

System layout and component values of dipole and quadrupole power supplies

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SYSTEM LAYOUT AND COMPONENT VALUES OF DIPOLE AND
QUADRUPOLE POWER SUPPLIES

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This paper summarizes the system layout, electrical configurations, and component values of the dipole-power supply, and the quadrupole power supply, including the quad-trim supply. Also the current and voltage ratings of the bus bars are included.

DIPOLE POWER SUPPLY

The physical size and cost of the magnet power supplies is governed by the product of the maximum voltage and the rms current. A tabulation of the important parameters used in sizing the dipole power supply is given in Table I. The calculated values are for 1.5 GEV protons and Heavy Ions, as listed in the preliminary Design Manual.

It is proposed that a common power supply be employed for the proton and heavy ion cycles. Since the rms currents are almost in the ratio of 2:1, the supply can be built in two half-sections, which can be series connected for proton operation and parallel connected for the heavy ion cycle. The maximum voltage for the proton cycle is three times that for the heavy ion cycle. Obviously the supplies will be under utilized in the heavy ion cycle by a factor of 2/3; and fully utilized in the proton cycle. This arrangement is economically efficient, as compared to two independent, fully utilized power supplies.

The basic dipole excitation consists of 5-1000 volt supplies sequentially switched on, each half section consist of 5 modules. In total this arrangement will require 10 modules, each rated 800 KVA. A system layout with ratings of major components is given in Figure 1.

As an alternative solution to the series-parallel connection of the power supply, it is proposed that the full magnet inductance of the dipole string be divided into two identical inductances. For the proton cycle the half-inductors are connected in parallel; for the heavy ion cycle, in series. This allows the same power supply to be employed for both cycles. A physical representation and the equivalent circuit of the scheme is given in Figures 2 and 3. In total this arrangement will require 5 modules, each rated 1600 kVA.

Each of the 36 dipoles consists of four pancake type coils. For this scheme each dipole has two pancake type coils wired in series and in turn wired in series with two coils from each of the remaining 35 dipoles. The magnetic coupling coefficient between each of the four coils in a dipole is nearly unity. Therefore, the currents will divide equally between the two parallel branches of the coils.

This scheme is analogous to multi-rating a power transformer, in which the primary, secondary, or both are wound in two identical sections. The two halves are connected in series or in parallel with voltage ratings of V or $V/2$ and current ratings of I or $2I$, respectively.

The major advantages for the second scheme are:

1. Reduction of peak voltage from 2500 volts to 1250 volts for the bus bar, cooling water and magnet windings.
2. Reduction of the number of power supply modules and controls from 10 to 5.

QUADRUPOLE POWER SUPPLY

A tabulation of the pertinent parameters used in sizing the quadruple power supply is given in Table II, and a tabulation of the quadrupole trim (tune) is given in Table III. The system layout is given in Figure 4. Since the quadrupole system requires a second (trim) power supply, it was decided to switch the supplies and have a fixed coil arrangement. In total this arrangement requires four modules each rated 360 kVA and two modules each rated 80 kVA.

The 48 quadrupole magnets are divided into 24 horizontal and 24 vertical quads and wired as to form a hair-pin loop around the ring. The loop is tapped and excited by the quad-trim power supply, such that the horizontal and vertical coils respond in a push-pull or balanced mode. The main power supply excites the two groups in a common or single-ended mode. The trim power supply is bidirectional and can unbalance the loop current symmetrically $\pm 10\%$. The trim power supply must always supply a positive voltage, varying between .45 and .55 of the main power supply voltage. The trim supply must function both as a rectifier and as an inverter. This supply can be constructed from two full-wave bridges, poled in opposite directions connected in parallel, and excited from a common transformer, as shown in the schematic of Figure 5.

| | Cycle | V_{max} (volts) | I_{max} (amp) | I_{rms} (amp) | Peak Power | | Power Supply Rating | | |
|--------------|-----------|----------------------|--------------------|--------------------|------------|-----------|---------------------|-----------|--|
| | | | | | V_{max} | I_{max} | V_{max} | I_{rms} | |
| | | | | | | (MW) | | (MVA) | |
| Calculated | Proton | 4669 | 2220 | 1550 | 10.37 | | 7. | | |
| | Heavy Ion | 1425 | 5200 | 3200 | 7.41 | | 4.56 | | |
| Design Value | Proton | 5000 | 2600 | 1600 | 13. | | 8. | | |
| | Heavy Ion | 2500 | 5200 | 3200 | 13. | | 8. | | |

