Ethernet link though hardware related error message are not accessible via this connection.

Investigating the Boot Process

Additional information about the boot process can be obtained by monitoring the POST code display.

After power on the **P**ower–**O**n–**S**elf–**T**est (POST) routine starts automatically. As the boot procedure progresses (it normally takes about one minute) a series of hex codes are displayed on the from panel. If an error is encountered then the code displayed will represent that particular error step or the last successfully completed step. Detailed lists of the code are beyond the scope of this manual. Suffice it to say that the final code should show "94" with a "93" or "95" appearing every 5s after a successful boot procedure.

TTY0 Port

The boot messages of the IPSO can be printed in a window of the TOPSPIN–PC by making an RS232 connection from tty0 of the IPSO front panel to a COM port of the TOPSPIN–PC.(This RS232 cable requires a crossover from the T and R pins).

The boot procedure (or re-booting after a reset) can then be observed by clicking on the CCU Hyperterminal icon (Windows systems) or using the ‘CU’ command (Linux systems).

Tips ‘n’ Tricks/Basic Troubleshooting *4.5*

An LVDS cable should never be removed from or connected to a powered controller. Corrupted data could be sampled as valid.

Do not connect a cable to the LVDS connector of slot 2 as this is reserved for the T-Controller.The LED below this connector is always off.

The successful completion of the boot process can be checked in TOPSPIN by typing.

ha

This will return the IP–Address of the connected IPSO.

Starting with the ‘ha’ command ***Figure 4.15.*** is a flow chart displaying how the recognized IPSO hardware units can be established. This is effectively the same information as can be ascertained from the uxnmr.info window displayed during the ”cf” routine (see ***Figure 4.11.***).

Figure 4.16. is another example of establishing more specific information regarding the Part number/ ECL/ serial, number of particular IPSO boards. Note that this level of detail (the BIS data) is not available in the uxnmr.info display.

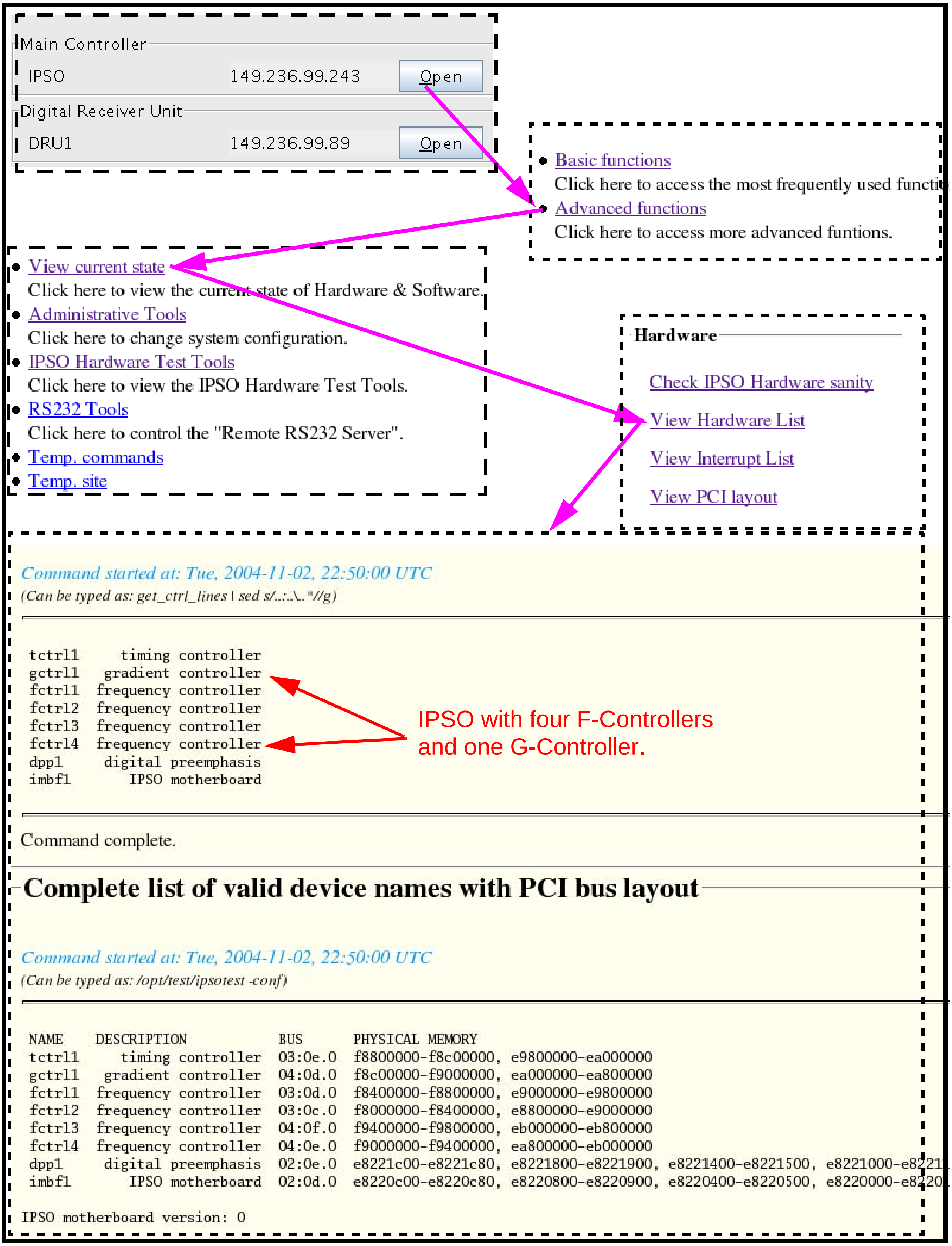


Figure 4.15. Establishing the Recognized IPSO Hardware

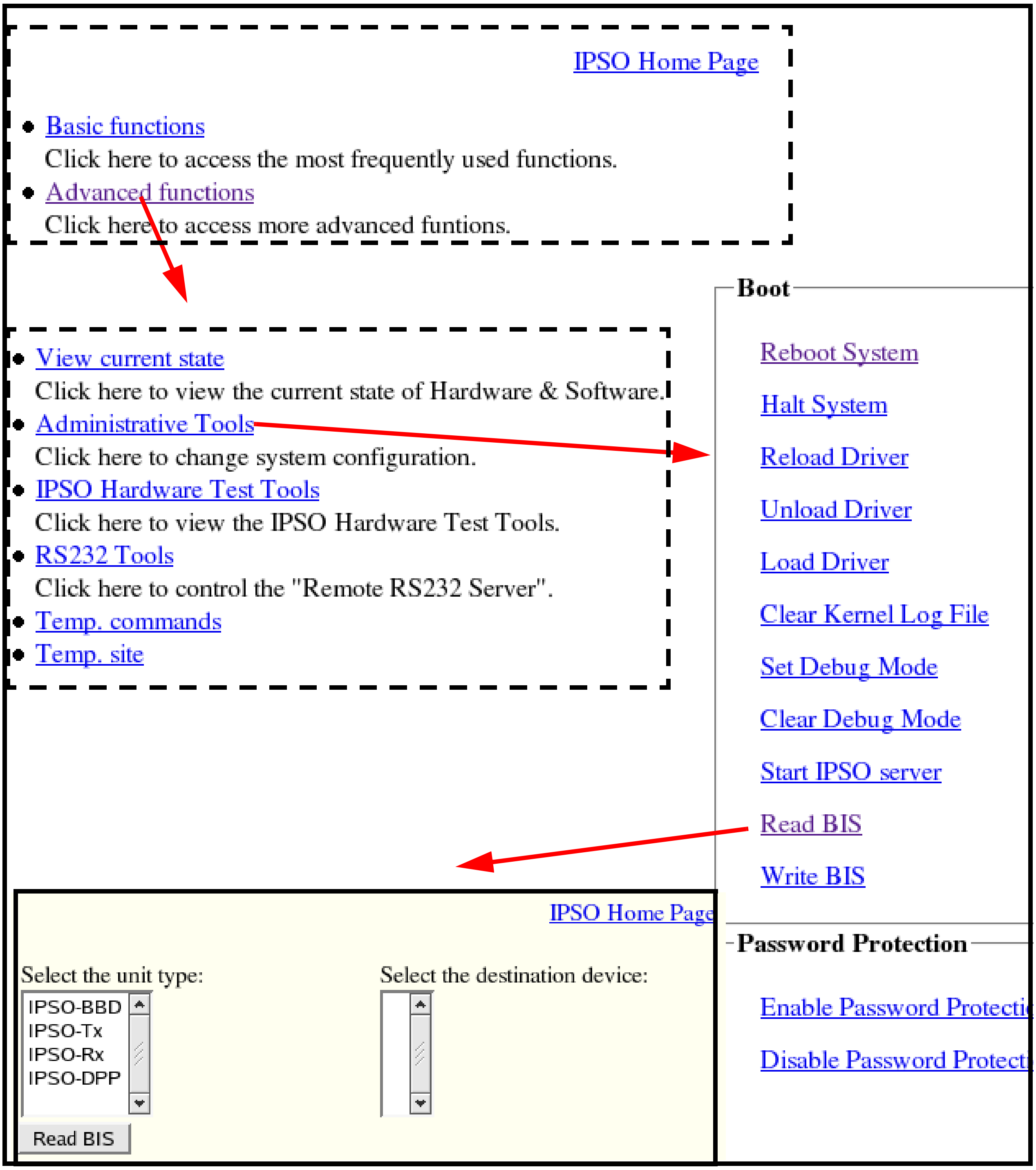


Figure 4.16. Accessing the BIS Information via the IPSO Service Web

Serial Number / ECL Level / Software Downloads *4.6*

To date there are only two configurations of IPSO and a single ECL of all boards. Although individual boards will no doubt undergo engineering upgrades in the future this has not happed as yet.

Other Required Signals / Units 4.7

To function the IPSO must have

- Power from the AQS backplane
- Functioning Ethernet link to the host workstation
- 20 MHz signal from the REF unit

Option or Core Item 4.8

Every AVANCE III system will have one and only one IPSO.

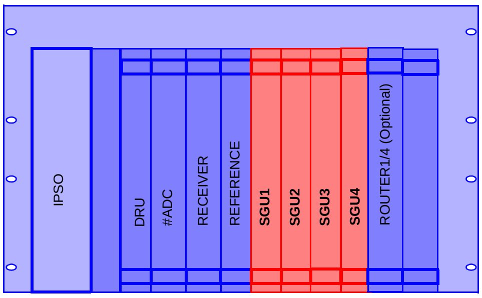
Further Information 4.9

IPSO 19" & IPSO AQS AVANCE III User Manual (P/N Z31819).

Signal Generation Unit (SGU/2)

5

Introduction 5.1



The output of all the IPSO boards, and in particular in the context of this chapter, the output of the F-Controllers, is entirely digital. The use of digital electronics has obvious benefits in terms of control, accuracy, reproducibility and reliability. The signals used to excite the NMR sample as well as the signals subsequently emitted are however inherently analog in nature and at some stage the transition from digital signals to analog and vice versa must occur. In this respect the SGU/2 can be thought of as a highly sophisticated DAC (digital to analog converter) turning real-time **digital** instructions received from the F-Controller into their **analog** equivalent. More than any other unit the SGU/2 represents the onset of the analog section of the spectrometer and in terms of defining the transmitted RF signals, the SGU/2 can be thought of as the heart of the spectrometer.

Terminology: The new SGU/2 version replaces the earlier SGU. For the purposes of this chapter the following use of terminology will apply. Where a description is specific to the new SGU/2 this term will be used. For all other information the more generic term SGU will be used.

On the transmission side, the SGU

- outputs the RF excitation signal with precise frequency and phase
- regulates the signal amplitude (including shape control)
- generates blanking and gating pulses used in various preamplifiers, amplifiers and the receiver.

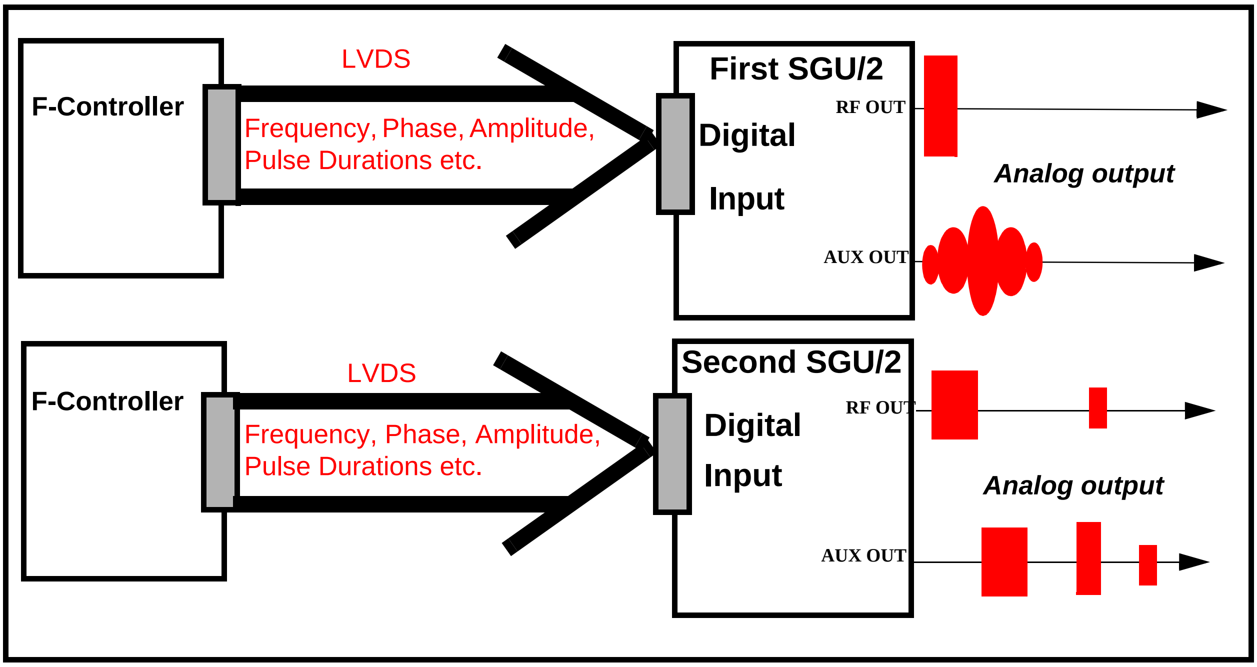


Figure 5.1. The SGU/2 Turns Real-time Digital Instructions Received from the F-Controller into Their Analog Equivalent

Table 5.1. SGU Generated Timing Signals

Signal	Purpose	Generated By /delivered To
RGP_RX	When active low receiver opens	OBS SGU/RXAD
Dwell-En	When active low DRU accepts data stream from RXAD	OBS SGU/DRU
RGP_ADC	When active low the ADC data is **not** zeroed	OBS SGU/DRU
RGP_HPPR (aka RGP_PA)	When active low OBS module of preamplifier opens	OBS SGU/Preamplifier
BLKTR	When active low amplifiers can transmit power	SGU/Amplifier

The RF output of the SGU should be an exact replica of the signal transmitted to the sample apart from overall amplitude and this output is often the starting point for many service engineers when troubleshooting a system. The only significant change to the RF signal between the SGU and final sample excitation is a **fixed** increase in power within the amplifiers. To this extent the SGU controls the shape and amplitude of the excitation pulses. The maximum output of an SGU is $1V_{pp}$ at a power setting of -6db.

The blanking and gating pulses in the amplifiers are required to ensure maximal noise suppression outside of signal transmission. By assigning the generation of blanking/gating pulses used at various locations throughout the spectrometer to the SGU, the synchronization of the pulse generation is optimized. Regardless of the path that an RF signal takes subsequently, any blanking or gating pulses applied originate from the same SGU that first generated the signal. Note that the

the blanking signals to the internal amplifiers are delivered via the AQS backplane. The blanking signals to the external amplifiers are first ported through the PSD3 located at the rear of the AQS.

Such is the flexibility of the system there are several possible methods that could be used to decide which blanking pulses are assigned to which amplifiers. The system that has been adopted is as follows.

1. A set of hardwired cables connect the PSD3 to the various amplifiers.
2. Each blanking pulses is hardwired to one and only one amplifier.
3. Whichever amplifier is connected to the cable labelled BLKTR1 becomes amplifier 1.
4. Whichever amplifier is connected to the cable labelled BLKTR2 becomes amplifier 2. etc.

To simplify the edsp/edasp display the order in which the amplifiers are displayed correspond to the BLKTR number. For example the first amplifier to appear in the display will be the amplifier gated by BLKTR1 and so on.

On the **receiving** side the SGU (see ***Table 5.1.***)

- gates the observe module of the preamplifier with the signal RGP_HPPR (aka RGP_PA)
- switches the LO (local oscillator) frequency for the RXAD receiver.
- generates the receiver gating pulses (RGP_RX) and ADC command (RGP_ADC)
- effectively gates the DRU with the Dwell-En signal

Note that the use of different signals to gate the receiver and preamplifier allows for the receiver to be opened later in respect to the preamplifier to prevent saturation.The timing of these signals can be adjusted using the ‘edscon ‘command.

The SGU no longer generates a Dwell Clock in the traditional sense. Dwell clocks usually refer to a clock signal that dictates the rate at which the sample and hold of an ADC operates. Since the RXAD has a constant ADC rate of 20 MHz (regardless of the Sweep Width) it simply uses the signal generated by the REF unit and not the OBS SGU. What is generated by the OBS SGU is a the Dwell-Enable signal which dictates when the DRU accepts the data stream from the RXAD.

The role played by the SGU in the generation of the LO frequency has changed since the introduction of the RXAD.The LO is required by the receiver to demodulate the genuine NMR signals from the spectrometer carrier frequency. (This is analogous to an FM radio receiver where the audio signals in the low Khz range are demodulated from the carrier frequency which for FM radio is in the 88-108 MHz range). The value of the LO is SFO1 + 720 MHz which is a very large frequency shift and indeed for 500 MHz spectrometers and above would require frequencies beyond the range of the SGU/2. However the SGU/2 now only has to make a minor shift which can be implemented by the on-board DDS (direct digital synthesis). The addition of the 720 MHz which is the major shift now takes place on the RXAD itself which also demodulates the received RF signal by subtracting the 720 MHz. Note that the DDS is clocked by 80 MHz which is the 20 MHz from the REF quadrupled. The REF is also the source of the mixing frequencies used in the RXAD. Hence the entire frequency generation and signal receiving is synchronized by the REF unit.

The receiver gating pulses (RGP_RX) ensures that the receiver is opened precisely when the excitation signal has ended to avoid the receiver being swamped by the excitation pulse.The trick here is to open the receiver as soon as the excitation signal has elapsed to receive as much of the emitted signal as possible, but not so soon as to catch the tail of the excitation signal.

The RXAD is constantly clocked at 20 MHz and discards the digitized data until it receives the start command (RGP_ADC) from the OBS SGU.This command is simply a command that initiates the storing of the digitized data.

From the above brief description it is apparent that in both transmission and receiving the SGU (and in particular the OBS SGU) plays a central role in spectrometer operation.Recall that the SGU/2 is synchronized with the same 20 MHz /80 MHz as all other AQS units.

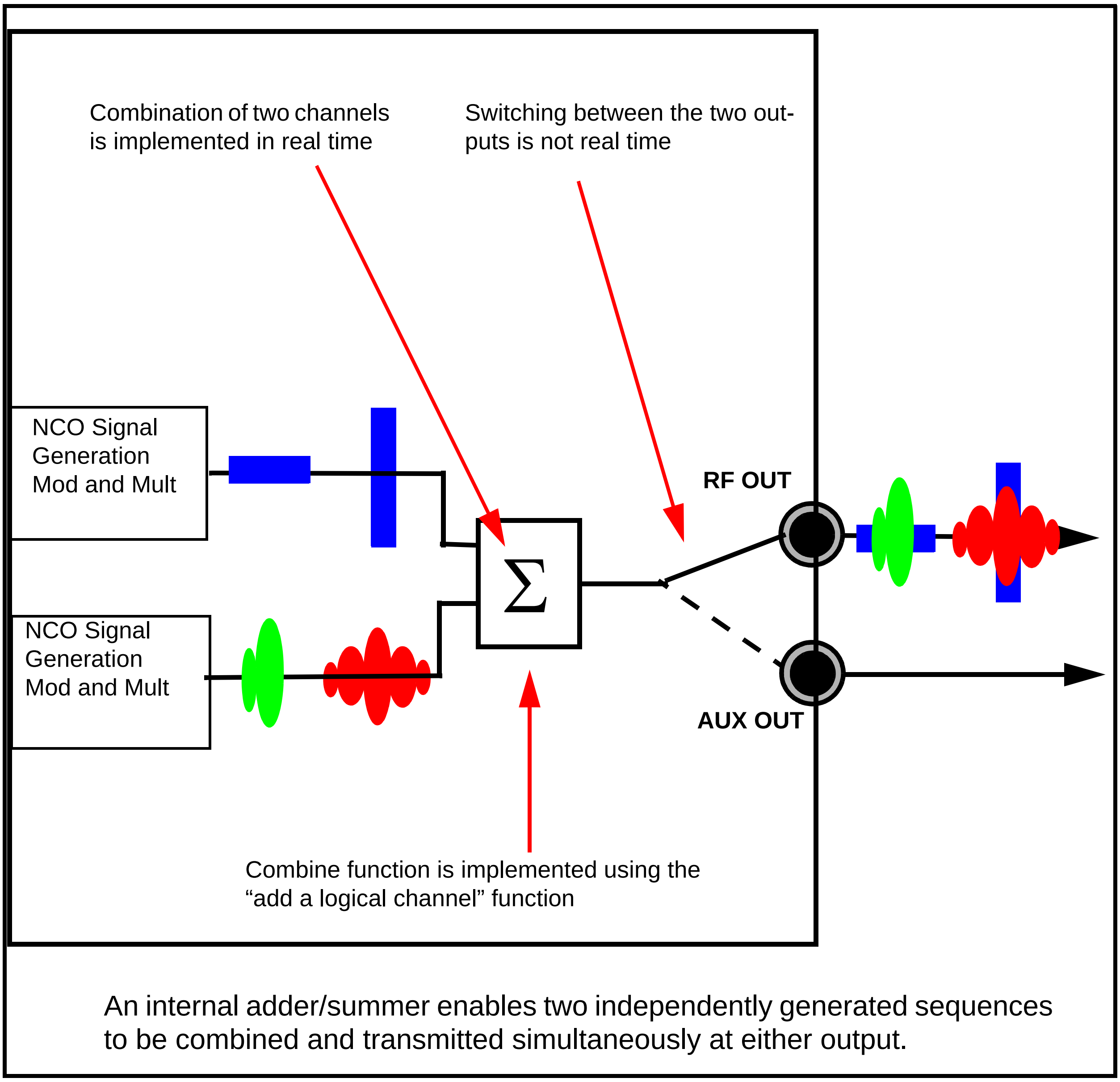


Figure 5.2. Schematic Representation of the Versatility of the SGU/2

It is worth emphasizing some of the ehanced capabilities of the new SGU/2. In particular the SGU/2 can deliver output at both the RF OUT and AUX OUT connection. Furthermore this output can be a combination of two signals generated independently and may be delivered at either output (see ***Figure 5.2.***). A typical application might be a two frequency presaturation.The only limitation is that two independently generated signal signals can not be delivered at the two outputs simultaneously. The output of the combiner will service only one or other of the two outputs. It can however be switched to either (though not in real time) The advantage of all this is that, assuming that both outputs are connected to amplifier inputs, then the SGU/2 is effectively acting as a ROUTER. One limitation on these new features is that the difference between the independently generated frequencies must not exceed $\pm$2.5 MHz.

As mentioned above this new SGU/2 feature has taken over some of the combining functions previously performed by the ROUTER. This new feature along with enhanced routing capabilities within the external amplifiers has enabled most systems be configured without a standard ROUTER. Where extra routing is required the AVANCE III is instead fitted with the new 1/4 ROUTER which will be described in Chapter ***9***

The delivery of the RF at both SGU/2 outputs has led to a new cabling arrangement which effectively enables each SGU/2 to transmit RF signals to two amplifiers (see ***Figure 5.5.***) A summary of the principal features of the newly developed SGU/2 along with a comparison with previous generations of SGU is given in ***Table 5.2.***

Table 5.2. Comparison of SGU/2 and SGU

SGU/2	Previous generations of SGU
IPSO compatible	IPSO incompatible
Each SGU/2 controlled by dedicated F-Controller	Up to 4 SGUs controlled by single FCU4 Up to 2 SGUs controlled by single FCU3
Both RF OUT and AUX OUT used for general RF transmission and connected to amplifiers	RF OUT only connected to amplifier. AUX OUT used only for the TUNE signal on one designated SGU
Ability to combine two signals at one output simultaneously. Signal generation is truly parallel	Combining not implemented. Signal generation is sequential
ROUTER not required. 1/4 ROUTER required in special cases only	ROUTER usually required for all but basic systems
FIFO architecture reduces the number of instructions to implement pulse program. When a parameter is set is independent of number of parameters to be set	Absence of FIFO architecture results in more complicated set of instructions.When a parameter is set depends on the number of parameters to be set
LVDS input is 48bit words at 80 MHz	LVDS input is 28 bit words at 20 MHz
Does not generate a Dwell Clock although it does gate the ADC with Dwell-En. Minor frequency jump in LO generation since all systems are fitted with DRU or DRUE as standard.	Generates Dwell Clock Major frequency jump in LO generation for systems without DRU
SYNC and DATA LEDs on front panel	Not available

Location and Photograph *5.2*

The SGUs are located in the analog section of the AQS rack between the REF unit and either the ROUTER (if fitted) or internal amplifiers (if fitted). See ***Figure 3.1.*** and ***Figure 3.2.***

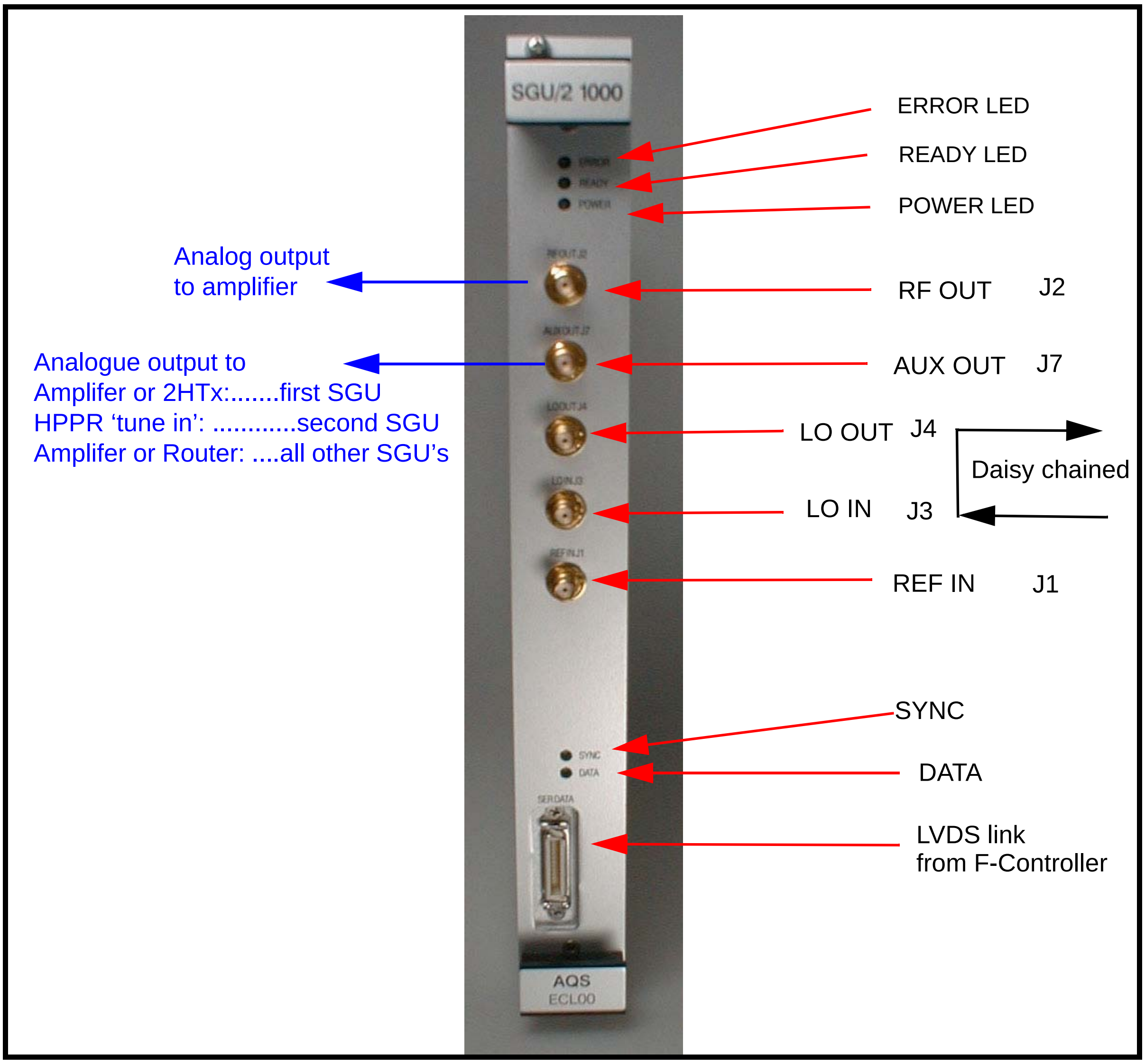


Figure 5.3. SGU/2 Front Panel

General Information, Configuration and Function *5.3*

As described in the preceding section the output of the SGU will be an exact replica of the final transmitted signal in terms of frequency and phase, shape and amplitude (apart from the fixed gain of the amplifier).

The maximum output of the SGUs are designed to be of the order of 1Volt peak to peak ($1V_{pp}$) in amplitude. This corresponds to a software power level setting of minus 6dB using the power level parameters pl1, pl2 etc. For historical reasons the max. power (min. attenuation) on any channel is minus 6db. This convention has been maintained to minimize changes for operators when working with the latest spectrometer systems.

For power level settings other than minus 6dB the SGU output is attenuated accordingly. Reduced power levels are achieved by increasing the attenuation level (measured in dB) applied to the SGU output within the range of minus 6dB to plus 120 dB see ***Figure 10.2.***.

As described each SGU/2 is capable of generating two RF signals using the RF OUT and AUX OUT ports. Although there is flexibility with regard to cabling the following table shows a standard configuration.

Table 5.3. SGU Cabling for External Amplifiers

SGU/2	Output	Destination
First SGU/2	RF OUT	Amplifier
	AUX OUT	2HTX or Amplifier
Second SGU/2	RF OUT	Amplifier
	AUX OUT	Tune in HPPR
Third SGU/2	RF OUT	Amplifier
	AUX OUT	Amplifier
Fourth SGU/2	RF OUT	Amplifier
	AUX OUT	ROUTER or Amplifier

The AUX OUT of the first SGU is reserved for the 2H-TX amplifier if fitted. Otherwise it will connected to an amplifier. The AUX OUT of the second SGU is reserved for use as the source of the Tune signal used in the wobble routine. All other outputs are connected to amplifiers.If a ROUTER is fitted the default configuration is that the AUX output of the fourth SGU /2 is connected to amplifiers via the ROUTER as in ***Figure 5.5.***.

For the equivalent cabling details for the internal amplifiers ***Table 11.2.*** and ***Figure 11.3.***

Regardless of the system the SGUs are lined up immediately to the right of the REF unit.

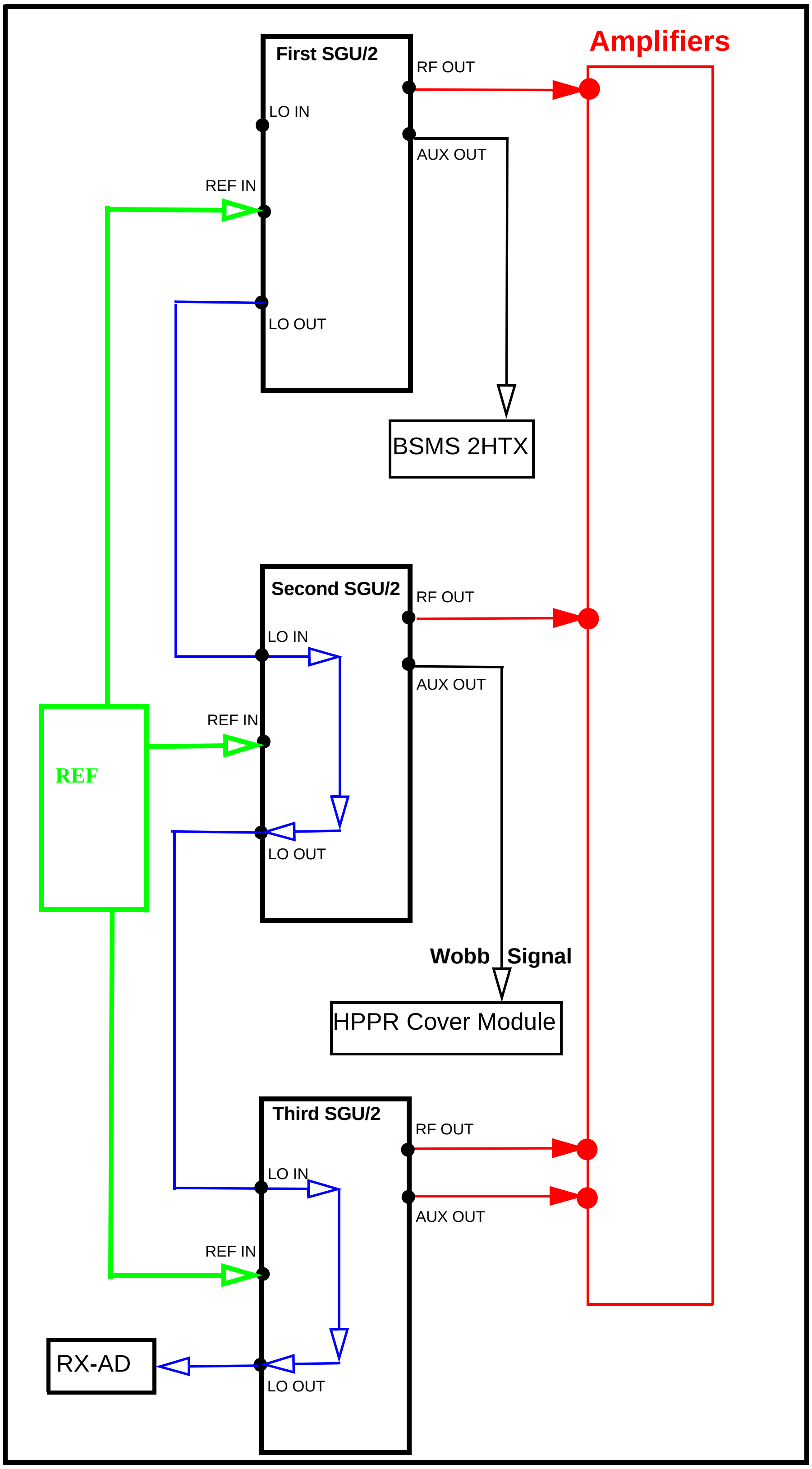


Figure 5.4. Standard Cabling of System with three SGU/2s , External Amplifiers, nc ROUTER, BSMS 2H-TX Unit.

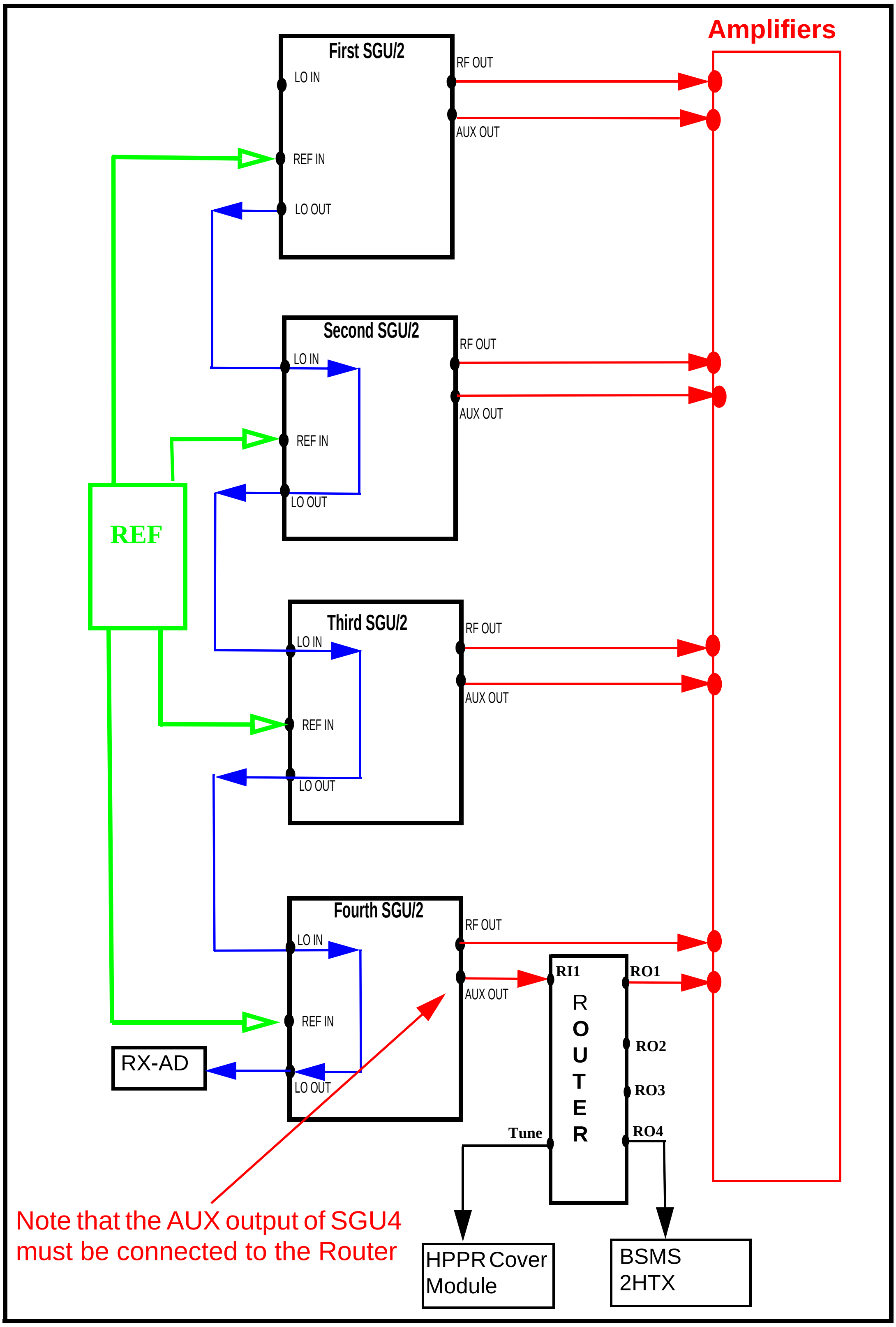


Figure 5.5. Standard Cabling of System with 4 SGU/2s, External Ampliers, ROUTER, BSMS 2H-TX Unit

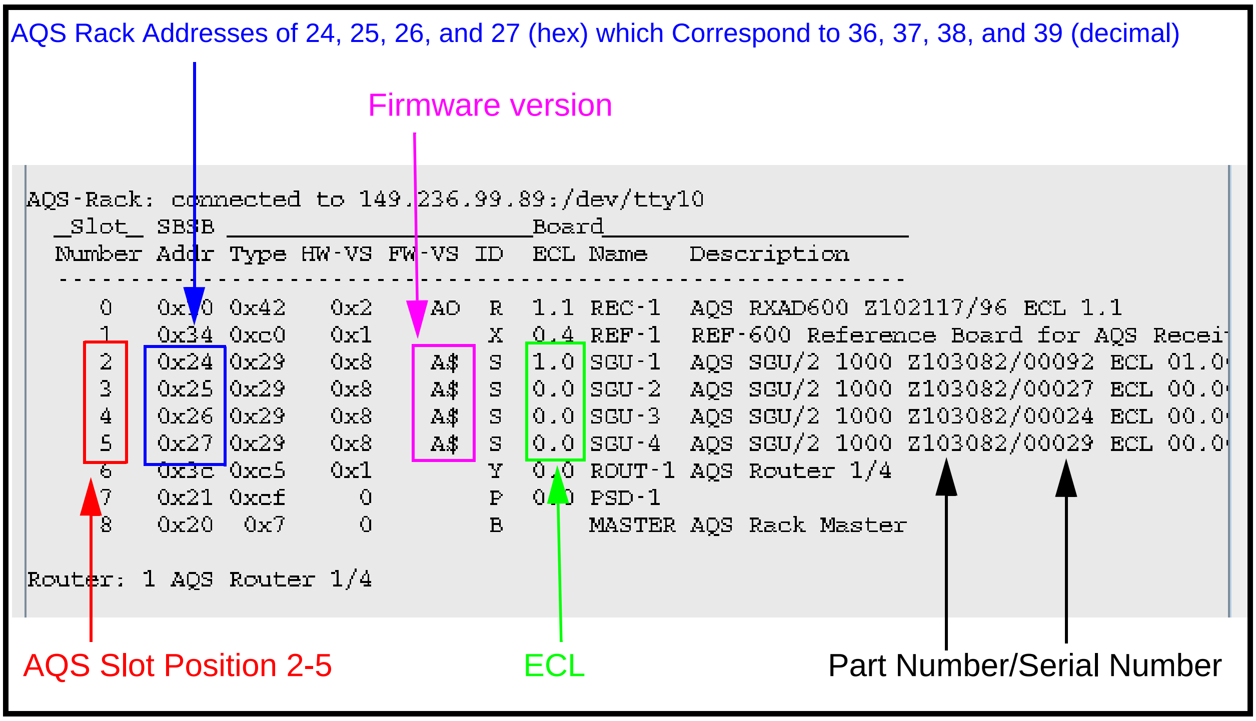


Figure 5.6. Extract from the ‘uxnmr.info’ File Displaying the Presence of four SGU/2s .

The number and slot location of each SGU/2 can be checked in the TOPSPIN window ‘uxnmr.info’ which is displayed during the ‘cf’ routine. (see ***Figure 5.6.***) The presence of the REF unit in slot1 is displayed in this figure and the SGU/2s immediately to the right. Note also that the part number, ECL number etc. is also listed. This information can also be accessed via the Unitool program which will be discussed in sec. ***5.5.1***.

An enhanced feature of the new SGU/2s already alluded to is the use of both RF OUT and AUX OUT as sources of RF. This means that the user has much greater flexibility in terms of cabling. A relatively new feature is the ability of the ‘cf’ routine to detect which outputs are connected to which amplifiers. During the routine RF is momentarily generated at **all** SGU/2 outputs which can then be detected by the directional couplers within the various external amplifiers. It is then a simple matter to determine which SGU/2 outputs are connected to which amplifier inputs. An example of this from a ‘uxnmrinfo’ generated file is shown in ***Figure 5.7.*** Note that RF OUT is termed ‘NORM OUT’ reflecting that heretofore only the RF OUT was normally used. Note also that the AUX output of the second SGU/2 is designated as ‘open’. This may be because it is simply not connected or because this output is used to generate the tune signal during the ‘wobb’ routine and as such is sent to the preamplifier as opposed to a transmitter. Since it is not detected by a transmitter then it is deemed unconnected or ‘open’. Unused outputs should not be left unconnected but terminated by a standard 50ohm terminator. Note also that the AUX output of SGU4 is connected to the ROUTER whose Output1 is connected to a transmitter. This router arrangement described in ***Figure 5.7.*** is consistent with the cabling drawn in ***Figure 5.5.*** When a ROUTER is fitted there is a standard cabling that connects the AUX output of SGU4 to the input of the ROUTER, This is because unlike the new amplifiers the ROUTER can not detect the presence of RF during the ‘cf’ routine. The solution is to connect as described above. The software will then automatically generate RF at the ROUTER input, switch this input to all four ROUTER outputs and hence detect which amplifiers if any are connected. In this way the cabling from the ROUTER outputs is determined. As long as the AUX output of SGU4 is connected to the ROUTER then the software will choose paths correctly.

```
RF cable connections (detected by 'confamp')
------------------------------------------------------------------
SGU1 NORM output -> input 1 of transmitter 2 (at TCP/IP address 149.236.99.251)
SGU1 AUX  output -> input 3 of transmitter 1 (at TCP/IP address 149.236.99.252)
SGU2 NORM output -> input 2 of transmitter 2 (at TCP/IP address 149.236.99.251)
SGU2 AUX  output -> open
SGU3 NORM output -> input 1 of transmitter 1 (at TCP/IP address 149.236.99.252)
SGU3 AUX  output -> input 3 of transmitter 2 (at TCP/IP address 149.236.99.251)
SGU4 NORM output -> input 2 of transmitter 1 (at TCP/IP address 149.236.99.252)
SGU4 AUX  output -> input of AQS Router 1/4
AQS Router 1/4 output 1 -> input 4 of transmitter 2 (at TCP/IP address 149.236.99.2
AQS Router 1/4 output 2 -> open
AQS Router 1/4 output 3 -> open
AQS Router 1/4 output 4 -> open
```

Figure 5.7. Example of SGU/2 Wiring Automatically Determined During the 'cf' Routine.

The reader should be aware that it is pointless trying to reconcile the SGU/2 hard wiring to the various transmitters with the EDSP display of same.Take the simple example of ***Figure 5.9.*** which displays the second SGU generating the observe 1H frequency and the first SGU generating the decouple 13C frequency. There is no way of telling from the edsp display alone which SGU/2 outputs will be used to carry the RF. The software will generate the signal at the output that is hardwired to the required amplifier.Given that each transmitter may have three inputs and many internal routing possibilities the operator should simply leave it to the software to switch the signals correctly.

It has already been mentioned that one new feature of the SGU/2 is the ability to deliver two frequencies at the one output, be it RF OUT or AUX OUT (see ***Figure 5.2.***)To use this the operator uses the 'add a logical channel' feature from within edsp. ***Figure 5.8.*** shows the result of this command applied to the second SGU.

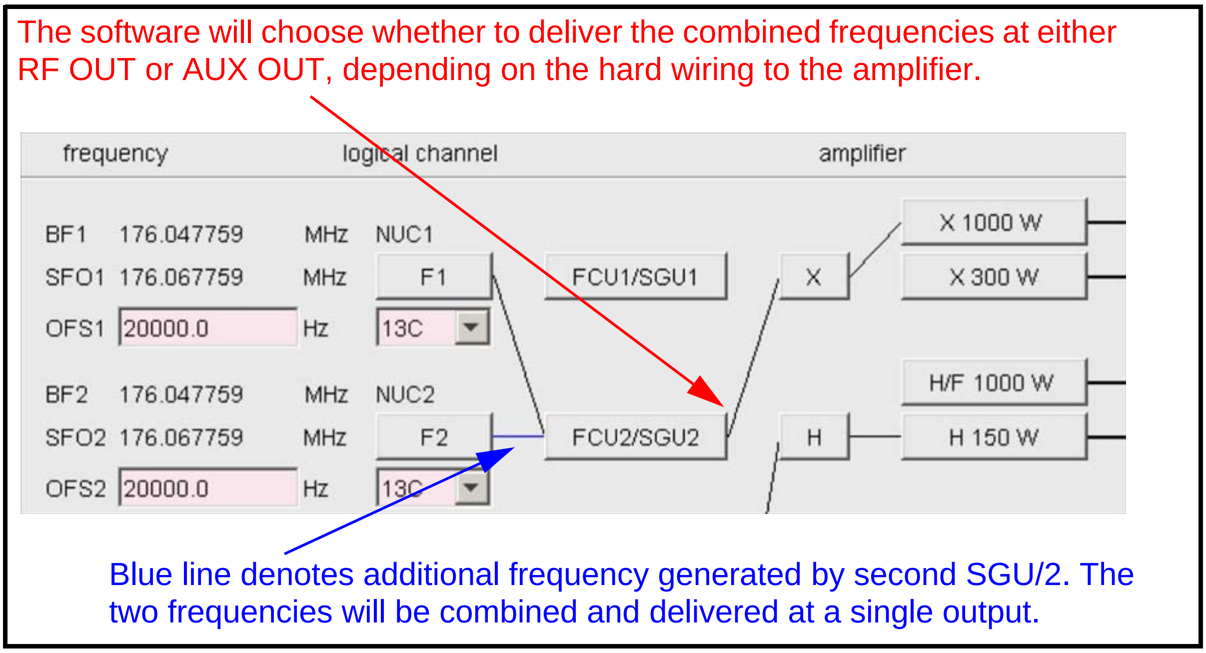


Figure 5.8. The edsp/edasp Display for 'adding a logical channel'

A special feature of all SGUs has always been the extra shielding provided by the unit casing. This is because of the importance of ensuring that the generated RF signals are free of distortion and interference. Bear in mind that any distortion present at the generation stage will be subsequently amplified by the transmitters.

Front Panel Connections *5.3.1*

It is instructive to describe the various signals that are accessible on the front panel (not forgetting of course that many of the digital signals are transmitted to the various units over the backplane. In the following description it may be helpful to refer to ***"SGU/2 Front Panel" on page 82***.

J1:REF IN

The various SGUs are synchronized by means of a 20 MHz clock signal (see ***Figure 5.4.*** and ***Figure 5.5.***). The clock signal originates on the REF unit. The synchronization is essential if the various RF channels are to be phase coherent etc. This input also contains various other frequencies used for on-board frequency generation.

J2: RF OUT

This is the analog RF output which eventually excites the sample and has a maximum output of $1V_{pp}$ at a power setting of -6db.This output is used by many service engineers to troubleshoot the instrument. Note that to capture this output on an oscilloscope pulse programs must use minimum delays as well as almost endless loops to maintain an output long enough to be examined.

J3:LO IN and J4 LO OUT

The only difference between the various SGUs in a system is that one SGU is designated as the OBS SGU and

- generates the DDS component of the LO frequency shift

- generates the receiver gating pulses used in the HPPR and the receiver itself
- generates a signal that instructs the ADC (which is constantly digitizing) to no longer discard the acquired data.

Any of the SGUs may be selected as the Observe SGU depending on the settings of the edsp/edasp menu. In this menu the logical channel F1 determines which SGU is assigned to generate the Observe nucleus frequency and the LO. For example if logical channel F1 is connected to the second SGU in the edsp/edasp menu, then the second SGU generates the OBS frequency and the LO frequency. The second SGU will always be steered by the second F-Controller. To enable all SGUs to generate the LO without the need for physical re-cabling, the LO signal is daisy chained through all SGUs via J3 and J4 as illustrated in ***Figure 5.10.***.

