SPECIFICATION

FOR THE BOOSTER

CORRECTOR MAGNET

POWER AMPLIFIERS

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1.0 INTRODUCTION

The following specification describes the requirements for the power amplifiers that will drive the current ramp for the new Booster Corrector Magnet Package. .

There are six separate magnets in the package which need their own individual amplifiers. Forty-eight Corrector Magnet Packages will be installed. Two hundred and eighty-eight power amplifiers will be installed. Each magnet is ramped independently.

The specification of the needed power amplifiers is given as four types based mainly on the voltage and slew rate parameters. The fourth type has a much different requirement than the others. It also has a much lower output current requirement.

2.0 TYPE 1: HORIZONTAL AND VERTICAL TRIM DIPOLES

2.1 MAGNET PARAMETERS

2.1.1 Integrated Field	0.0157 T-m
2.1.2 Maximum +/- Peak Current Pulse Duration = 33 ms, Off Time = 33 ms	38.1 Amp
2.1.3 Integrated Field per Amp	412.07E–6 T-m / Amp
2.1.4 Maximum Field Slew Rate	0.8 T-m / Sec
2.1.5 Magnet Inductance	14 mH
2.1.6 Magnet Resistance	0.315 Ohms
2.1.7 Maximum Magnet Voltage, $V = L (dI/dt) + I R$	+/-39.2Volts

2.2 AMPLIFIER PARAMETERS

2.2.1 Number of Power Amps of This Type Installed	96 Units
2.2.2 Maximum Input Operating Voltage	200 Volts
2.2.3 Minimum Reference Input Impedance	2000 Ohms
2.2.4 Reference Input Voltage Range	+/- 10 Volts
2.2.5 Reference Input Common Mode Rejection (0 to 360 Hz)	70 dB
2.2.6 Typical Reference Gain	10 Amps / Volt
2.2.7 Continuous Output Current	+/- 40 Amps
2.2.8 Maximum Output Voltage	+/- 45 Volts
2.2.9 Current Regulation (Accuracy)	+/- 2.0 %
2.2.10 Current Regulation (Repeatability)	+/- 1.0 %
2.2.11 Maximum Current Ripple With Given Magnet Load (1)	+/- 1.0 Amps
2.2.12 Maximum Current Slew Rate	2,000 Amp / Sec
2.2.13 Settling Time to Within +/- 250 mA (2)	0.25 mSec
2.2.14 Operating Temperature Range	0 to 35 degC

NOTES:

(1) The given magnet load is expressed as $R + j 2 \pi F_{ripple} L$ where, R is the resistance in ohms, F_{ripple} is the ripple frequency in Hz and L is the inductance in Henries. This also assumes a ripple frequency greater than 25 kHz.

(2) The settling time is measured from the end of the ramp for a ramp from 0 to +/-40 Amps and a ramp slope of 2,000 Amps / Sec.

3.0 TYPE 2: NORMAL QUADRUPOLE

3.1 MAGNET PARAMETERS

3.1.1 Integrated Field	0.176 T-m / m
3.1.2 Maximum +/- Peak Current Pulse Duration = 33 ms, Off Time = 33 ms	64.8 Amp
3.1.3 Integrated Field per Amp	2.72E-3 T / Amp
3.1.4 Maximum Field Slew Rate	160 T / Sec
3.1.5 Magnet Inductance	2.2 mH
3.1.6 Magnet Resistance	0.105 Ohms
3.1.7 Maximum Magnet Voltage, $V = L (dI/dt) + I R$	+/-136.4 Volts

3.2 AMPLIFIER PARAMETERS

3.2.1 Number of Power Amps of This Type Installed	48 Units
3.2.2 Maximum Input Operating Voltage	200 Volts
3.2.3 Minimum Reference Input Impedance	2000 Ohms
3.2.4 Reference Input Voltage Range	+/- 10 Volts
3.2.5 Reference Input Common Mode Rejection (0 to 360 Hz)	70 dB
3.2.6 Typical Reference Gain	10 Amps / Volt
3.2.7 Continuous Output Current	+/- 65 Amps
3.2.8 Maximum Output Voltage	+/- 137 Volts
3.2.9 Current Regulation (Accuracy)	+/- 2.0 %
3.2.10 Current Regulation (Repeatability)	+/- 1.0 %
3.2.11 Maximum Current Ripple With Given Magnet Load (3)	+/- 1.0 Amp
3.2.12 Maximum Current Slew Rate	59,000 Amp / Sec
3.2.13 Settling Time to Within +/- 250 mA (4)	0.25 mSec
3.2.14 Operating Temperature Range	0 to 35 degC