TABLE I
PARAMETERS FOR DIPOLE
POWER SUPPLY

| | Cycle | V_{max} (volts) | I_{max} (amp) | I_{rms} (amp) | Peak Power | | Power Supply Rating | |
|--------------|-----------|----------------------|--------------------|--------------------|------------|-----------|---------------------|-----------|
| | | | | | V_{max} | I_{max} | V_{max} | I_{rms} |
| | | | | | (MW) | | (MVA) | |
| Calculated | Proton | 787. | 2220 | 1600 | 1.75 | | 1.18 | |
| | Heavy Ion | 425 | 5200 | 3200 | 2.2 | | 1.36 | |
| Design Value | Proton | 900 | 2600 | 1600 | 2.34 | | 1.44 | |
| | Heavy Ion | 450 | 5200 | 3200 | 2.34 | | 1.44 | |

TABLE II

PARAMETERS FOR QUADRUPOLE
POWER SUPPLY

| | Cycle | V_{max} (volts) | I_{max} (amp) | I_{rms} (amp) | Peak Power | | Power Supply Rating | | |
|--------------|-----------|----------------------|--------------------|--------------------|------------|-----------|---------------------|-----------|--|
| | | | | | V_{max} | I_{max} | V_{max} | I_{rms} | |
| | | | | | | (KW) | | (KVA) | |
| Calculated | Proton | 432 | 444 | 320 | 192 | | 138 | | |
| | Heavy Ion | 234 | 1040 | 640 | 244 | | 150 | | |
| Design Value | Proton | 500 | 520 | 320 | 260 | | 160 | | |
| | Heavy Ion | 250 | 1040 | 640 | 260 | | 160 | | |

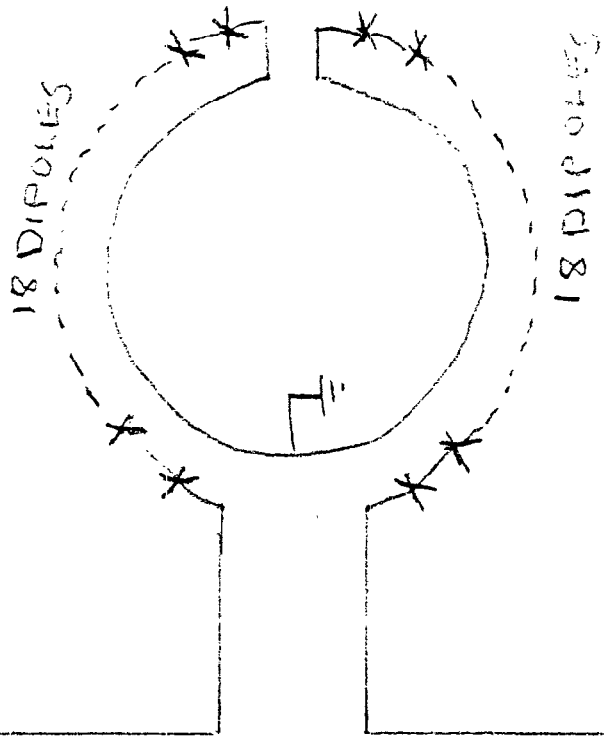
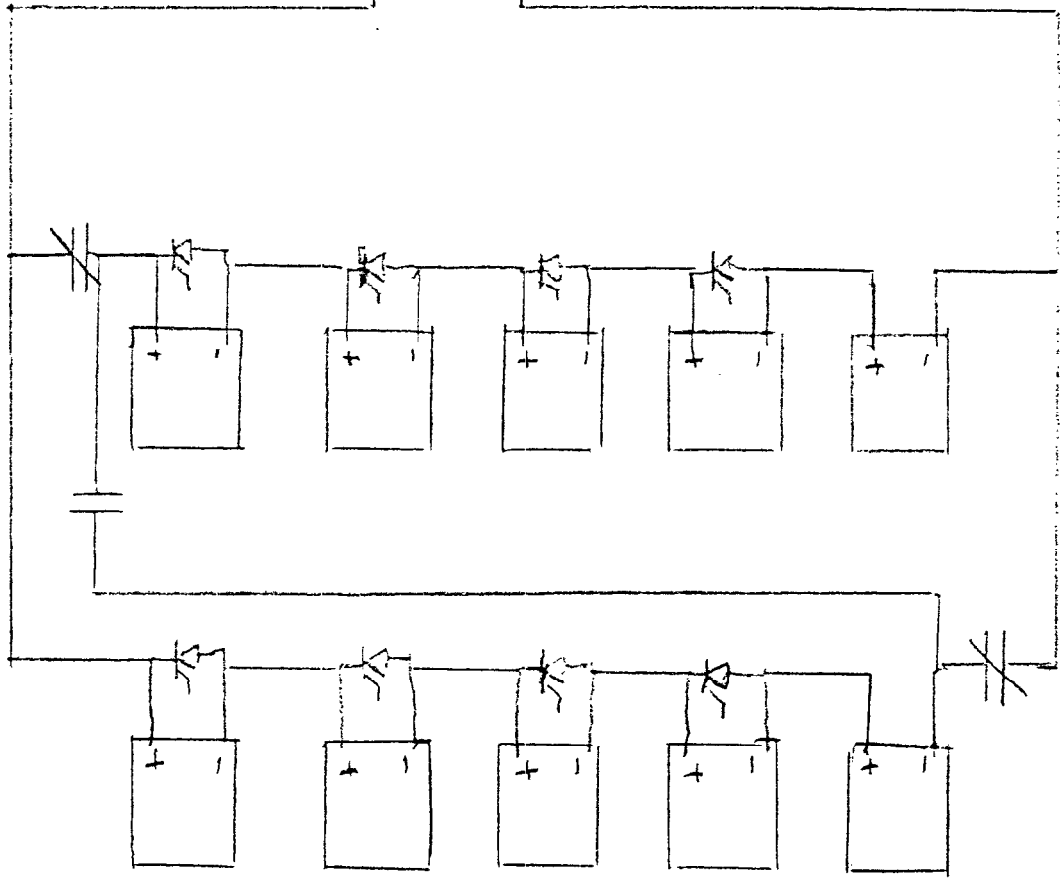
TABLE III