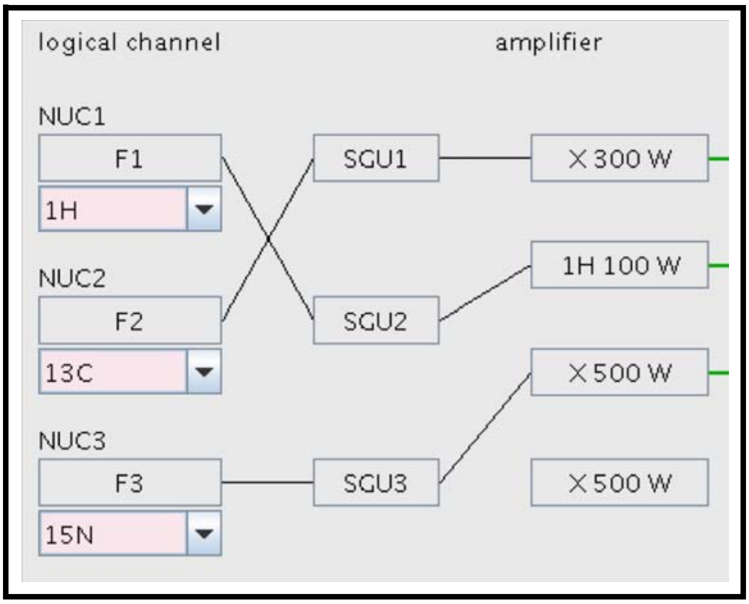


Figure 5.9. An edsp Display of Example Where the LO is Generated on the Second SGU.

J7: AUX OUT

This is the second RF output that can be used for general RF transmission. Its use on the first and second SGU is reserved however. The wobb signal used for tuning and matching the probe **always** comes from the AUX out of the second SGU since this is hardwired to the ‘Tuning in’ input of the preamplifier. On all other SGUs this AUX OUT output is the second RF output except for the case of the first SGU where it may be connected to the 2H-TX unit of the BSMS if present. (This signal was previously provided by the ROUTER but the new systems with IPSO do not require a ROUTER). Where a ROUTER1/4 is fitted the AUX OUT of the fourth SGU supplies the 2HTX if required.and the AUX OUT of the second SGU is simply hardwired to a transmitter (see ***Figure 5.5.***).

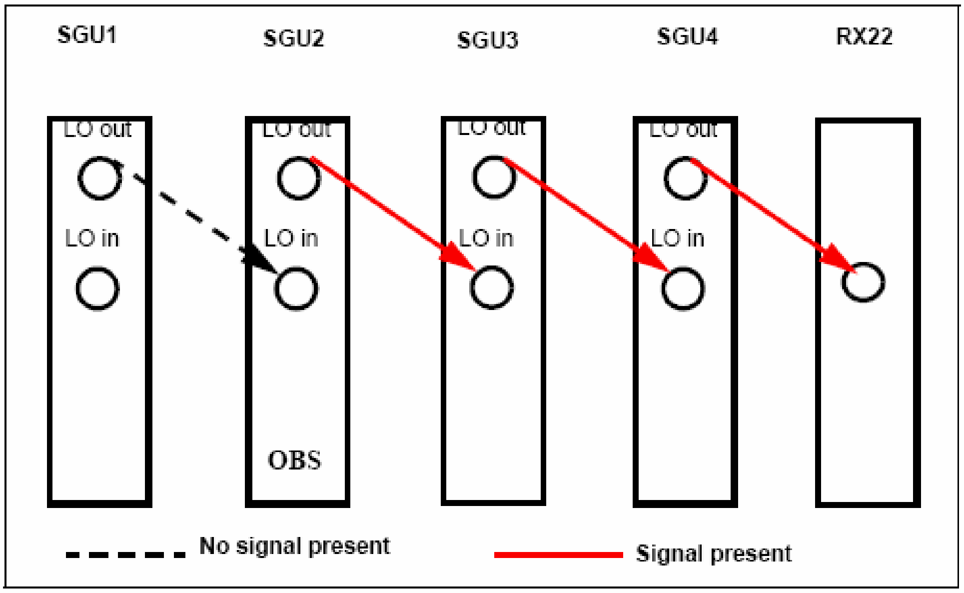


Figure 5.10. LO frequency Daisy Chain for Case where the Second SGU is the OBS SGU

SYNC LED: This is an indication that the various SGU/2s are synchronized. The LVDS link carries an 80 MHz clock signal to each SGU/2. (the F-Controller quadruples the 20 MHz signal from the REF to generate the 80 MHz) An on-board PLL (phase locked loop) tracks this signal. As long as the PLL remains locked the SGU/2 is synchronized and the LED remains lit.

DATA LED: This LED indicates data transfer over the LVDS. It can be used to determine which SGU/2s are involved in a particular acquisition.

LVDS link

Each SGU/2 has a dedicated hardwired LVDS link to an F-Controller. This high speed link transfers all NMR relevant real-time events in digital form to the corresponding SGU/2 (e.g. pulses, shapes, phase jumps, frequency shifts etc.). In this way the F-Controller steers the SGU/2 (see ***"Schematic of Principal Data Flow in F-Controller Operation." on page 60***).

Specifications 5.3.2

An appreciation of the SGU performance is best judged by considering some of its fundamental specifications. Ultimately the complexity of pulse sequences and the speed at which they can be implemented is limited to the performance of the SGU. Although, after examining the details below the reader may come to the conclusion that if anything, the SGUs are 'overspecced'. Bear in mind that the units are designed to accommodate future developments which will no doubt require ever more exacting performance. It is no coincidence that some of the specifications detailed below are identical to those of the various IPSO boards see ***"Comparison of the T-Controller Specifications with TCU3" on page 58***) since effectively the F-Controller is a standard type IPSO board and controls the timing of the SGU/2.The reader should note however that there is a difference between **setting** a new value for a parameter (e.g frequency setting) and having the new value actually implemented and stable (frequency switching). For example the time to **set** a frequency is specified below as 25 ns whereas the frequency **switching** time is specified as < 300 ns. The frequency setting refers to a digital operation that delivers and implements the new data whereas the switching time is a specification regarding how long it takes for the on-board DDS to actually change the signal itself and deliver the new frequency with a sufficiently stable phase. One feature of the new SGU/2 is that any number of parameters can be **set** simultaneously and setting always takes 25 ns regardless of whether a single or all parameters are to be set.

Timing:

Minimum output pulse duration: 25 ns.

Resolution: 12.5 ns

Pulse durations or lengths can thus be set to 25, 37.5, 50, 62.5, 75, 87.5 ns, etc.

The nanosecond resolution can be best appreciated when one considers that typical pulse lengths are of the order of microseconds.

Frequency:

Frequency Range: 3-1100 MHz. Three versions of the SGU/2 have been produced depending on the basic frequency of the spectrometer.

Frequency Stability: This is governed by the stability of a crystal oscillator whose drift is specified to 3 $x10^{-9}$/day and 1 $x10^{-8}$/year. This ensures that the frequency generation system will not drift appreciably over even extremely long periods of time.

Frequency Resolution: < 0.005 Hz.

Effectively this refers to the smallest change or increment in frequency that is possible. Bear in mind that the 0.005 Hz frequency resolution is associated with a base frequency that can be as high as 1100 MHz.

Frequency Setting Time: 25ns

Frequency Switching Time:< 300ns For frequency steps of less than 2.5 MHz.

For greater steps then the time required will be increased though will still be **<**2µs.

Phase:

Phase Resolution: < 0.006 °

Effectively this refers to the smallest change or increment in phase that is possible.

Phase Setting Time:25 ns

Phase Switching Time: < 300 ns.

Amplitude control: MOD and MULT

The signal amplitude control is achieved by means of a MOD signal which applies a shape or envelope to the signal and represents changes in amplitude **within** a pulse. Effectively the amplitude is **MOD**ulated and hence the signal name. The overall amplitude of the pulse is specified with a MULT signal. Effectively the modulated amplitude is **MULT**iplied by a fixed factor to vary the overall amplitude. Rectangular pulses only use the MULT signal while shaped pulses use a combination of MOD and MULT.

MOD range: 96 dB

This means that the variation in amplitude **within** a single pulse can be as much as 96 dB. Remember that the decibel is a logarithmic scale which is particularly

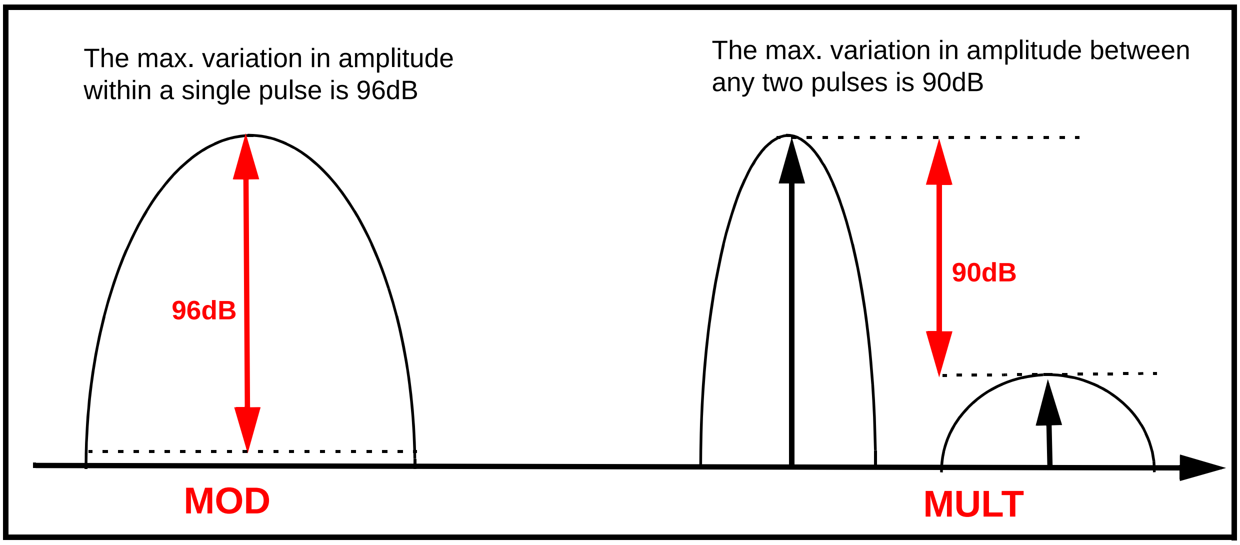


Figure 5.11. Schematic Representation of MOD and MULT Specifications (not to scale)

useful when dealing with a large range. For example a 96 dB variation represents a factor of 60,000 in amplitude.

MOD resolution: The modulation of an RF signal is done digitally with a resolution of 16 bits (65535 steps). The actual resolution of the RF pulse depends on the overall amplitude given by the MULT value.

MULT range: 90 dB

This means that the maximum variation in amplitude between any two pulses is 90 dB

MULT resolution: 0.1dB

Amplitude Setting Time: 25 ns

Amplitude Switching Time: 50 ns

Amplitude + phase switching time: 100 ns

Figure 5.12. displays some of the basic concepts of signal modulation. Clearly by assigning different amplitudes to the RF signal at fixed intervals the shape envelope can be defined. The resolution with which the shape can be controlled clearly depends on the minimum time interval and the minimum amplitude increment. For an SGU/2 the minimum time increment for an amplitude change is 25 ns which derives from the F-Controller spec. The minimum change in amplitude is < 0.005 dB. ***Figure 5.12.*** also shows how a variation in the timing clock (but still using the same amplitude setting sequence) will alter the shape.

Switching the Unit On and Off 5.4

The SGU/2 has no separate on/off switch, power on and off is controlled directly from the AQS mains switch. A power LED on the front panel will indicate that sufficient voltage to power the unit is available from the backplane.

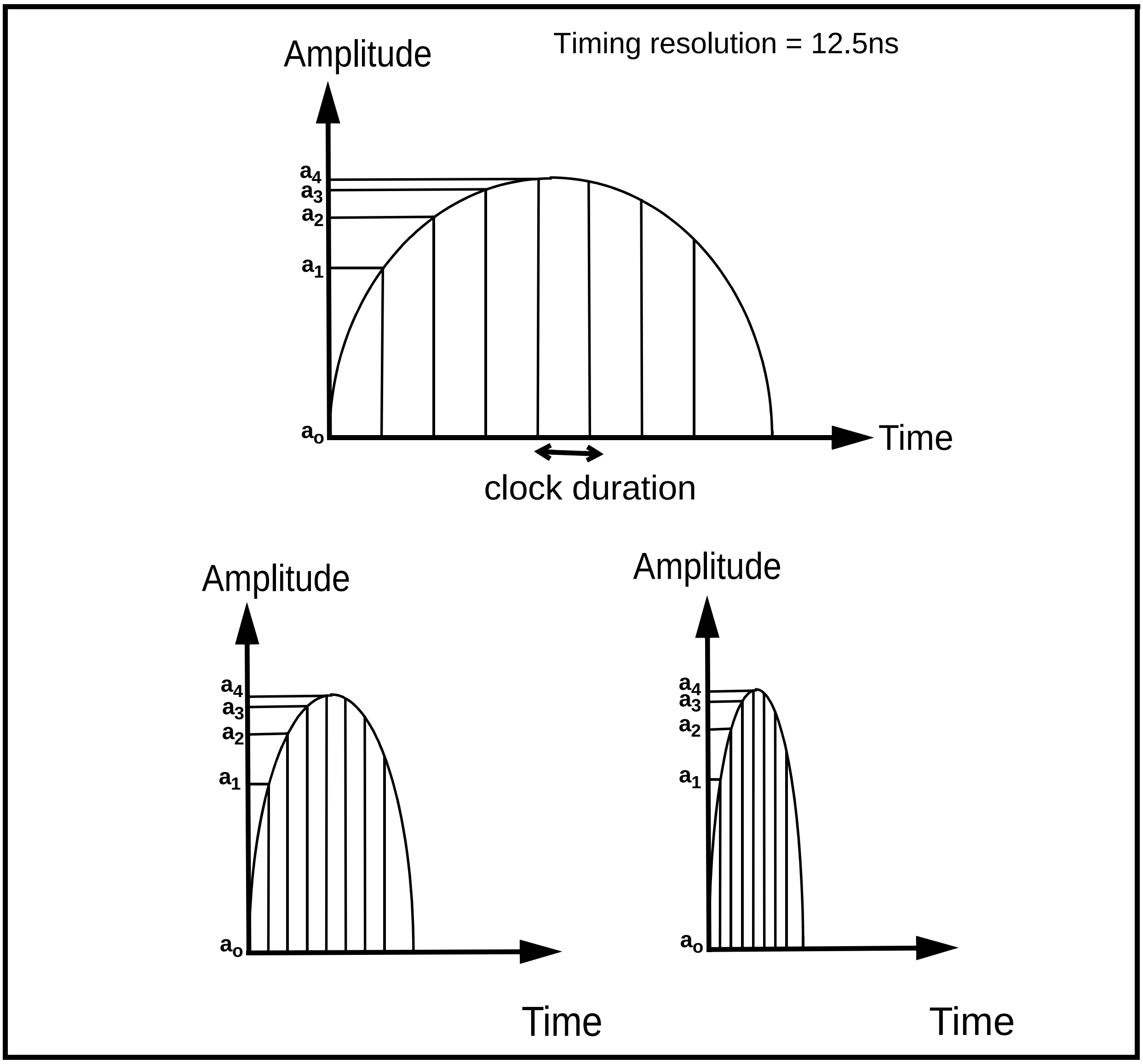


Figure 5.12. Amplitude Modulation: Same Shape with Three Different Clocks

Tips 'n' Tricks/Basic Troubleshooting 5.5

- Ensure that the LVDS cable from the F-Controller is properly connected. All cables are identical.
- All SGU/2s are identical and as such are fully interchangeable (trained service personnel only!). If units are swapped it is advisable to reconfigure the spectrometer with the 'cf' command to ensure that there are no inconsistencies in unit recognition see ***Figure 5.6.***.
- The power LED on the front panel indicates that **all** necessary voltages are present and at the correct level. If the voltage level drops then the LED will go out.
- Ensure that all SGUs are using the same firmware. This can be done using UNITOOL.

- The boot procedure of the SGUs is quite sophisticated. Even upon rebooting after a power off, the error LED on one or all of the SGUs may still light. It may be necessary to enter the command ‘ii’ (initialize interfaces) to clear this error.
- Do not open the SGU in the field.
- As described earlier, the SGU RF output should be an exact replica of the final RF signal albeit at a reduced amplitude. Since the max. output is $1V_{PP}$ these outputs present a useful and safe opportunity to check on an oscilloscope that signal is present.
- If cables are swapped they should be replaced with cables of the same length and identical construction.

SGU Unitool *5.5.1*

This section serves to introduce the reader to the various functions that are available via the Unitool which is a Bruker designed service tool. Although the features are board specific typically Unitool can be used to

- establish BIS type information regarding board type, part number, ECL, etc.
- establish the current firmware version
- download new firmware as required
- access board specific diagnostic info such as temperature, receiver gain etc.
- read and write data and in particular read and write to calibration data

The boards within the AQS that are directly accessible via Unitool are:

SGU, REF, RXAD, Internal amplifiers,

Unitool uses a RS485 protocol and the signals transmission takes place over the AQS backplane. Individual boards are accessed by entering that boards unique rack address. The reader is advised that certain functions within Unitool should be accessed by trained personnel only. In particular calibration data, firmware etc. can be corrupted by inexperienced users. As a rule operators are encouraged to seek information by other means (see uxnmr.info description below) before resorting to Unitool. For a more complete Unitool description see Chapter 9 of AQS with DRU Systems P/N Z31717 on the BASH CD.

The unique board address can be most easily established form the uxnmr.info file. ***Figure 5.6.*** shows a specific example with four SGU/2s having AQS Rack addresses (in hex) of 24, 25, 26, and 27 respectively which correspond to 36, 37, 38 and 39 in decimal. The first SGU/2 will always have an address = 36.

To start Unitool open a shell or the command prompt in the BRUKER Utilities folder when using Windows and enter

topspin -e UniTool

Figure 5.13. has been include to give the reader some idea of what SGU/2 facilities can be accessed via Unitool. The init feature will potentially prove useful if there are initialization errors that are not removed using the more conventional Topspin ‘ii’ command. You can easily check that you have addressed the correct board by checking which LEDS blink when a board is initialized via Unitool. The firmware download menu points are clearly seen in ***Figure 5.13.***. The board specific info is also displayed but as already discussed the operator is advised to check uxnmr.info first before resorting to Unitool.

.

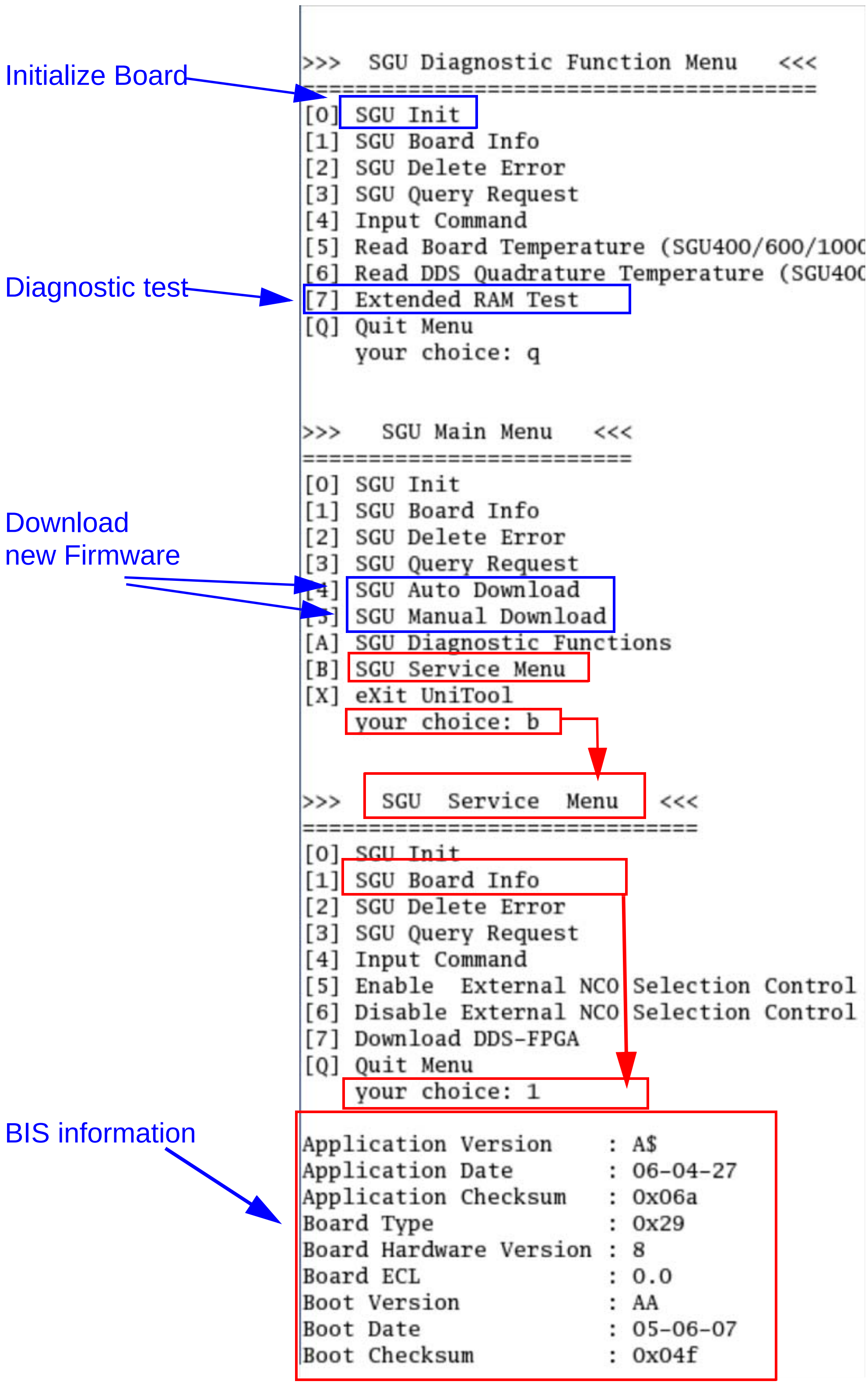


Figure 5.13. Some Features of the SGU Unitool Menu

Serial Number / ECL Level / Software Download 5.6

Three models of SGU/2 have been produced with upper frequency limits of 430 MHz, 643 MHz and 1072 MHz respectively. Key specifications and digital control remain the same for all models though clearly the SGU model fitted will depend on the spectrometer base frequency.

Through the ‘cf’ routine the DRU is used to establish the number and location of all installed SGUs. Each SGU in the AQS has a unique address by virtue of its physical position in the AQS rack and this is used to distinguish the various SGUs from each other. There are no jumpers that need to be set. SGUs with different ECLs can be supported within the one AQS rack.

The SGU/2 maintains a backup of the Firmware so even if a crash should occur during a software update it is a very simple matter to recover the previous version.

Other Required Signals / Units 5.7

The SGU/2 receives digital instructions from a corresponding F-Controller over the LVDS link which is clearly visible in the front panel as well as a clock signal from the REF unit at the front panel. All other signals are delivered over the backplane.

Option or Core Item 5.8

The SGU/2 is a core item though the number installed will depend on the number of channels since one SGU/2 can accommodate two frequency channels.

A MicroBay system will accommodate up to three SGUs.

A OneBay system with AQS IPSO will accommodate up to four SGUs (three if internal amplifiers are used).

A OneBay system with external IPSO will accommodate up to 6 SGUs.

A TwoBay system with external IPSO and second AQS rack could accommodate up to 8 SGUs.

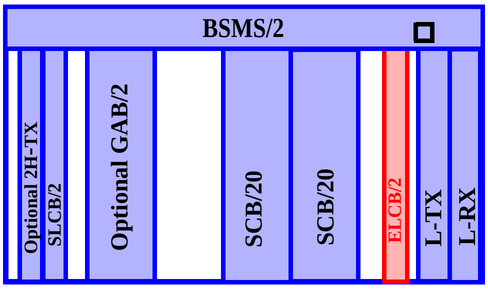
Further Information 5.9

See Chapter 10 of the manual entitled AQS Technical Manual with IPSO Systems, P/N: Z31810.

ELCB

6

Introduction 6.1



The Extended **L**ock **C**ontrol **B**oard is a relatively new BSMS/2 board which replaces the previous LCB and CPU/3 boards. In its role as CPU it controls the BSMS/2 and in particular the lock. It acts as master to all the BSMS/2 boards. It has Ethernet capability and also incorporates 2 TTY connectors for controlling external devices such as BACS, VTU, etc.The Ethernet capability has meant that Unitool is now redundant and has been replaced by a service web page.

Although the ELCB (as well as the GAB/2 and the SCB20) is a new board the BSMS/2 chassis has not changed.

Location and Photograph 6.2

The location of the ELCB can be seen in ***Figure 2.3.***.

General Information, Configuration and Function 6.3

The ELCB is best described in terms of its various functions which will now be detailed.

Lock system: In its most simplest form the L-TX and the L-RX constitute a separate standalone spectrometer based on analyzing the frequency of the NMR signal from deuterated solvents. The ELCB controls both boards. For example adjustments made by the operator to the lock power and lock gain are transmitted to the L-TX and L-RX respectively via the ELCB. A main function of the ELCB is to analyze the signals received from the L-RX and adjust the Ho current to maintain a constant field strength.

Master of BSMS/2: In this role the ELCB configures the various units in particular wrt firmware. The ELCB firmware controls the complete BSMS/2.

Ethernet link with the host workstation: There is a is a separate DSP Ethernet Board (DEB) plugged onto the ELCB base board. The Ethernet link facilitates the service web as well as general communication with the host workstation.

BSMS Log: All activities of the new BSMS/2 and the data exchange with the TopSpin application are logged by the ELCB software. This information is accessible via the service web page and, additionally, it is periodically transferred to the workstation in order to keep a detailed long term history for troubleshooting.

The new ELCB is fully compatible with the previous LCB and has the same or a better performance. All L-RX / L-TX board versions - including the 19F options - are supported by the new ELCB.

Front Panel Connections *6.3.1*

Power Leds: **Int,Ext,H0**

In operation all three power indicator LEDs should light.

State LEDs: Error and Ready: Self explanatory

SIG. When functioning properly this LED should blink once per second

LAN TX LED

Indicates transfer of Ethernet data outwards to the host workstation.

LAN RX LED

Indicates transfer of Ethernet data inwards from the host workstation.

LAN

This connection is used to transfer data to the host workstation.

10 MHz in: This is the basis of the clock signal used by the ELCB for all processing. Not surprisingly it originates on the REF unit.

Keyboard

Note that the keyboard is now only an optional extra. This RS485 connector for the Keyboard was previously located on the former CPU/3.

TTY1/TTY2 These RJ45 connectors are wired according to the 9 pin RS232 standard connector layout

RCP: RJ45 connector which is hardwired to the RJ45 connector on the IPSO front panel.These signals (the most important of which are LOCKHOLD and Homospoil described below) are generated by the IPSO T-Controller.

During a gradient pulse the field is (deliberately) distorted and the LOCKHOLD command temporarily turns off the lock.

The Homospoil signal provides a low current gradient in the Z axis by making an adjustment to the Z shim. It is sometimes viewed as a poor mans gradient.

The LED near the RCP connector is active when a RCP signal is actually received by the ELCB.

Specifications *6.3.2*

For the purposes of this manual there is no point in reproducing detailed specifications. The reader is referred to the manual entitled BSMS/2 Systems with ELCB P/N: Z108028 (correct). Suffice it to say the new ELCB has improved specifications compared to the previous LCB and CPU/3 units which it replaces.

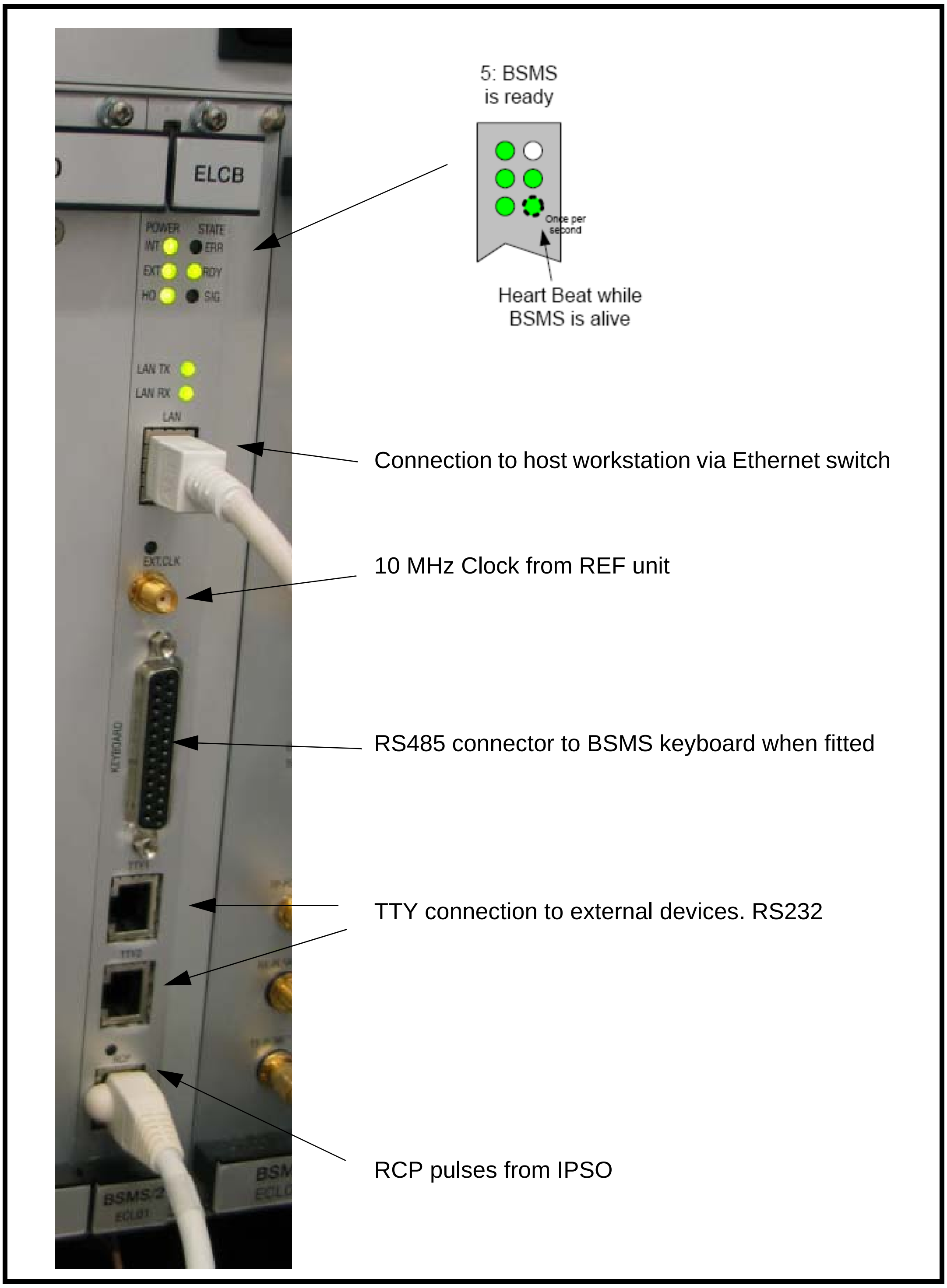


Figure 6.1. ELCB Front Panel

Switching the Unit On and Off 6.4

The ELCB has no separate power switch and is controlled by the BSMS main switch. Be aware however that the ELCB is also responsible for booting other units such as the GAB/2 and SCB/20.

For high field systems before switching off the BSMS the Shims should be ramped down softly. This is done via the service web by activating ‘Soft Shutdown Shims’ on the service page.

When the ramp down of the Shims is complete, the message

‘Shims shut down.’ Switch BSMS Power Off ‘appears, and the BSMS/2 can be switched off.

Tips ‘n’ Tricks/Basic Troubleshooting 6.5

In case of malfunction

1. Check the front panel display. If the power LEDs are not active then check the rear side of the BSMS/2 rack, where there are an additional two rows of LED‘s on the power supplies.
2. Check the BSMS service web see ***Figure 6.2.*** and ***Figure 6.3.***

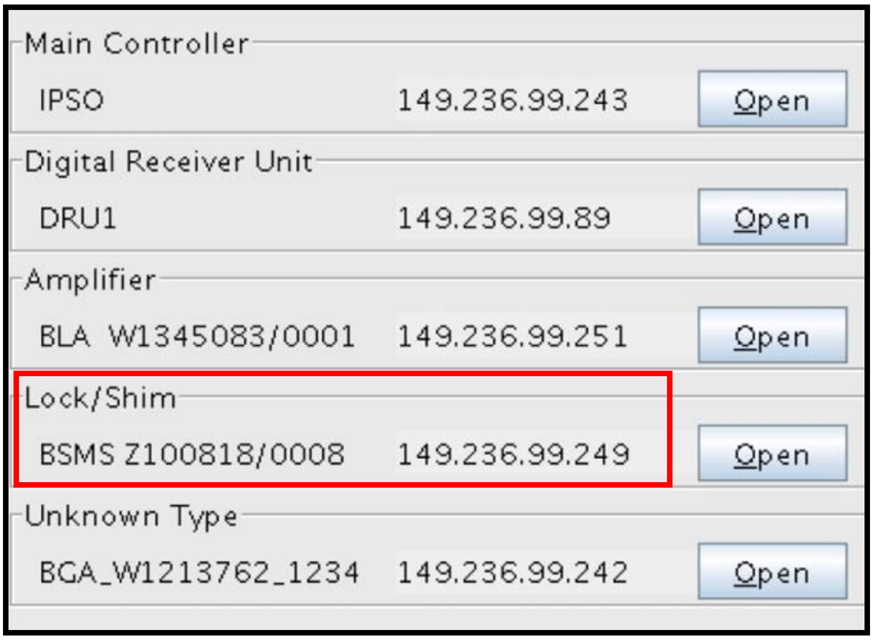


Figure 6.2. Use of ‘ha’ Command to Access the BSMS Service Web

Serial Number / ECL Level / Software Downloads 6.6

From the firmware perspective, the ELCB firmware controls the entire BSMS/2 Additionally any upgrades to SCB20 and the GAB/2 are implemented using two on-board FPGAs which are updated from the ELCB firmware.

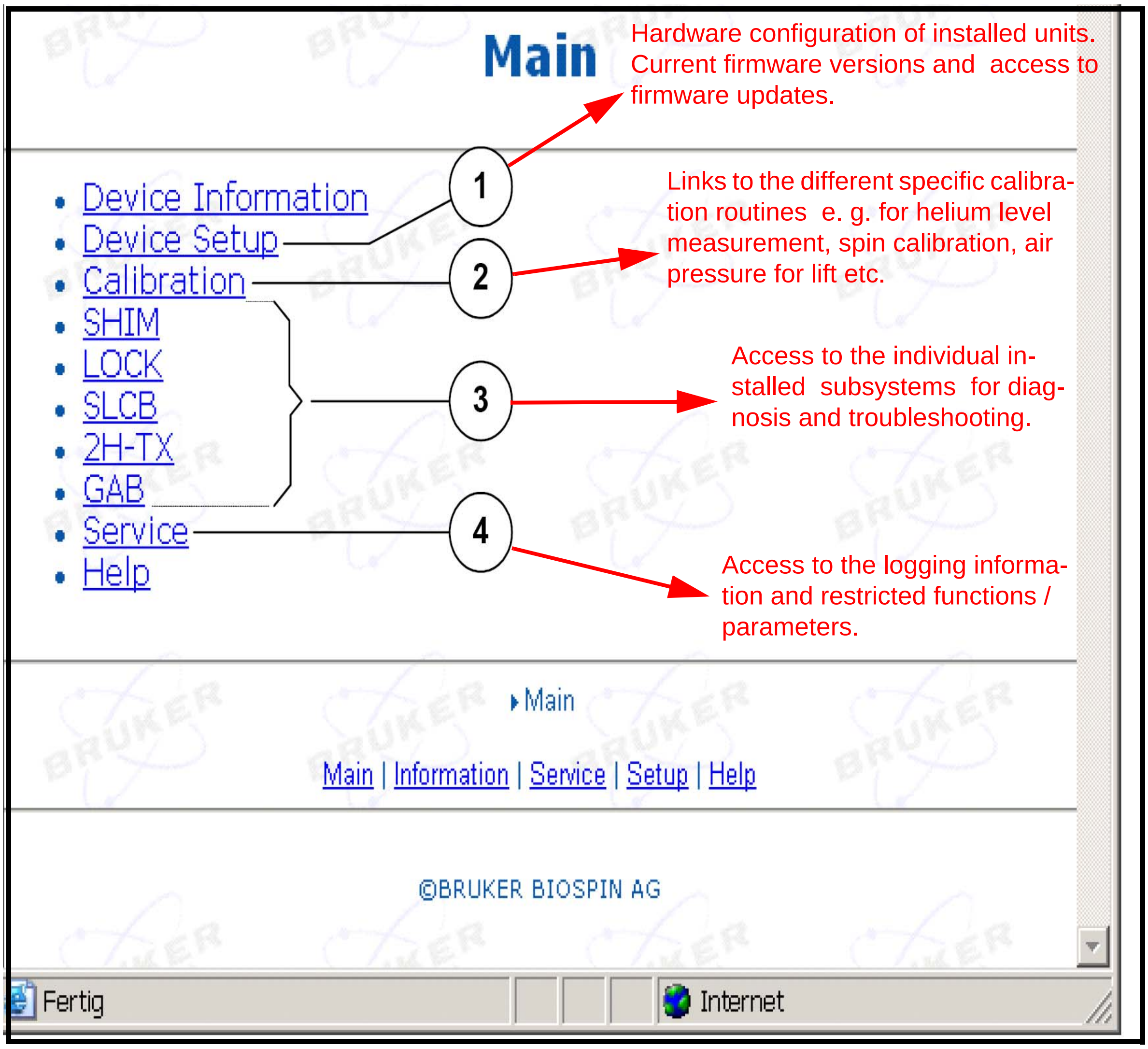


Figure 6.3. BSMS Service Web Overview

Other Interacting Signals and Units — *6.7*

The ELCB requires

- Power from the BSMS backplane
- 10 MHz from the REF
- Functioning Ethernet link with the NMR host workstation

Option or Core Item — *6.8*

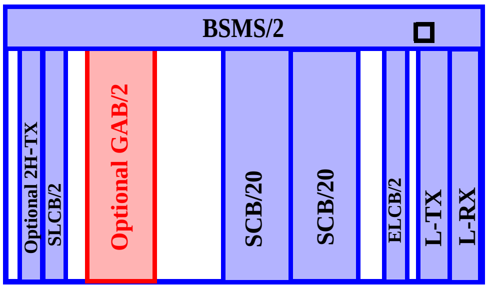
The ELCB is master of the BSMS/2 and hence is a core item.

Further Information *6.9*

BSMS/2 Systems with ELCB Technical Manual P/N: Z108028

GAB/2 7

Introduction 7.1



The GAB/2 (Gradient Amplifier Board) is an optional unit used for gradient spectroscopy (GRASP). Located within the BSMS/2 rack the GAB/2 generates gradient pulses which are effectively relatively large currents that are transmitted to the gradient coil of the probe.(To perform GRASP, the probe must be fitted with such a gradient coil). The GAB/2 receives digital inputs from the G-Controller (IPSO systems) and then generates the analog equivalent for transmission. The digital inputs which are effectively digital instructions are delivered in real-time via an LVDS link. Effectively the GAB/2 acts as a sophisticated high current DAC.

Location and Photograph 7.2

The GAB/2 is located in the BSMS/2 rack as displayed in ***Figure 2.3.***.

General Information, Configuration and Function 7.3

As mentioned in the introduction the GAB receives digital instructions from the G-Controller and generates the appropriate gradient currents. To some extent the GAB/2 is to a G-Controller what the SGU and amplifiers are to an F-Controller.

Although it is beyond the scope of this manual to explain the concept of gradient spectroscopy the following points need to be made.

There are two types of gradients, Z-Gradient (single axis) and XYZ-Gradient. GAB/2 supports Z-Gradient gradient spectroscopy.

Another GRASP issue is the requirement to compensate for the (unwanted) generation of eddy currents caused by the gradient pulses. To achieve this there has been a pre emphasis built into the new GAB/2.

In terms of control the GAB/2 has the ELCB as master. The GAB/2 is configured and initialized by the ELCB and all communication with the GAB/2 goes through the ELCB.

The GAB/2 is compatible with both, the former AVANCE II and the new IPSO based AVANCE III spectrometers.

LED display: Note that after a power up, all four LED‘s are on intermittently while data stored in a Flash memory within the board is downloaded.

POWER LED

When this LED is lit all the required power voltages are present and at the required level.

READY LED

Self explanatory.

ERROR LED

Note that this LED will light during a power up until the GAB/2 has been completely initialized by the ELCB. It should not remain on once initialized. In case of a genuine error on the GAB/2, an error message is transmitted to the Host workstation. As a result, the ERROR LED only lights for a short period even in the case of an error that persists.

PULSE LED

Lights during the transmission of a gradient pulse.

Continued lighting of this LED after power-up indicates a problem loading a valid file from the on-board Flash memory.

B_0 Output:

The function of gradient pulses is to modify the normally homogeneous magnetic field in a controlled way. In cases where the applied gradients cause the magnetic field strength to be shifted greatly a compensating current to readjust the B_o field can be applied via this output. This feature is used for imaging experiments (if at all) and the Bo output is typically connected to a BGU.

LVDS Links

This connection is made to either a G-Controller (AVANCE III) or GCU (AVANCE II). The spec of the data link is described in ***Table 7.1.***.

Monitor Output

A small fraction of the gradient pulse is tapped off and made available at this output for diagnostic purposes. Viewed on an oscilloscope this output can be used to monitor the amplitude and shape (or indeed the presence) of a gradient pulse. For each amp of current that appears at the main output 1 volt will be present at the monitor output. This connector is SMA type.

Gradient Output

This shielded cable carries the gradient currents to the probe.

.

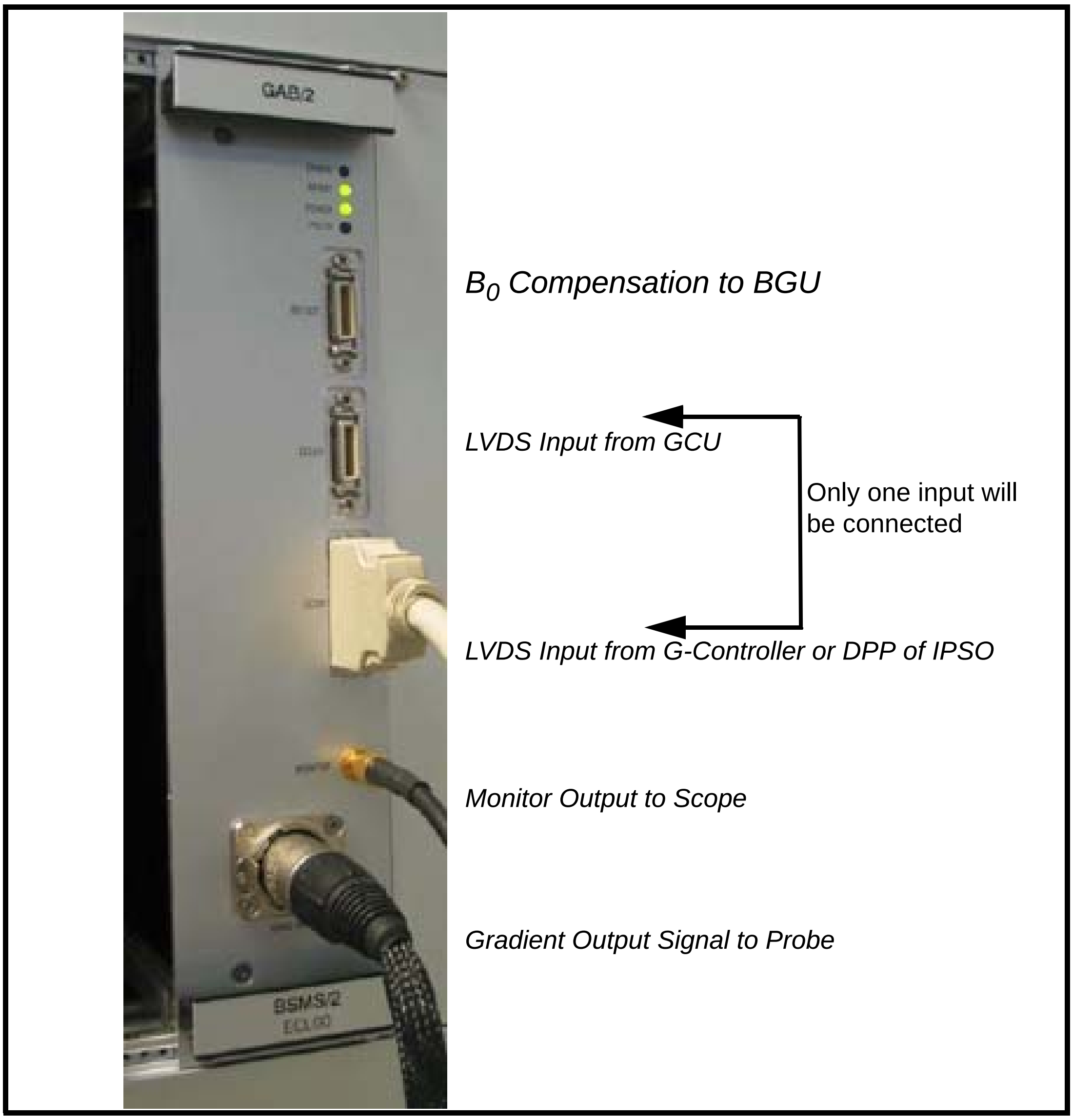


Figure 7.1. GAB/2 Front Panel

Specifications 7.3.2

Effectively the principal function of the GAB/2 is to generate stable currents at the required level. Hardly surprisingly then that many of the specifications listed in ***Table 7.1.*** deal with current.The GAB/2 can be viewed as a very powerful DAC receiving digital instructions from the G-Controller and as such there is a specified resolution associated with the DAC. Much of the GAB/2 technology is concerned with ensuring that the delivered current is independent of the resistance in cabling or any changes in the load caused by temperature effects at the probe etc.

Table 7.1. GAB/2 Specifications

Parameter	Value	Comment
Digital Input	LVDS 48 bit at 80 MHz. (IPSO) LVDS 28 bit at 20 MHz. (AVANCE II)	Depending on the connected gradient controller (G-Controller or GCU), the GAB/2 automatically selects the appropriate LVDS input. Shaped gradient pulses can be transmitted with a time resolution of up to one sample per microsecond
Max. Current	±10.0 Amp	This is Duty cycle limited. The max current is available during a maximum 50 ms every second (DC = 5%).
Max Voltage	± 33 Volts	Be aware that the gradient depends on the current flux and not the voltage.
Pulse Fall Time (90 - 10%)	10 µs	Characteristics of a good amplifier include the ability to produce pulses with steep rising and falling edges.
Resolution	20 bit	This resolution is only fully utilized when max current(±10.0 Amp) is applied.
Max.Pre-emphasis Current	±1.0 A	Pre-emphasis is used to compensate for residual eddy currents.
Residual current	±10.0 µA	The ideal residual current (no Gradient active) is zero as this effectively represents an unwanted distortion of the field

Switching the Unit On and Off 7.4

There is no separate on/off switch. Power is provided by the BSMS main switch. After power on, the ELCB carries out a software check on the GAB/2. Once this has been successfully completed the READY LED on the front panel will light.

Tips ‘n’ Tricks/Basic Troubleshooting 7.5

The ELCB effectively controls the GAB/2 and all diagnostic /service access is via the ELCB. In case of malfunction:

1. Check the LVDS cable from the controller.
2. Check that the ‘Ready’ and the ‘Power’ LEDs are lit and that the ‘Pulse’ LED flashes during gradient pulse.
3. Check In the Service Web that the state displayed is ‘operate’ and not set to ‘error’ (see ***Figure 7.2.***).
4. Check in the Service Web Log that the GAB/2 is actually receiving data from the G-Controller.Check also if the correct Gradient shape data have been transmitted.
5. Connect a scope to the ‘monitor’ output. Remember that 1 Volt at the monitor output corresponds to 1 Amp of Gradient current. To capture (trigger) the signal on the scope it will need to be repetitive. Be aware that although the moni-

tor output is greatly reduced the actual output will not and that this is normally connected to the probe. As such you are advised to use a no more than of 5 % of max power which should be easily observable on a scope adjusted to 100 mV/div.

6. The GAB/2 monitors the temperature and current internally. In case of excessive temperature or current, the GAB/2 is switched off, and an error message is sent to the TopSpin application as well as the BSMS Keyboard. (if fitted).
7. The GAB/2 has a Web service page for setup, calibration and diagnosis which can be accessed by entering the 'ha' command and clicking on BSMS (see ***Figure 6.2.***). Some of these Web functions are open for all users, other functions are reserved for service engineers - it is necessary to login and enter the required password before these functions can be accessed (description in the BSMS/2 Service Web chapter. Some of the features are summarized in ***Figure 7.2.***.
8. Offset Re-Calibration. Ideally when there is no gradient applied there should be zero current driven in the gradient coils During production, the GAB/2 is calibrated for minimum residual offset. This calibration is normally sufficient for a long time period and a wide temperature range. However, it may happen in rare circumstances that the dynamic offset compensator reaches its limitations. This is reported by an error message sent to the Top- Spin application and the BSMS Keyboard. It is then necessary to go to the page „main"-> „GAB"-> „GAB/2 Service Functionalism invoke the offset calibration again by depressing the button „Calibrating the row „Offset Calibration. The relevant service web page is shown in ***Figure 7.3.***.

