Science & Technology Facilities Council

ISIS

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REQUIREMENT SPECIFICATION FOR A RF AMPLIFIER

ISIS LINEAR ACCELERATOR

REQUIREMENT SPECIFICATION FOR A SOLID STATE RF AMPLIFIER

Approval

Title	Name	Signature / Date
TASK LEADER		
GROUP LEADER	Mark Keelan	

Revision History

Issue	Date	Author	Revision Comments
Preliminary	??	Mark Keelan	Draft

Contents

1. Preface

ISIS, sited at the Rutherford Appleton Laboratory (RAL), is the world's most productive pulsed neutron source. Intense bursts of neutrons are produced at 20mS intervals when a heavy metal target is bombarded by a high-energy (800 MeV) proton beam from a synchrotron accelerator releasing neutrons by the process of spallation.

The production of high energy protons may be split up into several stages:-

- The generation of H^- ions.
- The acceleration of the H^- ions to 70 MeV using a linear accelerator.
- The stripping of electrons from the H^- ions to produce protons (H^+) at 70 MeV.
- The bunching and acceleration of the protons to 800 MeV in the synchrotron ring.
- The delivery of the protons to the heavy metal target.

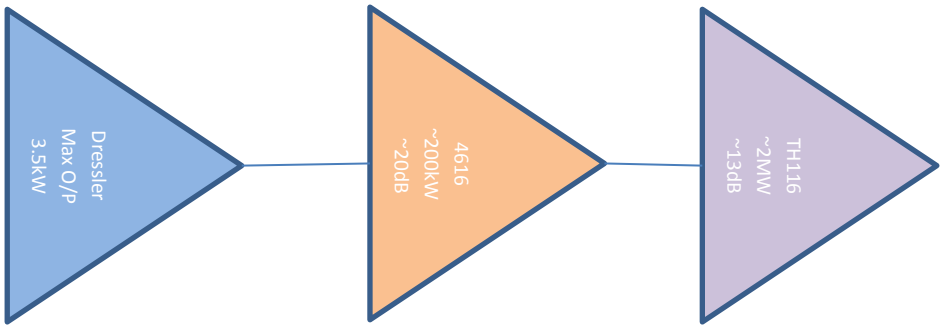
It is a RF Amplifier requirement for the linear accelerator that is the subject of this document.

The Linear accelerator beam current is presently ~25mA, increased machine power has placed increased requirements on the accelerating cavities and hence the loading of the RF amplifier chain. Capabilities requested within this specification are chosen to also accommodate potential future increases. Existing valve driven amplifier units are near to the limit of their power capability where reliability and longevity is proving more difficult. Therefore we wish to embark upon a programme to upgrade. Options are requested to be presented for use of high-powered solid state based approaches. We are seeking a solution to provide a high level of reliability, maintainability and compatibility within an existing amplifier chain.

2. Outline

The ISIS Linear Accelerator cavities are of an Alvarez design. They require a pulsed RF source at a frequency of 202.5MHz, repetition rate of up to 50Hz and pulse duration between 200µS and 800µS to generate the required accelerating electric fields.

Presently 3 stages of amplification are employed per cavity. It is the intermediate (~200kW indicated) stage being considered here for upgrade.



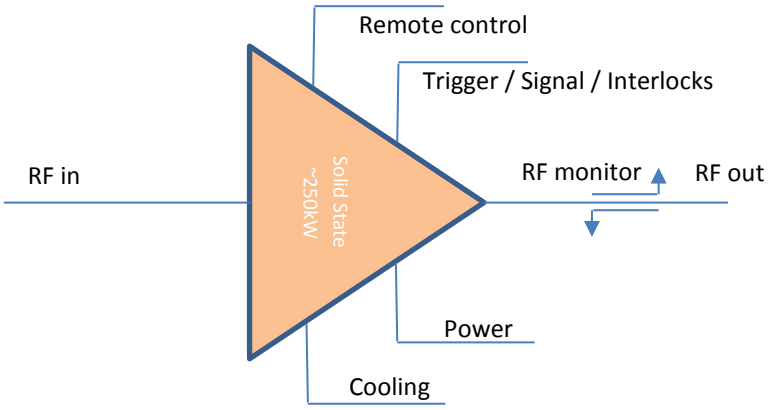
3. Requirements for the amplifier

The proposed amplifier unit should be enclosed within standard 19 inch cabinet footprint. It will perform within the operating parameters listed below. Its 'interlocks', both internal and external will afford protection to operators and equipment. Status will be displayed such that its operation is clear or fault finding is logically guided. A level of redundancy is to be incorporated that will permit continued operation (with limited/reduced capability or efficiency) while remaining at a functional level of ~200kW.

