

PEP STORAGE RING MAGNETS AND POWER SUPPLY SYSTEM*

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TABLE OF CONTENTS

	Page
Design and Performance of PEP DC Power Systems (T. Jackson)	2
PEP Magnet Power Supply Operations Report (C. A. Harris)	7
Testing of the PEP Magnet-Power-Supply Systems (H. Boatner and C. A. Harris)	58

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DESIGN AND PERFORMANCE OF PEP DC POWER SYSTEMS

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The PEP Magnet Power Supply System represents a significant departure from previous technology with the goal of improved performance at lower cost. In nineteen of the magnet families around the ring, "Chopper" power supplies are used. The many choppers are powered from two 2MW DC supplies, and control the average power to the various magnet loads by pulse-width modulation at a 2 kilohertz repetition rate. Each chopper utilizes SCR's for switching, and stores sufficient capacitive energy for turn-off on command. Most of the energy is recirculated, resulting in high-efficiency. The two kilohertz chopping rate allows a one kilohertz unity-gain bandwidth in the current-regulator loop, and this wide bandwidth, coupled with low drift components in the error-detection system, provides a high-performance system. The PEP system has also shown that the chopper system is economical compared to standard multi-pulse controlled-rectifier.

Before going into the Chopper system in more detail, it is appropriate to briefly describe the overall PEP Power Supply system. Additional detail on various aspects of the systems is available in previous conference papers,¹ so only the barest introduction will be given here. There are 240 power supplies in the system, each current regulated to a set-point provided by the digital control system. The supplies fall into three major categories: the Ring, Injection-transport, and Trim and Steering Systems.

Ring System

The Ring system is made up of the Choppers and the DC supplies that feed them. A simplified schematic is shown in figure 1, the SCR Choppers represented by switches. There are twenty-four of the 500V, 500A choppers, and two of the 500V, 1400A choppers. All of these supplies are located in standard racks at the Region 8 surface-building as shown in Figure 2. These supplies provide separately-controlled, current-regulated power to the following families of magnets: one Bend circuit, nine Quadrupole circuits, eight Sextupole circuits, and one Wiggler circuit. These magnet families are all series connected strings of magnets around the 6,575 foot long ring. Those families with more than 12 magnets in series require two choppers in series to achieve the required voltage. There are additionally boost supplies located at regions 12 and 4, one set for the 1400 amp Bend circuit, and the other set for one of the quadrupole circuits.

Three of the rows of racks in Fig. 2 each contain eight choppers (all the 500A choppers). The row in the middle houses the two 2MW DC power supplies which feed all the choppers. The soft ground (100 Ω) for the whole system is located electrically between the two supplies, so that the maximum voltage away from the ground on any magnet circuit is ± 500 volts in

normal operation. The two 1400 amp Bend choppers are located next to their respective + and - DC supplies, and fed from the output busses (located at the top of the DC supplies) through low inductance (0.8 μ h), parallel bus feeds. The rest of the 500A choppers are fed from the output busses through 4/0 quadraflex cables run through cable trays above the racks.

At the aisle-end of the row of racks containing the DC supplies and 1400A choppers, there are two racks housing all control equipment for the chopper system (Fig. 3). This equipment includes the following: CAMAC crates for input/output communication with the PEP Central Control Computer, CAMAC crates containing all the Chopper Controllers, a multiplexer and Digital Voltmeter for sampling magnet current levels in all the monitoring transducers (also the levels of the Loop transducers and references if necessary), cross-connect relay modules, and appropriate power supplies. There are up to eight Chopper Controller Cards per CAMAC crate. Each card contains a complete chopper control system from the input 16 bit reference word, clock signal, and feedback transducer signal, to the output firing pulses for the chopper and commutator SCR's (turn-on and turn-off pulses) of the associated chopper unit. Each of the pulses is conveyed from the short (upper) edge-connector of the CAMAC-card through a 50 Ω coaxial cable-connector system to a pulse transformer (insulated for 1600V) mounted in a shielded-box on the chopper unit.

There is a Chopper Crate-Controller card in each of the four CAMAC crates which distributes both digital command words and appropriately phased clock signals to each of the chopper cards. The clock signals are phased so as to minimize the rms current flowing in the large capacitor banks. The output signals on four plugs can be cabled to any of the Crate-Controller cards. The clock (which is in a separate card) can be either free-run with the frequency adjustable via a front-panel potentiometer, or line-frequency-locked through a phase-locked loop. The VCO generates 26 kHz which is then counted-down to give the various phased-clock signals.

Injection-Transport System

Power supplies for the transport magnets are located in three locations: at Sector 30 of the Linac building, where the North and South Injection Transport tunnels veer off from the linear accelerator for the PEP ring, and at the surface buildings at Regions 8 and 10, where the tunnels join the ring. The bulk of the power supplies are located in Sector 30, feeding the separately controlled but identical achromatic Bend families and Quadrupole magnet families in both tunnels. The remaining Bend, Quadrupole, and Bump magnets are fed from supplies in Regions 8 and 10. All of these supplies are 6 pulse, AC-line commutated SCR circuits purchased commercially. The requirements of these circuits are currents regulated to $\pm 0.1\%$, compared to $\pm 0.01\%$ for the main-ring chopper systems.

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This system is by far the most numerous of those employed at PEP, with 170 units installed in all the surface buildings and Sector 30. Most of the units are used for bipolar trim-and-steering applications with a rating of $\pm 37V$ at 60A but some are used as unipolar 120A units and others as 30A shunts around Bend magnets in the injection-magnet families. These units are used as power sources in conjunction with $\pm 42V$, 1000A power supplies. The power supply is located in the bottom of a double rack, and up to 24 actuators are mounted above it and plug into feeder busses extending up the center of the double rack. There are nine of these double racks used at PEP. The reference signals for both these units and the Injection comes from a CAMAC crate located nearby in an adjacent rack. The analog signals are developed in 12 bit D/A's in the CAMAC crate and processed through a Distribution chassis. With this brief description of the PEP system, the rest of the paper will concentrate on the chopper system.

The Chopper as a System Component

As stated in the introduction, the dual promises of high performance and economy fueled interest in using choppers as the controlling element in the PEP magnet-power-supply system. Both of these goals have been possible because of the particular nature of the load placed on the supplies and the favorable logistical nature of the PEP magnet system. Neither of these aspects are unique to the PEP system, and therefore choppers should see application beyond those now in use at PEP.

Early measurements on the first prototype PEP Bend and Quadrupole magnets in 1976 confirmed that the magnets were effective filters between applied AC voltages and their corresponding currents. Subsequent measurement have shown that with the additional shielding of the aluminum vacuum pipe, the attenuation of all frequency terms from a chopper running at 2.16 kHz is sufficient to reduce the magnetic field variation to less than $\pm 0.01\%$ in the bend magnets. The field measurements were made with a vacuum pipe and B coil that extended well beyond the end of the magnet coil, so as to measure any contribution of the stray field at the ends of the magnet. The magnets are laminated because of the construction technique used in their fabrication, but individual laminations were not coated, so there was no guarantee they would be wideband units. With this type of magnet as a load the high-frequency operation of the chopper either eliminates or minimizes the need for filtering the output voltage of the power supply.

With a chopper there is no firing circuit unbalance to introduce subharmonics as in a 6 or 12 pulse controlled rectifier. Running at 2.16 kHz the chopper current-loop unity-gain bandwidth can be as high as 1 kHz. The chopper therefore has substantial gain for any low-frequency voltages coming from the rectifiers. The one kHz unity-gain bandwidth of the chopper also provides relatively fast transient response to changes in the reference and reduction of line perturbations. Closing the loop at a frequency within a factor of two of the repetition frequency is generally not possible with line-commutated, multi-phase firing-circuits because oscillations develop at the sub-harmonic frequencies. The wide bandwidth of the chopper coupled with currently available operational amplifiers of very low drift and noise, provide the means for $\pm 0.01\%$ current regulation with 1 kHz bandwidth in the megawatt power range with better than 95% efficiency.

The economics of the PEP system are based on the fact that the beam cannot be stored in the ring unless all the families of magnets are operating and performing satisfactorily. Therefore, if any of the power supplies are not operating correctly or there is a trip-off in any one of them, it is permissible that all the power supplies be off. This commonality of demand on the supplies allows a similar commonality to exist on the feeders coming to the chopper power supplies: all the choppers are fed in common from either the positive or negative DC supplies, with no switchgear interposed between the DC supplies and the chopper controllers. The 2.0 MW DC supplies in turn are each fed from 2.5 MVA, 13KV/480V transformers, located outside the building, and with secondary breakers at the transformer pad and at the 2500A feeder entrance to the building.

These two standard distribution transformers and their related breakers at the pad and the building entrance are the only transformers and switchgear in the system, and they would have been provided as part of the normal AC utility-distribution system to the power-supply area independent of what kind of power supplies were used. So the cost of transformers and switchgear is eliminated from the power-supply expense. The circuit breakers employed operate as On-OFF contactors as well as circuit breakers. There is a fast-acting current-limiting fuse on the incoming lead that is not at common on each of the choppers, which acts if the chopper internal fast-turn-off does not commutate off a fault current.

The cost of the choppers under the condition described above is as follows (with DC busses):

(1) Cost of 500 V, 500 A chopper	\$10,600 (\$42/KW)
(2) Cost of 500 V, 1400 A chopper	\$12,700 (\$18/KW)
(3) Cost of 2MW DC feeder supplies	\$54,000 (\$27/KW)

These figures are not estimated figures, but represent the totals accumulated in the three accounts during the construction of PEP. The grand total of \$441,500 in the Chopper and DC supply accounts represents the costs for twentyfour small and two large choppers, the two DC feeder supplies at Region 8, and additionally the two 840 KW Bend Booster supplies at Regions 12 and 4. The chopper costs include the cost of the separate monitoring and loop transducers used in each chopper, and all the chopper controller cards, clock cards, crate controller cards, and modified CAMAC crates that make-up the controlling system. Installation costs are not available because they are part of a far larger Electrical Construction contract performed by a private contractor.

The maximum power capacity of all the choppers just described plus the two bend boost supplies at regions 12 and 4 is 9MW, whereas the maximum power required by all the ring magnet families at 18 GeV beam energy level is only 5MW. The sum of all the DC supplies at Regions 8, 12, and 4 is 5.7 MW; this number more closely matches the maximum power required. The discrepancy occurs because many of the sextupole and quadrupole circuits require less than the maximum voltage and current available from the choppers. The cost of the chopper units is optimized at the given current and voltage values based on the ratings of the fast turn-off SCR used (the Westcode R220). Therefore unless a future application could be matched closely to the chopper ratings the cost per KW figures are not directly applicable. A more accurate comparison for the specific PEP case is to

take the total construction cost of \$442K against the \$5M, for a figure of \$88/KW.

The reason that the 1400A chopper is so much more economical than the 600A unit, is because to raise the current rating of the chopper unit from 600A to 1400A basically requires only the addition of a second SCR of equivalent size to that already in operation, increasing number of 5µfd commutating capacitors from 3 to 10, and increasing the current capability of the bussing as required. Additional cooling air on the capacitors and snubbing were also required. But the great bulk of the cost in the rack fabrication, transducer and chopper controller remained essentially the same.

Performance and Operation

The choppers have performed their function as ±0.01% current regulators up to highest expectations. The current-monitoring multiplexed Digital Voltmeter, a Hewlett Packard 3455, shows performance better than the ±0.01% required. At higher performance levels than ±0.01%, both the monitoring and loop transducers have to be called into question, particularly with respect to line voltage variations.

The choppers have also operated reliably; most of down-time during the first year of operation has been from other parts of the power supply system. Two types of chopper hardware failures have occurred, and both of these only two or three times. The snubber-capacitor across the free-wheeling diode has failed, which then causes the diode to fail and possibly the chopper SCR to fail also. A different capacitor will soon be installed to correct this problem. The water-cooled resistor has also failed due to localized heating of the carborundum resistor near the ends. A new means of connection is now being tested.

In the larger chopper-power-supply system there have been two sources of operational difficulty: erratic operation of the 2MW DC power supplies, and erroneous digital-word reception at some of the chopper DACs. The most recent difficulty (in February) was the failure of one of the 2.5MVA distribution transformers feeding a DC supply; one of the 490V leads was not securely connected internally to a stud on the transformer, and arced in the oil until a phase-to-phase short was initiated. This transformer arcing intermittently may account for some of the power supply difficulties over the past year, but it seems clear that the firing circuit is unreasonably sensitive both to line voltage noise and the characteristics of a flip-flop used in the zero-crossing part of the circuit. The SCR-bridge and firing circuit, both mounted on a large panel, were purchased from Research, Inc. (RI), as a package, and subsequently mounted in a double-rack along with the LC filter, bussing, shorting-bars, etc., to become one of the four DC supplies used. Because the supplies are not used as current regulators, but as low-performance bus-supplies for the choppers and slave-supplies in the Bend circuit, using only one zero-crossing per cycle was not a problem. The fast turn-off under fault (sensed by current-transformer), and advertised insensitivity to line-voltage noise were desirable features. The firing circuits turned out to be very sensitive to the line voltage when operating above 1MW, and during the very-short P.S. check-out period (two weeks before PEP operation), were a source of grave concern. After various filtering schemes were unsuccessful, phasing the units from a separate feeder was finally adopted and is still in use.

During the initial P.S. checkout period, and

given the substantial difficulties with the DC supplies, it was very encouraging that the choppers were well-behaved and exhibited no problems of interaction due to running in parallel and series, or false triggering due to noise from other choppers. Two choppers had been run in parallel during the development program at LBL, but the series operation had never been attempted. A situation where noise of some kind is involved has arisen at 14.5 GeV operation during the "filling" operation of the ring where the Injection Bump magnets are ramped. In performing this operation on a non-chopper supply, the computer also sends "refresh" words to the choppers. In one group of choppers whose controllers are located in a particular CAPAC crate one chopper would randomly receive an incorrect reference word for a short period and cause the beam to "dump", and the "glitch" detector to indicate on the responsible chopper. The problem proved to be insensitive to the components involved, and more careful grounding of the two control racks seems to have solved the problem at the 14.5 GeV operation level, but why just one crate was involved is still a mystery.

Electromagnetic noise also appeared on the output of sensitive spark-chamber amplifiers in the experimental-hall at Interaction Region 8. The addition of air core chokes to both sides of the chopper outputs reduced the rise-time of the voltage output and reduced the noise below the detector threshold level. Similar noise problems for the experimenters at regions 4 and 12 from the Bend Booster supplies in those regions were solved by activating the LC filters already existing in the supplies.

Chopper and System Design

There is one aspect of the Chopper System design that is very closely tied to both operations and Chopper design: the output voltage range of the chopper. There are a variety of possible chopper circuit configurations to perform the basic function of turning-off the output voltage (V_0) on command. Of these various circuits only two will be discussed here: the current-commutated (Fig. 4 and 5) and the voltage-commutated circuits². The current-commutated-circuit (CCC) turns off the ON series SCR (labeled CR1) by circulating current through the reverse diode D1 across CR1 during the second-half-cycle of the ringing period of the high-Q resonant circuit (the first-half-cycle is through initiating CR3). The forward-voltage of D1 reverses biases CR1 during the time when the ringing current is greater than the load current (I_L): this time must be greater than the turn-off time (t_{off}) of the SCR at maximum I_L . The CCC has the advantage of being very efficient (because of the total cycle of ringing voltage), and generating relatively low reverse-recovery voltages; coupled with the disadvantage of having a minimum output voltage determined by the ratio of the ringing period of the LC circuit to the total period of the cycle of operation (the input and output are connected during the ringing period).

$$V_{\min} = (T_{LC}/T_{\text{per}}) V_B = (\text{rep rate}/f_0) V_B \quad (1)$$

The voltage-commutated circuit (VCC) has the advantage of providing full-range voltage control, counterbalanced by a propensity for large voltage spikes appearing across the commutating SCR during reverse-recovery. The voltage spike, even though below the rating of the SCR, occurring immediately following high-current conduction in the SCR, causes

high failure rate. Independent of which commutating circuit is used, there is a minimum allowable inductance that must effectively appear in series with the chopper SCR. This inductance is necessary to control the rate-of-change of current with time (1) upon turn-on of the chopper SCR.

$$L_{min} = V_B / I \quad (2)$$

The VCC was the initial choice to satisfy the early PEP requirements of 300V at 1200A for the Bend magnet circuit. The prototype chopper worked well at this supply voltage level, because the sum of V_B and the transient voltage was no more than 800V on 900V rated SCR's with moderate snubbers. When the magnet design changed and 600V operation was more appropriate, the reduction of transient voltages to acceptable levels became more difficult and costly and put far more uncertainty on long-term reliability. A quick circuit reconfiguration to current commutation was done, and immediate successful operation of the circuit, simplicity of operation, and easing of the transient problems resulted. It was then determined that the range requirements of the circuits could be satisfied with the chopper minimum of $V_D = 0.15 V_B$, where V_B varies above 100V proportional to beam energy. The SCR Bus supplies were originally chosen over diode-bridges primarily because of the quick turn-off feature and low cost (\$8/KW) of the Research, Inc. packaged controller. But now the controlled-output capabilities would also be used to follow a programmed input.

On the basis of the variable-voltage DC bus operation, the non-minimum output, current-commutated chopper was adopted for PEP. Since achieving operating status the minimum output of selected sextupole choppers has been lowered from 14% to 2% by running them from a 360 hertz clock rather than the 2.16 kHz clock used on the rest of the choppers. The decision to adopt the CCC has been justified by the excellent reliability the choppers have shown in service, but unfortunately leaves unanswered what additional development and cost the wider-range VCC would incur to achieve reliability.

Designing the current-commutated-chopper does not involve changing any of the basic circuit elements shown in Fig. 5, and therefore only the L, C, R, and L_B values are available as variables. The R is the least useful of the variables, serving to reduce the "ring-up" value of V_C above V_B during the period between commutation. If a satisfactory design can be achieved without R, it can be eliminated, resulting in a more efficient design. An additional variable not shown in Fig. 5 is the effective Q of the LC circuit. Selection of component values involves more than a simple LC circuit because of the final part of each commutation cycle. After D1 has carried the ringing current I_C that is greater than I_L for a long enough period to allow CR1 to recover, D3 stops conducting and I_L flows through C and L. Shortly after, when V_C becomes greater than V_B , the free-wheeling diode D3 starts conducting, and the capacitor voltage V_C increase in magnitude by:

$$\Delta V_C = I_C / \omega C \quad (3)$$

during the $\pi/2$ period that I_L commutates to D3. In the pictures shown in Fig. 5, conditions are such that D1 ceases conducting and D3 starts conducting at the same instant. The inductance of the bus, L_B , enters into the circuit during this last part of commutation, and enters Eq. 3 through $\omega = [(L_1 + L_B)C]^{-1/2}$.

Depending on the parameters involved in each application, the ringup voltage ΔV_C can be a help

or a hindrance. The limiting parameter for the PEP choppers turns out to be a maximum allowable capacitor voltage of 750V at the start of the commutation. Although specified for 1000V operation in this circuit, long-term failures occur due to thermal effects when the value of V_C exceeds 750V. With the capacitor voltage limitation, the DC bus voltage is not allowed to exceed 500V, where all the 18 GeV current requirements can be met. An opposite example, where the ringup voltage is desired, is in a group of choppers used for PEP experimenter magnets, where the $V_B = 120V$, and the $\Delta V_C = 339V$. The Bend, Quadrupole, and Experimenter choppers are listed in Table 1 with the appropriate parameters as three design examples.

Previous to discovering the long-term failure-mode in the commutating capacitors at approx. $E_{pk} = 700V$, the circuit was run to $E_{pk} = 900V$, with the R220 used for CR3 rated at 1200V. The R220 has a $T_{off} = 15 \mu\text{sec}$ for voltage commutation, and a $T_{off} = 17 \mu\text{sec}$ rating for current commutation (only 1 volt reverse voltage applied). Used also for CR1, the R220 with a 1000A_{rms} rating is used singly for the lower current choppers, and doubly with alternate pulse firing for the 1400A choppers. The 250kW and 700kW ratings on the choppers are because of the capacitor voltage limitation (otherwise 360kW and 840kW are appropriate at $V_D = 600V$).

Because the capacitor ringup voltage, ΔV_C , affects the peak ringing current and therefore the t_{off} applied to CR1, the load current I_L has to rise with a $\tau \gg T$ period, to allow V_{Cpk} to build-up in step with I_L . This condition is satisfied with inductive loads. With series choppers, both choppers have to be enabled simultaneously and the same buildup occurs in both units. If one of two series units is turned on first, the current from the first will flow through the free-wheeling diode D3 of the second unit until it is turned on. At the time the second unit is fired, if the I_L has reached a current higher than that which can be successfully commutated with just V_B stored on the commutating capacitor, the second unit will "latch-up" at full output.

To determine the chopper system efficiency, both the DC supplies, the bus and the chopper losses must be included. Without transformer losses to consider as part of the power supply, the rectifier itself loses less than 1 percent of rated power. The combination of bus and chopper losses are also less than 1 percent, so the overall efficiency should be 98 percent.

Conclusion

The chopper system provides a new approach to high-performance magnet-power-supply systems. Its performance and efficiency are superior and cost less than comparable size transformer-controlled-rectifier supplies. The problem of radiated EMI noise to the surrounding environment has to be reduced with choppers just as with 6 pulse supplies. Ripple in the magnetic field is lower if the magnet is laminated through high chopping rates. Minimum output-voltage requirements must be considered in the choice of the chopper circuit used. Two areas are particularly appropriate for chopper application: (1) large power supply systems with a common DC supply where the system using the power is disabled whenever any individual chopper must be shut-down, and (2) retrofitted on existing supplies where higher performance is required.

Table 1: Parameters of the Three Chopper Designs now in use at PEP

Chopper	I_{Lm}	V_B	L	L_B	C	ω	ω_1	Z_0	ΔE_c	V_{cpk1}	V_{c2}	I_{pk2}	t_{off}
	(A)	(V)	(μH)	(μH)	(μfd)	($\times 10^{-3}$)	($\times 10^{-3}$)	(Ω)	(V)	(V)	(V)	(A)	(μs)
Bend	1400	500	2	0.8	50	100	85	0.2	328	828	680	3059	21.9
Quad	500	500	7	3	15	97	82	0.68	250	813	601	795	18
Exptl.	600	120	5	3	25	89	71	0.45	339	459	459	920	19.2

Note: $\omega_1 = [(L + L_B)C]^{-1/2}$, $\Delta E_c = I_c/\omega_1 C$, $\omega_0 = (LC)^{-1/2}$, $Z_0 = (L/C)^{1/2}$,
 $V_{cpk1} = V_B + \Delta E_c = \text{peak } V_c \text{ at end of ringup,}$
 $V_{c2} = V_{cpk1} e^{-t/RC} = V_c \text{ at beginning of commutation (with } R_B = 50\Omega, R_Q = 100\Omega)$
 $I_{pk2} = 0.9 V_{c2}/Z_0 = \text{peak ringing current of 2nd half-cycle with } Q = 25,$
 $t_{off} = (90 - \sin^{-1} L_L/I_{pk2}) (90)^{-1} (\pi/\omega_0) = \text{time of ringing current above } L_L$

Acknowledgements

There are two separate groups that deserve praise for their efforts on this project. First the PEP power-supply group at LBL, for their long-term effort in bringing the various systems through the development, prototype, production, and finally checkout phase of the project. And then at SLAC the Experimental-Facilities Power-Supply Group under the able leadership of Slim Harris, and the Linac Operations Group, for all their efforts in bringing the equipment "on the air" and maintaining it since in the Injection-Transport and the Ring Systems.

Bibliography

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2. Dewan, S.B., and Straughen, A., "Power Semiconductor Circuits", Wiley, N.Y., 1975, pp. 298-334.

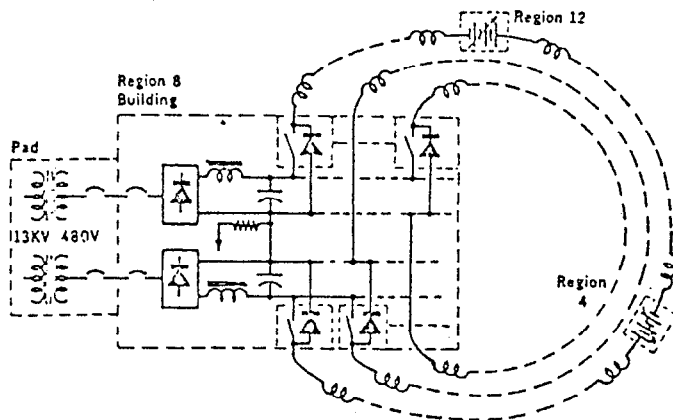


Fig. 1. PEP Chopper System Functional Schematic

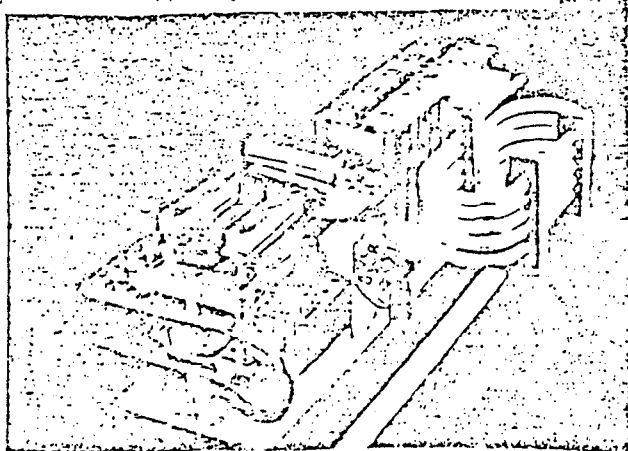


Fig. 4. 500A Chopper Module (hoses removed for clarity)

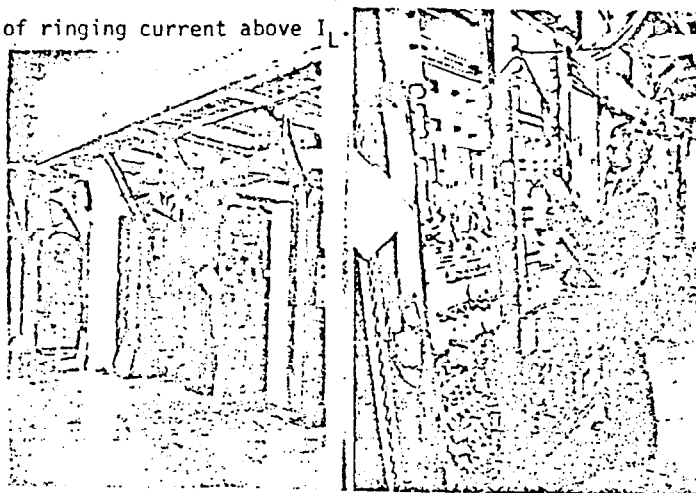
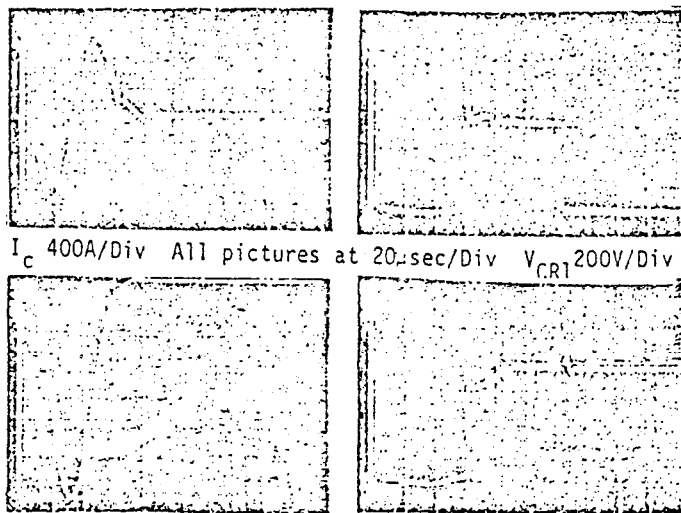


Fig. 2. Region 8 Chopper Racks Fig. 3. Control Racks



I_c 400A/Div All pictures at 20 μ sec/Div V_{cR1} 200V/Div

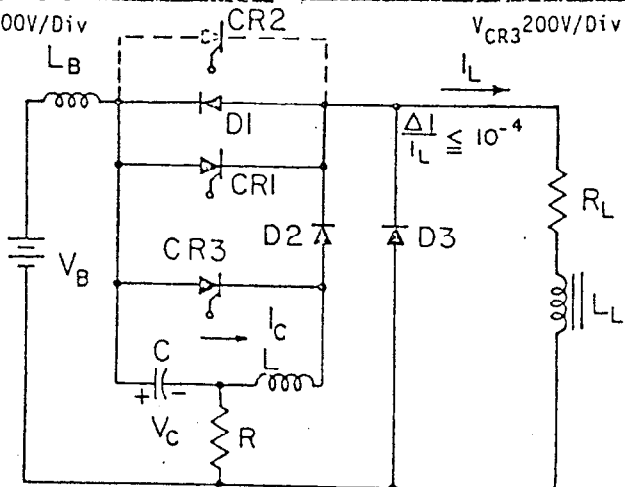


Fig. 5. Current-commutated Chopper Circuit

1. saved as WYL.RA.CAH.FEP3 on EDIT51 March 27, 1982

2.
3.
4. PEP Magnet Power Supply Operations Report

5.
6. Research Inc (RI) Power Supplies
7. Firing Circuits, Regulation and Protection Circuits
8. Operation and Maintenance
9.

10. Instructions

11.
12. Main Ring Power Supply SD-207-001-02

13.
14. Introduction

15.
16. This section will be devoted to the explanation of the voltage
17. regulation, control, and protection circuits built into the
18. Research Incorporated (RI) supplies that supply the regulated DC
19. voltage to the pulse width chopper regulators.

20.
21. It is assumed that the reader has had a thorough introduction to
22. the operation of Silicon Controlled Rectifiers (SCR's) used in
23. three phase bridge rectifiers. If the reader is not so
24. acquainted, then I suggest that he/she study the following
25. documents before continuing with this report.

26.
27. "AC/DC Power Systems & Miscellaneous Information"
28. C. A. Harris - June 30, 1978

29.
30. "Bridge Rectifier, Instruction Test Assembly" "The Beast"
31. C. A. Harris/F. Veldhuizen - March 5, 1981

32.
33. "Phase Controlled Current Regulated Power Supplies"
34. C. A. Harris/F. Veldhuizen - June 21, 1978

35.
36. "Three-Phase Power Controller Model 650"
37. Instruction Manual by Research Inc

38.
39.
40. Overall System Configuration See (Figure 1)

41.
42. The main dc power for the chopper regulation system for the PEP
43. Ring magnets is composed of:

44.
45. 1. Region 8; two power supplies each rated for 3,000 Amps dc at
46. 600 volts. (One is negative voltage output (-RI) and the other
47. is positive voltage output (+RI). Each of these units is
48. energized from a 2,500 KVA (12,470/480 volts) transformer located
49. on the transformer pad outside of the support building at Region
50. 8.

51.
52. 2. Region 4 and 12; additional booster power supplies are
53. required at Regions 4 and 12 are to supply enough total voltage
54. to supply the requirements of the 242 magnets in the "Bend"
55. system and the 60 magnets in the "4CF" system.

56.
57. The booster supplies for the main bend magnets are similar to the
58. "RI" power supplies at Region 8, except that they are each fed
59. from 1,500 KVA transformer. They have an output rated at 600

60. volts, 2,000 Amps.

61.
62. The booster supplies for the "4QF" system of magnets are located
63. at Regions 4 and 12. These supplies receive their primary 480
64. volts 3 phase power from the a-c buses in the Main Bend magnet
65. booster supplies; therefore, they are energized when the main
66. bend magnet boost supplies are turned on.

67.
68. There are two full wave bridge rectifiers (3 diodes and 3 SCR'S)
69. in each of these 4QF Boost power supplies with separate
70. transformers. These supplies are not voltage regulated, but
71. instead they are controlled in two steps using the 3 SCR'S in
72. each bridge. The output voltage steps (zero, 100, or 200 volts)
73. are determined by an analog 0-10 volt signal put into the
74. supplies from the CAMAC system from FFCR. More will be said
75. about these supplies later in this report.

76.
77. RI Supplies at Region 8

78.
79. The basic regulation system of booster RI supplies at Regions 4
80. and 12 is very close to the scheme at Region 8, so one
81. explanation should be sufficient. See print SD-207-001-02 At
82. sometime later this print may be divided into several separate
83. sheets.

84.
85. A C Power

86.
87. The main rectifier transformers for these supplies are located on
88. the transformer pads outside of the support buildings. They are
89. energized at all times from 12,470 volt fused disconnects also
90. located on the pad. See Figure 1.

91.
92. At Region 8 there are two (480 volts 3 phase) circuit breakers
93. (8PEP1 or 2 and 8PEP41 or 42) connected to the secondary of these
94. transformers. One (8PEP1 or 2) is located next to the
95. transformer on the pad; the other (8PEP41 or 42) is located in
96. the support buildings near the RI supplies. The outside breaker
97. is controlled at the outside breaker or from push buttons on the
98. cabinets of the circuit breakers in the support building. The
99. outside breaker is interlocked with the Kirk Key of the inside
100. breaker so that the Kirk Key must be in place before the outside
101. breaker can be turned on. It then stays on as long as the Kirk
102. Key is left in position at the inside breaker.

103.
104. Note that at Region 8 there is one delta-delta transformer and
105. one delta-wye transformer; this is to decrease the amount of 5th
106. and 7th harmonic currents on the 12 kV lines.