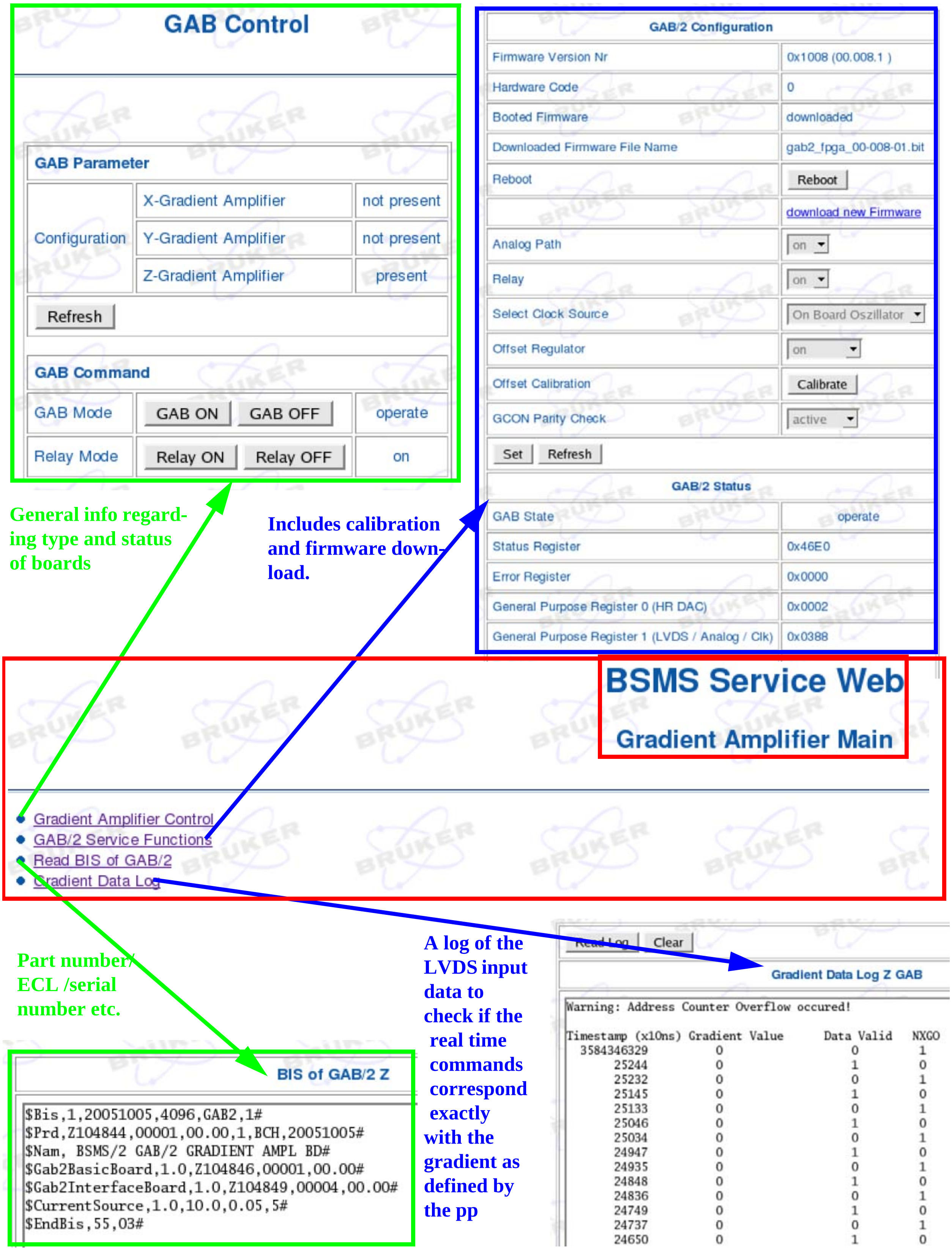


Figure 7.2. GAB/2 Service Web

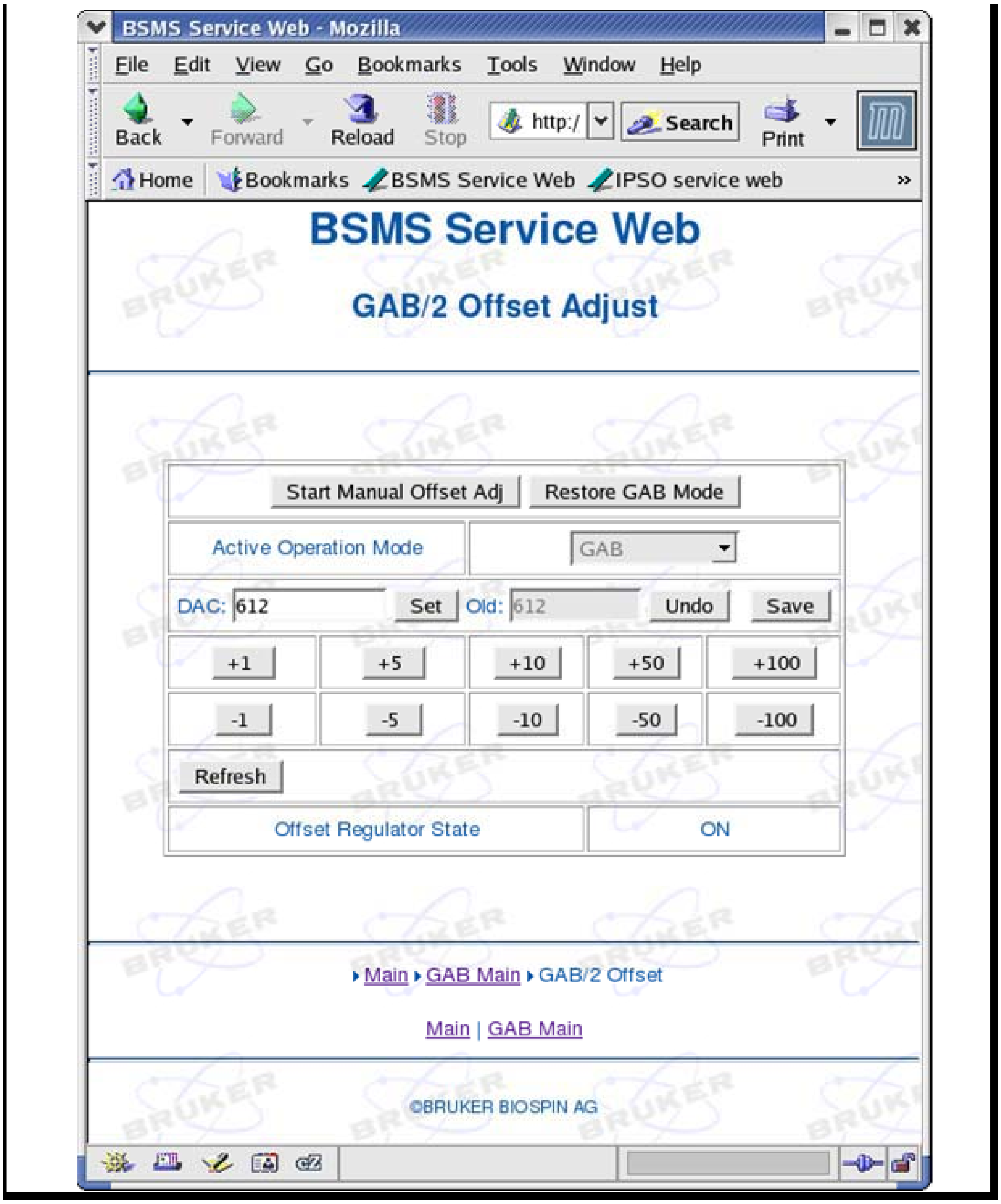


Figure 7.3. GAB/2 Offset Adjust

Serial Number / ECL Level / Software Downloads *7.6*

The uxnmr.info display gives no detailed information such as part number, ECL etc. regarding a specific GAB/2 unit. This info is available however through the service web (see ***Figure 7.2.***).

The GAB/2 has no specific firmware of its own. Any firmware upgrades are incorporated into the ELCB upgrades by means of an on-board FPGA.This GAB/2 FPGA is loaded each time the system boots.

Other Interacting Signals and Units 7.7

To function the GAB/2 requires

- Power from the BSMS backplane.
- Digital input from the G-Controller.
- Successful configuration by the ELCB.

Option or Core Item 7.8

Gradients are an optional extra.

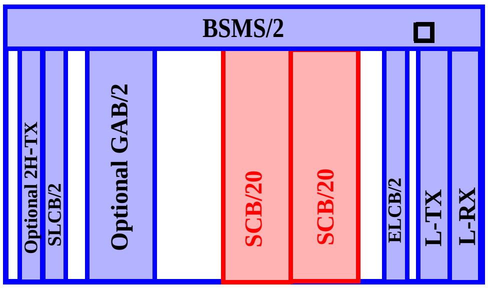
Further Information 7.9

BSMS Gradient Amplifier (GAB) User Manual (P/N Z31327).

SCB20

8

Introduction 8.1



The function of the **S**him **C**ontrol **B**oard is to supply and regulate the currents to the room temperature shims which are used to optimize the homogeneity of the magnetic field and as such have a significant bearing on the spectrometer resolution. Any unregulated variation in the value of these currents will degrade resolution with consequent effects such as line broadening etc.

There is now only one version of the SCB, the SCB20, which as the name suggests can supply currents for up to 20 shims. The SCB20 requires that the BSMS be fitted with an ELCB since this board is master of the SCB20 and effectively controls it.

There are only two possible configurations, either one or two SCB20s depending on the shim system. This is a simpler situation compared to earlier systems where various combinations of the SCB7 and the SCB13 were possible.

Among new advanced features of the BSMS20 are:

- greater number of current sources
- enhanced service access via the BSMS web page
- now easily upgradable in the field using the ELCB
- higher specifications wrt current regulation

The principal specifications for any shim systems are the current range, the resolution and the accuracy.

The SCB20 can supply up to 1 amp with 20 bit resolution and a max gain error of 0.5%. For further details on specifications see section ***8.3.2***.

The new SCB20 is compatible with all previous shim systems as far back as the BSN-18 though adapters will be required for older shim systems.

Location and Photograph 8.2

The position of the two units can be seen in ***"Front Panel of BSMS/2" on page 24***.

Where only one SCB20 is fitted (e.g. for a BOSS1 Shim System) it is recommended to plug the SCB20 into the leftmost of the two positions since this give access to a power supply of greater capacity. If there is a GAB or a GAB/2 in the same BSMS/2 rack, then this position is mandatory (due to a specific common ground connection) - an error message is generated if this condition is not fulfilled.

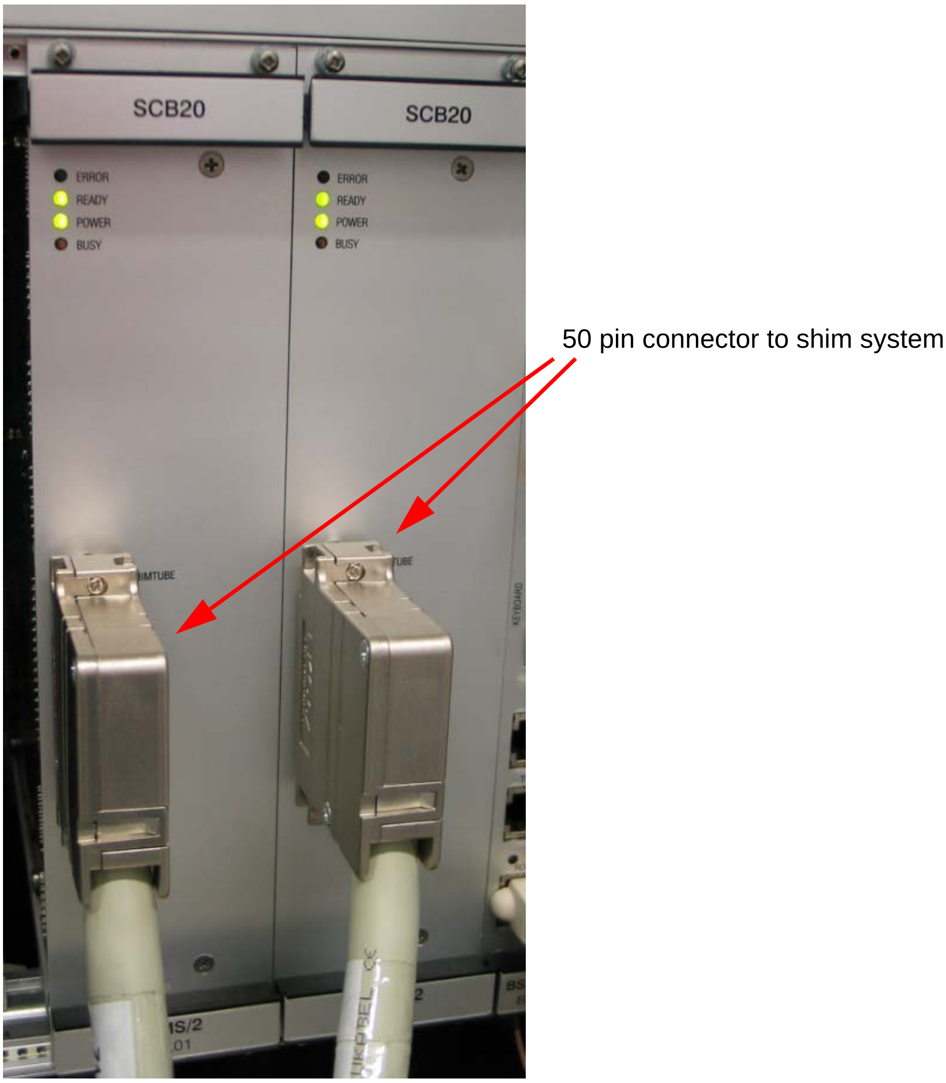


Figure 8.1. SCB20 Front Panel

General Information, Configuration and Function 8.3

Boss1 shim systems require one SCB20. Boss2/Boss3 systems requires a second SCB20.

The SCB20 is effectively under the complete control of the ELCB and performs relatively few functions independently. Its principal function is to provide the hardware to generate the shim currents. In conjunction with the ELCB it also

- supervises the magnitude of any currents to ensure that the shim system and magnet is protected at all times

- monitors the temperature inside the shim bore using a PT100(Platinum resistance temperature sensor).
- routes the H_0 current (which is actually generated by the ELCB) to the shim system.

If any errors are detected (such as excessive current or temperature the ELCB generates a command to immediately switch off the current sources.

Although the SCB20 actually generates the shim currents, the functions such as read/write shims and autoshim are all controlled by the ELCB. Any SCB20 intelligence is contained in the on board FPGA. The contents of the FPGA may be upgraded via the ELCB allowing for the possibility of changing SCB functions in the field.

Front Panel Connections *8.3.1*

The only connections are the physical connection to the shim systems. Adapters may be fitted depending on the specific type of shim system. Details of adapters can be found in the manual entitled ‘BSMS/2 Systems with ELCB’ (P/N: Z108028).

ERROR LED

This LED will light immediately after a Power ON until such time as the SCB20 has been initialized by the ELCB. Subsequent activation of this LED indicates that a genuine error has occurred such as excessive current or temperature. The current sources will have been shut down immediately.

READY LED

This LED is active as soon as the initial communication with the ELCB has been successfully completed and valid shim values have been are activated. Whenever a new set of shim values are being loaded it is temporarily turned off

POWER LED

Indicates that the SCB20 has power supply voltage at the correct level.

BUSY LED

Indicates communication with the ELCB (e.g. for initial setup, reading and writing of new shim values, etc.) Since all connected SCB20s are checked regularly by the ELCB software this LED will be regularly active.

Specifications *8.3.2*

Only the principal specifications are dealt with here.

Individual Current Range: $\pm$1.0 Amp (continuous)

Resolution: 20 Bit

Effectively the range of 2A ($\pm$1.0) is divided into 2^{20} -1 steps yielding a minimum step size

Minimum Step Size: 2 µA

Maximum Offset: $\pm$ 20 µA. This is the max deviation between the actual and desired current value. Since the shim currents are relative in their effect the actual value is of much less significance than the drift which is specified below.

Max. Gain Error: 0.5 %. (the shims currents are effectively current amplifiers and hence the gain specification)

Gain Drift: < 11 ppm / ^{o}C

Small Step (-100 to 100 mA) **Response time**: 20 ms

Large Step (-1 to 1 A) **Response time**: 160 ms

Switching the Unit On and Off *8.4*

The SCB20 has no separate on/off switch and is controlled by the BSMS/2 main switch. However for high field systems you are advised to carry out a soft shut down which effectively gradually reduces shim currents before a power down of the BSMS.

Tips ‘n’ Tricks/Basic Troubleshooting *8.5*

There is a complete sets of diagnostic functions (as well as the soft shut down feature mentioned above) accessible via the service web tool. These are comprehensively described in the manual entitled ‘BSMS/2 Systems with ELCB’ (P/N: Z108028) and these details will not be reproduced here. The reader is advised however that only service personnel should ever access calibration type data.

Serial Number / ECL Level / Software Downloads *8.6*

The location and number of installed SCB20s is automatically recognized by the ELCB during the CF routine (BSMS boot?). All the required software is contained within TopSpin. Any upgrades to the SCB20 would always take place via the ELCB.

Other Interacting Signals and Units *8.7*

The SCB20 receives power from the BSMS/2 power supplies. Communication with the ELCB over the BSMS backplane is also required.

Option or Core Item *8.8*

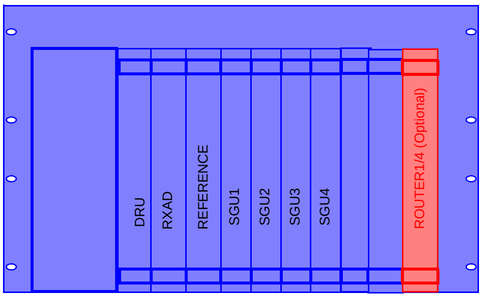
Each system must contain at least one SCB20. The second is optional.

Further Information *8.9*

BSMS/2 Systems with ELCB P/N: Z108028.

1/4 Router 9

Introduction 9.1



The new 1/4 ROUTER is optional and generally only fitted in

- systems configured with four or more SGU/2s
- systems that combine both high resolution and solids.

Unless the user requires an extremely high level of flexibility most high resolution IPSO systems will not require a 1/4 ROUTER. The name stems from the fact that it has one input and 4 main outputs in contrast to the original ROUTER which had 3 inputs and 5 outputs. With the original AVANCE, Routers were fitted as standard in most systems to give the user flexibility in terms of 'routing' RF signals through different paths. This was in systems where

- the SGU had a single RF output and was not configured to combine two different frequencies
- the external amplifiers had routing capability limited to the switching of the final output from which the amplified RF signal was to be transmitted.

The newly developed SGU/2 uses two RF outputs as standard as well as having the ability to combine two independently generated RF frequencies and deliver them simultaneously to either one of the two output. As mentioned in the SGU chapter to use this the operator simply uses the 'add a logical channel' feature from within edsp (see ***Figure 5.8.***). Furthermore the newest external amplifiers have internal mini-routers which allow comprehensive routing of the RF path as opposed to simply switching between the available outputs. These new features have resulted in the operator having much greater flexibility in terms of which signals are delivered to which amplifiers without any need for physical recabling. Furthermore the cabling arrangement from the various SGU/2 outputs to the amplifiers is made known to the software via the 'cf' routine. As a result the software and in particular the edsp/edasp menu can show all available routing possibilities as well as advising of any paths that are not physically connectable with an error message as in ***Figure 9.1.***.

A final development has allowed the operator to manually display the cabling from the final amplifier outputs to the HPPR2 in the edsp/edasp menu thus making the operator aware of any inappropriate signal paths. The net effect of these advances has been to make the traditional ROUTER redundant in most circumstances. Systems with internal amplifiers have hard-wired direct connections from the SGU to the amplifier and so these systems were never fitted with a ROUTER and this situation still pertains. The internal amplifiers already have built-in 'mini-routers' which allow the signal to be routed to the various amplifiers within the unit itself.

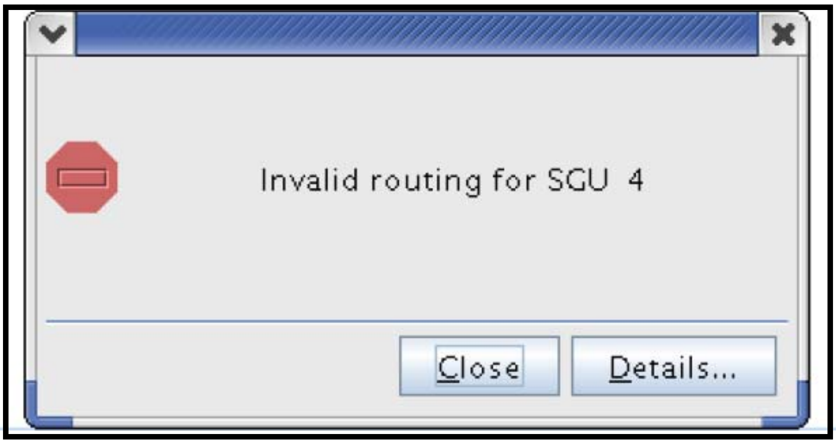


Figure 9.1. Error Message Arising from Unallowed Routing

Figure 9.2. shows the switching (i.e routing) capabilities of the 1/4 ROUTER. The single input can be routed to any one of the outputs leading to the possibility of inputting RF into any one of four possible amplifiers. Bear in mind also that the SGU/2's ability to combine signals means the two frequencies may be combined into one RF path. The various switching signals are generated by the DRU and delivered to the 1/4 ROUTER over the backplane.The block diagram also shows how the 1/4 ROUTER can be used to route the tune signal generated during the WOBB routine. This has the advantage of freeing up an SGU/2 output for transmitting during a standard acquisition when the WOBB routine is not running. The reader should note that the tune signal is not actually switched to the Tune output as shown in ***Figure 9.2.*** but is actually permanently available due to a directional coupler which taps off a small percentage of the RF signal.

.

Location and Photograph 9.2

The 1/4 ROUTER is located in the AQS/3 rack to the right of the SGU/2s.

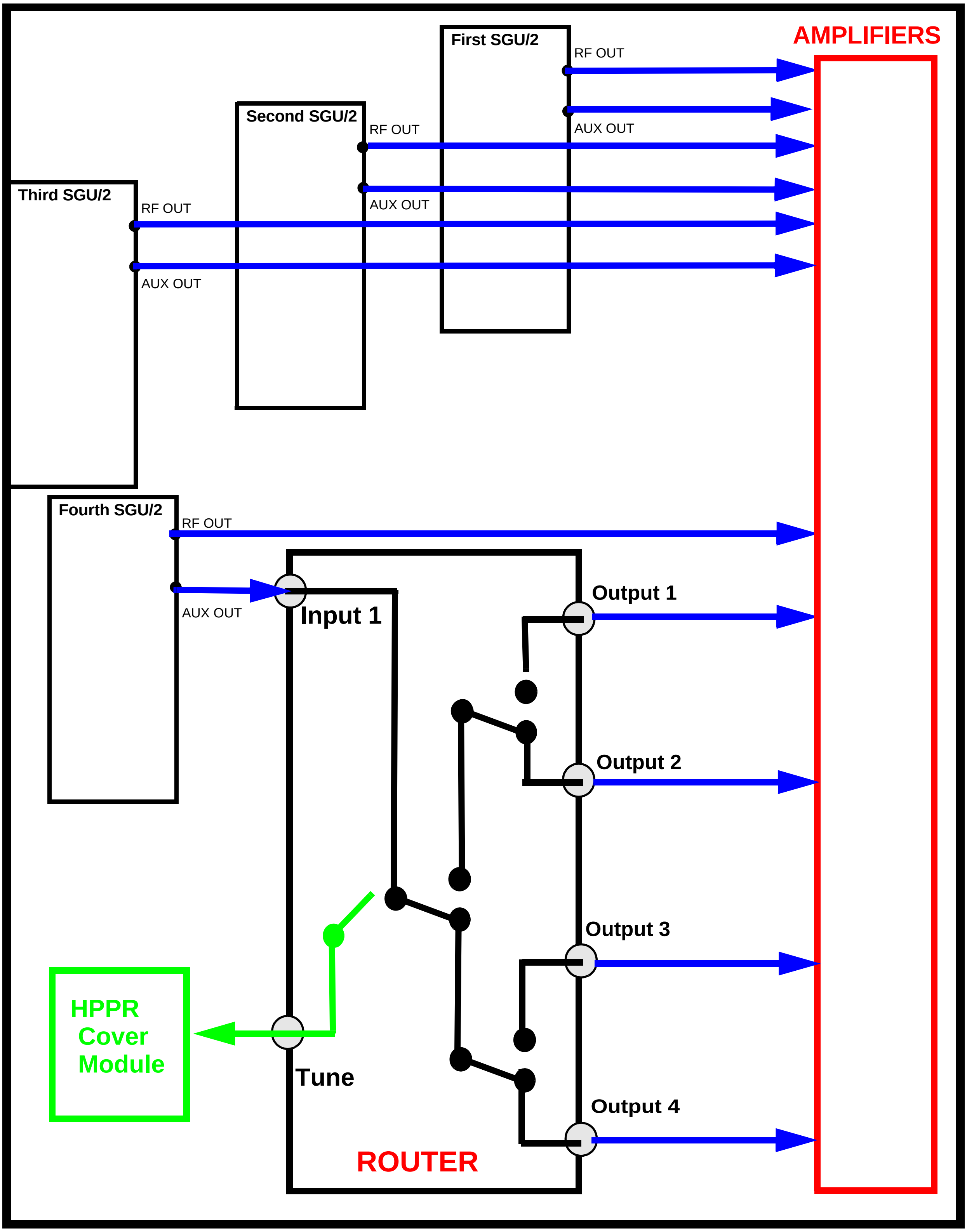


Figure 9.2. Typical Arrangement for 1/4 ROUTER

.

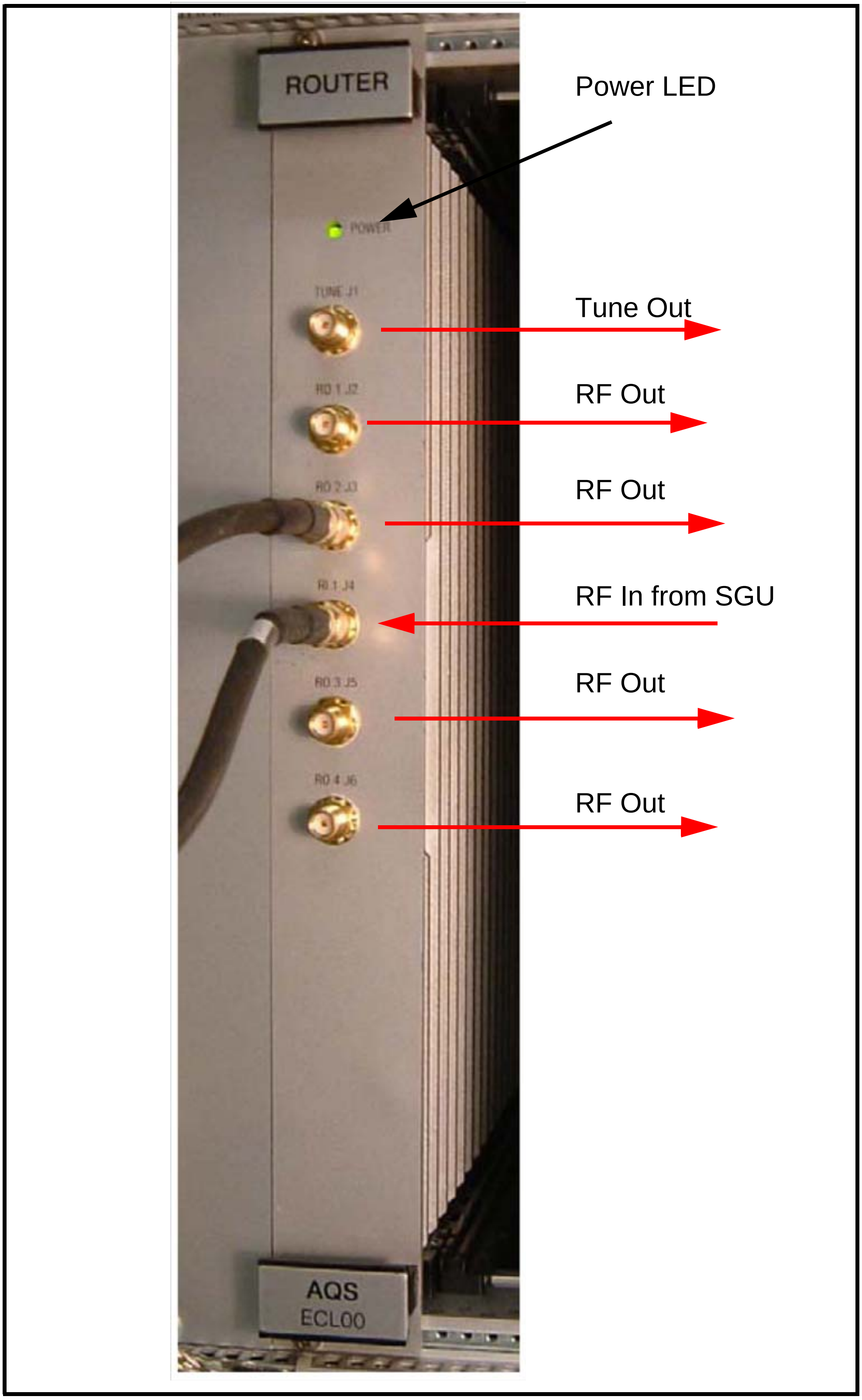


Figure 9.3. 1/4 ROUTER Front Panel

General Information, Configuration and Function 9.3

The 1/4 ROUTER is by Bruker standards a relatively unsophisticated unit. It simply responds to the switching signals generated by the DRU which enter the 1/4 ROUTER via the backplane. The unit requires no firmware download and can not be accessed by Unitool (there is no need as there is no information stored on board, no calibration data etc.). The upper section of ***Figure 9.4.*** shows a 1/4 ROUTER occupying slot 6. Note that there is no information regarding Firmware Version, part number, ECL etc. The lower excerpt of ***Figure 9.4.*** shows the cabling arrangement that has been automatically detected. The input is provided by the AUX output of the fourth SGU/2 and in this example only one of the outputs is connected to a transmitter. The reader should note that ROUTER outputs connected to non standard amplifiers or amplifiers such as the 2H-TX of the BSMS (see ***Figure 5.5.***) will not be automatically detected and will be recorded as ‘open’ in the uxnmr.info file.

Reference to the edsp/edasp window will show no evidence of any 1/4 ROUTER switching. This is because the routing is done automatically once the logical channel and amplifier have been selected by the operator.

How a particular signal is routed is determined by the setting of various control signals. These are controlled by software parameters which are automatically set depending on the signal paths chosen by the operator from the ‘edsp/edasp’ menu. The values are normally hidden from the user but can be checked by clicking ‘PARAM’ at the base of the edasp/edsp menu.

Table 9.1. Comparison of Routers

One input / 4 outputs	3 inputs / 5 outputs
Dedicated Tune output	NA
Compatible with AQS2/3 rack	Required rear Adapter for AQS2
No combining / this takes place within the SGU/2	Has combining role
Front panel Power supply LED	Not fitted

```
AQS-Rack: connected to 149.236.99.89:/dev/tty10
  _Slot_ SBSB _____________________Board_____________________
  Number Addr Type HW-VS FW-VS ID  ECL Name    Description
  ------------------------------------------------------------
     0   0x10 0x42   0x2    AO  R  1.1 REC-1   AQS RXAD600 Z102117/96 ECL 1.1
     1   0x34 0xc0   0x1        X  0.4 REF-1   REF-600 Reference Board for AQS
     2   0x24 0x29   0x8    A$  S  1.0 SGU-1   AQS SGU/2 1000 Z103082/00092 ECL
     3   0x25 0x29   0x8    A$  S  0.0 SGU-2   AQS SGU/2 1000 Z103082/00027 ECL
     4   0x26 0x29   0x8    A$  S  0.0 SGU-3   AQS SGU/2 1000 Z103082/00024 ECL
     5   0x27 0x29   0x8    A$  S  0.0 SGU-4   AQS SGU/2 1000 Z103082/00029 ECL
     6   0x3c 0xc5   0x1        Y  0.0 ROUT-1  AQS Router 1/4
     7   0x21 0xcf     0        P  0.0 PSD-1
     8   0x20  0x7     0        B      MASTER  AQS Rack Master

Router: 1 AQS Router 1/4
```

```
RF cable connections (detected by 'confamp')
----------------------------------------------------------------------
SGU1 NORM output -> input 1 of transmitter 2 (at TCP/IP address 149.236.99.251
SGU1 AUX  output -> input 3 of transmitter 1 (at TCP/IP address 149.236.99.252
SGU2 NORM output -> input 2 of transmitter 2 (at TCP/IP address 149.236.99.251
SGU2 AUX  output -> open
SGU3 NORM output -> input 1 of transmitter 1 (at TCP/IP address 149.236.99.252
SGU3 AUX  output -> input 3 of transmitter 2 (at TCP/IP address 149.236.99.251
SGU4 NORM output -> input 2 of transmitter 1 (at TCP/IP address 149.236.99.252
SGU4 AUX  output -> input of AQS Router 1/4
AQS Router 1/4 output 1 -> input 4 of transmitter 2 (at TCP/IP address 149.236
AQS Router 1/4 output 2 -> open
AQS Router 1/4 output 3 -> open
AQS Router 1/4 output 4 -> open
```

Figure 9.4. Two excerpts from the same uxnmr.info file showing details of the 1/4 ROUTER

Front Panel Connections 9.4

The front panel (***Figure 9.3.***) shows clearly the RF input from the SGU/2 and the array of four possible outputs.Note that unused output should be terminated with a 50 Ohm connector.

Switching the Unit On and Off 9.5

The unit has no separate on/off switch, power on and off is controlled directly from the AQS mains switch.

Tips ‘n’ Tricks/Basic Troubleshooting 9.6

- The ROUTER has almost no intelligence and hence there is no Unitool access, web service page etc.
- The 1/4 ROUTER is provided to enable the operator to have maximum flexibility in choosing signal paths. The 1/4 ROUTER can however be bypassed if it is suspected that it is faulty. Simply connect the SGU/2 output directly to the amplifier input (trained service personnel only!). Needless to say this is then a hardwired connection removing any possibility of routing the signal within the edsp/edasp window.
- Check the power supply indicator LED on the front panel.
- Check that the unit has been correctly recognised by the ‘cf’ routine (see ***Figure 9.4.***).

Serial Number / ECL Level / Software Download 9.7

To date only one version of the 1/4 Router has been made. Given the relative simplicity of the unit there is little possibility of significant engineering changes. No software download is required.

The original (3 input / 5 output) ROUTERS are not compatible with the IPSO spectrometer.

Other Required Signals / Units 9.8

Power is delivered from the backplane. The RF signals are not blanked in the ROUTER so all that is required is the control signals generated by the DRU and delivered via the AQS backplane.

Option or Core Item 9.9

The 1/4 ROUTER is optional and usually only fitted in systems configured with four or more SGU/2s or systems that combine both high resolution and solids.

Systems fitted with internal amplifiers do not require a ROUTER as this function is provided by using the built-in mini-routers.

External Amplifiers 10

Introduction 10.1

The principal function of all Bruker amplifiers is to apply a fixed gain to the RF signal generated by the SGU/2. External amplifiers can easily be distinguished from internal amplifiers in that unlike internal amplifiers they are not located within the AQS rack. As such they receive no signals over the AQS backplane. Of all the units within the AVANCE spectrometer they are possibly the easiest to troubleshoot since so many of the control signals are accessible at the front panel.

Other general distinguishing features of external amplifiers are that they:

- Have their own power supply powered from the mains.
- Have typically greater output power than the internal amplifiers.
- Have more sophisticated RF detection and protection circuitry.
- Are typically fitted to higher field systems compared to the internal amplifiers.

The newest developed external amplifiers have the following features:

- Ethernet capability (replacing the RS485 protocol previously used)
- Directional couplers that enable the software to automatically recognize which SGU/2 outputs are connected to which transmitter housing inputs.
- Greater routing/switching capability. New internal minirouters allow for enhanced routing/combining possibilities. The previous ‘switchbox’ (aka swibox) which allowed switching between the final outputs is no longer necessary and now only comes as an optional extra in the form of an external qnp accessory.

In this respect the concept of internal ‘minirouters’ first introduced with the internal amplifiers has been incorporated into the external amplifiers albeit in a more expanded form. Such has been the advance in internal routing that the external ROUTER is now only fitted to spectrometer configurations in special circumstances.

There is no ‘standard’ configuration of external amplifiers though there are obviously recommended configurations based primarily on the number of channels and of course typical customer requirements. The spectrometer has been designed to enable users to customize their system with the most suitable arrangement of amplifiers. There is also heavy emphasis on switching circuitry within the amplifiers as mentioned above to enable operators carry out a variety of popular experiments without the need to make any alterations to the cabling.

The principle function of the amplifiers is to increase the amplitude of the RF input signal from the SGU/2 to the appropriate level so as to optimally stimulate the NMR sample. The gain of a particular amplifier is fixed so that amplitude regulation is achieved by controlling the output of the SGU/2 prior to the amplifiers.

The maximum output of the SGU/2s are designed to be of the order of 1Volt peak to peak ($1V_{pp}$) in amplitude. For power level settings other than minus 6dB the SGU/2 output is attenuated accordingly. Reduced power levels are achieved by

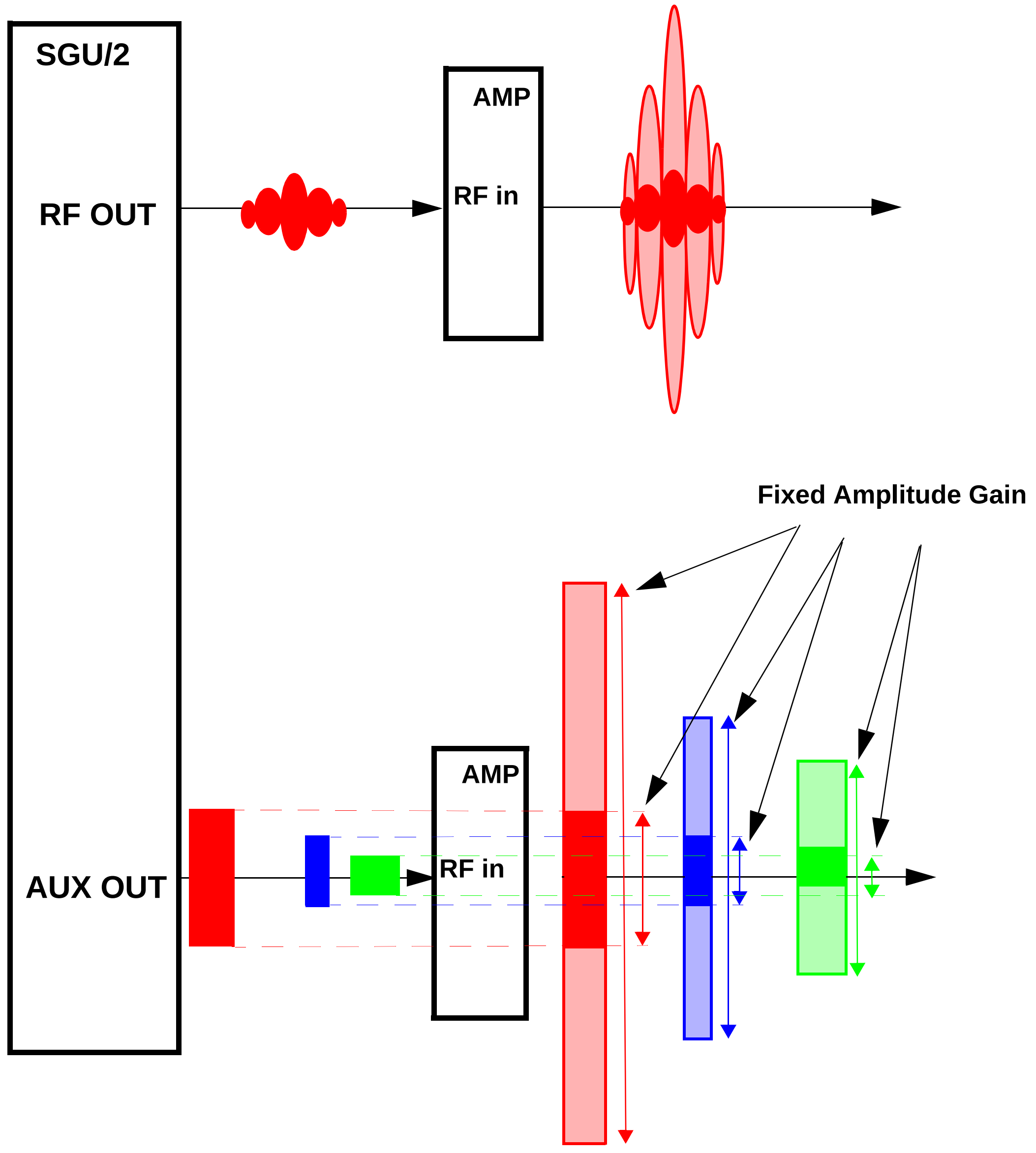


Figure 10.1. Amplitude Control takes place on the SGU/2. The Amplifiers provide a fixed gain. (diagram not to scale)

increasing the attenuation level (measured in dB) applied to the SGU/2 output within the range of minus 6dB to 120 dB see ***Figure 10.2.***

Different amplifiers will have different gains so that the amplitude of the final output for the same 'pl' value will differ for different amplifier types. Furthermore the gain of any amplifying circuit will always have a frequency dependency. For this reason the output power is usually specified as a minimum level for a particular frequency or frequency range.

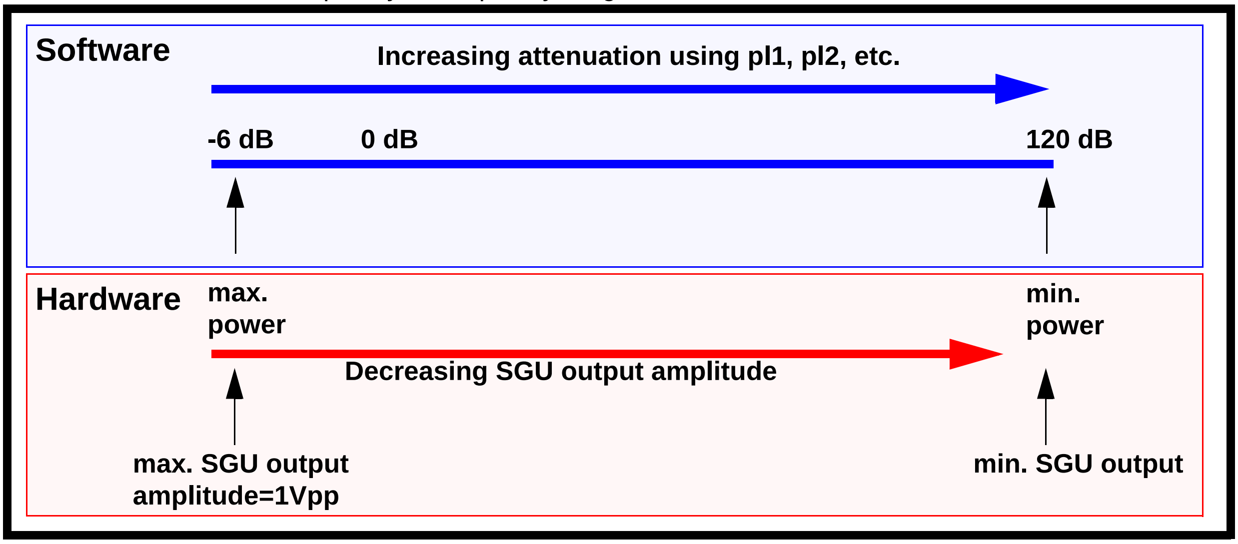


Figure 10.2. Relationship Between Hardware Output Power and Software Attenuation

Location and Photograph 10.2

The external amplifiers are standalone units and there is some degree of flexibility regarding their location inside the cabinet (see ***Figure 2.2.***). Although there will be reduced shielding from noise, it is also possible to mount additional amplifiers outside the system cabinet altogether.

General Information, Configuration and Function 10.3

Amplifiers are most easily categorized in terms of frequency. The two main types are **proton (^{1}H)** and **broadband (BB or X)** amplifiers. Dedicated proton amplifiers are specifically designed to be suitable for the relatively high frequencies associated with proton signals. Due to the proximity of the frequencies these amplifiers also serve to amplify ^{19}F frequencies and are sometimes referred to as ^{1}H/^{19}F amplifiers.The second principal category, BB or X amplifiers, are designed for all other frequencies up to ^{31}P. These frequencies are significantly lower than the equivalent proton frequencies.

In more recent times specialized 2H (deuterium) amplifiers have also been developed. One such low power (20W) deuterium amplifier is incorporated into the BSMS as an optional extra. Another type of deuterium amplifier with additional power of 80W is also an optional extra and is similar to more standard internal amplifiers in that it resides within the AQS rack.Finally a new BLAXH2H which is a conventional external amplifier with a dedicated deuterium channel has recently been introduced.

edsp/edasp Control *10.3.1*

Control of the amplifiers in terms of choosing a particular RF signal path is achieved using the edsp/edasp menu. In this menu the various amplifiers may be selected by the operator. Customising the edsp/edasp display to match the particular amplifier arrangement is automatic as long as the “cf” routine has been successful. During this routine several operations take place

- the number and type of amplifiers in the system is determined via the Ethernet connection
- which amplifier inputs are connected to which SGU/2 outputs is established by sending RF and blanking signals over all possible routes
- the operator is offered the opportunity to manually create a display of the existing hardwired cabling from the transmitter outputs to the various HPPR modules.Note that this feature is available for internal amplifiers as well as external amplifiers.

This last operation (the result of which is shown in ***Figure 10.3.***) is to help ensure that the operator does not route RF signal to an amplifier output that has no cable connection to a HPPR module or probe. For example the operator needs to be aware that one of the X500W amplifiers in ***Figure 10.3.*** is not connected to a HPPR module.

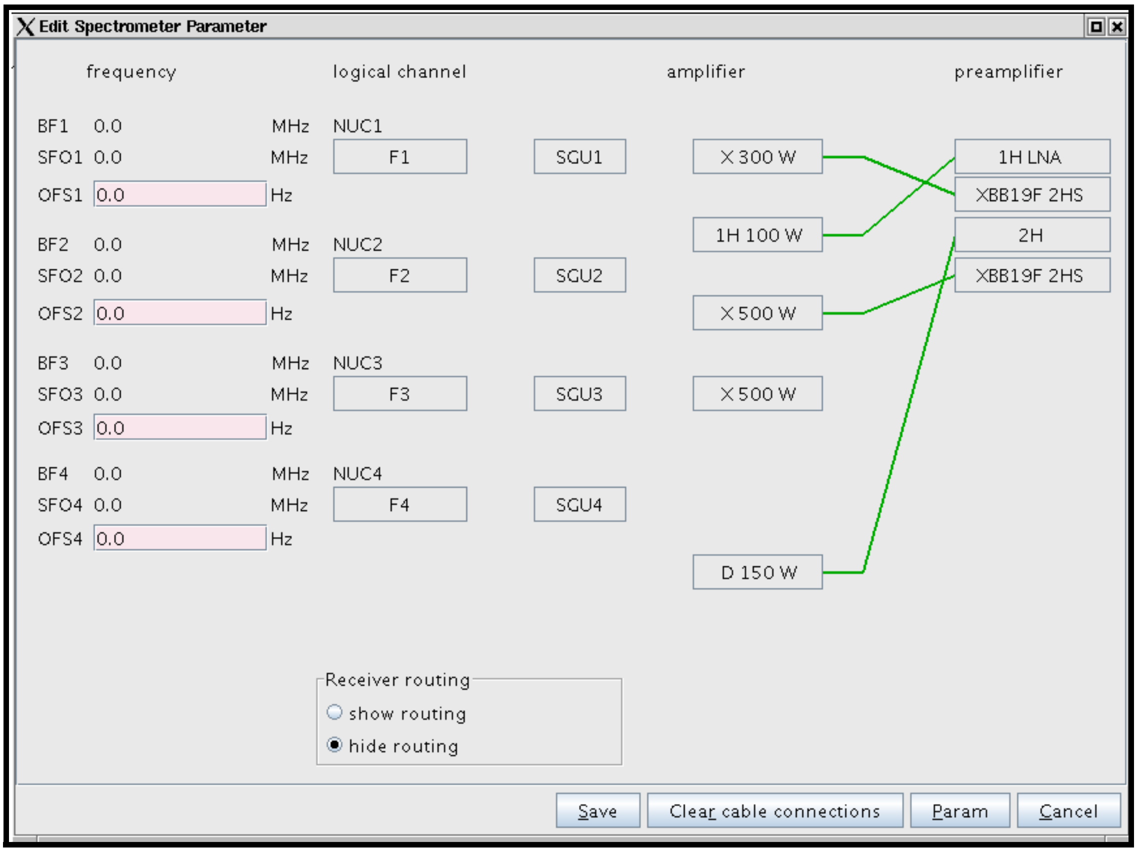


Figure 10.3. EDSP window showing cabling connections in green

Through the ‘cf’ routine the edsp/edasp display is customized for every system so that it corresponds to that particular spectrometer configuration. The operator can then choose any particular amplifier using the edsp/edasp menu and the software will automatically set the correct signal paths. What actually happens is that the software ensures that the appropriate SGU output is used to transmit the RF.

Note that there is no direct correlation between the individual amplifiers within a particular transmitter housing and the order in which they are displayed in edsp/edasp window. This is demonstrated in ***Figure 10.4.*** where the three amplifiers in blue rectangles actually reside within the one unit the BLAXH2H 300/100/150 transmitter housing.