Frequency	202.5MHz (fixed)
Input & Output Impedance	50Ω
Rated peak output Power	250kW (typical operation at ~200kW)
Duty	0.03125% to 4.0%
Gain	+73dB(min) up to 250kW (without pre-amp)
Gain flatness	±0.5dB, ±200kHz
Operation mode	class AB
Input power level	max 20mW
Input power level with existing preamp	≤3.5kW
Harmonics	-30dBc @ rated peak output power
Input VSWR	≤1.5
Output VSWR at rated peak power	6.0 without damage
Rise time	≤5µS
Fall time	≤10µS
RF Input connection	N type
RF output connection	3 1/8" EIA
Monitor output(s) connection	BNC
Monitor output(s) coupling	-73dB

Excess output VSWR should automatically limit output power such that damage cannot occur.

The following diagram indicates the expected inputs and outputs of an amplifier.



4. Services, Supplies & Connections

1. Electrical Supply.

A 4-wire (3phase + neutral) supply is available; UK Spec. 400VAC, +10%, -6%, 50Hz. (Please Note: local supply is typically ~440VAC)

Fuses in the ISIS distribution board will be 32A BS88/IEC269.

Supply connection via enclosed terminal block, protected with a suitably rated circuit breaker.

2. Cooling.

High purity demineralised water (up to ~70litre/min, supplied at ~26°C, conductivity ~1µS/cm) is available at the intended operating locations. Cooling channels within the amplifier must be compatible with high purity water and free from zinc.

A table or graph detailing the minimum permitted flow rate for operation at specific output power levels should be provided. (eg 100kW, 150kW, 200kW, 250kW).

Details should be given where specific requirements exist for:

1. Temperature limits or requirements
2. Pressure limits or requirements

Our preferred connection type is via 3/8" or 1/2" stainless steel Swagelok fitting.

Example of water fitting style used on other equipment

(ref www.swagelok.com/en/catalog) fitting eg SS-600-6

Air cooling orifices must incorporate particulate filtering.

Noise level must be stated for full load operation. An exposure level of 70dB must not be exceeded. (ref HSE - Noise at Work)

3. Input / Output.

The amplifier RF input will be coupled via an N type 50Ω coaxial cable

The amplifier RF output will be coupled via a 3 $^{1}/_{8}$" EIA coaxial line

The 3 $^{1}/_{8}$" EIA line is air insulated, with 50Ω impedance.

4. RF Monitoring

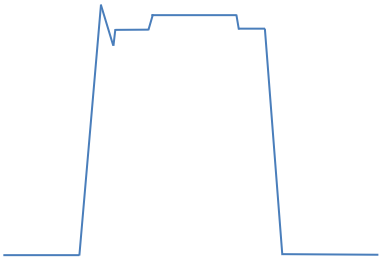
Forward and reflected power monitoring to be made available via BNC connectors.

Their calibrated coupling to be clearly marked

Suitable coupling ~ 73dB

Coupling should be adjustable by ±3dB.

This diagrams show the structural form of a typical RF pulse envelope.



5. Environmental

Typical environmental parameters / requirements for the area in which amplifier(s) will be used.

Maximum ambient temperature	+35 °C
Maximum daily average temperature	+35 °C
Minimum ambient temperature	5 °C
Storage temperature (non-operational)	-5 °C, + 40 °C
Relative humidity (EN 50155)	Average value ≤ 75%
Relative humidity (EN 50155)	Peak value ≤ 99%, non-condensing
Sealing level for closed areas	IP31 according to IEC 60529
Sealing level for ventilated areas	IP20 according to IEC 60529
Maximum altitude without derating	200m above sea level
Audible noise	<70 dBA @ 1 metre @ full load.

6. Controls & Interlocks

The following internal interlocks are required to initiate warning or as necessary shut down of the amplifier if activated: This list is not exhaustive. Other appropriate interlocks should also be suggested and advised.

- Emergency Stop button
- Cabinet door open (where hazards are present)
- Coolant flow not-correct
- Coolant Over/Under temperature
- Cabinet Over temperature
- Smoke detector
- Cooling Fan(s) non-operation
- Phase failure
- Supply Transformer temperature
- Internal Power supply fault (requires an interlock for each PSU rail)
- Timing pulses not acceptable
- RF splitter / combiner / load temperature(s)
- remote or local control selection

Amplifier protection:

In order to allow continued operation and self-protection from damage, a power limiting functionality should be incorporated. Indication must be given of the amplifier operating in a limited or reduced output power mode.