107.
108. The inside breakers 8PEP41 and 8PEP42 have given considerable
109. maintenance problems and it is difficult to obtain spare parts;
110. therefore, it is planned to replace these inside breakers with
111. contactors during the shut down starting July 1981.

112.
113. The control of the inside breaker is interlocked with the RI
114. power supply safety interlock system so that it can be closed
115. only when the safety interlocks so permits it to be closed. The
116. on/off controls can be either by local controls at the RI power
117. supplies or via CAMAC controls from FFCR.

118.
119. During times when ESOG is working in the racks of the ring power

120. supplies, or when persons are working near magnets in the ring it
121. is established procedure that the inside breakers be rolled out
122. to "TEST" position. Since the Kirk Key is removed for this
123. operation, it means that the outside breaker is also opened; this
124. applies also to the breakers for the FI's at Regions 4 and 12.

125. One must not roll the PEP41 and PEP42 breakers clear out because
126. the PPS interlocks depend upon the breakers being in the test
127. position to allow entrance into the ring.
128.
129.

130.
131. The Bridge Rectifier

132.
133. This is a conventional three phase bridge rectifier (see Section
134. A on the print or Figures 2, 3, & 4) using a single Hockey-Puck
135. type NI1699P SCR in each leg of the bridge.
136.

137. The bridge rectifier output is filtered with an L-C filter

138.
139. Region 4 and 12
140. 200 Micro-henries and 49,600 Micro-farads
141. Resonant frequency 50.8 Hertz
142.

143. Region 8
144. 200 Micro-henries and 86,800 Micro-farads
145. Resonant frequency 38.2 Hertz
146.

147. This large value of total capacitance is required to minimize the
148. voltage change in the output voltage during the operation of the
149. pulse width chopper regulators that are the connected load on
150. these power supplies.
151.

152. This capacitor bank is constructed in, individually fused,
153. parallel modules and in a manner to provide a low self
154. inductance. The leads that supply each chopper rack at Region 8
155. are either low inductance buses or four cables guaged to provide
156. a low inductance lead.
157.

158. For instance, the main bend choppers at 18GeV will be regulating
159. 1365 Amps; this current will be of a pulsed nature and may be a
160. length of 450 micro-seconds.
161.

162. Charge; Q = Amps x Time
163. = 1365 x 0.00045 seconds
164. = 0.614 coulombs.
165.

166. The voltage change during this pulse is then expected to be:

167.
168. Delta V = Q/C
169. = 0.614/0.0868
170. = 7.07 volts.
171.

172. This amount of voltage change, about 1.6%, is not expected to
173. cause a disturbance in the current regulation stability of other
174. choppers connected to the same capacitor bank.
175.

176. Of course one can expect larger transient voltage changes on the
177. voltage across the output capacitor because of the influence of
178. the sharp rise and fall of currents in the capacitors and the
179. self inductance of the capacitors and leads.

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239.

Another concern that one has, is relative to the resonant frequency of of the L-C filter (50.8 Hertz Region 4 and 12, and 38.2 Hertz Region 8). See Figure 2.

This frequency is determined by:

$$\begin{aligned} \text{frequency} &= 1 / (2 \times \text{Pi} \times \text{LC}) \\ \text{Pi} &= 3.1459 \\ \text{L} &= 0.0002 \text{ henries} \\ \text{C} &= 0.049 \text{ farads} \\ &= 50.8 \text{ Hertz} \end{aligned}$$

Note that if the value of the filter capacitor were to decrease to 0.035 farads, then the resonant frequency would be 60 Hertz. It is very imperative that such a resonant frequency of this filter be avoided since it would take only a small driving force at 60 Hertz to cause a large 60 Hertz oscillation. The filter is a high Q system. It is very easy to get a 60 Hertz output from a bridge rectifier to drive this resonance, because of slight unbalances of the triggers or line voltages. An unbalance of trigger timing is not very likely, because the six triggers are generated as a group from a phase lock loop system, but there could be a phase or voltage unbalance of the line voltages that could introduce 60 Hertz ripple. A loss of two of the eight fuses in Regions 4 or 12 would give a resonance of 58.7 Hertz which is too close to 60 Hertz for comfort. Interlocks are provided that require all of the capacitor bank fuses to be in operation.

SCR and Diode Voltage Transient Protection See Figure 3

The surge protection across the SCR's consists of an R-C circuit equivalent to 1 micro-farad in series with 4.16 ohms in parallel with 470K ohms. There are also some Thyrite type GE surge suppressors (V575FA80A) connected in parallel with the R-C networks. These devices have a very non-linear voltage-resistance characteristics and will absorb the energy in any voltage spike that exceeds 1,000 volts. The SCR's have a 1,200 volt rating. There is also an R-C surge protection network across the free-wheeling diode.

Surge protection circuits are required in parallel with most SCR's or Free-Wheeling diodes to absorb the stored energy in the stray inductances at the time the semi-conductor is recovering from the reverse current that clears the charge carriers.

There is also a bleeder resistor to discharge the stored energy of the capacitor bank. This is especially important at Region 8 where the only connected loads are the choppers which might be not pulsing, and therefore are not a load.

The SCR's (Region 8) have an average current rating of _____ amps; therefore, the bridge has a rating of _____ amps.

The transformers at Region 8 are rated at 2,500 kVA, 3,008 amps ac; therefore, they can feed a bridge rated up to 3,686 amps.

At Region 4 and 12 the transformers are rated at 1,500 kVA, 1,802 amps ac; therefore, can feed a bridge rated up to 2,208 amps. The

240. SCR's are rated for ___ amps and ___ volts which gives a bridge
241. rating up to _____ amps .

242.
243. The voltage out of all four transformers is 480 volts RMS which
244. gives a maximum of 600 volts dc when full on.

245.
246. We would not want to operate these transformers up to the full
247. current rating because they are standard distribution
248. transformers, and they are not constructed to handle the large
249. harmonic currents because of the rectifier service.

250.
251. Power Supply Metering

252.
253. The original power supply meters were located near the high
254. current ac buses of the bridge rectifier. This proved to be a
255. poor location, because the magnetic fields from the buses upset
256. the readings of various meters. These meters have been moved to
257. the top of the supply.

258.
259. The following meters have been provided:

260.
261. 1. Three ac line voltage meters; these are fed through
262. conventional 480/120 volt transformer (not instrument potential
263. transformers); therefore, they may not be precise.

264.
265. Oscilloscope probes (100 to 1) are provided connected to the 3
266. phase input 480 volt lines and the DC output of the bridge
267. rectifier before and after the filter for displaying the phase
268. relationships and wave forms. See Figure

269.
270. 2. DC output voltage

271.
272. 3. DC output current from a 1500A, 50MV shunt.

273.
274. 4. RMS ac line current into the bridge rectifier. This meter
275. indicates the highest of the three RMS line currents into the
276. bridge rectifier.

277.
278. The ac current into this bridge rectifier contains many harmonics
279. other than the 60 Hertz fundamental. The current read by this
280. meter is the same as indicated by the current meters on the pad
281. for 8PEP1 and 8PEP2, but their actual values may differ because
282. of the type of system used for readout. The wave form of the
283. current is as shown in Figure 19; note that it is not a flat top
284. as might be expected if the choke of the filter were infinitely
285. large. The 200 micro-henry choke lets through appreciable AC
286. current and this shows up on the wave form. One should also note
287. that the total AC current on the 8PEP2 transformer includes the
288. -RI supply plus the power to the auxiliary power panel known as
289. the FA panel. This panel feeds such loads as some of the
290. injection lines power supplies and Micro-beta supplies.

291.
292.
293. 5. Two meters to monitor the ac current input to the filter
294. capacitor and they may differ in readings:

295.
296. a. One is directly off of a current transformer.

297.
298. b. The second one is through an electronic circuit to read the
299. RMS value after some frequency roll-off that roughly compensates

300. for the current handling capabilities of the filter capacitors at
301. different frequencies.

302.
303. Note that these meters read the sum of the ac currents from the
304. bridge rectifier and the ac currents from the operation of all of
305. the pulse width chopper loads.

306.
307. 6. DC ground current meter relay that monitors the current in the
308. 100 ohm resistor used to ground the common bus between -R1 and
309. +R1. The meter has a full scale trip value of 510 MA but is
310. normally set for about 200 MA, because the normal ground current
311. is about 50 MA.

312.
313. Voltage Feedback Option Board Figure 7

314.
315. The voltage feedback option board contains operational amplifiers
316. to provide:

317.
318. 1. Isolation amplifier so that the regulation amplifier
319. system can be at ground potential and not tied to the
320. dc voltage buses.

321.
322. 2. Voltage output to CAMAC for readout in PEP Control,
323. Voltage feedback, Span (Range), etc
324. Zero adjustments are provided for calibration.

325.
326. 3. An adjustable "Voltage Limit" circuit that allows one
327. to set a limit on how high the voltage output can be set.

328.
329. The voltage take off from the power supply DC output to the
330. regulator (this is a voltage regulator not current regulator) is
331. from ahead of the I-C filter; this is to partially eliminate the
332. 50.8 or 38.2 Hertz resonance of the filter from the regulation
333. loop. The voltage take off ahead of the filter puts a large
334. voltage ripple signal into the optical isolation differential
335. amplifier AD284J, section G on the print, which is the first
336. active unit in the regulation loop. The following operational
337. amplifier has a frequency roll off 16 Hertz which makes it the
338. dominant roll-off frequency of the regulator and discriminates
339. against the ripple voltage output of the bridge rectifier.

340.
341. The next driver in the loop has a frequency roll off of 338 Hertz
342. and the comparator amplifier on the timing card rolls off at 50.2
343. Hertz.

344.
345. OVERALL REGULATION LOOP Figure 6

346.
347. See Figure 6 for a simplified block diagram of this voltage
348. regulation system for the R1 power supplies at Regions 4, 12,
349. and 8. Note that this regulation loop has the same sort of
350. elements that most of the current regulators for other power
351. supplies contain.

352.
353. The basic elements are:

354.
355. 1. SCR bridge rectifier.

356.
357. 2. Trigger generator. This is a phase locked loop system; all
358. triggers are controlled once per cycle as a group.

359.

360. The basic frequency of the phase lock loop allows a
361. jitter of the firing pulses of 50 micro-seconds which
362. corresponds to a jitter in output voltage of 2 percent.
363. This amount of jitter is not desired so we are replacing
364. this part of the regulation system with an analog type
365. triggering system for the bridge rectifier.
366.
367. 3. Comparator.
368.
369. 4. Reference voltage input with provisions for local control.
370.
371. 5. Voltage feed-back amplifiers with an isolation amplifier
372. so that the regulator circuits can be near ground potential.
373.
374. 6. Numerous SEAN(range) and zero adjustments of various
375. operation amplifier circuits.
376.
377.

378. The actual regulation circuit as shown in Section D of print
379. SD-207-001-02 is a universal type unit that can be used to
380. regulate various parameter of ac power. Certain jumpers are in
381. place on the card to set up the particular voltage regulation
382. system that we use at PEP. This means that some of the elements
383. on this card are not used.
384.

385. Reference Voltage SD-207-304-00
386.

387. The 0-10 volt signal used as a reference voltage comes from a 12
388. bit DAC (12 bits gives a least count of one in 4,096). This DAC
389. is located in the CAMAC crate in Rack 08CM40 and is carried to a
390. buffer amplifier in the BI power supply (see Section E, right
391. side of print, or Figure 8). The DAC signal has the negative
392. side of the voltage grounded in rack 40 so the rest of the
393. regulation system that ties electrically to this signal must be
394. isolated from ground to set up a one point grounding of the
395. regulation system. Note that the voltage feedback comes through a
396. optical isolation amplifier, and the trigger outputs to the SCR's
397. are also isolated with optical isolators (see Section C on
398. print).
399.

400. If any point in the regulation loops at the BI's becomes grounded
401. it will introduce electrical noise into the system and the
402. voltage output will not be properly regulated. One can check
403. that this circuit is isolated from ground by pulling the DAC
404. input signal plug P6 on the back of the RMS Ripple Current &
405. Blown fuse indicator chassis SD-207-304-00 in the BI, then check
406. test point 17 to ground with an ohmmeter. It is normally greater
407. than 2,000,000 ohms to ground at this point with P6 pulled.
408.

409. The RMS Ripple Current and Blown fuse indicator chassis has a
410. provision for local reference voltage with helipot control for
411. those times when you do not want to use the D/A converter in rack
412. 40.
413.

414. CURRENT CONTROL MODULE Figures 9 and 10 Ref KD4705
415.

416. This current control card contains;
417.

418. 1. Three current transformers and bridge rectifiers to
419. transform the normal 5 amp current transformer

420. currents, that measure the main rectifier input line
421. currents) into a low current dc.

422.
423. 2. Operational amplifiers IC-1 and MC14076 (a 4 Bit
424. D-Type Register) IC-4. The output of this circuit
425. selects the highest of the three dc signals
426. representing the ac line currents.

427.
428. 3. An analog Multiplexer CD4051 IC-5 that takes the
429. signal, from IC-4 above, that indicates which line
430. current is highest and connects that current signal
431. through IC-1 to an RMS converter IC-3.

432.
433. 4. A relay K1 is provided that picks up through a gate
434. signal into SCR1. This relay opens the interlock chain
435. as an ac line current trip.

436.
437. The input to the gate of the SCR1 comes from either
438. the:

439.
440. a. Sum of the three dc signals representing the ac line
441. currents. It's probably the highest one that will trip
442. the detector, or

443.
444. b. The dc output of the RMS converter that represents
445. the RMS of the highest of the three ac line currents.

446.
447. 5. The dc level representing the output of the RMS
448. converter also goes to an adjustable comparator so that
449. one can electrically set the maximum value of current
450. that the main power supply can go to. This signal goes
451. into the limit line of the timing board and is a fast
452. turn off signal to the SCR's. It will normally make
453. sure that the triggers to the main SCR's are removed
454. before the main contactor can open.

455.
456. A small latching SCR and Yellow LED is provided to
457. indicate if this signal has exceeded its preset limit.

458.
459. A small latching SCR and a Red LED is provided to
460. indicate if the sum of the three signals for the line
461. current has exceeded its set trip value. Both of these
462. signal SCR'S can be reset by disconnecting a marked
463. jumper on TB03 of the test blocks on the panel of the
464. RI's.

465.
466. 3-PHASE TIMING MODULE (Ref KD 46998)

467. This present card of the RI regulator contains the following
468. sections, but remember that this phase locked loop system
469. is being replaced with an analog type trigger system.

470.
471. a. Buffer amplifier for voltage feedback,

472.
473. b. Comparator amplifiers,

474.
475. c. Input for Fast limit turn off,

476.
477. d. a-c line voltage zero-cross-over circuit to
478. initiate a clock signal for timing.

479.

480. e. Phase-lock-loop circuit to generate six
481. triggers, equally spaced in one cycle of the 60
482. Hertz input voltage and high frequency clock signal.

483.
484. f. Circuit to delay all six triggers as a function
485. of the output of the comparator output voltage,

486.
487. g. Slow phase forward turn-on circuit for easy-on
488. (no voltage surge) at power turn-on.

489.
490. h. Circuit that counts and separates the train of
491. six triggers into single triggers for each of the
492. 6 SCR's.

493.
494. The 6 SCR trigger drivers for the main rectifier
495. SCR's are on the three top cards of this regulator package.

496.
497. The following will describe each of the above functional systems
498. and how they are coordinated together. Maintenance hints will be
499. given where possible.

500.
501. a. Buffer Voltage Feed-back Amplifier

502.
503. The C+ line is not used in this voltage

504.
505. The following switches are open for the voltage regulation mode
506. at PEP; S1-1, S1-2, S1-3, S1-4, S1-5 and S1-8.

507.
508. The following switches are closed for normal operation; S1-6, and
509. S1-7. regulation. We have also lifted the connections at R1 and
510. R19 to be sure a component failure will not cause an operative
511. problem.

512.
513. The buffer amplifier pins 8, 9 and 10 of IC-D4 is used to give
514. some signal isolation to the card and to insert the "SPAN"
515. potentiometer P2 that allows one to adjust the ratio of voltage
516. feed back signal to the actual dc output voltage of the power
517. supply.

518.
519. This ratio in effect sets the ratio of DAC Reference voltage
520. input to the DC Voltage output.

521.
522. The output of this op-Amp is fed through a FET to the summing
523. point of the comparator amplifier (pins 5, 6, & 7 of IC-D4).

524.
525. The FET is in the circuit of this universal card to allow a
526. special gated signal to be put into the regulator. Switch S1-2
527. is open; therefore, this circuit is not used.

528.
529. b. Comparator Amplifiers Figure 11

530.
531. The input to the comparator error amplifier receives a + (plus)
532. reference voltage input through a 120K resistor into the -SUM JCT
533. and a negative voltage feedback from the voltage feedback buffer
534. amplifier (a plus voltage comes from the Voltage Option Board).
535. S1-6 is closed to put a little fixed positive bias into the
536. summing junction. Potentiometer P1 allows an adjustment of this
537. bias level and is set so that the comparator amplifier will
538. slowly go to a negative output for a zero reference voltage input
539. and a zero dc voltage out of the bridge rectifier; this is

540. required to be sure the power supply comes on and up to voltage
541. and regulates at zero voltage. The output of this comparator goes
542. to the circuit that delays the triggers to the SCR bridge
543. rectifier.
544.

545. Note that the voltage range of this signal can cause a phase
546. shift of 180 degrees in timing while only 120 degrees is required
547. for 100 percent range of voltage control.
548.

549. The ac power into this regulator for both the -RI and +RI comes
550. from the same phase of ac control voltage and its zero cross-over
551. is the same for both systems. The -RI supply is fed from a
552. DELTA-DELTA transformer while the +RI is fed from a DELTA-WYE
553. transformer; therefore, a different absolute dc voltage is
554. required out of the comparator to give, say 150 volts out of each
555. bridge rectifier because of the 30 phase shift of secondary ac
556. voltage input. The range of control is sufficient for both of
557. these power supplies even though the timing starts out with the
558. same zero cross-over for both RI's at Region 8.
559.

560. A "LIMIT" circuit pin 11 on the plug brings in another circuit
561. that biases the output of the comparator to common whenever the
562. ac current input Peak, ac input current RMS, or DC voltage output
563. exceeds some preset limit. This is a fast protection circuit that
564. stops the next SCR pulse in case of a problem.
565.

566. There is also an input into pin 5 of the comparator that comes
567. from the phase-lock-loop system that biases off the comparator so
568. that it will start the SCR triggers at full off and come up to a
569. proper value slowly after a failure in the operation of the
570. phase-lock-loop system.
571.

572. RAMP GENERATOR Figure 12

573.
574. The circuit elements IC-D4 (pins 12, 13, & 14), IC-20 (pins 8, 9,
575. & 13) and Q2 (2N3053) comprise a ramp generator circuit.
576.

577. The output of the ramp is a negative going signal. The starting
578. time of the ramp is always the same time as controlled by the
579. gate into pin 12 of IC-D4 from IC-A5 in the phase locked loop
580. system.
581.

582. This negative going ramp and the (-) negative voltage level out
583. of the comparator IC-D4 (pins 5, 6, & 7) are compared in the
584. operational amplifier IC-D4 (pins 1, 2, & 3) to give a gate that
585. starts the train of six pulses to the main SCR'S. Note that this
586. signal re-occurs once each cycle of the 60 Hertz.
587.

1098.

1099.

SD-207-110-03

1100.

1101.

Ground Fault Detector Card (The chassis at the bottom of each chopper rack also contains the Transducer monitoring card.)

1102.

1103.

1104.

The ground fault detector card was designed to give an alarm and shut off the system whenever the current going out to a magnet is not the same as the current in the lead returning from a given magnet system. This measurement is via a torroidal transformer located in each chopper rack.

1105.

1106.

1107.

1108.

1109.

1110.

The intent was that the supply and return lead to a given magnet string would pass through the torroid in such a direction that the electronic circuit connected to a winding on the torroid would measure any differential current between these two main conductors.

1111.

1112.

1113.

1114.

1115.

1116.

Unfortunately, this is a pulsed system and the high potential lead going to the magnet also drives the stray capacitance of the many magnets in series. This means that there are pulsed currents into these stray capacitances that do not return through the return lead from the magnet. Consequently this ground detector may show a differential ground current trip or alarm when there is really no problem.

1117.

1118.

1119.

1120.

1121.

1122.

1123.

1124.

Some time in the future we will work over the circuit to make it not sensitive to these fast pulses. In the meantime, we have bugged out this alarm by either replacing the card with a dummy card with the interlock jumpered or jumpering the interlock on an active card. The meter may read off scale if an active card is in place, but this does not hurt.

1125.

1126.

1127.

1128.

1129.

1130.

1131.

The ground protection is still provided with a 100 ohm water cooled resistor in the positive 8RI that is connected to a meter relay. The full scale trip value of this circuit is about 210 MA. At 14.5 GeV this meter reads about 180 MA). Most of this current seems to be of an AC variety. When we by-pass this ground resistor with a large capacitor, the ground current meter reads only about 40 MA. The lead that does this by-passing is a green lead coming out of the bottom of the front door of the 8RI+ and connected to the external ground bus. This by-pass capacitor will slow the response time of the ground fault detection meter, but there will still be protection provided.

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1172.
1173.
1174.
1175.
1176.
1177.
1178.
1178.01
1178.02
1178.5
1179.
1180.
1181.
1182.
1183.
1184.
1185.
1186.
1187.
1188.
1189.
1190.
1191.
1192.
1193.
1194.
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1197.
1198.
1199.

SD-207-110-02

Transductor FWR Supply PCB Schematic

Two three-core transducers are mounted in most of the chopper racks. One of the transducers is called the monitor transducer; its output signal is routed through the CAMAC, Scanner and Digital Voltmeter in rack 40 to the PEP computer for monitoring the current into each of the magnet systems.

The other transducer is called the regulating transducer. The output of the regulating transducers are routed directly to chopper controllers in Rack 08CM41. There the signal is compared with the reference voltage and the difference voltage is used by the regulator to set the pulse width of the chopper to supply the correct average voltage to a magnet system.

The transducer output signal is grounded at the Scanner for the monitor transducer and at the Chopper Controller regulator in the case of the regulating transducers.

Two of the transducer cores are used to develop the appropriate output conversion signal to give a dc voltage proportional to the dc current being measured. The third core is used to provide filtering of the output signal and to couple in an appropriate ac signal to make the output signal clear of extraneous notches or spikes. The output signal of a transducer is electrically isolated from the bus carrying the high current.

These transducers are provided with some auxiliary windings used for calibrating the transducers against each other or to a standard. A special coax is connected sequentially from Rack 30 to Rack 67 to interconnect the calibration winding circuit. One ampere through this winding is equivalent to 500 ampere through the window of the 500 ampere transducer.

One ampere in the calibration winding of the 1,500 ampere transducer is equal to 1,500 ampere through the main one turn winding.

The calibration winding circuit is brought to Rack 08CM20 where it is available to be connected to a special high stability power supply for calibration purposes. The power supply for calibration must have a high impedance output to a voltage, otherwise the transducers will not operate satisfactorily.

During those times when the calibration windings are not in use, they must be disconnected from each other so that stray capacitance and cable capacitance will not cause voltage disturbances in the output signal. This isolation is provided with multi-pole switches on each of the of the the transducer cards. The switches are down for normal running.

We have also found that the cable between the transducer chassis and the transducer head had to be made up using shielded pairs for each of the separate transducer windings. If these wires were all under one single shield the capacitance between windings caused a 6 hertz error signal to be introduced on the output signal. This error signal was large enough to cause regulation problems with systems having closed loop gains of more than one at 60 HERTZ, because it introduced 60 Hertz ripple in the power supply output.

1200.
1201. A full discription as to how transducers work is given in other
1202. documentaticn.
1203.
1204. SD-207-102-00
1205.
1206. Clock Module
1207.
1208. Two clock modules are provided in the CAMAC crates in Rack C8CM41.
1209. One of these generates clock pulses at 360 Hertz, the other provide:
1210. a clock rate of 2160 Hertz. Note that both of these frequencies are
1211. harmonics of the 60 Hertz power line and are therefore synchronized
1212. to the line.
1213.
1214. A serial header is provided on the card to allow the choice of which
1215. output signal is desired by changing the connections to several
1216. counters on the card. A phase locked loop provides the initial 24K
1217. hertz that is used into the counters.
1218.
1219. There is a little problem with the phase locked loop stability that
1220. sometimes causes the output clock signal to oscillate about its
1221. synched signal, but overall it is satisfactory.
1222.
1223. The switch S2 on the front panel is normally in the line synch
1224. position for proper operation.
1225.
1226. The output pulses on J3, J4, J5, & J6 contains a master synch pulse
1227. and 12 output pulses. These are used in the crate controller to
1228. provide the appropriate triggers for balancing the chopper triggers
1229. in time, and to make for a more uniform loading on the output filter
1230. of the Main BI power supplies.
1231.
1232. SD-207-101-00
1233.
1234. CRATE CONTROLLER
1235.
1236. The crate controller has two cards that plug into position 23 and 2
1237. of the crate.
1238.
1239. The card in module 24 controls the relative phasing of the main
1240. triggers with respect to the master trigger and to each of the 8
1241. choppers in a crate. A special interconnect header is on this card
1242. V2 and V3 that allows a choice as to how each chopper is controlled
1243. relative to each other. Pins 1 to 12 on V2 and V3 are the 12
1244. triggers available; the time separation between possible pulses is
1245. one twelfth of the clock period. Pins 13 to 16 on V2 are the
1246. trigger drives for Modules 1/2, 3/4, 5/6, 7/8. Pins 13 to 16 on V3
1247. are the trigger drives for Modules 9/10, 11/12, 13/14, and 15/16.
1248.
1249. The header connections are set up to balance the AC transient
1250. loading on the filter capacitors of the main BI power supplies. Th
1251. headers are also set up so that each of the pair of double choppers
1252. receives its pulse from the same phase. If this is not done, the
1253. double choppers will not function properly.
1254.
1255. It is therefore vital that these pulse headers stay with a
1256. particular crate. We have modified the Crate Controllers so that it
1257. is easy to leave the headers in the appropriate Crates.
1258.
1259. SAVED AS WYL-RA.CAH.CAH1 ON EDIT51 NOV 24, 1980

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CHOPPER OPERATION

It is appropriate to discuss the main features of a chopper (Pulse Width Modulated) type of power supply and why it is used as a source of dc power to the main magnets in the PEP Ring.

The magnetic field, stability and reproducibility, in many of the magnets for the PEP Ring requires that the current regulation system be good to about 0.01%. The current must be adjusted over wide ranges. Some of the seriesed systems, there are 21 in all, were expected to have fairly short time constants (L / R).

It was thought that a six pulse bridge rectifier with a basic output frequency of 360 Hertz would not have a high enough frequency response to hold the magnet current within specifications during a typical type of expected line voltage transient.

A short deviation of the magnet current outside of the prescribed tolerances (even for a short time) may cause a loss of the beam that could take a long time to recover from; therefore, it is important that the regulator be able to regulate against most line voltage disturbances.

A typical current regulation system using an SCR controlled three pulse bridge rectifier might have a closed loop gain of one at only 20-30 Hertz.

One would have two main choices to get a higher frequency response.

- **1. Use a linear series regulator such as a transistor bank, or
- **2. go to a higher frequency.

The first is very costly and power wasteful.

In the second, it would be difficult to raise the frequency into a standard bridge rectifier, but it is easy to use a standard power supply to supply a regulated DC voltage and a high frequency (2K hertz) chopper type (Pulse Width Modulator) type controller to supply pulsed dc power to a magnet. Just as in our standard SCR bridge rectifier power supplies we use a freewheeling diode to maintain current in the load during those times that the power supply or chopper is not supplying pulsed voltage to the magnet.

The DC power supply must have a large capacitor filter on the output so that the output voltage is not significantly changed during a pulse or it would interfere with other choppers connected to the same terminals but delivering current to a different magnet string at a different but overlapping time.

**Figure 1 shows a typical SCR bridge rectifier and the wave shape of the voltage to the magnet when delivering about 25% of maximum voltage.

**Figure 2 shows a typical chopper (Pulse Width Modulator) type power supply and the wave shape of the voltage to a connected magnet load. With circuit of Figure 2, one is not tied to the 60 hertz line frequency, but can use a chopper frequency as high as practical considering the turn on and turn off times of the large SCR's. This

1320. is about 15,000 Hertz for the SCB's that we are using; that is the
1321. approximate basic frequency of the commutation pulse used to turn
1322. the main power SCR off.
1323.
1324. The choppers (or Pulse Width Modulators) for the PEP Ring must have
1325. a maximum pulse width much greater than the commutation Pulse;
1326. therefore a pulse repetition frequency of 2,160 Hertz is used for
1327. the critical circuits. 360 Hertz is used on sextapole circuits where
1328. a greater range of control is required. The sextapole circuits are
1329. also less critical in stability than the Bend magnets or QD and QF
1330. circuits. These two frequencies were chosen as harmonics of the 60
1331. Hertz line frequency so that they could be synchronized with the
1332. line frequency.
1333.
1334. Keep in mind that it is the average Volts of the pulses supplied to
1335. the magnet, and the magnet resistance that determines the average
1336. current in the magnet.
1337.
1338. In the case of the three pulse bridge rectifiers, we usually use a
1339. choke and filter capacitance (see Figure 1) with the free-wheeling
1340. diode to supply a ripple free Voltage to the magnet. The filter is
1341. used so that the closed loop regulation system is less sensitive to
1342. the frequency response of a given magnet (we may use one type of
1343. regulator to energize many different magnet systems). In the case of
1344. PEP, an attempt was made to use only the free-wheeling diode to
1345. maintain constant current in the magnet, and save the cost of the
1346. filters. This has proved satisfactory except that this means that
1347. the square wave Voltage pulses (with fast rise and fall times) are
1348. applied to the magnet terminals and cables. Since there is a
1349. considerable amount of stray capacitance of the magnets and cables
1350. to ground there is a considerable amount of transient ac pulse
1351. currents in the grounding network between the IR-8 Support Building
1352. and the Ring.
1353.
1354. These transients set up antennas that radiated into the experimental
1355. equipment at DELCO (Region 8). We have added chokes in series with
1356. each dc lead leaving the choppers in the support building of IR-8
1357. (See Figure 3-A). These chokes slow down the steep voltage rise
1358. times to the magnets. These chokes (#####) have lowered the
1359. frequency of the ringing and have eliminated the pick up problem at
1360. DELCO, but as a consequence one will see considerable ringing of the
1361. voltage square waves to the magnets. Sometime in the future, we may
1362. add R-C filters to ground to damp this ringing, but for now be aware
1363. that the ringing is present. The Voltage Wave forms in Figure 3B is
1364. an idealized wave without the ringing.
1365.
1366. At Region 2 the air core chokes were not enough so we added an R-C
1367. circuit (20 ohms and 0.1 MFD in series) from line to line and to
1368. ground to shift the frequency and damp out the ringing.
1369.
1370. We have also had a transient noise problem into the experimental
1371. equipment at Region 4. This was isolated as coming from the EI
1372. Booster supplies for the Main Ring Bend magnet system at this
1373. Region. To reduce this noise we installed some cores around all
1374. four DC leads leaving the top of the supply and connected 1.0 MFD
1375. capacitors from each of the DC leads, on the load side, to ground.
1376. This has reduced the noise pick up to tolerable levels.
1377.
1378.
1379.

UNDERSTANDING THE COMMUTATION CIRCUIT

1380.
1381. Refer to Figure 4 through 10: Note that under Figure 4B is a heavy
1382. line that indicates the time interval involved, and a heavy line in
1383. 4-A shows the path of the current during this interval.
1384.
1385. A discussion follows for each of the defined intervals of time.
1386.
1387. **Figure 4
1388.
1389. The magnet current is flowing in the magnet and free wheeling diode
1390. only at this time just before a Main trigger pulse.
1391.
1392. The transducer and a metering shunt are connected on the load side
1393. of the Free-wheeling diode of the Chopper so that they monitor the
1394. current in the magnet at all times, and are therefore not pulsed
1395. currents.
1396.
1397. The voltage on the Commutation Capacitor has been recharged to a
1398. Voltage higher than the supplied DC Voltage from the RI power
1399. supply; therefore, the resistor E(c) acts as a bleeder to reduce the
1400. capacitor voltage. It has been shown that this resistor connected
1401. from the COMMON to the junction of the commutation capacitor and
1402. inductance is not required for circuit operation. The voltage on
1403. the capacitor will be higher if one disconnects this loading
1404. resistor.
1405.
1406. The capacitor can be charged equally well through the Diode-2 and the
1407. Magnet. The resistor tends to hold down the over charging of the
1408. Capacitor by bleeding some of the energy out of the C between
1409. Commutation pulses.
1410.
1411. **Figure 5
1412.
1413. The main pulse trigger has turned on SCR-1 transferring the current
1414. out of the Free-Wheeling Diode. The magnet current is now being
1415. supplied from the large capacitor bank that is connected to the
1416. output of the RI DC power supply.
1417.
1418. A transient Voltage has occurred across the Free Wheeling Diode
1419. because when the SCR-1 is closed, the voltage from A-B is only the
1420. diode drop and there is a high current supplied in the reverse
1421. direction through the FWD to buck out the magnet current that was
1422. flowing just before the main pulse trigger. When the current
1423. through the FWD is buck down to zero there is then a small amount of
1424. reverse current to clear the carriers, then the diode goes to a
1425. blocking voltage polarity and the current from the power supply goes
1426. only to the Load. Note that the Commutation circuit is not
1427. functioning as yet.
1428.
1429. **Figure 6
1430.
1431. AT about 77 micro-sec before it is desired to end the pulse, (the
1432. current regulator determines the time) a Commutation trigger is
1433. given to SCR-2, and the first half of the commutation pulse passes
1434. current through the Commutation Capacitor, inductance and SCR-2.
1435. Note that the load current path is not involved.
1436.
1437. This circuit resonates at 12.9K Hertz for the main 1,400 amp
1438. choppers and 15.53K Hertz for the 700 amp choppers. At the end of
1439. the first half cycle of resonance, the current reverses and SCR-2

1440. can no longer carry current and it goes open. The voltage on the
1441. Commutation Capacitor is now of a reversed polarity.