PARAMETERS FOR QUADRUPOLE TRIM POWER SUPPLY

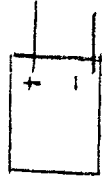
RATINGS :

BUS BAR 300A (RMS)

$V_{PEAK} = 2500 \text{ VOLTS}$



POWER SUPPLY
MODULE



500 VOLTS

SL70A005

2600A MAX

1600A (RMS)

800kVA

FIG 1

SYSTEM LAYOUT
POWER SUPPLY SWITCHING

FIG 2.

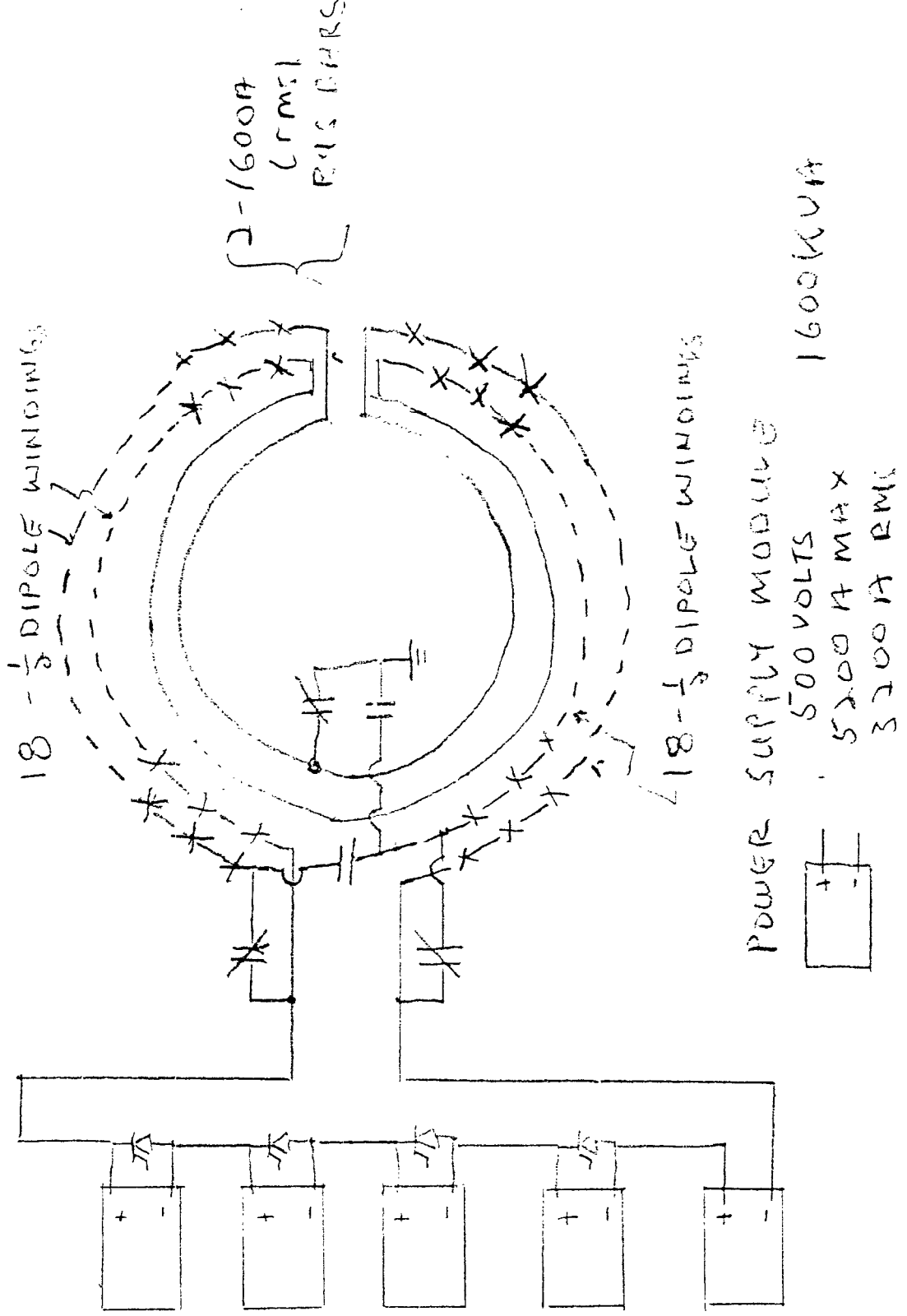
SYSTEM LAYOUT

MAGNET COIL SWITCHING

RITINGS

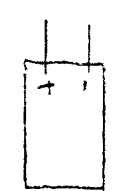
BUS BAR 3200A (RMS)

