MOTOR FIELD REGULATORS
F21 FIELD EXCITER SYSTEMS

I. INTRODUCTION

F21 Field Exciter systems are single phase, single quadrant converters for variable field excitation of motors or generators. A basic exciter unit described in I.L. 16-800-305 (20A) or I.L. 16-800-392 (30A with isolation) and a set of optional kits described in this I.L. provide the application flexibility on a building block basis. The present I.L. is confined to the regulator systems for motor field applications.

The basic unit and the optional controller kits have been designed such that they are independent of the type of power source connected to the motor armature. These exciter systems are compatible with medium and small motor drive systems. The field exciter described in I.L. 16-800-392 uses an isolated current feedback. Figure 1 shows both types of feedback techniques used. This difference is applicable for all the power configurations discussed in this I.L.

II. DESCRIPTION

General

The F21 motor field exciter system consists of the following functional blocks as shown in Figure 1.

a. AC incoming power source
b. Basic F21 controlled TPM assembly
c. Regulator & controller kits

Generally, a single phase isolation transformer is used for the incoming source. However, it is not required if the system has an isolation transformer sized properly with an auxiliary winding for the field circuit.

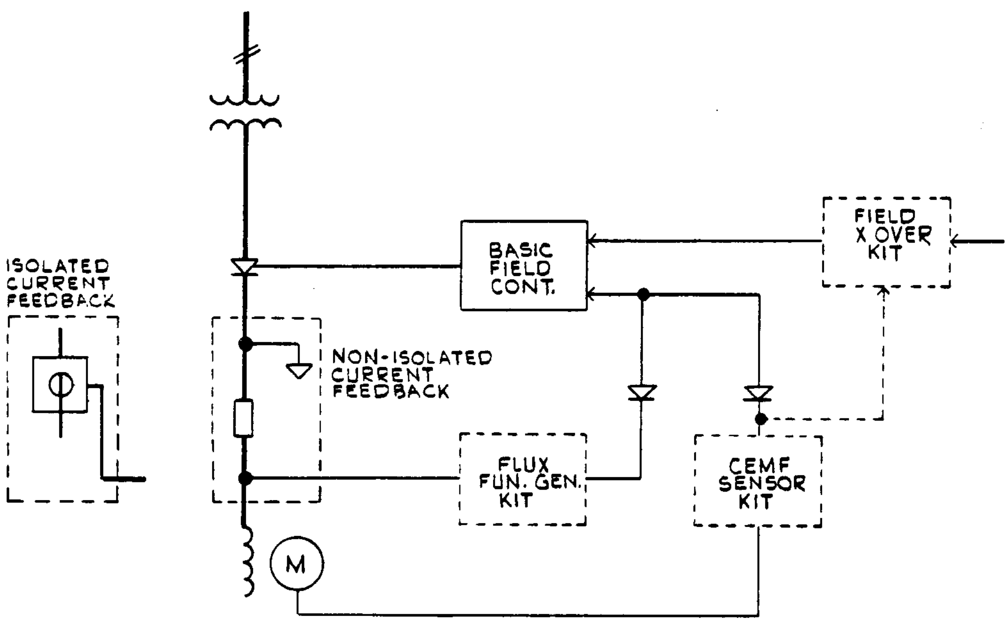

FIGURE 1. COMPONENTS OF F21 MOTOR FIELD EXCITER SHOWING SOME OF THE OPTIONAL KITS

SUPERSEDES I.L. 16-800-306A
EFFECTIVE JAN 1982

As described in I.L. 16-800-305 and 16-800-392 there are three configurations of the basic package. One, utilizing an integral thyristor diode bridge package, is rated for 180 VDC at 20 amps maximum and the other two are rated for 280 VDC at either 20 or 30 amps (with isolation) maximum. These ratings adequately cover field excitation requirements of dc motors up to at least 200 HP.

Seven regulator systems are described in this instruction leaflet as follows.

A. Field Current Regulator

This is the basic variable field exciter system. It permits the adjustment and regulation of motor field current from an operator's potentiometer or a variable voltage reference signal as shown in the system block diagram figure 2A1. Refer to I.L. 16-800-305 or 16-800-392 for the details of this basic regulator system.

The closed loop time constant of the field current regulator is given by

$$T = \frac{T_f}{18\ K_f K_1}$$

where T_f = Motor field time constant on the air-gap line (normally in the range of 0.3 to 2 seconds).

K_f = Forcing factor - 1.5 for 120V fields and 180V TPM or 180V fields and 280V TPM

K_1 = Current feedback calibration - Unity for standard calibration. For special calibrations it is one half of the signal voltage at $-I_f$ terminal at rated motor field current.

The signal polarities and voltage levels are as given in I.L. 16-800-305 and 16-800-392.

B. CEMF/Voltage Regulator

This regulator system provides control of motor CEMF/voltage by field regulation. The CEMF/voltage of the motor is sensed by a differential input amplifier and is used as a feedback. No other control loop is used. The overall system performance depends upon the selection of the sensor from drawing 1745A48. Four circuit configurations are identified by group designations G01 through G04. The system block diagram and the simplified schematic diagram for the basic cemf regulator is shown in figures 2B1 and 2B2. This system employs the cemf sensor S#1745A48G01 which provides the negative absolute value of the cemf for feedback.

The closed loop time constant of the cemf regulator can be expressed by

$$T = \frac{T_f}{18\ K_f K_\phi K_1} \bullet \frac{1}{(\overline{W}o)}$$

where K_ϕ = Flux gain (air gap saturation factor)

$\overline{W}o$ = Normalized motor speed (unity at base speed) and the other parameters are the same as defined earlier.

Since the time constant of the control loop as given above is inversely proportional and the gain of the control loop is directly proportional to the operating speed $\overline{W}_o$, the range of speed over which reasonable regulation can be expected is limited.

The CEMF/voltage sensor S#1745A48 is a 3.5" x 6" printed circuit card which mounts over the basic field controller board. There are four circuit configurations for groups G01 through G04 as represented by schematic diagrams given in figures 2B3 and 2B4. Front view of the component layout, given in figure 2B5, shows that there are eight screw type and four lance

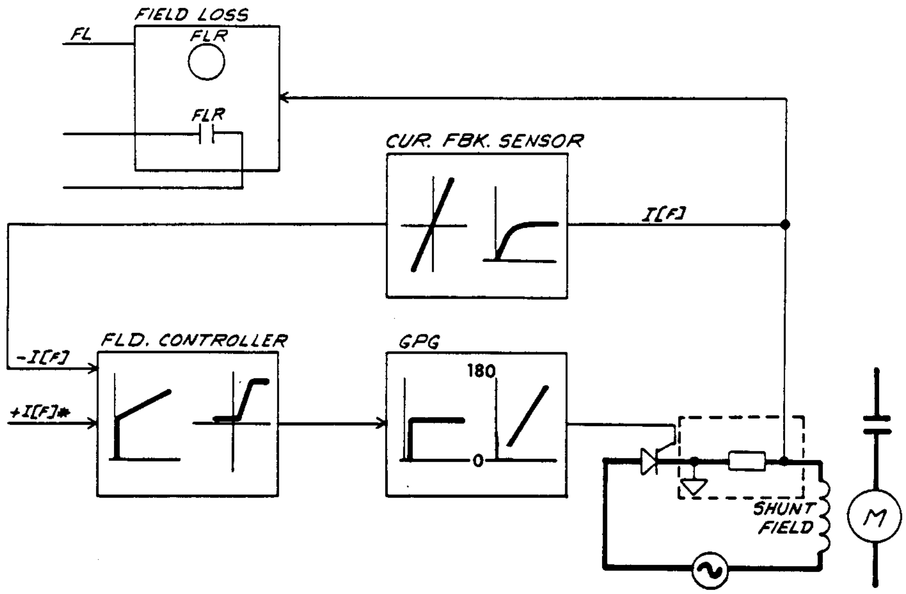

FIGURE 2A1 SYSTEM BLOCK DIAGRAM-FIELD CURRENT REGULATOR

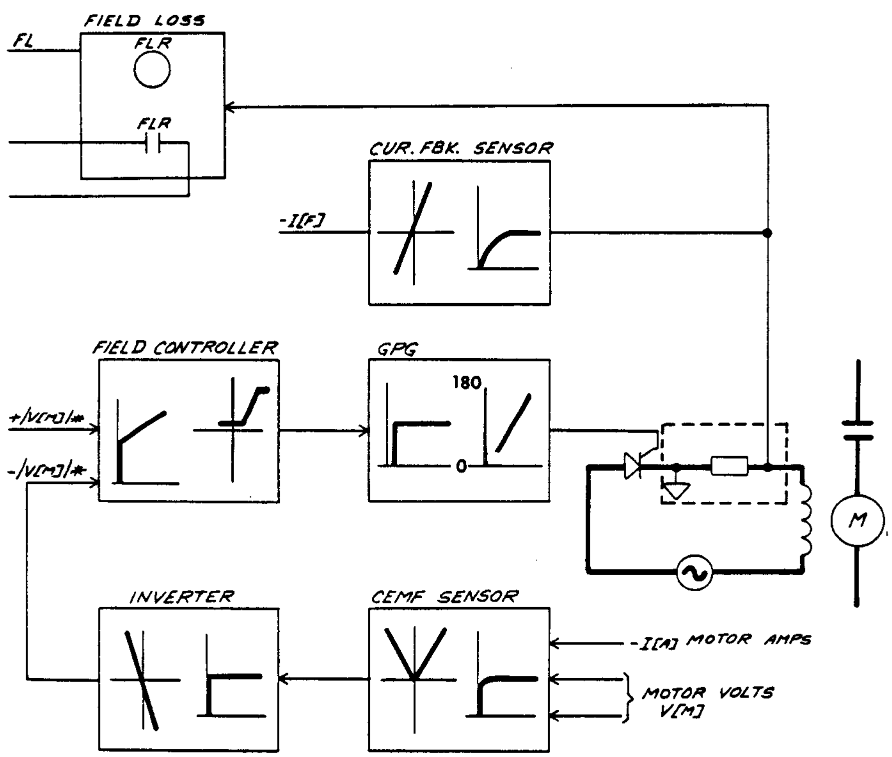

FIGURE 2B1 SYSTEM BLOCK DIAGRAM-MOTOR CEMF REGULATOR

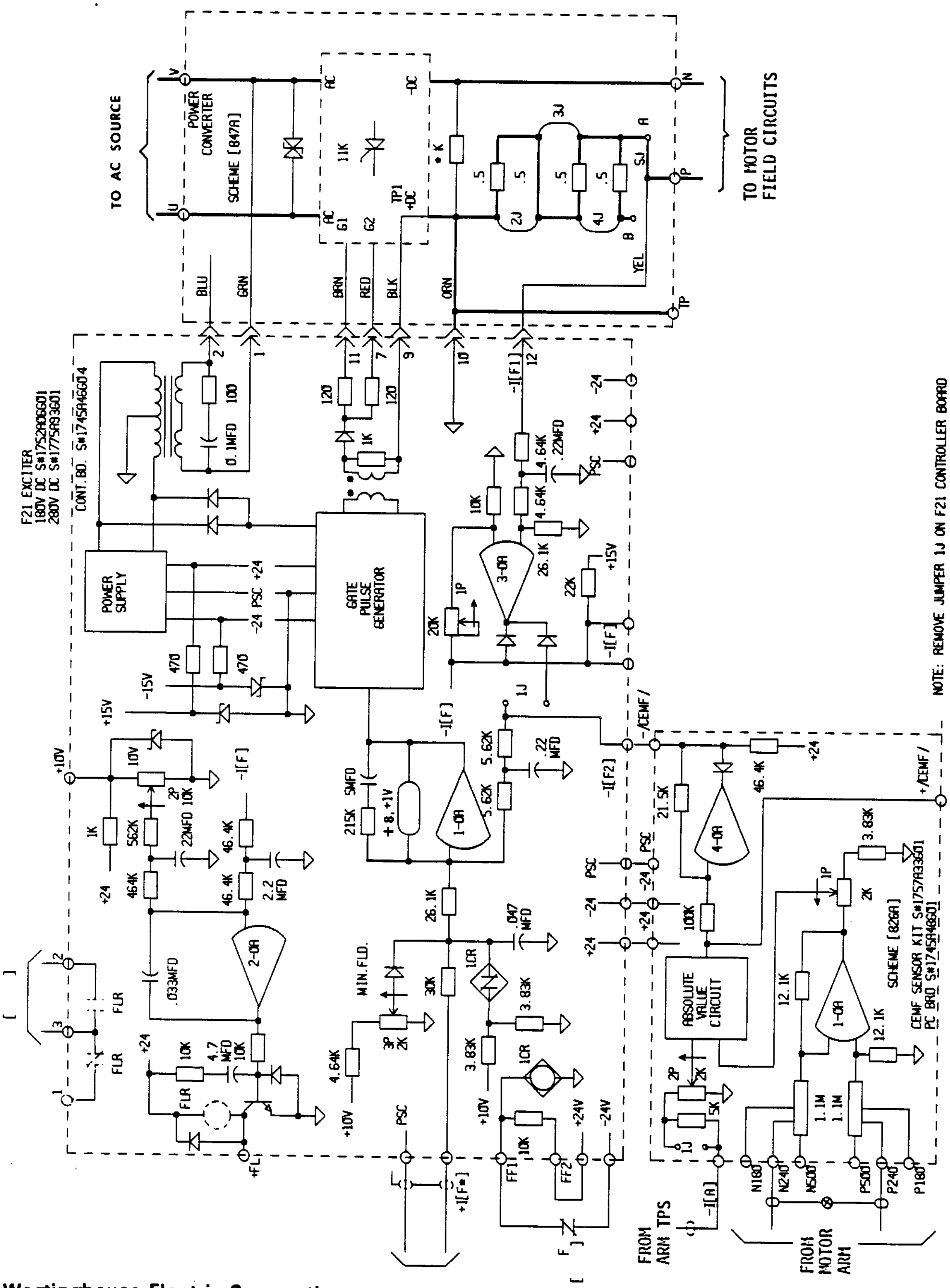

FIGURE 2B2 SIMPLIFIED SCHEMATIC DIAGRAM-FIELD CEMF REGULATOR SYSTEM

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type terminations provided on this board. Six of the screw type connections are for the armature voltage differential inputs designated by P & N pairs. The termination designated -I[A] is for the IR compensation input calibrated for 2V or 0.5V signal at rated armature current. The terminal marked +CEMF is connected to the output of 3-OA op-amp and is the output terminal for external connections. Of the four lance terminations, the three are for power supply connections (PSP,PSC & PSN). The fourth one is the output of 4-OA op-amp and is designated -CEMF. The circuits and application information for the four groups are given in two separate descriptions due to considerable differences in G01/G02 and G03/G04.