1442.
1443. **Figure 7

1444.
1445. The commutation current now passes through DIODE-2 and in opposition
1446. to the current in SCR-1. This current builds up to a value equal to
1447. the magnet current that was passing through SCR-1 and SCR-1 becomes
1448. back biased, and it goes out. Note that the peak current available
1449. from the commutation must be greater than the magnet current flowing
1450. at that time or the SCR-1 cannot be turned off. The peak
1451. commutation current, with 700 Volts on the capacitor is about 2,859
1452. Amps for the 1,400 amp choppers and 1,027 amps for the 700 amp
1453. choppers.

1454.
1455. Lower RI voltages will give a proportionately less commutation
1456. current for the same magnet current. The peak commutation current
1457. must always be at least 40% above the running current to give a
1458. safety operating margin.

1459.
1460. **Figure 8

1461.
1462. When the main SCR goes out, the commutation current changes over to
1463. DIODE-1, and the magnet current plus the commutation current passes
1464. through the commutation capacitor and into the magnet load. At some
1465. particular time the voltage at the magnet terminals is caused to be
1466. driven to zero. Note that the commutation capacitor is now being
1467. charged with a voltage of the same polarity as the main power
1468. supply voltage. At that time the Free-Wheeling diode starts to
1469. conduct current.

1470.
1471. **Figure 9

1472.
1473. There is still current flowing from the DC power supply through the
1474. Commutation Capacitor, Inductance, Diode-2 and through the FWD back
1475. to the common of the power supply. This current continues to flow
1476. recharging the commutation capacitor to a higher voltage until this
1477. current decreases to zero and the Diode-2 becomes back biased.
1478. There is now a short period of time when the load current is passing
1479. only through the Free-Wheeling diode and the cycle repeats itself.

1480.
1481. Go back to Figure 4. The cycle repeats itself.

1482.
1483.
1484. PULSE TRIGGER LIMITATIONS

1485.
1486. First note that from the time of the Commutation trigger to the time
1487. when the capacitor is fully recharge is about 90 micro-sec. We see
1488. then that (for maximum pulse width) the the commutation pulse
1489. trigger must never be later than about 90 micro-sec before the main
1490. pulse trigger. This will leave about 20 micro-seconds as the
1491. smallest allowable off time between pulses at 2,160 Hertz pulse
1492. rate; the next pulse may occur while the capacitor is being
1493. recharged, see Figure 9. The maximum pulse width is then 95.7% of
1494. the full pulse width for 2,160 Hertz or 99.3% for 360 Hertz pulse
1495. rate.

1496.
1497. The minimum voltage setting of a chopper is $(100/462) * 100 = 21.6$
1498. for 2,160 Hertz and $(100/2777) * 100 = 3.6\%$ for the 360 Hertz rate.
1499.

1500. The range of controlled output voltage is then 21.6 % to 95.7 % of
1501. the base power supply voltage for 2,160 Hertz and 3.6 % to 99.3 %
1502. for the 360 Hertz rate. Magnet system systems that require 0.01 %
1503. regulation are pulsed at the 2,160 rate. The systems, such as
1504. sextapoles that need only 0.1% regulation but need a wide range of
1505. control are pulsed at a rate of 360 Hertz.

1506.
1507. If the commutation pulse occurs ahead of the main pulse the voltage
1508. will be applied to the magnet. In actual set up and adjustment of
1509. the controller the minimum time of the commutation pulse is set at
1510. 30 micro-seconds after the main pulse; this means that the minimum
1511. pulse length could be as short as 100 micro-seconds for low magnet
1512. currents. At high magnet currents the minimum pulse length will be
1513. longer.

1514.
1515. The set up for the chopper controller card contains circuit
1516. adjustments that prevents the commutation pulse from coming earlier
1517. than about 30 micro-seconds after the main pulse and no later than
1518. about 90 micro-seconds before the next main pulse.

1519.
1520. The chopper control regulator compares a reference voltage with the
1521. magnet current transducer output. This difference signal is then
1522. compared with a ramp generated in the chopper controller (See Figure
1523. 11). A trigger is generated when the absolute voltage of the ramp
1524. Voltage exceeds the absolute voltage out of the comparator U27.

1525.
1526. Note that if the reference Voltage is raised to call for more
1527. current, that the cross over on the ramp Voltage is later in time
1528. making the pulse to the magnet longer.

1529.
1530. Two factors are combined to give a particular average voltage to the
1531. magnet.

1532.
1533. When the Main SCR is turned on, the full power supply Voltage is
1534. applied to the Magnet. The voltage to the magnet is removed about
1535. 50 micro-seconds after the commutation trigger is sent to the
1536. Commutation SCR.

1537.
1538. The average Voltage to the magnet is the Power Supply Voltage times
1539. the Duty factor for the timing of the applied Voltage.

1540.
1541. See Figure 12A and 12B. Note that the same average Voltage is
1542. delivered to a Load for an RI power supply Voltage of 600V with a
1543. Duty factor of 1/3 and that of an RI Voltage of 300V and a Duty
1544. factor of 2/3.

1545.
1546. Conversely one should note that when the regulator is regulating to
1547. some constant current and something causes the RI Voltage to go up,
1548. then the pulse length will automatically be made shorter to maintain
1549. the current constant.

1550.
1551. So if one notices, on an Oscilloscope, that the pulse length is
1552. varying, it can be either a problem in the chopper controller
1553. regulator or it is a consequence of a change in RI power supply
1554. Voltage.

1555.
1556. Figures 13A and 13B shows the relative time of the main and
1557. commutation pulses for the maximum and minimum pulse lengths.

1558.
1559. DUAL CHOPPER SYSTEMS

1560.
1561. The chopper system so far discussed is configured for a chopper
1562. connected to a positive voltage power supply, and gives positive
1563. voltage pulses to a magnet system. We also use chopper systems that
1564. have all of the SCR's and diodes reversed from those shown in Fig.
1565. 3-A. These choppers are connected to a negative voltage power
1566. supply and give out negative voltage pulses into a load.

1567.
1568. One negative and one positive chopper, connected to their respective
1569. negative and positive power supplies, is used for higher resistance
1570. magnet systems where the voltage is expected to be above 500 volts.
1571. (See Fig. 14)

1572.
1573. There are seven of these dual chopper systems. The bends and the 4Q
1574. circuits need more voltage than can be supplied by two chopper
1575. systems; in these two cases there are additional SCR voltage
1576. regulated power supplies located in the support buildings of IR-4
1577. and IR-12 that are connected in series with each of these systems.
1578. The output voltage of these SCR controlled booster power supplies is
1579. controlled through the computer.

1580.
1581.
1582. Figure 15 shows the various typical system connections of the
1583. choppers.

1584.
1585. A. Single positive chopper and a series of magnets around
1586. the ring; there are 6 systems:
1587. Q3, 1QF, 8QD, 1SD, 5SD, 7SD
1588.
1589. B. Single negative chopper and a series of magnets around
1590. the ring; there are 6 systems:
1591. 2QF, 3QF, 9QF, 1SF, 6SF, 6SD
1592.
1593. C. Two choppers (one negative, one positive) energizing the
1594. magnets around the ring; there are 5 systems:
1595. 1QD, 4QD, 3SF, 2SD, WIGGLER
1596.
1597. D. Two choppers (one negative, one positive) with two
1598. booster supplies energizing magnets around the ring; there
1599. are 2 systems:
1600. BENDS, 4QF

1601.
1602. The 480 volts to supply power for the 4QF boost circuit is
1603. derived from the 480 volt 3 phase buses in the RI power
1604. supply that supplies the boost supplies for the Bend
1605. Magnets.

1606.
1607. E. One other system of twelve magnets, 9SF, was installed and
1608. connected with water cooled cables the same as the rest of
1609. the magnets. It was originally planned to energize this
1610. system with a chopper, but this was not feasible because of
1611. the low voltage required. The 9SF system of magnets is now
1612. energized from a H.P. supply located in rack 08CM22.

1613. PRECAUTIONS WITH DUAL CHOPPERS

1614.
1615. The choppers in the dual mode must both be enabled at the same time
1616. The enabling for the dual choppers must only be done when the RI
1617. voltages at Region 8 are at least 100 volts dc, and any boost
1618. supplies at Regions 4 and 12 must be off. The penalty for violating
1619.

1620. these rules is that one of the choppers may turn on, but not have
1621. enough stored energy in the commutation capacitor to be sure that
1622. the next commutation pulse can turn the main SCR off.
1623.

1624. Note that when the commutation pulse is present on SCR-2 (Figure 3A)
1625. that there is a path to the load through DIODE-2; this applies a
1626. minimum pulse length voltage to the magnet system and there will be
1627. some magnet current even if no main pulse is given to SCR-2.
1628.

1629. If one chopper of a seriesed pair has commutation pulses and the
1630. other one does not there will be magnet current flowing through the
1631. free wheeling diode of the chopper not receiving pulses. This
1632. current decreases the possibility for that chopper being able to
1633. commutate of the current when first pulsed with a main trigger.
1634.

1635. The chopper controller cards applies both the commutation pulses and
1636. the main pulses when the controller is enabled. The computer
1637. program goes through the following steps in the order given to be
1638. sure that the choppers will function properly.
1639.

1640. 1. All RI's, Regions 4, 8, & 12 are turned off.
- 1641.
1642. 2. All chopper controllers are given appropriate signals
1643. to:
 - 1644.
 1645. a) Turn off the ENABLE
 1646. b) Set DAC's to zero.
 1647. c) Set read out from the chopper controller to
1648. transducer (not reference voltage).
 - 1649.
1650. 3. All single choppers are enabled; this gives a prelead on
1651. the RI's at Region 8 when they are turned on.
1652.
1653. 4. The RI's at Region 8 are turned on.
1654.
1655. 5. The RI's at Region 8 are ramped up to 100 volts.
1656.
1657. 6. The enables for the double choppers are turned on when, and
1658. only when, the voltage signal from the (-) and (+) RI's at
1659. Region 8 indicated that they are set to at least 100 volts.
1660. The main bend magnets are enabled first then the rest of the
1661. double choppers are enabled after a 5 second delay.
1662.
1663. 7. The remote boost power supplies at Regions 4 and 12 are
1664. turned on. The boost voltage out of the RI's at Regions
1665. 4 and 12 depends upon the current in the main bend magnets
1666. and is controlled by the computer.
 - 1667.
 1668. a. The boost voltage for the Bends is a linear function of the
1669. Bend
1670. I-Des, and it is set to go to 600 volts at 18 GeV. It is
1671. zero volts at about 4.5 GeV.
1672.
 1673. b. Each boost voltage for the 4QF circuit (one at Region 4, and
1674. one
1675. at Region 12) is controlled with a ramp voltage from the
1676. CAMAC in those regions, but the output voltage of each 4QF
1677. boost power supply is restricted to one of three valves
1678. 0.0, 100V or 200V.
1679. The ramp input is set by the computer so that the boost

1680. voltages come on at the appropriate times as a function of
1681. the Bend I-Des.

1682.
1683. 8. At this point the computer will adjust the DAC voltages
1684. into the chopper controller to set the individual magnet
1685. currents as desired.

1686.
1687. One should note that under "hand-controlled" testing of the magnet
1688. chopper system it would be possible that the above order might be
1689. violated. If one, for instance, turned on the remote Booster
1690. supplies first, there would be current flowing in the given magnet
1691. circuits. Under these conditions one could not then turn on the
1692. BI's at 8 and enable the choppers, because they may not commute
1693. off.

1694.
1695.
1696. If for some reason, one of the dual chopper systems hangs up (does
1697. not commute off) the regulator will see this as an increase in
1698. system voltage and automatically shorten the output pulse on the
1699. remaining chopper. If the pulse can not be shortened enough to keep
1700. the magnet current within tolerance of the chopper, you will find
1701. that the system will sit there as though there was no trouble,
1702. except that the display in the PEP control room would indicate that
1703. the current was out of tolerance. If the operator indicates to the
1704. PSOG technician that the I-MON is greater than the I-DES then the
1705. technician should suspect a "hung up" chopper if a dual chopper
1706. system is involved.

1707.
1708. If on the other hand the regulator could shorten the pulse width
1709. enough on the remaining chopper to keep the magnet current within
1710. tolerance, the PEP operators would not recognize a problem. In this
1711. case, the only way the trouble would be noted is for the PSOG
1712. technician to note that the output voltage of the seriesed voltage
1713. choppers were not equal. This must be something the technician
1714. should be aware of, and inspect for; the output voltages of each of
1715. a pair of dual choppers should be equal. Some day we may get around
1716. to installing an alarm for this type of malfunction.

1717.
1718. It would also be possible to build an electronic sensor that would
1719. detect the presence of an actual voltage turn off of the choppers a
1720. few micro-seconds after the commutation pulse is given to a chopper.
1721. This system would be function on all choppers as a signal of
1722. malfunction.

1723. Some day we may install such an alarm.

1724.
1725. The regulation loop operation to the dual choppers depends upon each
1726. chopper controller (Master and Slave) to generate its own main ad
1727. commutation pulses. The slave controller input is an analog dc
1728. voltage that is a function of the difference voltage between the
1729. reference voltage and transducer current feedback signal in the
1730. master controller.

1731.
1732. Since the commutation pulses and main pulses are generated within
1733. each controller and are a function of various adjustments (ramp
1734. voltages and timing) in the controller you will find that the main
1735. pulse and commutation pulses of a pair of seriesed choppers may not
1736. be exactly at the same time.

1737.
1738. We are considering a change in the method of deriving the pulses for
1739. the slave chopper. This would be by taking the pulses from the

1740. master controller and triggering the SCR's in the slave chopper
1741. directly instead of going through the slave normal controller. This
1742. would force the triggers to be at the same time and might eliminate
1743. much of the electronics in a "Slave" controller.
1744.
1745.

GENERAL COMMENTS

1746.
1747.
1748. There are times when the operators want to be sure that there is no
1749. magnet current in some of the systems; this is quite often done on
1750. the Wiggler circuit at high energies.
1751.

1752. The software program does not allow the operator to dis-able one of
1753. the chopper controllers from the control room. We have on occasion
1754. disabled the chopper controller by hand after the system has been
1755. adjusted to the desired levels, but this is not too satisfactory
1756. because it would have to be done every time the power supplies are
1757. off and turned back on or standardized. A better method has been to
1758. pull the commutation and main pulse trigger cables on the rear of
1759. the crate for that particular chopper circuit.
1760.

1761. One must keep in mind though that, if the chopper is in operation
1762. and one pulls the commutation trigger first that the main pulse will
1763. turn on the main SCR, but there will be no commutation pulse to turn
1764. it off; therefore, it will go full on.
1765.

1766. The order of disconnecting or plugging in the triggers is important.
1767.

1768. Turning Off: .

1769. First pull the main pulse then the commutation pulse.
1770.

1771. Turning On:

1772. First plug in the commutation pulse then the main pulse.
1773.

1774. Remember that on the Main Bend controllers, there are two main pulse
1775. triggers (two SCR's are gated alternately to be able to handle 1,400
1776. amps to the load).
1777.

1778. The peak current in the commutation circuit must exceed the magnet
1779. current, for a given steady state operation, with some safety margin
1780. or the chopper may not commutate off.
1781.

1782. The current on the commutation circuit is a direct function of the
1783. voltage on the capacitor of the commutation circuit. The capacitor
1784. voltage is higher than the RI voltage and is a function of the
1785. magnet current flowing. It, therefore, requires some previous
1786. pulses in the circuit at lower currents to be sure that the
1787. capacitor voltage is higher enough to commutate off a higher magnet
1788. current.
1789.

1790. The commutation capacitor voltages may be 200 volts or more above
1791. the RI voltage feeding the choppers at Region 8. In the case of the
1792. low voltage choppers in Region 2 that feed the SQ rotated quads of
1793. the 2-Gamma experiment you will find about 300 volts on the
1794. commutation capacitors for only 35 volts into the choppers from the
1795. basic power supply.
1796.

MAGNET ACCIDENTAL GROUNDS OR SHORTS

1800.
1801. A system of power supplies and magnets such as for the PEP magnets
1802. (there are 656 magnets) presents some problems when trying to find
1803. one magnet shorted to ground or if an intermittent coil to coil
1804. short exists on one magnet. We have had many shorts of both types.
1805.
1806. The hoses used to carry the Low Conductivity Water (LCW) to the
1807. various magnets is of a very high resistance SYNPLEX hose so that
1808. its resistance can be neglected. The LCW is very high resistance
1809. (about 10 Megohms across a face of a 1CM cube) and can usually be
1810. ignored. A typical 1/4 inch hose three feet long would measure
1811. about 100 Megohms. There are about 3,000 such hoses. So far, very
1812. rough numbers, the resistance to ground is to be expected to be in
1813. fact we measure about 27,000 ohms to ground for the entire circuit,
1814. which is reasonable.
1815.
1816. The complete magnet system is kept isolated from ground except at
1817. one point G (see Figs. 14 & 15)
1818.
1819. At that point we connect a 100 ohm resistor to ground through a
1820. knife switch. A knife switch is used so that this grounding
1821. resistor may be easily disconnected to enable a measurement of the
1822. system resistance to ground to be made. A bridge rectifier and a
1823. meter relay is connected across this resistor so that either
1824. polarity of voltage across the ground resistor R1 (FIGURE 14) will
1825. indicate on the meter M1.
1826.
1827. The pulsed choppers and the ac voltage of the RI power supplies
1828. working against the stray capacitances of the system to ground
1829. introduce considerable ac voltage across the ground resistor. An
1830. oil-paper capacitor C1 is connected across R1 to bypass this noise
1831. signal. The meter across the ground resistor is calibrated to about
1832. 300 Milliamps full scale. At present the ground meter reads about
1833. 20 Milliamps for 14.5 GeV magnet current settings.
1834.
1835. The wire that connects C1 to ground is a green wire coming out of
1836. the bottom under the door of the (+) RI. This allows one to
1837. temporarily disconnect the capacitor for special tests. Sometimes
1838. though, this wire is not out and available.
1839.
1840. M1 is set to trip at about 300 Milliamps if this occurs, then the
1841. complete magnet power supply system is turned off and a ground fault
1842. indication is locked out on the alarms.
1843.
1844.
1845. If a ground current trip is noted, then the first step one should
1846. take is to open up the (+) RI power supply, open the Grounding Knife
1847. switch, and measure the resistance of the system to ground on the
1848. common. It will be necessary to make up the key system with a door
1849. left open so that the grounding mechanism is open.
1850.
1851. One should use an analog type ohmmeter for this measurement (not
1852. the FLUKES) so that enough voltage is available from the ohm-meter
1853. to go through the free wheeling diodes of the dual chopper systems,
1854. and remote boost power supplies. If no trouble is found then one
1855. will have to set up for operation and go to "Energized Ground
1856. Checking" procedures, otherwise proceed to "Non-Energized Ground
1857. Checking".
1858.
1859. NON-ENERGIZED GROUND CHECKING

1860.
1861. Open one of the doors of each of the dual chopper systems and
1862. measure the resistance to ground from the magnet output terminal of
1863. each of the seven dual chopper systems. Be sure all other grounds
1864. and ground hooks are off for the measurement. If one of the magnet
1865. systems for the dual choppers does not show a lower resistance to
1866. ground the problem may be: system then the trouble may be:

1. One or more of the single chopper circuits.
2. One of the secondaries of the main RI transformers.

Note that these transformers are disconnected from the rest of the power supply system.

If one of the systems shows a lower resistance to ground than the others, the dc cables to the magnets of that system in the appropriate chopper racks should be disconnected and the systems be rechecked. It has usually been easy to isolate the faulty system by the above procedures. The next step is to find the the particular problem in a given circuit. Several different procedures have been used with varying amounts of success to find a specific grounded magnet.

1. Use a temporary 24 volt supply and connect its output to the magnet circuit leads as shown in Figure 16. Note that the magnet leads have been lifted from the chopper, and that the power supply and magnet now "floats" on the unknown resistance to ground of the defective system. The current rating of the temporary power supply must be at least 35 amps since the lowest resistance magnet circuit is 0.75 ohms for the 6SF and 1SF circuit. The highest resistance circuit is 4 ohms for the 4QF system where only 6 amps will flow for an applied 24 volts. SEE Table ?? for the resistances of the other circuits. A resistance R1 may be added to limit the current flowing in a circuit to match a lower rated power supply. Any added temporary power supply for testing must be applied in the same polarity as the normal chopper voltages to keep magnet residual fields unchanged.

One then measures the voltage to ground at points A and B and calculates the approximate position of the short to ground. Under ideal conditions, if there were no, other stray voltages to ground one would be able to go to that calculated position and (Keep in mind that there is additional voltage in the circuits of the Bends and 4QF because of the free wheeling diodes for the boosters) use a sensitive multi-voltmeter to find the exact spot of a single point ground. The polarity of the measured voltage to ground will change as you pass the grounded point.

One must be very careful when using a temporary power supply to energize one of the magnet strings. Large voltages can be generated, because of the inductance in the system of magnets, if one tries to open a magnet lead once the power supply is turned on. Be sure the temporary supply is turned off before connecting or disconnecting any leads.

During this measurement of small voltages, one should use a voltmeter whose internal impedance is high relative to the measured resistance to ground. The original resistance to ground should be measured with an analog meter that places a few volts on the

1920. systems; the resistance measurement should be made with both
1921. polarities of the ohm-meter and the average taken between the
1922. readings. If a difference in resistance to ground of the system is
1923. noted, it implies that there is some stray dc voltage biasing the
1924. system above ground potential. This voltage may be measured with a
1925. high impedance meter, say a FLUKE. Any voltages that can be
1926. measured from the system to ground, when all other known voltages
1927. such as the temporary 24 volt supply, are turned off, will cause the
1928. position of the calculated short to ground to be in error. Many
1929. times these stray voltages, caused by dissimilar metals and wet
1930. surfaces may create such large errors in trying to calculate the
1931. exact position of the short, by the ratio of voltages, that this
1932. method will not work effectively.
1933.

1934. In this case, one makes a general guess as to where the short may be
1935. and goes into the ring and disconnect magnet cables in some logical
1936. order to sectionize the areas to be checked.
1937.

1938. There are splice points on the water-cooled cables outside the ring,
1939. such as south of the support building Region 2, north of the access
1940. road Region 6, and near the transformer pad east of the Support
1941. building at Region 12, where one can gain access to the water-cooled
1942. cables, but it is a lot easier to go to the magnets in the ring to
1943. isolate the circuits.
1944.

1945. One must keep in mind that the problem could also be in the Booster
1946. power supplies at Regions 4 or 12 if the circuits for the Bend or
1947. 4QF are in trouble.
1948.

1949. The prints in the series WD-207-009-001 through WD-207-009-11 will
1950. be helpful to locate a given magnet that is connected to a given
1951. system in the ring. Each of the magnet circuits have identifying
1952. numbers that are noted on each magnet in the ring to aid in
1953. checking.
1954.

1955. One must be very careful in checking out the systems used for the
1956. MINI-BETA because of the reversing switches and by-pass regulators
1957. that are part of these systems. The systems involved with Mini-
1958. Beta are: Bends (Q1, Q2), Q3, 1QF, 2QF, 1QD, 3QF.
1959.

1960. ENERGIZED CHECKING FOR INTERMITTANT GROUNDS

1961. Many times there will be a ground fault indication only when one
1962. tries to go above some value of current. These are the more
1963. difficult type of grounds to locate. First of all, a very thorough
1964. understanding of how the system is connected and how it works must
1965. be had; otherwise, you may easily get off on the wrong track in
1966. looking for a problem.
1967.

1968. Two major types of problems may exist:

1969. 1. Voltage related breakdowns; water leakage on insulators, close
1970. clearances, etc.

1971. 2. Current or magnetic field related breakdowns where a magnetic
1972. piece of metal moves to hit a conductor or a magnet coil or lead
1973. moves in the magnet.
1974.

1975. First: Remember that this is a pulsed system; therefore, the voltage
1976. to a magnet string is a series of square wave blocks of voltage.
1977.
1978.
1979.

1980.
1981. Second: See Figure 15, note that there are both positive and
1982. negative voltage systems.
1983.
1984. Third: Note that it is possible to change the current in a given
1985. circuit without changing the applied peak pulse voltage. The magnet
1986. current will change as the duty factor of the applied pulse is
1987. changed.
1988.
1989. To start in solving this problem, I will assume that the ohmmeter
1990. does not indicate a problem.
1991.
1992. 1. Connect an oscilloscope to measure the voltage to ground of the
1993. ground bus. Set the vertical calibration of the scope to 2 volts D
1994. per CM; this gives 200 volts per CM because the dividers are 100 to
1995. 1.
1996.
1997. Set the sweep speed to about 8 MM-sec per CM so that one can
1998. recognize a 60 cps wave form. SYNCH the scope on the ac line so
1999. that there is always a trace on the scope.
2000.
2001. Now turn on the system via the computer and have the operator bring
2002. up the whole system of magnets slowly. Keep an eye on the above
2003. scope for an indication if the system turns off. I think that I
2004. would leave the booster voltages off for the first test.
2005.
2006. If the system does turn off on ground current, make a note in the
2007. log as to the dc voltage on the RI's and the Bend magnet current.
2008. Note also the type of signal and values on the oscilloscope at the
2009. time of failure.
2010.
2011. 1. Is it a negative voltage; What Value?
2012. 2. Is it a positive voltage; What Value?
2013. 3. Is it a 60 Hertz signal; What Value? What Wave Shape?
2014.
2015. The answers to the above questions will give some rough ideas where
2016. the problem may be. The dc voltage and polarity that shows up on
2017. the scope can be used to roughly determine where in the ring the
2018. problem may be once the particular system is identified. Now turn
2019. off the whole system and operate the choppers and RI's by hand.
2020.
2021. First disable all but one of the choppers. Leave on one that you
2022. may think is the culprit; keep in mind which polarity showed up on
2023. the scope during the previous check, this could help identify the
2024. correct system.
2025.
2026. Set the chopper current at minimum and bring up the one RI involved
2027. to the value of voltage that was present during the previous test.
2028.
2029. Now adjust the chopper width for high currents. Go up to the
2030. maximum possible. Control one chopper at a time for the given RI
2031. voltage. Control both single and dual chopper systems.
2032.
2033. While controlling the magnet current, one should watch the ground
2034. current meter for any unexplainable changes in measured ground
2035. current. You may want to disconnect the by-pass capacitor across
2036. the ground resistor to display the correct voltage wave form.
2037.
2038. Repeat this until all systems have been checked with one RI.
2039.

2040. If the trouble is not found, then go to the other RI polarity and
2041. repeat controlling each chopper involved.
2042.
2043. If the trouble has not been found yet, bring up both RI's to the
2044. operating voltage (without the booster supplies) and again check
2045. each chopper and new pairs of choppers to find the problem.
2046.
2047. Still no problem found? Turn on the booster supplies for the feeds
2048. then the 4QF's.
2049.
2050. If still no problem found, turn off everything and have the PEF
2051. operator bring up the system again as a total system again to see if
2052. the problem still exists.
2053.
2054. Once one finds which system is giving the problem, then it may pay
2055. to go into the ring and inspect those magnets closely for a problem
2056. One should especially inspect the magnets where one would guess the
2057. problem is by the voltage measurements on the ground resistor.
2058. This, by polarity, may at least say which way to go first.
2059.
2060. If one still has not found the problem, then try hi-potting the
2061. particular system up to a maximum of 2,500 volts dc. Be sure all
2062. other systems are grounded for such a hi-pot and of course the ring
2063. and all choppers and RI's must be closed for safety.
3002. CHOPPER CONTROL ICARI CHECK OUT
3003. + -----
3004.
3005. Print No. SD-207-103-00-R0
3006.
3007. Summary of Chopper Operation
3008. R.W. Fuller March 26, 1982
3009.
3010. The chopper can be simplified by comparing its main SCR (or
3011. SCR'S) to a switch being easily turned on with the main firing
3012. pulse (pulses) from the controller board. The commutator SCR
3013. is also a switch which turns on a ringing circuit that can
3014. shut off the main SCR and reset itself when given about 80
3015. micro seconds to complete its cycle.
3016.
3017. Therefore, by operating the main SCR(s) for a longer or
3018. shorter time into a magnet and repeating this cycle many times
3019. a second so that the magnet smoothes out the variations in
3020. current, a regulated current can be maintained in the magnet.
3021. If the commutator firing pulse is delayed further in time the
3022. current in the magnet will increase. If the main pulse is
3023. followed shortly by the commutator pulse, current in the
3024. magnet will decrease. The increments of increase or decrease
3025. are very small due to the shortness of the cycle compared to
3026. the time constant of the magnet.
3027.
3028. The purpose of the pulse controller is then to deliver a main
3029. pulse train and a commutator pulse train properly spaced
3030. for regulation in the 400A chopper. For the 1400 A chopper
3031. the main pulses must also be alternated between two SCR's so
3032. they can share the load current. The controller also
3033. establishes limits for the pulses to allow safe operation for
3034. the magnet and the chopper.
3035.
3036. The minimum pulse length to the magnet is 10% of the period at

3037. 2,000 hertz. The maximum pulse length is 95% of the period at
3038. 2,000 hertz. Some of the choppers run at 360 hertz, for this
3039. lower frequency the minimum pulse length is 1.8% of the period
3040. (the same number of micro-seconds), and the maximum length is
3041. 99% of the period. Note that the lower frequency gives a
3042. wider range at a sacrifice of frequency response.

Initial Set Up of Fin and Controller

3043.
3044.
3045.
3046.
3047.
3048. **1. Install the "MASTER BIN CNTRL" (207-101) in slot 24 and
3049. 25 of the CAMAC bin.
3050.
3051. **2. Install the "CLOCK MODULE" (207-102) in slot 18 of the
3052. bin. Connect the jumper cable from any one of J3 thru J6 on
3053. the "CLOCK MODULE" to J5-CLK connector on the "MASTER BIN
3054. CNTRL" module.
3055.
3056. **3. Install a "DATAWAY EXTENDER" FE01 in slot 2 of the CAMAC
3057. bin, and install a current meter (0-500 ma) in place of the
3058. -24V. jumper. An extender for both P1 and P2 are necessary
3059. for checkout through the bin connectors.
3060.
3061. **4. Set all switches on the "MASTER FIN CNTRL" to the
3062. following:
3063.
3064. Horizontally mounted (bit) switches numbered 1 thru 16 to the
3065. left or low position; "ICL"/"REM" switch to "ICL";
3066. "DAC"/"CNTRL" switch in "DAC"; "SIGT ADDRESS" switch to
3067. position 2.
3068.
3069. **5. Set the "LINE SYNC"/"NORMAL" to "LINE SYNC" and frequency
3070. switch to "24 KHz" on the "CLOCK MODULE".
3071.
3072.

Chopper Controller Check Out and Adjustment

3073. NOTE: If any condition of any step is not met, do not proceed
3074. to the next step without troubleshooting the problem.
3075.
3076.
3077.

3078. **1. On a new chopper controller module adjust R24, 27, 36
3079. and 48 for minimum settings of all regulators (R36 and R48
3080. clockwise, R27 and R24 counter clockwise.) For an operational
3081. unit check the respective regulator outputs first. If their
3082. voltage outputs are ok proceed to next step.
3083.

3084. **2. For the initial alignment of a new module remove U1, U2,
3085. and U21 IC's. On an operational unit in for troubleshooting
3086. it is only necessary to remove U1 and U2 if there is trouble
3087. with the unit missing or having improper output pulses. It
3088. should only be necessary to remove U21 if there is an indicated
3089. problem with the DAC not functioning properly.
3090.