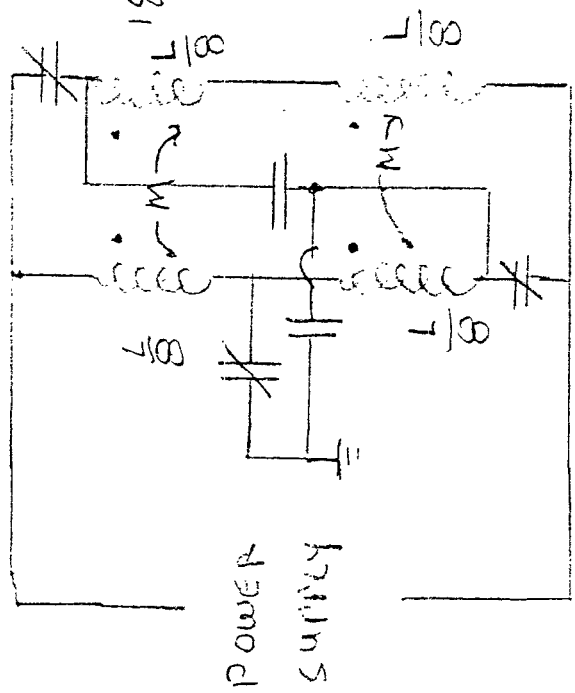
V_{PEAK} = 1250 VOLTS



POWER SUPPLY MODULE

500 VOLTS
 5200 A MAX
 3200 A RMS





1/8 - 1/8 DIPOLE WINDINGS
 COEFFICIENT OF COUPLING
 CLOSE TO UNITY