Expected causes of limited power mode:

- Excess RF reverse power (specific locations – combining/splitting?)
- Excess RF forward power (specific locations – combining/splitting?)
- RF module fault – identifying specific module

Status indications must be provided individually for each interlock or state to aid operation and fault-finding – These are to be visible on the front of the amplifier cabinet and also via remote interface.

External interlocks and controls:

- Two volt free contacts to indicate a good/not good status suitable for connection to external equipment eg a PLC system are to be provided. (closed = good state)

Control Power: Internal control supplies are to be derived from the main electrical supply

Local controls:

User enabling of remote control must be made physically at the amplifier. It must not be possible to remotely take control of the amplifier through a remote interface. Local controls must remain functional in either local or remote state.

Remote Controls.

Serial communication using MODBUS RTU over RS485 (half duplex – single twisted pair + screen) electrical standard should be provided.

- Commands for Off, On and reset are required
- A measurement of forward and reverse power should be available
- System and interlock statuses are required

7. EMC / EMF compliance

The equipment shall be designed to meet, as a minimum, the requirements of BS EN 61000

Certified EMC test results from similar equipment, which has been established in service, may be considered by the SFTC.

PHYSICAL Agents: EMF (Electromagnetic Fields) Directive.

Results of measured Electric, Magnetic and Electromagnetic field emissions produced by the amplifier will be required, findings should be presented as field plots. Emissions should not

exceed ICNIRP (http://www.icnirp.org/) 1998 EMF guidance reference levels for public exposure in areas accessible during operation.

8. Marking, Labelling

Electrical, input, output and control connections, Weight, lifting points, Cooling flow and return must be clearly marked.

Internal parts and cables must be adequately marked to facilitate fault-finding.

Mains supply terminals are to be marked L1, L2, L3 and N.

The earth terminal is to be marked with an Earth symbol: 

9. Materials

Wound components where necessary should be insulated to class H and vacuum impregnated

Circuit boards should be FR4

Cabinets should be constructed of steel, painted or powder coated inside and out. Paint must be removed where electrical continuity is required.

Electrical insulating materials should be fire retardant, low smoke and fume (circuit boards, wire insulation, non-conductive structures) to BS ISO/TR 13387:1999.

PVC based materials are to be avoided where possible.

Water channels must be compatible with high purity demineralised water and free from zinc.

10. Lifting & Moving

Input, output and control cables will enter the cabinet(s) at its base. There should be space of at least 100mm in the bottom of the cabinet to accommodate.

Provision for lifting by a crane is to be provided on the top of the cabinet

External lifting points must allow the complete unit to be lifted by a crane. Lifting eyes must be permanently fixed to the amplifier unit and suitably rated.

11. Testing & Documentation

A full capability factory acceptance will be requested.

The following requirements assume that the manufacturer of the equipment may have ceased trading during the expected lifetime of the equipment, such that RAL will have to maintain the equipment without assistance from the manufacturer, if necessary replacing all or part of the equipment during a projected lifetime of >20 years.

Each unit delivered should have an operating manual supplied with it which also details any features or settings particular to each unit.

As a minimum in a single document pack containing:

Functional description, circuit diagrams, mechanical drawings and parts lists that would allow operations staff to diagnose faults to module or circuit board level

Full descriptions and listings of software code including electronic backups. Electronic format (eg on CD, DVD, USB Drive)

Results of EMF survey must be included with the first amplifier unit.

12. Reliability / Maintainability / Safety

All input and output parameters of the amplifier are to be checked at the final test

Mean time between failure (MTBF), of the equipment in service or reliability evidence from similar equipment is to be advised to RAL for evaluation. (A failure being where any component requires replacement) Life duration of components with preventative maintenance should exceed the expected operational lifetime >20 years.

Access to internal components and modules must be provided. This may be for maintenance or repairs, including the replacement of components.

All components must be listed and described in sufficient detail to allow RAL staff to procure a replacement part.

Modules, boards and components must be easily replaceable – where possible without a need for recalibration.

Safety is of paramount importance for both personnel and equipment. A rigorous demonstration of safety will be required including a risk assessment. The demonstration should include identification and mitigation of hazards inherent in operation, interference with other plant, systems and networks.

Safety critical protection circuits must not be modifiable.

Reliance upon batteries, programmable parts or software for operation should be avoided.

Incoming external interlock is regarded as safety critical.

Failure of a single component must not cause a situation that is dangerous to personnel or detrimental to the connected load.

13. Spares

Suggested spare components should be identified and costed.

14. Warranty

The supplier shall provide a warranty, covering the amplifier and components, for all faults related to defective parts or manufacturing processes. The warranty period shall start at the commencement of operational life for a minimum of 3 years.