NOTES:

(3) The given magnet load is expressed as $R + j 2 \pi F_{ripple} L$ where, R is the resistance in ohms, F_{ripple} is the ripple frequency in Hz and L is the inductance in Henries. This also assumes a ripple frequency greater than 25 kHz.

(4) The settling time is measured from the end of the ramp for ramp from 0 to +/-65 Amps and a ramp slope of 59,000 Amps / Sec.

4.0 TYPE 3: NORMAL AND SKEW SEXTUPOLES

4.1 MAGNET PARAMETERS

4.1.1 Integrated Field	2.0 T-m / m^2
4.1.2 Maximum +/- Peak Current Pulse Duration = 33 ms, Off Time = 33 ms	40 Amp
4.1.3 Integrated Field per Amp	50.0E-3 T / m / Amp
4.1.4 Maximum Field Slew Rate	2,690 T / m / Sec
This has the magnet slewing from full field plus to minus in 1.5 mSec.	
4.1.5 Magnet Inductance	2.5 mH
4.1.6 Magnet Resistance	0.263 Ohms
4.1.7 Maximum Magnet Voltage, V = L (dI/dt) + I R	+/-145 Volts

4.2 AMPLIFIER PARAMETERS

4.2.1 Number of Power Amps of This Type Installed	96 Units
4.2.2 Maximum Input Operating Voltage	200 Volts
4.2.3 Minimum Reference Input Impedance	2,000 Ohms
4.2.4 Reference Input Voltage Range	+/- 10 Volts
4.2.5 Reference Input Common Mode Rejection (0 to 360 Hz)	70 dB
4.2.6 Typical Reference Gain	10 Amps / Volt
4.2.7 Continuos Output Current	+/- 40 Amps
4.2.8 Maximum Output Voltage	+/- 145 Volts
4.2.9 Current Regulation (Accuracy)	+/- 2.0 %
4.2.10 Current Regulation (Repeatability)	+/- 1.0 %
4.2.11 Maximum Current Ripple With Given Magnet Load (5)	+/- 1.0 Amp
4.2.12 Maximum Current Slew Rate	56,000 Amp / Sec
4.2.13 Settling Time to Within +/- 250 mA (6)	0.25 mSec
4.2.14 Operating Temperature Range	0 to 35 degC

NOTES:

(5) The given magnet load is expressed as $R + j\,2\,\pi\,F_{ripple}\,L$ where, R is the resistance in ohms, F_{ripple} is the ripple frequency in Hz and L is the inductance in Henries. This also assumes a ripple frequency greater than 25 kHz.

(6) The settling time is measured from the end of the ramp for ramp from 0 to +/-40 Amps and a ramp slope of 46,000 Amps / Sec.

5.0 TYPE 4: SKEW QUADRUPOLE

5.1 MAGNET PARAMETERS

5.1.1 Integrated Field	0.0115 T-m / m
5.1.2 Maximum Peak Current	2.7 Amp
5.1.3 Integrated Field per Amp	4.26E-3 T / Amp
5.1.4 Maximum Field Slew Rate	0.8 T / Sec
5.1.5 Magnet Inductance	4.0 mH
5.1.6 Magnet Resistance	1.68 Ohms
5.1.7 Maximum Magnet Voltage, $V = L (dI/dt) + I R$	5.3 Volts