B1. Circuit Descriptions S#1745A48G01/G02

This sensor consists of three stages. The first stage op-amp 1-OA, is a differential input stage with calibration for various armature voltages, (500, 240, 180). The second stage, consisting of 2-OA and 3-OA, is an absolute value summing circuit with a small filter. The third stage, op-amp 4-OA is a gain attenuator with polarity inversion. As shown in the figure 2B3, the difference between G01 and G02 is only in the first stage. The difference in the signal levels and the input filter time constants are given in the Table I in Section IV of this I.L.

For the basic CEMF/voltage regulator system, the output at -CEMF (lance type) terminal is adjusted for -2 volts at the rated CEMF/voltage. The output of 4-OA contains a diode resistor network, which is a part of the switching circuit used in the field crossover systems described in the next section. It has no effect in this system. A wire jumper in the 34R location connects the output of the switching diode 7D to the lance terminal (-CEMF).

The transfer functions for the two outputs are as follows.

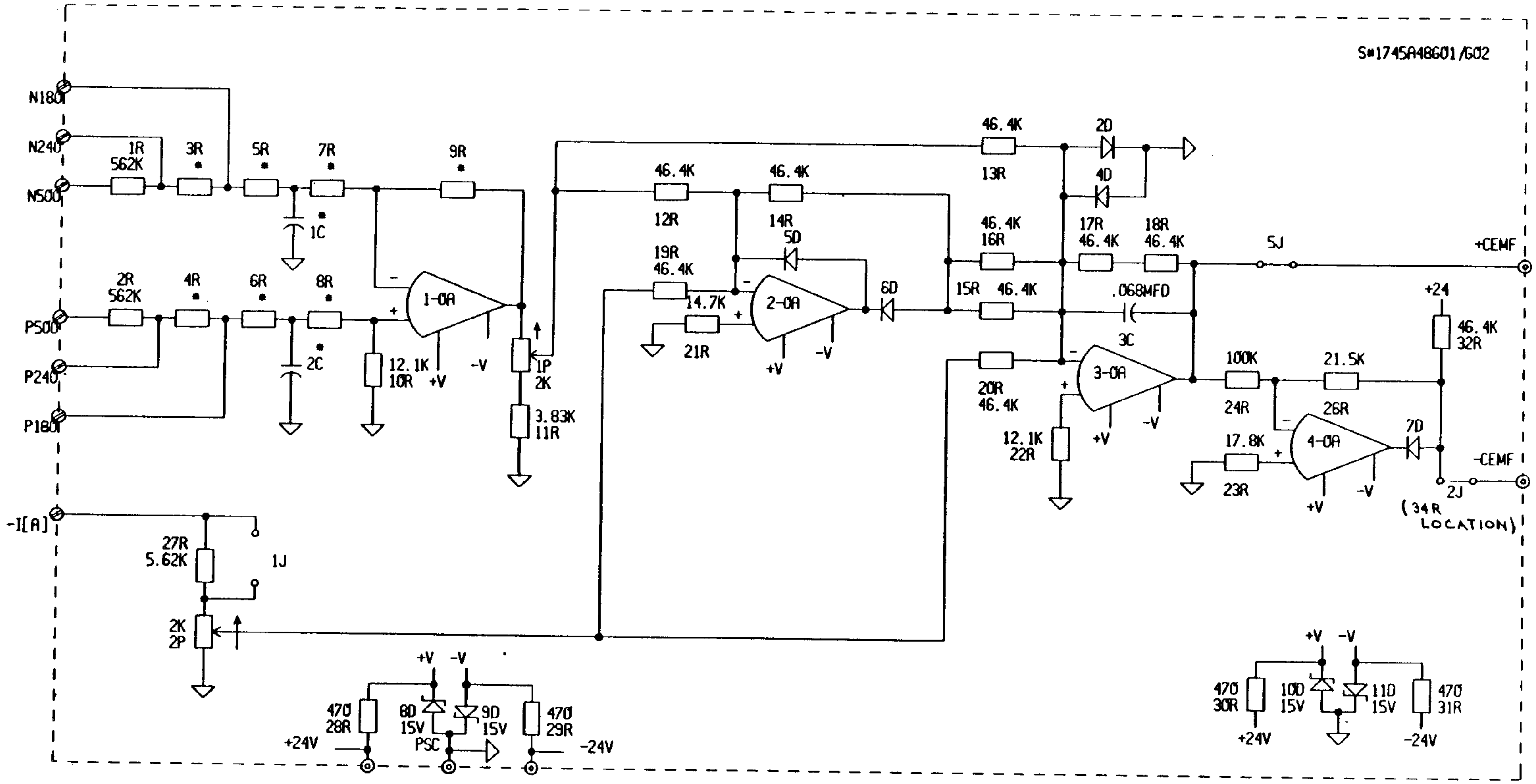
$$V(+CEMF) = \frac{+1}{(1+ST_2)} \left| \left[2\alpha_1 \cdot \frac{G_1 V_1}{(1+ST_1)} + \alpha_2 \cdot I_{(A)} \right] \right| \text{ @ Screw Terminal}$$

$$V(-CEMF) = -.215\ V(+CEMF) \text{ @ Lance Terminal}$$

Where G_1 = Gain of the first stage as given in the Table I
V_1 = Input voltage at (P180 & N180) terminals.
α_1 = 1P potentiometer setting $.657 \leqslant \alpha_1 \leqslant 1$
α_2 = 2P potentiometer setting $0 \leqslant \alpha_2 \leqslant 1$
T_1 = First stage filter time constant as given in the Table I
T_2 = Second stage filter time constant
and $I_{(A)}$ = Current feedback signal in volts

B2. Circuit Description S#1745A48G03/G04

This sensor also consists of three stages. The first stage of G03 is identical to the first stage of G02. However, the first stage of G04 has different gain values than that of G03. While terminal markings remain the same for all four groups, the G04 has been designed for use with motor armatures powered by single phase thyristor supplies at 90V and 180V rated voltages. Terminal pair P500 and N500 is not used at all in this group. The second stage consists of an inverting summer where the signals proportional to the terminal voltage and the armature current are added to produce a signal proportional to the CEMF. The third stage is a simple inverter, op-amp 4-OA, with a gain of -1. The outputs of both the stages (3-OA and 4-OA) are connected to RC filters consisting of a 10Ω resistor and a 100 Pf capacitor. This filter minimizes the effect of noise from long leads when used for carrying signals to remotely located controllers.



COMPONENT VALUE	G01	G02
3R, 4R	147K	261K
5R, 6R	215K	147K
7R, 8R	178K	121K
9R	12.1K	14.7K
1C, 2C [MFD]	.0068	.01

NOTE:

JUMPERS 5J & 2J ARE NOT PROVIDED ON BOARDS ASSEMBLED ON SUBC PRINTED CIRCUITS.

FIGURE 2B3 CEMF/VOLTAGE SENSOR SCHEMATIC DIAGRAM

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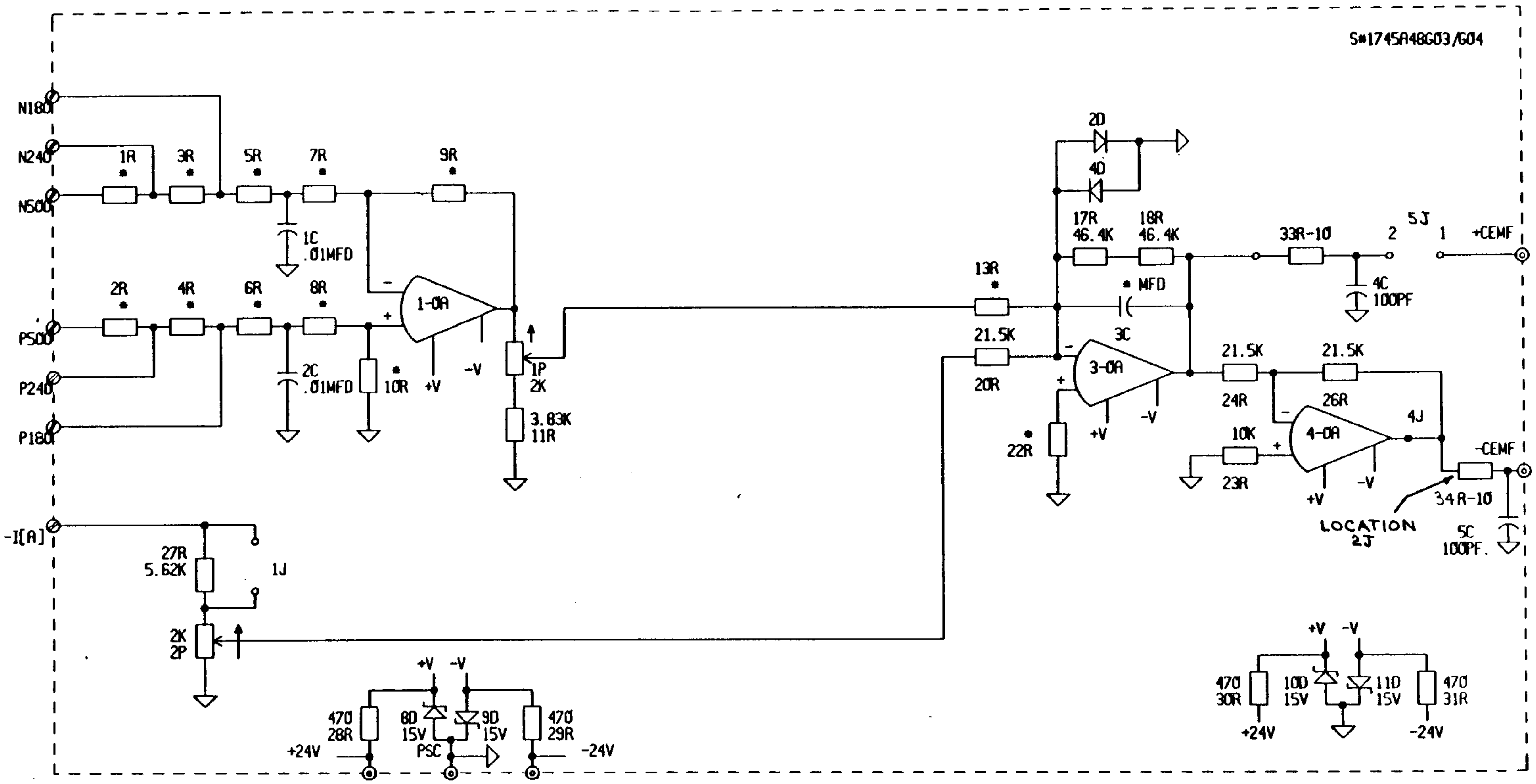


COMPONENT VALUE	G04	G03
3R, 4R	215K	261K
5R, 6R	100K	147K
7R, 8R	100K	121K
9R, 10R	12.1K	14.7K
3C	.22	.068
1R, 2R	DELETE	562K
13R	38.3K	46.4K
22R	10K	12.1K

NOTE:

JUMPERS 5J & 2J ARE NOT PROVIDED ON BOARDS ASSEMBLED ON SUBC PRINTED CIRCUITS.

FIGURE 2B4 CEMF/VOLTAGE SENSOR SCHEMATIC DIAGRAM

The transfer functions for the two outputs are as follows:

$$V(+\,CEMF) = \frac{1}{(1+ST_2)} \left(\frac{\alpha_1\, G_1\, V_1}{(1+ST_1)} + \alpha_2\, I_A \right) \quad @ \text{ Screw Terminal}$$

$$V(-CEMF) = -V(+CEMF) \quad @ \text{ Lance Terminal}$$

Where the parameters are defined the same way as those for G01 and G02 assemblies.

C. Field Crossover Regulator (Speed Reg. Armature)

This system is used on speed regulated armature drives to obtain constant horsepower operation beyond base speed. As system block diagram in figure 2C1 indicates, it combines the previously mentioned two systems in a parallel operating mode. The field current is regulated at its rated value until the motor CEMF reaches rated value. Beyond this point, the motor CEMF is held constant by closing the CEMF loop and opening the field current loop through the switching diodes in the outputs of the two sensors. The mathematical analysis and hardware is same as for the two previously described systems.

The difference is in the connections of the jumper 1J on the field controller board and the signals to the terminals. Refer to the simplified schematic diagram in figure 2C2. The normally closed "F: interlock provides a means of field economy when the drive is not running.

D. Field Crossover Regulator (Voltage Reg. Armature)

This system is used on voltage regulated armature drives to obtain constant horsepower operation beyond base speed. Block diagram in figure 2D1 shows the functional blocks that make up the system. A non-linear function generator is added in the field current feedback path so that the flux of the motor becomes linearly proportional to the regulator reference. A reference limiter circuit is also added which accepts the input reference and generates two outputs - one for armature voltage regulator and the other for the motor field flux regulator. The reference to the flux regulator is held at 10 volts for drive operations below base speed. Beyond base speed, the armature regulator reference is held constant but the reference to the flux is decreased proportionally to the change in the input reference beyond the base speed level.

As shown in the figure 2D2, the system comprises the basic exciter package with flux function generator (S#1745A47G01) and the field crossover (S#1848A60) board.

The flux function generator S#1745A47G01 is a 2.5" x 2.7" printed circuit card which mounts over the basic field controller. The schematic diagram for the function generator is given in the figure 2D3A. The input/output transfer function is given in figure 2D3B. The first stage consists of 1-OA in a proportional amplifier configuration. Diodes 3D and 4D are back biased by the 8R, 9R and 1P connected to the -15V source. However, as the output voltage of 1-OA increases beyond the bias voltage levels, 3D and 4D start conducting. This reduces the amplifier gain as well as the break points producing a functional approximation of the motor field saturation curve. Potentiometer 1P has an affect on both the break points and the gains of the three segments of the saturation curve. The output of the function generator is scaled for -2 volts to represent the rated motor flux. This means the input $(-I_f)$ signal should be calibrated according to the saturation curve for higher than 2 volts at rated field current. The dynamic response of the output to a step input change is instantaneous limited only by the bandwidth of the op-amps. For all practical purposes, there is no delay. The dynamics of the flux loop, therefore, is almost the same as that of the field current regulator.

The field crossover circuit board S#1848A60 is a 3.5" x 6.00" printed circuit card which mounts over the basic field controller board. There are two circuit configurations identified by G01 and G02. The detail schematic representation of both groups is given in figure 2D4. Two non-linear reference signals are generated at OUT1 and OUT2 from one linear input signal connected to the input terminal "IN".