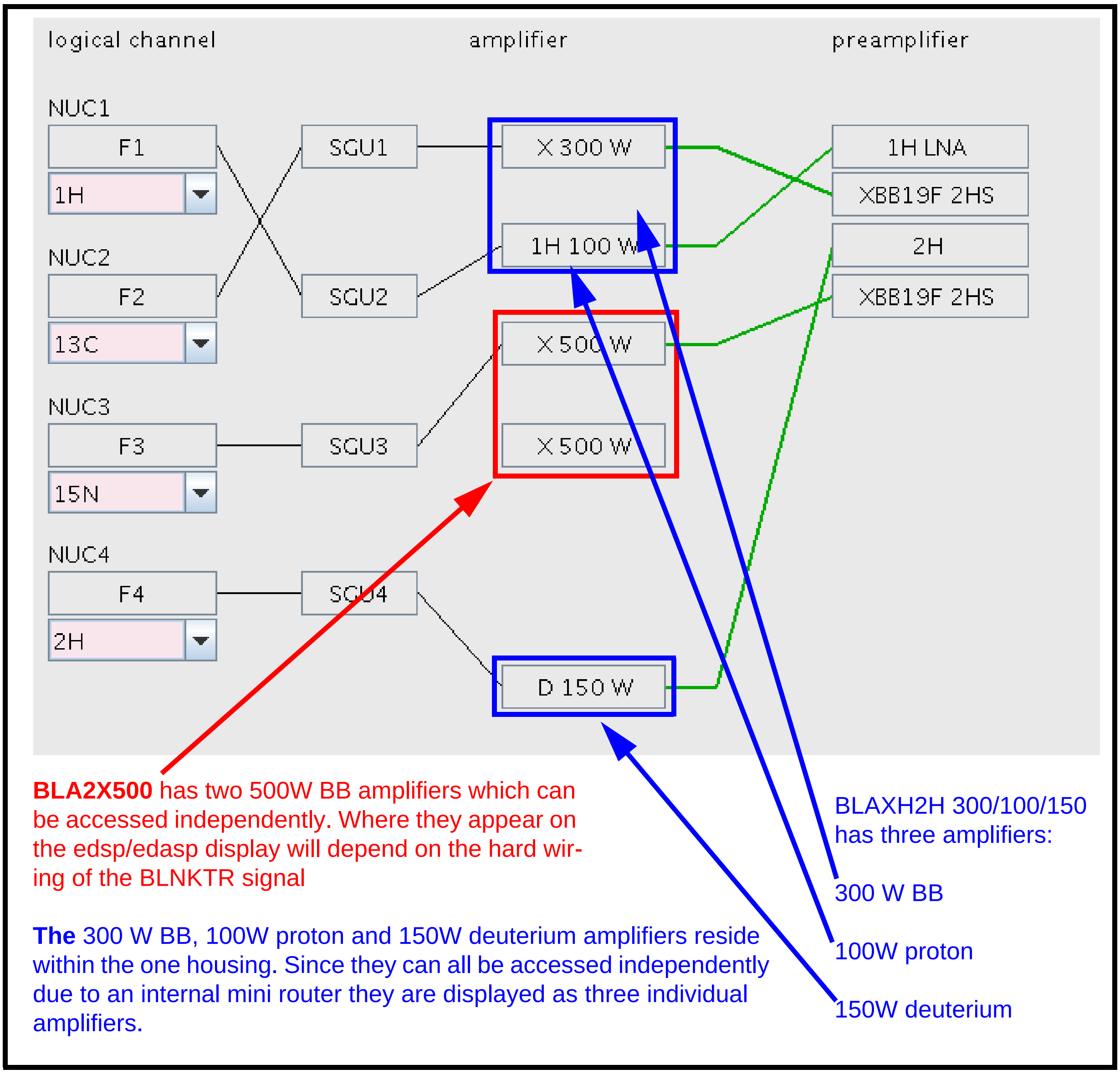
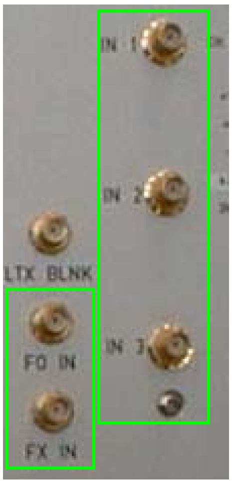


Figure 10.4. The edsp/edasp Display of Amplifiers.

Reference to ***Figure 10.5.*** will demonstrate how the edsp/edasp display shows only the information required to choose the correct path appropriate to the experiment. The operator simply chooses which amplifier to use for a particular RF frequency. Details of the particular SGU/2 output (RF OUT or AUX OUT) that needs to be used to connect the RF to the required amplifier are handled by the software. Furthermore most amplifiers will have multiple RF inputs leading to an internal mini-router which can connect the input to the various amplifiers within the transmitter housing. Once again ***Figure 10.5.*** demonstrates that this level of detail is not displayed in the edsp/edasp window as it is handled automatically by the software. This all presupposes that the ‘cf’ routine has correctly identified the hardware in terms of both amplifiers and connections to the SGU/2.

Extract from uxnmr.info showing **transmitter 1**(BLAX2X500) with three inputs connected to an SGU and **transmitter 2** (BLAXH2H) with 4 inputs connected to an SGU

```
RF cable connections (detected by 'confamp')
--------------------------------------------------------------------
SGU1 NORM output -> input 1 of transmitter 2 (at TCP/IP address 149.236.99.25
SGU1 AUX  output -> input 3 of transmitter 1 (at TCP/IP address 149.236.99.25
SGU2 NORM output -> input 2 of transmitter 2 (at TCP/IP address 149.236.99.25
SGU2 AUX  output -> open
SGU3 NORM output -> input 1 of transmitter 1 (at TCP/IP address 149.236.99.25
SGU3 AUX  output -> input 3 of transmitter 2 (at TCP/IP address 149.236.99.25
SGU4 NORM output -> input 2 of transmitter 1 (at TCP/IP address 149.236.99.25
SGU4 AUX  output -> input of AQS Router 1/4
AQS Router 1/4 output 1 -> input 4 of transmitter 2 (at TCP/IP address 149.23
AQS Router 1/4 output 2 -> open
AQS Router 1/4 output 3 -> open
AQS Router 1/4 output 4 -> open
```



BLAXH2H 300/100/150 actually has 5 RF inputs connected to the internal minirouter. This level of detail is not shown in the edsp/edasp display. Similarly the BLA2X500 will have multiple inputs and these will not be shown.

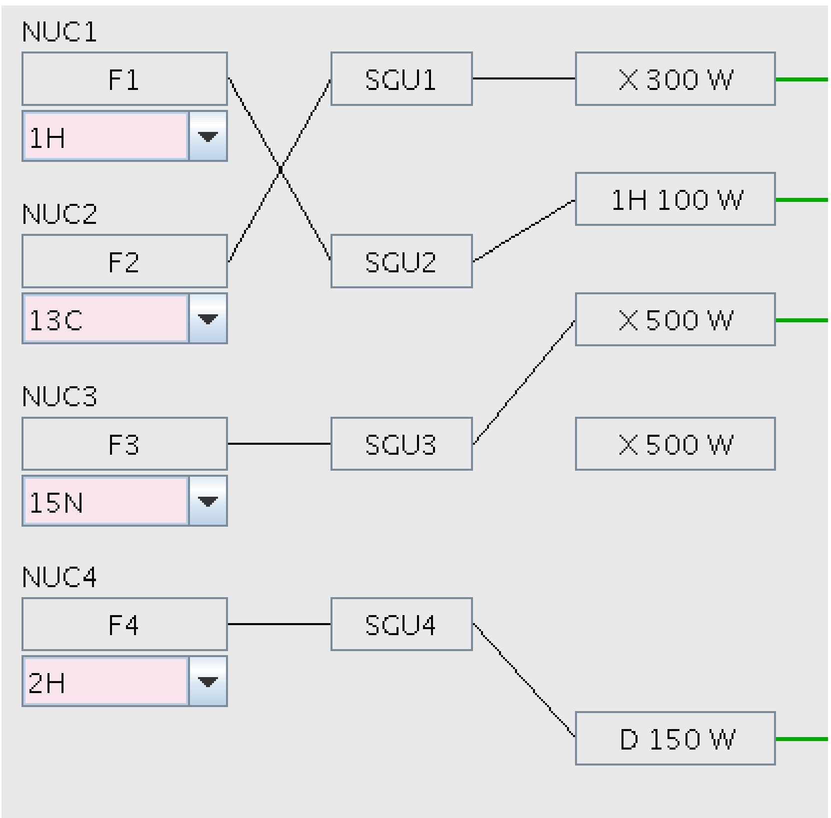


Figure 10.5. edsp/edasp Displaying Individual Amplifiers Without Details of Multiple Inputs

Mini-router and Combiners 10.3.2

Figure 10.6. has been included to explain the concept of mini-router and combiners. The transmitter housing shown has three RF inputs which are hardwired to corresponding SGU outputs. The three RF inputs are connected internally to two amplifiers via the minirouter and combiner. It is clear that any RF input can be routed to either of the two amplifiers. The combiner also allows any combination of the RF inputs to be directed into either one or the other amplifier. The control signals based on the edsp/edasp settings are transmitted to the external amplifiers via the Ethernet connection. This does not allow for real-time fast switching within the minirouter though with the flexibility of the latest system this should not be an issue.Although the SGU outputs are hardwired to the amplifier RF inputs this does not represent a routing limitation since the SGUs are entirely broadband. Staying with the example of ***Figure 10.6.***, if three frequencies are to be generated then any of the SGU outputs can be chosen as the source of any of the three frequencies. Effectively despite the hardwiring any combination of frequencies can be routed to any combination of amplifiers.This flexibility is incorporated into the corresponding edsp/edasp display also shown in ***Figure 10.6.*** The is no limitation on the connections between the SGUs and the amplifiers. Whatever path is chosen the software will ensure that the correct frequency is connected to the chosen amplifier. This concept is also displayed in ***Figure 10.4.*** where the edsp/edasp displays shows a bank of SGUs and a bank of amplifiers. There is no restriction on which SGU is connected to which amplifier. The display of the amplifiers and in particular the order in which they appear in edsp/edasp does not necessarily correspond with their actual physical location within a transmitter housing.

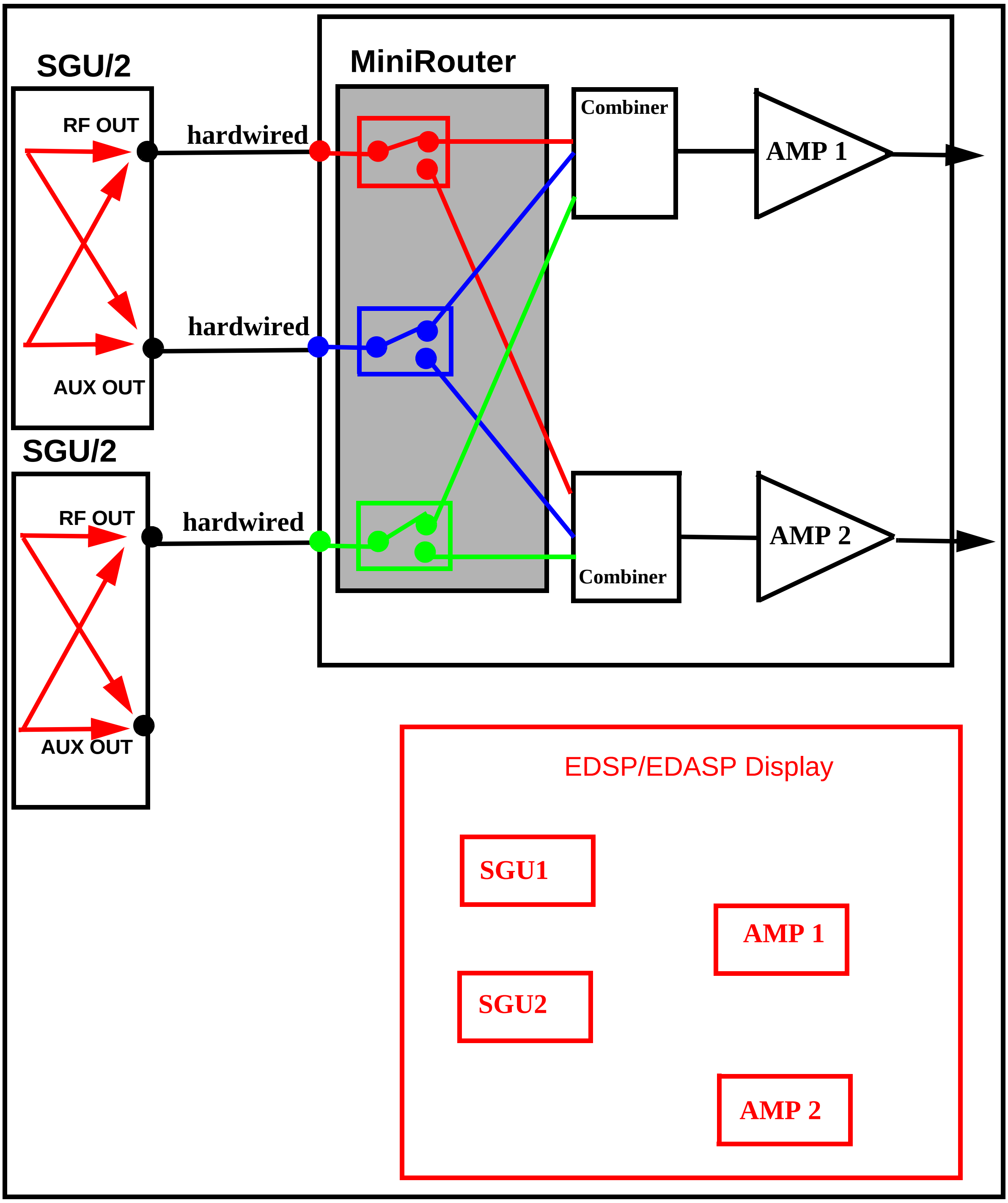


Figure 10.6. Example of Amplifier Housing with Mini-router/Combiner and Corresponding edsp/edasp Display

Amplifier Types

The various amplifiers can most easily be described in terms of:

- the number of channels
- the frequency range
- the output power

Details of the most popular types are given later in ***Table 10.1.***but before describing these a brief explanation of the naming conventions used by Bruker may help.

Amplifier Naming Convention *10.3.3*

Bruker amplifiers are linear amplifiers in that the ratio of the output amplitude to the input amplitude (i.e the gain) is fixed.The first three letters BLA in the amplifier name refer to **B**ruker **L**inear **A**mplifiers.

The letter H appended to the name indicates that this is a proton amplifier i.e BLA**H**.

The letter X appended to the name indicates that the amplifier is broadband i.e BLA**X**.

2H appended to the name indicates that the amplifier has a dedicated 2H amplifier i.e BLA**2H**.

Various combinations of the above are possible.The letters XH appended to the name indicates that the amplifier has both broadband and proton channels i.e BLA**XH**. The BLA**XH2H** has three channels, broadband, proton and deuterium.

Numbers appended to the amplifier name are an indication of the wattage output of the channel at max. power e.g BLAH100 has a 100W output for an RF signal of 1Vpp. (The specified power output always assumes an RF input of 1Vpp.) Where two channels are present then the wattage is arranged in the same sequence as the amplifier name e.g. in the BLAXH300/100 the 300 refers to the X channel and the 100 to the H channel.

For three channel amplifiers the same naming convention applies:

BLAXH2H 300/100/150 has

- X channel with 300W max output
- H with 100W max output
- 2H with 1500W max output

Introduction to the Amplifier Service Web *10.3.4*

One of the major advances of the new range of amplifiers is the ease of access to information regarding amplifiers via the Ethernet connection (which has replaced the RS485 connection) on the front panel. ***Figure 10.7.*** is a compilation of various menu points beginning with the Topspin ‘ha’ command and the equivalent display of the edsp/edasp window is also shown. It is clear that each transmitter housing now has an individual IP address that allows the operator to address one specific transmitter. ***Figure 10.7.*** shows extracts from the device information menu for two amplifiers. A more detailed explanation will be given later.

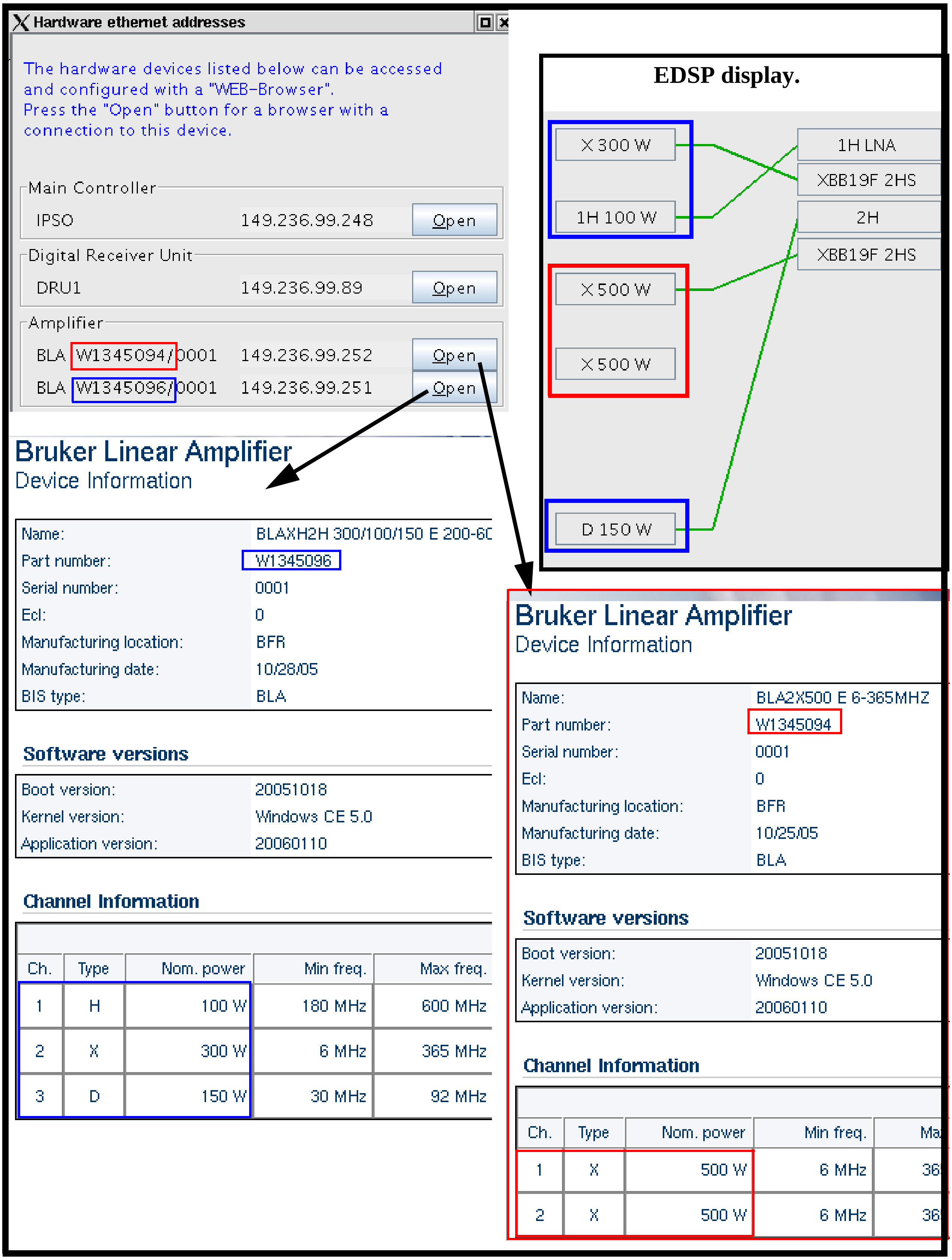


Figure 10.7. Extracts for two BLA service web home pages and corresponding EDSP display

Table 10.1. Summary of Popular Amplifier Types

Name	Description	Max. output for 1Vpp input	Max. PW at max. power	Max. DC at max. power	Max. CW
BLAH100	Single proton channel	100W	100ms	25%	25W
BLAX300	Single BB channel	300W	100ms	10%	30W
BLAX500	Single BB channel	500W	60ms	6%	30W
BLA2X500	Two identical BB channels	2 x 500W	60ms	6%	30W
BLAXH 300/100	Single BB channel and single proton channel	1 x 300W 1 x 100W	100ms 100ms	10% 25%	30W 25W
BLAXH2H 300/ 100/150	Single BB channel, Single proton channel and Single deuterium channel	300W 100W 150W	100ms 100ms 5ms	10% 25% 10%	30W 35W 15W

Proton Amplifier *10.3.5*

BLAH 100

This is the standard single channel proton amplifier.

Input HIN: 100W output for RF input of 1Vpp over a frequency range of 180 - 600 MHz for the standard unit.The 100W output would correspond to a power level setting of minus 6dB.

The amplifier has several safety features designed to ensure that the output power is not excessive. At 100W output the maximum allowed pulse length is 100ms, while the maximum allowed Duty Cycle is 25%. Longer pulses and higher duty cycles are allowed, but with the average output power maintained at or below an average of 25W. Effectively this means that at 100% Duty Cycle the unit can be operated continuously (CW) with a maximum output of 25W.

BB Amplifier 10.3.6

There are three versions of this amplifier

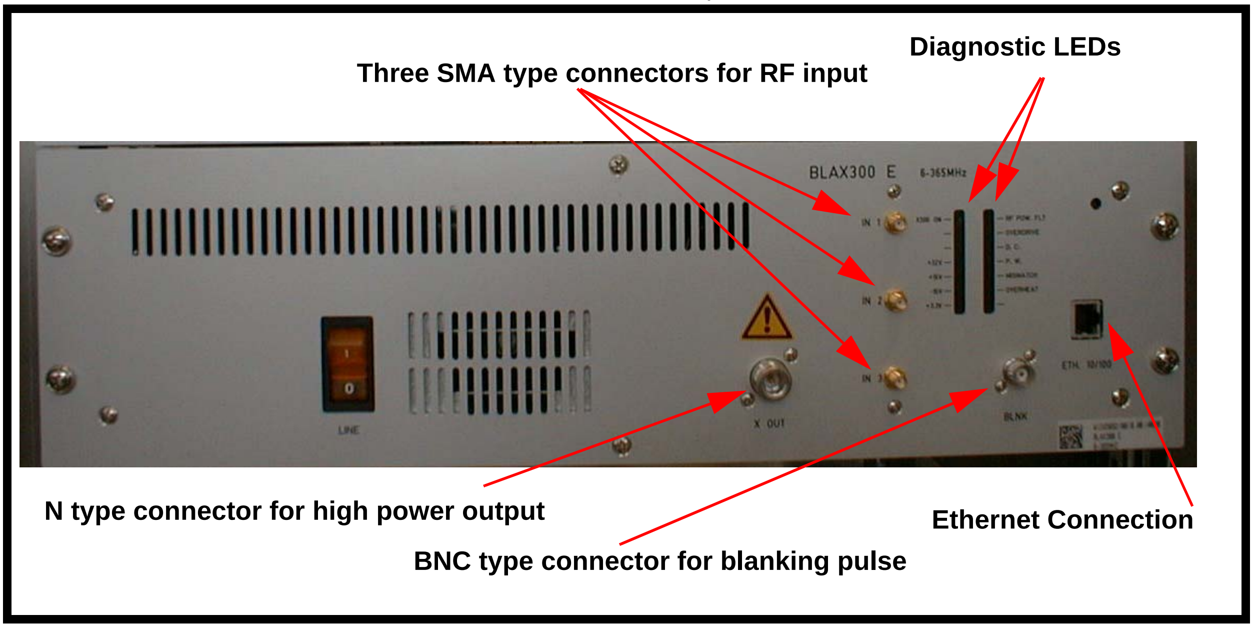


Figure 10.8. Front Panel of BLAX300 E

BLAX500

This is the standard single channel X frequency amplifier.

Input XIN: 500W output for RF input of 1Vpp over a frequency range of 6 - 365 MHz for the standard unit.The 500W output would correspond to a power level setting of minus 6dB.

BLA2X500

As above except the amplifier has two BB channels instead of one. see ***Figure 10.4.***

BLAX300

As with the BLAX500 except the output is 300W.

The amplifier has several safety features designed to ensure that the output power is not excessive. At max output power the maximum allowed pulse length is 100ms for the BLAX300 (60ms for the BLAX500). The maximum allowed Duty Cycle is 10% for the BLAX300 (6% for the BLAX500). Longer pulses and higher duty cycles are allowed, but with the average output power maintained at or below 30W. Effectively this means that at 100% Duty Cycle the unit can be operated continuously (CW) with a maximum output of 30W.

Combined Proton and BB Amplifier *10.3.7*

BLAXH 300/100

This has two RF channels.

Input XIN: 300W output power for RF input of 1Vpp over a frequency range of 6 - 365 MHz.

Input HIN: 100W output power for RF input of 1Vpp over a frequency range of 180 - 600 MHz.

At max output power (300W on the X channel or 100W on the proton channel) the maximum allowed pulse length is 100ms. The maximum allowed Duty Cycle is 10% on the X channel or 25% on proton channel. Longer pulses and higher duty cycles are allowed, but with the average output power maintained at or below an average of 30W on the X channel and 25W on the proton channel. Effectively this means that at 100% Duty cycle the unit can be operated continuously (CW) with a maximum output of 30W on the X Channel and 25W on the proton channel.

Combined Proton, Deuterium and BB Amplifier *10.3.8*

BLAXH2H 300/100/150.

This has three RF amplifiers and has been developed to facilitate the special requirements of Deuterium experiments. The front panel is displayed in ***Figure 10.13.*** and the relevant device information page from the service web is shown in ***Figure 10.11.***.

This amplifier can be viewed as a combination of a high power 2H-TX and a BLAXH in one housing.This is reflected in the front panel connectors and the cable routing which are analogous to the BLAXH and the 2HTX respectively.

The three RF inputs IN 1, IN 2 and IN 3 are connected to an internal minirouter/ combiner. The operation of mini routers was described in sec. ***10.3.2***. It is clear from ***Figure 10.9.*** that any of the three RF inputs IN 1, IN 2 and IN 3 can be routed to either Xout or Hout.

The proton amplifier connected to Hout will deliver 100W output power for RF input of 1Vpp over a frequency range of 180 - 600 MHz.

The BB amplifier connected to Xout will deliver 300W output power for RF input of 1Vpp over a frequency range of 6 - 365 MHz.

The final RF input FX IN is hardwired internally to the deuterium amplifier which is connected to 2Hout.The Deuterium channel delivers 150W output power for RF input of 1Vpp over the entire range of Deuterium frequencies.

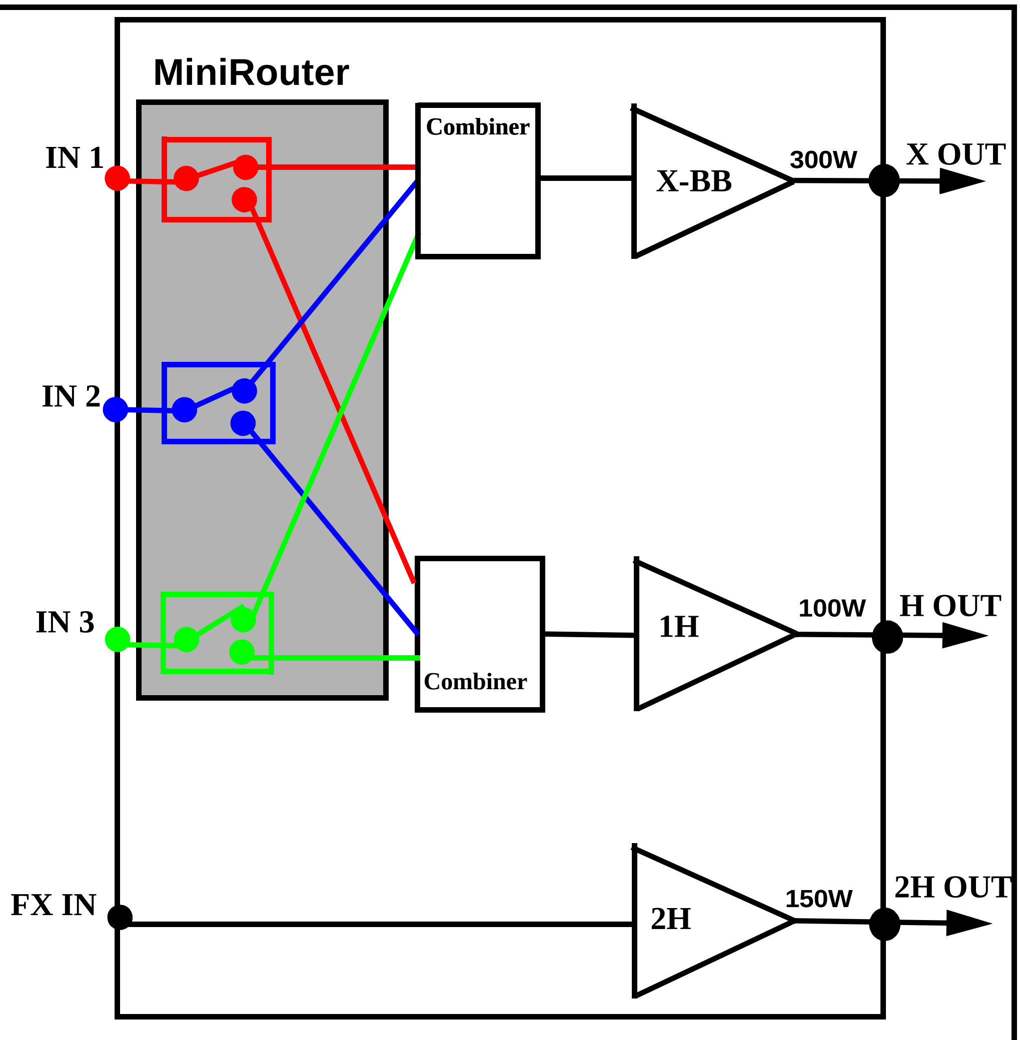


Figure 10.9. RF paths within the BLAXH2H 300/100/150

At max output power (300W on the X channel or 100W on the proton channel) the maximum allowed pulse length is 100ms. The maximum allowed Duty Cycle is 10% on the X channel or 25% on proton channel. Longer pulses and higher duty cycles are allowed, but with the average output power maintained at or below an average of 30W on the X channel and 35W on the proton channel. Effectively this means that at 100% Duty cycle the unit can be operated continuously (CW) with a maximum output of 30W on the X Channel and 35W on the proton channel.

The Deuterium channel delivers 150W max power for pulse durations up to 5ms. The maximum allowed Duty Cycle at full power is 10%. The max CW power is 15W.

The pulse length and Duty cycle information for all popular amplifiers has been summarised in ***Table 10.1.***

Now that we have discussed the details of some of the more popular amplifiers ***Figure 10.10.*** and ***Figure 10.11.*** have been include to show the reader how the information is displayed in the BLA service web which was first introduced in section ***10.3.4***

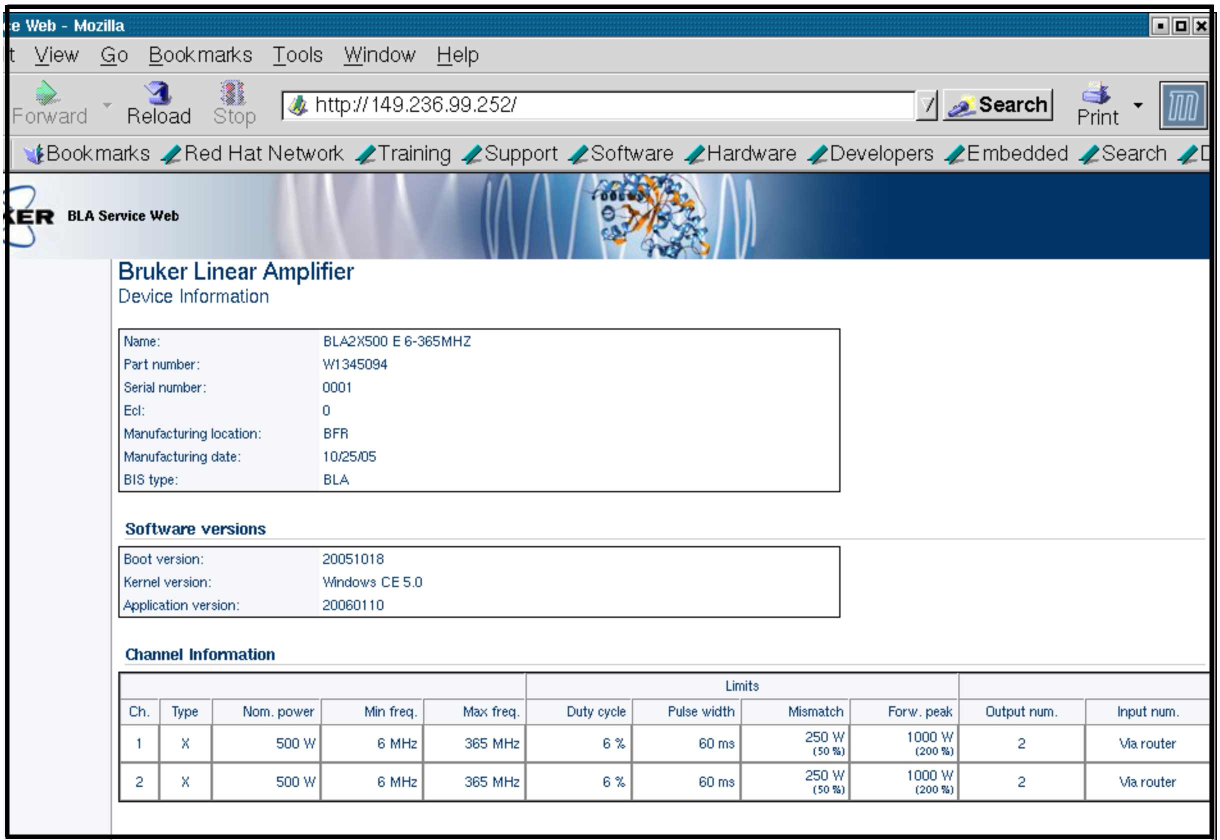


Figure 10.10.BLA2X500E Service Web Page

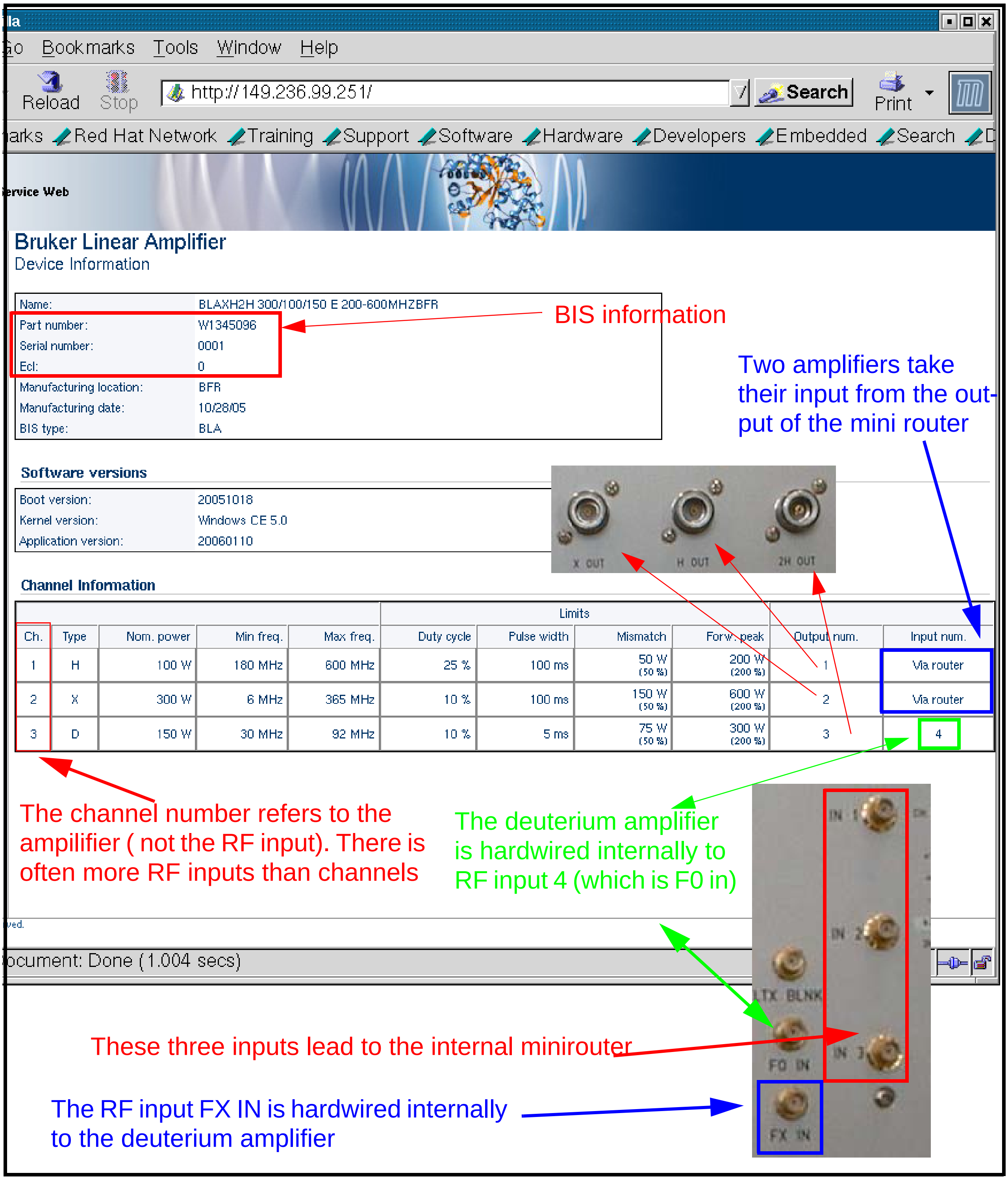


Figure 10.11.Device Information for the BLAXH2H 300/100/150 E

Finally ***Figure 10.12.*** has been included to demonstrate how the uxnmr.info file can be used to get amplifier information. Note that the uxnmr.info display has less detail than the service web pages.

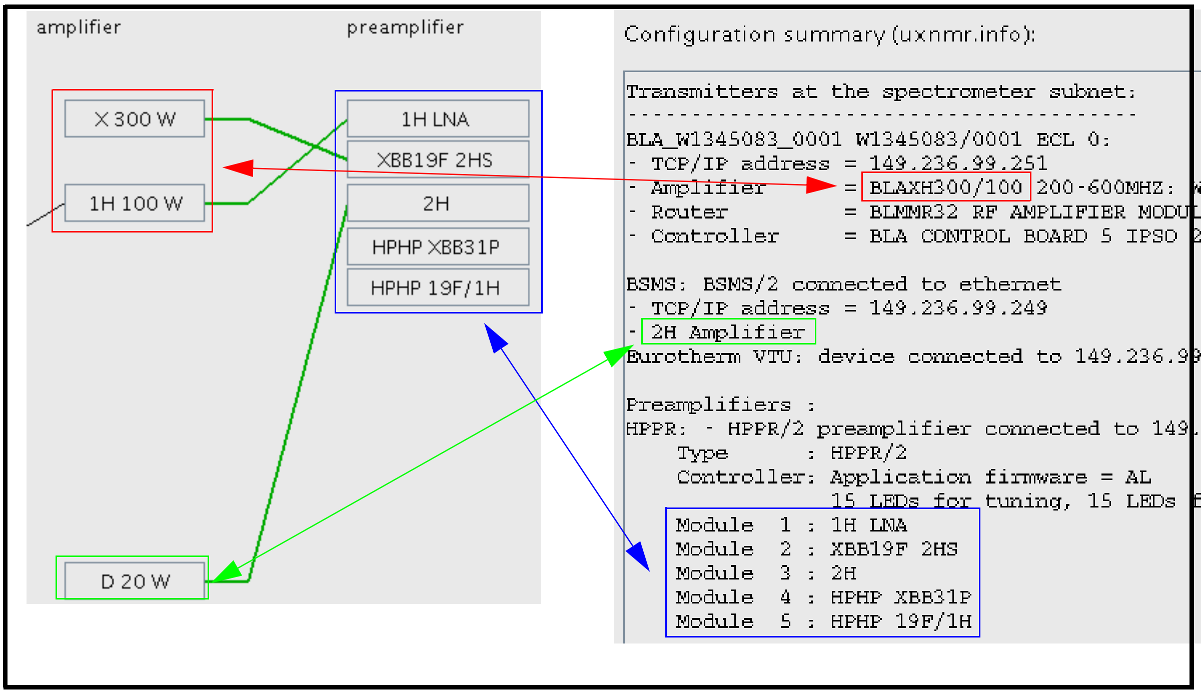


Figure 10.12.EDSP Display (left) and Corresponding Entries in uxnmr.info

Front Panel 10.3.9

Figure 10.13.Front Panel of BLAXH2H300/100/150

Unlike the internal amplifiers the external amplifiers have no connections to the AQS backplane and so all signals are accessible at the front panel.

Although the exact details of various amplifiers will vary there are many generic features and so it is instructive to discuss the various connections as shown in ***Figure 10.13.*** The description here refers to theBLAXH2H300/100/150 as it is the most comprehensive in terms of detail, but the information is easily extrapolated to other amplifiers.

RF INPUTS

The three RF inputs (IN1, IN2 and IN3) transmit signals which originate at the SGU/2. Two additional RF inputs are

FO IN: Connection from the L-TX 2H-TR of the BSMS. This is the 2H lock signal and since it will only ever carry the deuterium frequency it is hardwired internally to the deuterium amplifier and then on to the corresponding pre-amplifier. In this mode the amplifier will not significantly alter the amplitude of the signal and the amplifier is used effectively to give the lock signal access to the 2H coil of the probe.

FX IN: Connection from the ROUTER or the SGU/2 auxiliary RF output. This input is hardwired internally to the deuterium amplifier.This input would be used is to observe or decouple deuterium and the lock is effectively switched off (or a 19F lock used). In this case the signal would be amplified for by the 2H amplifier.

BLANKING CONTROL INPUTS

These signals (BLNK X and BLNK H and SEL 2H AMP) are standard blanking signals used to ensure maximum suppression of noise etc. outside of signal transmission. Although the SGU/2 has no output outside of signal transmission it is still desirable to ensure that the amplifiers are also off during these periods.

The blanking signals are digital (TTL level) operating on active low logic. When the signal is high (5V approx.) transmission is prevented, when it goes low (0V approx) transmission is allowed.

Precise software timing control of the start time of the amplifier blanking pulses (BLKTR1-8) can be controlled via the '**edscon**' table.The blanking signals are generated by the SGU/2 and delivered to the external amplifiers via the PSD/3.

LTX BLNK: Connection from L-TX of BSMS: This signal is a blanking signal at the 16.66KHz lock modulation frequency and is used to blank the amplifier in normal lock mode to minimize noise.

HIGH POWER RF OUTPUTS

From these connections (XOUT and HOUT and 2HOUT) the cabling carries the RF signals directly to the HPPR before final transmission to the sample.

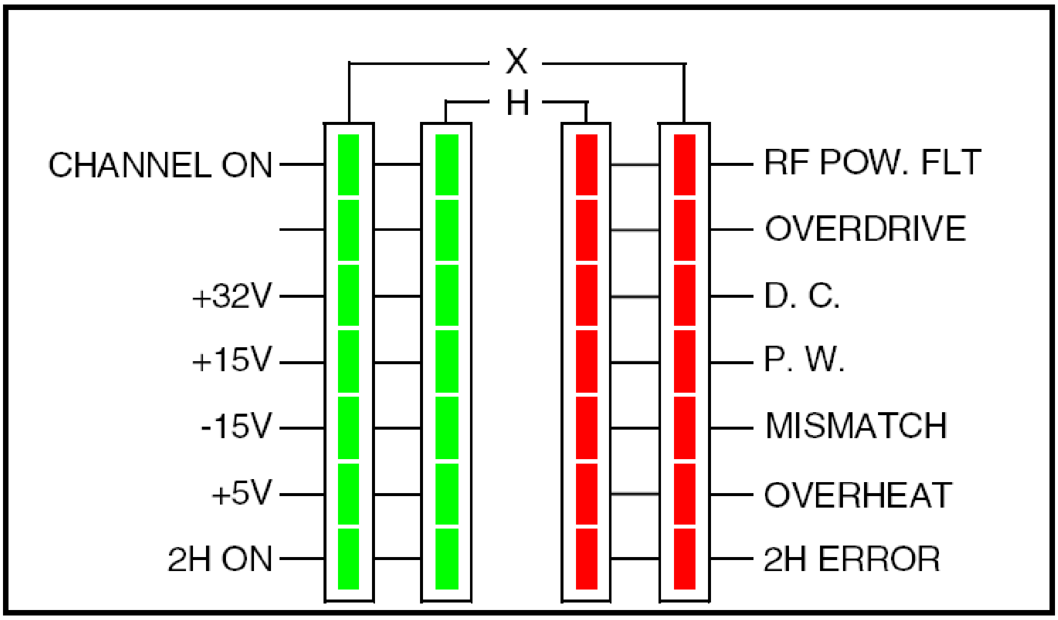


Figure 10.14.Front Panel Amplifier LED Display

DIAGNOSTIC LEDs

The various LEDs are described below. Many of the features are to protect the amplifier or NMR sample from too much power.

Channel ON H: Channel ON X: 2H ON

RF pulses whose power level is within approximately 20-30dB of the max output for that channel (be that 300W or 100W or 150W) will cause this LED to light. Any power levels below this will still be transmitted but will not light the LED. Note that this is a real measurement of the RF made at the output and is not merely activated by the presence of a blanking pulse.

VOLTAGE LED’s

These LEDs will light whenever the power voltage lies within a specified range (typically $\pm$ 10%) of the nominal value.

RF Pow. FLT (RF Power Fault)

This is a general diagnostic LED which lights whenever any other LEDs in the same display column (with the exception of ‘overheat’) light.

OVERDRIVE

This LED will light whenever the output power of the high power channel exceeds the specified cut out level. The default cut out level is twice (200%) the nominal output power. A cut out might be caused when the input RF was somehow greater than 1Vpp. The amplifier would then be temporarily disabled for 1 - 4s. After this period has elapsed the amplifier will be automatically re-enabled. Further detection of excessive output power will disable the amplifier for a further 1 - 4s. This process will continue until the cause of the overdrive is removed. Note that the overdrive limit is termed ‘Forw Peak’ in the Device information page displayed in ***Figure 10.11.***

D.C. (DUTY CYCLE)

This LED will light if the specified max. Duty Cycle of the amplifier is exceeded. The amplifier itself will be temporarily disabled as described in the section OVERDRIVE above. ***Figure 10.11.*** demonstrates that the specified max. D.C. depends on the actual amplifier with values typically set at 10-25%.

Note: Depending on the hardware configuration there are amplifiers where the Duty Cycle LED will light without disabling the amplifier. This can be verified by checking the RF Pow. FLT LED which will only light when the output has indeed been disabled.

PW (PULSE WIDTH)

This LED will light if the max. specified pulse width of the particular amplifier is exceeded. The amplifier itself will be temporarily disabled as described in the section OVERDRIVE above. The Pulse Width function is active for the high power output only and again will vary from amplifier type to amplifier type.

MISMATCH

This LED will light whenever the reflected power is above a specified level. This level corresponds at maximum power to a VSWR (Voltage Wave Standing Ratio) of 6 which corresponds to 50% reflection of forward power.

Overheat

A temperature sensor located within the amplifier monitors the temperature. Should the temperature rise above specified limits (non-adjustable) then the amplifier will automatically be disabled. The amplifier will remain disabled until the temperature has dropped sufficiently whereupon it will be automatically re-enabled.

2H Error

2H Error indicates when an error has occurred on the 2H channel.This is a generic LED that could be a Duty cycle error, Pulse width error or overheat error.

Ethernet Connection.

One function of this link is to enable the various units in the spectrometer to be identified by the software during the ‘cf’ routine so that the edsp/edasp display can mirror the precise number and type of amplifiers installed.The Ethernet link is also used to carry signals for the forward and reflected power displays of the graphics monitor. It also serves as the provider for the BLA service Web as well as switching signals for the mini router.

Characteristic of Good Amplifiers *10.3.10*

Below are just a few of the most important features of RF amplifiers.This will hopefully place much of this chapter in context.They are generic and apply to all amplifiers. Specific details of internal amplifiers with reference to actual specifications will be given in sec. ***11.9.1***. For more information refer to section ***10.9***

Power output: Amplifiers are specified in terms of their power output which, when suitably high, enables short excitation pulses to be used. One feature of electronic amplifiers is that the power output drops as the frequency increases so expect higher specified outputs for X frequency amplifiers when compared with proton frequency amplifiers. Also be aware that the max. permitted power output for CW (continuous wave) and pulsed operation are very different. To protect the amplifier (principally from overheating) the maximum allowed output power in CW mode may be limited. The duty cycle implicit in pulsed operation allows for adequate cooling.

Frequency range: A measure of the frequency range over which the amplifier is designed to be used. RF signals at frequencies outside this range may have significantly reduced gain though they will not damage the amplifier. This is very much an X (broadband) frequency issue as opposed to proton where the frequency range is relatively narrow. Note also the amplifiers represent the first frequency dependent element in the RF generation. The preceding units (SGU/2, 1/4 ROUTER etc. are all entirely broadband).

Reproduction of input signal: Ideally the output should be an identical but amplified reproduction of the RF input signal. Thus the precise duration, frequency and phase must not be altered or the shape (if not rectangular) must not be distorted as a result of the amplification process.

Reproducibility: Bruker amplifiers have a fixed amplification factor or gain. In order to avoid having to re calibrate pulse lengths this gain should always be constant (for a given frequency).

Short rise and fall times: The important features of rectangular pulses are good on/off ratios as well steep rising and falling edges. It is desirable that the amplifier does not lengthen the pulse rise and fall times.

Switching the Unit On and Off 10.4

Each external amplifier has its own separate power supply which is controlled by the front panel on/off switch. If an amplifier is to be correctly configured and displayed in the edsp/edasp menu it must be switched on. Even when not in use amplifiers are usually left switched on.

Tips ‘n’ Tricks/Basic Troubleshooting 10.5

- Unlike the internal amplifiers the external amplifiers have no connection to the AQS backplane and so all signals are delivered at the front panel. From a service point of view this makes the external amplifiers very accessible to troubleshooting though this should be attempted by service personnel only. The amplifiers require a functioning Ethernet link, power, RF input and blanking signals to operate.
- One obvious check is that the power voltage LEDs at the bottom left of the diagnostic LEDs display are lit. Check also other various safety LEDs (e.g. OVERDRIVE, PULSE WIDTH, DUTY CYCLE etc.).
- The operator should be aware that although all units are manufactured identically to a very tight specification individual variations in power levels are inevitable. For this reason if an SGU/2, ROUTER or Amplifier are exchanged or indeed if the cabling is altered then a fine tuning of precise pulse length and power levels may be required.

Serial Number / ECL Level / Software Download 10.6

Of all the units in the AVANCE series the amplifiers are possibly the least sensitive to ECL level, software downloads etc.

On older units the RS 485 connector on the front panel enables the BIS (Bruker Information System) data to be accessed. On newer versions with Ethernet capability the BIS information is accessible via the BLA service web page.