3091. **3. Connect controller board to the extender and turn on
3092. power to CAMAC bin. Allow 1 minute for clock to stabilize and
3093. monitor it at the end of R113 closest to U8. Adjust the
3094. frequency if necessary to 2,160 Hz (463 micro seconds for a
3095. high frequency type module or 2777 micro seconds for the
3096. 360 Hz low frequency type clock module. +/- 10 micro seconds

3097. between pulses) by changing the adjustment pot marked "LINE"
3098. on the "CLCCK MODULE").
3099.
3100. **4. Monitor current in the -24 V power supply while
3101. adjusting R36 until the voltage reaches -15.0V at the output
3102. (pin 3) of VR 4, current must not rise above 250 ma and will
3103. be about 50 to 100 ma. Turn power off and move the current
3104. meter to the +24 V. jumper and reinstall the -24V. jumper.
3105.
3106. **5. Monitor the current in the +24V power supply while
3107. adjusting R48. The voltage at pin 3 of VR3 should come up to
3108. +15.0 without exceeding 260 ma.
3109.
3110. **6. Adjust R27 so that pin 3 of VR1 reads +11.75 V +/- 0.25
3111. before the current in the +24 V line reaches 260 ma.
3112.
3113. **7. Adjust R24 so that pin 3 of VR2 reads +5.0 V, but do not
3114. exceed 260 ma in the +24 V power supply. Shut -off the CAMAC
3115. bin power.
3116.
3117. **8. Connect or check connection between point A and B near
3118. U39, and adjust R110 for a resistance of 5.11 kilohms
3119. measured from U39, pin 12 to common, using a Fluke DMM
3120. set on the 20K range. Restore power to the board.
3121.
3122. **9. Measure voltage at A, it should be about -9 volts, then
3123. at E39 it will be about 9V. Also, check pin 12 of U38 to see
3124. that it is within 1% of the reading at E39.
3125.
3126. **10. Check for clock pulses at pin 12 of U10, they should be
3127. positive going 10-14 V peak and about 5 micro-seconds in
3128. length, f=2160 Hz for a high frequency type module and
3129. f=360 Hz for a low frequency type module.
3130.
3131. **11. Check and adjust R19 (Trig. Delay) for an 80 micro
3132. second width out of the one shot multivibrator U10 pin 10.
3133.
3134. **12. Output of U10 pin 6 should be a 5-8 micro second pulse
3135. rising to about 12 V starting when pin 5 goes low. Check pin
3136. 7 for the inverse of the pulse and then the output of U13 pin
3137. 13 for the original pulse amplitude and duration.
3138.
3139. **13. Check U38 pin 1 and adjust R101 for a voltage ramp
3140. rising from about 0.2 V to 11 V in a certain time period, which
3141. results from C70 being charged with a constant current source.
3142. The capacitance value required for C70 is 0.22 micro-farads
3143. in the low frequency type module and 0.1 micro-farads in the
3144. high frequency type module. The rise time is adjusted to
3145. 2777 micro seconds or 463 micro seconds respectively.
3146.
3147. **14. Check for unity gain from pin 10 to 8 U39.
3148.
3149. **15. Switch the mode switch to "LCC" and check at E27 (near
3150. U35) for -10 V +/- 1 VDC when R114 (on front panel) is set in
3151. maximum clock-wise position.
3152.
3153.
3154. **16. At E25 (near U32) check for a pulse which has variable
3155. width as R114 ("LOCAL") is changed (pulse will disappear with
3156. low setting of "LOCAL"). A commutator pulse is produced when

3157. U34 goes low at pin 7 which determines how long the chopper
3158. main SCR(s) stay on in a cycle. Current in the magnet is
3159. proportional to this duty cycle.
3160.
3161. **17. Plug the test cable with the dual banana plug on one
3162. end into the "EXTERNAL" jack on the back of the CAMAC crate
3163. marked COS02, J10. This point is available on the Chopper
3164. Controller Patch Panel and is labelled J10.
3165.
3166. Short the banana plug with a clip lead and apply an AC voltage
3167. (of 60-10,000 Hz, no offset) between the clip lead and the
3168. shield wire of no more than 5 VRMS. Observe the output of U36
3169. at pin 14 (or E32) and adjust R92 for minimum AC voltage.
3170.
3171. In a "Slaved" controller this amplifier is used as
3172. a buffer on the signal from the "Master"
3173. controller to generate the main pulse trigger from
3174. the ramp in the slave controller.
3175.
3176. Turn on power to the Chopper Controller Module Test Chassis.
3177.
3178. **18. Remove jumper and AC voltage. Connect the dual banana
3179. plug to a 0-10 V. positive DC supply, ground on plug is low.
3180. Output of U36 at E32 should now track the input voltage but
3181. with opposite polarity. Switching the mode switch to "EXT
3182. ERR" should now cause the output of U34 (E25) to change pulse
3183. width as voltage changes positive on E30. Remove connector
3184. from COS02, J10.
3185.
3186. Set all bit switches on the Master Bin Controller Module (1-16)
3187. to their low position.
3188.
3189. Remove power. Install U21, and restore power. Put
3190. "LCL"/"REM" switch in "LCL" and push "SEND" button. Monitor
3191. voltage at U25 pin 6 and adjust "OFFSET", control, R43, for
3192. 0.00000 V.
3193.
3194. Move probe to E17 and see that it is also 0.000 V. Switch bit
3195. switches to high position and press "SEND", an output of 10.0
3196. V should be read. Monitor pin 6 of U25 again and adjust this
3197. point to 10.0000 V with R45 ("GAIN"). Repeat until both
3198. readings are correct.
3199.
3200. **20. Switch 16 to low position and push "SEND".
3201.
3202. Monitor pin 6 of U25 again (it will be 5.00 V) and then change
3203. each bit switch in order down to the bit 1 switch, each time
3204. pressing "SEND" and observing the 50% decrease in voltage at
3205. U25 or E17, for each bit.
3206.
3207. **21. Connect the cable used to test "EXTERNAL" input to the
3208. "XDCTR" connector COS02, J9. This point is available on
3209. the Chopper Controller Patch Panel and is labelled J9.
3210. Put a clip lead between the pins of the banana plug and check
3211. the output of U31 for 0.00v. Connect the AC source (0-10000 Hz)
3212. used in step **17 to the clip lead and shield of the test cable
3213. and observe the output of U31 with a scope while minimizing
3214. the output with the adjustment of R75.
3215.
3216. This procedure tests the common mode rejection of

3217. Amp U31 used to buffer the transducer signal into
3218. the differential amplifier. There should be less
3219. than 100 micro-volts peak to peak at E20 for an
3220. input of 1 volt peak to peak of any frequency from
3221. DC to 10,000 hertz. Any loss of common mode
3222. rejection introduces noise (sometimes 60 or 120
3223. hertz) in the output of the chopper that can not
3224. be taken out by the regulator. There is a large
3225. common mode signal on the transducer output with
3226. respect to the rack frames.
3227.

**22. Remove the clip lead and AC supply and connect the dual
3228. banana plug to the 0-10 volts positive DC power supply. Set
3229. the supply for 10 volts Check E20 for a -10 V output and
3230. reduce the DC to 5 V to see that the output tracks the input
3231. within +/-1%.
3232.
3233.

**23. With input of 5 V to U31 set bit 15 to high and press
3234. "SEND". Set mode switch to "ERR". Connect a scope to E27
3235. (near U35) and set it to observe a +/- 15 V swing as bit 16 is
3236. toggled high and low (each change must be followed by a "SEND"
3237. command).
3238.
3239.

**24. Monitor E19 (near U30) with a volt meter as the input
3240. to U31 is changed. R112 should cause about a 14% change in
3241. gain from stop to stop. Set R112 to read the same as E20 (it
3242. will be opposite polarity) and change the input to U31 to see
3243. that input and output track, then return to 5 V.
3244.
3245.

**25. Set all bit switches high and press "SEND", then change
3246. "DAC"/ "CNTRL" switch to "CNTRL". Set all bit switches low,
3247. now while monitoring the output of U24 at E15 with a
3248. voltmeter, toggle bit 13 high and low, followed each time by a
3249. "SEND" command. When bit 13 is high, voltage at E15 will be
3250. the same as at E19 (5V). E15 will be the same as E17 or E16
3251. (10V) when bit 13 is low. Now connect an isolated voltmeter
3252. to pins A and E of COS02 J5; the reading will be the same as
3253. at E15, pin A will be positive.
3254.
3255.

**26. Push the chopper controller "RESET" button, "GL" light
3256. should be out. Momentarily, remove the input to U31 to verify
3257. that the glitch detector circuit lights the "GL" light, then
3258. push "RESET" again to extinguish it.
3259.
3260.

**27. Adjust R87 to maximum counter-clockwise position, and
3261. set the input to U31 at 9.20V. Reset the controller board
3262. ("CC" over current light should be out) and slowly adjust R87
3263. clockwise until the "OC" light comes on. Lower the input
3264. voltage and reset again, then raise input voltage until the
3265. "OC" light comes on. Read this voltage and if it is not 9.2V
3266. adjust R87 until it is within 0.1 volts. Lower input of U31
3267. to 7V and push "RESET" to extinguish all lights.
3268.
3269.

**28. Turn off power to the board, then connect the KRP 11
3270. 24 VDC relay and test connector assembly to the "OC RELAY"
3271. receptacle, COS02, J6. This has already been done via the
3272. patch panel and is labelled accordingly. Restore power, then
3273. as the input to the circuit is raised to 9.2 v the relay will
3274. release and when the voltage falls to approximately 7 volts
3275. it will pull in. The status of the relay is indicated on the
3276.

3277. patch panel by two LEDs labelled "CC RELAY". Check between
3278. pins A and C with an ohmmeter for the relay blocking diode
3279. as indicated on the schematic. Restore power to the bin only
3280. and push "RESET", all lights will now be off.
3281.
3282. **29. With Bin Controller "DAC"/CNTRL" switch in "CNTRL"
3283. position enable the controller board by switching only bit 15
3284. to high and pushing "SEND".
3285.
3286. The "EN" light will come on and remain on.
3287.
3288. **30. Switch bit 16 to high, all others low, and push "SEND",
3289. this will extinguish the "EN" light.
3290.
3291. **31. Repeat step 29.
3292.
3293. **32. Short pins 11 and 12 together on U5, all lights will
3294. now be on except the "OC" light. Set the input voltage to U31
3295. to +10 volts to trip the overcurrent protection circuit and
3296. light the "OC" light. When the "OC" light comes on the "EN"
3297. light will go out.
3298.
3299. **33. Switch bit 14 to high and press "SEND", the "OC" and
3300. MP" lights will go out; "EN" will come on if bit 15 has been
3301. left high.
3302.
3303. **34. Switch bit 12 to high and press "SEND", the "GL" light
3304. should go out.
3305.
3306. NOTE: The "CC", "MP", and "EN" circuits are very similar
3307. because the led's have built in current limitation which
3308. allows them to be driven by simple emitter followers in a
3309. CA3082 I.C. The 4043, quad R-S latch, toggles output at Q
3310. either high if S is high or low if R is high. If both are
3311. high, output at Q goes high; if none are low, no change of
3312. output state occurs. The 6N139 is an optically coupled
3313. isolator which repeats the input signal at its output.
3314.
3315. **35. Set up a scope to chop two inputs and with one channel
3316. check for a pulse with no offset rising to +12V at socket for
3317. U2 pins 9 thru 12. Period of pulse will be 463 (2,777 for low
3318. frequency controller) micro second and pulse width will be 5
3319. to 8 micro-seconds. This is the single chopper main pulse.
3320.
3321. **36. Enable module. Move the probe to the socket of U1,
3322. pins 9 thru 12 and sync the scope to that channel. It will be
3323. a similar pulse to that in 35 but with a period of
3324. approximately 926 micro-seconds for the high frequency
3325. controller and approximately 5,555 micro-seconds for the low
3326. frequency controller. Connect the channel 2
3327. probe to U1 socket, pins 2 thru 5, the two traces now will
3328. show the pulses appearing on alternate channels at 463 micro
3329. second intervals for the high frequency controllers and 2,777
3330. micro-second interval intervals for the low frequency
3331. controllers. This is to allow the 1400 A choppers two main
3332. SCR's to be fired on alternate main pulses and divide the
3333. average load current equally between them. U5 is the JK
3334. flip-flop that provides this alternation by keeping one of the
3335. U3's one shot multivibrators from firing on alternate "TRIG"
3336. pulses (which are delayed clock pulses). See Chopper

3337. Controller Schematic.

3338.

3339. **37. Repeat step 30 while monitoring the main pulses at U1
3340. and U2, all should disappear when "EN" light goes off.

3341.

3342. **38. Disconnect the clock input to the chopper controller by
3343. switching the "12KHz/EXT/24 KHz" switch on the clock module to
3344. "EXT" and check pins 4 and 11 on both U1 and U2 sockets for a
3345. DC voltage, none of these should be more than 10 milli-volts.

3346.

3347. **39. Shut off power to the controller board install U1 and
3348. U2 and return clock module switch to original position.
3349. Restore power to the board, turn "LOCAL" pot fully c.c.w., and
3350. switch mode to "LCC".

3351.

3352. **40. Move channel 1 scope probe to "TRIG" output at U10, pin
3353. 6, SYNC on this channel and connect 2 probe to U9, pin 6, then
3354. adjust "EARLY" control (R15) so that the channel 2 pulse is 30
3355. micro second +/- 5 micro second wide. Both pulses will be 12
3356. V peak with no offset.

3357.

3358. **41. Move the channel 2 probe to the end of R8 closest to U2
3359. (the pulse will be 12v, 5 to 8 micro-seconds in duration),
3360. rotate the local pot fully clockwise and see that the pulse
3361. moves (measured from the leading edge) from a point 30 micro-
3362. seconds +/- 5 micro-seconds to 373 micro-seconds +/- 10 micro-
3363. seconds for a low frequency type module. For the high frequency
3364. type module the pulse should range from 30 micro-seconds +/- 5
3365. micro-seconds to 2,333 micro-seconds +/- 50 micro-seconds.

3366.

3367. **42. Move the channel 1 probe to pin 6 of U9 and turn "LOCAL"
3368. pot fully clockwise. Reconnect the 10 VDC supply to the input
3369. of U31 to trip the "CC" light. Both the main firing pulse and
3370. the commutation pulse will disappear due to the enable
3371. modification which takes away all pulses if the enable of the
3372. module is lost.

3373.

3374. **43. Push the "RESET" button and enable the unit. The "MP"
3375. light will come on when pin 10 of U4 socket is grounded
3376. momentarily with a jumper. Push "RESET" on the controller
3377. front panel and the light will go out. Remove power from board
3378. and disconnect the 10 V supply.

3379.

3380.

3381. The commutator pulse control circuit is composed of U10, 1/4
3382. U13 (pins 9-12, and 13), U38, U35, U39 (excluding "ERROR
3383. BUFFER"), U34, U9 (Early Limit) U8, U6, 1/4 U7 (pins 4,5, and
3384. 6) and U4 (output pin 10).

3385.

3386. U10 supplies a pulse 5-8 micro second wide, delayed behind the
3387. clock by the setting of R19. This pulse, called "TRIG" on the
3388. Chopper Controller Schematic, is used to set the "Q" output of
3389. U8 high and is then lengthened by the setting of R15 and
3390. applied to pins 9 and 12 of U6. Both CR gates of U6 will now
3391. have high outputs which cause U7 pin 4 to be high. When the
3392. output of U9 goes low after the ("EARLY LIMIT") delay the
3393. output one or both U6 OR gates (and consequently the output of
3394. U7) may go low if the error input from the comparator, U34, is
3395. low (U6 pin 13 is still set high from TRIG pulse applied to
3396. U8). This will fire the one shot multivibrator (U4) for the

3397. commutator circuit since it is set to respond to a negative
3398. going waveform.

3399.
3400. If the comparator, U34, has not gone to a low output, U6 pin8
3401. will be high and its output will not change state, so there
3402. can be no change of state at U7 pin 4 or U4, pin 10.

3403.
3404. If an over current fault happens after this point in time, U8
3405. gets reset by a high on pin 12, which brings pin 15 low along
3406. with the outputs of U6 (pin11) and U7 (pin 4), which fires the
3407. commutator one shot multivibrator. Through the succeeding
3408. cycles if the over current remains neither the main pulse nor
3409. the commutation pulse will appear due to the enable
3410. modification.

3411.
3412. If there is no change of state of the comparator (U34) or no
3413. over current fault, the commutator pulse is supplied when the
3414. next clock pulse acts on U8 to transfer the low at pin 10 to
3415. pin 15, which will make the output of U6 (pin 11) and U7 (pin
3416. 4) go low to fire the commutator one shot multi-vibrator
3417. (M.V.)

3418.
3419. During normal regulation cycles the commutator pulse is placed
3420. between the early and late limits by comparing an error or
3421. reference signal (some DC level between 0 and -10 V, with a
3422. positively ramping voltage of between about .2 and + 11V. At
3423. the point in the time that the absolute value of the two are
3424. equal at U34, pin 3's output goes low and causes U6, pin 10,
3425. to go low. Since U6 pin 11 was high from the action of TRIG
3426. setting U8 pin 15 high, the resulting negative going waveform
3427. changes the state of U7 pin 4 and fires the commutator one
3428. shot m.v. The voltage ramp for the comparator input is
3429. initiated by an inverted TRIG signal driving the pin 1, 2, and
3430. 3 transistor of U38 to saturation and discharging C70, which
3431. is then allowed to recharge with a constant current source
3432. composed of U39 and the remaining transistors of U30 and U39.
3433. This ramp is linear when points A and E are connected but may
3434. be (by connecting A to C) instantaneously changed with an
3435. input (FEED FWD) from the chopper power supply voltage. This
3436. change pre-compensated the commutator pulse so that the
3437. feed-back loop does not have to respond to the resulting
3438. change of magnet current caused by power supply voltage
3439. variation.

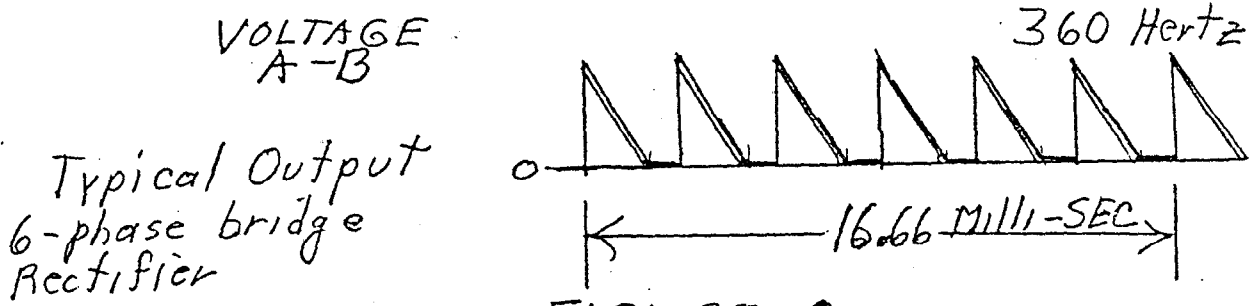
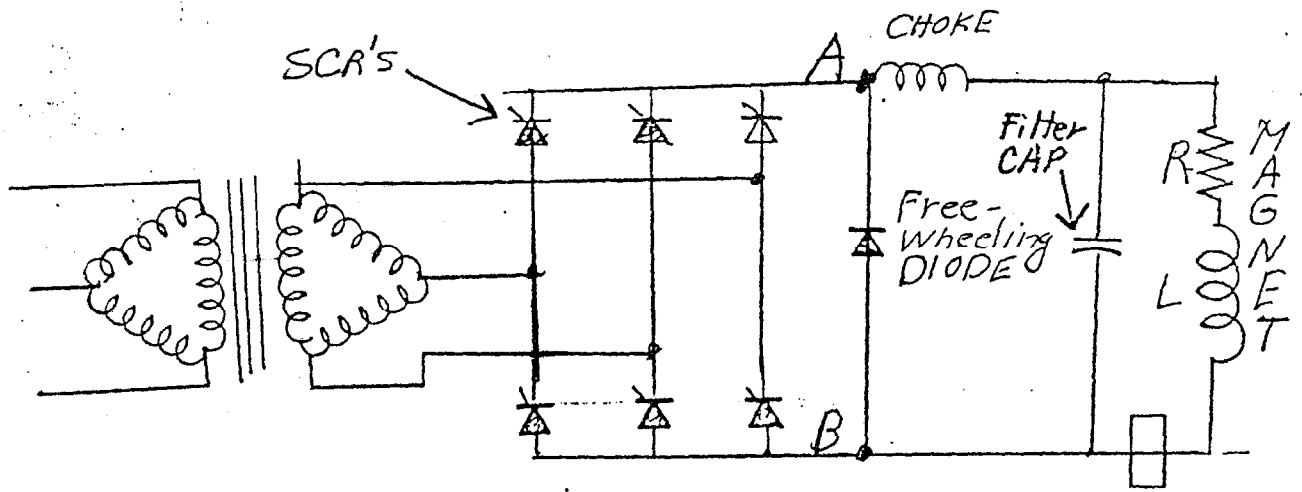
3440.
3441. **44. Disconnect P2 and connect test plug A. Connect yellow
3442. lead of the test plug to pin 23 of P1. Connect the black lead
3443. of the test plug to the board ground. This is the lead
3444. referred to as "Clip Lead" in the following text. Restore
3445. power to board.

3446.
3447. **45. Monitor pin 1 of U 18, it should be low when the clip
3448. lead is attached and high when not. Now monitor pin 11 of
3449. U18, it will be high with the clip connected and low when not.

3450.
3451. **46. Switch mode to "DAC REF" and monitor pin 60 of P1,U18 pin
3452. 16, connect the clip lead to the resistor as in step 45, pin 60
3453. will be low. Switch the mode to "ERR" while monitoring pin
3454. 60, it will remain low until the clip lead is momentarily
3455. removed, and when reconnected will go high.

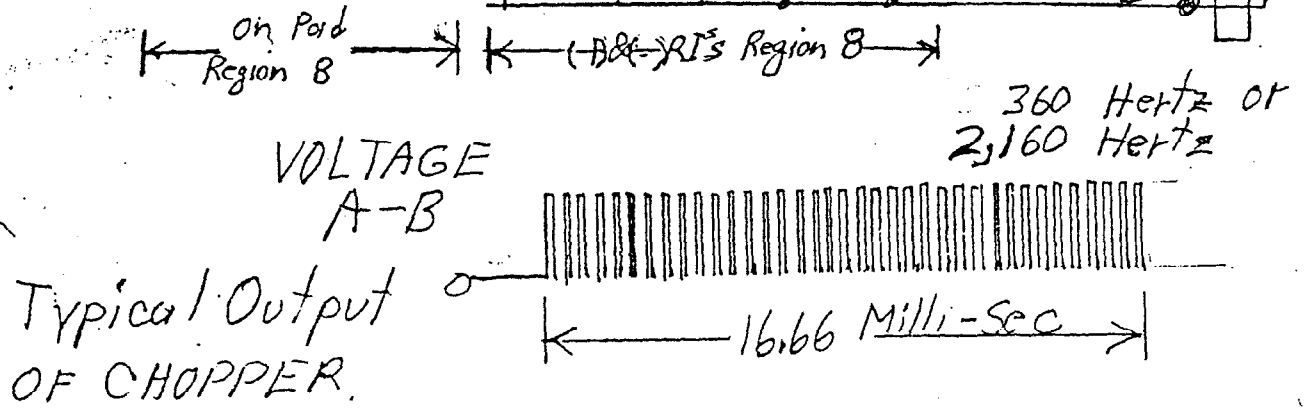
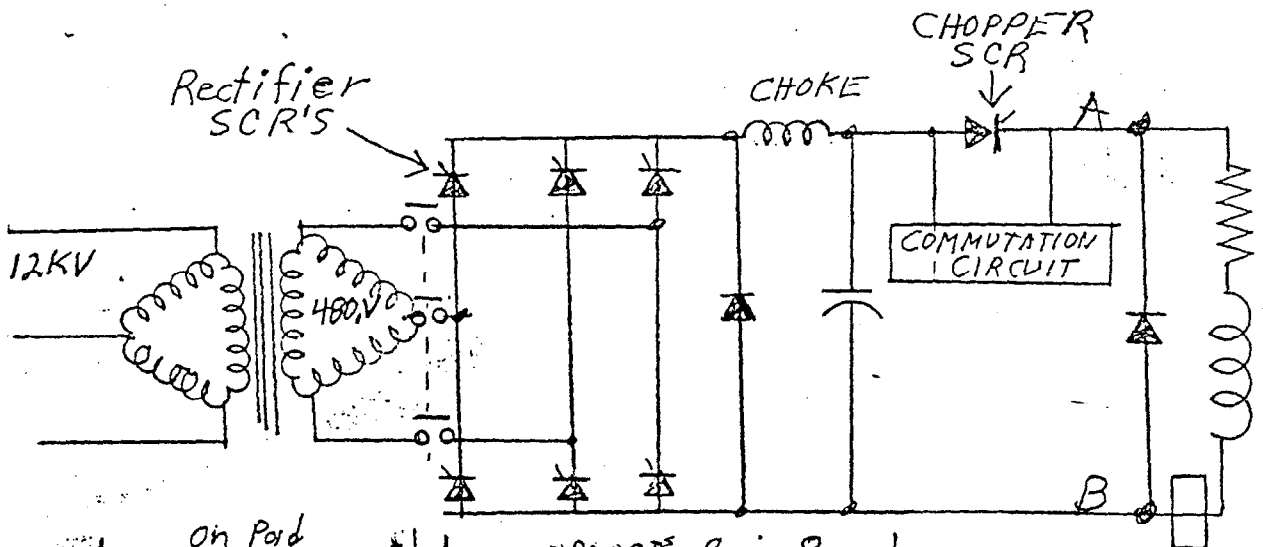
3456.

1457. Data is shifted to the output of U18 when U14 is clocked high
1458. on pin 10 or 11, data is held and accessible while those pins
1459. are low.
1460.
1461. **47. Monitor pin 59 of P1, U18 pin 9, it will be low. Switch
1462. mode to "EXT ERR" and momentarily disconnect clip lead as in
1463. step 46, pin 59 will now be high.
1464.
1465. **48. Monitor pin 61, U18 pin 15, it will be low. Switch mode
1466. to "LOC" and momentarily disconnect the clip lead, pin 61 will
1467. now be high.
1468.
1469. **49. Monitor pin 62, U18 pin 12, it will be low. Switch mode
1470. to "EXT ERR" and momentarily disconnect the clip lead, pin 62
1471. will now be high.
1472.
1473. **50. Monitor pins 57 and 58, U18 pin 5 and pin 6 respectively,
1474. push "RESET" and confirm that the "OC" and "GL" lights are out.
1475. Momentarily disconnect the clip lead and both pins will now be
1476. high.
1477.
1478. **51. Connect the 10 volt power supply to the gray leads on
1479. test plug A (Black is positive) to momentarily trip the "OC"
1480. and "GL" lights on. Now momentarily disconnect the Black clip
1481. lead while monitoring pins 57 and 58, U18 pin 5 and pin 6, the
1482. pins will now both be low.
1483.
1484. Disconnect power to the board, then install or check for a
1485. wire from E46 to F2-16.
1486.
1487. **52. Remove test plug A completely. Reconnect P2. Jumper
1488. point F to point D (both near U35) check to see if E is
1489. already wired to D and if so, remove wire at E and move to F.
1490. Restore power to board, then switch the mode switch to "LOC"
1491. and check U39 "ERROR EUP" for unity gain and inversion with
1492. the "LOCAL" pot. Check pins A and E of the "BUFF ERROR"
1493. receptacle (COS02), J7) for the same positive output as
1494. monitored at the output of U39 (E36), use an isolated
1495. voltmeter; pin A will be positive.
1496.
1497. **53. Move the plug from the "INDUCTR" J9 of COS02 and connect
1498. it to the "FIELD FWD", J8. With the supply connected and set
1499. to + 10V., check with an isolated voltmeter at E40 and E41 for
1500. the same voltage; E40 will be positive.
1501.
1502. **54. Remove the extender. Install the controller board in
1503. position 2 of the bin and restore power.
1504.
1505. **55. Enable the board by repeating step 29, also push reset.
1506.
1507. **56. Run a 20' or longer RG58 (or equivalent impedance)
1508. cable to COS02 J1 and terminate the line with a 50 ohm load
1509. teeing off to the scope input. Observe each of the outputs J1
1510. thru J4 to be a minimum of 35 V Peak 10 +/- 1.5 micro second
1511. wide at the 40 V level, with a rise time of 200 nano-seconds.
1512.
1513.
1514.
1515.



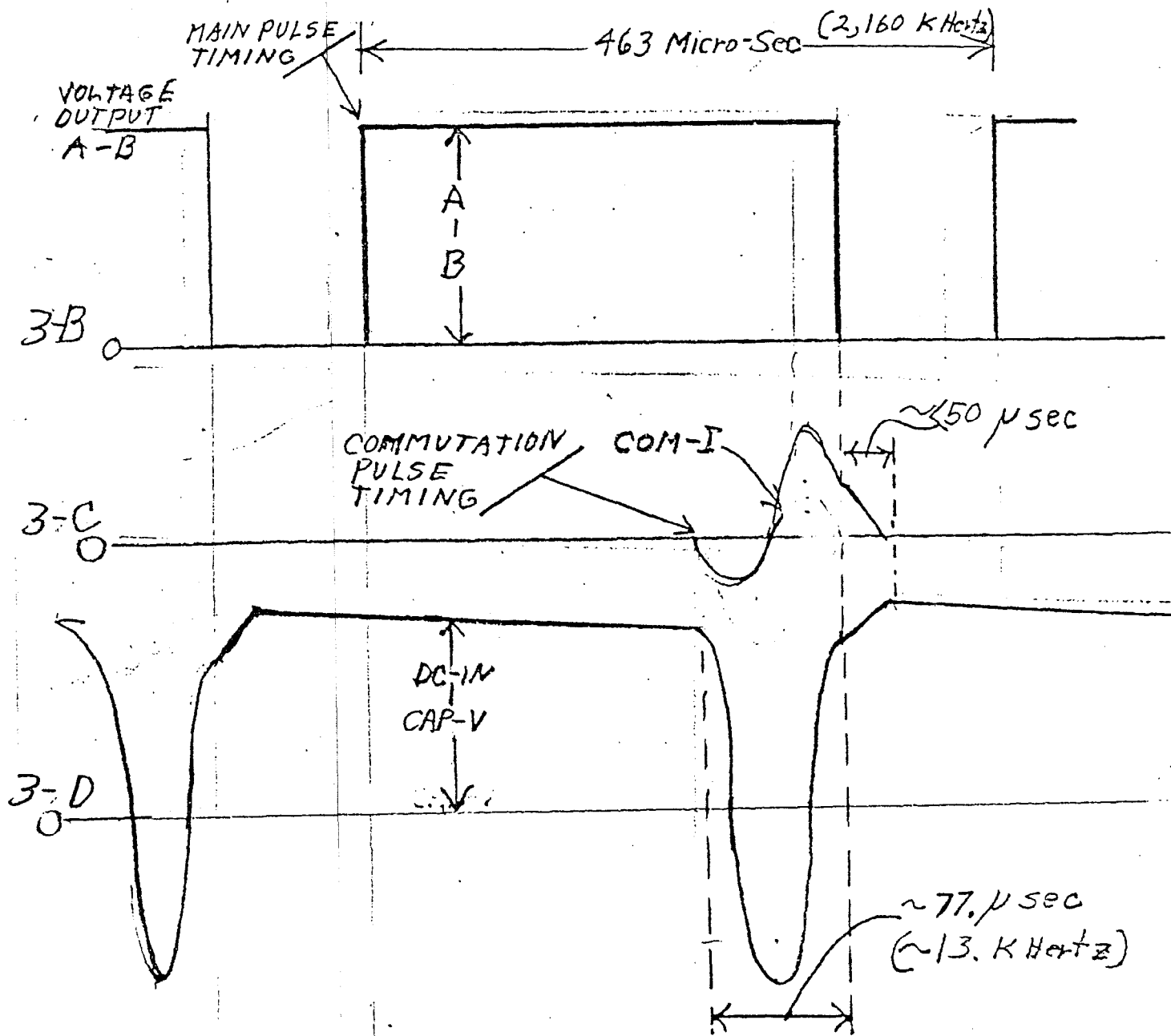
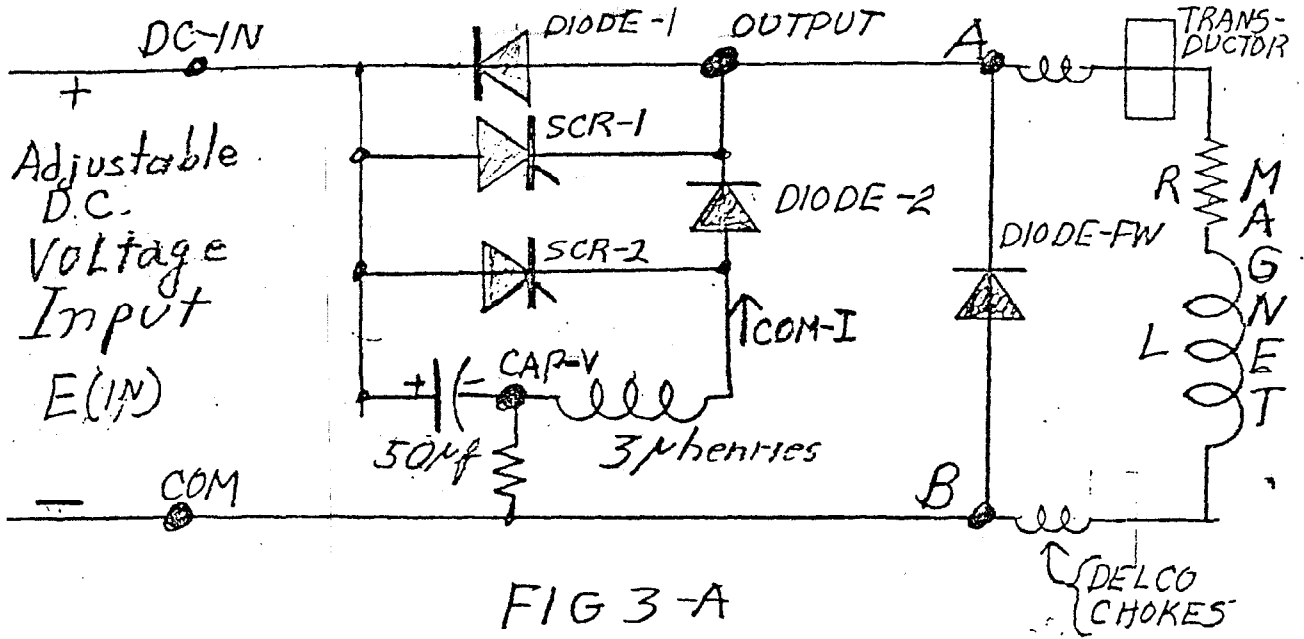
Typical Output
6-phase bridge
Rectifier

FIGURE 1



Typical Output
OF CHOPPER.