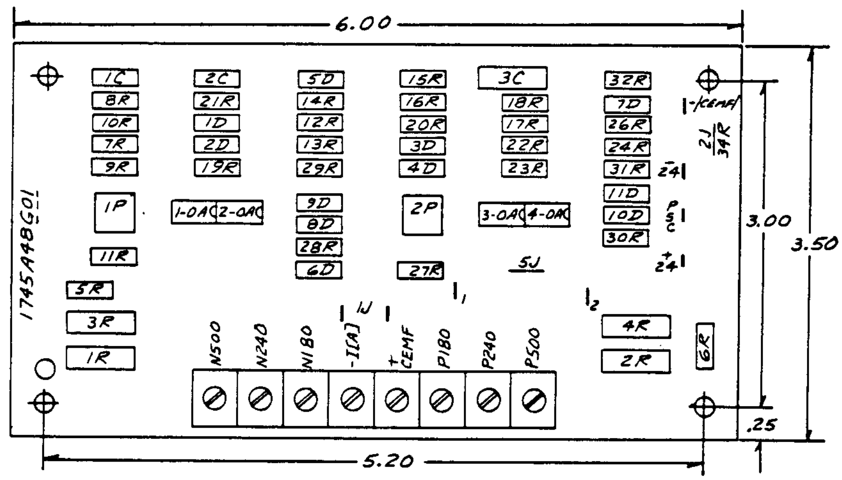


FIGURE 2B5 CEMF/VOLTAGE SENSOR-COMPONENT LAYOUT

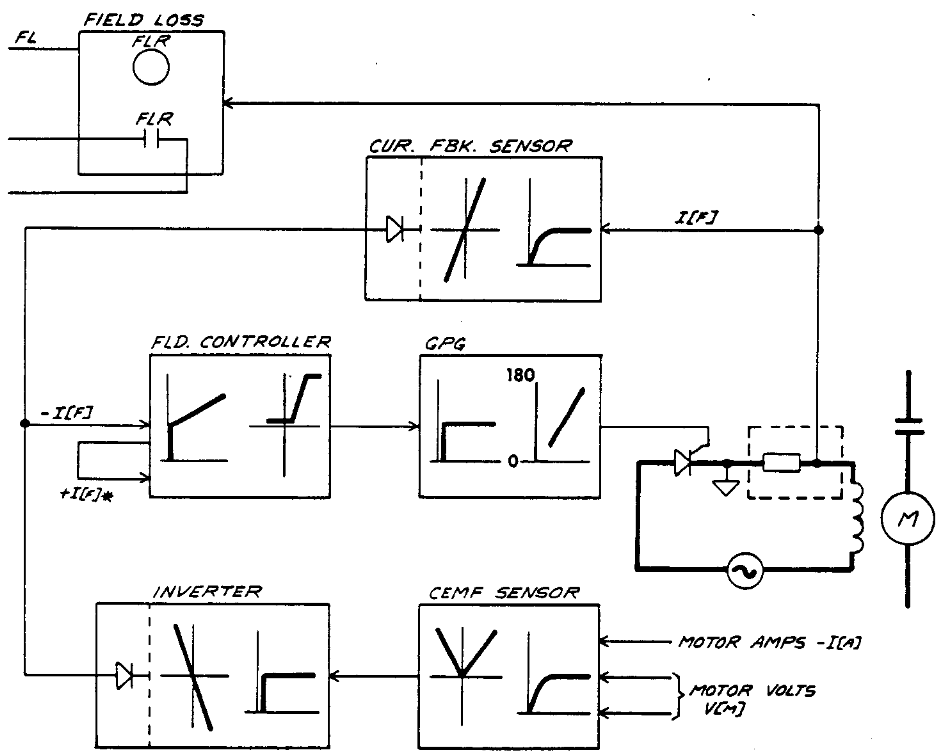


FIGURE 2C1 SYSTEM BLOCK DIAGRAM-FIELD CROSSOVER REGULATOR
(WITH SPEED REGULATED ARMATURE)

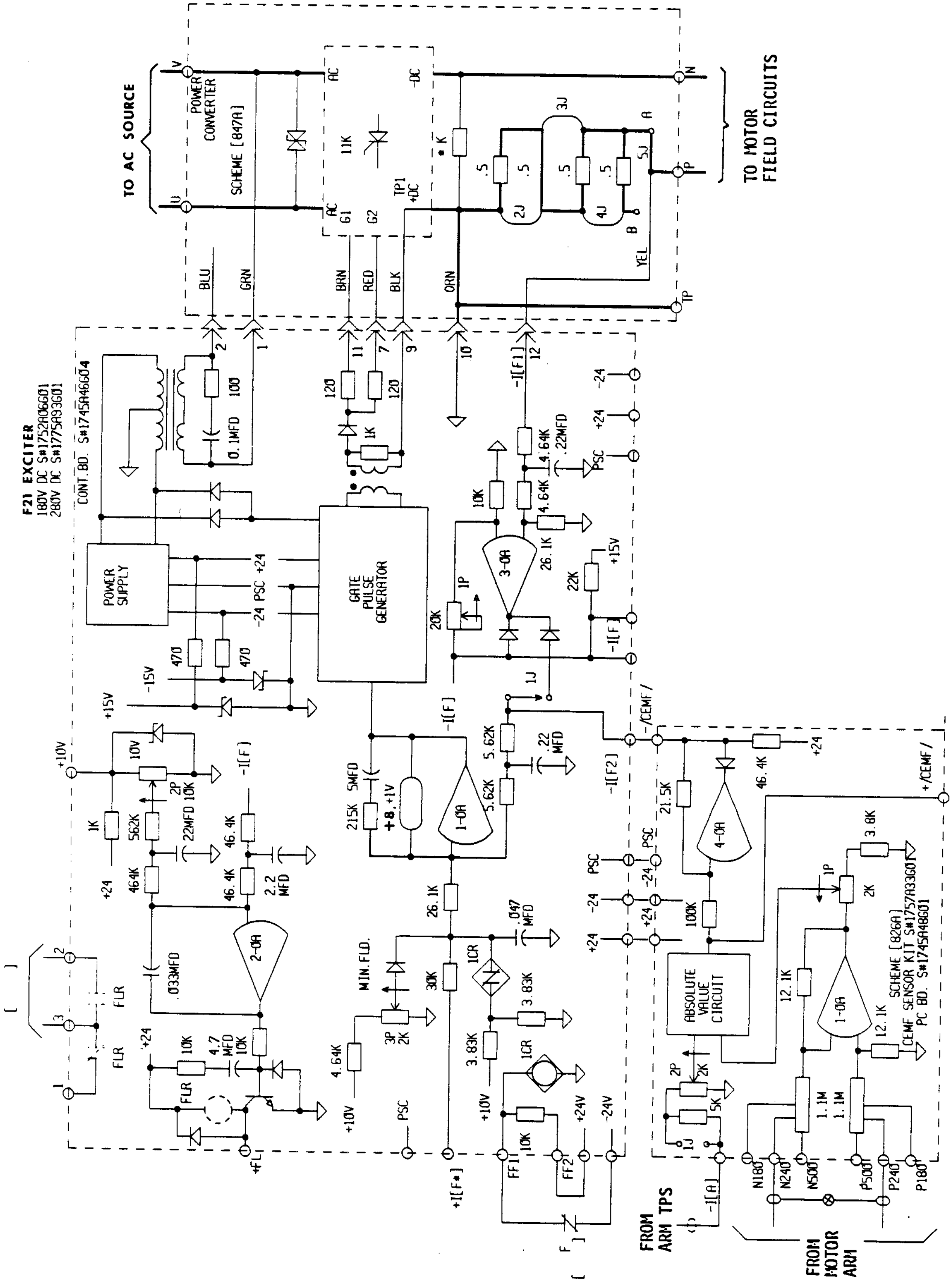


FIGURE 2C2 SIMPLIFIED SCHEMATIC DIAGRAM-FIELD CROSSOVER SYSTEM (SPEED REG. ARM.)

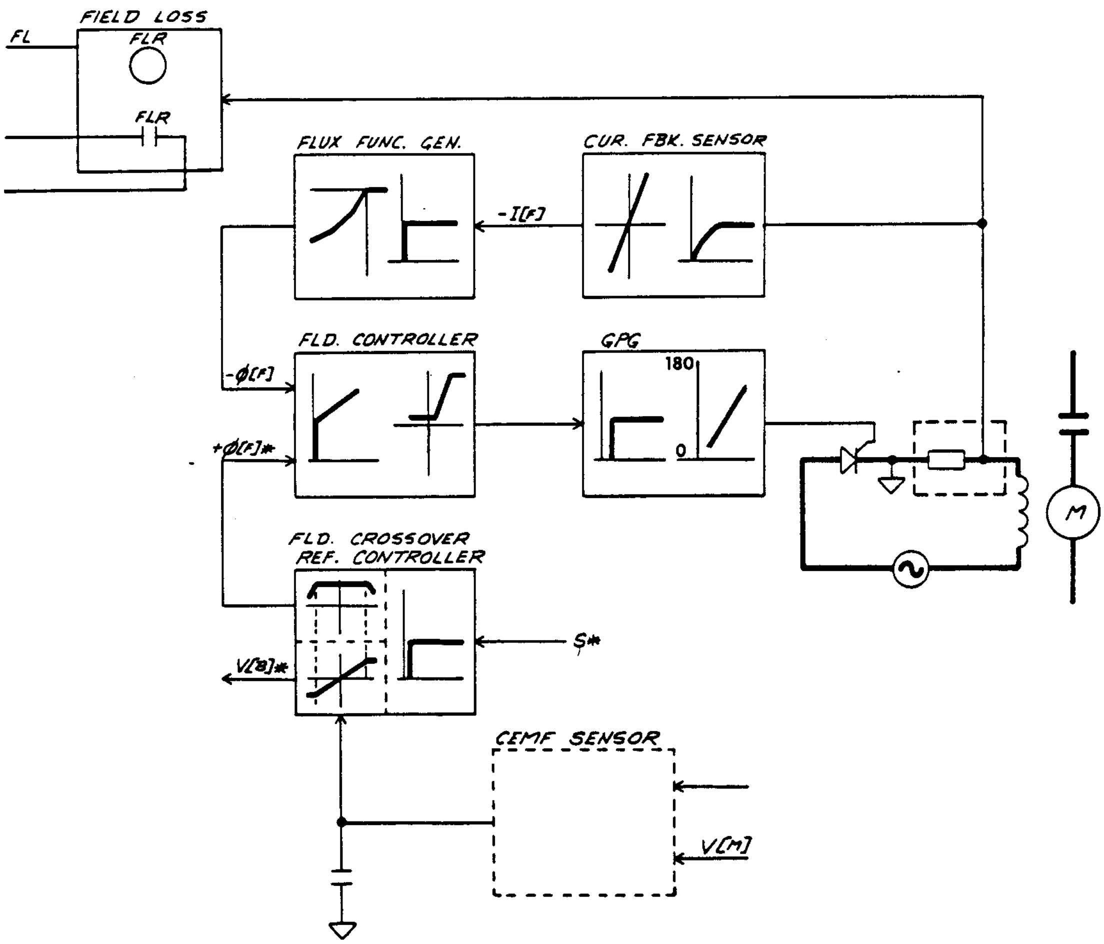


FIGURE 2D1 SYSTEM BLOCK DIAGRAM-FIELD CROSSOVER REGULATOR (WITH VOLTAGE REGULATED ARMATURE)

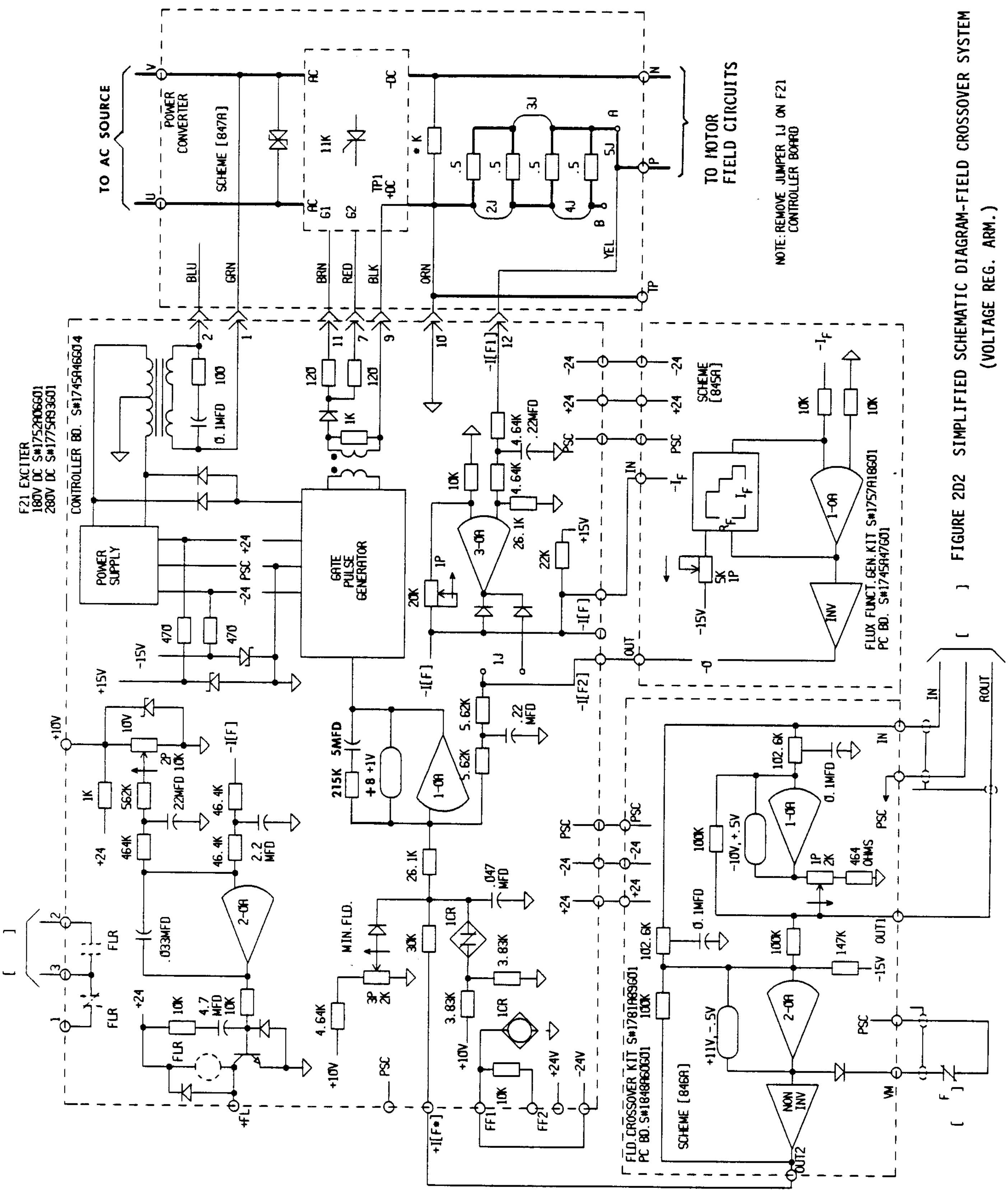


FIGURE 2D2 SIMPLIFIED SCHEMATIC DIAGRAM-FIELD CROSSOVER SYSTEM
(VOLTAGE REG. ARM.)