Other Required Signals /units 10.7

The external amplifiers compared to many other units in the spectrometer are to some extent remarkably independent. All they require to operate is a functioning Ethernet link, mains power, RF input ($1V_{pp}$ max.) and blanking signals. The correct operation of the minirouter will require switching signals but even in their absence power will be transmitted to the default output.

Option or Core Item 10.8

Every system will require amplifiers be they internal or external. The type and number installed is however very varied depending on the customer requirements.

Further Information *10.9*

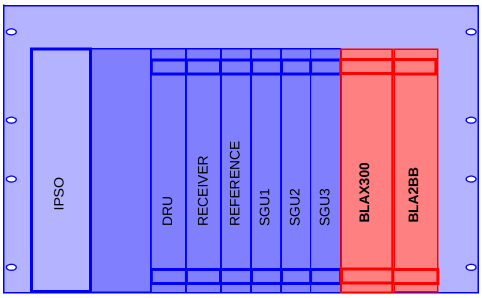
For specific amplifier specifications see the individual technical manual for that amplifier on the BASH CD. The manuals pertaining to the amplifiers discussed in this chapter are listed below.

- BLAH 100 Amplifier 200-600 MHz (Operating & Service Manual) Z31638
- BLAXH 300/100 Amplifier 200-600 MHz (Operating & Service Manual) Z31636
- BLA2X500, BLAX500 & BLAX300 Amplifier 6-365 MHz Z31595

For a general discussion of the meaning of the various amplifier specifications and more details on the amplifier front panel see AV Service Manual P/N Z31634.

Internal Amplifiers 11

Introduction 11.1



The internal amplifiers are so named because they are located **within** the AQS rack.They are slot-in type units with fixed positions in the AQS rack. They represent a low cost and particularly compact solution to customers carrying out routine work such as quality control etc.

The two standard models available are the BLA2BB and the BLAX300. The BLA2BB has two channels, one for proton and one for X frequencies and is the basic internal amplifier. Additionally an optional BLAX300 can be fitted as a third channel for X frequencies at higher power.

For 500/600 MHz systems a new BLAXH with 300W output for X frequencies and 50W output for proton has been developed (see ***Table 11.1.***).

Table 11.1. Summary of Internal Amplifiers

BLA2BB	60 W ^{1}H 150W up to ^{31}P	4/2	200-400 500/600
BLAX300	300W up to ^{31}P	2/1	200-600
BLAXH	50W ^{1}H 300W up to ^{31}P	2/2	500/600

In terms of their general function they are no different to the external amplifiers described in the previous chapter. The amplifier output is a fixed linear amplification of the input since amplitude control is implemented solely on the SGU prior to the internal amplifier. Like the external amplifiers the maximum RF input to the amplifiers is 1Vpp or 4 dBm (corresponding to a software power level setting of minus 6dB using the power level parameters ‘pl1’, ‘pl2’ etc.) and the specified output powers assume this level of input. The amplitude regulation is similar to the external amplifiers see ***"Relationship Between Hardware Output Power and Software Attenuation" on page 125***. They differ from the external amplifiers in performance and specification, the principal difference being the max output power. Other major differences are:

- blanking pulses and internal switching signals are transmitted over the backplane as opposed to being connected at the front panel.
- power is supplied by dedicated units at the rear of the AQS as opposed to the mains

- no Ethernet capability
- no ability to detect RF and hence hard wiring from SGUs to amplifier inputs is fixed

For some general information regarding the most important amplifier characteristics (be they internal or external) refer to ***"Characteristic of Good Amplifiers" on page 142***.

Location and Photograph *11.2*

Both internal amplifiers require dedicated power supply units located at the rear of the AQS rack and so their position is fixed at the right most two slots (facing the AQS rack) see ***Figure 3.2.***.

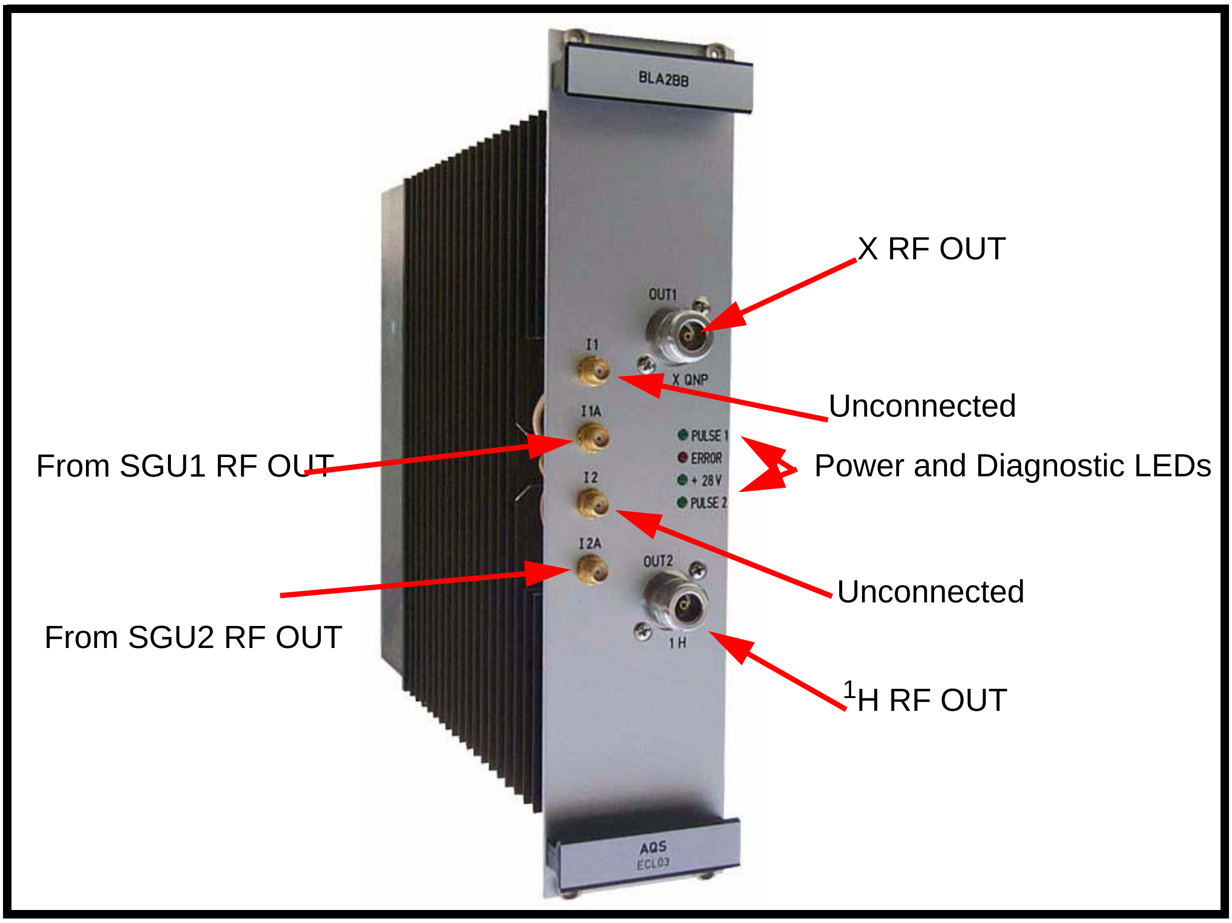


Figure 11.1. BLA2BB

General Information, Configuration and Function *11.3*

BLA2BB stands for **B**ruker **L**inear **2** **B**road**B**and channels.

In standard configuration the BLA2BB is capable of delivering 60W at the proton frequency and 150W for X frequencies up to ^{31}P. A single version is capable of delivering the specified output for 200/300/400 MHz spectrometers. A separate version is available for 500 and 600 MHz spectrometers.

If additional power or an extra channel is required then the system can be fitted with a BLAX300. There is a single version of the BLAX300 capable of delivering 300W on all frequencies up to ^{31}P on a 600 MHz spectrometer.

Table 11.2. Default Hardwiring Between the SGUs and the Internal Amplifiers

SGU	Output	Amplifier input
SGU1	RF_{out}	IN1 of BLA2BB
SGU1	AUX_{out}	2H-TX
SGU2	RF_{out}	IN2 of BLA2BB
SGU2	AUX_{out}	Tune in of preamp
SGU3	RF_{out}	BLAX300
SGU3	AUX_{out}	unconnected

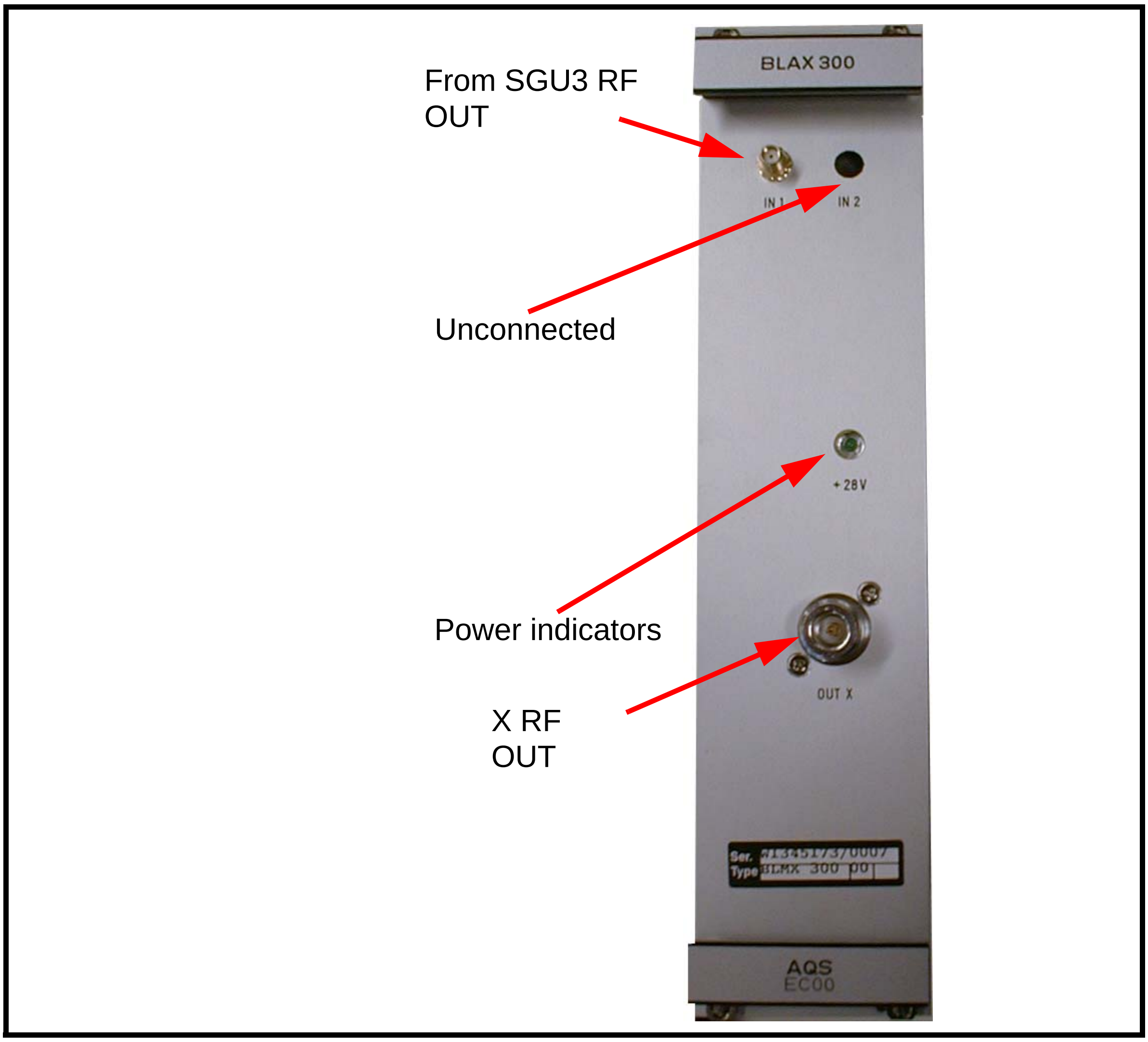


Figure 11.2. BLAX300 Front Panel

The combination of the two internal amplifiers gives three channel capability. If a greater number of channels is required then external amplifiers must be used. Note that the presence of both internal and external amplifiers in the same system is not possible.

Each internal amplifier is capable of detecting the level of forward RF power output which can be shown in the ACB display. This is achieved by transmitting the data from the internal amplifiers to the DRU over an I2C bus along the AQS backplane and then to the host monitor via the DRU Ethernet connection.

Configuration of the amplifiers is automatic during the ‘cf’ routine and enables the edsp/edasp window to display either one or two internal amplifiers depending on the system. The presence and type of amplifiers is recognized by the DRU via the BIS (Bruker Information System) which is stored in the amplifiers.

The software will take account of the hard wiring (assuming that is has been connected correctly) between the SGUs and the internal amplifiers (see ***Table 11.2.***) as well as any required internal switching. The operator need only select the desired output in the edsp/edasp menu and the software will automatically select the appropriate SGU as well as set any required internal switching within the amplifier.

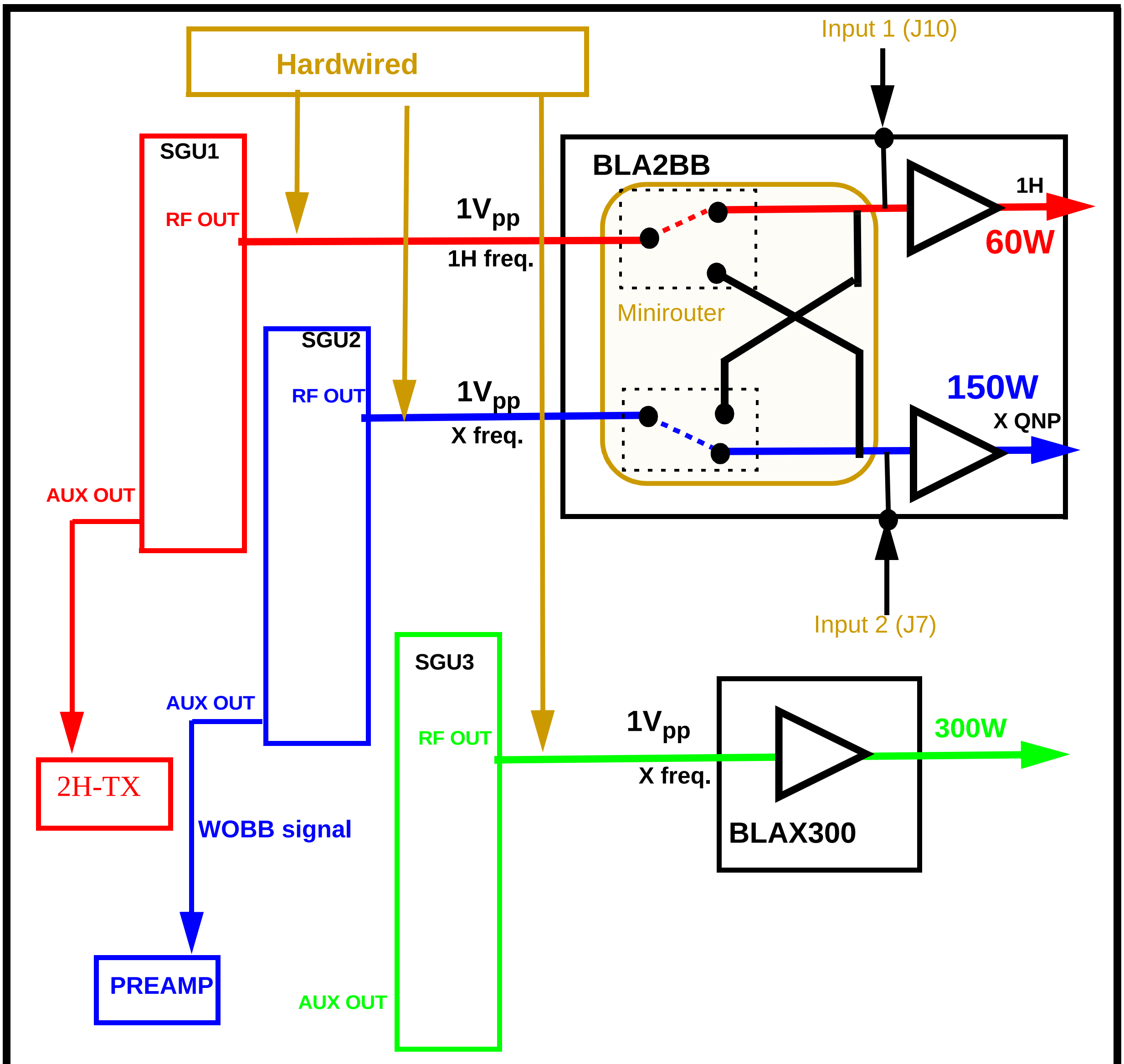


Figure 11.3. Default wiring of internal amplifiers to SGU/2s

BLA2BB Front Panel *11.3.1*

Unlike the external amplifiers the internal amplifiers are connected to the AQS backplane and so not all signals are accessible at the front panel. However it is instructive to discuss the various connections on the front panel as shown in ***Figure 11.1.***.

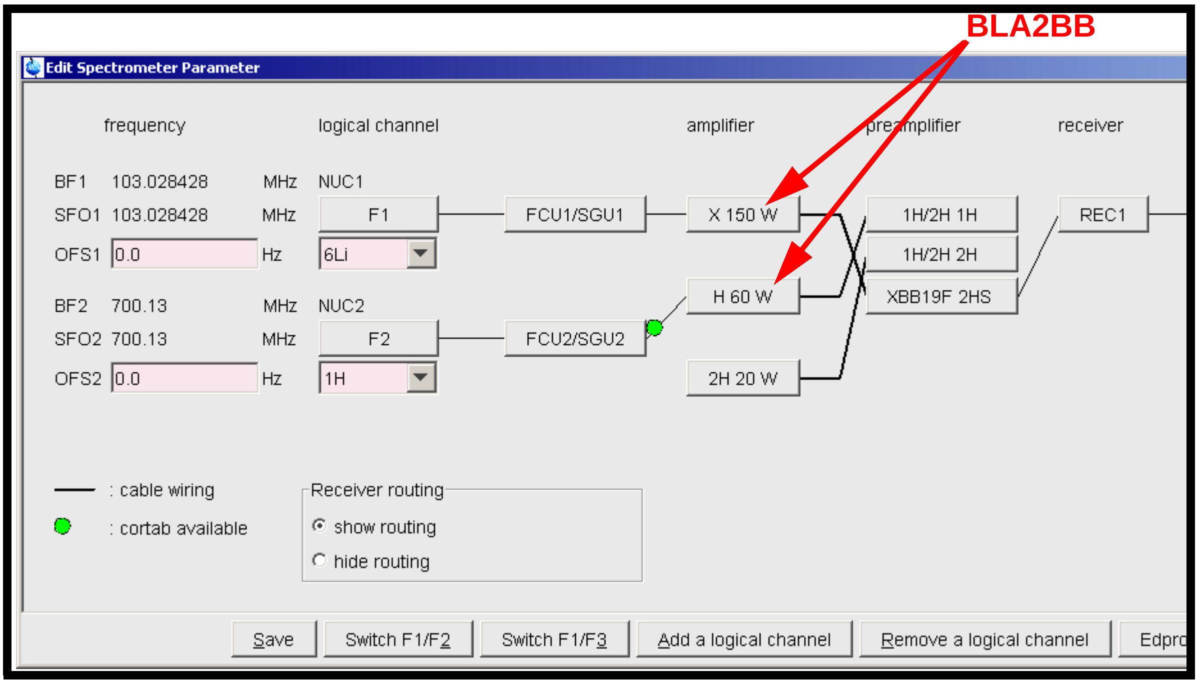


Figure 11.4. edsp/edasp Showing Internal Amplifiers

Input 1A (J9): This input is hard-wired directly to the RF OUT of the first SGU. With the minirouter the signal can be connected to either the ^{1}H or the X QNP end stage prior to amplification. Default is the ^{1}H output, though this can be switched using the edsp / edasp menu.

Input 2A (J8): This input is hard-wired directly to the RF OUT of the second SGU. With the minirouter the signal can be connected to either the ^{1}H or the X QNP end stage prior to amplification. Default is the X QNP output, though this can be switched using the edsp / edasp menu.

Input 1 (J10) and Input 2 (J7): Both of these inputs are not connected in standard configurations. They have been provided to enable additional frequencies to be amplified. For example Input 1 could be connected to the output of SGU 3 if fitted. Input 1 is hardwired internally to the ^{1}H output and Input 2 is hardwired internally to the X QNP output. Note however that the limitation of two outputs is fixed regardless of the number of inputs.

28V LED: This LED is an indication that the 28V voltage supply provided by dedicated power units at the rear of the AQS is present.

Outputs: With the BLA2BB the ^{1}H output is connected to the ^{1}H preamplifier module and the X QNP output connected to the X-BB preamplifier module. If the system also contains an internal BLAX300 then there are two possible X amplifiers. For whichever X amplifier is chosen a cable must connect the output of this amplifier to the appropriate preamplifier X-BB module or to the probe directly. Please note that if the system is used in automation then the operator must check that the default output is correctly connected to the preamplifier or probe.

Internal switching: Although the BLA2BB is described in terms of two channels (H and X) the two channels are in fact identical. As with all RF amplifiers the power output varies strongly with frequency. ***Figure 11.5.*** shows the frequency response of the BLA2BB for an input of 4dBm($1V_{pp}$) which is the max output of an SGU corresponding to software setting of PL = minus 6dB. Since the two channels are in fact identical the user is free to use either channel for any frequency, they should just be aware that the power output will fall with increasing frequency. (The graph shows that in fact the BLA2BB will deliver up to 88W at 400 MHz and so the specified 60W is easily surpassed.).

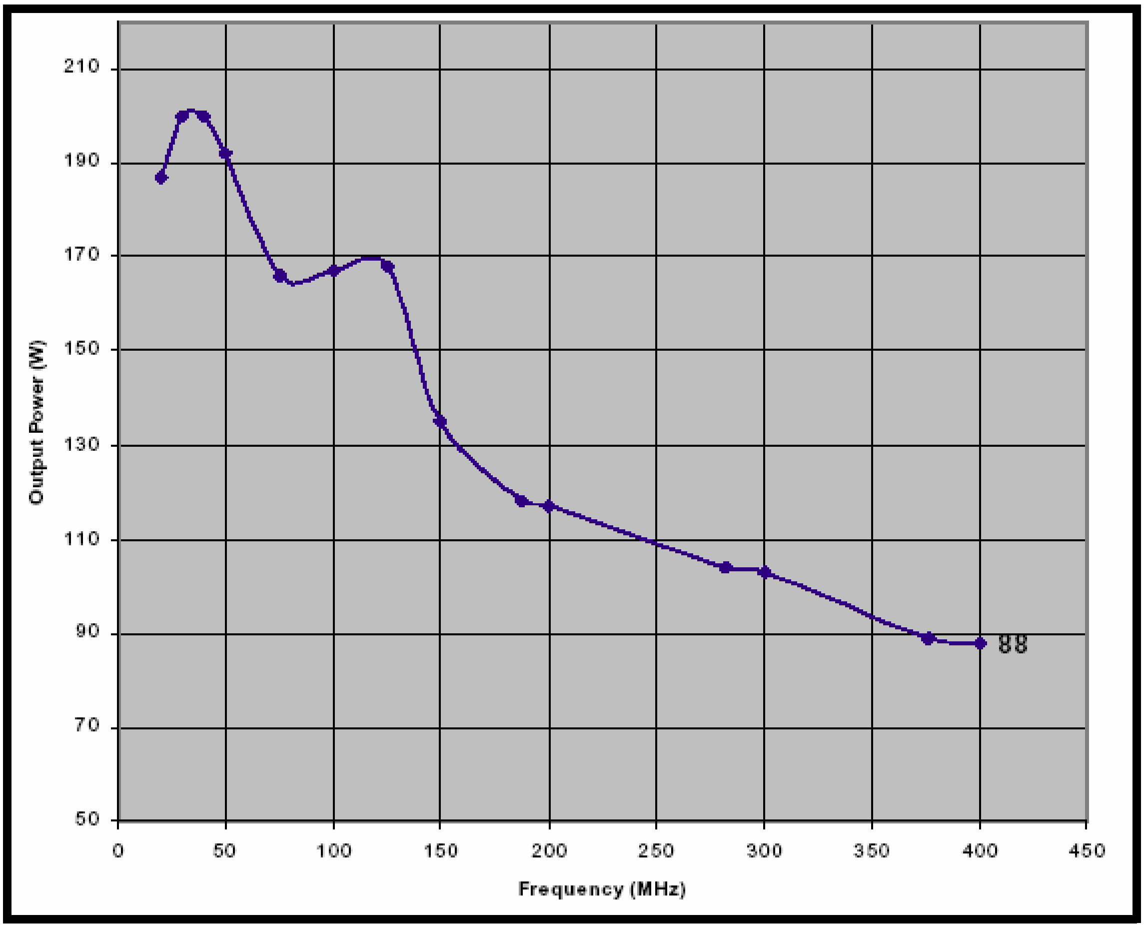


Figure 11.5. BLA2BB: Variation of Output Power with Frequency for Input Power of 4dBm(1V_{pp})

BLAX300 Front Panel 11.3.2

IN1: This input is hardwired directly to the RF output of SGU3.There is no internal switching within the BLAX300 as there is a single X output.

OUT X: This output is hardwired to a preamplifier module or directly to the probe.

28V LED: This LED is an indication that the 28V voltage supply is present.

Switching the Unit On and Off 11.4

The internal amplifiers have no separate on/off switch, power on and off is controlled directly from the AQS mains switch.

Tips 'n' Tricks/Basic Troubleshooting 11.5

- Check that the 28V LEDs are lighting.
- Check the PSUs at the rear of the AQS.
- To replace a unit simply power off the AQS, replace the unit, power on and reboot. To check that the unit has been correctly identified you should reconfigure the spectrometer using the 'cf' routine and check that the amplifier has been displayed in the edsp/edasp menu.
- The internal amplifiers are relatively standalone. They require power, RF inputs and blanking/gating signals to operate. Even if the internal switching signals are absent output will still be present at default outputs. The blanking signals from the SGU are however delivered over the AQS backplane and are as such inaccessible.
- If a problem with the minirouter is suspected then this can be bypassed by connecting the RF signal directly into Input 1 (J10) or Input 2 (J7).

Serial Number / ECL Level / Software Download 11.6

A single version of the BLA2BB is capable of delivering the specified output for 200/300/400 MHz spectrometers. A separate version is available for 500 and 600 MHz spectrometers. There are only single version of the BLAX300 and BLAXH.

The internal amplifiers support BIS. The ECL level and serial number etc. are printed on the front panel. The BIS info is also available via the DRU and can be accessed with UniTool.There are no software downloads required for the internal amplifiers.

Other Required Signals / Units 11.7

The internal amplifiers need power from dedicated power units at the AQS rear (see ***Figure 3.10.***) and blanking and switching signal from the SGU.

Option or Core Item 11.8

For systems not using external amplifiers the BLA2BB is core. The BLAX300 is optional.

Further Information 11.9

For specific amplifier specifications see the individual technical manual for that amplifier on the BASH CD.

AQS BLA2BB Amplifier 200-400 MHz (Operating & Service Manual) P/N Z31608

AQS BLA2BB & BLAX300 P/N Z31479

There is also a useful description of the internal amplifiers in the AV Service Manual P/N Z31634.

Amplifier Specifications 11.9.1

A comprehensive list of specifications is now available for all Bruker linear amplifiers. This section describes how these specifications are defined. Example figures quoted here refer to the specifications of the BLAX 300RS which are contained at the end of this chapter

Frequency Range

A measure of the frequency range over which the amplifier is designed to be used. RF signals at frequencies outside this range may have significantly reduced gain.

Gain Flatness

The amplifier gain will be somewhat dependent on the absolute frequency. The GAIN FLATNESS is quoted for the specified frequency range. e.g. for the BLAX 300RS the gain is specified not to vary by more than 1.5 dB for any frequency within the 6 - 243 MHz range.

Linear Gain

This is measured well within the linear region of the amplifier, typically at 10 dB below max. output. The linear gain will differ from the gain at the specified max. output. For the BLAX 300RS an input of 1Vpp (4 dBm) will produce an output of 300W (55 dBm) i.e. gain = 51 dB.

A brief glance at figure 12.6 should show however that the gain within the linear region will be greater (in the case of the BLAX300 54 dB).

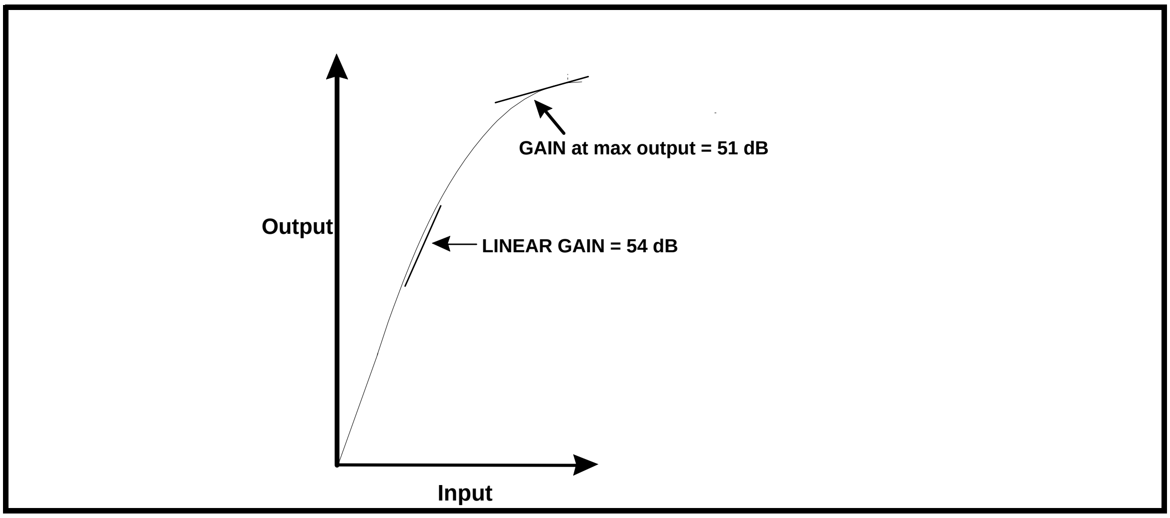


Figure 11.6. Linear Gain for BLAX300 (not to scale)

CW Output Power

The BLA Control Board limits the maximum allowed output power in CW mode to the specified value.

Linear Output Power

At high output powers the linearity of the amplifier will suffer. The amplifier is defined as linear up to the power level where the actual output deviates from the perfectly linear output by 1 dB. This level is referred to as the 1 dB compression point

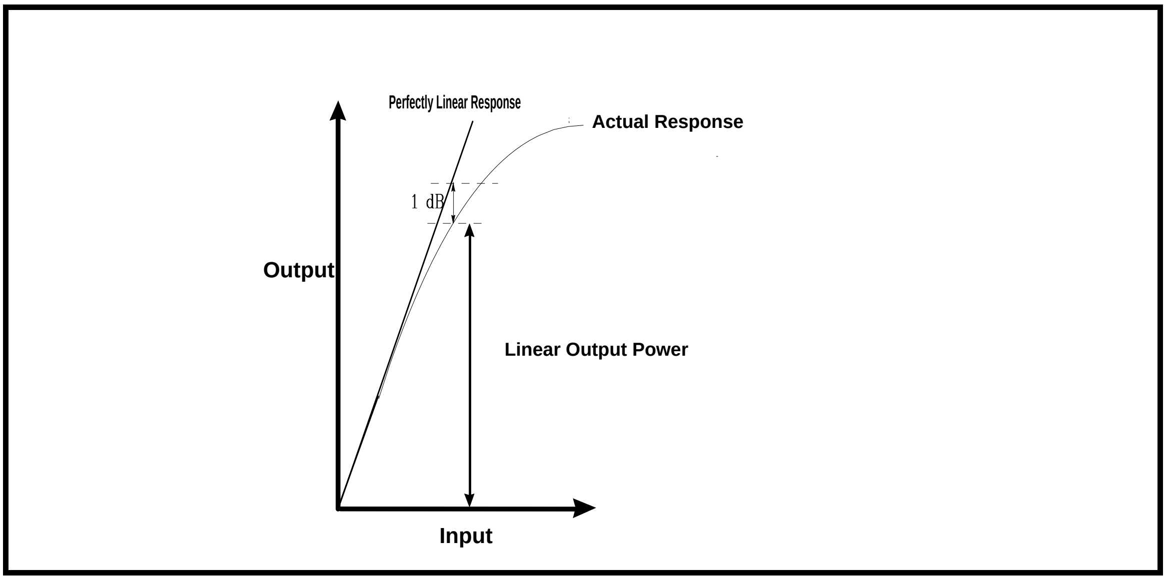


Figure 11.7. Linear Output Power (not to scale)

Amplifier Biasing

All Bruker linear amplifiers are class AB.

Blanking Delay

The blanking within the amplifier is implemented using MOSFET's. These transistors have a certain response time and should ideally be activated prior to the arrival of the RF signal. The blanking delay is the time which should be allowed to ensure that the MOSFET's are correctly biased to allow RF transmission.

Rf Rise Time

The time taken for an RF pulse to rise from 10% to 90% of its final voltage.

Rf Fall Time

The time taken for an rf pulse to fall from 90% to 10% of its final voltage.

D C Ringing

This is a consequence of the sharp rise and fall of the blanking pulses (BLKTR) applied within the amplifier. The ringing will occur at the start and end of the blanking pulse and may last several µseconds. The ringing is independent of the RF power.

Input Noise Figure

If the amplifier were perfect then noise and signal would both be amplified by the same factor i.e. the Gain “G”. In reality the amplifier will add it’s own noise to the output and the output noise will be greater than Nt x G where ‘Nt’ is the thermal noise at the input. The output noise can be represented by Nt x(G + F) where G is the Gain and F the Noise Figure in dB.

Output Noise Power (Unblanked)

The thermal noise at 300K has a power level of - 174 dBm measured over a bandwidth of 1Hz. Add to this the 7 dB Noise Figure along with the 54 dB LINEAR GAIN to yield an output noise power of - 113 dBm/Hz.

Output Noise Power(Blanked)

The blanking will remove the amplification of the final stage of the amplifier as well as the 1W driver amplifier. There will still inevitably be some crosstalk between the first two amplifier stages which in the BLAX 300 has a net effect of 10 dB amplification of the thermal noise when blanked.

Input V.S.W.R.

A Measure Of The Voltage Standing Wave Ratio Which Can Be Used To Quantify The Ratio Of The Forward Power To Reflected Power. The Typical Max. Value Of 1.3 Represents A Reflection Factor Of 13%.

Amplitude Droop

The output of any amplifier may decrease over the duration of a long pulse as a result of fluctuations in the power supply, input and output impedances, operating point etc. The droop is defined in terms of the percent drop in amplitude compared to an ideally stable output.

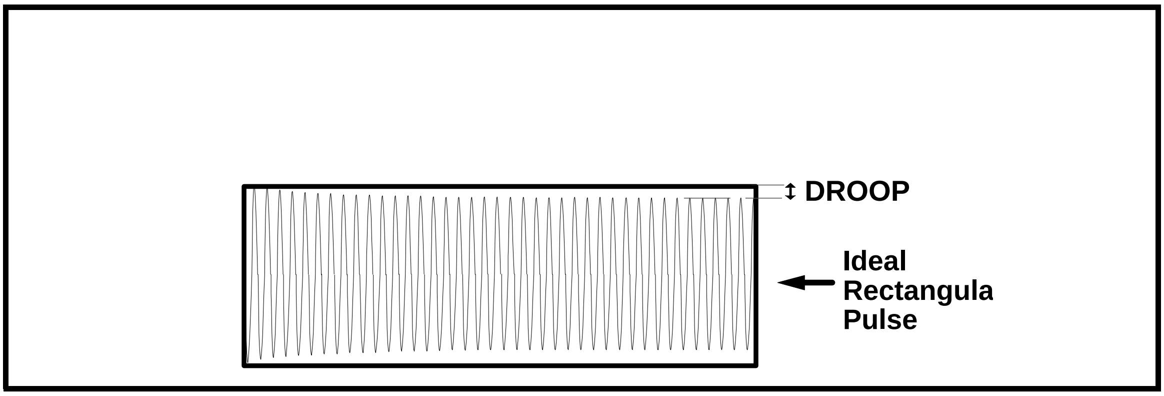


Figure 11.8. Amplitude Droop

RF SPECIFICATIONS	CHANNEL X
Frequency range	6 to 243 MHz
Linear Gain	54 dB ± 1 typ.
Gain Flatness	± 1,5dB max.
Minimum Pulsed Output Power	300 W min.(at nominal input +4dBm)
CW Output Power	30 W max.
Linear Output Power	250 W min. at 1dB compression
Amplifier Biasing	Class AB Operation
Blanking Delay	< 1 µs typ.
RF Rise Time	< 100 ns
RF Fall Time	< 50 ns
DC Ringing	±100 mV typ. (due to blanking signal)
Input Noise Figure	7 dB max.
Output Noise Power (Unblanked)	-113 dBm @ 1 Hz
Output Noise Power (Blanked)	< -164 dBm @ 1 Hz (< 10dB over Thermal Noise)
IN/OUT Impedance	50 ohms
Input V.S.W.R.	1,3 max.
Pulse Width	up to 10 ms @ 300 W
Duty Cycle	up to 10 % @ 300 W
Amplitude Droop	< 6 % @ 300 W for 10 ms Pulse Width < 3 % @ 30 W for 500 ms Pulse Width

Figure 11.9. BLAX300 Specifications

Internal Preamplifiers 12

Introduction 12.1

The functions (as well as the performance specifications) of the internal preamplifiers and the external HPPR/2 are effectively identical. Although the preamplifiers carry the excitation signal ***to*** the sample they are primarily concerned with amplifying the relatively weak NMR signals emitted ***from*** the sample.The internal amplifiers also transmit and receive the deuterium lock signal and are used in the wobble routine to tune the probe. Whether the system is fitted with either **internal** preamplifiers (located within the AQS) or **external** HPPR/2 (located at the base of the magnet) will depend usually on the field strength. One advantage of the HPPR/2 is that shorter cables can be used and the received signal is effectively amplified sooner. This advantage is usually only justified for higher field systems. Secondly the total number of individual modules/preamplifiers that can be incorporated into the HPPR/2 is 8 whereas for the internal preamps this is limited to three. Again more than three modules is usually only required for the higher field systems. Indeed the internal preamplifiers are currently available for up to 400 MHz systems only. Higher field systems are automatically fitted with the HPPR/2. The principal advantage of the internal amplifiers are reduced cost and they are the preferred option for lower cost systems fitted with internal amplifiers.

The HPPR/2 hardware will be dealt with in chapter ***13***. Since many of the functions are identical the reader is advised that they may find much of the material in the next chapter quite useful. In particular section ***13.3*** has a description of the various modes of operation (OBS, Decouple, Lock, WOBB etc.) which is equally applicable to the internal preamplifiers.

The internal preamplifier modules are located in the AQS rack. Up to two individual modules($^1H/^2H$ and X-BB) incorporating three preamplifiers can be accommodated.The ^2H preamplifier is used to transmit and receive the lock signal. Much of the preamplifier technology is concerned with what is known as the Transmit / Receive switching. Effectively the signal going to the probe is transmitted without any action apart from frequency filtering to minimize noise. Once this transmit signal has elapsed the signal path within the preamplifier is altered so as to amplify the received signal from the probe by typically 30dB. The trick is to make this switch as fast as possible and suppress leakage so that the tail of the transmitted signal does not swamp the start of the received signal.The timing of this switching is controlled by the OBS SGU.

One difference from previous generations is the absence of a separate preamplifier controller board. Control is now handled by the standard DRU (not DRU-E!).

Location and Photograph *12.2*

The location of the internal modules can be seen in ***Figure 3.1.***. They are located immediately to the right of the SGUs. As these two modules have no direct access to the AQS backplane all relevant signals including power must be transmitted over a front panel ribbon cable.

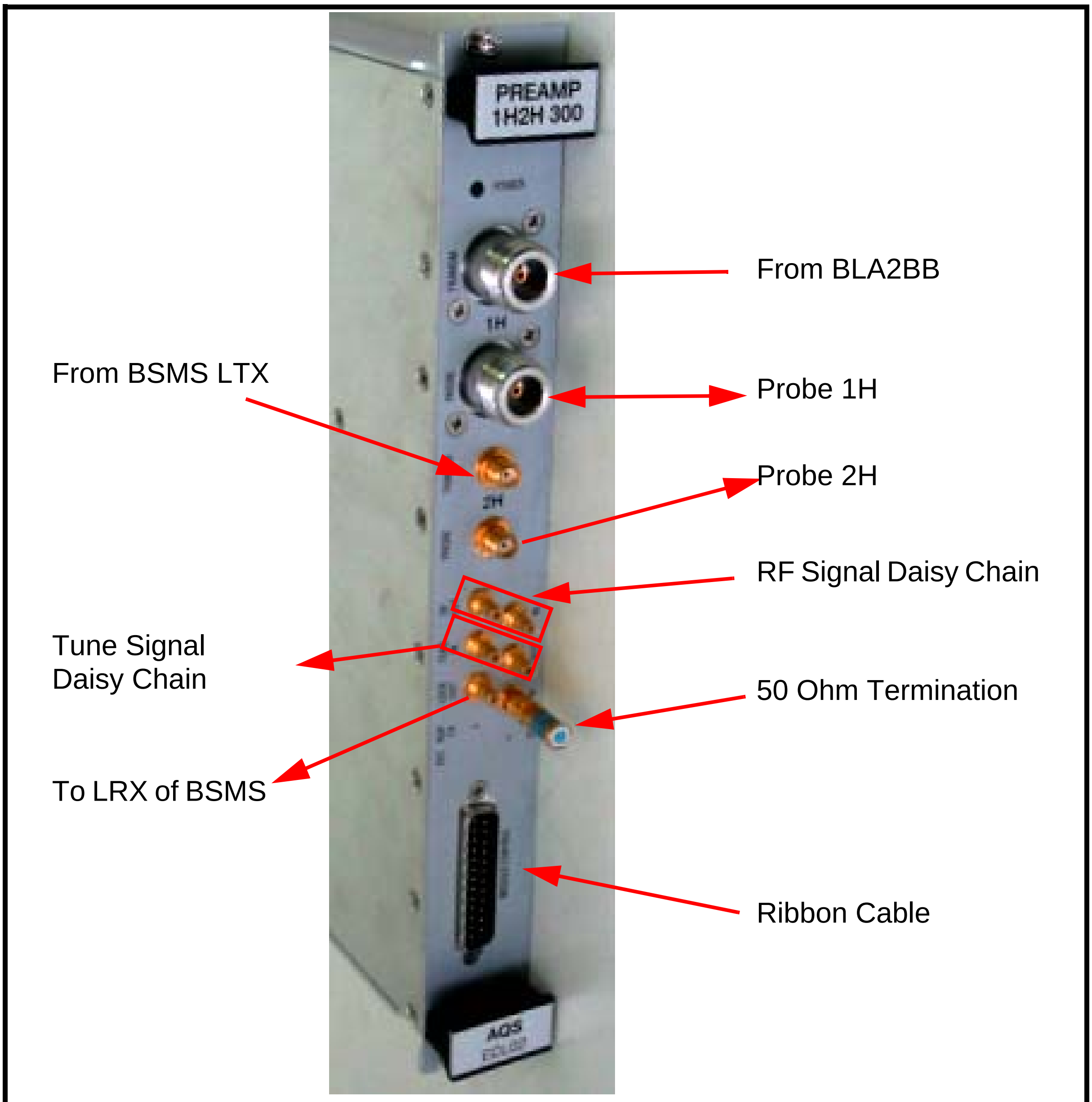


Figure 12.1. Front Panel of $^1H/^2H$ Internal Preamplifier Module

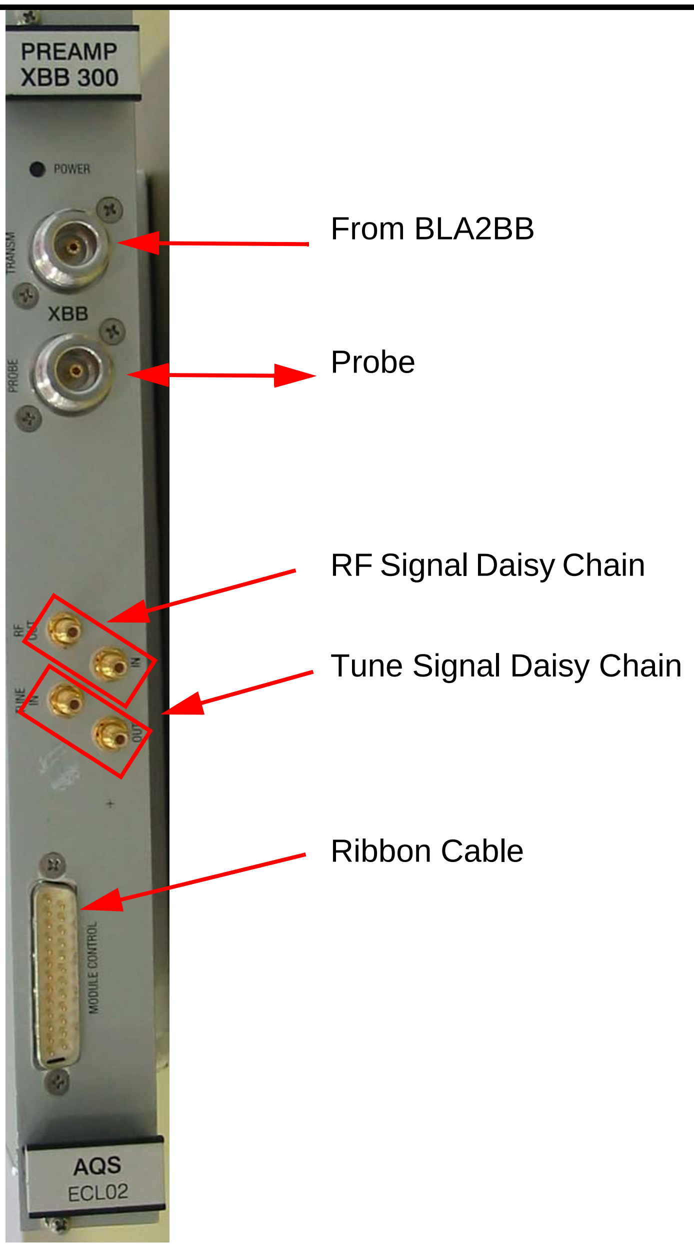


Figure 12.2. Front Panel of X-BB Internal Preamplifier Module

General Information, Configuration and Function 12.3

Two modules, both of which are system frequency dependent are currently available for systems up to 400 MHz.

The $^{1}H/^{2}H$ module: This is actually two separate independent preamplifiers within a single housing. One preamplifier caters for the higher proton frequencies. The other is tuned to the deuterium frequencies and as such transmits and receives the lock frequencies as well as being available for observing or decoupling deuterium. This single module can thus be used to observe or decouple proton while maintaining a deuterium lock

The X-BB module: This caters for all other frequencies up to ^{31}P.

Principal functions of the preamplifiers are to:

- Amplify the relatively weak NMR signal emitted by the sample
- Filter the transmitted excitation and decoupling signals
- Perform the T/R switching
- Transmit and receive the lock signals(^{2}H module)
- Perform the wobb routine

DRU control:

All aspects of the preamplifier control are now handled directly by the DRU. (The reader should note that the internal preamplifiers require a DRU and not a DRU-E. (The E in DRU-E signifies **external preamplifiers** i.e. HPPR/2).

Among the features under the DRU control are

- Configuration of the preamplifiers via the ‘cf’ routine.
- Designation of the OBS module as per the edsp/edasp window.
- Access to BIS (Bruker Informations System).
- Service access via UniTool
- Transmission of power protection signals that will, in case of failure, immediately suspend power transmission to protect the probe.The preamps have an internal directional coupler that can detect excessive reflected power: In this case they generate an emergency stop signal that is transmitted to the IPSO and power transmission is stopped.
- Voltage power supplies.

All of the above are implemented using signals transmitted over the front panel ribbon cable which is daisy chained from the DRU to each preamplifier.

The T/R switching signal is generated by the OBS SGU to ensure overall synchronization with the acquisitions. The signal itself is transmitted to the DRU over the backplane and from here to the individual preamplifiers via the front panel ribbon cable.

Front Panel Connections: $^{1}H/^{2}H$ Module *12.3.1*

The front panel connectors shall be described from the top connector downwards.

TRANSM ^{1}H: (N-Type)

This signal is the amplified proton/^{19}F excitation signal from the BLA2BB. The only conditioning of the signal within the 1H portion of the preamplifier module is frequency filtering though there will always be an inevitable insertion loss of typically 1dB.

PROBE ^{1}H: (N-Type)

The excitation signal is transmitted to the probe via this connection and hence the requirement for the heavy duty N-type connector. This connection will also carry the received NMR signal from the probe for the case where the ^{1}H module has been chosen as the OBS module.The received signal is amplified within the preamplifier by typically 30dB.

TRANSM ^{2}H: (SMA type)

This connector has the Deuterium lock excitation signal from the LTX unit of the BSMS/2 or the 2HTX of the AQS as an input.

Probe ^{2}H: (SMA type)

From here the lock excitation signal is transmitted to the probe. The cable will also carry the received deuterium lock signal.

RF_{in} /RF_{out}: (SMA type)

The received NMR signal is daisy chained through both preamplifier modules. This is because there is only one hardwired connection back to the RX-AD although either preamplifier module may chosen as the OBS module and hence act as the first amplifier of the received RF.The daisy chain ends at the RF_{out} of the ^{1}H/^{2}H module.

Tune in/Tune out: (SMA type)

In order for the wobb routine to function the tune signal must be transmitted to the probe and hence must be ported through the preamplifier. Since the tune signal may be directed to all probe coils it must be daisy chained through both preamplifier modules.The source of the tune signal is the AUX out (J7) of the second SGU/2 and the daisy chain starts at the 'Tune in' of the ^{1}H/^{2}H module.

Lock Out: (SMA type)

This is the received lock signal and is transmitted back to the Lock Receiver of the BSMS/2.This connector will not be found on the X-BB preamplifier module.