FIGURE 2



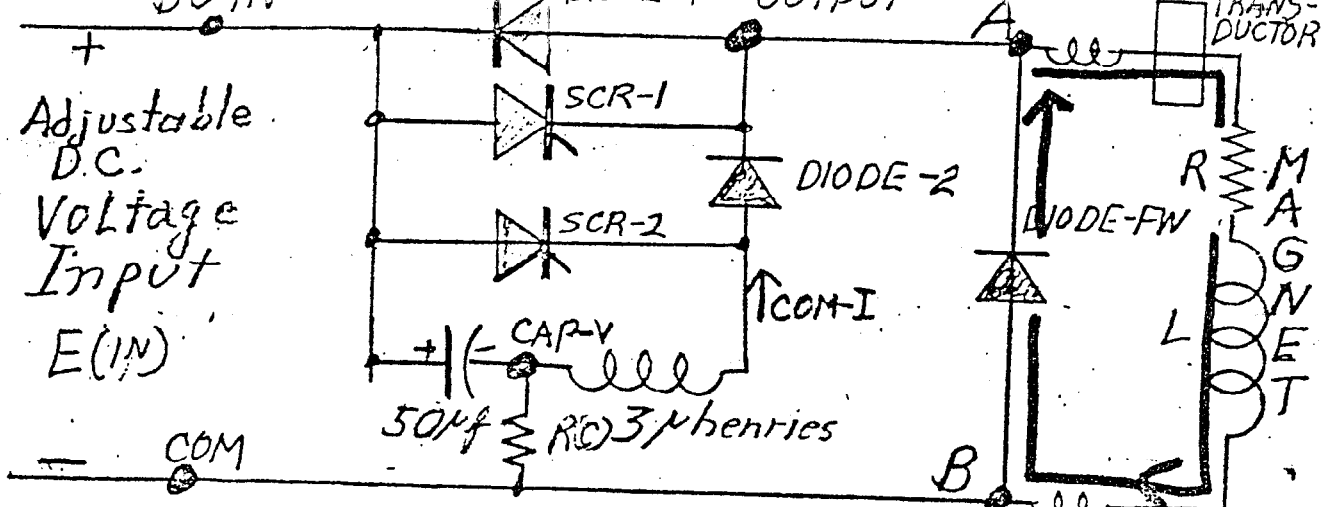
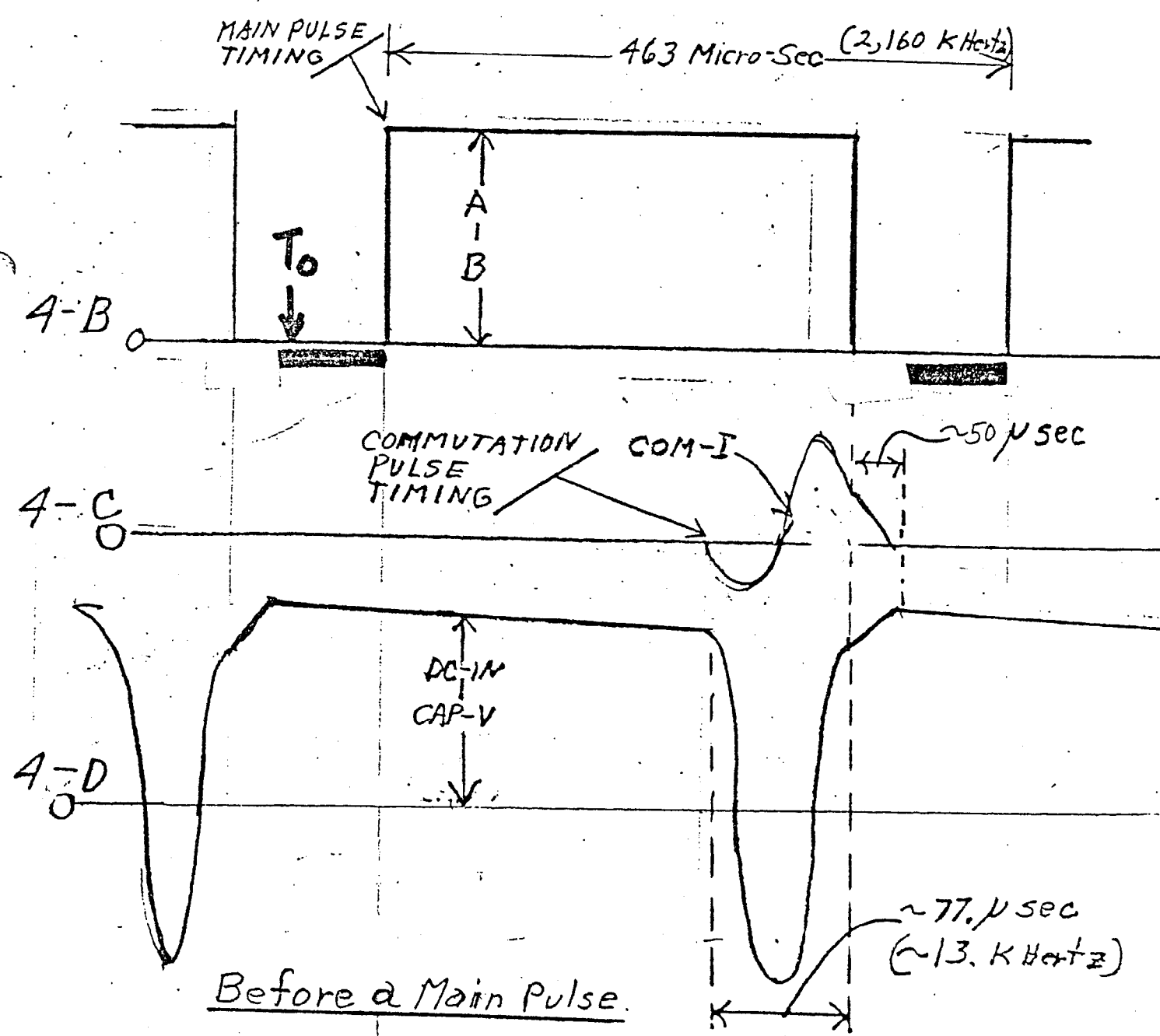


FIG 4-A



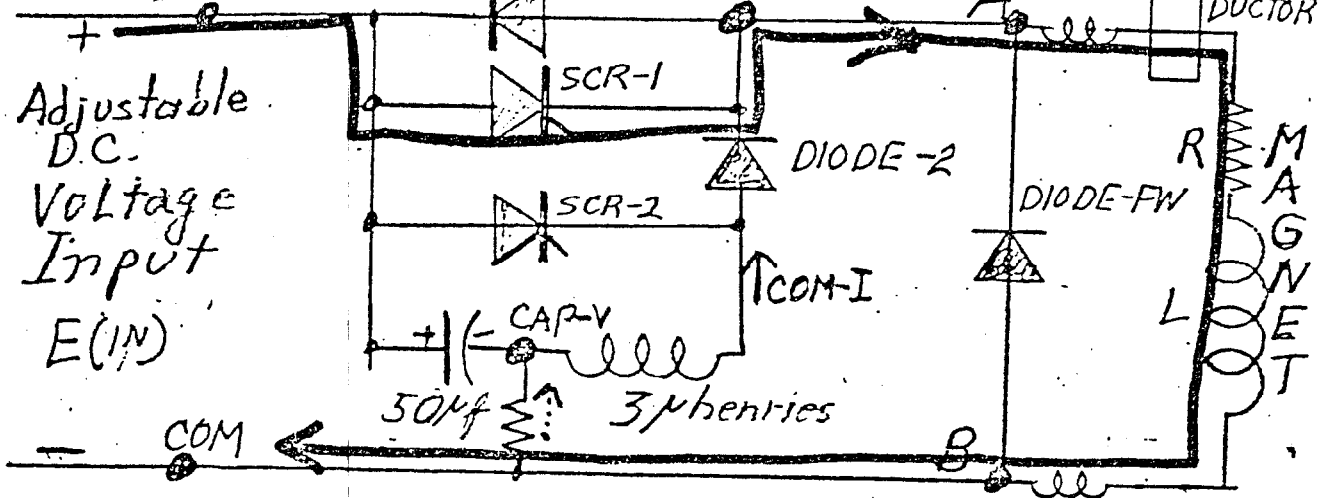
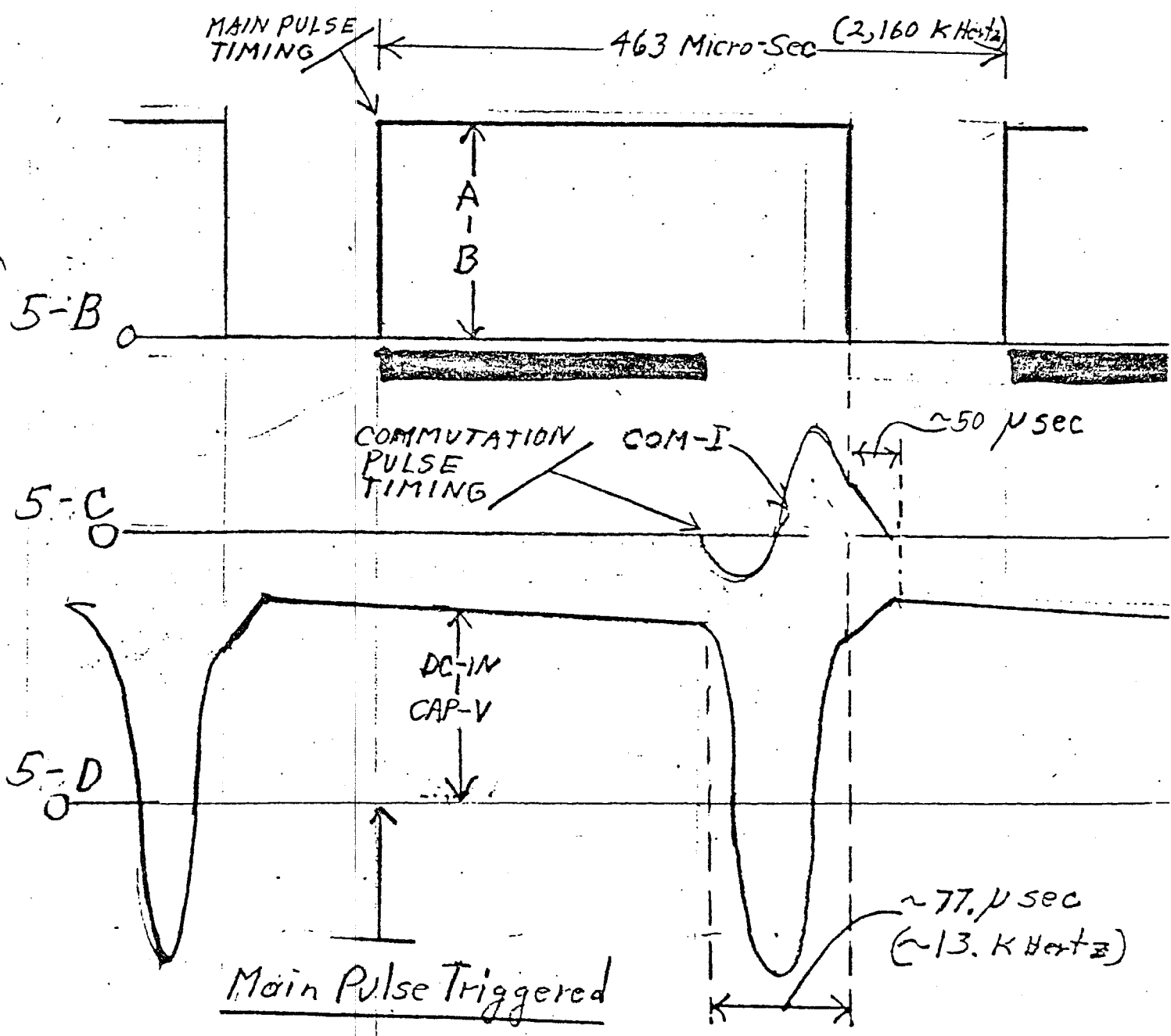


FIG 5-A



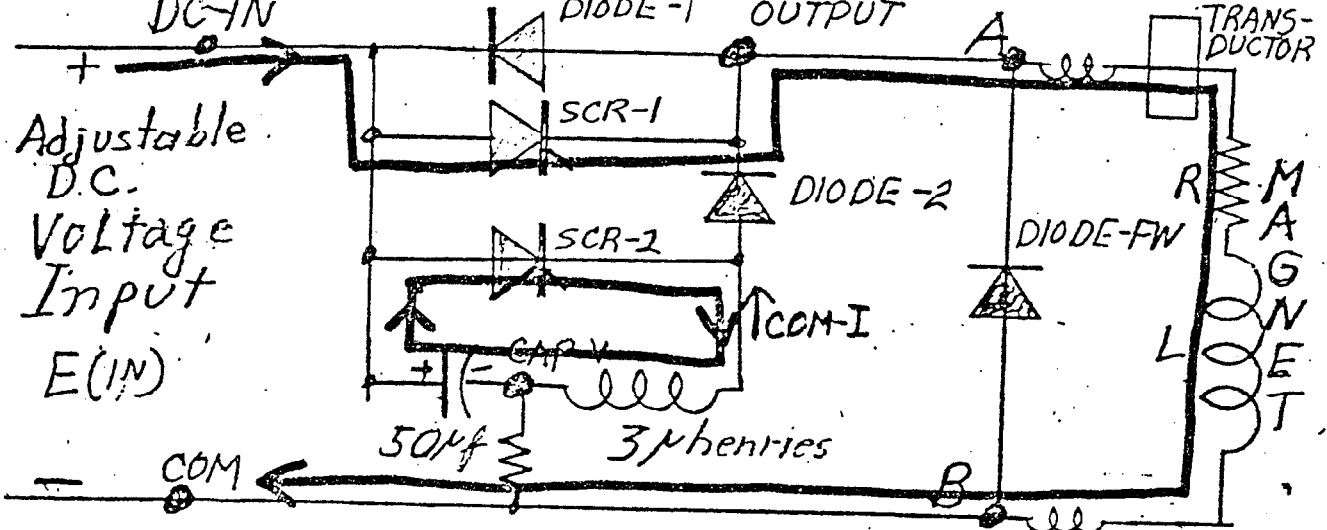
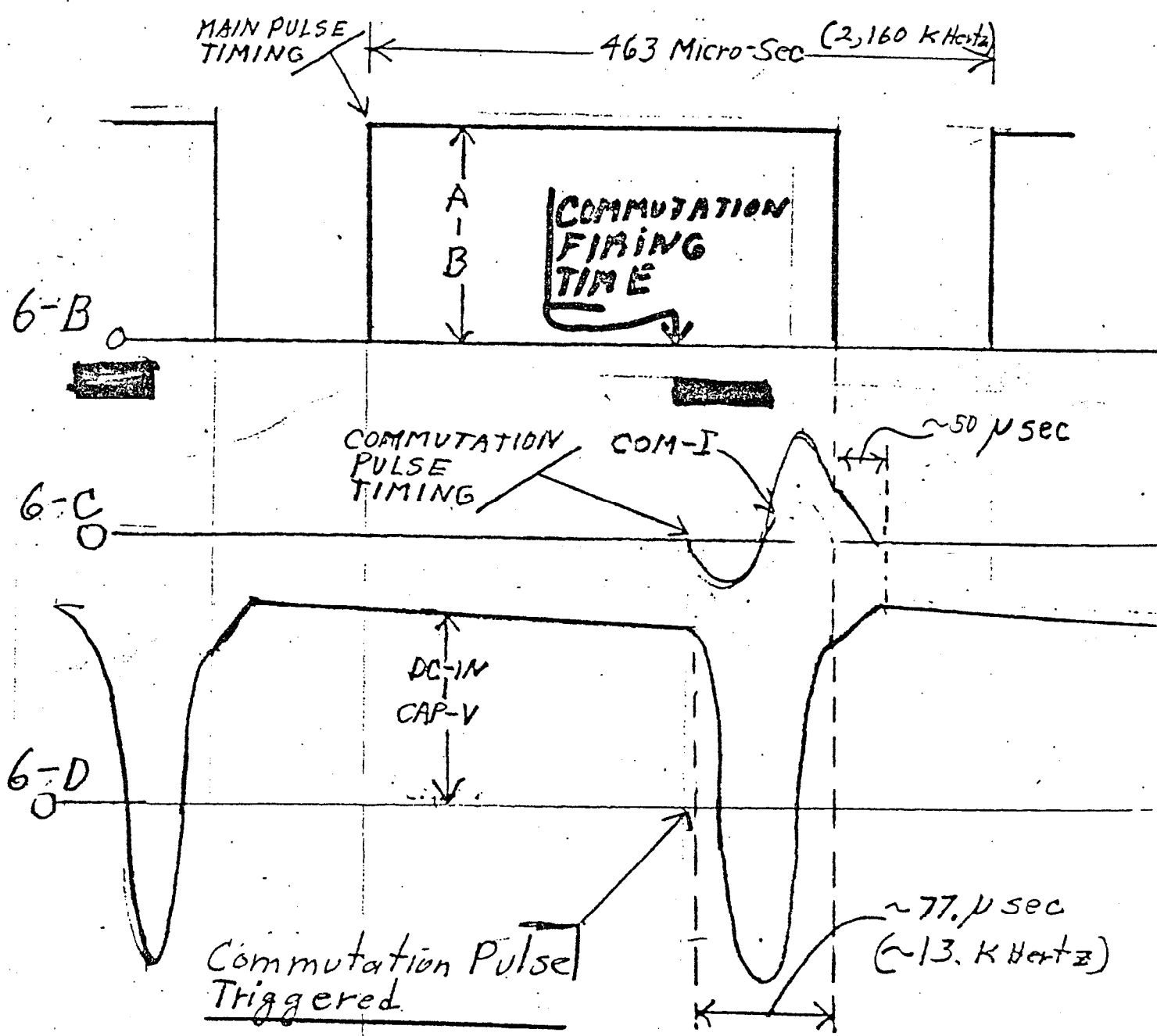


FIG 6-A



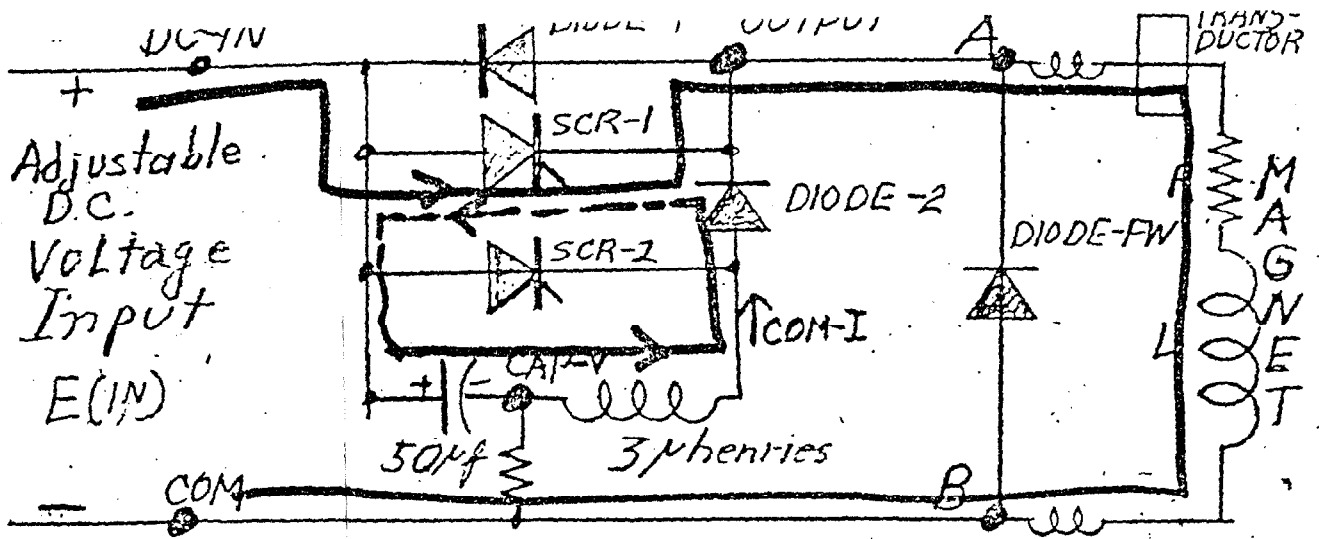
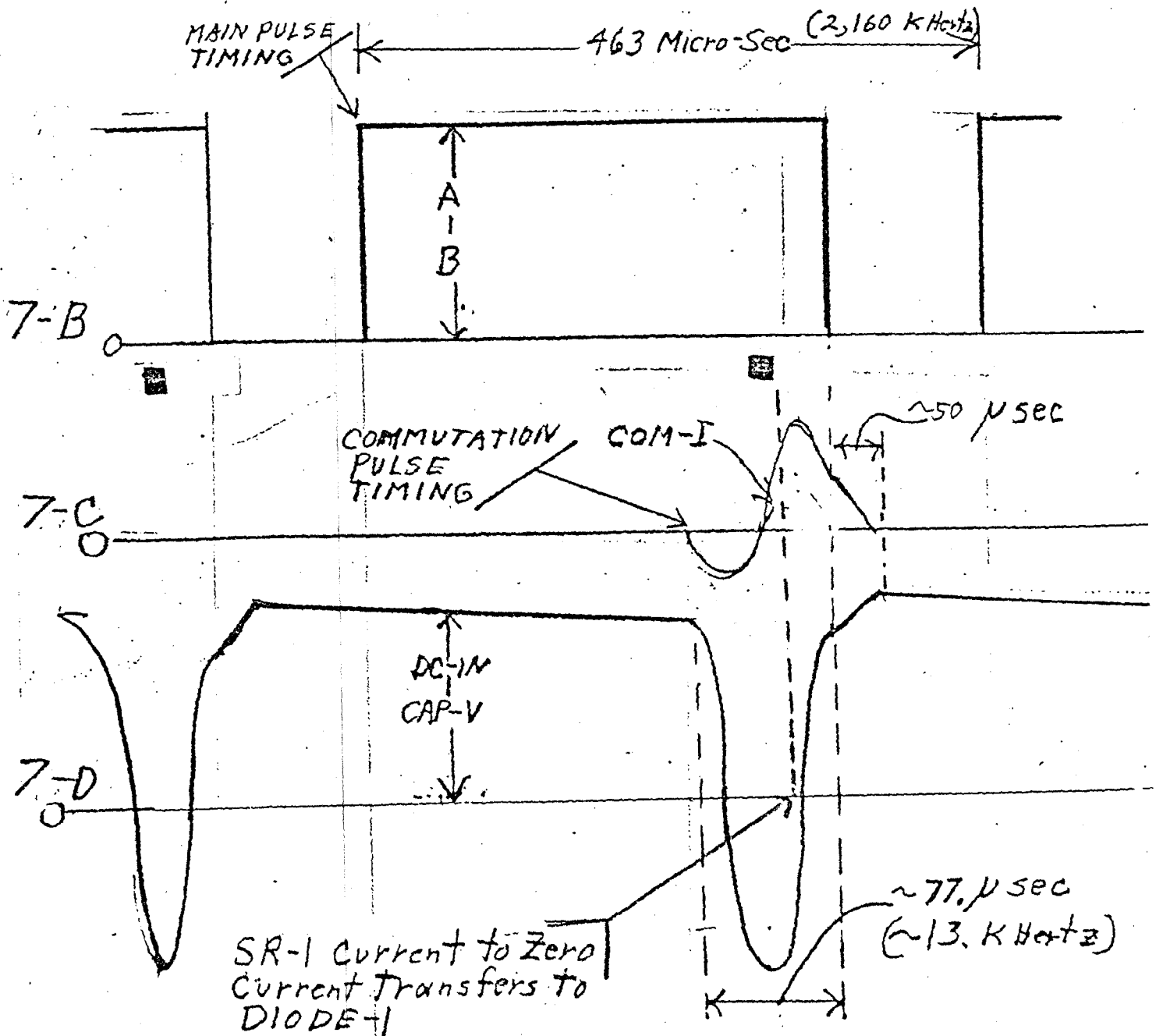
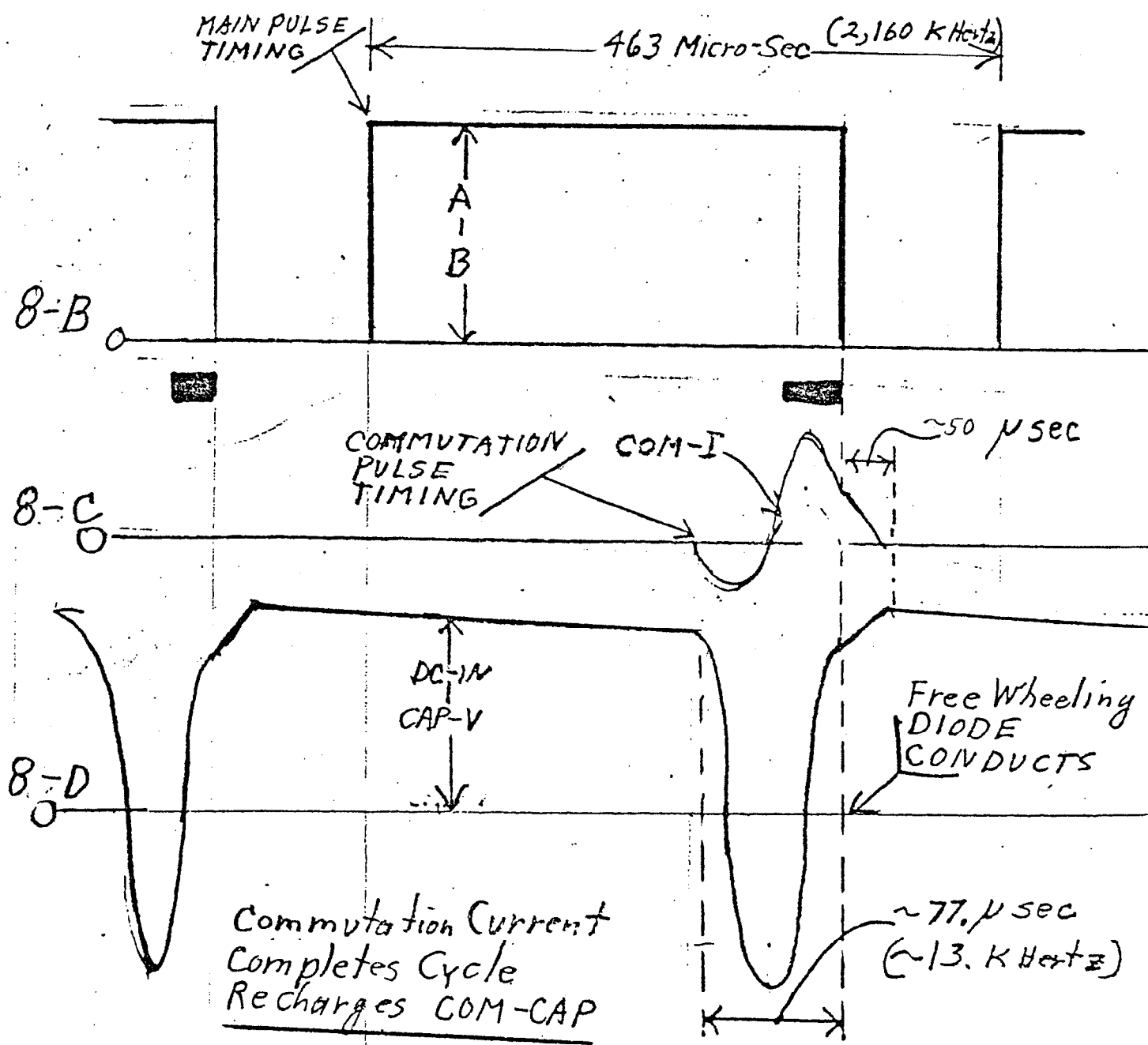
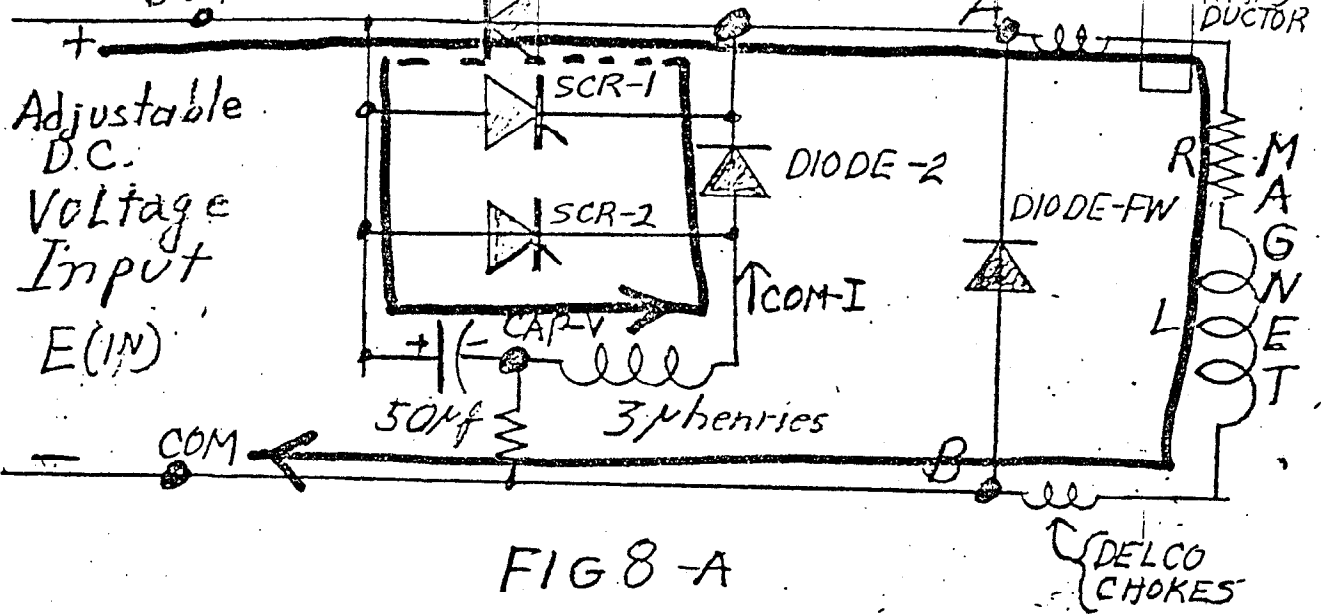


FIG 7-A





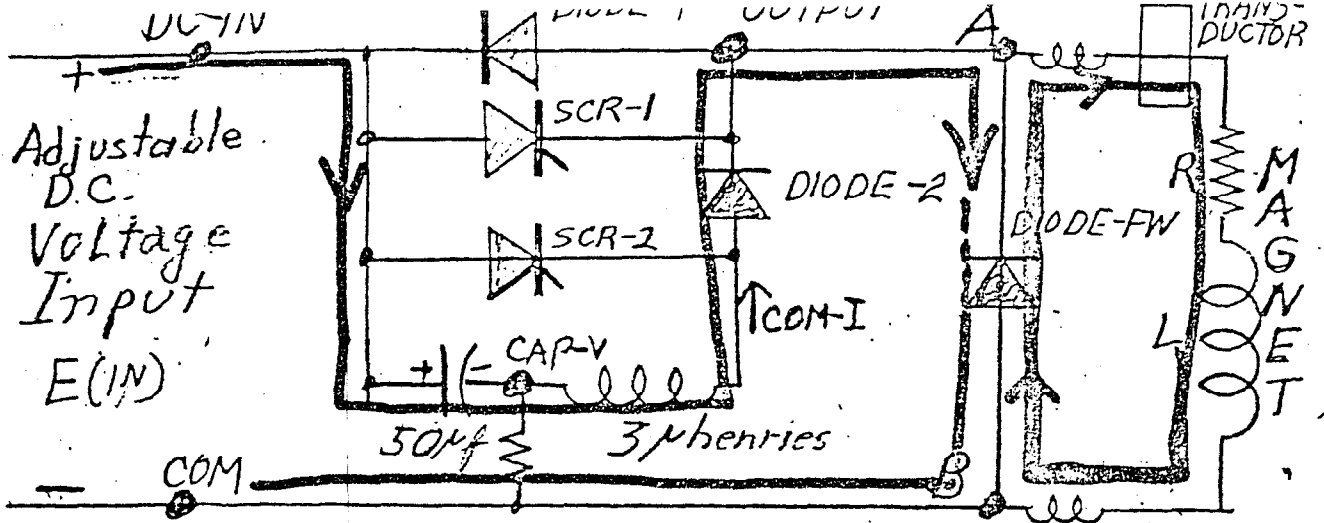
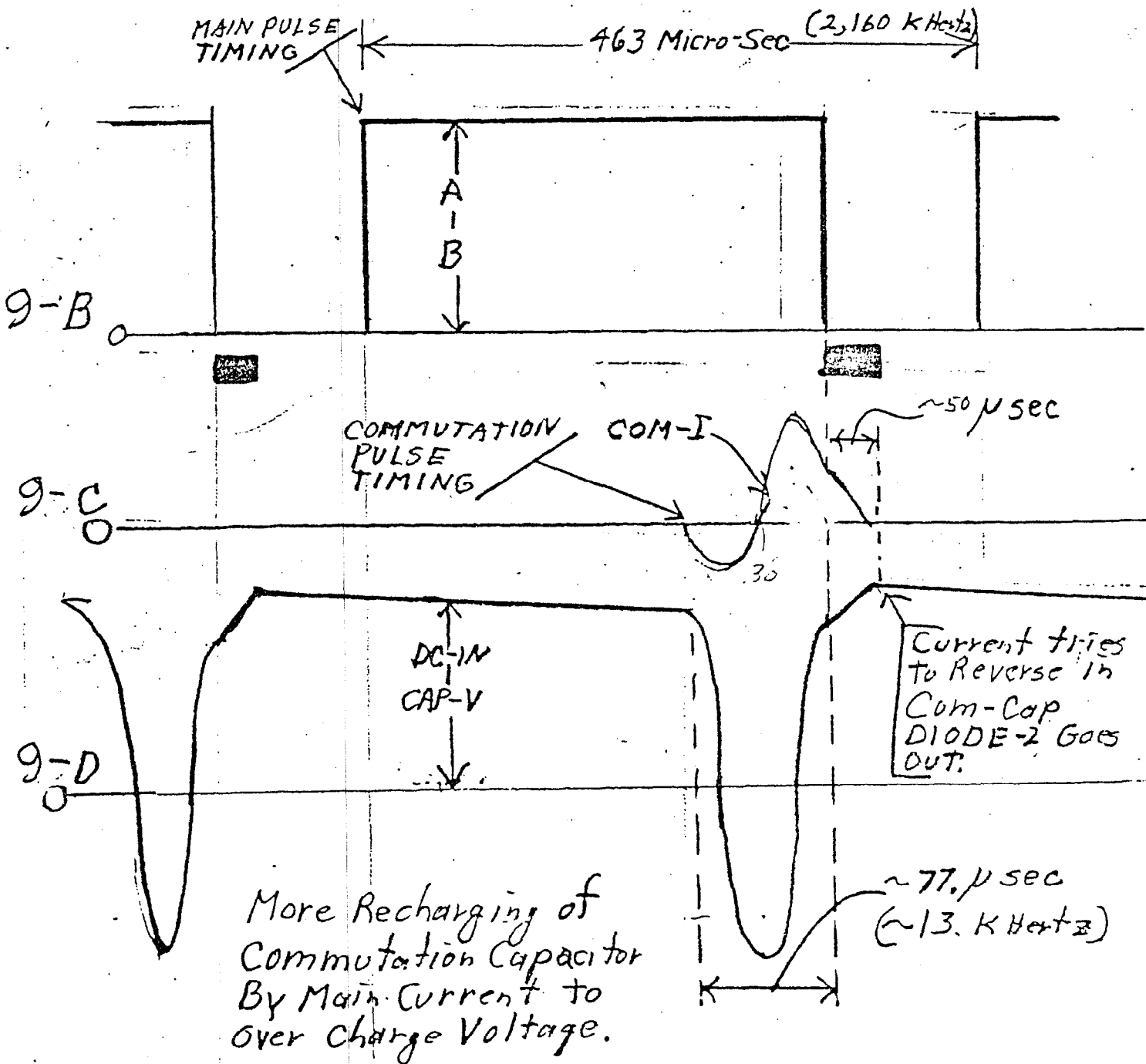