FLUX FUNCTION GENERATOR S#1745A47G01

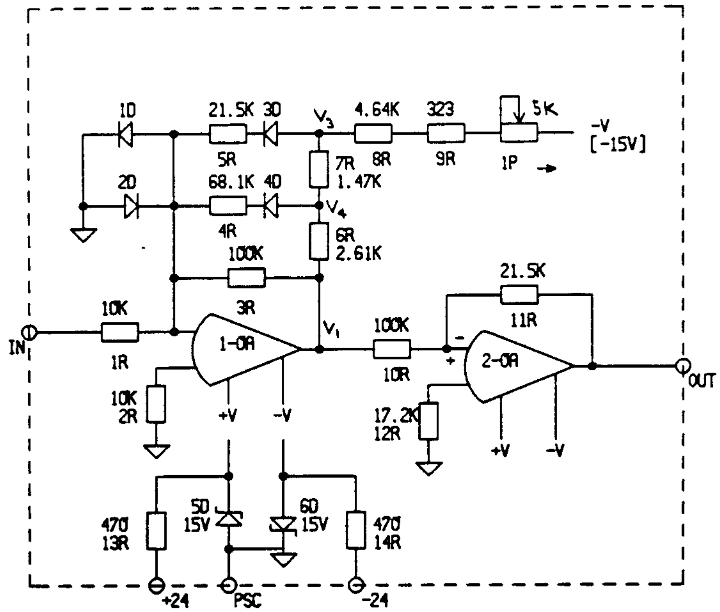


FIGURE 203A - SCHEMATIC DIAGRAM

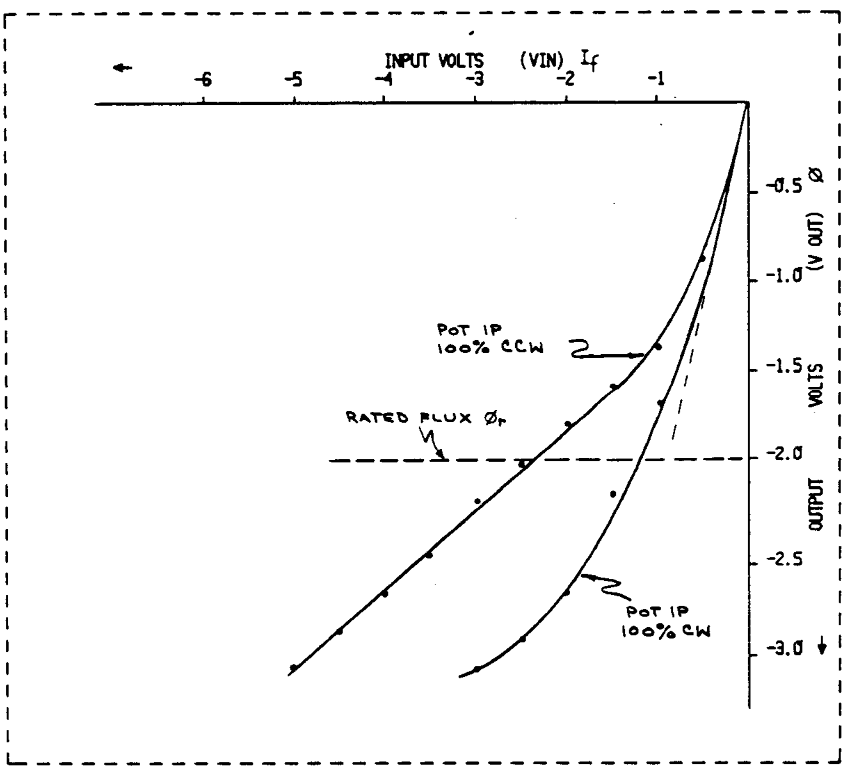


FIGURE 203B - TRANSFER CURVE OF THE FUNCTION GEN.

The op-amp 1-OA and its associated circuitry is an inverting amplifier with a variable gain range of 1 to 5 adjustable by potentiometer 1P. Zener diode 2D, diode 1D and the resistor 4R circuit make up a feedback limiter which limits the output to 10V max. The output signal at terminal OUT1 is, therefore, limited to -10V. Diode 3D provides the positive limit at about +.5V. At what input level the output reaches its limit value is determined by the potentiometer setting of 1P. If the gain of 1-OA is set for unity, the OUT1 will reach its limit of -10V when input reaches +10V. However, if the gain is set for 2.5, the OUT1 will reach its saturation limit when input reaches +4V. The signal OUT1 is, therefore, used as a reference for the voltage regulator of the armature power supply. The -10V level at OUT1 establishes rated voltage at the motor armature. The op-amp 2-OA and its associated circuitry makes up a proportional controller with a non-inverting buffer stage for series limiting function, through diode 9D. There are three inputs to this controller. One input through 11R connected to -15V, establishes an output bias level at about +10V. The other two inputs are directly and indirectly connected to the input signal at 'IN.' As long as 1-OA is not clamped by the limiter action, these two inputs cancel each other with no resultant effect on the OUT2 signal. However, as soon as 1-OA reaches its output limit, signal through 10R also reaches its limit. Beyond this point, the direct input through the T filter (12R, 13R and 3C) starts subtracting from the bias signal, thus causing output at OUT2 to decrease linearly with increase in the input signal. The signal at OUT2 is used as a reference for the flux regulator of the motor field. Figure 2D5a through 2D5c provide output/input transfer curves for three positions of 1P. The series limiter signal (terminal V_M) through diode 9D provides a means of clamping output at OUT2 from reaching full +10V level in the absence of the input signal. If the signal at V_M is grounded to PSC, the OUT2 terminal will be clamped to zero volts (subjected to the diode drop of 9D). However, a zero volt reference input to the flux regulator at I_F* terminal forces the flux level to minimum level set by the "Min. field" potentiometer 3P on the field controller board. On basic systems of this type, terminal V_M is grounded through the normally closed interlock of the motor armature contactor so as to prevent motor flashover due to sudden loss of input reference signal while motor is operating at speeds beyond base speed. In the circuit configuration of G02, the 9D diode circuit is connected to the 3-OA op-amp controller circuit. A signal proportional to the motor armature voltage, from the CEMF sensor S#1745A48, is connected to terminal V_M as a feedback. In the event of loss of input reference signal, the controller 2-OA switches 'off' and the controller 3-OA switches 'on' for regulating the motor armature voltage through the flux loop. This method provides a positive voltage clamping of the CEMF and a faster deceleration through dynamic braking (if used).

It should be noted that this crossover system does not provide linear relationship between reference and motor speed unless the flux function generator is adjusted to provide motor flux inversely proportional to the change in reference signal beyond base speed reference.

A front view layout of the components for both circuit boards is shown in figures 2D6a and 2D6b.

E. <u>Field Curr/Flux Regulator (Reel Systems)</u>

This system is used on reel drive systems to obtain constant horsepower operation at all reel diameters. The motor field current or flux is regulated to the value dictated by the reference signal from the standard reel controller. A CEMF sensor is ordered as a part of this system. However, its output is used by the coil diameter calculator in the Reel Controller. The output of the coil diameter calculator establishes reference level for the current/flux regulator. If the flux control is used, the reference from the coil diameter calculator represents the coil diameter accurately. If only the field current is regulated, the reference input to the field regulator does not represent the diameter accurately and, therefore, cannot be used for calculating inertia compensation signal or any other signals related to the diameter.

A typical system block diagram is given in figure 2E1. It represents a system in which linear CEMF sensor S#1745A48G03 is used for signal feedback to the coil diameter calculator of the "Reel Controller." Variations of this system include use of CEMF sensor with an absolute value output (S#1745A48G01/G02) or a plug-in type Flux Function Generator mounted in the Reel Controller. For details of any given system, refer to the applicable schematic diagram.

The description of the flux function generator S#1745A47G01 and the CEMF sensor S#1745A48 is given in the previous sections of this I.L. Refer to appropriate I.L.'s for description of other types of flux function generators and/or CEMF sensor, if used in the system.

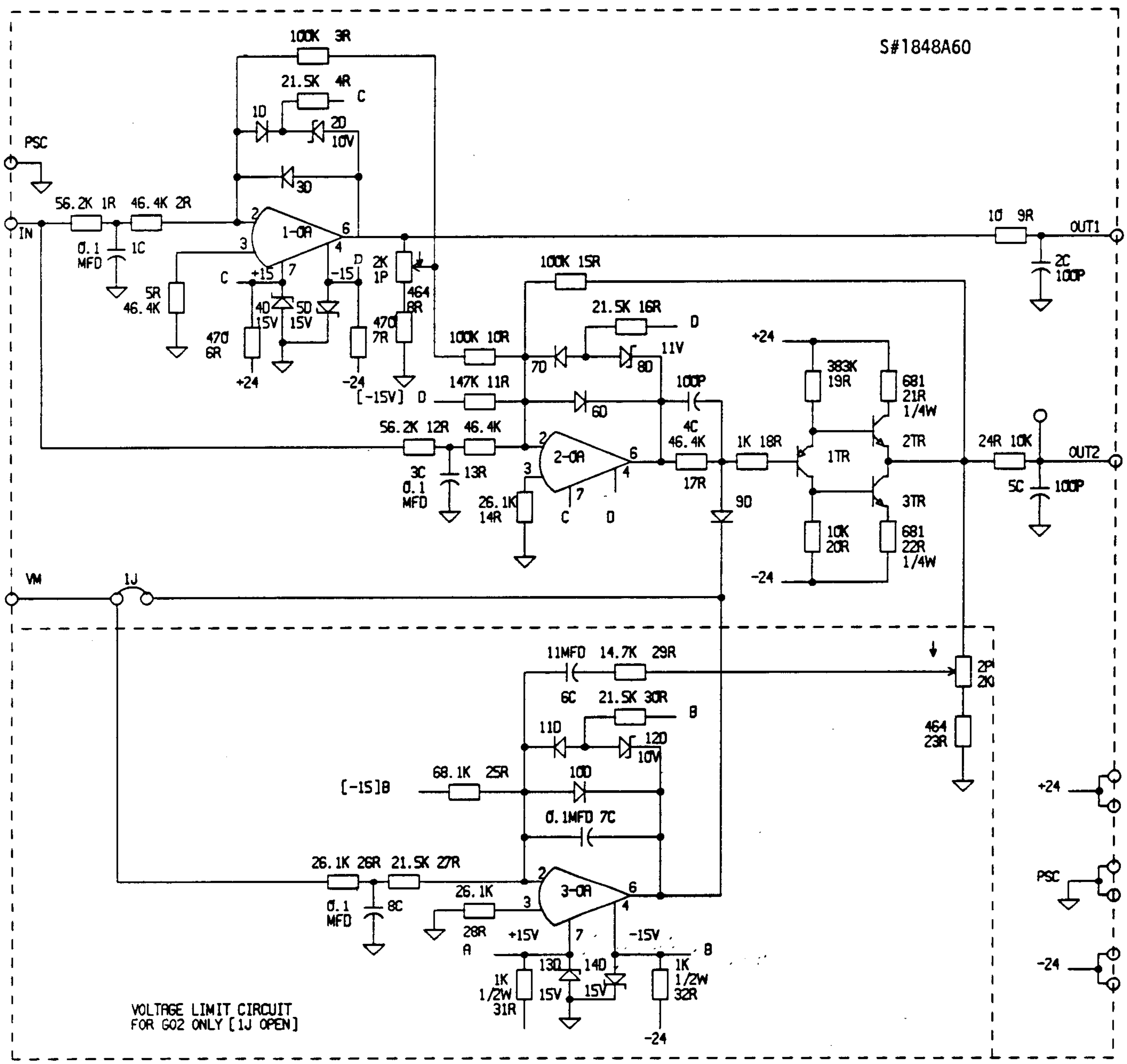


FIGURE 2D4 FIELD CROSSOVER REFERENCE CIRCUIT

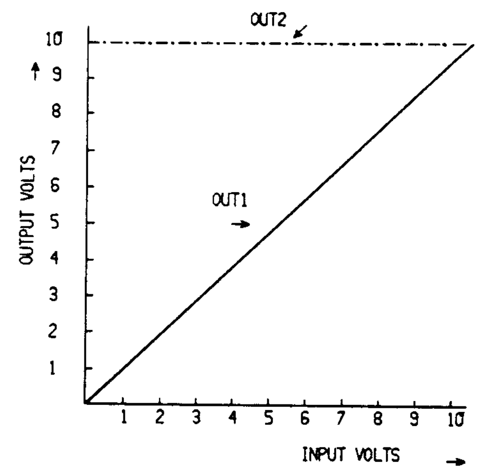


FIGURE 205A:

TRANSFER CHARACTERISTICS OF THE FIELD CROSSOVER CIRCUIT POTENTIOMETER 1P SET FOR 0% CW

GAIN OF 1-OA, =1

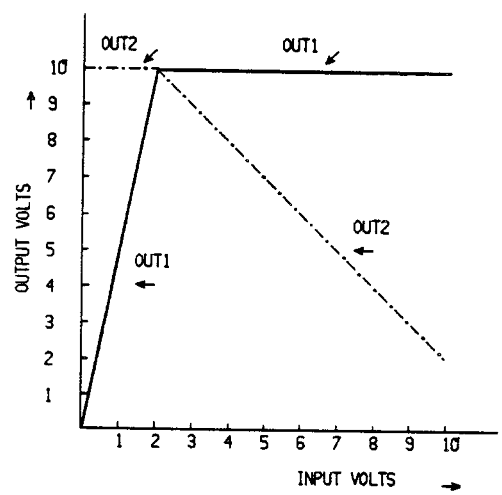


FIGURE 205B:

TRANSFER CHARACTERISTICS OF THE FIELD-CROSSOVER CIRCUIT POTENTIOMETER 1P SET FOR 100% CW.