50 Ohm Termination: (SMA type)

In all current configurations this connection is not required and is simply terminated with 50 Ohms. This connector will also not be found on the X-BB module.

Control Module: Ribbon Cable

As the preamplifier modules have no direct connection to the AQS back plane a range of signals are transmitted over the ribbon cable. These signals are

T/R switching signal

BIS information

CF Information

Experiment setup such as which preamp is the OBS Module.

Power Protection

Unitool info

Power supply

Front Panel Connections: X-BB Module 12.3.2

These are effectively a reduced version of the $^1H/^2H$ module and only the differences need to be highlighted.

1. There is no connection to the LRX or LTX of the BSMS/2 as the lock signal need only ever be ported through the 2H module. Similarly there is no connection to the 2H probe.
2. There is no connection to the RXAD as the signal is first ported through the $^1H/^2H$ module.
3. There is no 50 Ohm termination.

Specifications 12.3.3

As mentioned already these are identical to the HPPR/2 and will be dealt with in the next chapter.

Switching the Unit On and Off 12.4

The internal modules are controlled by the AQS /2 main switch.

Tips ‘n’ Tricks/Basic Troubleshooting 12.5

- Check the power indicator LED’s on the front panel.
- Unitool access (via the DRU) is available which can be used for troubleshooting.
- Check that the modules have been correctly identified in the edsp/edasp window.
- Check the uxnmr.info file contains the correct entry for each module.

Serial Number / ECL Level / Software Downloads 12.6

Unitool can be used to establish BIS (Bruker Informations System) type information regarding board type, part number, ECL, etc. as well as establish the current firmware version. UniTool can also be used to download new firmware as required.

Other Interacting Signals and Units 12.7

The internal preamplifiers are under the complete control of the DRU.To function correctly the DRU must provide:

Power, T/R switching signal, control signals selecting the various models as OBS, Decouple, Lock etc.

Option or Core Item *12.8*

Preamplifiers are a core item but systems up to and including 400 MHz field strength may be fitted with either internal preamplifiers or external HPPR/2. For 500 MHz and above HPPR/2 is standard.

Further Information *12.9*

There is no separate manual for the Internal preamplifiers. Readers are advised to seek information in the HPPR/2 manuals which are listed in the next chapter.

HPPR/2

Introduction 13.1

Reference to the HPPR/2 has already been made in the preceding chapter **12** which dealt with the internal preamplifiers. In that context the HPPR and HPPR/2 are sometimes referred to as the external preamplifiers in that they are located external to the cabinet at the base of the magnet. This is so they can amplify the NMR signal at the earliest possible opportunity and thus minimize losses along the cable. Once the signal has been amplified within the preamplifiers any subsequent losses in cabling are less critical.

Although the HPPR/2 (High Performance Preamplifier) carries the transmitted signal **to** the sample it is primarily concerned with amplifying the relatively weak signals emitted **from** the sample.

The preamplifier also transmits and receives the deuterium (or fluorine) lock signals and is used in the wobble routine. Regardless of the version or configuration all modules will automatically be displayed in the edsp/edasp window once the 'cf' routine is successfully completed.

The AVANCE III is fitted with the HPPR/2 and only this version will be dealt with in this chapter. However some readers may wish to compare the different versions and this is summarized in the table below. The reader is reminded that in terms of performance specifications all three versions are effectively identical.

Table 13.1. Summary of Preamplifier Versions

Name	Location	Configuration
HPPR	Base of magnet	Up to 5 individual modules excluding cover module
HPPR/2	Base of magnet	Up to 8 individual modules excluding cover module
Internal Preamp	AQS/2	2 modules (three preamplifiers) currently available

A very common configuration of the HPPR/2 consists of a cover module along with three individual modules, ^{1}H, ^{2}H and an X-BB. Regardless of the number of individual modules there must always be a cover module installed. This configuration along with the associated cabling is illustrated in ***Figure 13.4.***.

Location and Photograph 13.2

The HPPR/2 is shown in ***Figure 13.1.*** and as mentioned above is located at the base of the magnet.

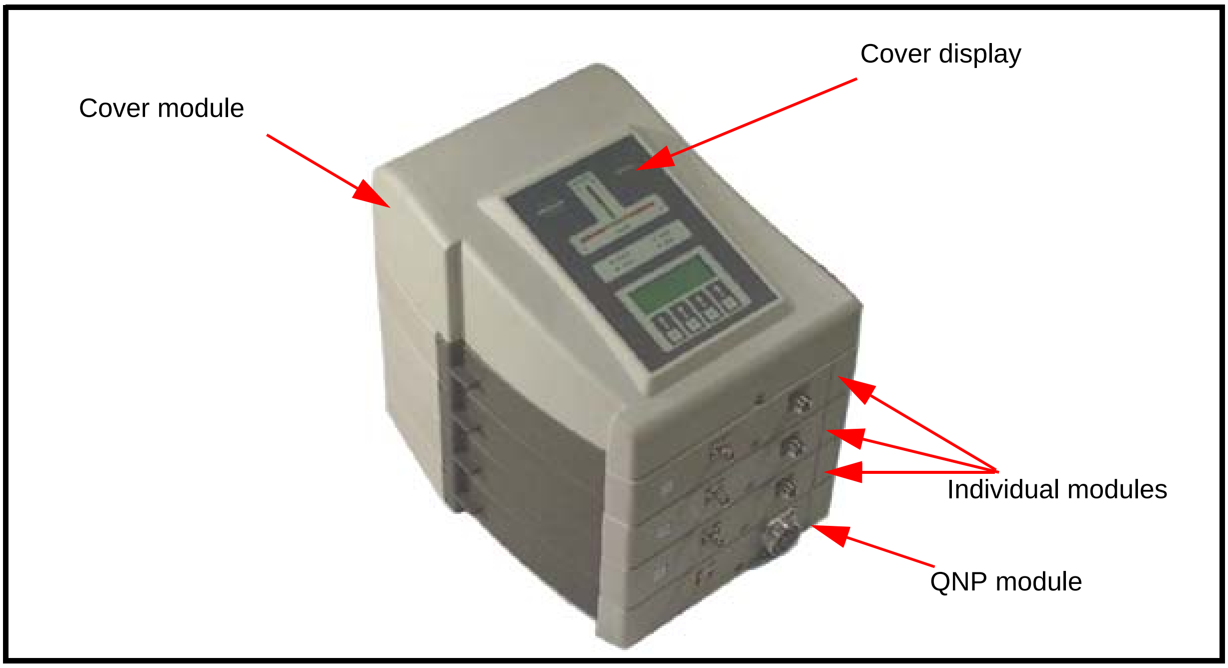


Figure 13.1. HPPR/2

General Information, Configuration and Function 13.3

The number and type of modules fitted is made known to the software via the ‘cf’ routine. For the HPPR/2 this info is ported through the PSD3 and thus is made known to the DRU.This info may be checked in the uxnmr.info window shown during the ‘cf’ routine.(see ***Figure 13.6.***)

Each individual preamplifier module is effectively identical except for the operating frequency range which dictates in particular the design of the various filters and amplification stages within the module. To understand the operation of the preamplifier it is best to consider the various modes of operation (OBS, Decouple, Lock and WOBB) of any given module and these will now be discussed. Note that while the following description has been written in the context of the HPPR it is also equally applicable to the internal preamplifiers.

OBS Mode 13.3.1

Signal Source: Amplifier **Signal Receiver: RX-AD**

Much of the preamplifier technology is concerned with what is known as the Transmit / Receive switching. Effectively the signal going to the probe is transmitted without any action apart from frequency filtering to minimize noise. There will also be an inevitable insertion loss of typically 1dB. Once this transmit signal has elapsed the signal path within the OBS preamplifier is altered so as to amplify the received signal from the probe by typically 30dB. The trick is to make this switch as fast as possible and suppress leakage so that the tail of the transmitted signal does not swamp the received signal. The switching is controlled by the RGP_HPPR signal described below. The received signal exits the HPPR/2 via the BNC labelled RF-OUT of the rear of the cover module (see ***Figure 13.2.***.) The equivalent signals leaves the front panel of the internal preamplifiers via an SMA connector also labelled RF OUT.

The OBS module is the only module that performs the T/R switching and is thus effectively the only source of signal for the receiver during an acquisition.

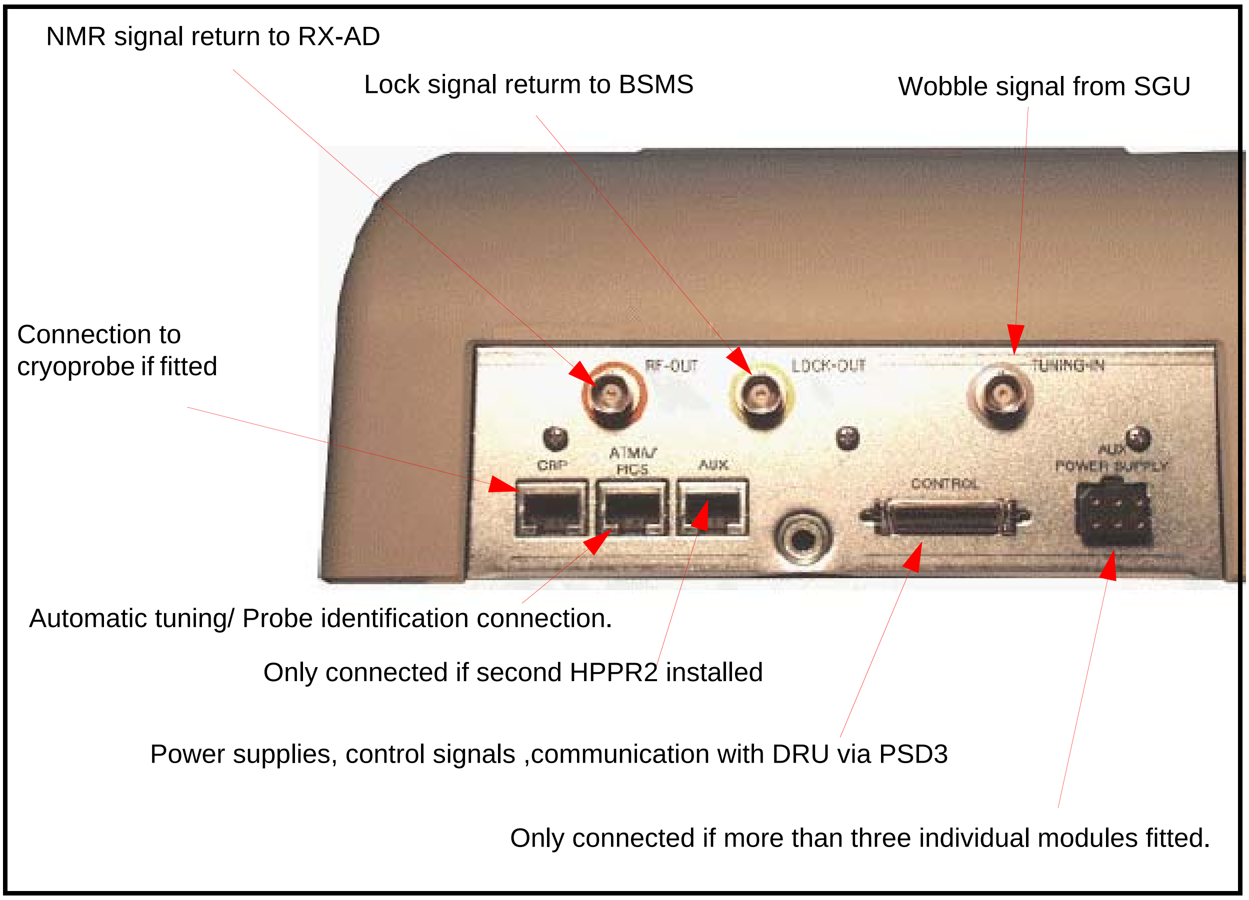


Figure 13.2. Rear of Cover Module HPPR/2

RGP_HPPR (Preamplifier receiver gating pulse, aka RGP_PA)

This pulse is generated by the observe SGU and is used to gate the OBS module of the preamplifier and thus implement the transmit/ receive switching. The timing of the pulse can be modified with the ‘edscon’ parameters.This signal is routed via the PSD3 to the observe module in the preamplifier of the HPPR/2. All other non lock HPPR modules are left permanently in transmission mode. For the internal HPPR the T/R switching signal is also generated by the SGU/2 and delivered by the DRU over the ribbon cable.

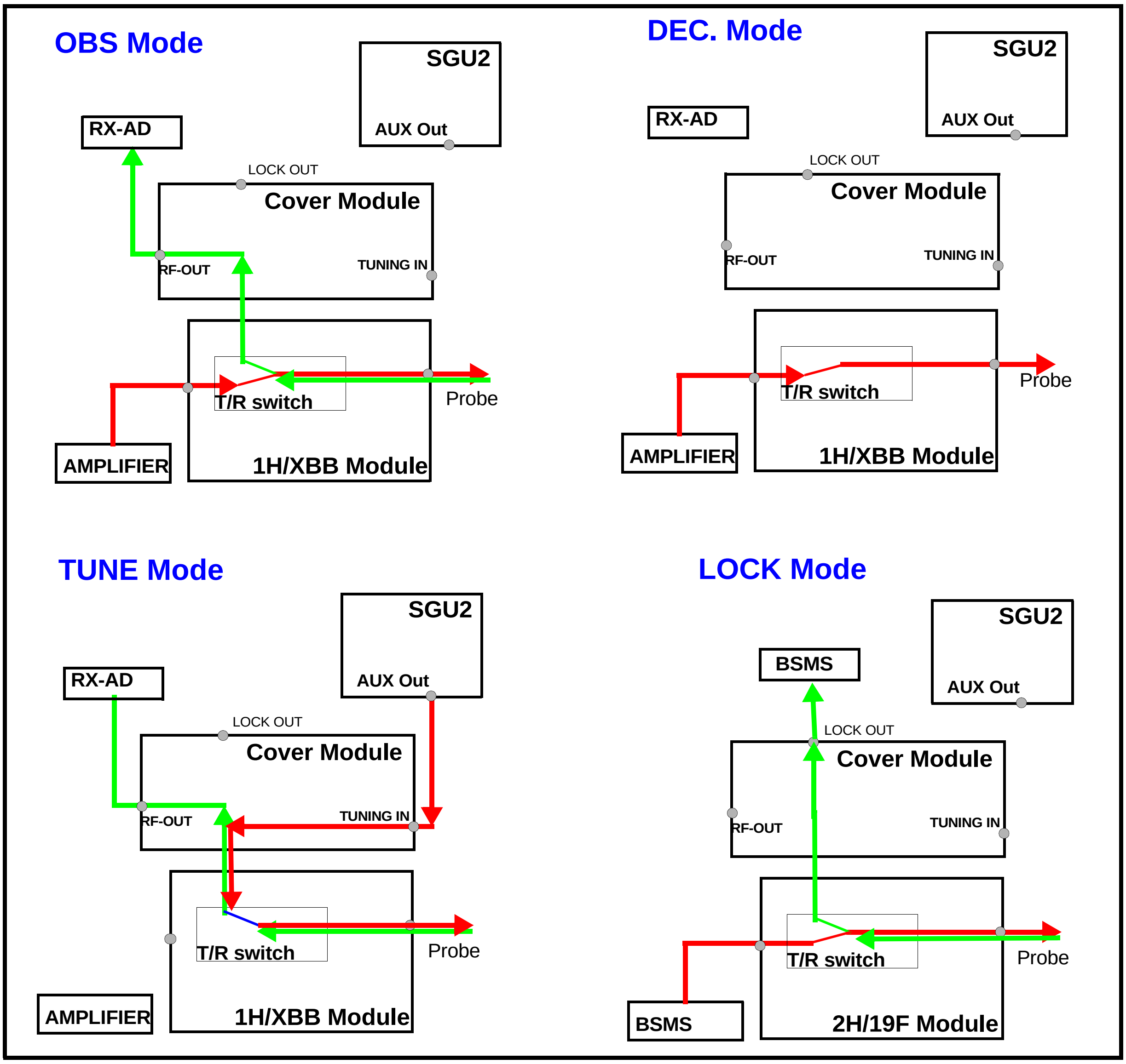


Figure 13.3. HPPR modes of operation

Decouple Mode 13.3.2

Signal Source: Amplifier **Signal Receiver: n/a**

A module when in this mode will transmit decoupling signals to the probe and will remain effectively in transmit mode permanently. The module will not respond to the T/R switching signal which is routed to the OBS module only. The single role played by a module in decouple mode is to filter the signal to the probe to minimize noise.

Lock Mode *13.3.3*

Signal Source: BSMS LTX **Signal Receiver: BSMS LRX**

The preamplifier module will transmit the lock excitation signal which originates in the BSMS/2 to the probe and return the emitted signal to the lock receiver unit of the BSMS/2 where it is amplified.

For the HPPR/2 the received signal exits the rear of the cover module via the BNC labelled LOCK-OUT (see ***Figure 13.2.***). A similarly labelled SMA connector carries the received lock signal from the front panel of the combined $^{1}H/^{2}H$ internal preamp.

While theoretically any module can be placed in lock mode, in practice only modules that can transmit either ^{2}H or ^{19}F frequencies are used.

Note that the X-BB internal preamplifier module does not support a 19F lock.

Tune Mode *13.3.4*

Signal Source: Second SGU/2 **Signal Receiver: RX-AD.**

When in wobble mode a low voltage signal is generated by the second SGU/2 (non router systems) which is then routed to the required module. The received signal is routed back to the RX-AD.

The excitation signal originates from the AUX OUT of SGU/2 and enters the rear of the cover module via the BNC labelled Tuning _IN (see ***Figure 13.2.***) and exits via the normal receiver BNC labelled RF-OUT. For the case of internal amplifiers the signal enters the $^{1}H/^{2}H$ module by the SMA connector labelled ‘Tune in’.

How the HPPR/2 modules are cabled is displayed in ***Figure 13.4.*** The reader should note that this cabling is hard-wired and is effectively the only section in the RF path that can not be switched using software commands. In particular the operator must ensure that whenever power is transmitted to an amplifier output that this output is connected to an appropriate preamplifier module. To assist in this the operator is offered the opportunity to manually create a display of the existing hard-wired cabling from the transmitter outputs to the various HPPR modules during the cf routine as described in section ***10.3.1***.

HPPR/2 Cover Displays *13.3.5*

There are four status LEDs on the top cover

ERROR:

Note that when the HPPR/2 is rebooting after a power down or when new firmware is being downloaded the ERROR LED will blink, but this is not a genuine error. A genuine error is signified by the LED permanently lighting.

SLEEP:

This indicates that an acquisition may be in progress and that the Cover Module activities are minimized to reduce potential source of noise.

COM:

Indicates exchange of data with the DRU via the PSD3.

READY:

This LED lights in normal operating mode.

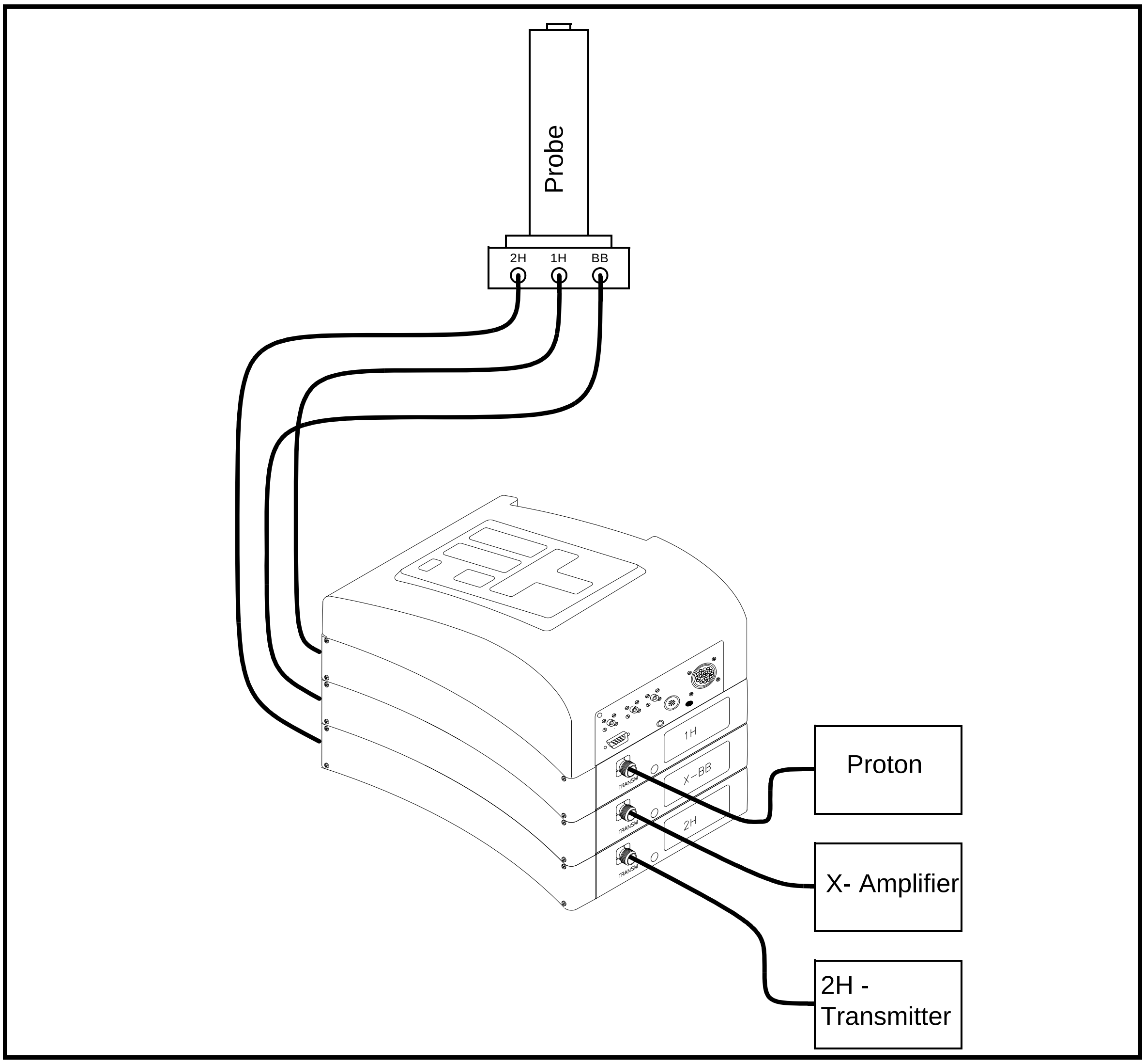


Figure 13.4. Typical Preamplifier Cabling (HPPR and HPPR/2) for the Popular Th Module Configuration

There is also a set of functions F1-F4 on the cover module.From this display (see ***Figure 13.5.***) the operator can establish

- the number and type of modules installed
- which module is chosen as the OBS module
- which module is chosen as the Lock module

A comprehensive description of the various menu points is available in the individual technical manuals. (see section ***13.9***).

A final two sets of LEDs arranged in the shaped of an inverted T enable the user observe the quality of the tuning and matching in terms of the reflected signal.

Figure 13.5. Principal Features of HPPR/2 Cover Module Display

Specifications 13.3.6

These will vary somewhat from module to module and the reader is referred to the manual listed at the end of the chapter for detailed specifications. To give the reader some guidance of the relevant specs ***Table 13.2.*** shows the principal specifications for one particular module in this case the X-BB module (300-700).

Table 13.2. HPPR/2 X-BB Specifications

Gain (typ)	28dB
Noise Figure (typ)2	2 dB
Max. Power Rating	500W, 100us, 2% Duty Cycle
Insertion Loss	<=1dB

Switching the Unit On and Off 13.4

The HPPR/2 receives its power from the PSD3 and is effectively controlled by the AQS/2 main switch.

Tips ‘n’ Tricks/Basic Troubleshooting 13.5

- Check that the edsp/edasp display corresponds to the hardware configuration.
- Check the diagnostic indicator LED’s on the front panel.

- The top cover display of the HPPR/2 has an LED display leading to extensive diagnostic information using the F1 to F4 buttons. In particular all power supply voltages are monitored by the cover module and an error message is generated if not at the required levels.
- Unitool access (via the DRU-E) is available which can be used for troubleshooting as well as establishing which modules are installed, their ECL etc.
- Check the uxnmr.info file for the correct entry for each module (***Figure 13.6.***).

```
Preamplifiers :
HPPR: - HPPR/2 preamplifier connected to 149.236.99.89:/dev/tty10
    Type       : HPPR/2
    Controller: Application firmware = AL
                15 LEDs for tuning, 15 LEDs for matching
    Module  1 : 1H LNA
    Module  2 : XBB19F 2HS
    Module  3 : 2H
    Module  4 : HPHP XBB31P
    Module  5 : HPHP 19F/1H
```

Figure 13.6. Extract from uxnmr.info Window Showing HPPR/2 Details

Serial Number / ECL Level / Software Download 13.6

The HPPR/2 modules are BIS (Bruker Informations System) compatible which will allow access to ECL information using UniTool. UniTool can also be used should firmware need to be downloaded.

Other Required Signals/Units 13.7

To function correctly the preamplifiers require:

- Power from the PSD3
- T/R switching signal
- Control signals selecting the various models as OBS, Decouple, Lock etc.

Option or Core Item 13.8

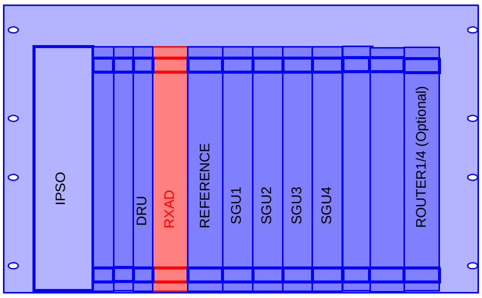
Every system has at least one preamplifier assembly which will consist of one cover module and a selection of individual modules.

Further Information 13.9

For a detailed technical description refer to the HPPR/2 Technical Manual Version 003 P/N: Z31559.

Receiver 14

Introduction 14.1



Much of the drive in recent NMR development has concentrated on the receiver. The most significant recent hardware advances have been

- the integration of a receiver and digitizer into a single unit
- oversampling with the use of the max digitizer rate (2 X 20 MHz) regardless of SW
- the increase of the IF (Intermediate frequency) from 22 MHz to 720 MHz.
- the delivery of the digitized data to the DRU exclusively over the backplane via an LVDS type link

Since the development of IPSO and the use of an IF of 720 MHz the RX22 is not fitted in AVANCE III systems and so shall not be discussed in any detail. The two current AVANCE III receivers are the RXAD and the RXAD-BB. Both these receivers have effectively identical operation and differ principally in terms of the Sweep Width over which the gain and in particular the gain flatness is specified. The RXAD-BB is used for solids and the components used in the receiver section allow the gain flatness to be specified over a SW of 5 MHz. The RX-AD is used for high resolution NMR and the gain is specified over a narrower SW of 1 MHz. The other principal difference is that only one version of the RXAD-BB (the RXAD-BB1000) is produced which covers all current spectrometer frequencies whereas three (frequency dependent) versions of the RX-AD are available. As a result of the similarities between the RXAD and RXAD-BB (the front panel of both receivers have identical connections!) this chapter will use the term RXAD or simply receiver to apply to both types. Where a distinction needs to be made this will made clear within the context of the description.

Table 14.1. Comparison of two Types of Receiver

Receiver	RXAD	RXAD-BB
Available Versions	RXAD400 RXAD600 RXAD1000	RXAD-BB1000
Corresponding REF board	REF400 REF600 REF1000 or REF/2 1000	REF1000 or REF/2 1000
Gain flatness	3dB at 1 MHz	3dB at 5 MHz

General Information, Configuration and Function 14.2

The principal functions of the RXAD are to

- receive and demodulate the NMR signal
- amplify the signal so that it matches the range of the on-board ADC
- digitize the amplified signal using an on-board ADC
- transmit the digitized data to the DRU over the backplane.

The RXAD is a receiver combined with an on-board digitizer and hence previous standalone digitizers such as the SADC,HADC/2 or FADC will not be found in an AVANCE III spectrometer. The digitizer specifications of the RXAD are better than the specs of earlier standalone digitizers and will be dealt with later in the chapter. The RXAD uses a new backplane which has an LVDS type connection to the DRU which is available on the AQS/2 and AQS/3 only.

To aid in the description, the receiver will be dealt with in two sections: the receiving function and the digitizing function.

Receiving Function 14.2.1

The receiver is one of the most critical hardware elements in any modern spectrometer. As the name suggests the receiver is concerned with the amplification of the signal ‘received’ from the sample and uses an intermediate frequency of approximately 720 MHz. (The concept of intermediate frequencies will be explained later). After the amplification the signal is sent to the on-board digitizer. The unamplified signal from the sample will typically be of the order of microvolts which will then be amplified, first in the preamplifier and then in the RXAD, so as to match the input range of the digitizer section($\pm$5V). If the signal is overamplified (i.e. gain set too high so that the receiver output is greater than 5V) then the digitizer is saturated and all signals greater than 5V will be detected as having the same amplitude. A ‘clipped’ FID is the result of saturating the digitizer (see ***Figure 14.1.***) On the other hand if the gain is too low then only a small part of the digitizer range will be used and the digitizer will not be able to deliver the optimum resolution. Clearly setting the most appropriate gain (many operators use the ‘rga’ command) is very important and much of the receiver technology is designed to ensure that the receiver output best matches the input range of the digitizer section.

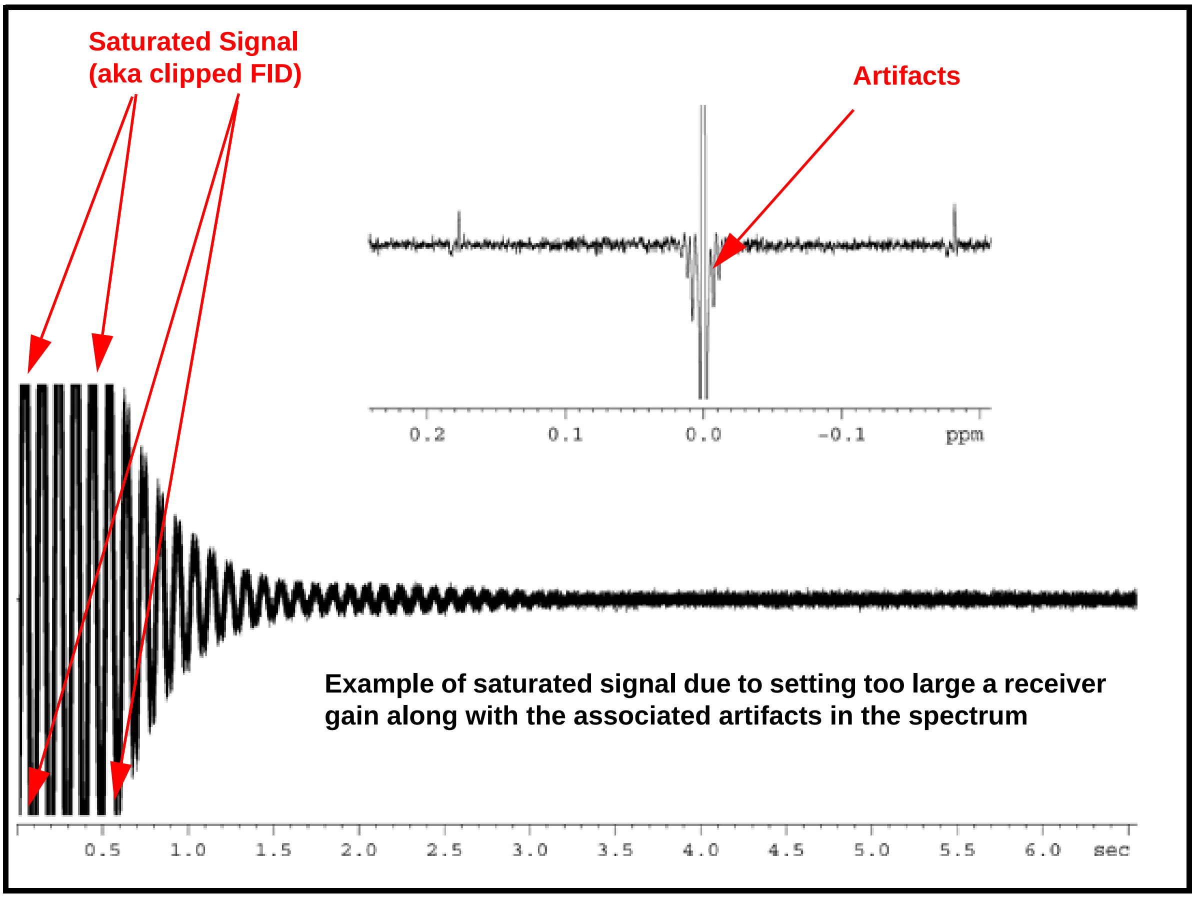


Figure 14.1. Example of Saturated Signal

Some of the features that characterize a good receiver are:

Equal amplification of all frequencies: Effectively the receiver must amplify all frequencies within the chosen SW equally (see gain flatness spec. in ***Table 14.1.***). Otherwise quantitative information based on the amplitude of the peaks would be unreliable. Note that saturation of the digitizer as described above would also render quantitative measurements unreliable.

Phase response: The signals entering the receiver have a certain phase. The ability to maintain the precise phase relationship of all RF signals is an important feature of RF receivers. This is particularly important when spectra are to be accumulated over a number of scans and, as will be explained below, a phase correction is done as part of the processing.The reader should at this stage make a distinction between **unwelcome analog shifts in signal phase** that occur within the receiver section of the RXAD and **controlled receiver phase control** (i.e phase cycling) which is implemented digitally within the DRU.

Changes in setup (e.g. cable length or RG or SFO1) will inevitably result in a phase shift. Phase shifts that are constant (i.e. independent of frequency) are termed zero order phase shifts. For any given experiment (assuming no change in RG value, cable lengths etc. between scans) the zero order phase correction is constant.

The other phase correction that is normally carried out in spectrum analysis is to correct for the inevitable variation in phase with frequency which if linear is easily compensated for. This is termed a first order phase correction. For any given experiment the first order phase correction is constant as long as the OBS frequency and sweep width etc. are not changed.

Dynamic range: This range refers to the maximum and minimum amplification. The RXAD has a range of 78 dB. Expressed in numbers, the smallest gain is 0.25 and the largest gain is 2050.

Gain resolution: The receiver enables a gain of 78dB to be set in 1dB steps.

Note: When an RG value is entered in the software and this value does not correspond exactly to a hardware value, then the nearest value is taken.

Temperature regulation: Small phase and gain drifts can be caused by temperature fluctuations. (This is a feature of the electronic circuitry performance, not of the RF signal) The receiver has a heater and regulation circuit used to monitor and maintain a constant temperature in sensitive modules such as the quad module.The Unitool service tool which will be dealt with subsequently (see section ***14.5***) allows the user to read out the temperature within the quad module.

Hardware adjustments: Regardless of design no two electronic circuits are identical and differences in the two channels of the quad module (see later) need to be compensated for. The most common adjustment is the DC offset which can be done via Unitool.

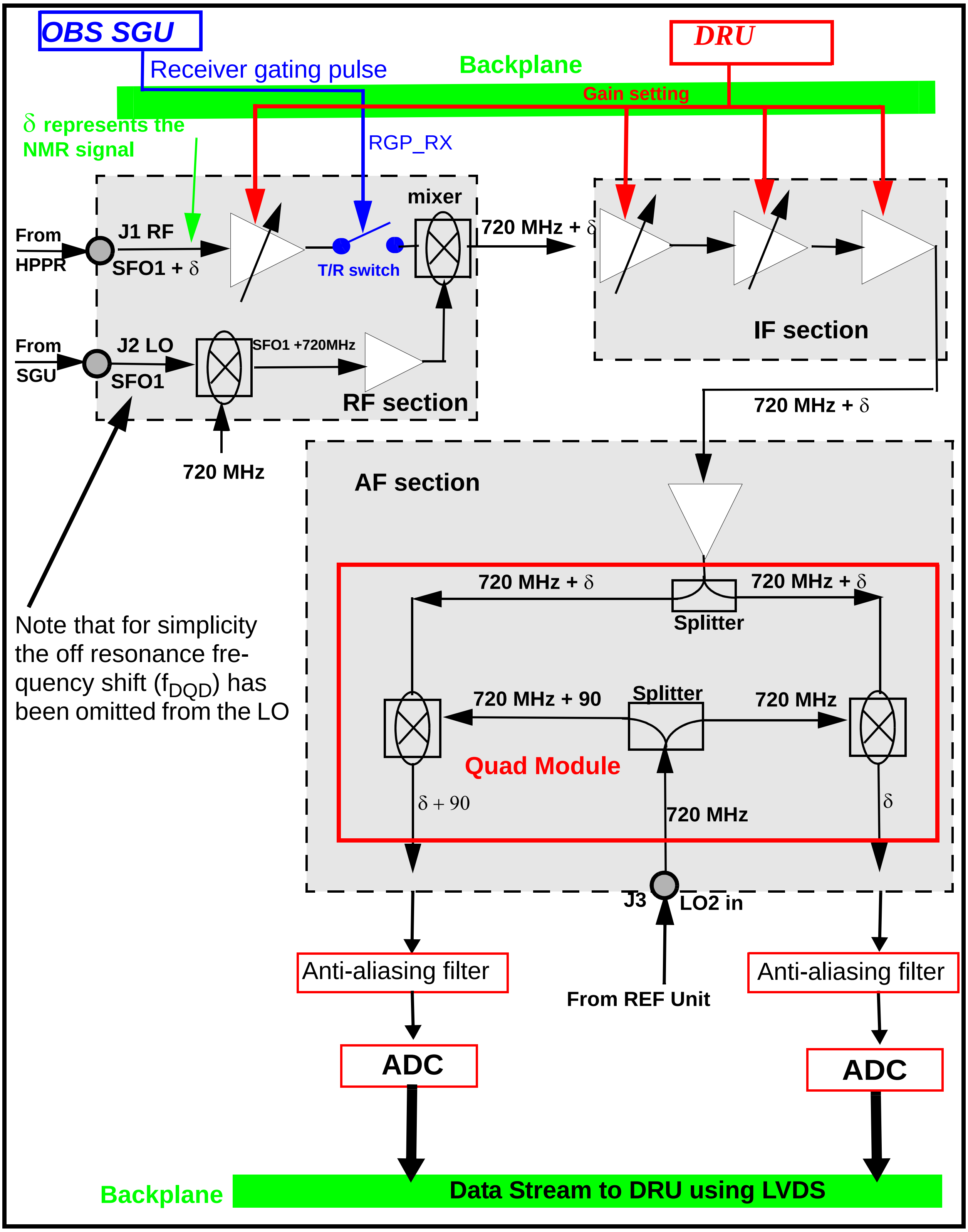


Figure 14.2. Simplified Schematic of the RXAD and RXAD-BB Receiver

Amplification and quadrature detection: The RF input is amplified in several stages to increase the dynamic range. The output of one section is cascaded into the input of the next. In this way components can be optimally matched to the signal strength at each stage. The RG value is transferred to the receiver via the backplane. Effectively different amplifying stages are switched in or out depending on the required gain. This change in the amplification path is the source of the phase shift (discussed earlier) that occurs when the RG value has been changed between scans.Calibration of the receiver at the production facility has made it possible for the gain to be set in 1 dB steps.

At the final stage of the receiver the RF signal is split into two channels with a phase difference of 90 degrees, a standard method known as quadrature detection which is used to suppress mirrored signals. In order to ensure that the two channels provide identical amplification slight adjustment to the phase and gain of these channels may be necessary. This can be done via Unitool. The final outputs (channel A and channel B) are connected directly to the ADC. The two signals should be in the range of $\pm$5V and the amplitude should change with the value of RG.The only distinction between the two signals is a 90 degree phase shift and the subsequent spectra resulting from Fourier Transformation are often referred to as the ‘real’ and imaginary’ spectra. Once digitized the two data streams are delivered onto the backplane where they are transmitted over a LVDS type link along the backplane to the DRU (see ***Figure 14.2.***).

Receiver gating: The timing of the receiver opening and closing (aka gating) is critical. The receiver should only be open when genuine NMR signals are emitted from the sample. The desire will be to open the receiver immediately after the excitation signals have elapsed. However opening the receiver too soon may cause the receiver to be swamped by the tail of the excitation pulse. (The frequency of excitation is of course the frequency emitted at resonance or close to it in the case of off-resonance excitation). Note also that this is one reason why it is important that rectangular excitation pulses have steep falling edges.

Opening the receiver too slowly however will mean that sensitivity will be decreased due to loss of signal. This switching from transmit mode to receive mode is often referred to as T/R switching and is controlled in AVANCE systems using a signal generated by the OBS SGU (RGP_RX) delivered to the RXAD over the backplane. A similar signal (RGP_PA) is used to control the T/R switching of the signal path in the HPPR. Although the two signals will have slightly different timing (due to different hardware responses) they are both generated on the OBS SGU to ensure synchronization between the RXAD and the HPPR/internal preamplifier. Experienced users may modify the timing of these and other signals using the ‘edscon’ command (see ***Figure 14.3.***). How the gating signal is transmitted to the HPPR/internal preamplifier will be discussed in the front panel section (see ***14.3.1***.).

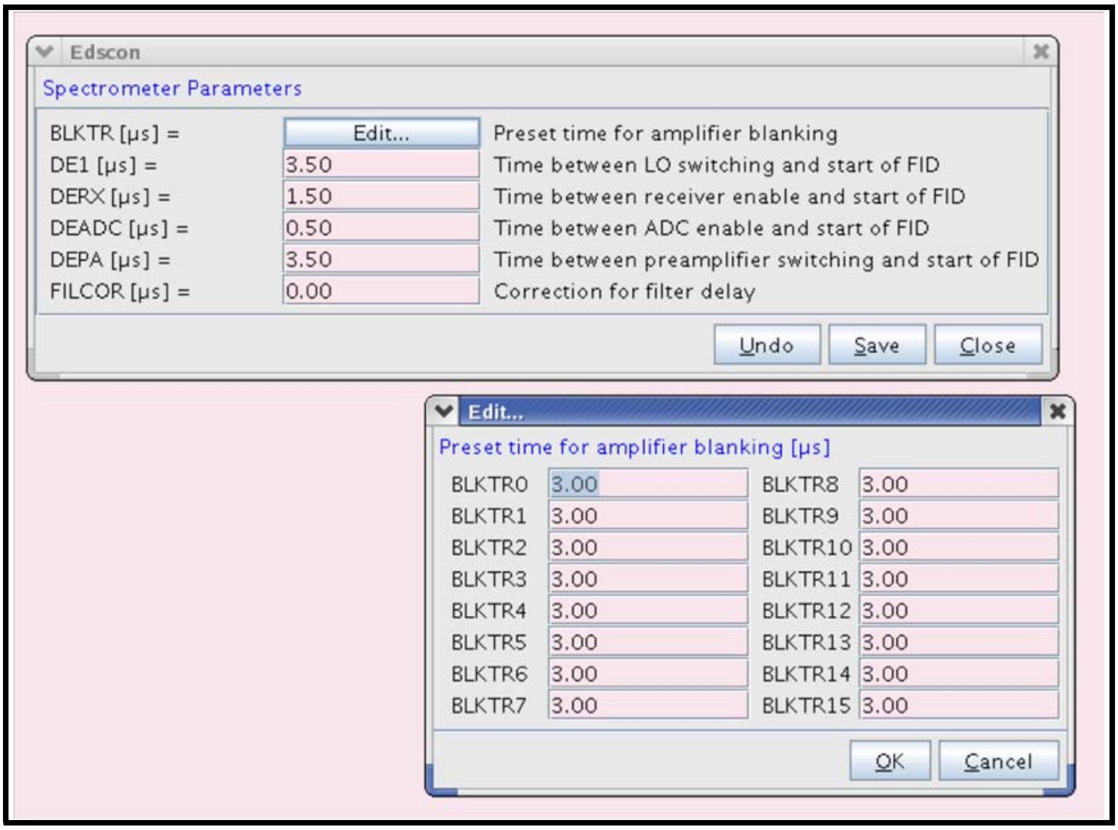


Figure 14.3. EDSCON

Demodulation: A signal with specific frequency (the LO frequency) is required by the receiver to demodulate the genuine NMR signals from the spectrometer carrier frequency. (This is analogous to an FM radio receiver where the audio signals in the low Khz range are demodulated from the carrier frequency which for FM radio is in the MHz range).

For the RXAD and RXAD-BB the LO frequency has a value of SFO1+720 MHz. The 720 MHz is delivered directly from the REF unit to the front panel J3 connector.

Digitizing Section 14.2.2

Modern processing of information is entirely digital and the next step after amplification of the NMR signal within the RXAD is digitalization. Digitizers work on the ‘sample and hold’ principle whereby in a repetitive manner the sample is analyzed and its amplitude determined. The amplitude is ‘held’ at a fixed value for a short period of time to enable the ADC to assign a value to this amplitude.This is all done at a set rate (the sampling rate) to build up a digital (quantized) picture of the analog signal as in ***Figure 14.4.***. The time interval between successive sampling events is called the dwell time and has the value of 50ns in the RXAD.The RXAD is constantly digitizing but the DRU discards the digitized data (actually it sets it to zero) until it receives the command pulse (RGP_ADC) from the OBS SGU.This command is simply a signal that initiates the storing (as opposed to storing zeros) of the digitized data.This method is used to minimize the disturbance (i.e. noise) during an acquisition. In effect the digitizer is always active, the only difference between acquiring and not acquiring is whether the data is zeroed or not by the DRU.

Assuming that the dwell time (DW) is sufficiently short, then, the greater the number of bits assigned to each amplitude determination, the more accurate the digital representation of the analog signal (see ***Figure 14.4.***).The two most important features of digitizers are thus the minimum dwell time and the resolution which are discussed below.

Min. dwell time: This is measured in microseconds or nanoseconds and is defined as the minimum time between two successive sampling events. To correctly determine the frequency of any signal according to the Nyquist theorem a minimum of two points within each period or cycle of the signal must be sampled. Otherwise high frequency signals will be detected at a lower and incorrect frequency. Thus the max sampling rate determines the maximum sweep width. The two are linked by the formula Sampling Rate = 2*SW where Sampling Rate has units of samples per second and SW has units of Hz. Another useful formula is that the Dwell Time is the reciprocal of the sampling rate. Modern digitizers have sampling rates of the order of MHz and associated dwell times of nanoseconds. As will be explained later, although the Nyquist theorem dictates a minimum dwell time for correct frequency determination, modern spectrometers use even shorter dwell times in a technique known as oversampling. The benefit from this is an improvement in resolution (see ***Table 14.2.*** for resolutions specifications). For AVANCE III systems the DW is fixed at 50ns regardless of the SW.The source of this timing is the 20 MHz signal derived from the AQS backplane. Reference to ***Figure 16.2.*** will demonstrate that this is the same signal that clocks all AQS units (and in particular the SGU) as well as the IPSO itself. Since there are two channels in the RXAD each clocked at 20 MHz, the effective sampling rate is 2 X 20 MHz and so the max SW is 20 MHz and not 10 MHz.

Resolution: This is measured in terms of number of bits and represents the number of binary bits assigned to the amplitude determination. The greater the number of bits the more precise the amplitude determination and in particular the better the chance of distinguishing between peaks with similar amplitudes. As you will see from ***Table 14.2.*** digitizers used in AVANCE spectrometers have typically between 12 and 22 bit resolution depending upon the SW.

Anti-Aliasing Filters *14.2.3*

One of the major issues with all high frequency digitizers is the concept of aliasing or folded signals. Effectively this is predicted by the Nyquist theorem discussed above. There will always exist the possibility of signals or noise at frequencies outside or above the SW. These high frequency signals will not be sampled at a sufficiently high rate and so they will be interpreted as lower frequencies and may appear as ‘folded’ signals inside the spectral window. To overcome this problem analog filters are used prior to digitalization to remove the frequencies outside the spectral window. Earlier generation digitizers had a comprehensive range of analog filters which were set automatically to suit the SW.

With the introduction of digital filtering the RXAD requires only one analog filter on each channel prior to the digitalization.The purpose of this filter is simply to ensure that no folded signals fall within the digital filter where they would not be suppressed see ***Figure 14.5.***. The performance of the digital filters which are applied in the DRU is far superior to the analog filters in that their frequency response at

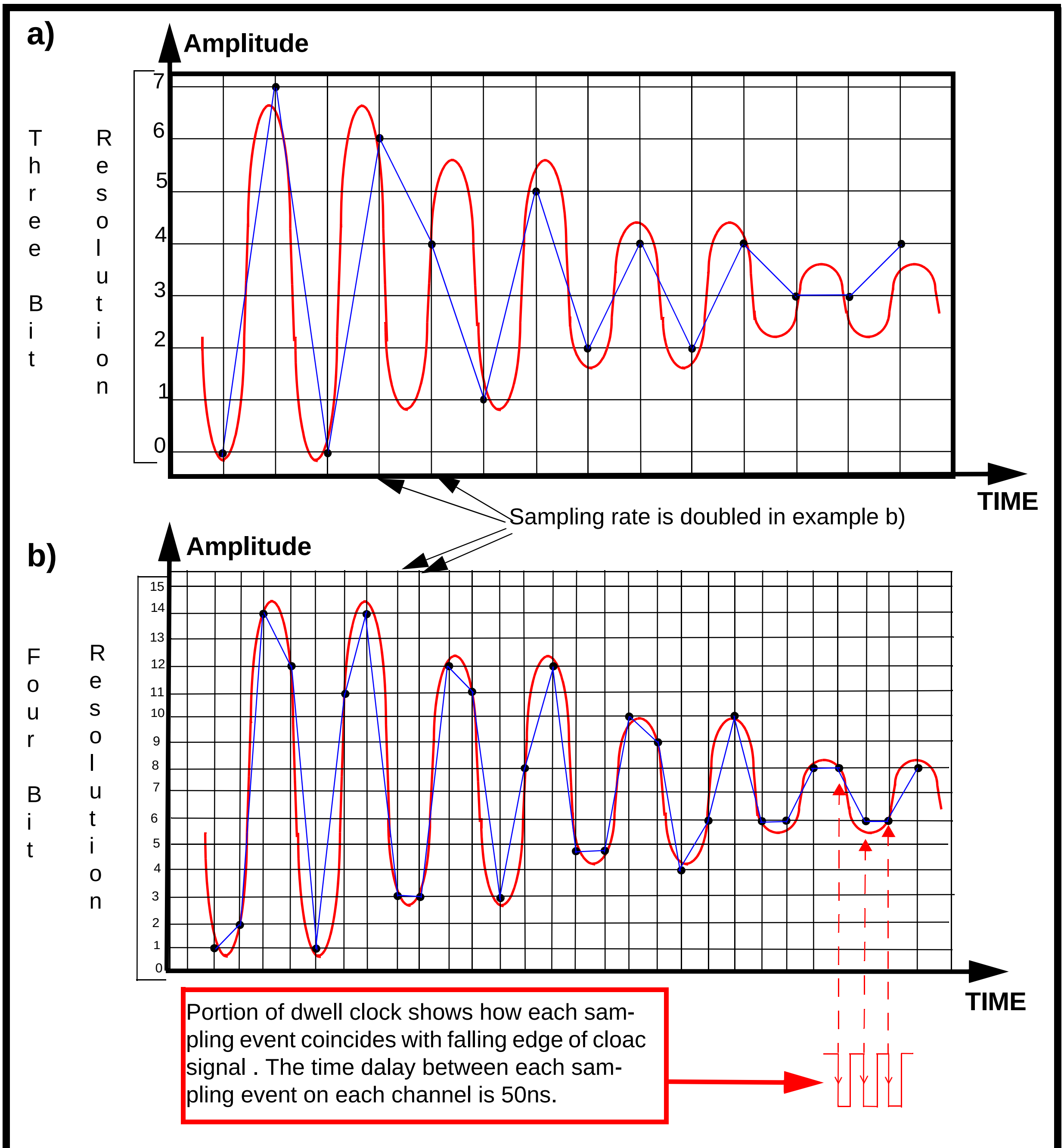


Figure 14.4. Effect of sampling rate and resolution of digitalization

mid range is much flatter and the roll-off rate at the edges is far steeper. Digital filters employ oversampling which corresponds to sampling at rates well above the minimum required by the Nyquist. With the higher sampling rate the high frequency signals are not misinterpreted and so are filtered out by software as opposed to appearing folded into the spectral window.