FIG 9-A

DELCO CHOKES



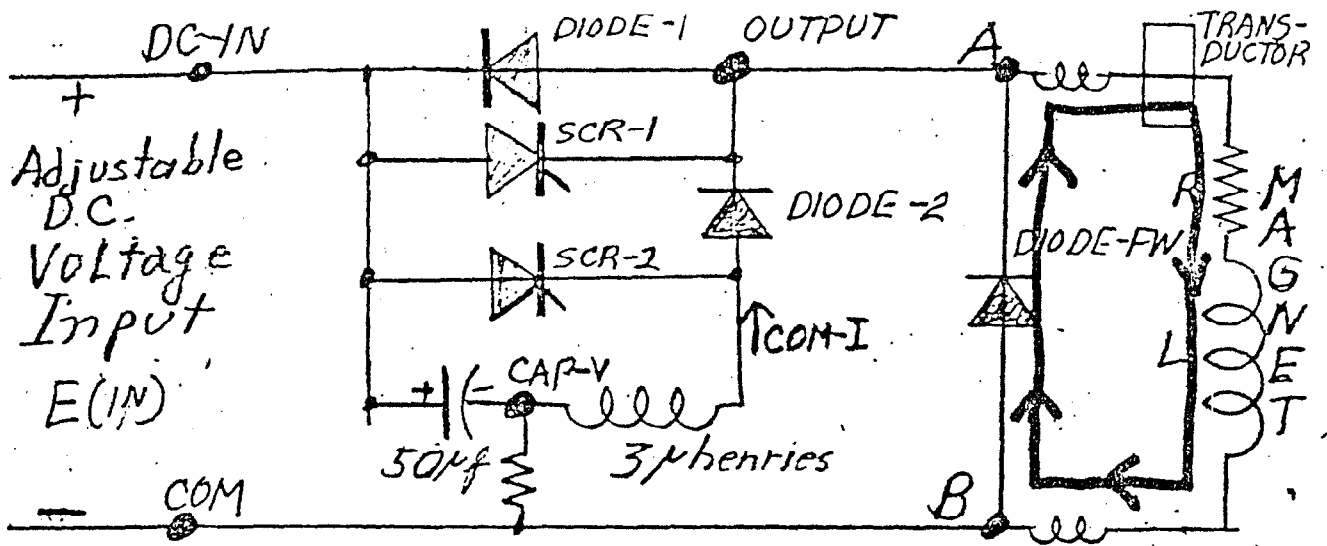
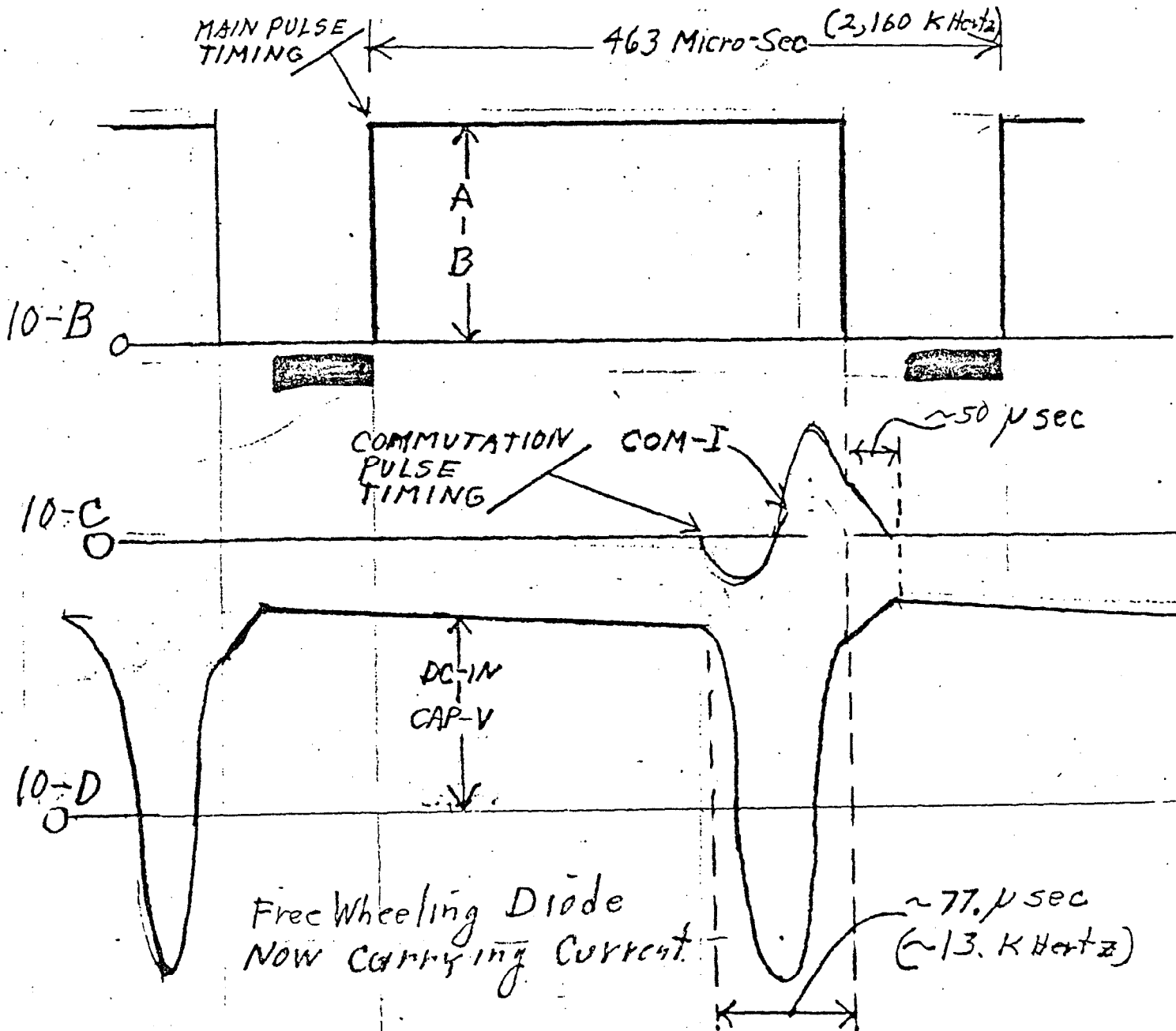


FIG 10-A



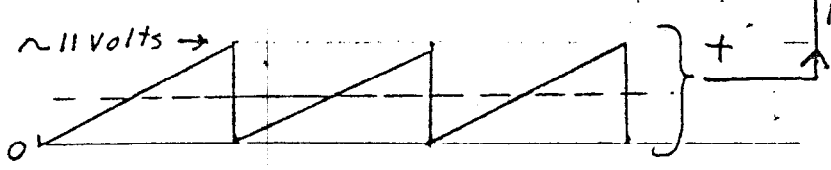
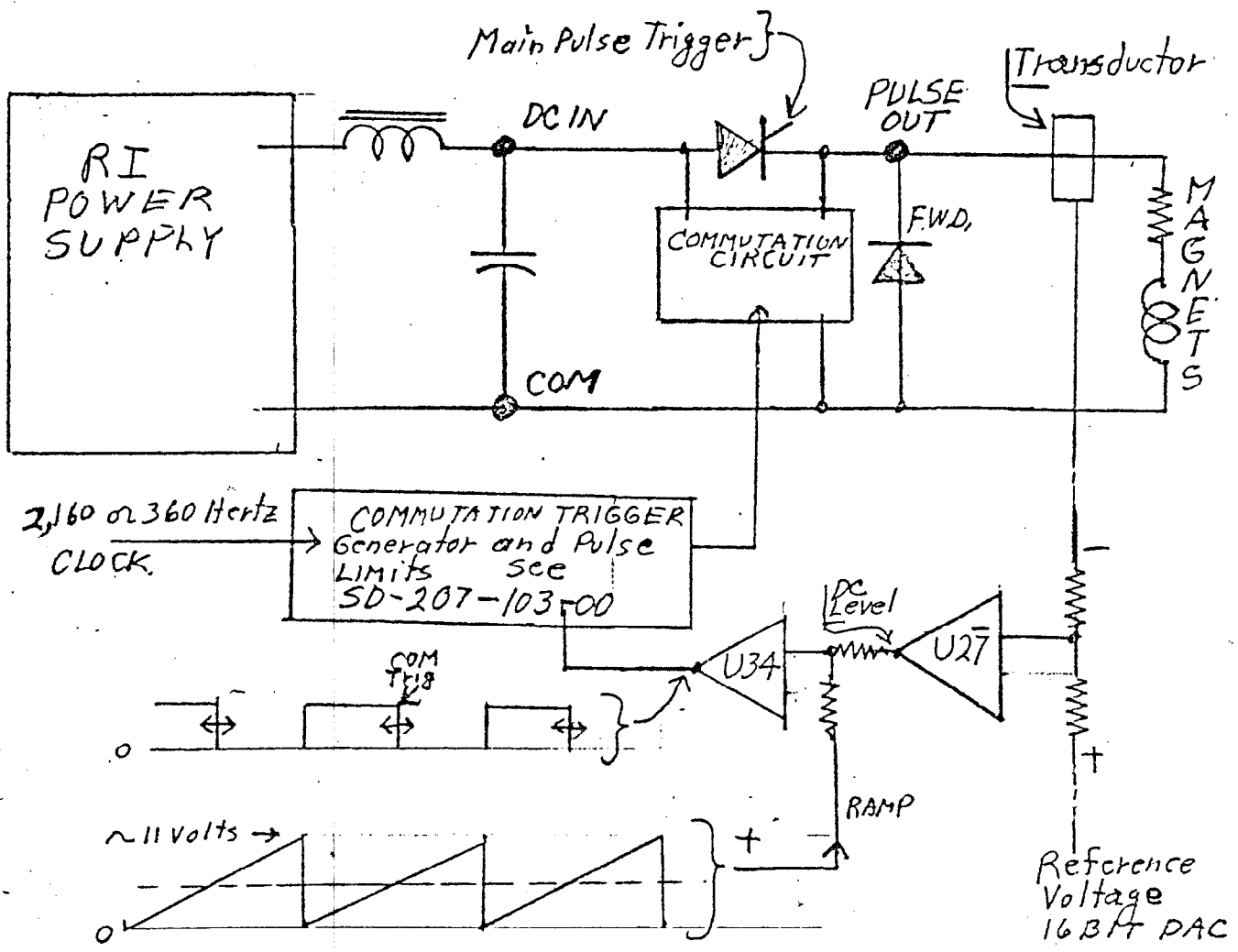


FIGURE 11

Timing of Main pulse

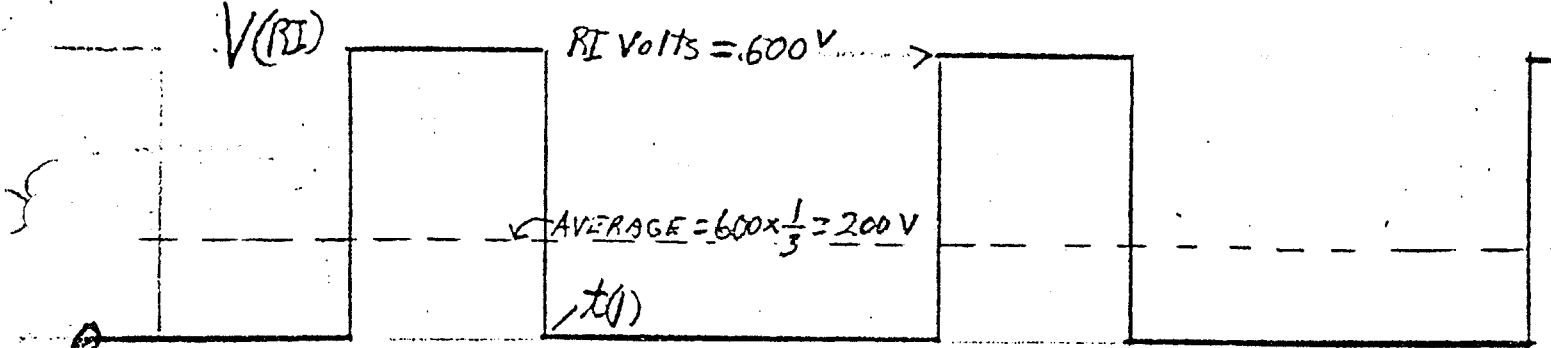
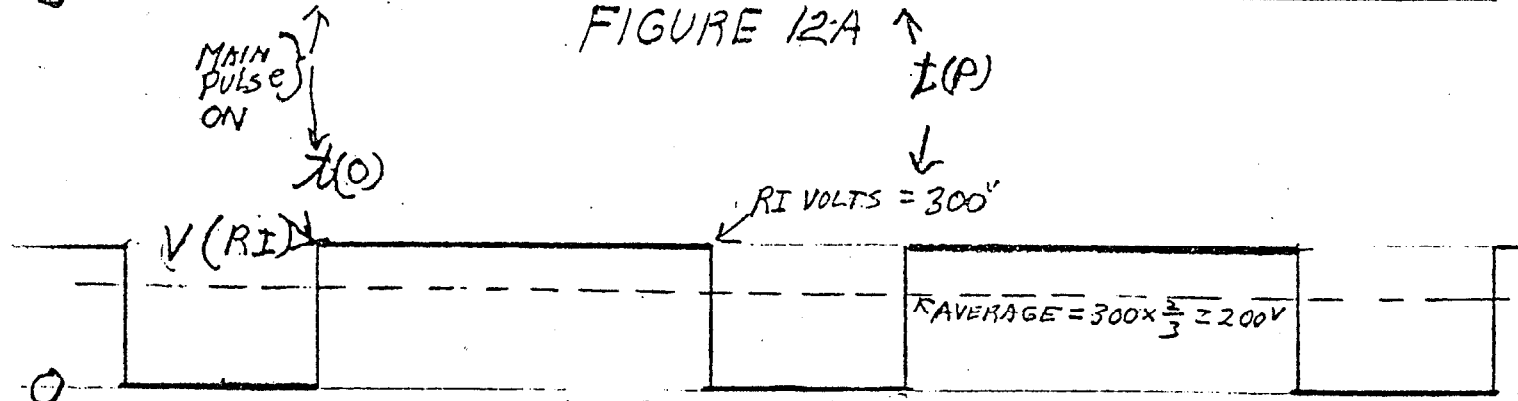
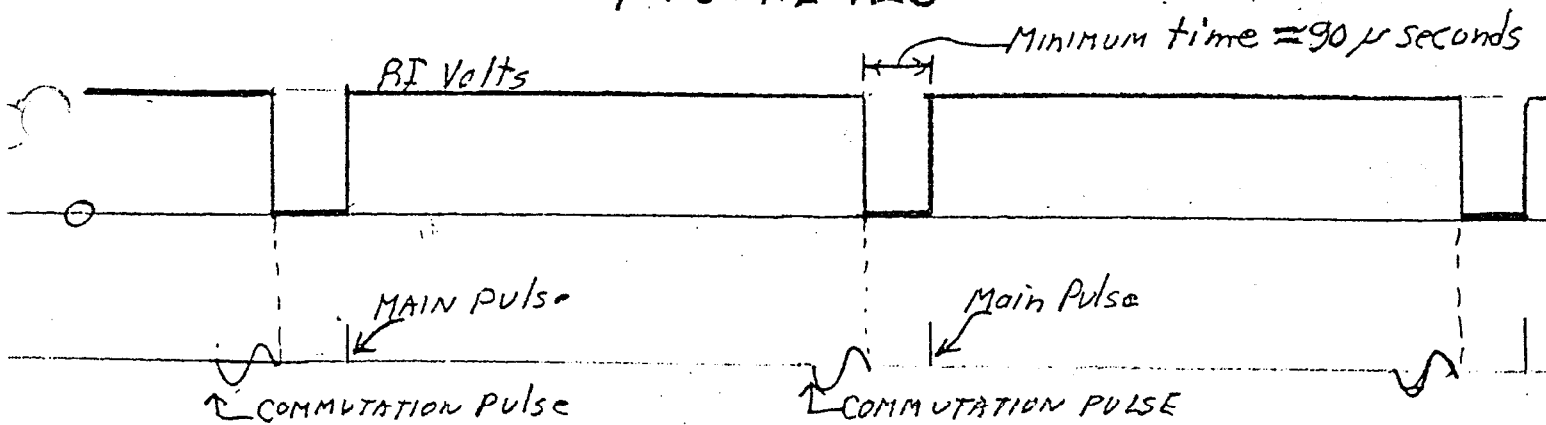


FIGURE 12A



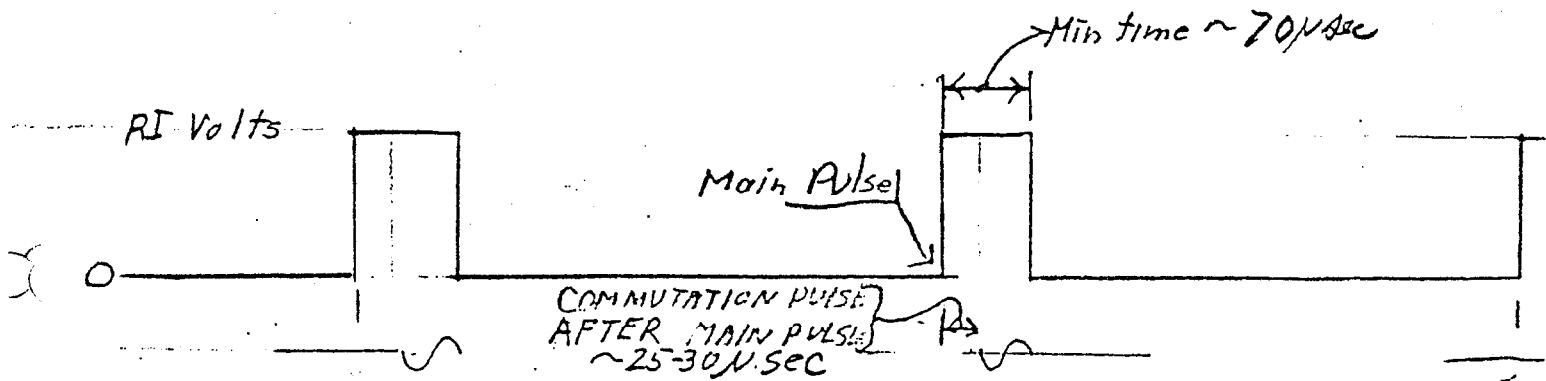
$$AVERAGE = V(PI) \times \frac{t(1)}{t(P)}$$

FIGURE 12B



PULSE TIMING FOR MAX PULSE LENGTH

FIGURE 13A



PULSE TIMING FOR MINIMUM PULSE LENGTH

FIGURE 13B

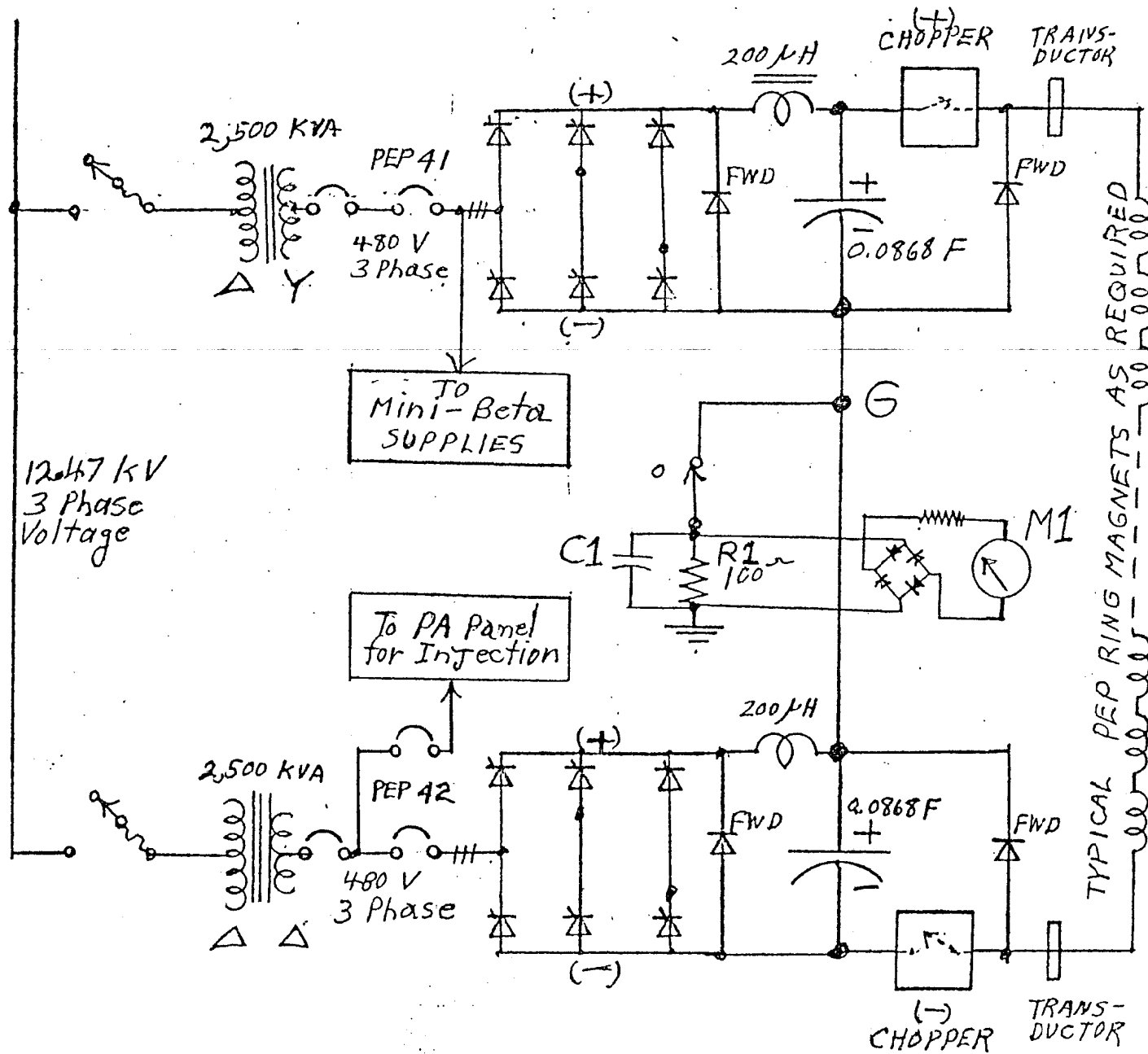


FIGURE 14

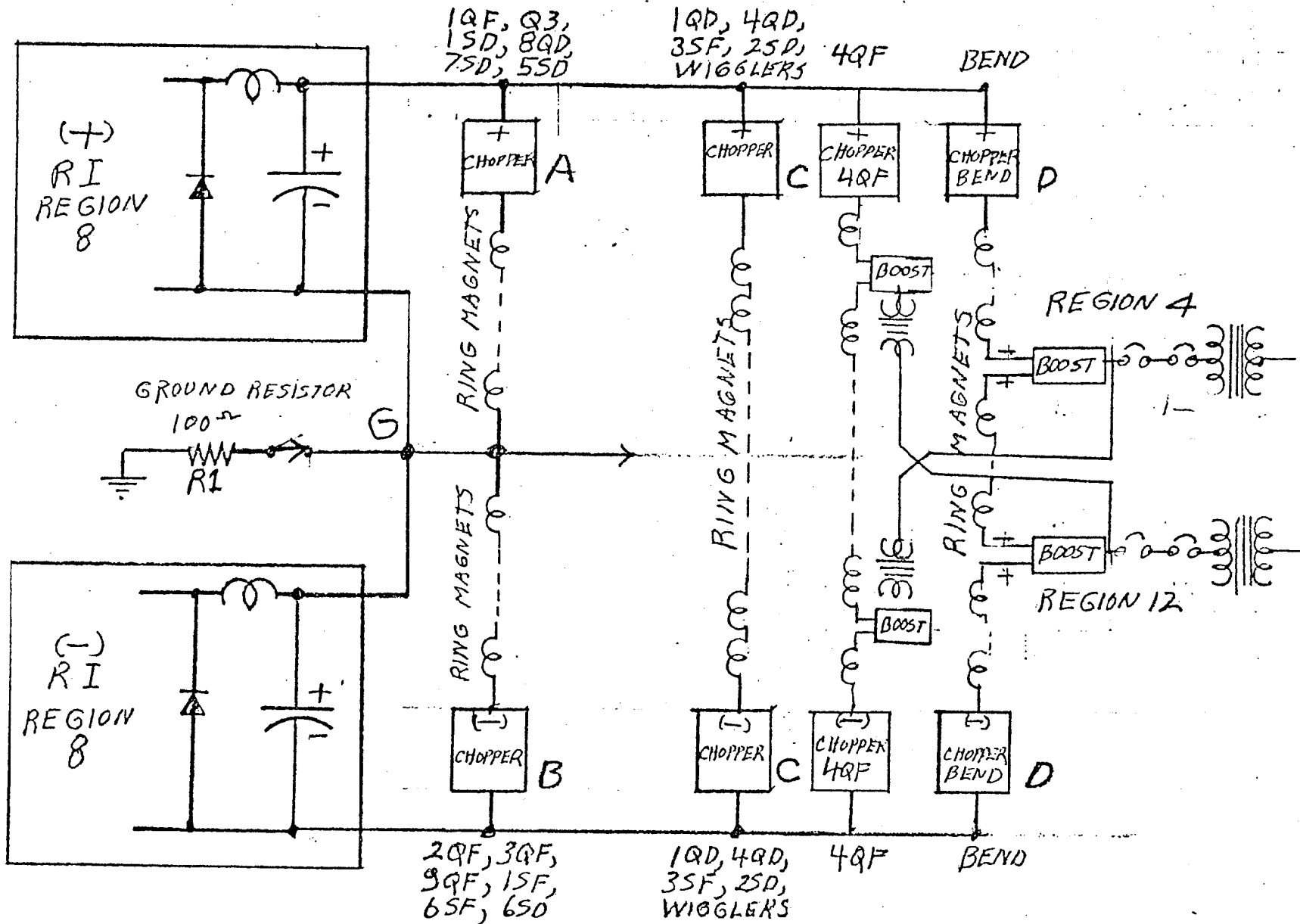
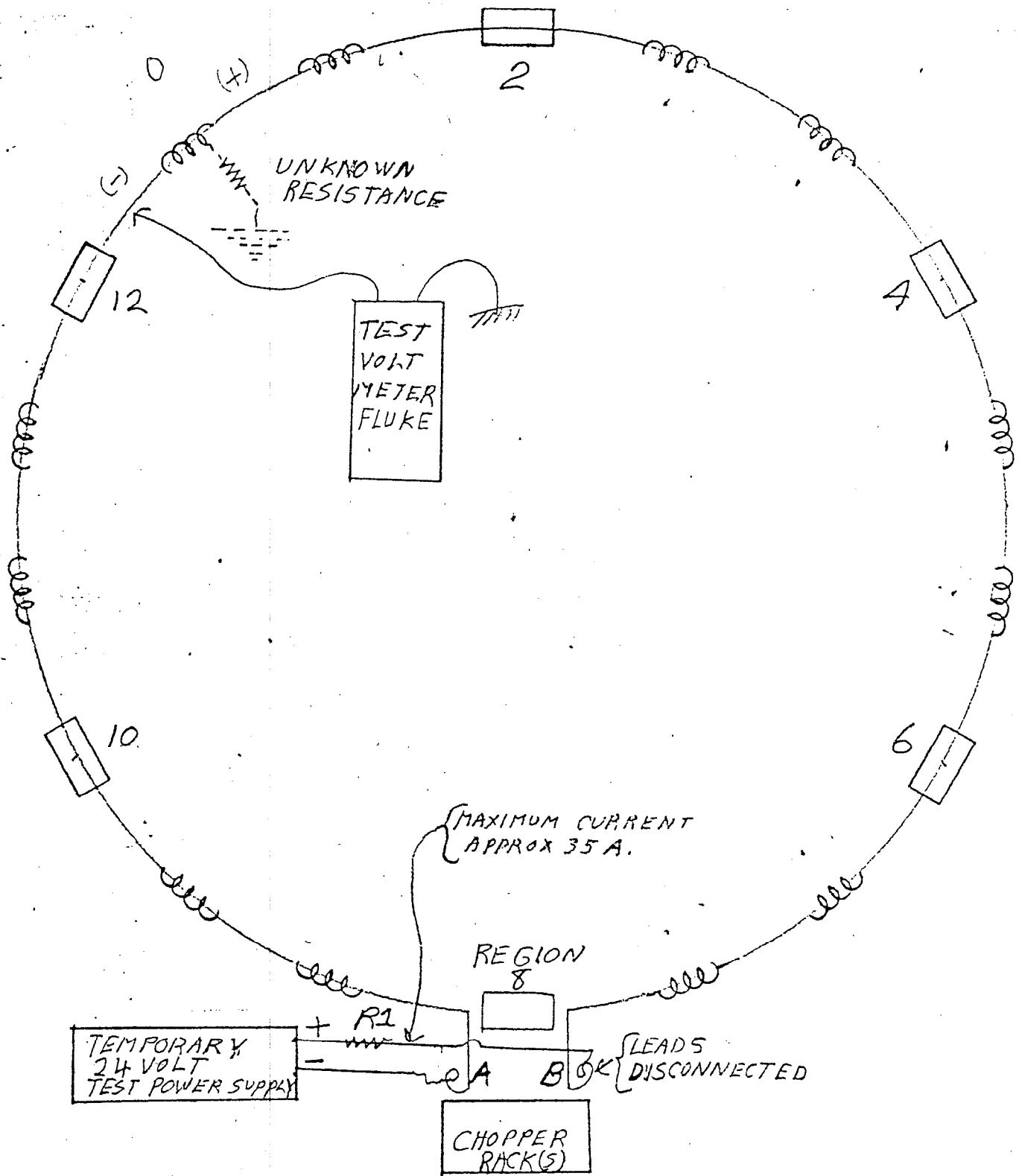
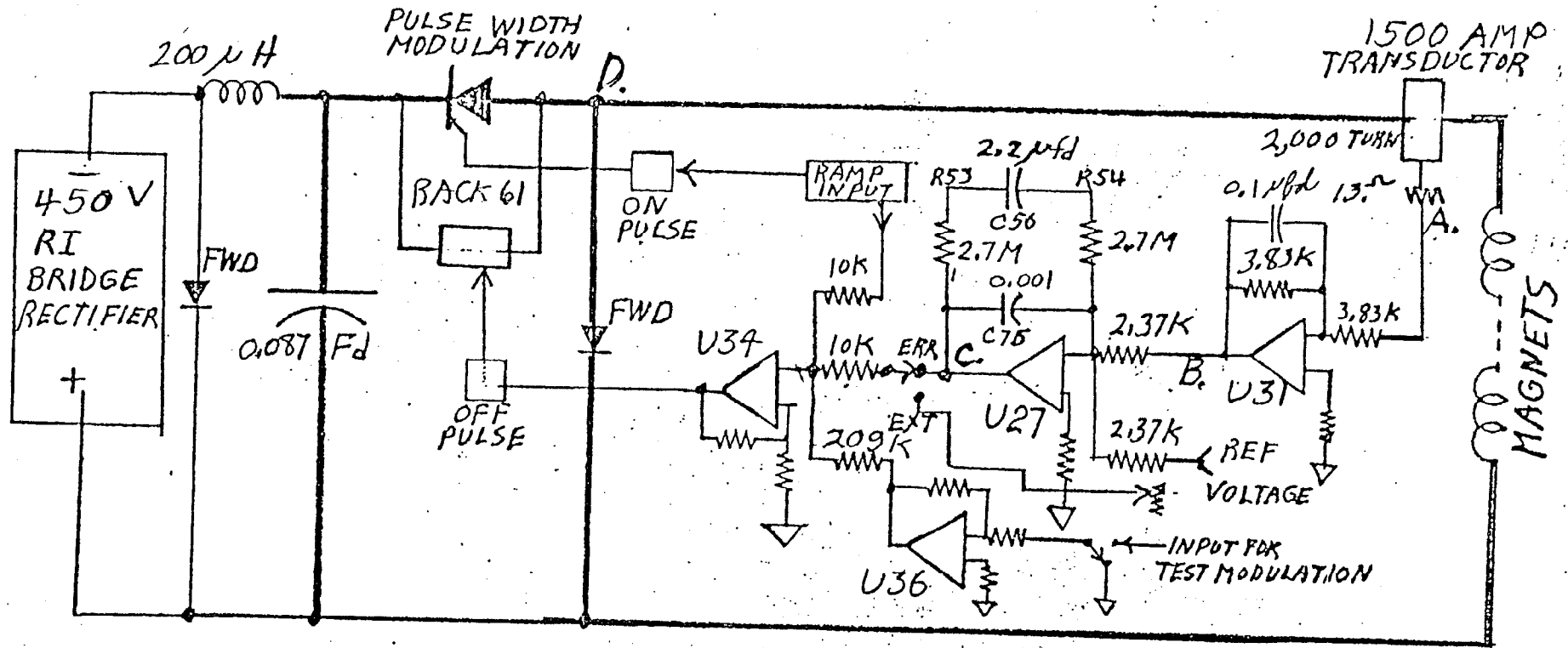