GAIN OF 1-OA, =0.2

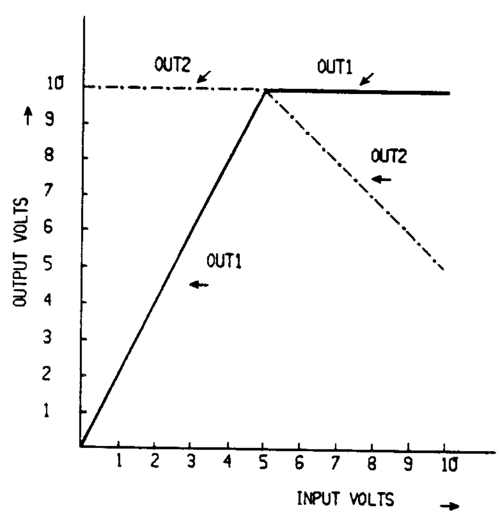
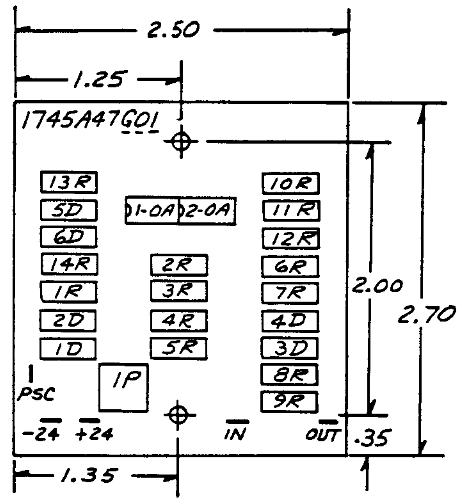


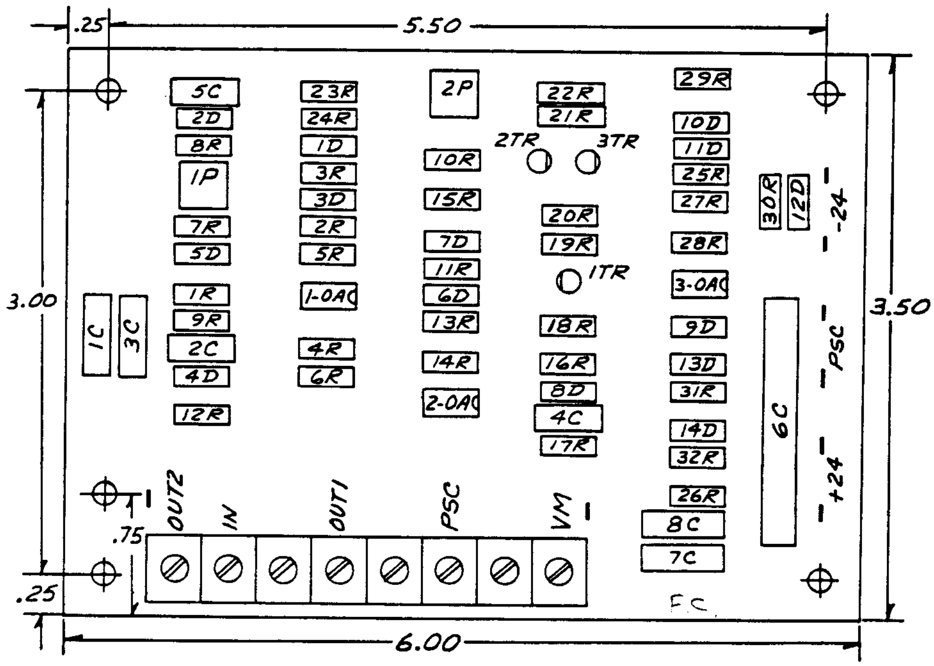
FIGURE 205C:

TRANSFER CHARACTERISTICS OF THE FIELD CROSSOVER CIRCUIT POTENTIOMETER 1P SET FOR 63% CW

GAIN OF 1-OA, = 0.5



A) FLUX FUNCTION GENERATOR S#1745A47G01



B) FIELD CROSSOVER CONTROLLER S#1848A60G01/G02

FIGURE 2D6 COMPONENT LAYOUTS OF P.C. BOARDS

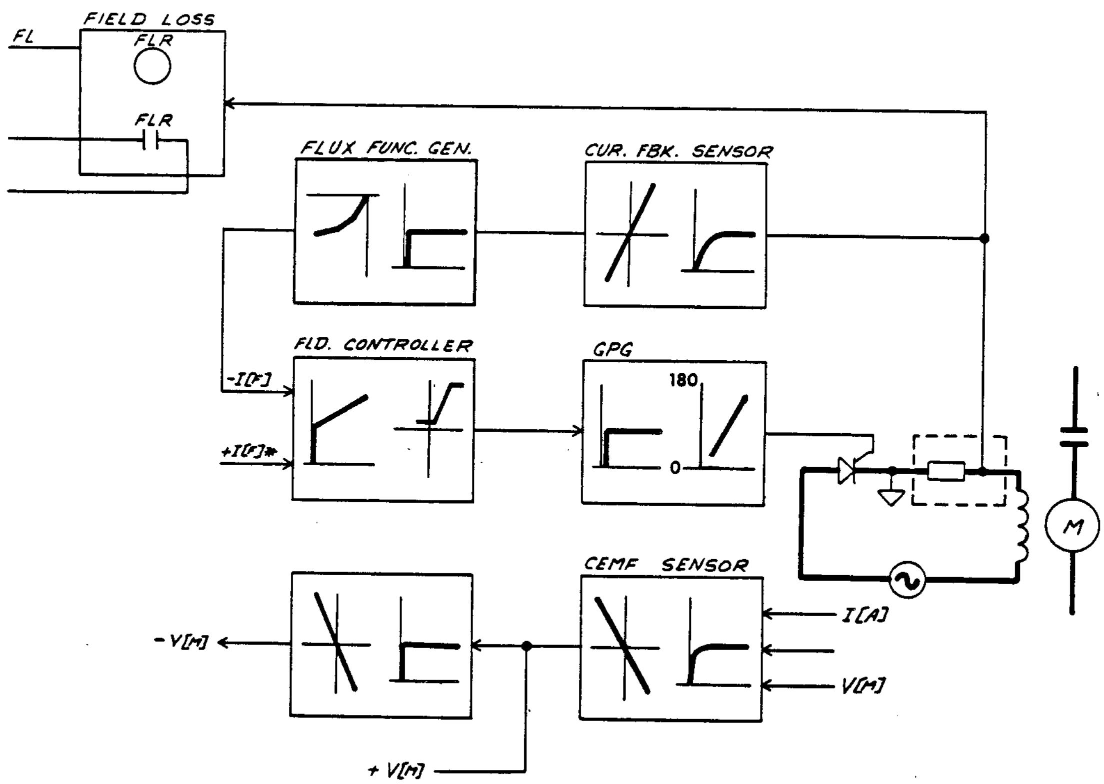


Figure 2E1 Systems Block Diagram - Field Curr/Flux Regulator
(Reel Systems)

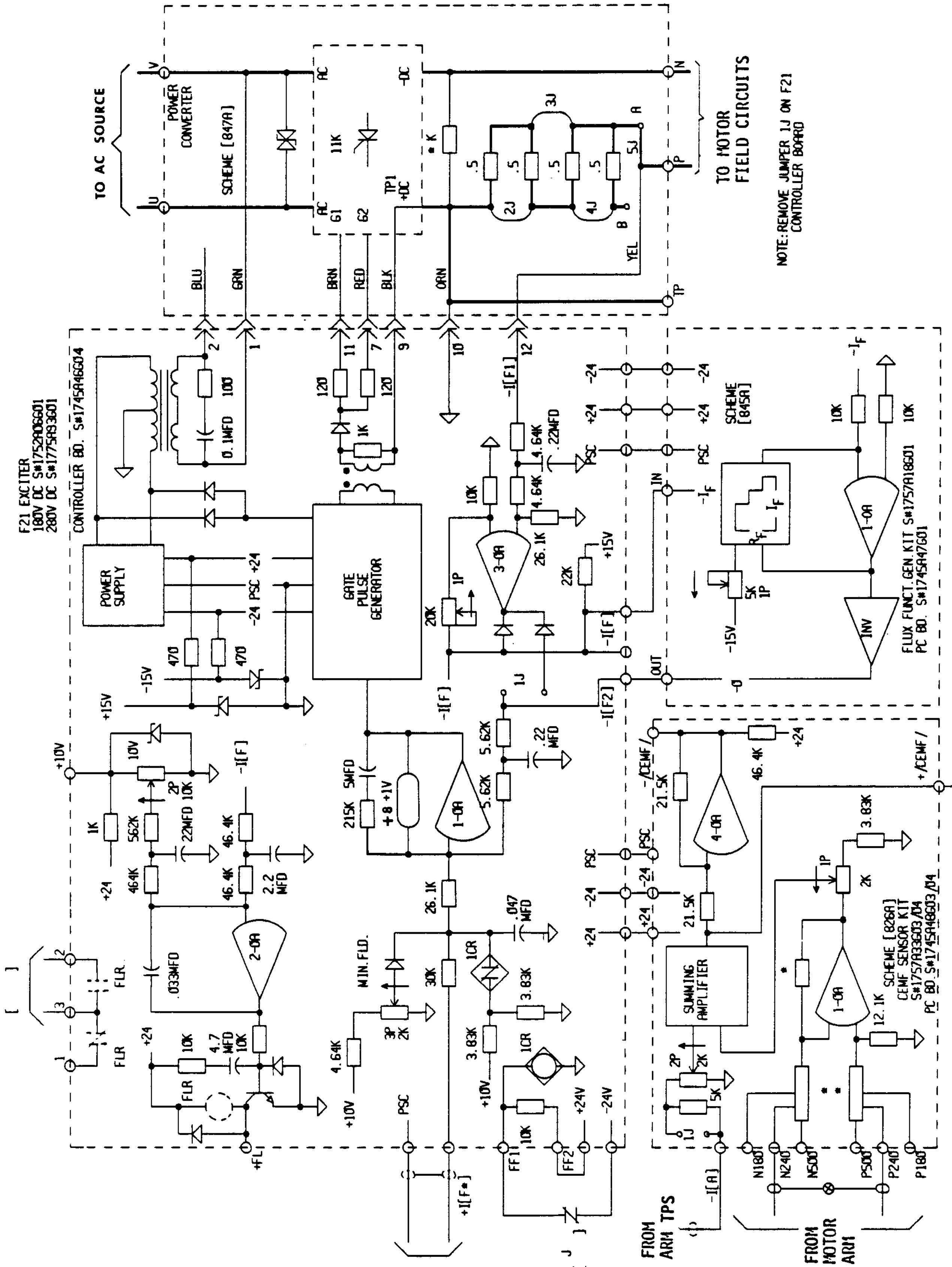


Figure 2E2 Simplified Schematic Diagram - Field Curr/Flux Regulator (Reel Systems)

* FOR VALUES SEE FIG. 2B4

F. Linear Speed Follow

This regulator system provides an open loop control of motor speed by varying the input to a field flux regulated motor field. The flux loop is the same as that described in Section D. With a fixed voltage across the armature terminals of a d.c. motor, the speed varies inversely with the motor flux. In order to control the motor speed linearly with an input signal to the motor field, the flux loop reference must be varied in an inverse proportion to this signal. The system block diagram and the simplified schematic is shown in figures 2F1 and 2F2 respectively. This system consists of the flux loop regulator system and a piggyback mounted reference function generator S#1781A21G01. The dynamic characteristic of the flux loop is the same as that of the field current regulator described in Sections A and D.

The reference function generator board S#1781A21G01 is a 3.5" x 6.00" printed circuit card which mounts over the basic field controller board. There are three basic circuit configurations identified by G01, G02 and G03. The detail schematic representation of the groups G01 and G02 is given in figure 2F3. Use of the G03 circuit is described in the next section. As obvious from the schematic, the G02 is different from G01 only by an inverter circuit in the output. The op-amp 1-0A and its associated circuitry is a differential input amplifier for current source signals. Jumper 1J offers a choice of burden resistors such that the output at test point TP1 is 10 volts at 20ma. for 1J position 1 and at 50ma. for 1J in position 2. The op-amp 3-0A and its associated circuitry generates a -2 volt signal at test point TP3 from the +24 (PSP) power supply signal. This -2 volt signal is used as a numerator input (Z) into the divider (1M/D) and also as a variable bias through 1P into op-amp 2-0A circuit. The op-amp 2-0A and its associated circuitry constitutes a summing samplifier for the signals from 1-0A, potentiometer 1P and the voltage signal inputs at E_1 and E_2. The output of 2-0A is limited within a range of +0.5V to -10.5 volts. Potentiometer 4P provides a gain calibration range of 0.5 to 2.65 with respect to the current and voltage signal inputs. The output of 2-0A provides the denominator input (Y) into the divider (1M/D). The output signal at OUT1 is then reciprocal of the input at (IN-IP), E_1 or E_2.

For linear motor speed follow, (IN-IP) input is used if the reference signal is from a current source and terminal E_1 is used if it is from a voltage source. The standard transfer curves of the circuit are given in figure 2F4. If the motor speed is to follow a sum of two input signals, they are connected to E_1 and E_2 respectively. However, if the input is from a manually adjustable potentiometer, one end of that potentiometer is connected to terminal E_3 while the other end is connected to a voltage source with the wiper connected to E_1 or E_2 terminal.

A front view layout of the components of the circuit board is shown in figure 2F5.

G. Linear Flux Follow

This regulator system provides control of the motor field flux as a signal follow from a voltage and/or current source. The flux loop is same as that described in Section D. A linear summing amplifier circuit is used for generating reference signal for the flux regulator as shown in block diagram and simplified schematic of figures 2G1 and 2G2.

The reference function generator S#1781A21G03 is similar to that described in Section F except that the output is directly proportional to the input instead of inversely proportional. The detail circuit is presented in figure 2F3. The circuits for G01 and G02 are described in the preceding section. That description, except for the divider (1M/D), also applies to G03. The transfer function of the circuit is

$$V_{OUT2} = -V_{TP2} = 0.5G\left[\frac{E_1 + E_2 + IR}{(1 + ST_1)} - 3.3\right]$$

where, G is the gain adjustable by 4P over a range 1 to 5.3
T_1 is the filter delay of 0.1 ms.
α is the per unit setting of 1P over a range 0 to 1
R is 0.2K for 1J at position 1 and 0.5K for position 2

A front view layout of the components of the circuit board is shown in figure 2F5.