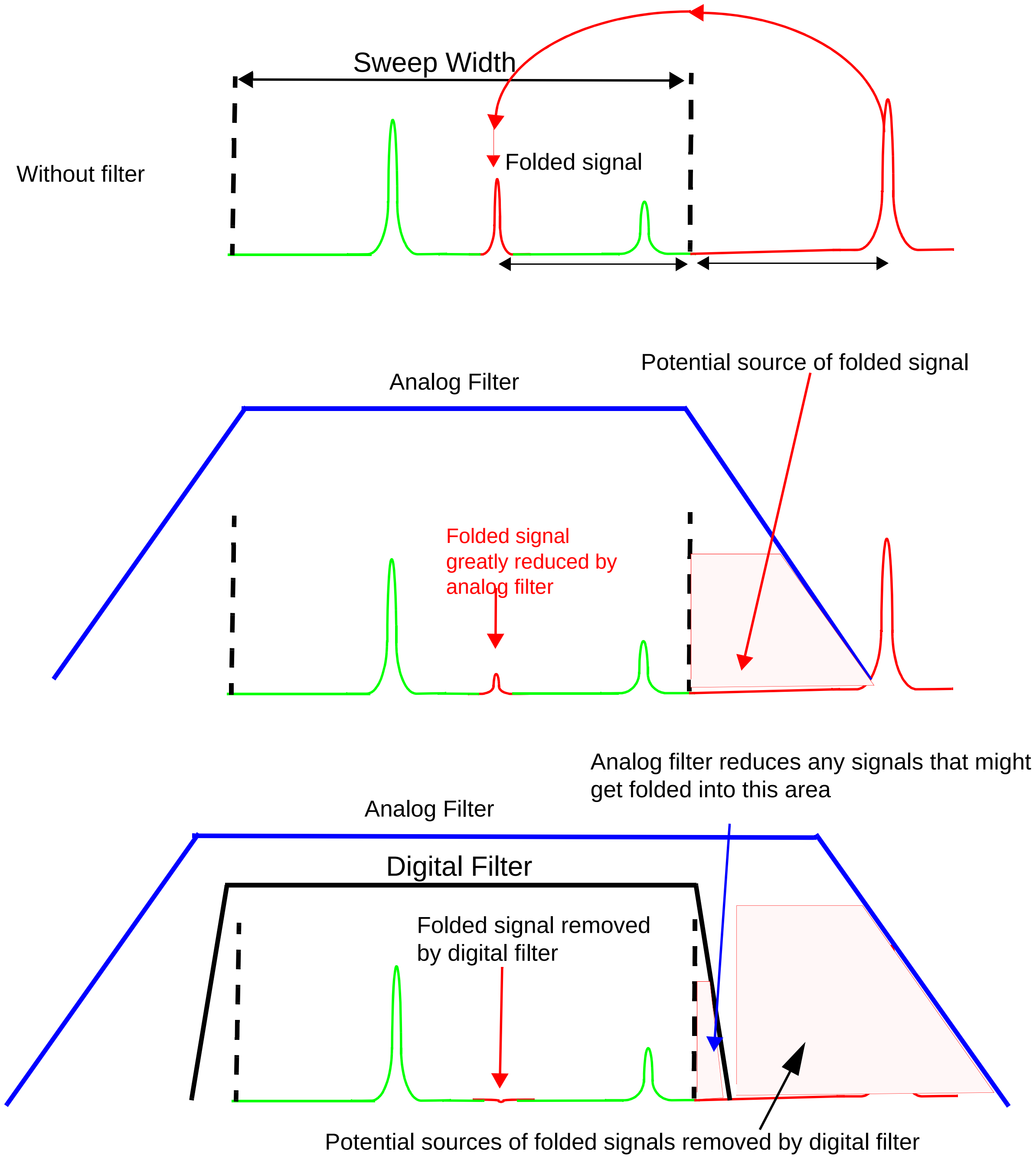


Figure 14.5. Schematic representation of folded signals and effect of anti-aliasing filters

One effect of oversampling is that, depending on the required Sweep Width and the type of digitizer, the resolution of the digitizer may be improved to typically 20-22 bits. In oversampling many more data points than strictly necessary are accumulated. The DRU has the ability to use this extra data to compute a running weighted average of the sampled points and so improve the resolution. Note that when the max. Sweep Width is required there is no oversampling and so no improvement in resolution is achieved. For this reason the digitizer resolution should always be quoted at a specific sweep width.(see table ***Table 14.2.***)

Table 14.2. Principal RXAD and RXAD-BB specifications

Parameter	Specification
Dynamic Range	78dB
Gain resolution	1dB
Gain Flatness	3 dB at 1 MHz (RXAD) 3 dB at 5 MHz (RXAD-BB)
IF	720 MHz
Min. Dwell time	50ns
Max. SW	20 MHz
Resolution	12 bit at 20 MHz, 16 bit at 5 MHz, 20 bit at 200KHZ >21bit at 10kHz

Location and Photograph 14.3

The RXAD is located between the DRU and the REF (see ***Figure 3.1.***.) to avail of the LVDS link between slots1 and 2 to facilitate data transfer between the RXAD and the DRU. There is also an LVDS link between slots 5 and 6 for multi receiver systems with a second RXAD and a second DRU. Note that the RXAD slot is the first of the 10 analog slots. An extract from the uxnmr.info file is shown in ***Figure 14.6.***

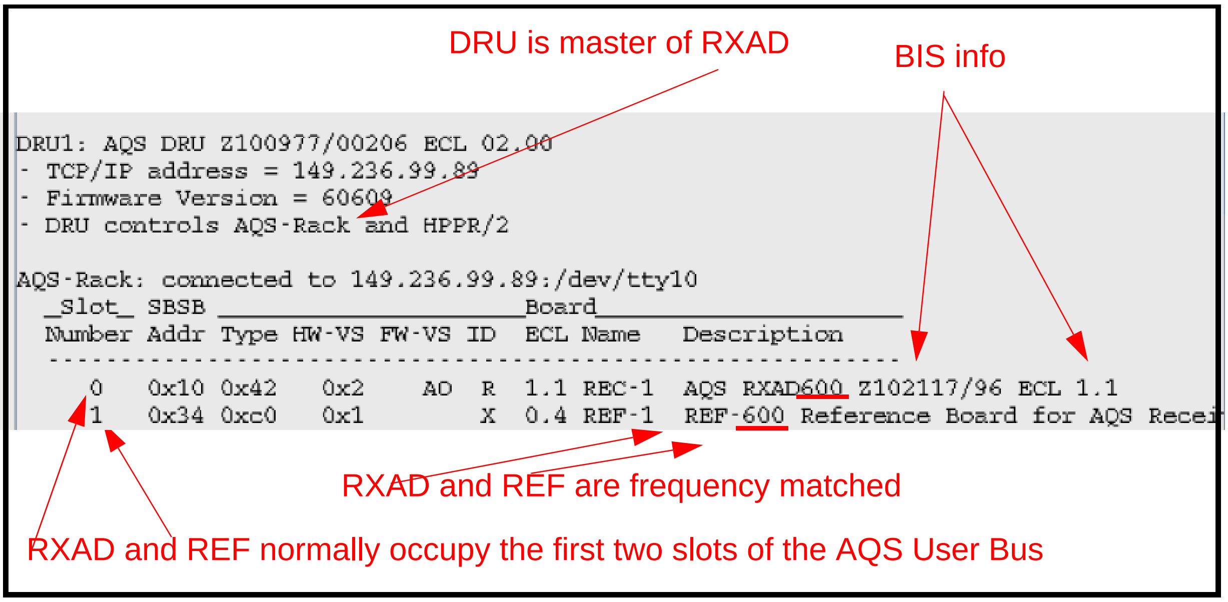


Figure 14.6. Extract from uxnmr.info File

Front Panel RXAD-BB and RXAD *14.3.1*

As mentioned earlier the two front panels have the same connections

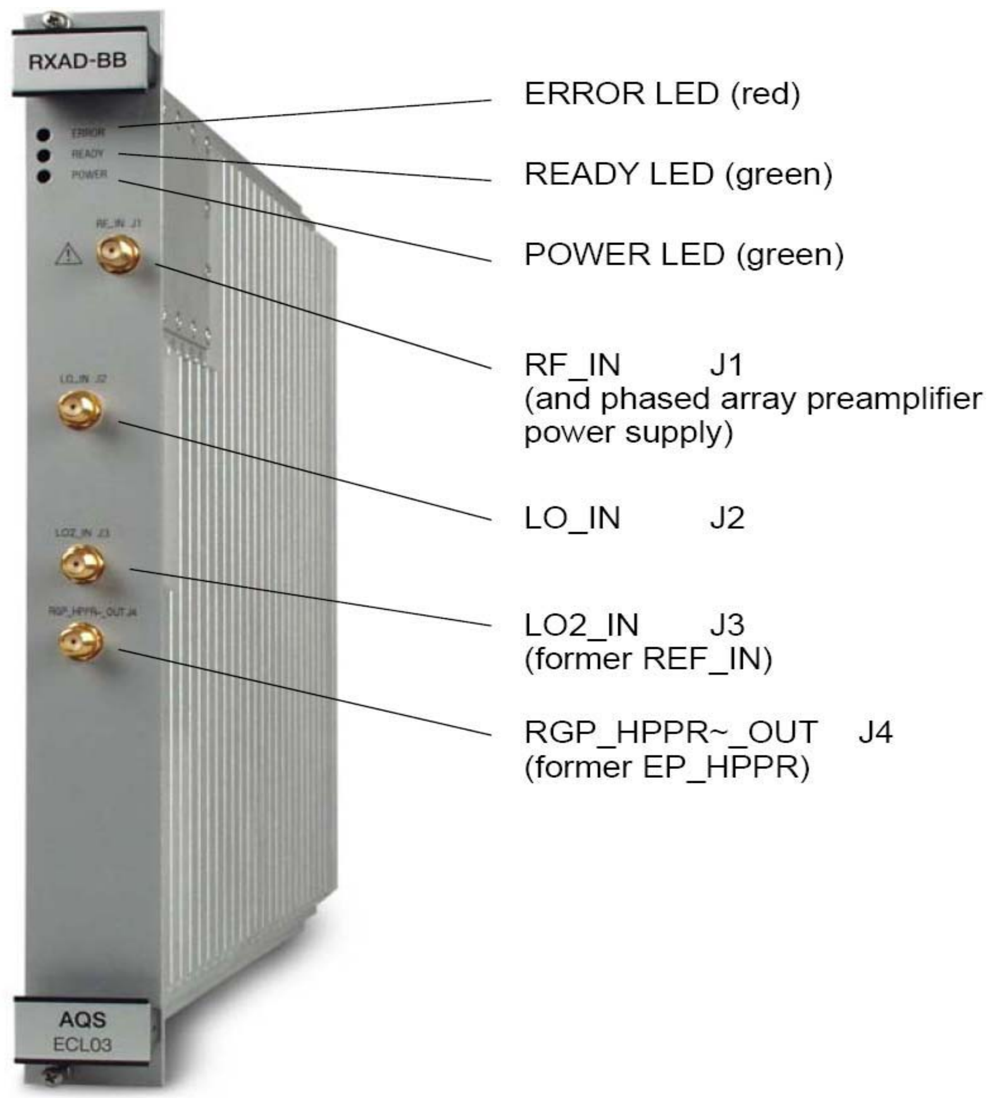


Figure 14.7. Receiver Front Panel

ERROR LED and READY LED

There are a selection of possible states (on, off or blinking) for these two LEDs. A blinking ERROR LED may indicate a warning as opposed to an actual error. For example the ERROR LED will blink slowly during wobb, gs or RGA The state is termed a warning because in these dynamic modes of operation, parameters need to be adjusted. As a result the RXAD controller module (which goes into sleep mode at the start of a normal acquisition) will need to be active. Any activity on the receiver during an acquisition will potentially cause spikes and so the operator is simply being warned that sensitive NMR experiments are not recommended in this modes due to possible disturbances originating from the controller activity.

The ERROR LED will also blink rapidly during boot mode.

Although there are many possibilities, a combination of the ERROR blinking slowly (3HZ) and READY set to OFF is a definite indication of an RXAD error. For details of the various LED combinations and their meaning see the RXAD chapter in the manual entitled AQS Technical Manual with IPSO Systems P/N: Z31810 on the BASH CD.

Power LEDS

The power for the receiver is supplied from the backplane. The Power LED lights only when all the required voltages are available and at the correct level.If one of the AQS power supply voltages fails the LED will go off.

J1 RF In

This is the NMR signal emitted from the sample that is transmitted back to the receiver via the HPPR/internal preamplifier.

J2 LO In

This signal has a frequency of SFO1 + f_{dqd} and is only present when the receiver is open. The signal which is generated by the Observe SGU is used to demodulate the NMR signal from the carrier frequency to yield a signal of 720 MHz plus δ where δ is the NMR signal (see ***Figure 14.2.***)

J3 LO2 in

IF reference from REF unit. This is a 720 MHz sinusoidal wave, and used to demodulate the NMR signal from an intermediate frequency

J4 EP_HPPR

This signal (now called RGP_PA) is the gating signal that is used in preamplifiers to switch between transmit and receive mode.Normally in single receiver systems the signal is delivered to the HPPR controller module via the PSD unit.The signal originates on the OBS SGU and is simply passed along the backplane to the internal preamplifiers and made available to external preamplifiers by porting it through the PSD/3.In standard single receiver systems the J4 output will therefore remain unconnected. The J4 output is required in multi-receiver systems only where there will be more than one OBS preamplifier module. In multi receiver systems it will be connected directly to the SMA connectors at the side of the appropriate HPPR module.

Switching the Unit On and Off *14.4*

The receiver has no separate on/off switch, power on and off is controlled directly from the AQS mains switch.

Tips 'n' Tricks/Basic Troubleshooting 14.5

To replace the unit simply switch off the AQS rack, replace the board and switch the AQS rack on (trained personnel only!). Having inserted a new AQS RXAD the spectrometer should be re-configured with "cf" and the entry in the file uxmnr.info checked (see ***Figure 14.6.***.)

The RXAD has no Ethernet capability and so there is no equivalent Bruker service web page. Instead the receiver has a diagnostic program entitled Unitool which runs via the DRU. From this tool you can:

1. read and write the receiver gain
2. adjust the gain, phase and baseline for the quad module (the quad module is a final critical element of the receiver which implements quadrature detection.(see ***Figure 14.2.***)
3. download new firmware
4. read the temp of the quad module
5. read / write BIS (Bruker Information System) data to File
6. read /write calibration data

Be aware that the corruption of calibration data can lead to the incorrect operation of the unit and this menu point should be entered by service personnel only.

When a received NMR signal is not apparent it can be difficult to establish if the problem lies with the receiver itself or is as a result of the absence of a genuine RF input. It is relatively easy to simulate an NMR signal but be aware that the level of signal expected from the sample is of the order of microvolts and possibly millivolts after the HPPR / internal preamplifier. A suggested amplitude might be 1Vpp RF signal (easily available from a standard signal generator) passed through 80dB attenuation to reduce it to 0.1mV. This can be fed directly into the J1 RF normal input (see ***Figure 14.7.***). Remember that to observe a signal of say 10kHz the simulated input must be 10kHz either above or below the value of SFO1. The operator should also note that when testing the receiver it is easy to forget what is happening on the transmit side. A pulse program will most likely continue to run so remember to check power levels of transmitted pulses to ensure that they do not damage the probe.

Serial Number / ECL Level / Software Download 14.6

Calibration and production data, software version, EC level etc. are stored in an on board flash EPROM in the form of BIS (Bruker Information System) data.This data can be accessed using the Unitool mentioned above. The EC level, part number etc. can also be easily established from the uxnmr.info file (see ***Figure 14.6.***). Unitool can be used to download new firmware. Normally no new firmware is required as it has not changed in recent times. The firmware is not updated when a new version of Topspin is loaded.

Other Required Signals / Units 14.7

The receiver requires:

- Receiver gating pulses (RGP_RX) generated by the observe SGU and delivered over the backplane
- Power supply voltages from the backplane

An LO signal from the SGU (LO = SFO1 + f_{dqd})

- A 720 MHz signal from the REF unit
- Gain settings (based on the value of RG) and other info such as phase/amplitude and dc offset adjustment in the quadrature module which are transferred via a RS485 type -Interface which runs over the backplane.

The DRU is master of the RXAD and all communication with the AQS RXAD take place using the link along the backplane.There is no direct Ethernet access to the RXAD. The operator adjustments are transmitted to the Receiver via the DRU

Table 14.3. is a summary of the various timing pulses relevant to acquisition.

Table 14.3. Summary of Receiver Timing Signals

Signal	Purpose	Generated By /Delivered To
RGP_RX	When active the receiver opens	OBS SGU/RXAD
RGP_ADC	When active the ADC data is not zeroed	OBS SGU/DRU
Dwell-En	DRU accepts data stream from RXAD	OBS SGU/DRU
20 MHz Clock signal	Timing synchronization of spectrometer	ref board / All timing critical AQS units and IPSO
RGP_PA	When active OBS module of HPPR is in receive mode	OBS SGU/HPPR (via PSD) OBS SGU/Internal preamp

Option or Core Item 14.8

Every system has at least one receiver though different generations of spectrometer will have different models. Multi receiver systems will of course have more that one receiver

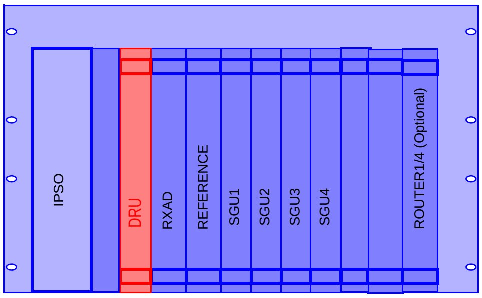
Further Information 14.9

For information on the RXBB see AQS For RCU Systems (Technical Guide) P/N Z31560.

For information on the RXAD see AQS For DRU Systems (Technical Guide) P/N Z31717.

DRU 15

Introduction 15.1



The Digital Receiver Unit as the name suggests is primarily concerned with the processing of received data. As rack master of the AQS/3 the DRU also has a major role to play in terms of how various other AQS units communicate with the host workstation.

In the context of NMR spectroscopy many of the most significant advances in recent years have been in the processing of the received data. With the introduction of oversampling, subsequent decimation as well as digital filtering the need for a dedicated unit to control the handling of the received digitized data has become essential.

The DRU **replaces the RCU** found in earlier spectrometer generations. There are actually two versions of the DRU (DRU and DRU-E) and they will only be differentiated where necessary. The principal distinction is that the DRU-E is used with the external HPPR and the DRU with internal preamplifiers.The DRU is mainly used for low field NMR systems whereas the DRU-E is fitted on systems using external preamps which are usually higher field systems.

The DRU **controls the RXAD** which as we have seen in the previous chapter generally operates at max. sampling rate regardless of the SW. This of course generates extra data which needs to be processed. A major feature of the DRU is that it performs the processing 'on the fly' so to speak i.e. as the data is acquired it is processed simultaneously.This includes the application of the appropriate digital filters. As part of the data processing the DRU handles the accumulation of the data over the assigned number of scans. The OBS SGU is responsible for the generation of a signal that gates the receiver (RGP_RX) and a signal that initiates the storage of data from the ADC (RGP-ADC) once started. Actually the storage of data is controlled by two signals. The Dwell_Enable signal controls whether the DRU stores data or not. The state of the RGP-ADC signal dictates whether real data or simply zeros are stored. Both these signals are generated by the OBS SGU as can be seen in ***Figure 15.1.***

As always the DRU uses the 20 MHz clock signal generated by the REF board and delivered over the backplane to maintain synchronization (see ***Figure 16.2.***).

Once the acquisition is completed the DRU bypasses the IPSO and transmits the data directly to the host workstation via an Ethernet link (see ***Figure 15.1.***).

In terms of the operators understanding of how the spectrometer functions, many of the DRU functions take place automatically in the background and for this reason the unit will be dealt with relatively briefly.

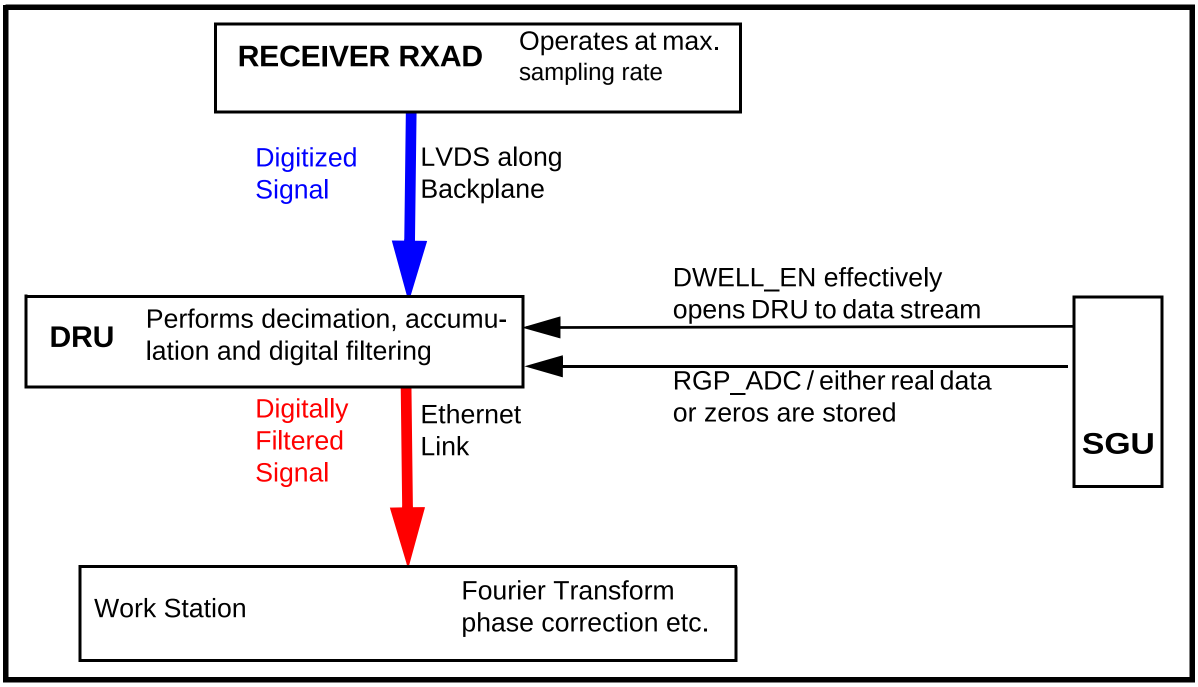


Figure 15.1. Schematic View of Handling of Acquired Signal by DRU with RX AD

Location and Photograph — *15.2*

The DRU is located at the left most end of the analog section of the AQS/3 rack (see ***Figure 3.3.***)

General Information, Configuration and Function — *15.3*

Principal Functions:

1. Receive and process digitized data from RXAD.

The RXAD is continually digitizing and delivers the raw data at a rate of 20M samples per sec. with 12 bit resolution. To perform the data processing the DRU remains active or ‘awake’ during the acquisition so that the progress of the acquisition can be monitored.This includes adjustments to the receiver phase (phase cycling) as required as well as monitoring of the acquisition in terms of progress and number of scans etc.

Based on the state of the RGP_ADC pulse the DRU either accepts the data for storage and further processing or simply stores zeros. (RGP_ADC is the digitizer gating command which is generated by the OBS SGU and delivered over the backplane.) In this way the transmission and receiving sections are completely synchronized. Processing includes application of digital filters and decimation.

2. Special functions such as wobb and RGA.

The data acquired during the wobb routine requires particular processing to facilitate the on screen display. During RGA the received signal is analyzed (in particular for peak amplitudes) and the most appropriate RG value automatically selected.

3. Data accumulation and transfer

Once the data has been processed it is accumulated, buffered and transferred to the host workstation via a Fast Ethernet (LAN) link (see ***Figure 4.10.***).

For the DRU-E there is an additional LVDS link to the R-Controller of the IPSO, bypassing the Ethernet link to the TOPSPIN–PC (which is the normal pathway for acquired data.)The purpose of this link is to enable the user observe the progress and results of an acquisition on-the-fly and make adjustments as appropriate. The DSP capability of the R-Controller enables the acquired data to be processed in real-time. As a result real-time decisions based on the progress of the acquisition can be made and the results transmitted to other IPSO boards via the standard PCI bus. This feature is particularly useful for imaging experiments but it is likely to become more a feature of high resolution experiments. This connection can be seen in ***Figure 4.10.***.

4. Rack master.

In previous spectrometer generations this role was performed by an SGU. As master, all communication between the host workstation and individual AQS units is ported through the DRU. This is facilitated by a dedicated fast Ethernet connection between the DRU and the host workstation.The connection can be clearly seen on the front panel (see ***Figure 15.2.***)

Among the typical information/data that is ported via the DRU is

- configuration information on the AQS rack during ‘cf’. Through the ‘cf’ routine the DRU is used to establish the number, type and location of the various AQS units (analog section).
- RG info to the RXAD.
- ACB display data is transmitted from the **internal** amplifiers to the DRU over a I2C bus along the AQS backplane and transmitted to the host monitor via the DRU Ethernet connection. (For external amplifiers the information goes directly from the Ethernet of the external amplifier front panel to the host via the Ethernet switchbox.)

In multi receiver systems with more that one DRU each DRU is simply master of the rack in which it is located.

Table 15.1. Comparison of the DRU-E with the DRU

DRU-E	DRU
For lower field systems with internal preamps	For higher field systems with external preamps (i.e HPPR)
Not fitted	Has PICS,ATMA
Can accept 16bit data stream	Accepts 12bit data stream
LVDS link to IPSO for real-time analysis of acquisition data.	Not available

DRU and DRU-E Front Panel 15.3.1

It should be noted that where possible signals are delivered to the DRU over the backplane (as opposed to the previous generation RCU where many timing signals were delivered over the front panel).

DRU LED

Indicates that on-board power voltages are at the correct level.

ERROR and READY: self explanatory

ADC LED

Indicates that an acquisition is in progress.

LAN TX LED

Indicates transfer of data outwards to the host workstation.

LAN RX LED

Indicates transfer of data inwards from the host workstation.

LAN

This connection is used to transfer the processed data to the host workstation.

DRU-E (not DRU)

Trigger RCP out:

This output may be unconnected. It is a potential trigger pulse output, the function of which is not pre-determined. Effectively the customer is free to program this output.

High Speed Data Out:

This link was originally designed for imaging experiments which require real-time control of experimental parameters. It is anticipated that this link will find more and more application in HR NMR.This output data stream would be connected directly to the R-Controller of IPSO.

DRU only (not DRU-E)

Preamplifier Modules:

This connection is for internal AQS preamplifier modules.

CRP

This connection is for the control of Cryoprobes.

ATMA/PICS

This connection is for Automatic Tuning and Matching and Probe Identification and Control System.

TP-F0

This signal controls the lock transmitter but may be unconnected as the signal can also be transmitted over the backplane if the system is fitted with a PSD/3.

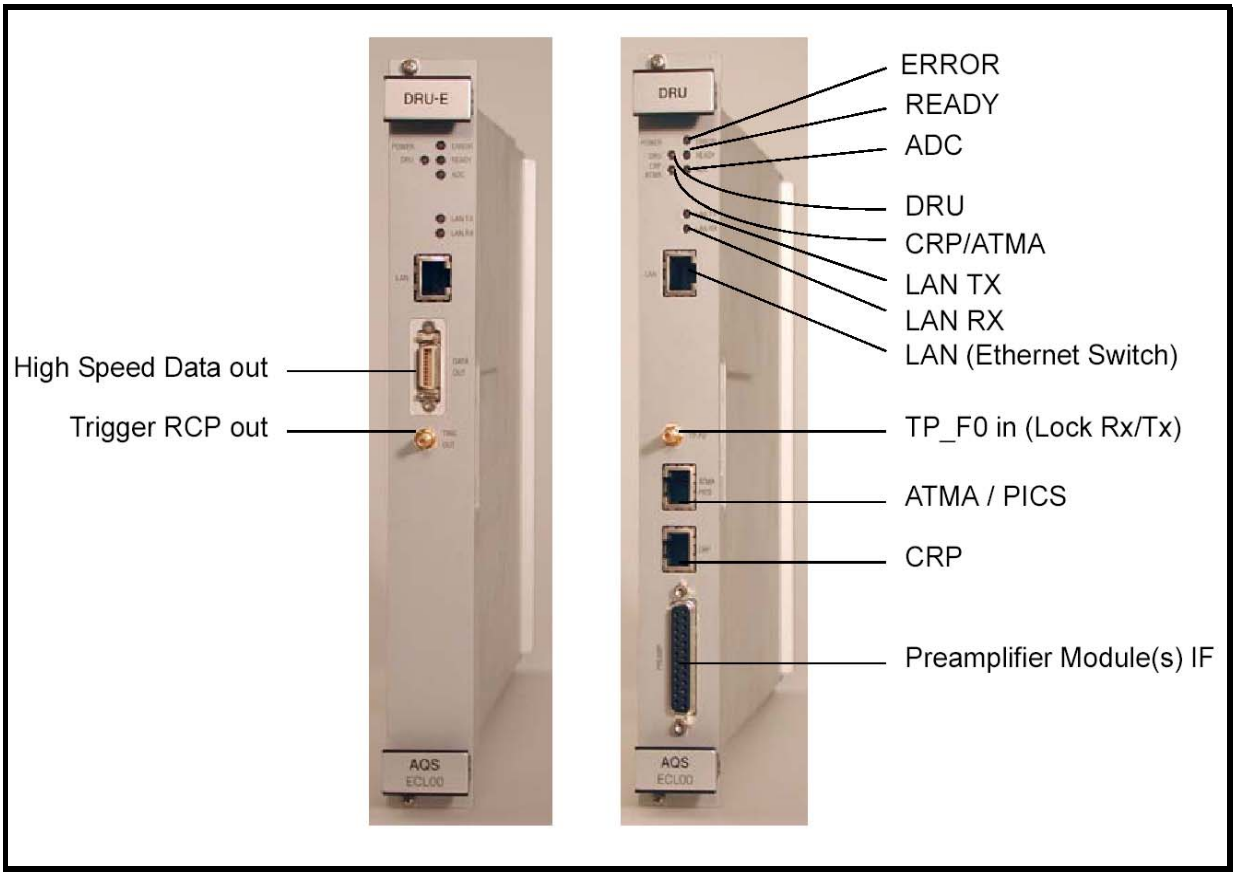


Figure 15.2. DRU-E and DRU Front Panel

DRU Specifications

Acquisition Memory (DRAM):4MByte

Stored Memory:16MByte

Sampling Rate of incoming digitized data: 2 X 20 MHz

Switching the Unit On and Off 15.4

The units have no separate on/off switch, power on and off is controlled directly from the AQS/3 mains switch.

Tips 'n' Tricks/Basic Troubleshooting 15.5

The DRU is such a high speed digital board that access to many of the signals is difficult making troubleshooting almost impossible.

1. Checking the front panel LED's is an obvious starting point. In particular the READY LED should be observed to flicker continuously. Every 500ms this LED is turned off for 20ms, resulting in a faint flicker. If this flicker is missing, the

DRU is not running properly and must be reset by switching off the AQS mains switch for about 10 seconds.

2. The Ethernet link to the workstation should also be checked in case of error. Check that the cable is physically connected correctly to the Ethernet switch and from there to the workstation. Use the 'ping' command to electronically check the link.

Check the entry in the uxnmr.info file.***Figure 15.3.*** displays that the DRU and DRU-E are clearly differentiated. The role of DRU as rack master is also alluded to in the uxnmr.info displays of ***Figure 15.3.***. The first DRU or DRUE in any system will always have the IP address 149.236.99.89. A second if fitted will have the IP address 149.236.99.88. The DRU/DRU-E are the only AQS units with a permanent IP address.

```
System        : Avance II+ NMR spectrometer
1H-frequency  : 600.13 MHz
Hardware info: detected by hardware itself

IPSO: connected to spectrometer subnet
- TCP/IP address = 149.236.99.248
- Tctrl : 1
- Fctrls: 4
- Gctrl : without digital preemphasis
- Rctrl : 1

DRU1: AQS DRU Z100977/00206 ECL 02.00
- TCP/IP address = 149.236.99.89
- Firmware Version = 60609
- DRU controls AQS-Rack and HPPR/2
```

```
DRU1: AQS DRU-E Z102520/00194 ECL 02.00
- TCP/IP address = 149.236.99.89
- Firmware Version = 60705
- DRU controls AQS-Rack and HPPR/2
```

Figure 15.3. Extract from two 'uxnmr.info' Windows Displaying the Presence of a DRU (above) and DRU-E (below)

3. web page access. An extensive web page has been developed which can be opened by clicking on DRU after entering the 'ha; command. ***Figure 15.4.*** is a summary of some of the features. From this menu it is possible to

- download new firmware
- access BBIS data
- test some features

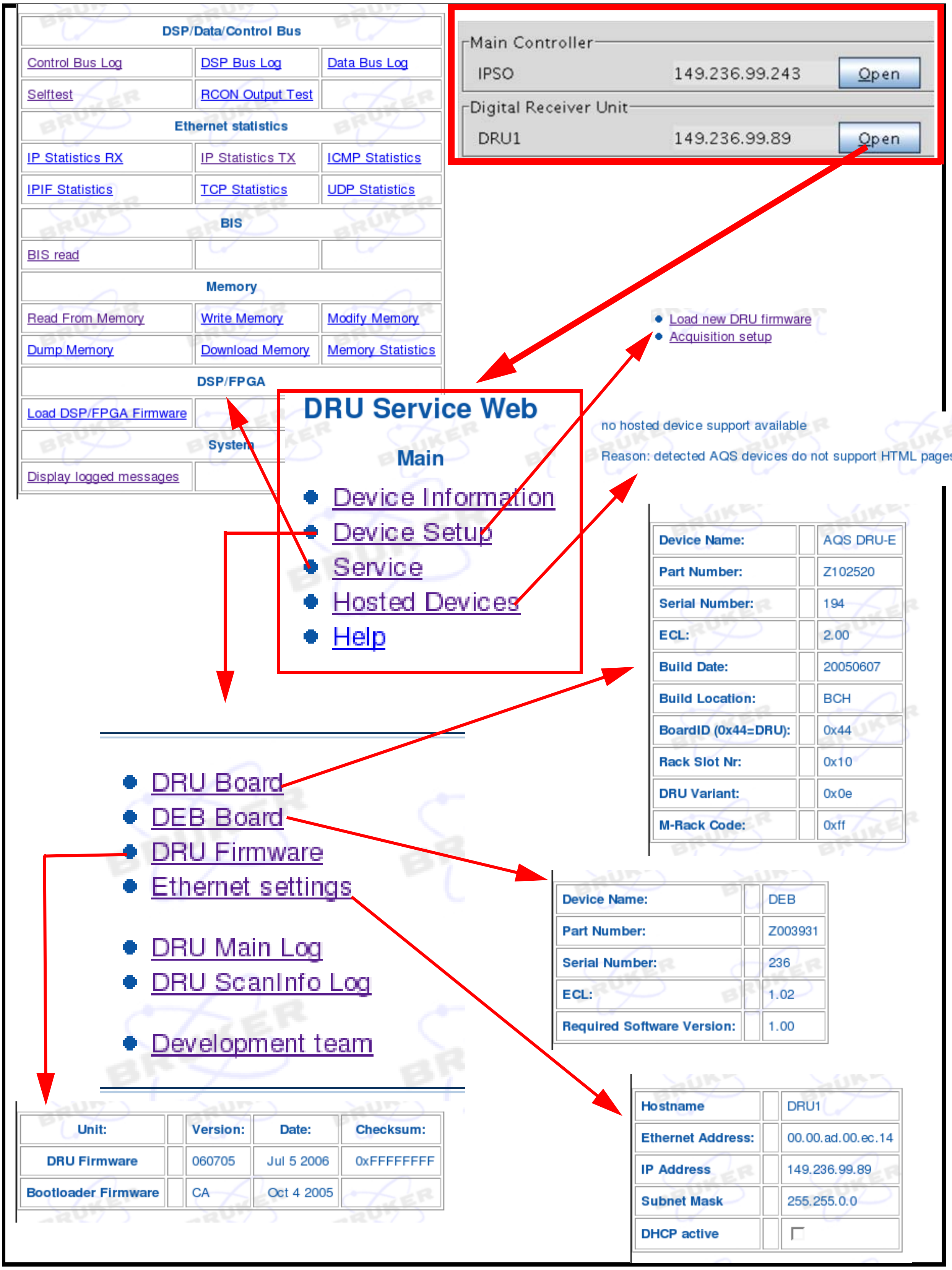


Figure 15.4. Aspects of the DRU service web

Serial Number / ECL Level / Software Download *15.6*

By virtue of the direct Ethernet link to the host workstation downloading new firmware to the DRU and DRU-E can now be done via any standard web browser. This can also be used to access production info such as serial number, ECL level etc.see ***Figure 15.4.***.

Other Required Signals / Units *15.7*

The DRU requires:

- RGP_ADC and the Dwell_Enable signals from the OBS SGU (delivered over the backplane) An active Dwell_Enable signal effectively means that the DRU will accept data from the RXAD. It will go active at the start of an acquisition.
- A functioning Ethernet link to the host workstation.
- A 20 MHz signal from the REF unit (delivered over the backplane).
- The digital power supply at the required voltage levels via the backplane.

Option or Core Item *15.8*

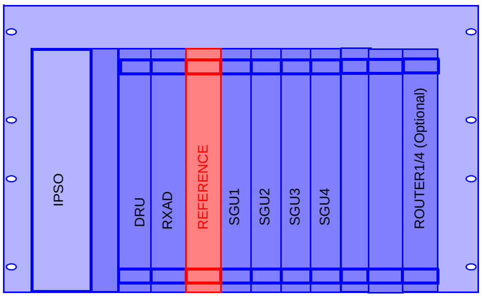
Regardless of the number of channels each spectrometer requires one and only one DRU when used for high resolution or solid applications. MRI applications use more than one DRU. Whether a DRU or DRU-E is installed will depend on whether the preamplifiers are internal (DRU) or external (DRU-E).

Further Information *15.9*

For a technical description of the DRU see the manual entitled AQS for DRU Systems (Technical Guide) P/N Z31717.

Reference Unit

Introduction 16.1



The REF unit is a relatively new development and was introduced when spectrometers were first fitted with SGUs.The aim of the REF unit is to ensure that all timing critical signals are derived from a single source that is originally generated on one specific unit.

As spectrometers become more sophisticated the importance of phase coherence between the various channels as well as between the transmission and receiving paths is more and more important. To ensure synchronised operation the more recent spectrometer series are designed so that all RF signals as well as all clocks originate from one source. This source is a temperature controlled crystal oscillator at the heart of the REF unit. At time of writing several generations of REF unit have been developed. For AVANCE III spectrometers it is sufficient to describe two versions namely the REF and the REF/2. We shall not describe the REF22 from previous spectrometer generations.The essential differences between the three principal versions are discussed below and are summarized in ***Table 16.1.***

The REF unit will provide the necessary RF signals for up to 4 SGUs.If more channels are required then the newer REF /2 unit can provide for 6 SGUs.

The other essential difference is in the value of the intermediate frequency (If) which has been increased from 22 MHz to 720 MHz for both the REF and the REF/2 units.

As the basic function and operating principle of the various versions is the same, most of this chapter will simply refer to the REF unit. Where a specific feature is version specific this will be made clear in the particular context.

Table 16.1. Summary of Three Generations of REF Units

Unit Name	IF	Comment
REF 22	22 MHz	Can cater for 4 SGUs
REF	720 MHz	Can cater for 4 SGUs
REF /2	720 MHz	Can cater for 6 SGUs

Location and Photograph *16.2*

Although there is some flexibility regarding slot position, to-date the REF unit has typically been located between the Receiver and the bank of SGUs (see ***Figure 3.1.***).

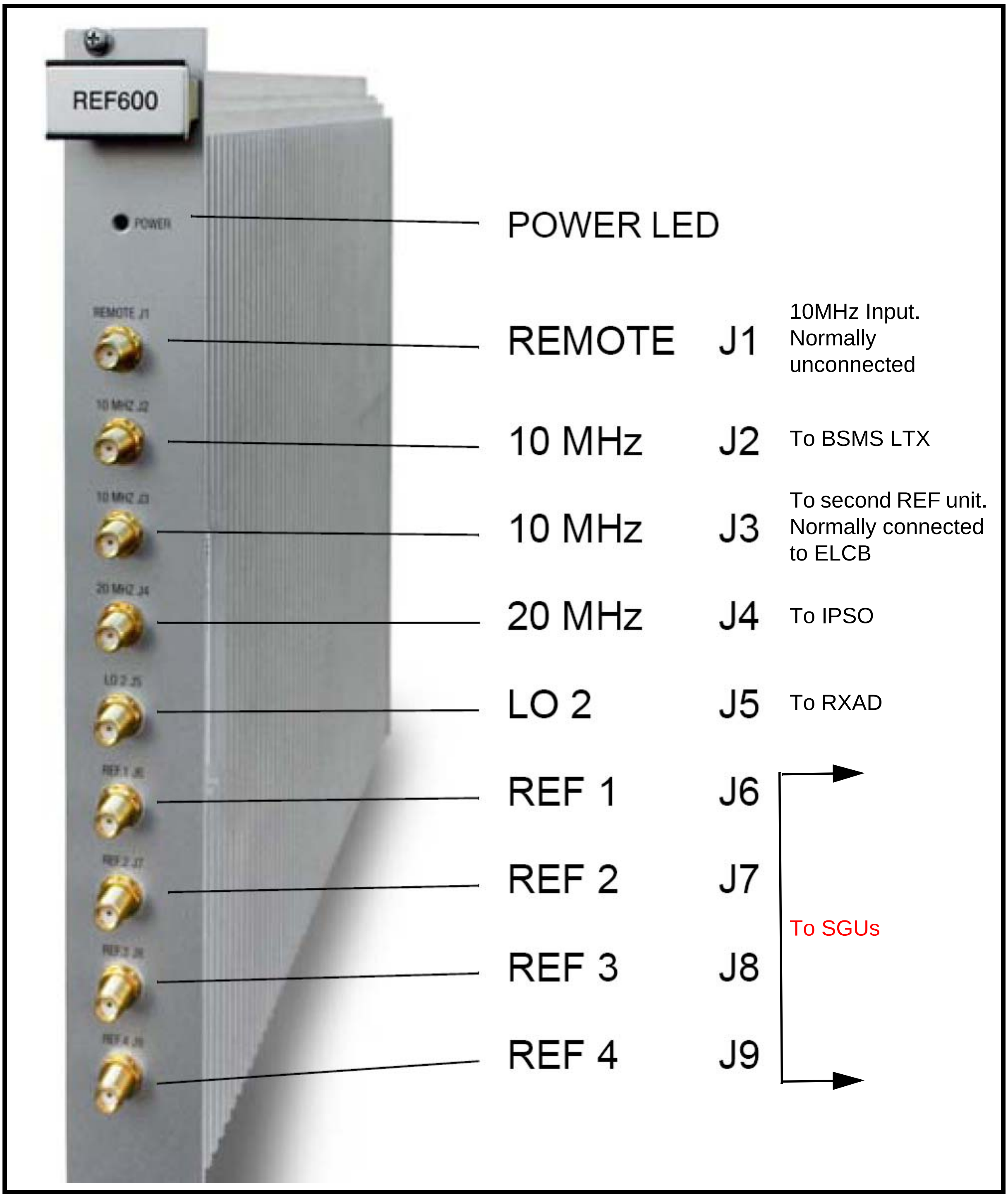


Figure 16.1. REF600 Front Panel

General Information, Configuration and Function 16.3

The simplest way to appreciate the role played by the REF unit is to list some of the generated signals:

1. Intermediate frequencies for receivers: IF of 720 MHz for the RXAD-BB and RXAD
2. 20 MHz synchronization clock available to all AQS connected units and in particular the SGUs as well as IPSO
3. Mixture of six frequencies to be used for frequency generation on up to four/six SGUs
4. 10 MHz signal for the BSMS Lock Transmitter Unit
5. 10 MHz signal for the BSMS ELCB

It can be seen from point two above that although the IPSO is ultimately responsible for timing control of transmitted signals, the original clock is generated on the REF unit.Furthermore the frequency generation on the SGU is based on frequencies from the REF.

A brief consideration of the role played by the REF unit in signals used to receive the NMR signal will show that the REF unit generates the IF for the receiver (point 1 above) and also clocks the SGU which in turn generates the minor LO frequency DDS shift. In this way the REF ensures phase synchronization which is particularly critical for the Receiver operation.

Operation of 20 MHz Clocking Signal

The heart of the REF unit is an oven controlled crystal oscillator (OXCO) with a frequency of 10 MHz see ***Figure 16.2.***. The specs are given later. The crystal output is used to supply the various 10 MHz outputs (J2 and J3) directly. The oscillator output is then doubled to 20 MHz, undergoes some signal conditioning and is then transmitted onto the User Bus of the backplane.As a result all AQS units and in particular the SGUs are clocked with this identical signal. The User Bus clock signal is also ported back through the REF unit and out through J4 from where it is connected to the IPSO. As a result the IPSO as well as other AQS units work off the same identical clock.

The reader should note that while there is often reference made to the IPSO delivering 48–bit words at a clock rate of 80 MHz over the LVDS link, the 80 MHz clock signal is derived from a quadrupling of the 20 MHz signal (see ***Figure 16.2.***).

REF Outputs

There is little point in synchronizing the digital timing of the spectrometer if the RF signals are not also synchronised. The source of RF for NMR transmission is the SGUs and to generate a wide range of frequencies they mix digitally generated frequencies (using so called DDS units) with various frequencies. The DDS is also clocked by the 20 MHz from the User Bus on the backplane. The 6 RF mixing frequencies are generated on the REF unit but all originate from the 20 MHz from the REF.

Path Lengths

Note also that the system designs ensures that all synchronised signal paths are equal in length. This ensures that the signals are all phase shifted by the same amount.The design of the user bus is such that regardless of the specific location of say an SGU the user bus clock signal will still have the same physical path length. This is also the case for the frequency mix of signals sent from the REF front panel (J6-J9) to the various SGUs. These are all cables of identical length (26cm as it happens). The operator is advised that should such a cable need to be replaced the new cable should be identical in terms of construction and length.

Finally it has been mentioned that there are four/six REF outputs servicing the SGUs. Where these outputs are not connected they should be terminated with 50 Ohms.

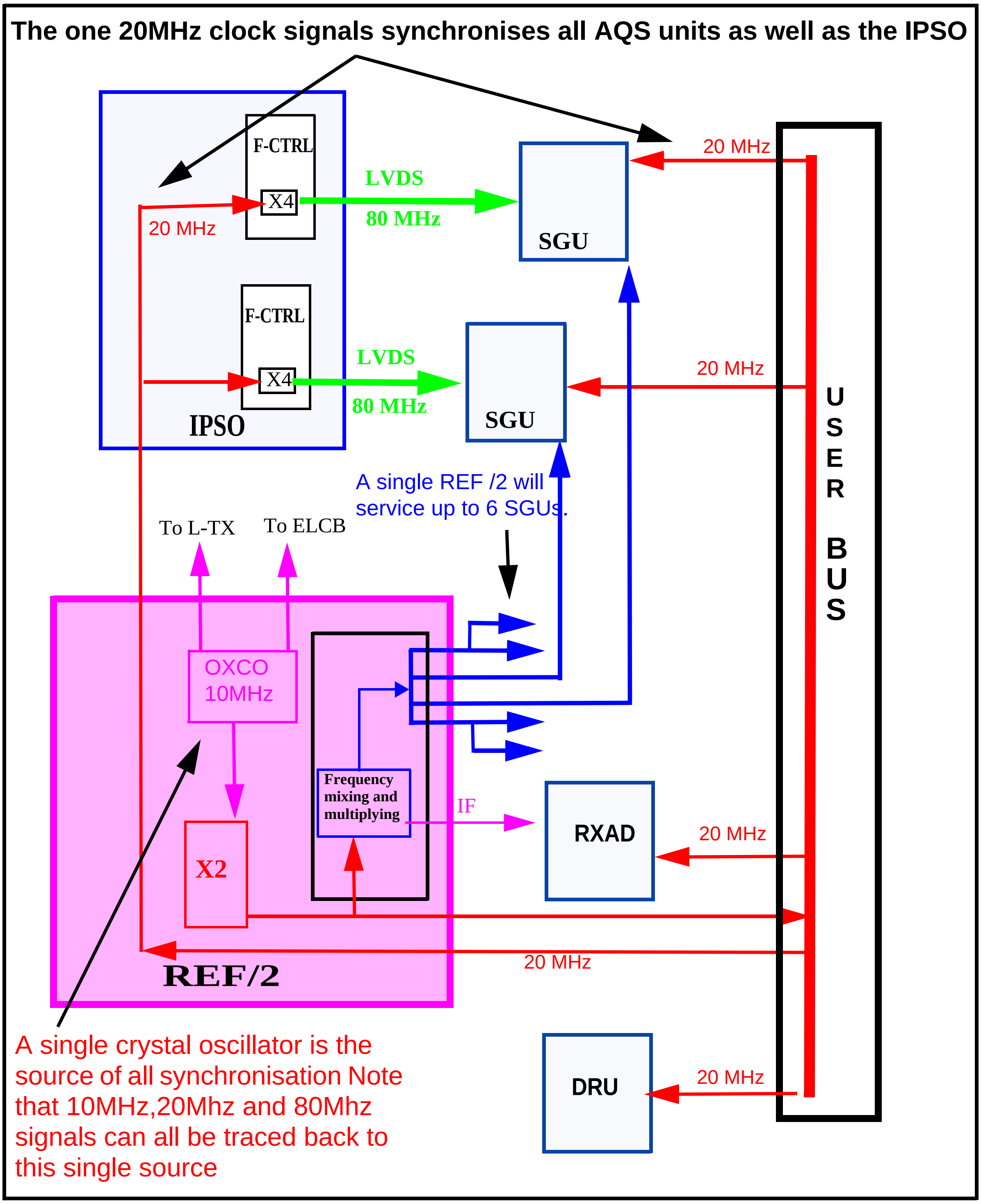


Figure 16.2. Synchronization of IPSO, SGUs and RXAD by Signals Generated on the REF Unit.