$$M \approx \frac{L}{8}$$

L is the inductance
 of the full dipole
 string, series circuit

FIG 3

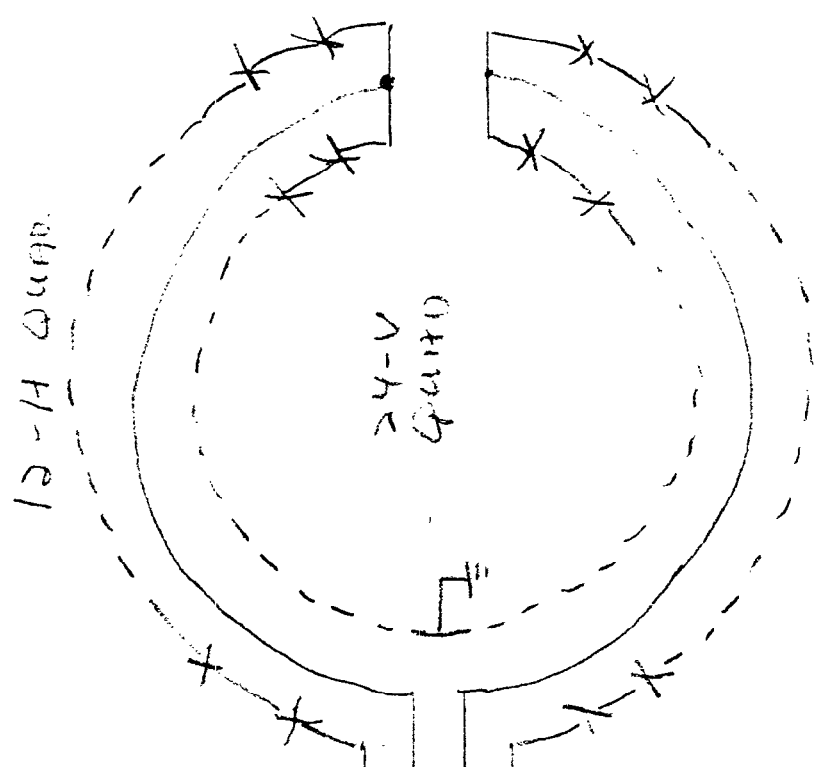
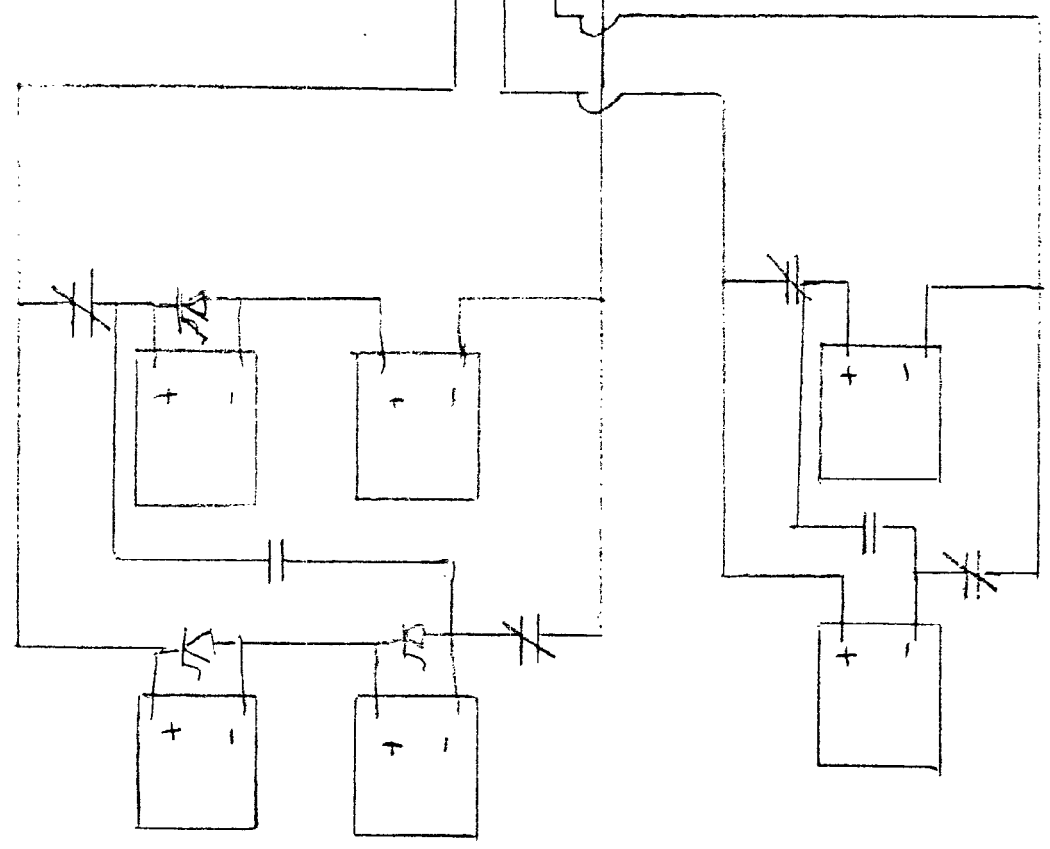
EQUIVALENT
 CIRCUIT