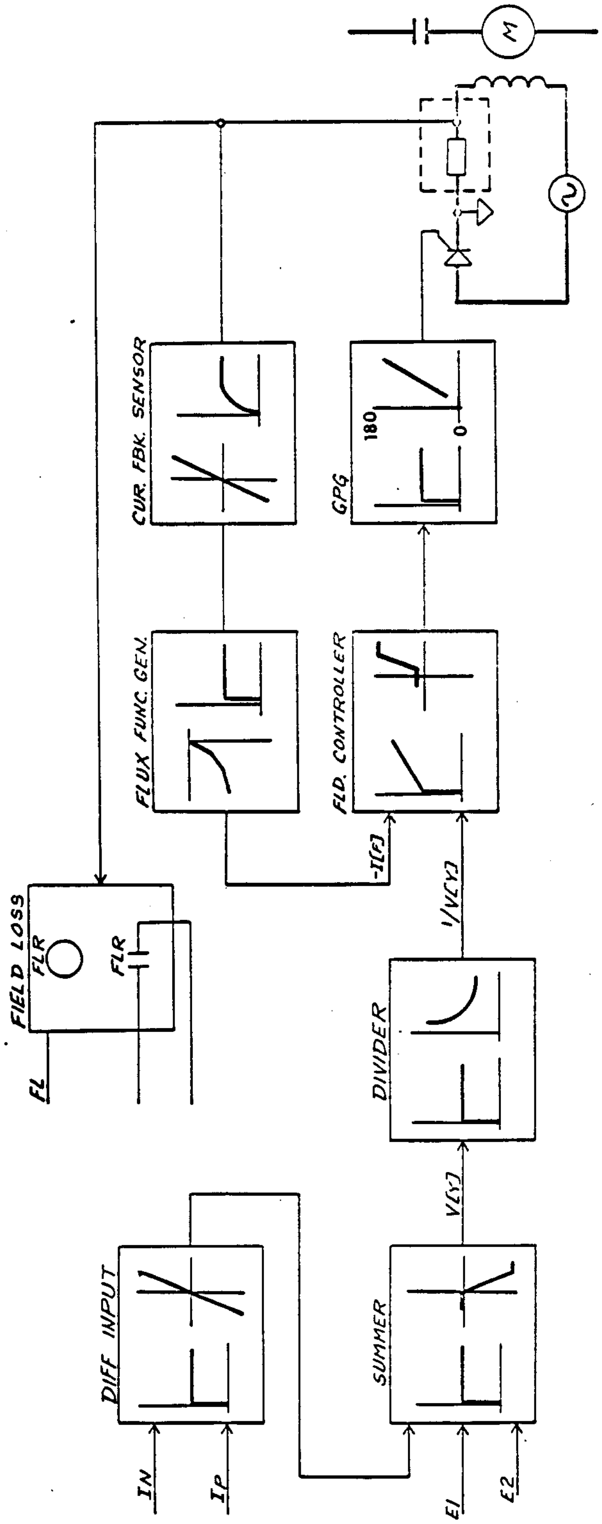


Figure 2F1 Systems Block Diagram Motor Field Regulator (Linear Speed Follow)

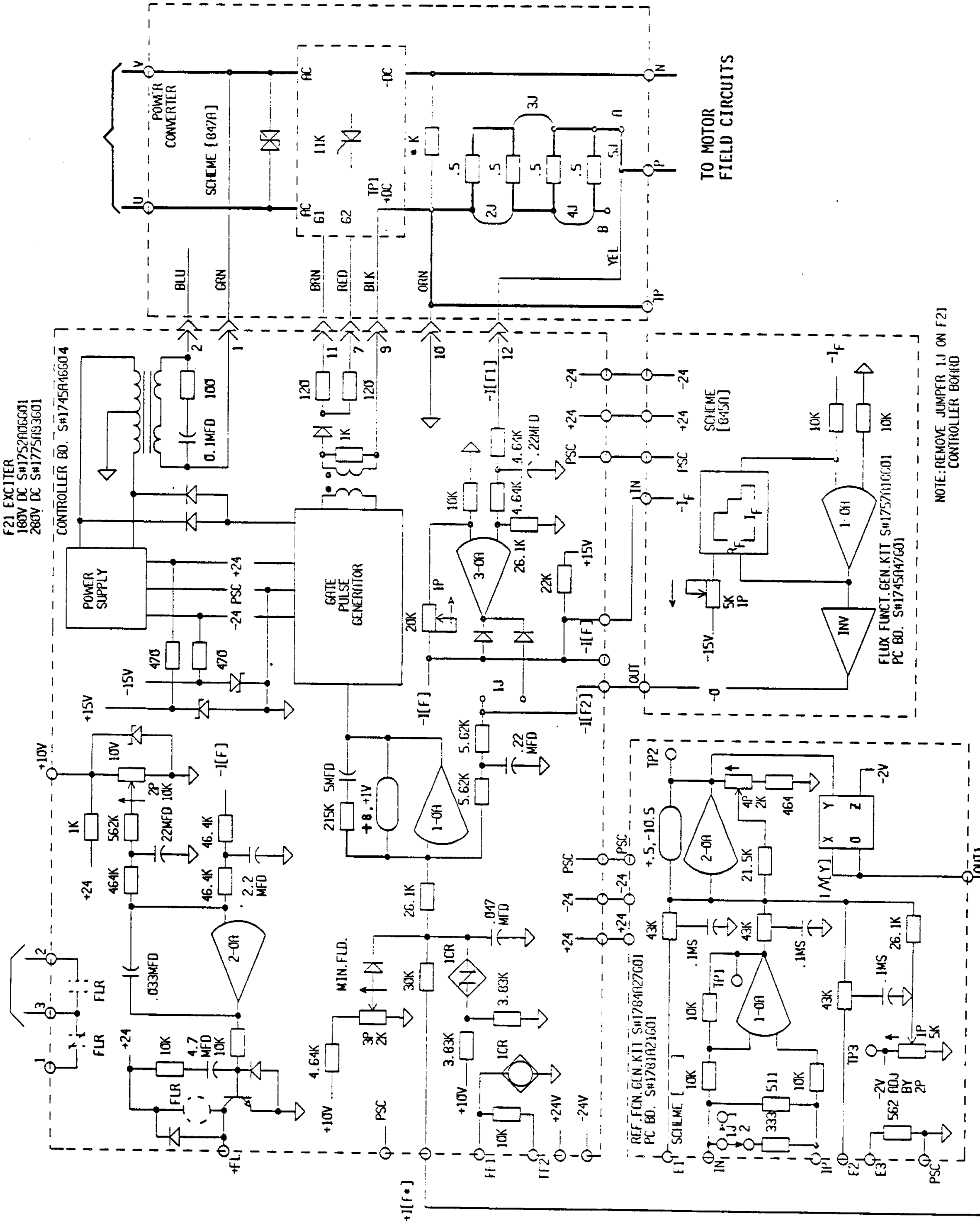
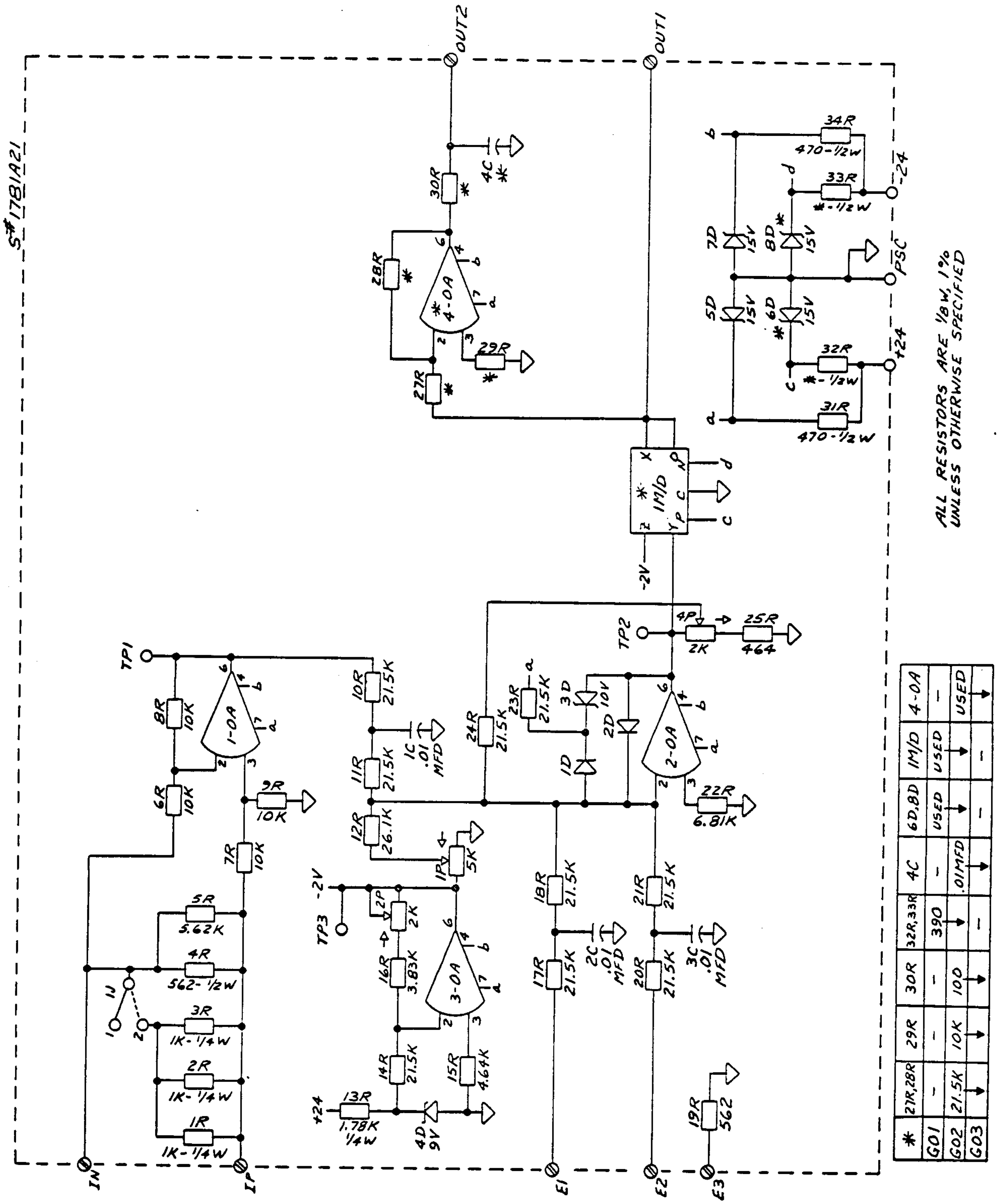


Fig. 2F2 Simplified Schematic Diagram Motor Field Regulator (Liniar Speed Follow)



*	21R,28R	29R	30R	32R,33R	4C	6D,8D	1M/D	4-0A
G01	-	-	-	390	-	USED	USED	-
G02	21.5K	10K	100	→	.01MFD	→	→	USED
G03	→	→	→	-	→	-	-	→