Specification

The principal specification is that of the stability of the crystal oscillator which is specified to 1 x10^{-9}/day.

1 x 10^{-9}/day on the REF1000 and REF/2 1000

2 x 10^{-9}/day on the REF400 and REF600

Front Panel *16.3.1*

J1 REMOTE IN

This is normally not connected except when a second REF unit is installed. The presence of this signal will automatically switch off the internal 10 MHz clock generated by the crystal oscillator and so only one REF unit acts as a source of synchronization. With the ability of the REF/2 to drive 6 SGUs there is effectively no reason to use this and the presence of this connector is effectively historical.

J2 10 MHz OUT

This output is used to clock the BSMS lock transmitter board (aka the LTX board). This effectively means that the lock system and the main acquisition system are synchronised. (1.4 Vpp @ 50 Ohm).

J3 10 MHz OUT

Output for synchronization with second REF unit where installed. See J1 above.(1.4 Vpp @ 50 Ohm).

J4 20 MHz OUT

This is the clock signal to the IPSO. Reference to ***Figure 16.2.*** shows that this signal is taken from the AQS User Bus to ensure that it is identical to the clock of all other AQS units. This is the principal synchronization signal for the entire spectrometer. It is also used to clock the LVDS 80 MHz link from the various IPSO T-X controllers to the SGUs. (1 Vpp @ 50 Ohm).

J5 LO 2 OUT

This is the IF reference to the RXAD or RXAD-BB with a value of 720 MHz. (1 Vpp @ 50 Ohm).

J6 - J9 Ref 1-4 OUT

Frequency mixture (six frequencies) to SGUs. These frequencies are the basis of all frequency mixing on the SGU. Note that the REF/2 board has extra voltage delivered at outputs J8 and J9. This is explained in the table below.

Table 16.2. Reference Board Outputs

REF400 REF600 REF1000	2.2 V_{pp}	2.2 V_{pp}	Caters for up to 4 SGUs
REF/2	2.2 V_{pp}	4.4 V_{pp}	Caters for up to 6 SGUs by using splitters at J8- J9

Power LED

The REF uses several power supply voltages from the backplane The power LED on the front panel indicates that all necessary voltages are present and at the correct level.

Switching the Unit On and Off *16.4*

The unit has no separate on/off switch, power on and off is controlled directly from the AQS mains switch. A power LED on the front panel will indicate that sufficient voltage to power the unit is available over the backplane.

Tips ‘n’ Tricks/Basic Troubleshooting *16.5*

- All of the REF unit front panel outputs are easily observed on an oscilloscope and in this respect the unit is relatively easy to troubleshoot.For information on precise voltage levels refer to section ***16.3.1***.
- To maintain phase synchronization, all signals should be carried over cables of equal length. If cables are to be replaced then the same length cable should be used.
- Any unconnected outputs should be terminated with 50 Ohm.
- If you suspect the on board crystal oscillator is faulty switch to an external 10 MHz signal which can be connected to the J1 input. (This input should have a level of 1.0 - 1.4 Vpp @ 50 Ohm).
- In terms of intelligence the REF board is remarkably simple and there are no diagnostics tests. It has no Ethernet connection and its presence is made known to the software via the DRU during the ‘cf’ routine.As long as it has power and 10 MHz it should operate.
- The entry in the uxnmr.info file is easily checked (see ***Figure 14.6.***).

Serial Number / ECL Level / Software Download *16.6*

The unit is automatically recognized through the ‘cf’ routine. Where a second REF unit is installed, the distinction between the first and second depends entirely on the presence of the J1 REMOTE IN signal. This signal is connected for the second REF unit only.

BIS (Bruker Information System) data is stored on-board with details of ECL level etc. These are accessed via the DRU which acts as rack master.

Four versions of AQS Reference Boards are available. They differ in terms of the maximum NMR frequency that can be generated as well as the max number of SGUs that can be serviced.

Table 16.3. Reference Board Versions

REF400	For systems up to and including 400 MHz	4
REF600	For systems up to and including 600 MHz	4
REF1000	For systems up to and including 1000 MHz	4
REF/2 1000	For systems up to and including 1000 MHz	6 (using 2 BB splitters)

Other Required Signals / Units *16.7*

As a source of synchronized signal the REF unit is very independent. It requires only power and a working connection with the backplane to function.

Option or Core Item *16.8*

Every AVANCE spectrometer fitted with SGUs requires at least one REF unit. Systems fitted with more than 4 channels will require a second REF unit unless they have an REF /2 which can cater for 6 SGUs.

Further Information *16.9*

See Chapter 7 of the manual entitled AQS For RCU Systems (Technical Guide) Z31560.

See Chapter 5 of the manual entitled AQS For DRU Systems (Technical Guide) Z31717.

PSD/3 Board 17

Introduction 17.1

The PSD/3 Board is used to link the AQS/2 with devices such as the HPPR/2 and external amplifiers that have no direct connection with the AQS backplane. Signals either generated by or required by the AQS/2 are simply ported through the PSD3 (which does have access to the AQS/2 backplane).

The principal functions of the PSD/3 are to supply the HPPR/2 with power voltages and DRU generated control signals as well as porting blanking signals to the external amplifiers. The PSD/3 has virtually no on-board intelligence, it simply acts as a conduit between the AQS and external devices such as the HPPR and the external amplifiers.

To date there have been three versions produced: the original PSD, the PSD/2 and the PSD/3. Systems with IPSO are fitted with the PSD/3 and this chapter will deal exclusively with this version.

Location and Photograph 17.2

This unit (see ***Figure 3.10.***) is located at the rear of the AQS in the leftmost slot.

General Information, Configuration and Function 17.3

The functions of the PSD/3 are listed below

- Power Supply to the HPPR/2.

  Depending on the number of HPPR/2 modules either one or two connectors may be required for this power supply.

- Communication with the DRU-E via an RS485 type link (SBS-BUS).

  This link is used to establish which modules are installed via the ‘cf’ routine, which modules are designated as the OBS module, Lock Module etc. for a particular experiment

- Transmission of the Transmit/Receive (RGP_HPPR aka RGP_PA) switching signal.

  This signal (the function of which was described in chapter ***13***) is generated by the OBS SGU/2 and ported via the DRU-E to the PSD/3 and onwards to the HPPR/2

- Transmission of Emergency Stop signals from the HPPR/2.

  If and when a fault is detected by the HPPR/2 the system can be shut down thus protecting the probe. This signal is generated whenever the IPSO is

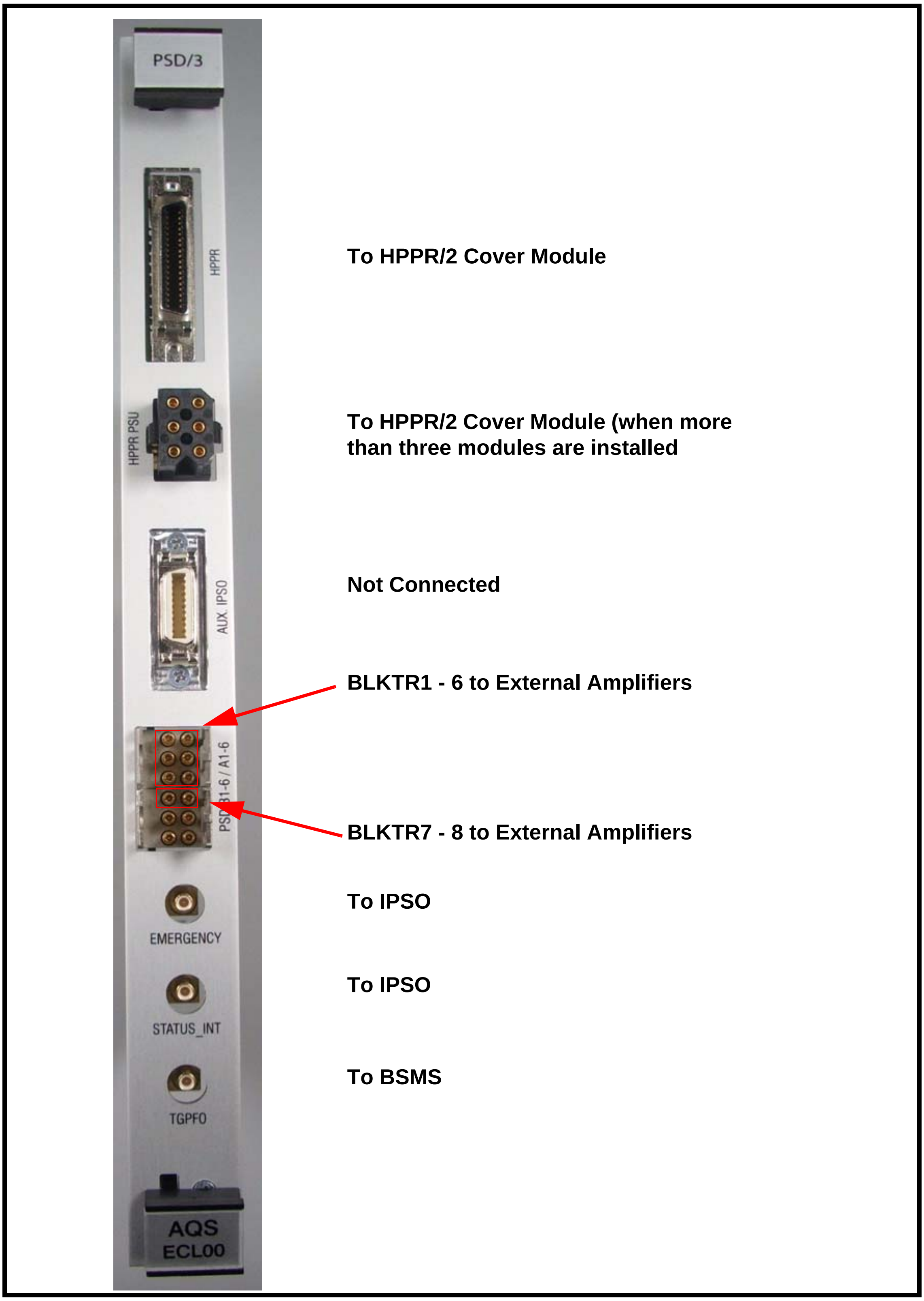


Figure 17.1. PSD/3 Front Panel

shut down, when an amplifier detects excessive reflected power, whenever the HPPR/2 detects excessive reflected power etc.

- Porting of the SGU generated blanking signals (BLKTR1-8) to the various external amplifiers.

  This is a hard wired connection the order of which ultimately decides the order of the amplifiers as they appear in the edsp/edasp window. This amplifier assignment was described in section ***5.1***. of the SGU chapter.

Front Panel Connections *17.3.1*

HPPR

This is the principal 36 pin connection to the HPPR/2 cover module and this link as well as providing power voltages also allows the DRU-E to communicate with the HPPR/2. Furthermore IPSO generated emergency stop signals are also transmitted as well as the lock gating pulse TGPF0

HPPR: PSU

This is an additional power supply to the HPPR/2 cover module that is only required when more than three modules are installed. No other signals except power voltages are used on this connection.

PSD B1-6/A1-6

These are the outputs BLKTR1-8 that are hardwired to the various external amplifers. Only B1-6 and A1-2 are used and depending on the number of amplifiers not all of these may be physically connected.

Emergency

This is a direct connection to the IPSO connector Z and is used to either transmit an emergency stop from the IPSO to the HPPR/2 or vice versa.

Status_INT

This signal is generated whenever a non-critical situation has been detected during an experiment. It may be activated by the HPPR and other AQS units. Power transmission is not stopped by the IPSO upon receipt of this signal. However the IPSO will establish the status of relevant units before it starts any subsequent experiments.

TGPF0

This is the lock gating pulse that is received from the BSMS and transmitted to the HPPR/2 cover module via the principal 36 pin connection to the HPPR/2 cover module described above.

Specifications *17.3.2*

The PSD/3 does not generate any signals itself and hence specifications are determined by the signal sources such as for example the SGU/2 which generates the amplifier blanking signals.t

Switching the Unit On and Off 17.4

This is controlled by the AQS mains switch. Since the board has no on-board intelligence there is no boot procedure.

Tips ‘n’ Tricks/Basic Troubleshooting 17.5

There are no diagnostic features as the board has no intelligence.

Serial Number / ECL Level / Software Downloads 17.6

The PSD/3 is not BIS compatible and so production data such as ECL number etc. are physically labelled on the board itself. To date there has been only one version and with the limited functions there is no prospect of the board requiring an upgrade.

Other Interacting Signals and Units 17.7

The PSD/3 simply requires a functioning link to the AQS/2 backplane from where it is supplied with power and relevant control signals.

Option or Core Item 17.8

AVANCE III systems require one and only one PDSD/3 board.

Further information 17.9

AQS PSD/3 BOARD User Manual P/N: Z31761.

GREAT 1/10 *and* 3/10 18

Introduction 18.1

WIth AVANCE III systems there are several hardware options for performing gradient spectroscopy, namely the GAB/2, the GREAT1/10 and the GREAT3/10.

The GAB/2 (Gradient Amplifier Board) located within the BSMS/2 rack has already been described in chapter **7**. The GAB/2 receives digital inputs from the G-Controller (and or DPP see below) and then generates the analog equivalent for transmission. Another alternative is to use a separate standalone gradient amplifier such as the GREAT1/10 which effectively perform the same functions as the GAB/2. Like the GAB/2 the gradient amplifier receives digital instructions form the G-Controller/DPP and converts these in real time to analogue current pulses that are then transmitted to the gradient coil. The third option is the GREAT3/10 which supports three axis gradient spectroscopy.

There are two types of gradients, Z-Gradient (single axis) and XYZ-Gradient. The GAB/2 supports Z-Gradient gradient spectroscopy as does the GREAT 1/10. For XYZ gradient spectroscopy the GREAT3/10 must be used.The specifications for the GREAT1/10 and GREAT3/10 are identical except that the GREAT3/10 has three outputs. In this chapter the term GREAT amplifier will be used to refer to both the GREAT1/10 and the GREAT3/10. Where a distinction needs to be made this will be clear from the context.

Another issue is the use of pre-emphasis to compensate for the (unwanted) generation of eddy currents caused by the gradient pulses. For pre-emphasis an extra DPP board located in the PCI slot of the external IPSO is available as an option.The GREAT amplifiers can be used with or without the DPP unit.

Among the most notable features of the GREAT amplifiers are

- compatibility with the 48bit LVDS from the G-Controller/DPP.
- Ethernet control and service web access
- on-board intelligence through a BLA controller

Location and Photograph 18.2

The GREAT amplifiers along with the other RF external amplifiers are mounted within the cabinet. For the case where there is not enough space they can actually be placed on top of the cabinet although this is not particularly recommended.

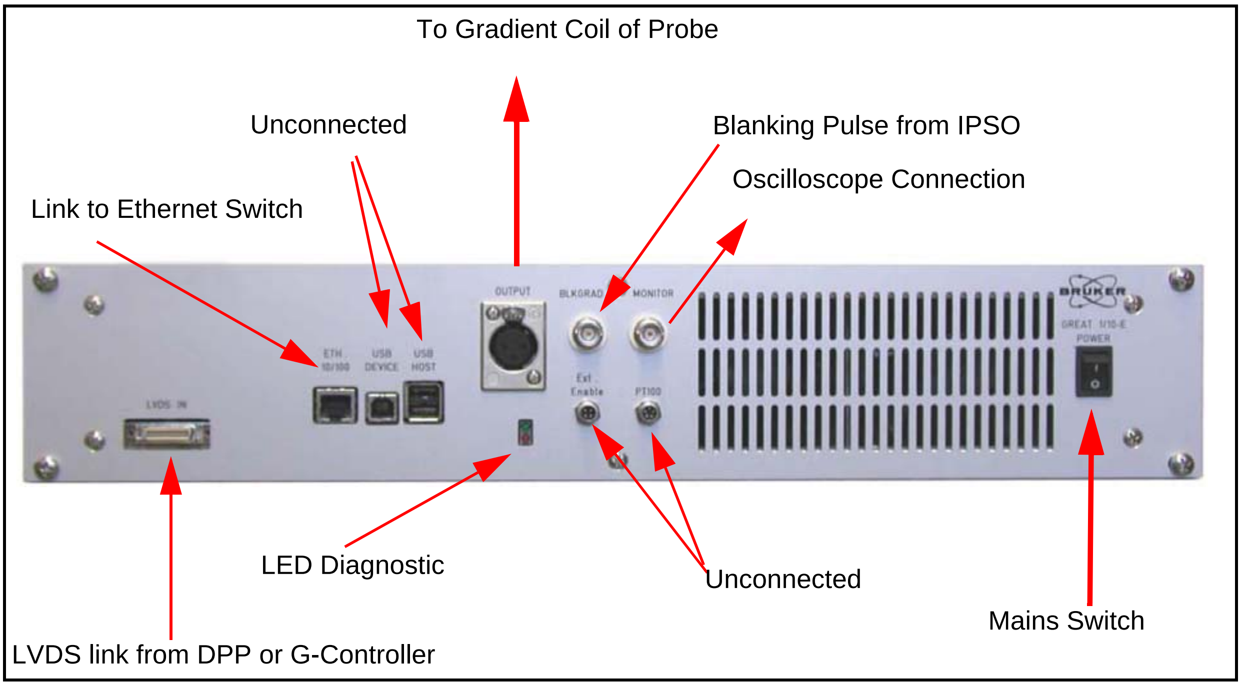


Figure 18.1. Front Panel of GREAT 1/10

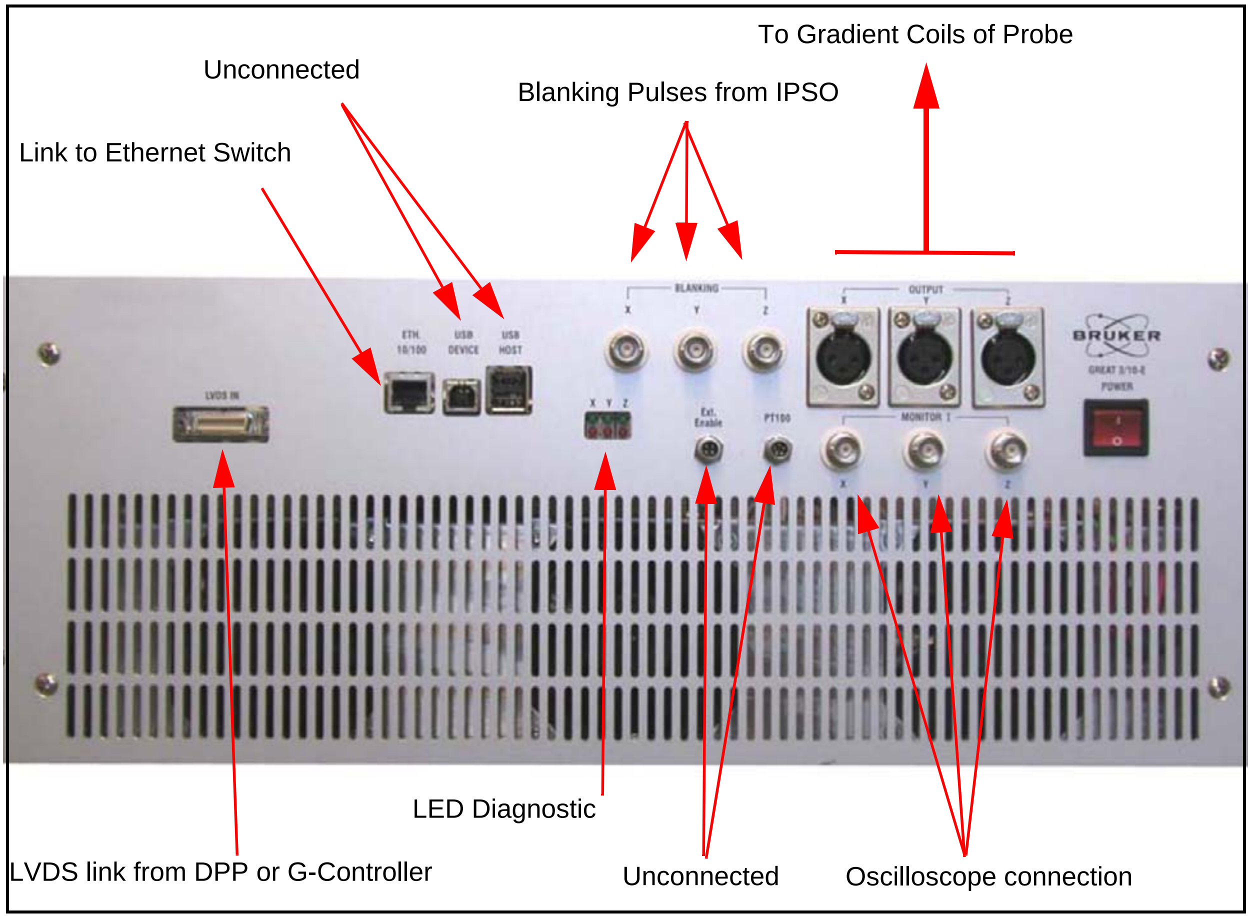


Figure 18.2. Front Panel of GREAT 3/10

General Information, Configuration and Function *18.2.1*

As mentioned in the introduction the GREAT amplifiers receive digital instructions from the G-Controller and or DPP and generate the appropriate gradient currents. The gradient amplifiers have some similarities to the external amplifiers that were described in chapter ***10***. They have separate power supply, require blanking pulses for transmission, and are controlled by an on board BLA controller similar to those used in the external amplifiers.

The principal differences are:

- They receive digital inputs from the DPP or G-Controller and not RF inputs from the SGU/2.
- Their output is connected directly to the gradient coils as opposed to a preamplifer.
- Most notably the nature of the output is very different in that they generate pulses of current as opposed to RF signals.

Front Panel Connections: GREAT3/10 *18.2.2*

Diagnostic LEDs:

Green LED's lighting show that the amplifiers are operating normally whereas red LED's indicate that the amplifier has a fault as reported by the BLA controller. I

LVDS input:

This connection is made to either a G-Controller or DPP card in the PCI slot of the IPSO. The LVDS input contains all the information in terms of timing, magnitude, shape etc. required to generate the gradient pulses. The specifications of this data link was described in Table 7.1.

Monitor Output:

A small fraction of the gradient pulse is tapped off and made available at this output for diagnostic purposes. Viewed on an oscilloscope this output can be used to monitor the amplitude and shape (or indeed the presence) of a gradient pulse. For each amp of current that appears at the main output 1 volt will be present at the monitor output. There is one BNC connector for each gradient.

Gradient Output:

A shielded cable carries the gradient currents to the probe coils.

Blanking:

Blanking inputs from the IPSO. The three signals BLK_GRAD_X, BLK_GRAD_Y, BLK_GRAD_Z were described in Table 4.3. The amplifiers can only transmit while the blank pulse is low. Note that for systems fitted with the AQS IPSO, external blanking is not available as standard.

The amplifiers can also use internal blanking received via the LVDS connector on the front panel.The status of the internal blanking (whether it is inhibited or not) can be determined from the BGA service web (see ***Figure 18.4.***)

Ethernet 10/100 connector:

This cable is connected to the ethernet switch and enables communication between the host workstation and the amplifier. This connection facilitates configuration of the amplifier as well as the service web page.

USB device: USB Host:

Not used and is for service access only.

PT100:

Presently not used but this does allow for future implementation of a temperature sensor connection to monitor the coil temperature

Mains Switch:

As mentioned earlier the GREAT amplifiers have a separate power supply.

Front Panel Connections: GREAT1/10 *18.2.3*

These are effectively identical to the GREAT3/10 except for:

- one (as opposed to three) output to the gradient coils
- one (as opposed to three) blanking pulse inputs, monitor outputs and LED display.

Specifications *18.2.4*

Effectively the principal function of the GREAT amplifiers is to generate stable currents at the required level. Hardly surprisingly then that many of the specifications listed in ***Table 18.1.*** deal with current.The GREAT amplifiers can be viewed as a very powerful DAC receiving digital instructions from the G-Controller or DPP and as such there is a specified resolution associated with the DAC. Much of the amplifier technology is concerned with ensuring that the delivered current is independent of the resistance in cabling or any changes in the load caused by temperature effects at the probe etc.

Table 18.1. GREAT1/10 and GREAT3/10 Specifications

Parameter	Value	Comment
Digital Input	LVDS 48 bit at 80 MHz. (IPSO)	Shaped gradient pulses can be transmitted with a time resolution of up to one sample per microsecond.
Max. Current	±10.0 Amp	This is Duty cycle limited. The max current is available during a maximum 50 ms every second (DC = 5%).
Max Voltage	± 33 Volts	Be aware that the gradient depends on the current flux and not the voltage.
Pulse Fall Time (90 - 10%)	10 µs	Characteristics of a good amplifier include the ability to produce pulses with steep rising and falling edges.
Resolution	20 bit	This resolution is only fully utilized when max current (±10.0 Amp) is applied.
Max.Preemphasis Current	±1.0 A	Pre-emphasis is used to compensate for residual eddy currents. For additional pre-emphasis an extra DPP board located in the PCI slot of the external IPSO is available as an option.
Residual current	±10.0 µA	The ideal residual current (no Gradient active) is zero as this effectively represents an unwanted distortion of the field.

Switching the Unit On and Off 18.3

Separate mains switch on front panel.

Tips 'n' Tricks/Basic Troubleshooting 18.4

In case of malfunction

1. Check the LVDS cable from the G- controller/DPP.
2. Check that the green LEDs are lit as opposed to the red
3. Check the service report in the Service Web for error messages.(see ***Figure 18.4.***)
4. Check the entry in the uxnmr.info file (see ***Figure 18.3.***)
5. Connect a scope to the 'monitor' output. Remember that 1 Volt at the monitor output corresponds to 1 Amp of Gradient current. To capture (trigger) the signal on the scope it will need to be repetitive. Be aware that although the monitor output is greatly reduced the actual output will not and that this is normally connected to the probe. As such you are advised to use a no more than of 5% of max power which should be easily observable on a scope adjusted to 100mV/div.

```
IPSO: connected to spectrometer subnet
- TCP/IP address = 149.236.99.254
- Tctrl : 1
- Fctrls: 4
- Gctrl : without digital preemphasis
- Rctrl : none

Gradient amplifiers at the spectrometer subnet:
----------------------------------------------
BGA1: BGA_W1213762_0012
- TCP/IP address = 149.236.99.248
```

Figure 18.3. Two extract from a uxnmr.info file showing gradient details

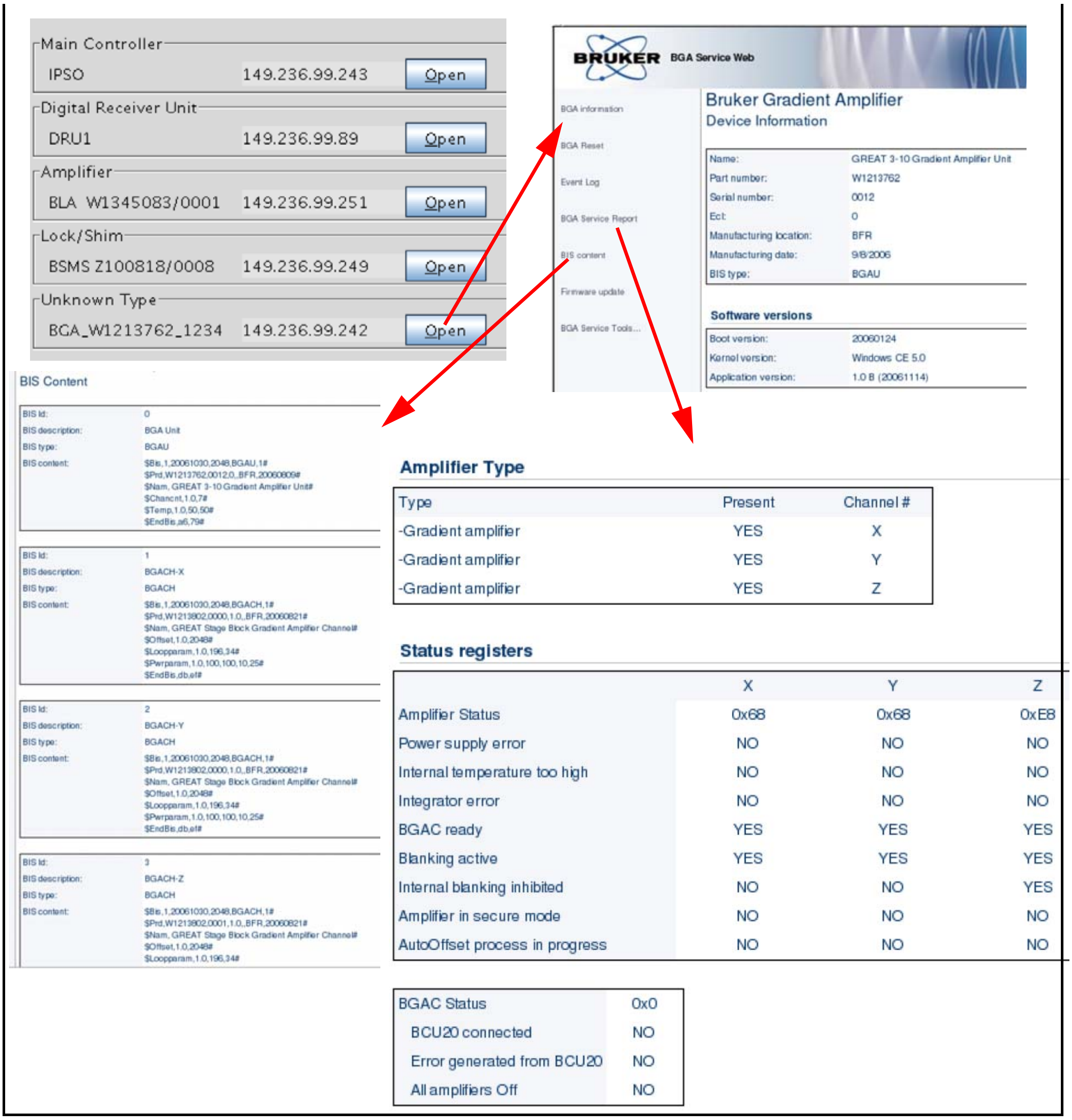


Figure 18.4. Some features of the BGA Service Web

Serial Number / ECL Level / Software Downloads *18.5*

Limited information is available from the uxnmr.info display (see ***Figure 18.3.***) though more detailed information can be accessed via the BIS content menu point in the service web page (see ***Figure 18.4.***). There is also a separate page for firmware download though the user is strongly advised that corrupted firmware or an incomplete download can have serious consequences and is advised to leave this operation to trained personnel only (see ***Figure 18.5.***).

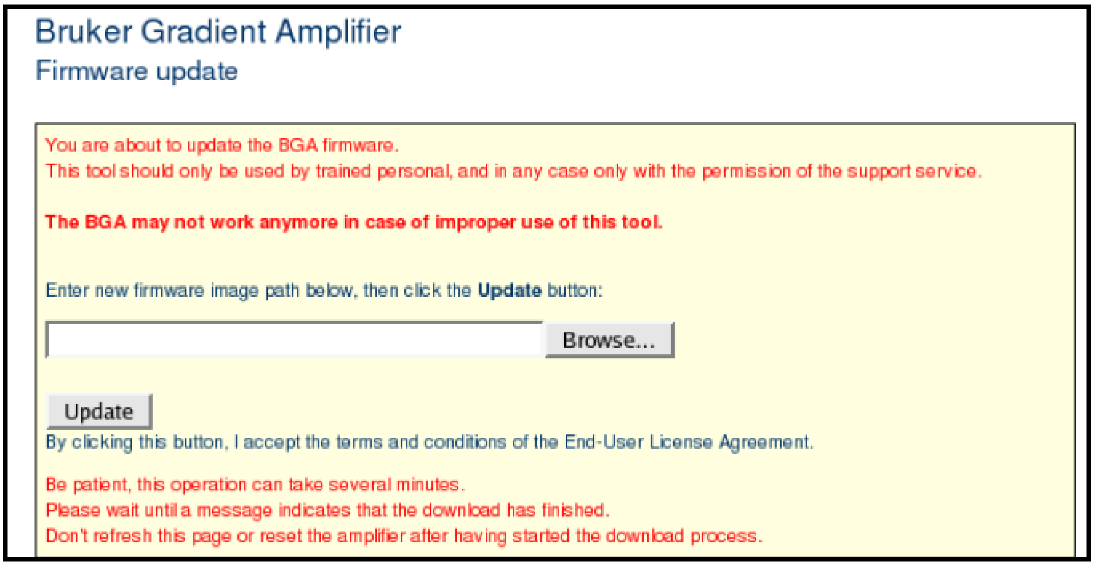


Figure 18.5. Firmware update page from BGA service web

Other Interacting Signals and Units *18.6*

To operate the GREAT amplifiers require:

- Mains Power.
- Digital input from the G-Controller or DPP.
- Successful configuration by the host workstations.
- Blanking pulses from the IPSO.

Option or Core Item *18.7*

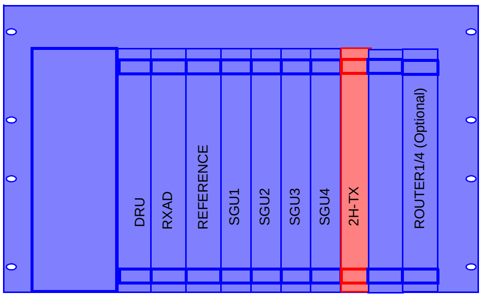
Gradients are an option.

Further Information *18.8*

GREAT1/10 and GREAT3/10 Installation and User manual P/N Z31815.

AQS 2H-TX 19

Introduction 19.1



In terms of hardware development deuterium has always received special attention as it is of course the most commonly used lock nucleus. There are several options available for experiments that require deuterium observe or decoupling while facilitating either a permanent 19F lock or intermittent deuterium lock.

The BSMS/2 can be fitted with a 20W deuterium amplifier primarily designed to facilitate experiments that require deuterium decoupling. This low power however would not be suitable for experiments that are designed with deuterium as the OBS nucleus.

There is also an AQS version with 80W output power which is enough to observe deuterium although the 90 degree pulses are still relatively long.

Finally there is also a BLAXH2H external amplifier which delivers 150W on the deuterium channel (up to 600 MHz systems) and 250W on the deuterium channel (700-900 MHz systems).

This chapter will briefly describe the optional AQS 80W deuterium amplifier which to distinguish it from other amplifiers will be referred to as the 2H-TX(80W).

Two versions of the board are available. One is for 200-400 MHz systems, the other for 500-1000 MHz. systems

In terms of operation the 2H-TX (80W) is very similar to other Bruker amplifiers in that it applies a fixed amplification to the RF input. A minimum of 80W is delivered at the output for an input of 1Vpp (4dBm). For lower outputs the amplitude regulation and or shape control takes place within the SGU/2. The distinguishing feature of the deuterium amplifiers is that they must be able to operate in the lock mode as well as in the standard amplifier mode. This as we shall see is achieved using the SEL2H /DEC signal pulse generated by IPSO.

(There is no blanking pulse required for the 2H-TX. Controlling Lock mode or 2H-TX mode is done via the signal SEL2H/DEC from the IPSO)

Location and Photograph 19.2

SItuated in the AQS/3 the 2H-TX (80W) if present will be located immediately to the right of the SGUs (see ***Figure 3.2.***.).Where internal amplifiers such as the BLAXH, BLA2BB or BLAX300 are also present then the 2H-TX (80W) is located in the slot nearest the SGU/2s followed by the remaining internal amps as shown in ***Figure 19.1.***.

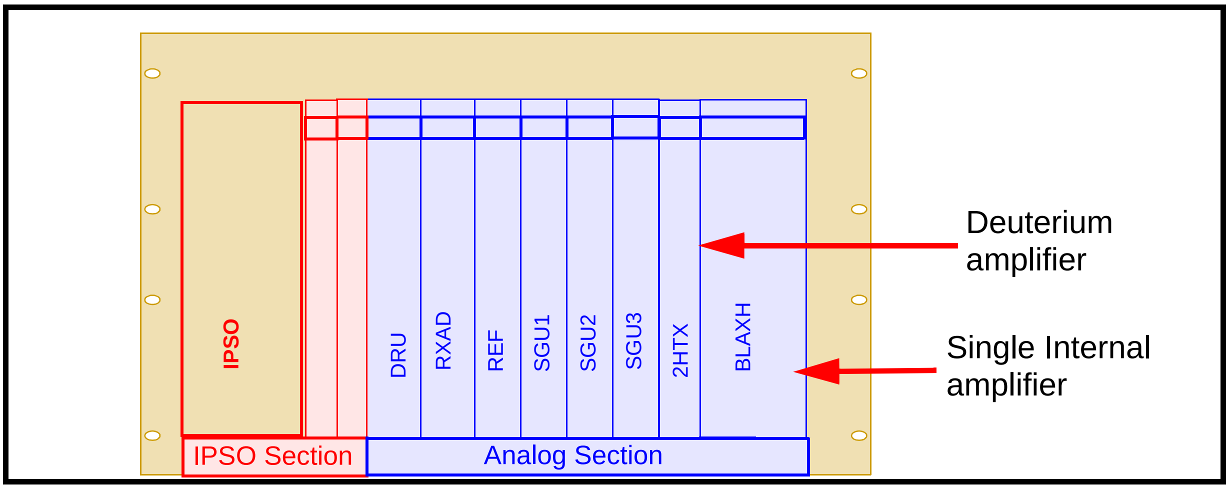


Figure 19.1. AQS/3 with Three Channels 2H-TX and Internal Amplifier

General Information, Configuration and Function *19.3*

As with all AQS boards the 2H-TX (80W) board is controlled by the DRU which detects and configures the board as well as making its presence known to the system. In this way the unit will appear as a separate 80W amplifier in the edsp/ edasp window.

There is only one connection to the 2H HPPR preamplifier module and hence the 2H-TX (80W) board must be able to switch from the standard deuterium lock mode to either observing or decoupling deuterium. This is achieved using an IPSO generated switching signal (SEL2H /DEC). The operation of the board can be best understood by considering the front panel connections which are described below.

Front Panel Connections 19.3.1

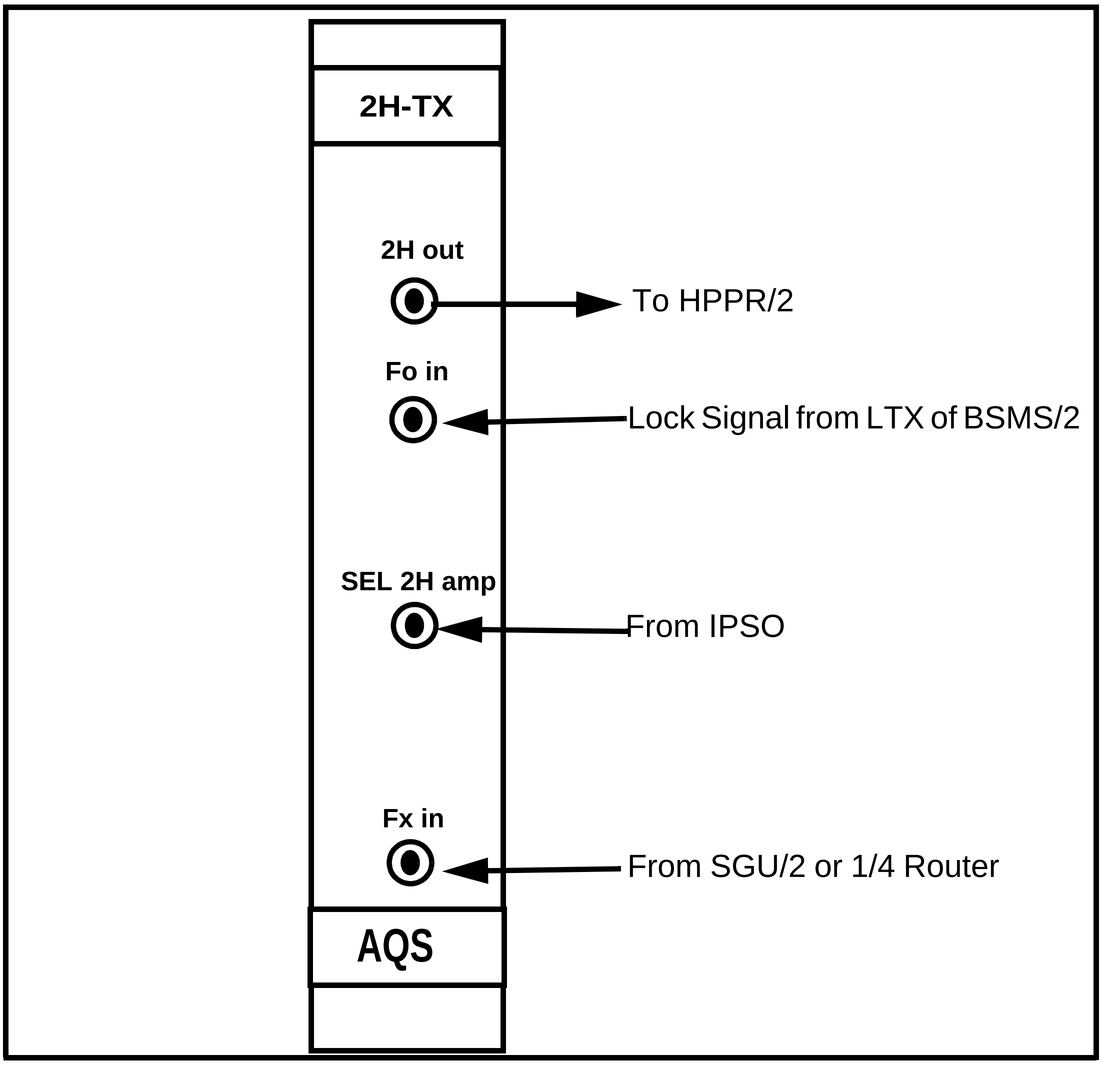


Figure 19.2. 2H-TX (80W) Front Panel

Fx In:

This signal is the deuterium frequency as generated by the SGU/2 which may arrive via the 1/4 Router if fitted. This signal will have a max voltage of 1Vpp and will only be present when the amplifier is in OBS or decouple deuterium mode. Within the amplifier the RF signal will receive a fixed amplification. All amplitude regulation/shaping etc. will have already taken place in the SGU/2.

2H out:

This connection carries either the amplified RF signal or the standard lock excitation signal to the HPPR/2 deuterium module and from there to the probe.

FO IN

This is the lock excitation signal from the BSMS/2 Lock Transmitter board. On systems without the optional 2H-TX(80W) board this signal would go directly to the HPPR/2 deuterium module.

SEL-2H amp

This is the input for the switching signal (SEL2H /DEC) that either connects the lock signal or the amplified RF to the 2H out connector. The action of this switching signal is shown in see ***Figure 19.3.***. The signal is a real time clock pulse (RCP) generated by the IPSO and as such has the same spec as outlined in ***"RCP Output Specifications and Programming" on page 57***. The actual switching speed is specified in ***Table 19.1.*** as being less than or equal to 2µs.

The operator depending upon the spectrometer configuration has several options.

If the spectrometer is fitted with a 19F lock then the 80W amplifier is permanently available for ODS/DEC deuterium type experiments.

Note also that the 80W amplifier is blanked by the standard BLKTR pulses generate by the SGU/2 and delivered to the unit over the backplane (see ***Figure 19.3.***).

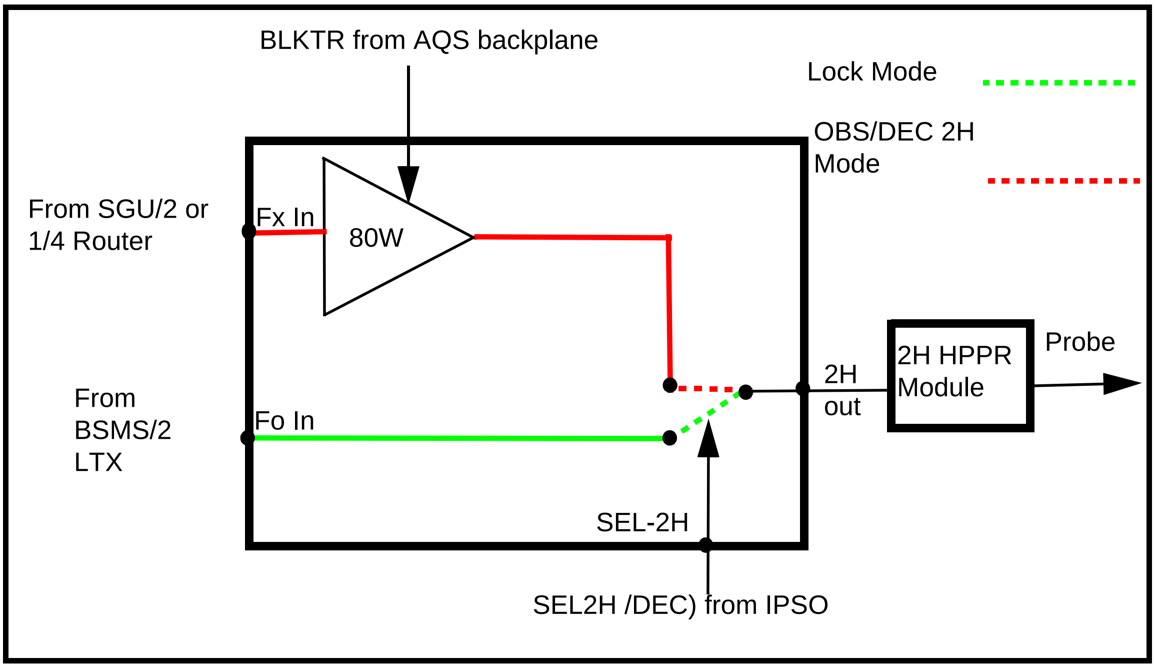


Figure 19.3. Simplified Schematic of 2H-TX (80W) Board

Specifications — *19.3.2*

The table below lists the principal specifications for the 500-100 MHz module. For an explanation of the meaning of the various specifications refer to ***"Amplifier Specifications" on page 153***.

Table 19.1. 2H-TX (80W) Specifications

Frequency Range	76 - 154 MHz
Minimum Pulsed Output Power (at 4 dBm Input)	80 W
CW Output Power	10 W
1dB Compression	80 W
Amplifier Biasing	Class AB
Blanking Delay	< 1 µs
RF Rise Time (10->90%, 2µs blanked in advance)	<100 ns
RF Fall Time (90->10%)	<100 ns
Noise Figure	<=6 dB
In/Out Impedance	50 Ohm
Input VSWR	1.2 maximum
Output Harmonics 2*fc, 3*fc at 80 W	30 dBc, 20 dBc
Output Noise Power (Blanked)	< 30 dB over thermal Noise
Pulse Width	10 ms @ 80 W
Duty Cycle	12% @ 80 W
Switching Speed of Lock/Amp Switch	<= 2 µs
Amplitude Droop	<= +-3% @ 80 W for 10 ms Pulse Width

Switching the Unit On and Off *19.4*

The unit is controlled by the AQS mains switch.

Tips 'n' Tricks/Basic Troubleshooting *19.5*

In case of error:

- Check the uxnmr.info entry.
- Check that the amplifier appears in the edsp/edasp window.
- Limited diagnostic features are available with UniTool.

Serial Number / ECL Level / Software Downloads *19.6*

Limited information such as the part number will be available from the uxnmr.info file. More detailed BIS information is stored on board and is available via Unitool. Firmware upgrades can also be implemented using UniTool.

Other Interacting Signals and Units 19.7

To function correctly the 2H-TX(80W) board requires:

- Power from the AQS backplane.
- RF input from an SGU2/Router and blanking signals from the backplane.
- Lock excitation signal from the BSMS.
- Correct setting of the SEL2H /DEC switching signal.

Option or Core Item 19.8

The 2H-TX (80W) is an optional extra.

Further Information 19.9

For a technical description of the 2H-TX see the manual entitled AQS Technical Manual with IPSO Systems P/N Z31810.

Figures

Tables

Index

Numerics

A

B

C

D

E

F

G

H

I

L

M

N

O

P

Notes:

Bruker BioSpin, your solution partner

Bruker BioSpin provides a world class, market-leading range of analysis solutions for your life and materials science needs.

Our ongoing efforts and considerable investment in research and development illustrates our long-term commitment to technological innovation on behalf of our customers. With more than 40 years of experience meeting the professional scientific sector's needs across a range of disciplines, Bruker BioSpin has built an enviable rapport with the scientific community and various specialist fields through understanding specific demand, and providing attentive and responsive service.

Our solution-oriented approach enables us to work closely with you to further establish your specific needs and determine the relevant solution package from our comprehensive range, or even collaborate with you on new developments.

Bruker BioSpin Group

info@bruker-biospin.com
www.bruker-biospin.com