MAGNET COIL SUBSTANTIALLY

MAIN QUAD MODULES
 225 VOLTS
 26000 MHX
 1600A RMS
 360KV/A

RATINGS.

MAIN BUS (60) 360KV (RMS)
 PEAK VOLTAGE 450VOLTS
 TRIM BUS (MTC 640A (RMS))



QUAD A-e1

FIG 4
 SYSTEM WAVEFORMS
 QUAD POWER SUPPLY

350 VOLTS
 5200 MHX
 3200 RMS
 80KV/A

QUAD-TRIM MODULE

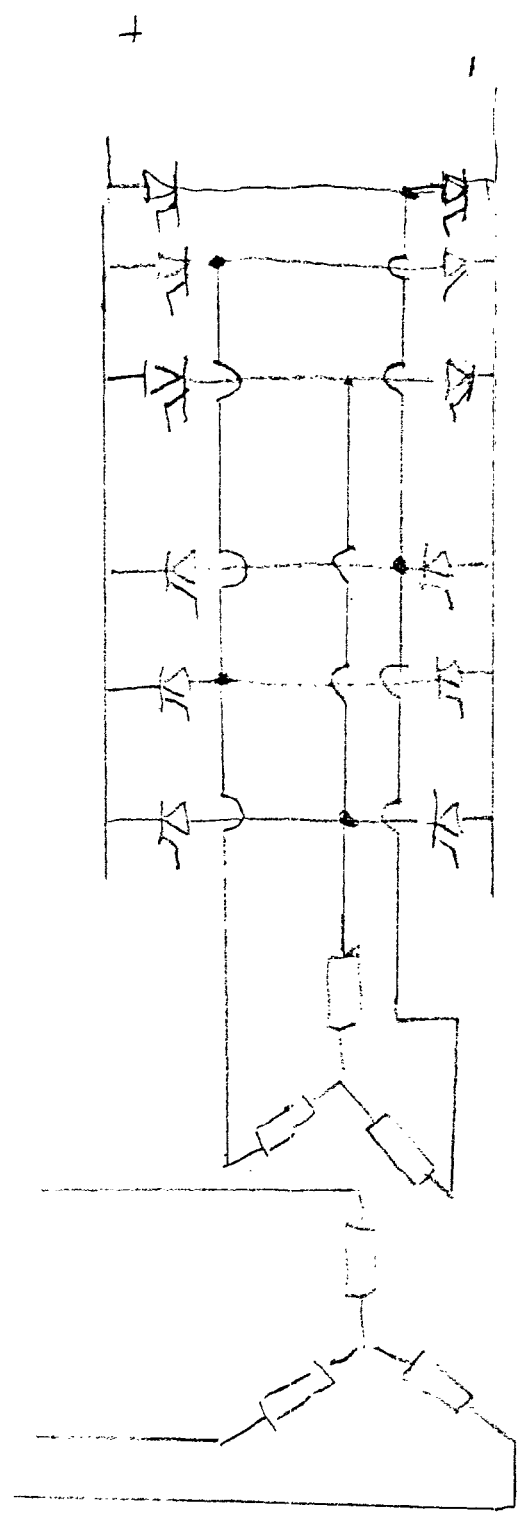


FIG 5
SCHEMATIC OF
QUAD-TRIM
POWER SUPPLY