FIGURE 15



SEE PRINTS WD-207-009-001 -
 Thru WD-207-009-011
 FOR DETAILS

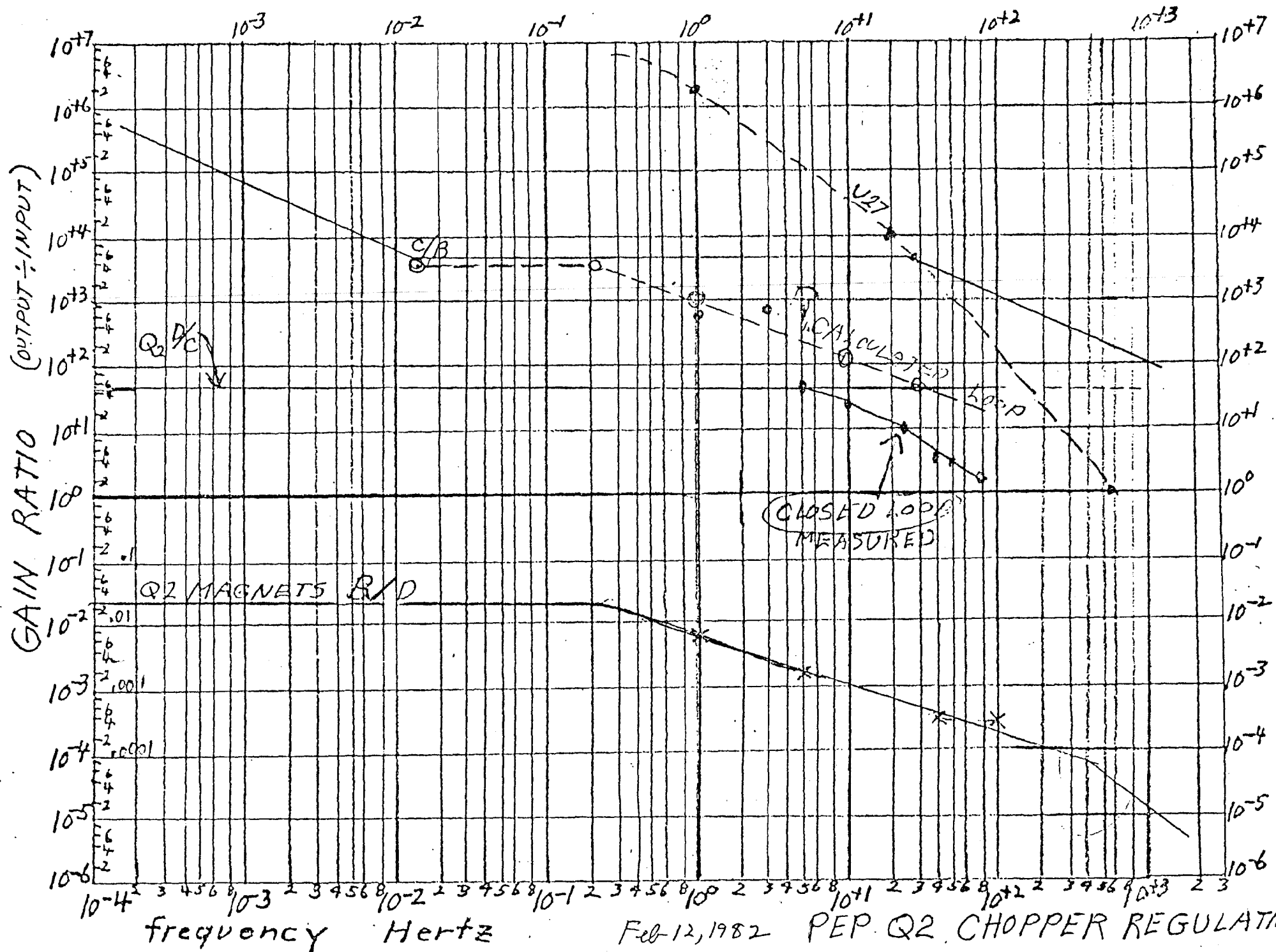
FIGURE 16



$R_{ack} = 61$
 $R_L = 0.307 \Omega$
 12 of 160 Q1500

Feb 12, 1982
 PEP Q2
 CHOPPER HF
 REGULATION

- 57 -



frequency Hertz

Feb-12, 1982

PEP Q2 CHOPPER REGULATION

```

1. .sr pubmyhs = 3
2. .sr pubmyhm = 3
3. .sr pubmytm = 7
4. .im syspub layout=manual ll=66
. .cm .wd in effect
6. .hy add ccmes
7. .hy add title
8. .hy add after
9. .hy add begin
10. .hy add semi-cclcn
11. .hy add other-wise
12. .tt 1 ///Testing of the PEP Magnet-Power-Supply Systems/
13. .tt 2 ///H. Boatner, C.A. Harris, MARCH 25, 1982 /
14. .titlepage
15. .ce * OPERATIONS MEMORANDUM * STANFORD UNIVERSITY * SLAC *
16. .ce;.up *experimental facilities department*
17. .ce;.up *power supply operations group*
18. .sp 9
19.
20. .ce;.up;TESTING OF THE PEP MAGNET-POWER-SUPPLY SYSTEMS
21. .ce;"Preliminary Report"
22.
23. .ce H. Boatner/ C.A. Harris
24. .ce MARCH 25, 1982
25. .chapter 'Introduction'
26.
27.     Saved as PEP2 on edit52
28.
29. .chapter 'Misc Information'
30.
31.     The following table shows the number of main and trim windings turns.
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Magnet System or Type	Main Winding Turns	Trim Winding Turns	Max Current Water Pres Diff 74 PSI
Q1	104	64	
Q2	104	64	
Bend	32	19+1	Trim 20 A @ 13 Volts
L.F. Bend	2	43 (vert)	
71C5400			1,487. amps
100Q1000			395.
100Q730			286. (65 C out)
100Q550			346.
120S250			546.
120S450			352.
Wiggler			545. "

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50. .chapter 'Expanding the Systems to Full Ring Operation'
51.

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.tabbegin

DBOFR 'MAIN PEP MAGNET SYSTEMS, POWER PARAMETERS Rev 8, Sept 15, 1981 C. Harris'													
THE VOLTAGES SHOWN IN THIS TABLE ARE FOR AS MEASURED LOOP RESISTANCES.													
Magnet Sys.	Cable I.D.#	Backs Used	Magnet Type	Mags Used	Magnet Basis @ 10** ⁻³ Ohms each	Bus Basis @ 10** ⁻³ Ohms Total	Total Loop Basis @ 10** ⁻³ Ohms Measur*	Run Amps	Run Volts	Run Amps	Run Volts	Run Amps	Run Volts
Q1	13,19	42/47	160Q2000	12	12.2		*	*	*	*	*	*	*
OBL	13,19	42/47	71C2700	12	0.362		*	*	*	*	*	*	*
1BL	13,19	42/47	71C2700	12	0.362		*	*	*	*	*	*	*
BENDS	13,19	42/47	71C5400	181	5.5	82.	1,372.	1,037	1,451	1,073.	1,556.	283.	410.
Q3	15	37	100Q1000	12	144.0	148.	1,757.	114	193*	122.	207.*	38.	64.*
1QF	20	136	100Q1000	12	137.6	148.	1,602.	132	222*	142.	240.*	39.	66.*
1QD	12	132/35	100Q550	136	82.5	154.	3,183.	182	561*	194.	598.*	42.	129.*
2QF	17	131	100Q1000	12	144.	148.	1,954.*	146	251*	156.	269.*	28.	48.*
3QF	11	130	100Q730	12	105.2	148.	1,415.*	184	250*	198.	269.*	35.	48.*
4QF	18	133/34	100Q730	160	105.2	160.	6,864.*	145	891*	156.	959.*	34.	209.*
4QD	3	153/54	100Q550	148	82.5	168.	4,101.*	159	637*	171.	685.*	41.	164.*
8QD	9	155	100Q730	12	105.2	148.	1,407.*	157	213*	168.	228.*	42.	57.*
9QF	21	152	100Q550	13	82.5	146.	1,137.*	110	134*	118.	144.*	29.	35.*
Q2	4	161	160Q1500	12	9.87	148.	328.*	753	231*	807.	248.*	215.	66.*
1SD	16	166	120S450	12	81.5	148.	1,114.*	30	33*	32.	36.*	20.	22.*
5SD	2	157	120S450	12	81.5	148.	1,157.*	87	96*	93.	102.*	50.	55.*
6SF	14	151	120S250	12	50.7	148.	744.*	37	27*	39.	28.*	70.	51.*
6SD	6	150	120S450	12	81.5	148.	1,137.*	91	101*	98.	108.*	80.	88.*
7SD	1	156	120S450	12	81.5	148.	1,162.*	174	194*	186.	206.*	80.	88.*
3SF	8	162/65	120S250	160	50.7	161.	3,152.*	122	373*	130.	397.*	30.	92.*
2SD	10	163/64	120S250	148	50.7	157.	2,571.*	113	280*	120.	298.*	35.	87.*
BW	5	160/67	Wiggler	3	250.	144.	900.*	34	31*	34.	31.*	400.	360.*
9SF	7	122 HP	120S250	12	50.7	148.	756.*	??	??*	?.	??*	???	???
1SF			120S250	12	NOT	CONNECTED TO A.*WATER COOLED LOOP							*

(1) Aluminum round water cooled bus @ 20.38 X 10**⁻⁶ Ohms/foot @ 20 degrees C.
(2) Bends use 2 of 500MCM in parallel for jumpers; @ 0.0222 ohms/ 1,000 ft. 8 1/2 feet per magnet.
(3) Quads and Sextapoles use 250MCM for jumpers; @ 0.0444 ohms/ 1,000 ft. Ten feet per magnet.
(4) One loop around the ring is 6,575 feet long.

112. .tabend

113. .tablegin
 114. .table DISCPM 'MAIN PEP MAGNET SYSTEMS , POWER PARAMETERS Rev 7, Sept 15, 1981 C. Harris'
 115. THE VOLTAGES SHOWN IN THIS TABLE ARE FOR AS MEASURED LOOP RESISTANCES.
 116.

Magnet Sys.	Cable I.L.#	Racks Used	Magnet Type	Mags Used	Magnet Basis X 10 ⁺⁻³	Bus Resis Ohms Total	Total Loop Resis 10 ⁺⁻³ Measur	Run Amps	Run Volts	Run Amps	Run Volts	Run Amps	Run Volts	Run Amps	Run Volts
Q1	13,19	42/47	160Q2000	12	12.2		*	*	*	*	*	*	*	*	*
OBL	13,19	42/47	71C2700	12	0.362		*	*	*	*	*	*	*	*	*
IBL	13,19	42/47	71C2700	12	0.362		*	*	*	*	*	*	*	*	*
BENDS	13,19	42/47	71C5400	181	5.5	82.	1,372.*	1,365	1,979*	786.	1,140.*	283.	410.*		
Q3	15	37	100Q1000	12	144.0	148.	1,757.*	204	346*	90.	153.*	38.	64.*		
QF	20	36	100Q1000	12	137.6	148.	1,602.*	247	416*	104.	175.*	39.	66.*		
QD	12	32/35	100Q550	36	82.5	154.	3,183.*	250	771*	144.	444.*	42.	126.*		
QF	17	31	100Q1000	12	144.	148.	1,954.*	236	406*	114.	196.*	28.	48.*		
QF	11	30	100Q730	12	105.2	148.	1,415.*	253	344*	144.	196.*	35.	48.*		
QF	18	33/34	100Q730	160	105.2	160.	16,864.*	215	1,321*	114.	701.*	34.	209.*		
QD	3	153/54	100Q550	48	82.5	168.	4,101.*	214	857*	124.	497.*	41.	165.*		
QD	9	155	100Q730	12	105.2	148.	1,407.*	218	296*	123.	167.*	42.	57.*		
QD	21	152	100Q550	113	82.5	146.	1,137.*	155	189*	87.	106.*	29.	35.*		
QF	4	161	160Q1500	12	9.8	148.	328.*	968	297*	591.	181.*	215.	66.*		
SD	16	166	120S450	12	81.5	148.	1,114.*	350	390*	23.	26.*	20.	22.*		
SD	2	157	120S450	12	81.5	148.	1,157.*	216	238*	67.	74.*	50.	55.*		
SD	14	151	120S250	12	50.7	148.	744.*	404	292*	27.	20.*	70.	51.*		
SD	6	150	120S450	12	81.5	148.	1,137.*	404	447*	70.	77.*	80.	88.*		
SD	1	156	120S450	12	81.5	148.	1,162.*	404	450*	133.	148.*	80.	89.*		
SF	8	162/65	120S250	160	50.7	161.	3,152.*	243	743*	102.	312.*	30.	92.*		
SD	10	163/64	120S250	148	50.7	157.	2,571.*	244	606*	98.	243.*	35.	87.*		
SW	5	160/67	Wiggler	3	250.	144.	900.*	000	000*	275.	248.*	400.	360.*		
SF	7	122 HP	120S250	12	50.7	148.	756.*	90	82*	5.	4.5*	00.	0.0*		
1SF			120S250	12	NC1	CONNECTED TO A. WATER COOLED LOOP									

117. (1) Aluminum round water cooled bus 2 20.38 X 10⁺⁻⁶ ohms/foot @ 20 degrees C.
 118. (2) Bends use 2 of 500MCM in parallel for jumpers; @ 0.0222 ohms/ 1,000 ft. 8 1/2 feet per magnet.
 119. (3) Quads and Sextapoles use 250MCM for jumpers; @ 0.0444 ohms/ 1,000 ft. Ten feet per magnet.
 120. (4) One loop around the ring is 6,575 feet long.
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	SOUTH INJECTION MAGNETS*						June 8, 1980
	Magnet System	Power Supply Location	Reference Prints	Cable Size	Loop Ohms	Nominal Amps	Nominal Volts
173.	.tabbegin						
174.	.table SIM 'SOUTH INJECTION MAGNETS'						
175.							
176.							
177.	----- ----- ----- ----- ----- -----						
177.						-14.5GeV-	
178.	40B1	Sec 30	ID-308-515-41			740.	13.6
179.							
180.	40B2	Sec 30	ID-308-515-41			798.	
181.							
182.	41B3	Sec 30	ID-308-515-41			794.	19.6
183.	41B4	"	" "			"	19.1
184.	41B5	"	" "			"	18.5
185.							
186.	41B6	Sec 30	ID-308-515-41			795.	18.8
187.	41B7	"	" "			"	19.9
188.	41B8	"	" "			"	19.3
189.	41B9	"	" "			"	20.1
190.							
191.	41QD1	Sec 30	ID-308-515-40			87.3	80.
192.	41QF2	"	" "			"	
193.	41QD3	"	" "			"	
194.	41QF4	"	" "			"	
195.	41QD5	"	" "			"	
196.	41QF6	"	" "			"	
197.	41QD7	"	" "			"	
198.	41QF8	"	" "			"	
199.							
200.	41QD9	Sec 30	ID-308-515-40			87.3	110.
201.	41QF10	"	" "			"	
202.	41QD11	"	" "			"	
203.	41QF12	"	" "			"	
204.	41QF14	"	" "			"	
205.	41QD15	"	" "			"	
206.	41QF16	"	" "			"	
207.							
208.	.tabend						

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209. .tabbegin
210. .table SIMcon 'SOUTH INJECTION MAGNETS, PART 2'
211.
212. Magnet Power Supply Reference Cable Loop Nominal Nominal
213. System Location Prints Size Ohms Amps Volts
214. |-----|-----|-----|-----|-----|-----|-----|
215. 41QD13 Sec 30 ID-308-515-40
216.
217. 41QD17 Sec 30 ID-308-515-40
218.
219. 41BVA Sec 30 105. 19.
220.
221. 41BV1 Sec 30 ID-308-515-41
222. 41BV2 Sec 30 ID-308-515-41
223. 41BV3 Sec 30 ID-308-515-41
224. 41BV4 Sec 30 ID-308-515-41
225. 41BV5 Sec 30 ID-308-515-41
226. 41BV6 Sec 30 ID-308-515-41
227.
228. E. F. S. Gate
229.
230. 41QF18>>24 C8CM25 ID-308-515-40 3/0 0.83 ? 100. 83.
231. 41QD19>> 3/0 100.
232. 41QF20>> 3/0 100.
233. 41B10 C8CM10 ID-308-515-41 2X250M 0.018 784. 14.1
234. 41QD21>> 3/0 100.
235. 41BH1 C8CM26-31 ID-308-515-41 #6 AWG 1.0 20. 20.
236. 41QF22>> 3/0 100.
237. 41BV7 C8CM27-29 ID-308-515-41 #6 AWG 0.9 20. 18.
238. 41QD23>> 3/0 100.
239. 8EBM4 C8CM27-25 ID-308-515-41 #2 AWG 0.8 60. 48.
240. 41BH2 C8CM26-29 ID-308-515-41 #6 AWG 1.0 20. 20.
241. 41QF24>> 3/0 100.
242. 8EBM3 C8CM27-27 ID-308-515-41 #2 AWG 0.9 60. 54.
243. 41B11 C8CM11 ID-308-515-41 2X250MC 0.02 508. 10.2
244. 8EBM2 C8CM09 ID-308-515-41 #2 AWG 0.49 100. 49.
245. 8EBM1 C8CM26-27 ID-308-515-41 #2 AWG 0.5 60. 30.
246.
247. .tabend
248.
249. .chapter 'Testing of the Injection Magnets, NIT'
250.

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							June 8, 1980
	Magnet System	Power Supply Location	Reference Prints	Cable Size	Loop Ohms	Nominal Amps	Nominal Volts
							14.5-GeV
251.	.tabbegin						
252.	.table NIM 'NORTH INJECTION MAGNETS'						
253.							
254.							
255.	----- ----- ----- ----- ----- ----- -----						
256.	42B1	Sec 30	ID-308-515-41			740.	
257.							
258.	42B2 41B1	Sec 30	ID-308-515-41			801.	14.1
259.							
260.	42B3	Sec 30	ID-308-515-41			798.	18.8
261.	42B4	"	" "			"	19.0
262.	42B5	"	" "			"	18.4
263.							
264.	42B6	Sec 30	ID-308-515-41			797.	18.5
265.	42B7	"	" "			"	20.6
266.	42B8	"	" "			"	19.3
267.	42B9	"	" "			"	18.7
268.							
269.	42QD1	Sec 30	ID-308-515-40			87.3	82.
270.	42QF2	"	" "			"	
271.	42QD3	"	" "			"	
272.	42QF4	"	" "			"	
273.	42QD5	"	" "			"	
274.	42QF6	"	" "			"	
275.	42QD7	"	" "			"	
276.	42QF8	"	" "			"	
277.							
278.	42QD9	Sec 30	ID-308-515-40			87.4	110.
279.	42QF10	"	" "			"	
280.	42QD11	"	" "			"	
281.	42QF12	"	" "			"	
282.	42QF14	"	" "			"	
283.	42QD15	"	" "			"	
284.	42QF16	"	" "			"	
285.							
286.	.tabend						

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287. .tabbegin
288. .table NIMcon 'NORTH INJECTION MAGNETS, PART 2'
289.
290.
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295.
296.
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299.
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Magnet System	Power Supply Location	Reference Prints	Cable Size	Loop Ohms	Nominal Amps	Nominal Volts
----- ----- ----- ----- ----- ----- -----						
42QD13	Sec 30	ID-308-515-40				
42QD17	Sec 30	ID-308-515-40				
42BVA-1					108.	20.
42BV1	Sec 30	ID-308-515-41				
42BV2	Sec 30	ID-308-515-41				
42BV3	Sec 30	ID-308-515-41				
42BV4	Sec 30	ID-308-515-41				
42BV5	Sec 30	ID-308-515-41				
42BV6	Sec 30	ID-308-515-41				
F.P.S. Gate						
42QF18>>>24	10CM15	ID-308-515-40	3/0	0.78	100.	78.
42QD19>>>					100.	
42QF20>>>					100.	
42B10	10CM20	ID-308-515-41	2X250M	0.016	784.	12.5
42QD21>>>					100.	
42BH1	10CM12-31	ID-308-515-41	#6 AWG	0.7	20.	14.
42QF22>>>					100.	
42BV7	10CM13-31	ID-308-515-41	#6 AWG	0.7	20.	14. R3/
42QD23>>>					100.	
10ABM4	10CM13-25	ID-308-515-41	#2 AWG	0.7	60.	42.
42BH2	10CM12-29	ID-308-515-41	#6 AWG	0.6	20.	12.
42QF24>>>					100.	
10ABM3	10CM13-27	ID-308-515-41	#2 AWG	0.6	60.	12.
42B11	10CM21	ID-308-515-41	2X250M	0.0185	508.	9.4
10ABM2	10CM12-25	ID-308-515-41	#2 AWG	0.4	120.	48.
10ABM1	10CM12-27	ID-308-515-41	#2 AWG	0.4	60.	24.

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327. .tabend
328.
329. .chapter 'Testing the Steering Magnets For PEP'
330.
331. .section 'Test Steering Magnet Systems Region 2'
332.

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333. .tablegin
334.
335. .table STEER2 'STEERING MAGNETS, REGIONS: 1B, 2A, Exp Hall, 2B, 3A' June 8, 1980
336. Magnet Power Supply Reference Loop Nominal Nominal
337. System Location Prints Ohms Amps Volts
3 |-----|-----|-----|-----|-----|
339.
340. 1E8EV 02CC12-31 WD-207-009-01,1 1.4 20. 28.
341. 1E8E1/2 TRM 02CC12-27 WD-207-009-01,1 2.0 20. 40.
342.
343. 1E6B1/2 TRM 02CC12-38 3 WD-207-009-01,1 1.714 20. 34. leads = 0.3954
344. 1E4EV 02CC12-29 WD-207-009-01,3 1.4 20. 28.
345. 1E4E1/2 TRM 02CC12-25 WD-207-009-01,3 1.7 20. 34.
346.
347. 1E2E1/2 TRM 02CC12-36 6 WD-207-009-01,4 1.615 20. 32. leads = 0.2622 Ohms
348. 1E1E1/2 TRM 02CC12-23 WD-207-009-01,4 1.6 20. 32.
349.
350. 1E0EL/1EL-V 02CC12-17 WD-207-009-01,4 .60 20. 12.
351.
352. 2AQ2/2EQ2TRM 02CC12-15 WD-207-009-01,4 0.75 60. 45. 0.235 ohms at magnet
353.
354. MULTI 2AMBE 02CC12-21 WD-207-009-01,4 1.7 20. 34.
355. " 2AMB0 02CC12-19 WD-207-009-01,4 1.7 20. 34.
356. " 2AMRQ 08CM23-19 WD-207-009-07,4
357.
358. 2AQ1/2EQ1TRM 02CC11-15 WD-207-009-01,4 0.85 60. 51. 0.298 ohms at magnet
359.
360. See next table for Power sources for the Experimental Interaction Region #2
361.
362. 2BQ1/2AQ1TRM 02CC11-15 WD-207-009-01,4 See 2AQ1/2BQ1TRM 0.299 ohms at magnet
363.
364. MULTI 2BMBE 02CC11-21 WD-207-009-01,4 1.7 20. 34.
365. " 2BMB0 02CC11-19 WD-207-009-01,4 1.75 20. 35.
366. " 2BMRQ 08CM24-19 WD-207-009-07,4
367.
368. 2EQ2/2AQ2TRM 02CC12-15 WD-207-009-01,4 See 2AQ2/2BQ2TRM 0.234 ohms at magnet
369.
370. 3A0EL/1EL-V 02CC11-17 WD-207-009-03,1 0.67 20. 13.4
371.
372. 3A1E1/2 TRM 02CC11-23 WD-207-009-03,1 1.68 20. 34.
373. 3A2B1/2 TRM 02CC11-36 4 WD-207-009-03,1 1.66 20. 33. leads = 0.3133 ohms
374.
375. 3A4E1/2 TRM 02CC11-25 WD-207-009-03,2 1.8 20. 36.
376. 3A4EV 02CC11-29 WD-207-009-03,2 1.4 20. 28.
377. 3A6E1/2 TRM 02CC11-38 8 WD-207-009-03,2 1.756 20. 35. leads = 0.4114 ohms
378.
379. 3A8E1/2 TRM 02CC11-27 WD-207-009-03,2 2.0 20. 40.
380. 3A8EV 02CC11-31 WD-207-009-03,2 1.5 20. 30.
381.
382. .tabend
383.
384. .section 'EXPERIMENTAL HALL POWER SOURCES REGION 2'
385.

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386. .tabbegin
387. .table EXPR2 'EXPERIMENTAL HALL POWER SOURCES REGION 2' June 8, 1980
388.
389. # 2-Gamma Septum Magnet 1,100 A @ 209 V 1.2 MW supply #1 (Load= 230kW)
390. (Probably limited to 1,100 amps do to saturation)
391. # TFC 2-Gamma Skew Quads Choppers 200 kW supply
392. 1 Chopper 500 A @ 72 V
393. 3 Choppers 500 A @ 34 V ( None used )
394. TPC 2,200 A @ 486 Volts 1.2 MW Supply #2 (Load=1.07 MW)
395. TFC Superconducting Compensators (From LBL; Rob Smit)
396. Ohms AMps
397. -----|-----
398. # 2EXP-A 02CC11-40 ID-308-515-48 Left racks 4 Required:
399. # 2EXP-B 02CC11-38 ID-308-515-48 " "
400. # 2EXP-C 02CC11-36 ID-308-515-48 " "
401. # 2EXP-D 02CC12-40 ID-308-515-48 Right racks " "
402. # 2EXP-E 02CC12-38 ID-308-515-48 future, not
403. # 2EXP-F 02CC12-36 ID-308-515-48 future, not
404.
405. .tabend
406.
407. .section 'Test Steering Magnet Systems Region 4'
408.

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.tabbegin							June 8, 1980	
.table STEEB4 'STEERING MAGNETS, REGIONS: 3E, 4A, Exp Hall, 4B, 5A'								
	Magnet System	Power Supply Location	Reference Prints	Loop Ohms	Nominal Amps	Nominal Volts		
409.								
410.								
411.								
412.								
413.								
415.	3E8EV	04DC12-31	WD-207-009-03,3	1.6	20.	32.		
416.	3E8B1/2 TRM	04DC12-27	WD-207-009-03,3	2.0	20.	40.		
417.								
418.	3E6E1/2 TRM	04DC12-38	6 WD-207-009-03,3	1.8	20.	36.	leads = 0.4538 ohms	
419.	3B4EV	04DC12-29	WD-207-009-03,3	1.5	20.	30.		
420.	3B4E1/2 TRM	04DC12-25	WD-207-009-03,3	1.9	20.	38.		
421.								
422.	3B2E1/2 TRM	04DC12-36	WD-207-009-03-4	1.76896	20.	34.	leads = 0.3487 ohms	
423.	3B1E1/2 TRM	04DC12-23	WD-207-009-03-4	1.70	20.	34.		
424.								
425.	3E0E1/1BL-V	04DC12-17	WD-207-009-03,4	.60	20.	12.		
426.								
427.	4AQ2/4EQ2TRM	04DC12-15	WD-207-009-03,4	0.70	60.	42.	0.236 ohms at magnet	
428.								
429.	MULTI 4MBE	04DC12-21	WD-207-009-03,4	1.8	20.	36.		
430.	" 4MBB	04DC12-19	WD-207-009-03,4	1.8	20.	36.		
431.	" 4MBRQ	08CM23-19	WD-207-009-07,4					
432.								
433.	4AQ1/4BQ1TRM	04DC11-15	WD-207-009-03,4	0.9	60.	54.	0.300 ohms at magnet	
434.								
435.	See next table for Power sources for the Experimental Interaction Region #4							
436.								
437.	4EQ1/4AQ1TRM	04DC11-15	WD-207-009-03,4	See 4AQ1/4BQ1TRM			0.303 ohms at magnet	
438.								
439.	MULTI 4MBE	04DC11-21	WD-207-009-03,4	1.8	20.	36.		
440.	" 4MBB	04DC11-19	WD-207-009-03,4	1.7	20.	34.		
441.	" 4MBRQ	08CM24-19	WD-207-009-07,4					
442.								
443.	4EQ2/4AQ2TRM	04CC12-15	WD-207-009-03,4	See 4AQ2/4BQ2TRM			0.236 ohms at magnet	
444.								
445.	5A0E1/1BL-V	04DC11-17	WD-207-009-05,1	0.6	20.	12.		
446.								
447.	5A1E1/2 TRM	04DC11-23	WD-207-009-05,1	1.7	20.	34.		
448.	5A2E1/2 TRM	04DC11-236	4 WD-207-009-05,1	1.7639	20.	34.	leads = 0.2993 ohms	
449.								
450.	5A4E1/2 TRM	04DC11-25	WD-207-009-05,2	1.8	20.	36.		
451.	5A4EV	04DC11-29	WD-207-009-05,2	1.5	20.	30.		
452.	5A6E1/2 TRM	04DC11-38	3 WD-207-009-05,2	1.766	20.	36.	leads = 0.422 ohms	
453.								
454.	5A8E1/2 TRM	04DC11-27	WD-207-009-05,2	1.9	20.	38.		
455.	5A8EV	04DC15-31	WD-207-009-05,2	1.4	20.	28.		
456.								
457.	.tabend							
458.								
459.	.section 'EXPERIMENTAL HALL POWER SOURCES REGION 4'							
460.								

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461. .tabbegin
462. .table EXPR4 'EXPERIMENTAL HALL POWER SOURCES REGION 4'           June 8, 1980
463.
464. # MAC Solenoid      6,000 A @ 150 V (0.025 ohms)    1.5 MW P.S.    (Load= 90kW)
465.     (5 kg)
466.
467. # MAC Toroids      2,500 A @ 96 V (0.0384 ohms)    400 kW supply (Load= 240kW)
468.     (20 kg)
469.
470.                                     Ohms      Amps      Volts
471.                                     -----|-----|-----
472.
473. # 4EXP-A            04CC11-40      ID-308-515-48    1.25      25.      32. Left racks  MAC Hor Ste
474. # 4EXP-B            04CC11-38      ID-308-515-48    1.45      25.      37.             MAC Vert St
475. # 4EXP-C            04CC11-36      ID-308-515-48    1.55      25.      39.             MAC Solenoi
476. # 4EXP-D            04CC12-40      ID-308-515-48    1.25      25.      32. Right racks Spare
477. # 4EXP-E            04CC12-38      ID-308-515-48    1.3       25.      33.             MAC Vert St
478. # 4EXP-F            04CC12-36      ID-308-515-48
479.                                     MAC Hor Ste
480. .tabend
481. .section 'Test Steering Magnet Systems Region 6'
482.

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483. .tabbegin
484. .table STEER6 'STEERING MAGNETS, REGIONS: 5B, 6A, Exp Hall, 6B, 7A' June 8, 1980
485. Magnet Power Supply Reference Loop Nominal Nominal
486. System Location Prints Ohms Amps Volts
487. |-----|-----|-----|-----|-----|-----|
488. 4
489. 5B8EV 06CC12-31 WD-207-009-05,3 1.22 20. 24.2
490. 5B8E1/2 TRM 06CC12-27 WD-207-009-05,3 1.72 20. 34.4
491.
492. 5B6E1/2 TRM 06CC12-38 6 WD-207-009-05,3 1.6419 20. 32.4 leads = 0.2969 ohms
493. 5B4EV 06CC12-29 WD-207-009-05,3 1.13 20. 22.6
494. 5B4E1/2 TRM 06CC12-25 WD-207-009-05,3 1.62 20. 32.4
495.
496. 5B2E1/2 TRM 06CC12-36 8 WD-207-009-05,4 1.5438 20. 30. leads = 0.1984 ohms
497. 5B1E1/2 TRM 06CC12-23 WD-207-009-05,4 1.5 20. 30.
498.
499. 5B0BL/1BL-V 06CC12-17 WD-207-009-05,4 .5 20. 10.
500.
501. 6AQ2/6BQ2TRM 06CC12-15 WD-207-009-05,4 0.70 60. 42. 0.233 ohms at magnet
502.
503. MULTI 6AMBE 06CC12-21 WD-207-009-05,4 1.6 20. 32.
504. " 6AMBO 06CC12-19 WD-207-009-05,4 1.4 20. 28.
505. " 6AMRQ 08CM23-19 ID-308-515-60 20.
506.
507. 6AQ1/6EQ1TRM 06CC11-15 WD-207-009-05,4 0.9 60. 54. 0.313 ohms at magnet
508.
509. See next table for Power sources for the Experimental Interaction Region #6
510.
511. 6EQ1/6AQ1TRM 06CC11-15 WD-207-009-05,4 See 6AQ1/6BQ1TRM 0.300 ohms at magnet
512.
513. MULTI 6BMBE 06CC11-21 WD-207-009-05,4 1.75 20. 35. resis 3/4
514. " 6BMBO 06CC11-19 WD-207-009-05,4 1.7 20. 34. resis 3/4
515. " 6BMRQ 08CM24-19 ID-308-515-60
516.
517. 6EQ2/6AQ2TRM 06CC12-15 WD-207-009-05,4 See 6AQ2/6BQ2TRM 0.238 ohms at magnet
518.
519. 7A0EL/1BL-V 06CC11-17 WD-207-009-07,1 0.61 20. 12.2 R 3/4 R
520.
521. 7A1E1/2 TRM 06CC11-23 WD-207-009-07,1 1.34 20. 26.8 resis 3/4 R
522. 7A2E1/2 TRM 06CC11-36 4 WD-207-009-07,1 1.3564 20. 26.8 leads = 0.3621
523.
524. 7A4E1/2 TRM 06CC11-25 WD-207-009-07,2 1.7 20. 34. resis 3/4
525. 7A4EV 06CC11-29 WD-207-009-07,2 1.3 20. 26. B3/11
526. 7A6E1/2 TRM 06CC11-38 3 WD-207-009-07,2 1.806 20. 34. leads 0.4584 ohms
527.
528. 7A8E1/2 TRM 06CC11-27 WD-207-009-07,2 1.7 20. 34. resis 3/4
529. 7A8EV 06CC11-31 WD-207-009-07,2 1.5 20. 30. B3/11
530.
531. .tabend
532.
533. .section 'EXPERIMENTAL HALL POWER SOURCES REGION 6'
534.

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535. .tabbegin
536. .table EXPR6 'EXPERIMENTAL HALL POWER SOURCES REGION 6' June 8, 1980
537.
538. # HRS Solenoid superconducting supply (2,000 amps @ 10v 30kW)
539.
540. # HRS Compensator superconducting supply (560 amps @ 8V 5kw)
541.
542. # HRS Skew Quads
543.
544.
545.
546. # 6EXP-A 06CC11-40 ID-308-515-48 chassis not installed Left racks leads 0.2735 ohms
547. # 7A6B1/2 06CC11-38 ID-308-515-48 Leads 0.2772 ohms
548. # 7A2B1/2 06CC11-36 ID-308-515-48 Leads 0.2756 ohms
549. # 6EXP-D 06CC12-40 ID-308-515-48 chassis not installed Right racks
550. # 5B6B1/2 06CC12-38 ID-308-515-48
551. # 5B2B1/2 06CC12-36 ID-308-515-48
552.
553. # 6SQ1A/B
