Fermilab
Fermi National Accelerator Laboratory

Specification for
325 MHz, 7 kW, RF Circulator
PIP-II Project

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Description

325 MHz, 7 kW, RF Circulator, 3 Port

Specifications

1. Ports
   - 1.0 Number of ports: 3
   - 1.1 Port 1 shall be the RF power input from the amplifier.
   - 1.2 Port 2 will provide RF power to a superconducting RF cavity.
   - 1.3 Port 3 will connect to an isolation load. The load will be supplied by the customer unless the vendor requires otherwise.
   - 1.4 Port 1 and Port 2 shall be on opposite sides of the circulator.
   - 1.5 The centers of the Port 1 and Port 2 flanges shall be aligned.
   - 1.6 Port 1 connector: 3-1/8” EIA flange. (Consult with customer if other ports will require larger flange sizes.)

2. Center Frequency: 325.0 MHz

3. RF bandwidth: 6 MHz

4. Power: 7 kW CW with occasional pulsed operation

5. Operational modes
   - 5.0 The circulator shall provide appropriate reverse isolation for continuous full reflection at any phase angle and at full design incident power level.
   - 5.1 Special Requirement: The circulator shall provide appropriate reverse isolation when a millisecond scale decaying pulse of 4 times incident power returns into Port 2 regardless of the presence of power into Port 1. (See special considerations below.) Note the circulator may have any EIA flange size on Port 2 needed to meet the above requirement regardless of the flange sizes requested for the other ports.

6. Insertion loss: 0.3 dB maximum

7. VSWR: 1.20:1 maximum

8. Isolation: 20 dB minimum

9. Operating temperature: 0°C to 40°C ambient.

10. Cooling
    - 10.0 De-ionized water.
    - 10.1 Full required flow shall be achieved with an inlet to outlet differential pressure of 60 PSI or less.
    - 10.2 Supply temperature can be controlled by customer to +/- 2°C.

11. Mounting
    11.0 Tapped holes or brackets shall be provided for mounting the circulator to a base plate.
    11.1 Typical orientation is with Ports 1 & 2 facing horizontally and Port 3 facing up.
12. Options: The vendor may propose active compensation (temperature, magnetic field, etc.) to meet the above specifications.

Special Considerations for operation with Superconducting Cavities

Some special operational considerations for RF circulators apply when powering superconducting cavities:

1. The cavities are often operated highly over-coupled, thus the cavity system is not matched to the feedline impedance and essentially all of the incident RF power is reflected.
2. Operation at full specified incident power will occur with cavity off-resonance (low stored energy) and full reflection.
3. At the end of the RF drive pulse, the energy stored in the cavity is flows back into the feedline.
4. In a highly over-coupled cavity, the return pulse peak power is 4 times the prior incident power. Incident power is this situation will be less than full design power.
5. During normal operation, when beam is not present, the incident power to the cavity is reduced to roughly half of the maximum needed at full beam.
6. Coupling to the cavity could approach matched conditions during full design beam intensity but there may be very short (microsecond scale) intervals when full amplifier power is applied to the cavity before or after beam arrives.