Fig. 2F3 - Reference Function Generator

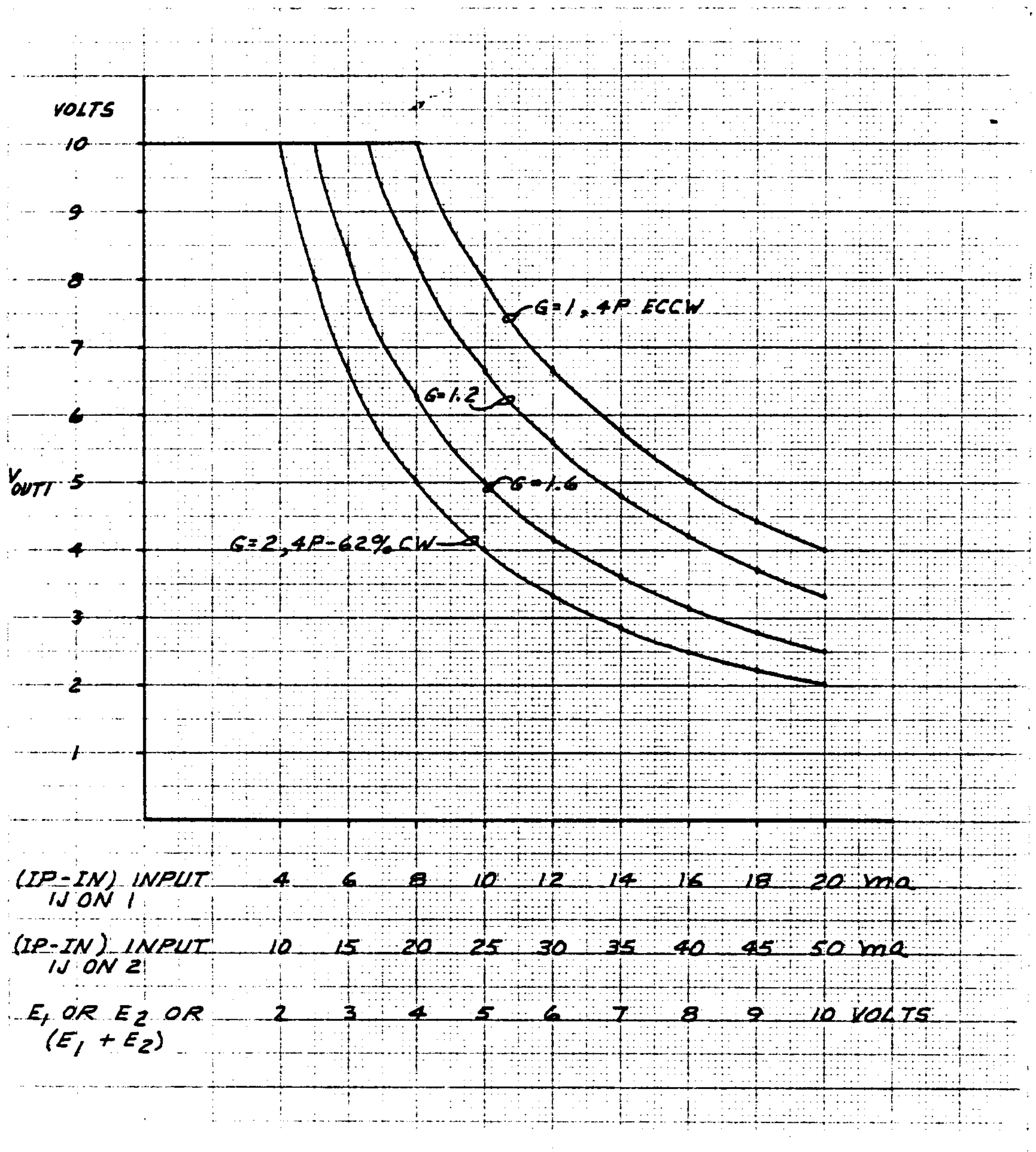
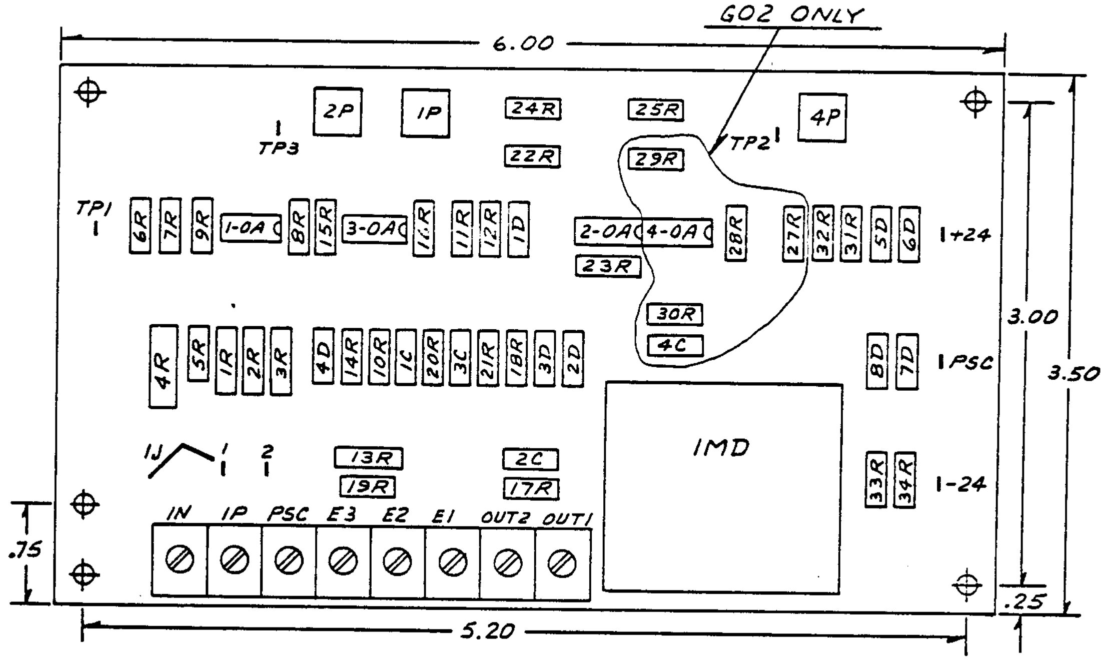
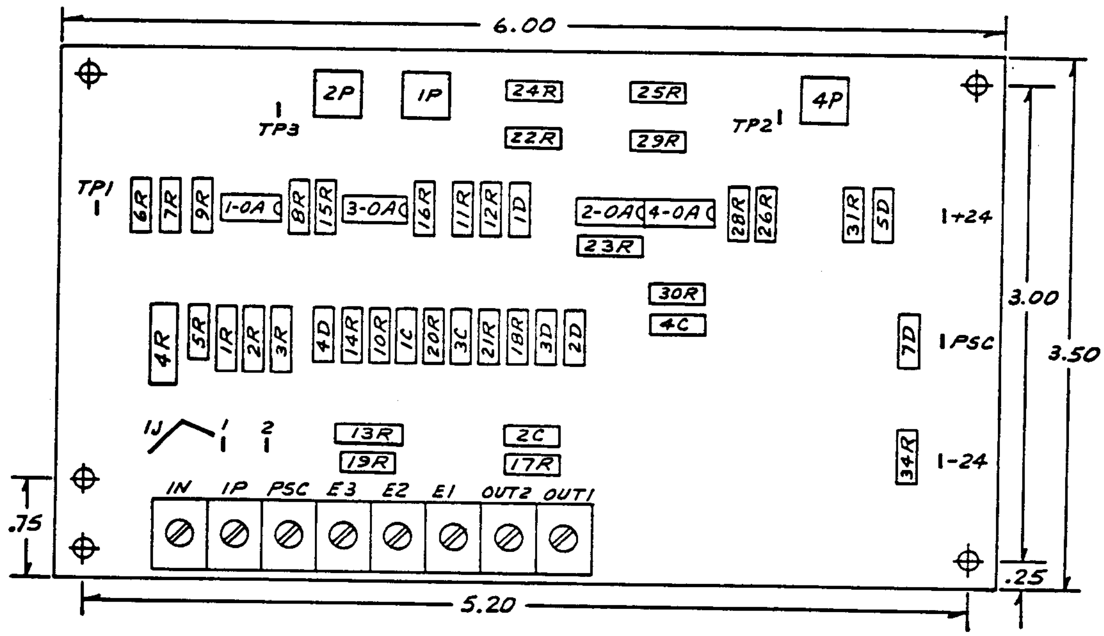


Fig. 2F4 Transfer Curves - Ref Function Generator



A. Ref. Function Generator 1781A21G01, G02



B. Ref. Function Generator 1781A21G03

Fig. 2F5 Component Layout of P.C. Boards

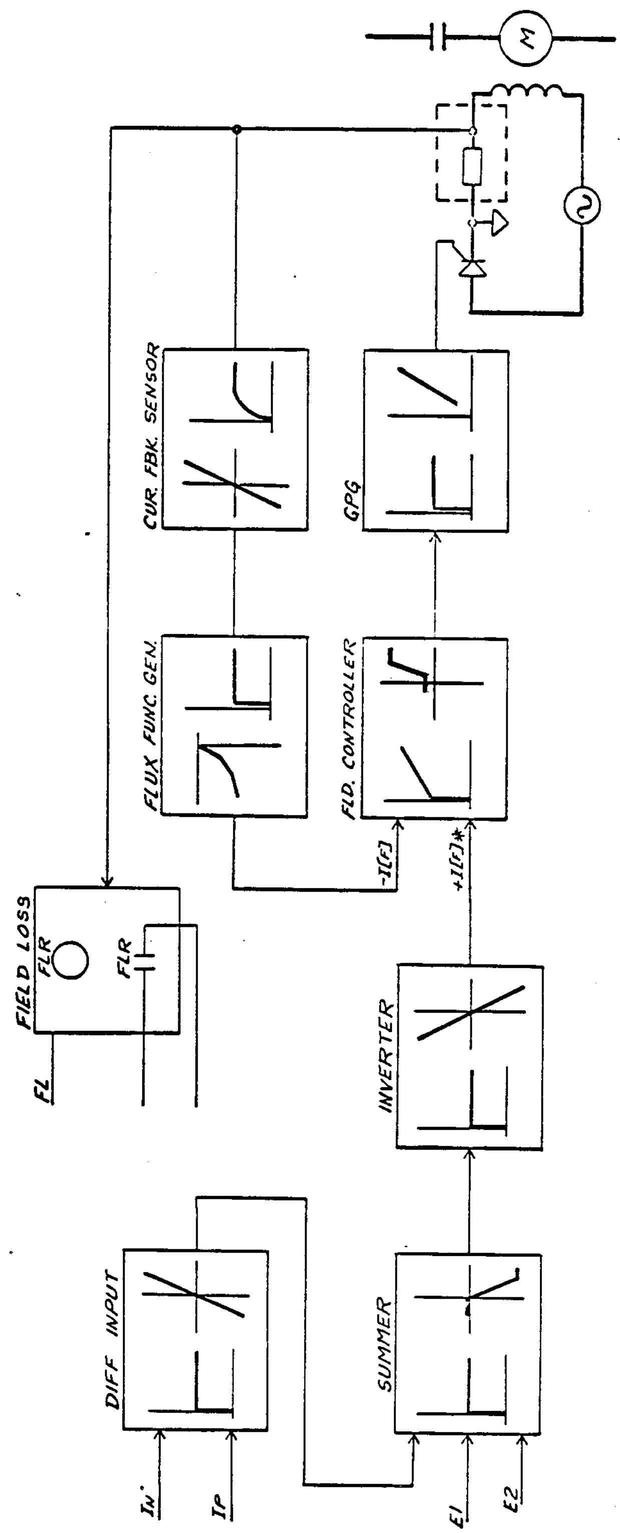


Fig. 2G1 Systems Block Diagram Motor Field Regulator
(Linear Flux Follow)

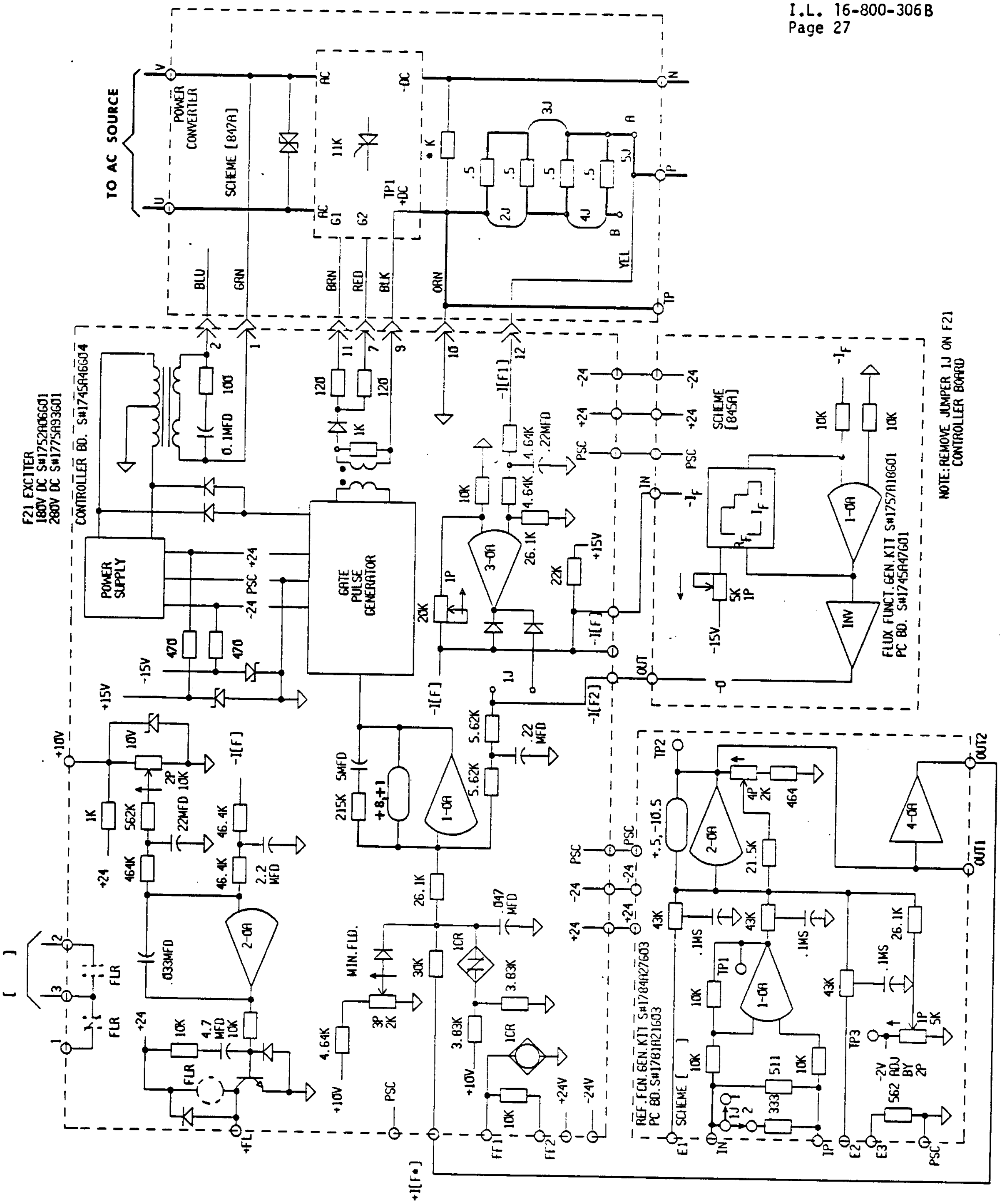


Fig. 2G2 Simplified Schematic Diagram - Motor Field Regulator
(Linear Flux Follow)

III. ALIGNMENT & START-UP PROCEDURE

Irrespective of the type of system employed, it is desirable that the basic field exciter package be checked and tuned as a field current regulator (system A). Following steps provide a guideline for this purpose.

A. Field Current Loop

A1. Temporarily disconnect input/output signals from the piggyback circuit boards and close jumper 1J on the field controller board if open. The schematic given in Figure 3 of the I.L. 16-800-305 or I.L. 16-800-392 should then be applicable.

A2. With leads U & V disconnected from the field exciter, energize the field transformer or the main transformer as the case may be to check the secondary voltage. It should correspond to that shown in the applicable schematic.

A3. Reconnect a-c secondary leads to U & V. Disconnect the input signal from the terminal $+I_f^*$ on the controller board. Connect a 0 to +15V variable control signal across terminal $+I_f^*$ and PSC. Check the connections of current feedback resistors for conformance with the applicable schematic diagram and regulator setup data. (Refer to the table in I.L. 16-800-305). For the isolated feedback package, the correct number of turns is required. (Refer to I.L. 16-800-392).

A4. With min field pot 3P extremely CCW, 0V at $+I_f^*$ and terminal FF1 tied to PSN, apply the a-c voltage to the exciter. The exciter output current should be zero.

A5. Vary the input voltage from 0 to 10V, the output current should vary linearly with input voltage. Set input voltage at +10V, adjust 1P on the controller board for rated field current.

A6. Set input signal at $+I_f^*$ for 0 volts. Adjust min field pot 3P for field current level of 80% of desired minimum field current and adjust 2P for field loss signal. The +FL terminal goes to open circuit votlage level dictated by external connections to it under the field loss condition.

The inputs and outputs should be calibrated for the values provided in the regulator setup data sheets of the applicable schematic.

B. CEMF Regulator System

The alignment procedure for this system consists mainly of the calibration of the CEMF/voltage sensor. However, to achieve independent adjustments of the sensor from close loop regulator effects, it is suggested that the system be temporarily changed over to basic current loop as outlined below.

B1. Remove the jumper connection between the CEMF sensor output and the $-I_f^2$ point on the field controller board. Use the same jumper in position 1J for direct current feedback.

B2. Checkout the basic regulator system as per the procedure outlined for system A except step A6.

B3. With +10V input at I_F^* terminal (rated field current) calibrate the CEMF sensor as described in detail later in this section.

B4. Reconnect the CEMF sensor back to the original state while removing the direct field current feedback.

B5. Calibrate the "Min Field and "Field Loss" adjustments as per step A6.