554. # 6SQ2A/B11 06CC13-36 CH B9 0.408 60. 24.5 Hags 0.142 & 0.141 ohms Term 162 TB01-361
555. # 6SQ3A/B 06CC13-38 CHB-10 0.437 60. 26.2 Hags 0.142 & 0.140 ohms Term 364 TB02-361
556. # 6SQ4A/B 06CC13-40 CH|B9 0.463 60. 27.7 Hags 0.140 & 0.141 ohms Term 566 TB03-361
557.
558.
559. HRS PEP Region 6 controls (see J.J. Lipari)
560.
561. Crate 1422 Module 19 Control Functions
562. Channel 1 DC CN Command
563. Channel 2 FC CFF Command
564. Channel 3 Fast Discharge switch OFF
565. Channel 4 Fast Discharge switch ON
566.
567. Crate 1422 Module 18 Status Signals
568. Channel 1 IC CN
569. Channel 2 System Ready
570. Channel 3 FCR Beam Control
571. Channel 4 Fast Discharge Switch OFF
572. Channel 5 Fast Discharge Switch ON
573. Channel 13 D-A Converter at ZERO
574. Channel 14 Emergency Dump Switch Status
575.
576. Crate 1422 Module 17 DAC Control Module
577. Channel 16 BIT
578. .tabend
579. .section 'Test Steering Magnet Systems Region 8'
580.

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.tabbegin		.table STEER8 'STEERING MAGNETS, REGIONS: 7B, 8A, Exp Hall, 8B, 9A'					June 8, 1980
581.	Magnet	Power Supply	Reference	Loop	Nominal	Nominal	
582.	System	Location	Prints	Ohms	Amps	Volts	
583.	----- ----- ----- ----- ----- -----						
584.							
585.							
5							
587.	7B8EV	08CC15-31	WD-207-009-07,3	1.6	20.	32.	
588.	7E8B1/2 TRM	08CC15-27	WD-207-009-07,3	1.97	20.	39.4	
589.							
590.	7B6E1/2 TRM	08CC15-38	6 WD-207-009-07,3	1.7214	20.	36. leads = 0.3379 ohms	
591.	7B4EV	08CC15-29	WD-207-009-07,3	1.5	20.	30.	
592.	7B4E1/2 TRM	08CC15-25	WD-207-009-07,3	1.81	20.	36.	
593.							
594.	7B2E1/2 TRM	08CC15-36	8 WD-207-009-07,4	1.76181	20.	34. leads = 0.2787 ohms	
595.	7E1E1/2 TRM	08CC15-23	WD-207-009-07,4	1.70	20.	34.	
596.							
597.	7E0EL/1EL-V	08CC15-17	WD-207-009-07,4	.70	20.	14.	
598.							
599.	8AQ2/8BQ2TRM	08CC15-15	WD-207-009-07,4	0.70	60.	42. 0.234 ohms at magnet	
600.							
601.	MULTI 8AMB	08CC15-21	WD-207-009-07,4	1.68	20.	34.6	
602.	" 8AMB	08CC15-19	WD-207-009-07,4	1.68	20.	33.6	
603.	" 8AMBQ	08CM23-19	WD-207-009-07,4				
604.							
605.	8AQ1/8EQ1TRM	08CC16-15	WD-207-009-07,4	0.875	60.	52.5 0.306 ohms at magnet	
606.							
607.	See next table for Power sources for the Experimental Interaction Region #8						
608.							
609.	8EQ1/8AQ1TRM	08CC16-15	WD-207-009- 48	See 8AQ1/8BQ1TRM		0.305 ohms at magnet	
610.							
611.	MULTI 8BMB	08CC16-21	WD-207-009-07,4	1.72	20.	34.4	
612.	" 8BMB	08CC16-19	WD-207-009-07,4	1.75	20.	35.	
613.	" 8BMBQ	08CM24-19	WD-207-009-07-4				
614.							
615.	8EQ2/8AQ2TRM	08CC15-15	WD-207-009- 48	See 8AQ2/8BQ2TRM		0.233 ohms at magnet	
616.							
617.	9A0EL/1EL-V	08CC16-17	WD-207-009-09,1	0.6	20.	12.	
618.							
619.	9A1E1/2 TRM	08CC16-23	WD-207-009-09,1	1.7	20.	34.	
620.	9A2E1/2 TRM	08CC16-36	4 WD-207-009-09,1	1.6666	20.	34. leads = 0.3379 ohms	
621.							
622.	9A4E1/2 TRM	08CC16-25	WD-207-009-09,1	1.78	20.	35.6	
623.	9A4EV	08CC16-29	WD-207-009-09,1	1.5	20.	30.	
624.	9A6E1/2 TRM	08CC16-38	3 WD-207-009-09,1	1.766	20.	35.6 leads = 0.4262 ohms	
625.							
626.	9A8E1/2 TRM	08CC16-27	WD-207-009-09,1	1.9	20.	38.	
627.	9A8EV	08CC16-31	WD-207-009-09,1	1.7	20.	34.	
628.							
629.	.tabend						
630.							
631.	.section 'EXPERIMENTAL HALL POWER SOURCES REGION 8'						
632.							

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633. .tabbegin
634. .table EXPR8 'EXPERIMENTAL HALL POWER SOURCES REGION 8' June 8, 1980
635.
636. # DELCO (3kg) 3,000 A @ 190V (0.0569 ohms) 825 kW power supply #1
637.
6 . # Micro-Beta 2 of 8Q48 magnets (2 * 0.038 ohms) 826 kW Supply #2
639.
640.
641.
642. # 8EXP-A 08CC15-40 ID-308-515-48 0.8 25. 20. left racks DELCO, Hor
643. # 8EXP-B 08CC15-38 ID-308-515-48 0.8 25. 20. DELCO, Ver
644. # 8EXP-C 08CC15-36 ID-308-515-48 --- --- --- DELCO, Sol
645. # 8EXP-D 08CC16-40 ID-308-515-48 0.8 25. 20. Right racks SPARE
646. # 8EXP-E 08CC16-38 ID-308-515-48 0.8 25. 20. DELCO, Ver
647. # 8EXP-F 08CC16-36 ID-308-515-48 0.8 25. 20. DELCO,,Hor
648.
649. .tabend
650.

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651. .tabbegin
652. .table STEM10 'STIFFERING MAGNETS, REGIONS: 9B, 10A, Exp Hall, 10B, 11B' June 8, 1980
653. Magnet Power Supply Reference Loop Nominal Nominal
654. System Location Prints Ohms Amps Volts
655. |-----|-----|-----|-----|-----|-----|
6.
657. 9B8EV 10CC13-31 WD-207-009-09,3 1.4 20. 28.
658. 9E8E1/2 TRM 10CC13-27 WD-207-009-09,3 1.9 20. 38.
659.
660. 9E6E1/2 TRM 10CC13-38 3 WD-207-009-09,3 1.696 20. 34. leads = 0.3644 ohms
661. 9B4EV 10CC13-29 WD-207-009-09,3 1.3 20. 26.
662. 9E4E1/2 TRM 10CC13-25 WD-207-009-09,3 1.7 20. 34.
663.
664. 9B2E1/2 TRM 10CC13-36 4 WD-207-009-09,4 1.606 20. 32. leads = 0.2704 ohms
665. 9B1B1/2 TRM 10CC13-23 WD-207-009-09,4 1.6 20. 32.
666.
667. 9E0EL/1BL-V 10CC13-17 WD-207-009-09,4 .56 20. 11.2
668.
669. 10AQ2/10EQ2T 10CC13-15 WD-207-009-09,4 0.68 60. 40.8 0.233 ohms at magnet
670.
671. MULII 10AMBE 10CC13-21 WD-207-009-09,4 1.5 20. 30.
672. " 10AMBO 10CC13-19 WD-207-009-09,4 1.5 20. 30.
673. " 10AMRQ C8CM23-19 WD-207-009-07,4
674.
675. 10AQ1/10BQ1T 10CC14-15 WD-207-009-09,4 1.0 60. 60. 0.301 ohms at magnet
676.
677. See next table for Power sources for the Experimental Interaction Region #10
678.
679. 10BQ1/10AQ1T 10CC14-15 WD-207-009-09,4 See 10AQ1/10BQ1T 0.302 ohms at magnet
680.
681. MULII 10EMBE 10CC14-21 WD-207-009-09,4 1.8 20. 36.
682. " 10EMBO 10CC14-19 WD-207-009-09,4 1.8 20. 36.
683. " 10EMRQ C8CM24-19 WD-207-009-07,4
684.
685. 10BQ2/10AQ2T 10CC13-15 WD-207-009-09,4 See 10AQ2/10BQ2T 0.234 ohms at magnet
686.
687. 11A0BL/1BL-V 10CC14-17 WD-207-009-11,1 0.58 20. 11.6
688.
689. 11A1E1/2 TRM 10CC14-23 WD-207-009-11,1 1.6 20. 28.
690. 11A2E1/2 TRM 10CC14-36 8 WD-207-009-11,1 1.6 29820. 28. leads = 0.2948 ohms
691.
692. 11A4E1/2 TRM 10CC14-25 WD-207-009-11,1 1.8 20. 36.
693. 11A4EV 10CC14-29 WD-207-009-11,2 1.28 20. 13.6
694. 11A6E1/2 TRM 10CC14-38 6 WD-207-009-11,1 1.7242 20. 36. leads = 0.3828 ohms
695.
696. 11A8E1/2 TRM 10CC14-27 WD-207-009-11,2 1.7 20. 34.
697.
698. 11A8EV 10CC14-31 WD-207-009-11,2 1.4 20. 28.
699.
700. .tabend
701.
702.
703. .section 'EXPERIMENTAL HALL POWER SOURCES REGION 10'
704.

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705.
706.
707.
708.
709.
7
711.
712.
713.
714.
715.
716.
717.
718.

.tabbegin
.table EXP10 'EXPERIMENTAL HALL POWER SOURCES REGION 10'

June 8, 1980

			Ohms	Amps			
	# 10EXP-A	10CC14-40	ID-308-515-48		Left racks	(none now)	Leads 0.1981 ohms
	# 10EXP-E	10CC14-38	ID-308-515-48			(none now)	Leads 0.1978 ohms
	# 10EXP-C	10CC14-36	ID-308-515-48			(none now)	Leads 0.1981 ohms
	# 10EXP-D	10CC13-40	ID-308-515-48		Right racks	(none now)	
	# 10EXP-E	10CC13-38	ID-308-515-48			(none now)	
	# 10EXP-F	10CC13-36	ID-308-515-48			(none now)	

.tabend

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719. .tabbegin
720. .table STEM12 'STEERING MAGNETS, REGION: 11E, 12A, Exp Hall, 12B, 1A' June 8, 1980
721. Magnet Power Supply Reference Loop Nominal Nominal
722. System Location Prints Ohms Amps Volts
723. |-----|-----|-----|-----|-----|
7.
725. 11E8EV 12CC12-31 WD-207-009-11,3 1.4 20. 28.
726. 11E8E1/2 TRM 12CC12-27 WD-207-009-11,3 1.9 20. 38.
727.
728. 11B6E1/2 TRM 12CC12-38 6 WD-207-009-11,3 1.758 20. 36. leads = 0.4206 ohms
729. 11B4EV 12CC12-29 WD-207-009-11,3 1.32 20. 26.
730. 11B4E1/2 TRM 12CC12-25 WD-207-009-11,3 1.8 20. 36.
731.
732. 11B2E1/2 TRM 12CC12-36 8 WD-207-009-11,4 1.68 20. 34. leads = 0.3363 ohms
733. 11B1E1/2 TRM 12CC12-23 WD-207-009-11,4 1.70 20. 34.
734.
735. 11E0EL/1EL-V 12CC12-17 WD-207-009-11,4 .6 20. 12.
736.
737. 12AQ2/12BQ2T 12CC12-15 WD-207-009-11,4 0.80 60. 48. 0.233 ohms at magnet
738.
739. MULTI 12AMBE 12CC12-21 WD-207-009-11,4 1.8 20. 36.
740. " 12AMBO 12CC12-19 WD-207-009-11,4 1.8 20. 36.
741. " 12AMRQ 12CC12-19 WD-207-009-11,4
742.
743. 12AQ1/12BQ1T 12CC11-15 WD-207-009-11,4 0.75 60. 45. 0.300 ohms at magnet
744.
745. See next table for Power sources for the Experimental Interaction Region #12
746.
747. 12BQ1/12AQ1T 12CC11-15 WD-207-009-11,1 See 12AQ1/12BQ1T 0.299 ohms at magnet
748.
749. MULTI 12BMBE 12CC11-21 WD-207-009-11,4 1.8 20. 36.
750. " 12BMBO 12CC11-19 WD-207-009-11,4 1.7 20. 34.
751. " 12BMRQ 08CM24-19 WD-207-009-07,4
752.
753. 12BQ2/12AQ2T 12CC12-15 WD-207-009-11,1 See 12AQ2/12BQ2T 0.232 ohms at magnet
754.
755. 1A0EL/1BL-V 12CC11-17 WD-207-009-01,1 0.6 20. 12.
756.
757. 1A1E1/2 TRM 12CC11-23 WD-207-009-01,1 1.7 20. 34.
758. 1A2E1/2 TRM 12CC11-36 4 WD-207-009-01,1 1.705 20. 34. leads = 0.375 ohms
759.
760. 1A4E1/2 TRM 12CC11-25 WD-207-009-01,2 1.5 20. 30.
761. 1A4EV 12CC11-29 WD-207-009-01,2 1.4 20. 28.
762. 1A6E1/2 TRM 12CC11-38 3 WD-207-009-01,2 1.807 20. 36. leads = 0.475 ohms
763.
764. 1A8E1/2 TRM 12CC11-27 WD-207-009-01,2 1.8 20. 36.
765. 1A8EV 12CC11-31 WD-207-009-01,2 1.45 20. 29.
766.
767. .tabend
768.
769. .section 'EXPERIMENTAL HALL POWER SOURCES REGION 12'
770.

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771. .tabbegin
 772. .table EXP12 'EXPERIMENTAL HALL POWER SOURCES REGION 12' June 8, 1980
 773.

774. # MBEK-II magnet; 4,500A at (500) 3.4kW P.S. (Used 2,650 kW) new
 775. 4,500 at 300 Volts (0.1288 ohms) Repaired coil March 23, 1982
 776.

			Chas	Amps	Volts	
777.						
778.						
779.	# 12EXP-I	12CC11-40	ID-308-515-48	1.4	25.	35. Left racks
780.	# 12EXP-E	12CC11-38	ID-308-515-48	1.0	25.	25. MK II Hor Steering
781.	# 12EXP-C	12CC11-36	ID-308-515-48	1.2	25.	30. MK II Ver Steering
782.	# 12EXP-D	12CC12-40	ID-308-515-48	1.3	25.	33. Right racks
783.	# 12EXP-E	12CC12-38	ID-308-515-48	1.15	25.	29. MK II Sol Trim 40 amp max
784.	# 12EXP-F	12CC12-36	ID-308-515-48			
785.	#					
786.	.tabend					

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787. .tabbegin
788. .table DVHAS 'ASSIGNMENT OF DVM SCANNER POSITIONS, RACK 08CM41'          Sept 15, 1981
789.
790.
791.   MAG SYS      PEP CCNT      REGLOOP  CHOPPER      NOMINAL      CHOPPER      CHOPPER      TRIGGER      8 GeV
791.   I. D.        MCNITCR      OR REF    RACK(S)      CALIBR      CONTROL      FREQ.       PFASE       Volts
791.   .              CHAN #      CHAN #    USED         AMPS/V      POSITION      HERTZ      POSITION
793.   -----|-----|-----|-----|-----|-----|-----|-----|-----|-----
794.
795.       3CF        00          30         H 30         50.         4137,1/2    2040        7           130.
796.       2CF        01          31         H 31         50.         4137,3/4    2040        8           125.
797.       1CD A/E     02          32         H 32/35      50.         4137,5/6    2040        6           160.
798.       4CF A/B     03          33         H 33/34      50.         4137,7/8    2040        9           230.
799.       4CF E/A     04 (Ref)    34         H 34/33      40.         4137,9/10   2040        9           160.
800.       1CD E/A     05 (None)   35         H 35/32      50.         4137,11/12  2040        6           140.
801.
802.       1CF        06          36         H 36         50.         4137,13/14  2040        5           100.
803.       Q3         07          37         H 37         50.         4137,15/16  2040        4           85.
804.
805.       * Q2        19          49         L 61         150.        4132,1/2    2040        3
806.
807.       BEND A/B    08 (Ref)    38         H 42/47      150.        4132,3/4    2040        6           132.
808.
809.       BEND E/A    09 (None)   39         H 47/42      150.        4132,5/6    2040        1           100.
810.
811.       Q2-Micro
812.       6SD         10          40         L 50         50.         4132,7/8    2040        2           160.
813.       6SF         11          41         L 51         50.         4132,9/10   2040        1
814.
815.       * 9CF        12          42         L 52         50.         4132,11/12  2040        5
816.       4CD A/B     13          43         L 53/54      50.         4132,13/14  2040        3
817.       4CD E/A     14 (None)   44         L 54/53      50.         4132,15/16  2040        9           50.
818.       8CD         15          45         L 55         50.         4127,13/14  360        10          40.
819.       7SD         16          46         L 56         50.         4127,1/2    360        2           60.
820.       5SD         17          47         L 57         50.         4127,3/4    360        3           185.
821.       * BW A/B     18          48         L 60/67      50.         4127,5/6    360        3           145.
822.
823.       3SF A/B     20          50         L 62/65      50.         4127,7/8    360        7           100.
824.       2SD A/B     21          51         L 63/64      50.         4127,9/10   360        11          45.
825.       2SD E/A     22 (None)   52         L 64/63      50.         4127,11/12  360        1           40.
826.       3SF B/A     23 (None)   53         L 65/62      50.         4122,13/14  360        9
827.       * 1SD        24          54         L 66         50.         4122,1/2    360        12          150.
828.       * BW E/A     25          55         L 67/60      50.         4122,3/4    360        6           95.
829.       Special    26
830.       Special    27
831.       Special    28
832.       Special    29
833.       +RI ACAMP   31
834.       -RI ACAMP   32
835.
836.
837. .TABEND
838. .chapter 'Testing the Power Supplies for the BI Experimenters'
839.
840. .chapter 'Future Chapters to be Added'
841. .section 'Diary of the Testing of These Systems'
842. .section 'Special Information for Future Ring Magnet Testing'
843. .section 'Special Topics Good for Conference Reports'
844. .section 'Summary of Test Results'
845. .contents

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846. FEF CHOPPER BACKS CABLE ASSIGNMENTS Sept 15, 1981

	CIRCUIT	RACK #	COMMON LEAD	OUTPUT LEAD	
847.					
848.	CIRCUIT	RACK #	COMMON LEAD	OUTPUT LEAD	
849.					
850.	9SF	HF 22	- Region 9 #7	+ Region 7 #7	
851.					
852.	3QF	H 30	+ Region 9 #11	- Region 7 #11	MINI-BETA
853.					
854.	2QF	H 31	+ Region 9 #17	- Region 7 #17	MINI-BETA
855.					
856.	1QD	H 32 / 35		- Region 7 #12	MINI-BETA
857.					
858.	QF (4CF)	H 33 / 34		- Region 7 #18	
859.					
860.	QF (4CF)	H 34 / 33		+ Region 9 #18	
861.					
862.	1QD	H 35 / 32		+ Region 9 #12	
863.					
864.	1QF	H 36	- Region 7 #20	+ Region 9 #20	MINI-BETA
865.					
866.	Q3	H 37	- Region 7 #15	+ Region 9 #15	MINI-BETA
867.					
868.	BEND	H 42 / 47		- Region 9 #13,19	
869.					
870.	BEND	H 47 / 42		+ Region 7 #13,19	
871.					
872.	6SD	L 50	+ Region 7 #6	- Region 9 #6	
873.					
874.	6SF	L 51	+ Region 7 #14	- Region 9 #14	
875.					
876.	9QF	L 52	+ Region 9 #21	- Region 7 #21	
877.					
878.	QD (4QD)	L 53/54		- Region 7 #3	
879.					
880.	QD (4QD)	L 54/53		+ Region 9 #3	
881.					
882.	8QD	L 55	- Region 7 #9	+ Region 9 #9	
883.					
884.	7SD	L 56	- Region 9 #1	+ Region 7 #1	
885.					
886.	5SD	L 57	- Region 7 #2	+ Region 9 #2	
887.					
888.	BW	L 60 / 67		- Region 7 #5	
889.					
890.	Q2	H 61	+ Region 7 #4	- Region 9 #4	
891.					
892.	SF (3SF)	L 62 / 65		- Region 7 #8	
893.					
894.	2SD	L 63 / 64		- Region 7 #10	
895.					
896.	2SD	L 64 / 63		+ Region 9 #10	
897.					
898.	SF (3SF)	L 65 / 62		+ Region 9 #8	
899.					
900.	1SD	L 66	- Region 9 #16	+ Region 7 #16	
901.					
902.	BW	L 67 / 60		+ Region 9 #5	

904. SF NOT USED, NOT WIBED TO A BUS.

905. .tabbegin
 906. .table MAGTE 'MAIN PEF MAGNET SYSTEMS TO BE TESTED at RI 8 '
 907. Sept 15, 1981
 908. THE RESISTANCES FOR THE LOOPS HAVE NOT BEEN CORRECTED FOR MEASURED VALUES.
 909.

	Magnet Sys.	Cable I.D.#	Racks Used	Magnet Type	Mags Used	Loop * Loop	Loop * Resis	Loop * Resis	Loop * Resis	
						10**-3*10**-3	10**-3*10**-3	10**-3*10**-3		
						Ohms	Ohms	Ohms		
						Calcul*10 amp		11 GeV*14.5GeV		
916.	Q1	13,19	42/47	160Q2000	12	10/79*	10/79	7/80*	3/82	
917.	Q2	13,19	42/47	160Q1500	12	*		*		
918.	OBL	13,19	42/47	71C2700	12	*		*		
919.	1BL	13,19	42/47	71C2700	12	*		*		
920.	BENDS	13,19	42/47	71C5400	193	1,415.*	1,440.	1,568.*	1,372	FEND
921.						*		*		
922.	Q3	15	37 +	100Q1000	12	1,606.*	1,840.	1,696.*	1,757	Q3
923.										
924.	1QF	20	36 +	100Q1000	12	1,606.*	1,743.	1,685.*	1,602	1QF
925.										
926.	1QD	12	32/35	100Q550	36	2,771.*	3,300.	3,084.*	3,183	1QD
927.						*		*		
928.	2QF	17	31 -	100Q1000	12	1,606.*	1,870.	1,722.*	1,954	2QF
929.										
930.	3QF	11	30 -	100Q730	12	1,250.*	1,410.	1,361.*	1,415	3QF
931.										
932.	4QF	18	33/34	100Q730	60	5,668.*	6,480.	6,148.*	6,864	4QF
933.						*		*		
934.	4QD L	3	53/54	100Q550	48	3,658.*	4,105.	4,007.*	4,101	4QD
935.						*		*		
936.	8QD L	9	55 +	100Q730	12	1,250.*	1,401.	1,357.*	1,407	8QD
937.										
938.	9QF L	21	52 -	100Q550	13	1,018.*	1,254.	1,217.*	1,137	9QF
939.										
940.	Q2	4	61 -	160Q1500	12	266.*	307.	.*	0.328	Q2
941.						*		*		
942.	1SD L	16	66 +	120S450	12	1,044.*	1,300.	1,114.*		1SD
943.										
944.	5SD L	2	57 +	120S450	12	988.*	1,220.	1,103.*	1,157	5SD
945.										
946.	6SF L	14	51 -	120S250	12	676.*	840.	724.*	0.744	6SF
947.										
948.	6SD L	6	50 -	120S450	12	988.*	1,276.	1,106.*	1,137	6SD
949.										
950.	7SD L	1	56 +	120S450	12	988.*	1,080.	1,113.*	1,162	7SD
951.						*		*		
952.	3SF L	8	62/65	120S250	60	2,801.*	3,290.	3,057.*	3,152	3SF
953.										
954.	2SD L	10	63/64	120S250	48	2,269.*	2,576.	2,482.*	2,571	2SD
955.										
956.	BW	5	60/67	Wiggler	3	894.*	900.	900.*		* BW
957.						*		*		
958.	9SF	7	22 HP	120S250	12	676.*	910.	*		9SF
959.						*		*		
960.	1SF			120S250	12	NOT CONNECTED TO A.*WATER COOLED7LOOP				*
961.						*		*		
962.						*		*		
963.	(1) Aluminum round water cooled bus @ 20.38 X 10**-6 Ohms/foot @ 20 degrees C.									
964.	(2) Bends use 2 of 500NCM in parallel for jumpers; @ 0.0222 ohms/ 1,000 ft. 8 1/2 feet per									

965. | (3) Quads and Sextapoles use 250MCM for jumpers; @ 0.0444 ohms/ 1,000 ft. Ten feet per mag
966. | (4) One loop around the ring is 6,575 feet long.
967. .tabend

968.
969. .chapter 'Testing of the Injection Magnets, SIT'
970. .CHAPTER 'MISC NAMEPLATE DATA'

971.
972. TWO TRANSFORMERS FOR THE BRIDGE RECTIFIERS OF 8RI- AND 8RI+
973. ONE IS DELTA - DELTA, THE OTHER IS DELTA - WYE.

974.
975. Standard Transformer Inc
976. Warren, Ohio USA

977.
978. 3 phase Type B
979. 2,500 / 2,800 kVA CA continuous rating
980. 3,125 / 3,500 kVA FA continuous rating

981.
982. Class OA/FFA 55/65 degrees C rise

983.
984. Primary 12,470 Delta
985. Secondary 480 Delta for the 8RI- supply

986.
987. LV amps 1,736 amps; SHOULD BE 3008 AMPS LINE CURRENT.

988.
989. 5.51% impedance at 2,500 kVA

990.
991. Serial PJF 1942
992. Spec E325D1222-8XX0100

993.
994. 5 primary taps 13,094 to 11,846 volts
995. primary amps, 110.1

997. -----

998.
999.
1000. Main chopper design info
1001. 500 amps max for Quads, Sextapoles, and Wigglers
1002. commutation inductance 7 micro-henries
1003. capacitance 3 X 5 micro-farads

1004.
1005. resonance freq approx 15.53 k hertz
1006. Impedance L = 0.683 ohms.
1007. Peak current approx 1,025 amps (600v on RI, 700V on caps)

1008.
1009. 1,500 amp max for Main Bend choppers.
1010. commutation inductance 3 micro-henries
1011. capacitance 10 X 5 micro-farads

1012.
1013. Resonance freq approx 12.99 K hertz
1014. Impedance L = 0.2448 ohms
1015. Peak current approx 2,859. amps (600V on RI, 700V on caps)
1016.

1017. -----

1018.
1019. region 8 support bldg PA panel breakers
1020. Injection 50 amps

1021. W Trip Pac, type IC 200 k amps trip
1022. Type FB3060FL
1023.
1024. Also there are some W HFB3040 at 25 kamps ??? is that too low???
1025.

1026.
1027.
1028.
1029. TTransformer at RI 4 and 12 Support Building
1030.
1031. 1500 / 1680 Kva OA rated
1032. 1725 / 1932 Kva FA rated
1033.
1034. 12,470 delta primary
1035. 480 delta secondary
1036.
1037. low voltage amps 1802.
1038.
1039. impedance 5.55% 75 degree C at 1,500 kVA
1040.
1041. serial PJD 1757
1042. Spec B3L5D12228XX010
1043.

1044.
1045.
1046. Frames for power supplies at Regions 4 and 12 to boost the 4qf
1047. voltage are ERDA 39540M and 38541M
1048.

1049.
1050. Westinghouse bus ways fro main transformers to the RI's
1051.
1052. "LOW-R-WAY
1053. BUSWAY
1054.
1055. Style 66-E-5624A-93
1056.
1057. 2,500 amps 600V 3 wire
1058.
1059. 50% ground bus

1060.
1061.
1062. STUFF for 4QF boost circuit
1063.
1064. Shawmut fuses form 101
1065. 300 amp cat # A25X300
1066. 250 vclt Type 4
1067.
1068. Posssible diodes
1069. IR 70U50
1070. 70U100A HB
1071. 70UR100A cathode on lead, stud type.
1072. 70UR90A same

1073. W 439K diodes
1074. W 1N4051 diodes
1075.

10 .

1077. June 22, 1981 The inductance of the water cooled cable around
1078. PEP for the Wiggler circuit (no magnets) is;
1079. 0.0028 Henries at 60 Hertz
1080. 0.0017 Henries at 1,000 Hertz (Q= 6.25)
1081. X(L) = 10.66 ohms R = 0.144 ohms
1082.

-----K-----
1083.
1084.
1085. June 22, 1981 The inductance of the Bend system: (no DC excitation)
1086. 1.01 Henries (108 volts Pk/Pk at 0.1 amps 60 Hertz)
1087. X(L) = 381.9 Ohms
1088.

1089.
1090.
1091. Inductance of Prototype Q2 magnet at 60 Hertz (np. DC excitation)
1092. 0.016 Henries 13 turns , no beam pipe
1093. 0.0063 Henries 8 turns , no beam pipe
1094. 0.0092 Henries 13 turns , with beam pipe
1095. 60 Hertz ripple inside pipe reduced by 100/1
1096.

1097.