5.2 AMPLIFIER PARAMETERS

5.2.1 Number of Power Amps of This Type Installed	48 Units
5.2.2 Maximum Input Operating Voltage	+/-15 Volts
5.2.3 Minimum Reference Input Impedance	2000 Ohms
5.2.4 Reference Input Voltage Range	+/- 10 Volts
5.2.5 Reference Input Common Mode Rejection (0 to 360 Hz)	70 dB
5.2.6 Typical Reference Gain	1 Amps / Volt
5.2.7 Continuous Output Current	+/- 3 Amps
5.2.8 Maximum Output Voltage	+/- 6 Volts
5.2.9 Current Regulation (Accuracy)	+/- 2.0 %
5.2.10 Current Regulation (Repeatability)	+/- 1.0 %
5.2.11 Maximum Current Ripple With Given Magnet Load (7)	+/- 0.05 Amp
5.2.12 Maximum Current Slew Rate	188 Amp / Sec
5.2.13 Settling Time to Within +/- 25 mA (8)	0.25 mSec
5.2.14 Operating Temperature Range	0 to 35 degC

NOTES:

(7) The given magnet load is expressed as $R + j 2 \pi F_{ripple} L$ where,
R is the resistance in ohms, F_{ripple} is the ripple frequency in Hz and L is the inductance in Henries. This also assumes a ripple frequency greater than 25 kHz.

(8) The settling time is measured from the end of the ramp for ramp from 0 to +/-3 Amps and a ramp slope of 188 Amps / Sec.

6.0 REMOTE MONITORING AND CONTROL

The power amplifiers need to have the following remote monitoring and control features.

Current Monitor : +/- 1V per 10 Amps, or +/- 1V per 5 Amps.
Voltage Monitor : +/- 1V per 20 V
Remote Enable : TTL or contact closure.
Remote Inhibit : TTL or contact closure.

Status Outputs : Output Enabled
Amp Normal
Amp Fault
Over Voltage
Over-Current
Over-Temperature

Amplifier Protection :
Input reference voltage limiter
Over-Temperature Shutdown
Over-Current Shutdown
Over-Voltage Shutdown
Under-Voltage Shutdown

7.0 MECHANICAL SIZE AND INSTALLATION REQUIREMENTS

The power amplifiers for the corrector magnet packages will be installed in relay racks located in 6 locations around the Booster accelerator. The power amplifiers in each location will power 8 of the 6 element packages. That is 48 power amplifiers per location.

The power amplifiers and associated bulk power supplies for each location must fit into 4 relay racks. The relay rack dimensions are 70” high x 19” wide x 22” deep.

Revisions:

7/27/05

1. Added pulse duration and off time specification to the Maximum Peak Current specifications.
2. Loosened the settling time spec to be +/- 250 mA within 0.25 ms instead of +/- 100 mA.
3. Omitted the Temperature Coefficient spec in lieu of Operating Ambient Temperature Range in conjunction with Accuracy and Repeatability specs.

10/21/05

4. Specifications for the Normal Quadrupole field strength had to be increased, so a major re-design of the magnet was made. The length of the magnet was increased to a maximum allowable dimension, thus decreasing many of the power supply requirements.
5. An appendix of parameter changes for this revision was added.

Parameter Changes In This Revision, 10/21/05

2.0 TYPE 1: HORIZONTAL AND VERTICAL TRIM DIPOLES

2.1 MAGNET PARAMETERS

	New Value 10/21/05	Previous Value	Change
2.1.1 Integrated Field	0.0157 T-m	0.0175 T-m	**Decreased**
2.1.2 Maximum +/- Peak Current	38.1 Amp	50 Amp	**Decreased**
2.1.3 Integrated Field per Amp	412.07E–6 T-m / Amp	87.5E–6 T-m / Amp	**Increased**
2.1.4 Maximum Field Slew Rate	0.8 T-m / Sec	3.5 T-m / Sec	**Decreased**
2.1.5 Magnet Inductance	14 mH	7.84 mH	**Increased**
2.1.6 Magnet Resistance	0.315 Ohms	0.270 Ohms	**Increased**
2.1.7 Maximum Magnet Voltage, V = L (dI/dt) + I R	+/-39.2Volts	+/-92Volts	**Decreased**

2.2 AMPLIFIER PARAMETERS

	New Value 10/21/05	Previous Value	Change
2.2.7 Continuos Output Current	+/- 40 Amps	+/- 50 Amps	**Decreased**
2.2.8 Maximum Output Voltage	+/- 45 Volts	+/- 92 Volts	**Decreased**
2.2.12 Maximum Current Slew Rate	2,000 Amp / Sec	10,000 Amp / Sec	**Decreased**

5.0 TYPE 2: NORMAL QUADRUPOLE

5.1 MAGNET PARAMETERS

	New Value 10/21/05	Previous Value	Change
3.1.1 Integrated Field	0.176 T-m / m	0.094 T-m / m	**Increased**
3.1.2 Maximum +/- Peak Current	64.8 Amp	50.0 Amp	**Increased**
3.1.3 Integrated Field per Amp	2.72E-3 T / Amp	1.88E-3 T / Amp	**Increased**
3.1.4 Maximum Field Slew Rate	160 T / Sec	160 T / Sec	
3.1.5 Magnet Inductance	2.2 mH	1.104 mH	**Increased**
3.1.6 Magnet Resistance	0.105 Ohms	0.166 Ohms	**Decreased**
3.1.7 Maximum Magnet Voltage, V = L (dI/dt) + I R	+/-136.4 Volts	+/-102Volts	**Increased**

3.2 AMPLIFIER PARAMETERS

	New Value 10/21/05	Previous Value	Change
3.2.7 Continuous Output Current	+/- 65 Amps	+/- 50 Amps	**Increased**
3.2.8 Maximum Output Voltage	+/- 137 Volts	+/- 105 Volts	**Increased**
3.2.12 Maximum Current Slew Rate	59,000 Amp / Sec	85,106 Amp / Sec	**Decreased**

6.0 TYPE 3: NORMAL AND SKEW SEXTUPOLES

6.1 MAGNET PARAMETERS

	New Value 10/21/05	Previous Value	Change
4.1.1 Integrated Field	2.0 T-m / m^2	1.48 T-m / m^2	**Increased**
4.1.2 Maximum +/- Peak Current	40 Amp	50 Amp	**Decreased**
4.1.3 Integrated Field per Amp	50.0E-3 T / m / Amp	29.6E-3 T / m / Amp	**Increased**
4.1.4 Maximum Field Slew Rate	2,690 T / m / Sec	2,279 T / m / Sec	**Increased**
4.1.5 Magnet Inductance	2.5 mH	1.76 mH	**Increased**
4.1.6 Magnet Resistance	0.263 Ohms	0.187 Ohms	**Increased**
4.1.7 Maximum Magnet Voltage, V = L (dI/dt) + I R	+/-145 Volts	+/-145 Volts	

4.2 AMPLIFIER PARAMETERS

	New Value 10/21/05	Previous Value	Change
4.2.7 Continuos Output Current	+/- 40 Amps	+/- 50 Amps	**Decreased**
4.2.8 Maximum Output Voltage	+/- 145 Volts	+/- 145 Volts	
4.2.12 Maximum Current Slew Rate	46,000 Amp / Sec	77,000 Amp / Sec	**Decreased**

5.0 TYPE 4: SKEW QUADRUPOLE

5.1 MAGNET PARAMETERS

	New Value 10/21/05	Previous Value	Change
5.1.1 Integrated Field	0.0115 T-m / m	0.0275 T-m / m	**Decreased**
5.1.2 Maximum Peak Current	2.7 Amp	5 Amp	**Decreased**
5.1.3 Integrated Field per Amp	4.26E-3 T / Amp	5.5E-3 T / Amp	**Decreased**
5.1.4 Maximum Field Slew Rate	0.8 T / Sec	0.8 T / Sec	
5.1.5 Magnet Inductance	4.0 mH	6.4 mH	**Decreased**
5.1.6 Magnet Resistance	1.68 Ohms	0.35 Ohms	**Increased**
5.1.7 Maximum Magnet Voltage, V = L (dI/dt) + I R	5.3 Volts	2.7 Volts	**Increased**

5.2 AMPLIFIER PARAMETERS

	New Value 10/21/05	Previous Value	Change
5.2.7 Continuous Output Current	+/- 3 Amps	+/- 5 Amps	**Decreased**
5.2.8 Maximum Output Voltage	+/- 6 Volts	+/- 2 Volts	**Increased**
5.2.11 Maximum Current Ripple With Given Magnet Load	+/- 0.05 Amp	+/- 1.0 Amp	**Decreased**
5.2.12 Maximum Current Slew Rate	188 Amp / Sec	145.5 Amp / Sec	**Increased**