CEMF/Voltage Sensor Calibration

The calibration of the sensor depends upon the group number of the S#1745A48 and the need for accuracy in the IR compensation adjustment. Since the voltage limit of the armature TPS is almost 104% (for M5B's & M4C's) of its nominal rating, the singal calibration levels are always based on using the motor terminal voltage as the rated value whether the cemf or the terminal voltage is being used and whether the drive motor is in a motoring or a regenerating mode.

To understand the implications of the above statement, let us take a look at the generalized voltage equation of a d.c. machine.

$$V_T = E + (R + La \frac{d}{dt}) \; Ia$$

Where V_T is the terminal (bus) voltage
E is the cemf of the machine
I_a is the armature current
R is the total armature circuit resistance
La is the total armature circuit inductance
$\frac{d}{dt}$ the time derivative

Normalizing the above equation and using the laplace transform we get.

$$\frac{V_T}{V_{Tr}} = \frac{E}{V_{Tr}} + (1 + Ta\ S) \frac{\overline{Ia}\ R\ Iar}{V_{Tr}}$$

Where V_{Tr} is the rated terminal voltage and Iar is the rated armature current.

Representing the above in a more compact form

$$\overline{V_T} = \overline{E} + D \quad (1 + Ta\ S) \ \overline{Ia}$$

Where D is the rated normalized droop $\frac{IarR}{V_{Tr}}$ and T_a is the armature circuit time constant $\frac{La}{Ra}$.

As evident from the above equation, a perfect compensation would require $I_a R_a$ as well as $La \frac{d\,Ia}{dt}$ signals. However, in simple systems this precision is not necessary and therefore, only the steady-state IaRa compensation is provided. The above equation simplifies to

$$\overline{V_T} = \overline{E} + D\ \overline{Ia}$$

This equation takes on four different forms depending upon the application.

1. For dc machine in a motoring mode with bus voltage control

   $\overline{V_T} = \overline{E} + D\ \overline{I_a}$ ----------- B1

2. For dc machine in a motoring mode with cemf control

   $\overline{E} = \overline{V_T} - D\ \overline{I_a}$ ----------- B2

3. For dc machine in a regenerative mode with bus voltage control

   $\overline{V_T} = \overline{E} - D\ \overline{I_a}$ ----------- B3

4. For dc machine in a regenerative mode with cemf control

   $\overline{E} = \overline{V_T} - D\ \overline{I_a}$ ----------- B4

Since $\overline{VT}$ is always to be limited to a maximum of 1, the calibration for $\overline{E}$ depends upon the droop D. For example, a drive system with a 10% armature droop (having a value of D equal to .1) would require different calibration for the sensor output for the four different application conditions as shown in the table below.

DRIVE APPLICATION		WITH RATED NO LOAD (INPUT) VOLTS ADJUST 1P FOR				RATIO FACTOR γ
		S#1745A48G01/G02		S#1745A48G03/G04		
		OUTPUT @ +/CEMF/	OUTPUT @ -/CEMF/	OUTPUT @ +/CEMF/	OUTPUT @ -/CEMF/	
1	Motoring Bus Volt.Cont	+9.3V	-2V	-10V	+10V	1
2	Motoring CEMF Control	+10.23V	-2.2V	-11V	+11V	(1+D)
3	Regenerating Bus Volt. Cont	+9.3V	-2V	-10V	+10V	1
4	Regenerating CEMF Control	8.45V	-1.82V	-9.09V	+9.09V	$\frac{1}{(1+D)}$

These values have been arrived at by computing a ratio factor (γ) for these four applications from the value of normalized droop D (0.1 in this case) and then multiplying the rated output signal levels by this factor. The per unit value of D is computed by first measuring the IR drop at the input terminals of the sensor board with rated arm.current circulating under the stall condition. The measured IR drop is then divided by the rated arm.bus voltage (500V,240V,180V or 90V),to yield the value of D. For TPS units with-I(A) signal level of .5V at rated current, jumper 1J is used to short out the 27R. The potentiometer 2P has a compensation range of 0 to 10% IR drop . 100% Clockwise setting of 2P represents 10% droop compensation. The % 2P setting is, therefore, computed by multiplying the value of D by 1000. For example, if D is .1 the % 2P setting is 100% CW. For TPS units with 2V at rated current, the jumper 1J is left open. Percentage relationships of potentiometer setting and the value of D remain the same as before. For -I(A) signal levels between .5V and 2V at rated armature current, appropriate resistor must be connected across 27R (Lance terminals for 1J) so as to provide a .5V drop across 2P.

C. <u>Field Crossover Regulator (Speed Regulated Armature)</u>

The alignment procedure for this system is a combination of the previously described alignment procedure for the field current and CEMF regulator system.

1. Disconnect the jumper connecting -/CEMF/ of the sensor board to the -/CEMF/ terminal of the controller board.

2. Calibrate the field current loop as per the steps in A above.

3. Calibrate the CEMF sensor as outlined in B above.

4. Reconnect the jumper connecting -/CEMF/ of the sensor board to the -/CEMF/ terminal of the controller board.

5. Operate the drive through its entire speed range and check the crossover voltage level. If necessary, adjust 1P on the CEMF sensor board for the desired level.

6. If IR compensation is used for exact CEMF crossover, the terminal voltage at crossover will depend upon the load current. In no case should it be allowed to reach 104% of the TPS (Thyristor power supply) rating.

D. Field Crossover System (Voltage Regulated Armature)

The alignment procedure for this system consists of calibration of three circuits as follows:

D1. Disconnect the flux function generator output from the controller board -I[F2] terminal. Use the same jumper as 1J on the field controller board for direct current feedback.

D2. Calibrate and check the basic current loop operation as per the procedure outlined for system A. except step 6 for "Field Loss" calbiration.

D3. Calibrate the "Field Crossover" reference circuit as outlined in this section.

D4. Calibrate the "Flux Function Generator" circuit as outlined in this section, or applicable I.L. if a different Flux Function Generator is used.

D5. Reconnect the "Flux Function Generator" output back to the main field controller and remove jumper 1J.

D6. Calibrate the "Field Loss" and Min Fld" ajustments per step 6 of Section A.

D7. Operate the drive over the desired speed range by changing input reference from 0 to 10V and check the motor speed.

NOTE: - Since the reference to the field flux regulator is changed linearly beyond base speed point, a non-linear speed operation would result. If linear speed change is desired, the flux function generator shape must be changed to compensate for this non-linearity.

Field Crossover Reference Circuit

Connect a 0 to +10V control signal to the IN and PSC terminals of the circuit.

Set input voltage to +10V and adjust the potentiometer 1P for an output voltage at "OUT 2" terminal equal to +10V divided by the ratio of top motor speed to rated motor speed. For example, if the speed ratio is 2 to 1, set the "OUT 2" output for +5V but if the ratio is 3 to 1 set the output for 3.33V.

Flux Function Generator Circuit

Since the flux function generator (FFG) must approximate the saturation characteristics of the machine, two points on this characteristic are required. The rated field current (Ifr) for the rated no load speed at rated voltage and the value of the field current Ifo at which the initial slope crosses the rated voltage line on the open circuit (No load Sat. Curve) characteristic of the machine. The value of the Ifo can be calculated by multiplying the field current for three to four times the rated speed point (available from the machine data sheet) by the ratio of this speed to rated speed. The potentiometer 1P on the controller board is adjusted for producting -0.93V at -If terminal when Ifo current is flowing through the field. This establishes the linear part of the saturation characteristics. The potentiometer 1P on the FFG is adjusted to produce -2V output at the "OUT" terminal when rated field current Ifr is flowing in the field.

E. Flux Regulator System (for Reel Drives)

This system is a combination of systems B and D. The adjustment procedures outlined for these systems is as described below:

E1. Follow the steps outlined for the calbiration of the flux function generator FFG and the flux loop as per system D except for step D3.

E2. Follow the procedure outlined for the calibration of the CEMF/Voltage sensor as per the steps for system B. The output of the sensor is used as a feedback for the "Coil Diameter Calculator" of the Reel Controller subsystem.

IV. CHARACTERISTICS & RATING

A. Rated Signal levels and polarities

The five systems described in this IL are designed on the basis of a set of standards for signal levels and polarities as given below.

1. A positive change ΔI_f implies an increase in the field current level.
2. A +10V signal at $+i_f$* terminal produces rated field current or rated field flux or rated CEMF.
3. A -2 volt signal from the current sensor represents rated field current except for flux regulator systems.
4. Open circuit to PSC at terminal +FL indicates loss of field current or a field current level below preset level

B. The CEMF Sensor:

Power Supply Requirements: ±24V @ 40 m.a. from the main field controller board.

S#	Table I. PARAMETERS AND SIGNAL LEVELS								
	G1*	T_1	T_2	P500/N500	P240/N240	P180/N180	+/CEMF/	-/CEMF/	-I[A]
1745A48G01	.031	.66 ms	6.3 ms	500V	240V	180V	+9.3V	-2V	-2V @ Rated Current with 1J open. -0.5V @ Rated Current with 1J close.
1745A48G02	.055	.66 ms	6.3 ms	500V	240V	120V	+9.3V	-2V	
1745A48G03	.055	.66 ms	6.3 ms	500V	240V	120V	10V	-10V	
1745A48G04	.061	.5 ms	20.4 ms	—	180V	90V	10V	-10V	

* G_1 is computed with respect to input terminals P180/N180

C. The Flux Function Generator

Power Supply Requirements: ± 24V @ 20 m.a. from the main field controller board

Input "IN" 10K Impedance @ 0 to -3 volts.

Output "OUT" 0 to 3 volts non-linear function generator.

D. The Field Crossover Reference Circuit

Power Suppy Requirements: ±24V @ 30 m.a. for G01, and 40 m.a. for G02, from the main field controller board.

Inputs: IN Terminal - 51.3K @ 0 to +10 volts

V_m Terminal - (a) Contact closure to PSC for field economy and over voltage protection.

(b) +/Cemf/sensor output at 0 to +10V for Cemf limit function.

Outputs: "OUT 1" - -10V @ 1 m.a. for Rated V_b**

"OUT 2" - +10V @ 5 m.a. for Maximum I_f*

V. ISOLATION OF FIELD WINDING

A. Non-Isolated System

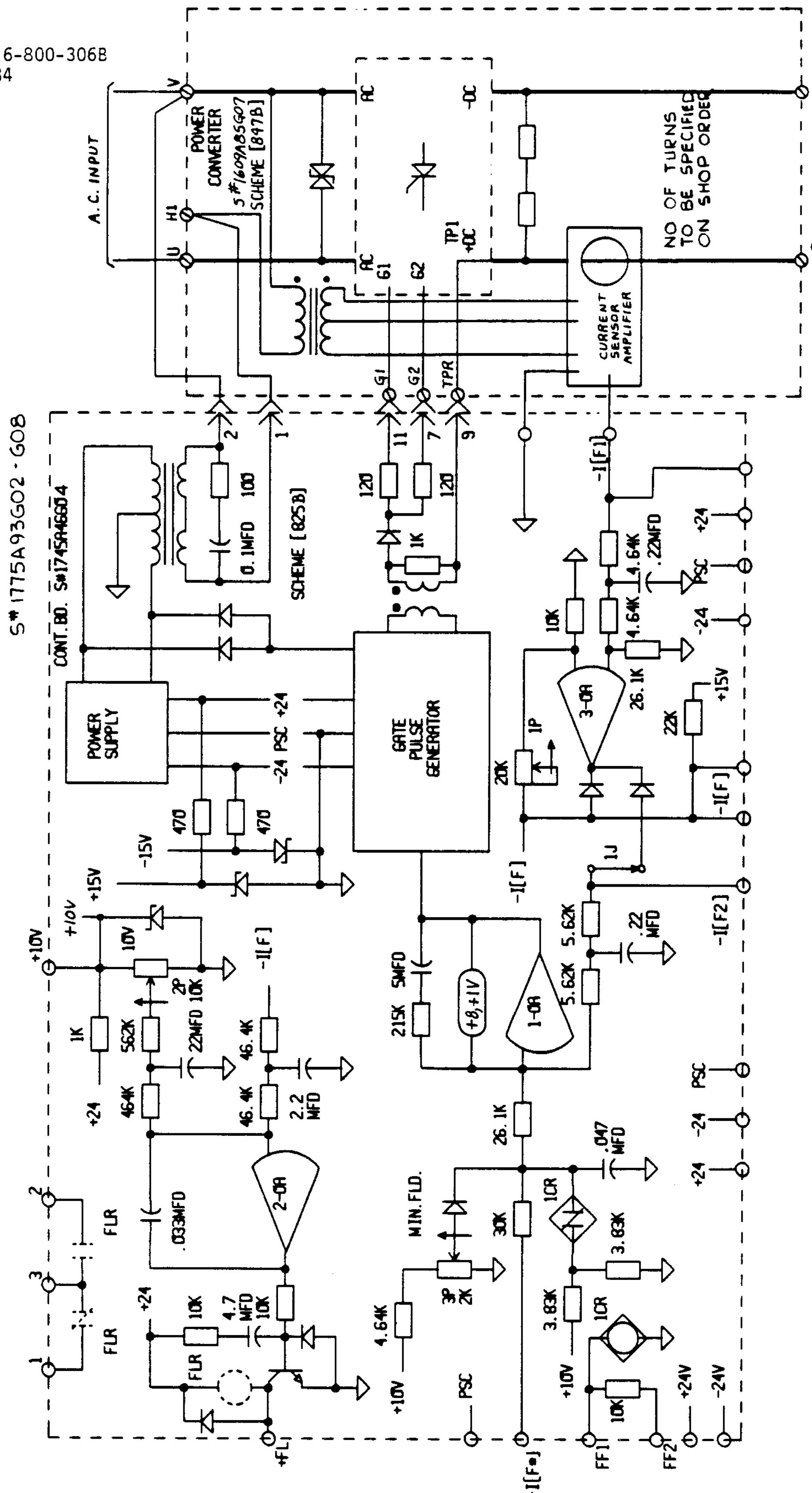
The Field Exciter package described in I.L. 16-800-305 connects the output of the field converter to signal common (PSC). The reference inputs are also referenced to signal common. Except for the current sensing resistors, one side of the motor field is tied to signal common and eventually to an earth ground.

B. Isolated System

The Field Exciter described in I.L. 16-800-392 utilizes a hall effect current sensor to measure the field current. In this package complete electrical isolation exists between the power circuitry and the electronic circuitry and thus no ground is imposed upon the motor field. The simplified schematic for this exciter is shown in Figure 5B1. The various field exciter systems described in this I.L. can be used with either field package.

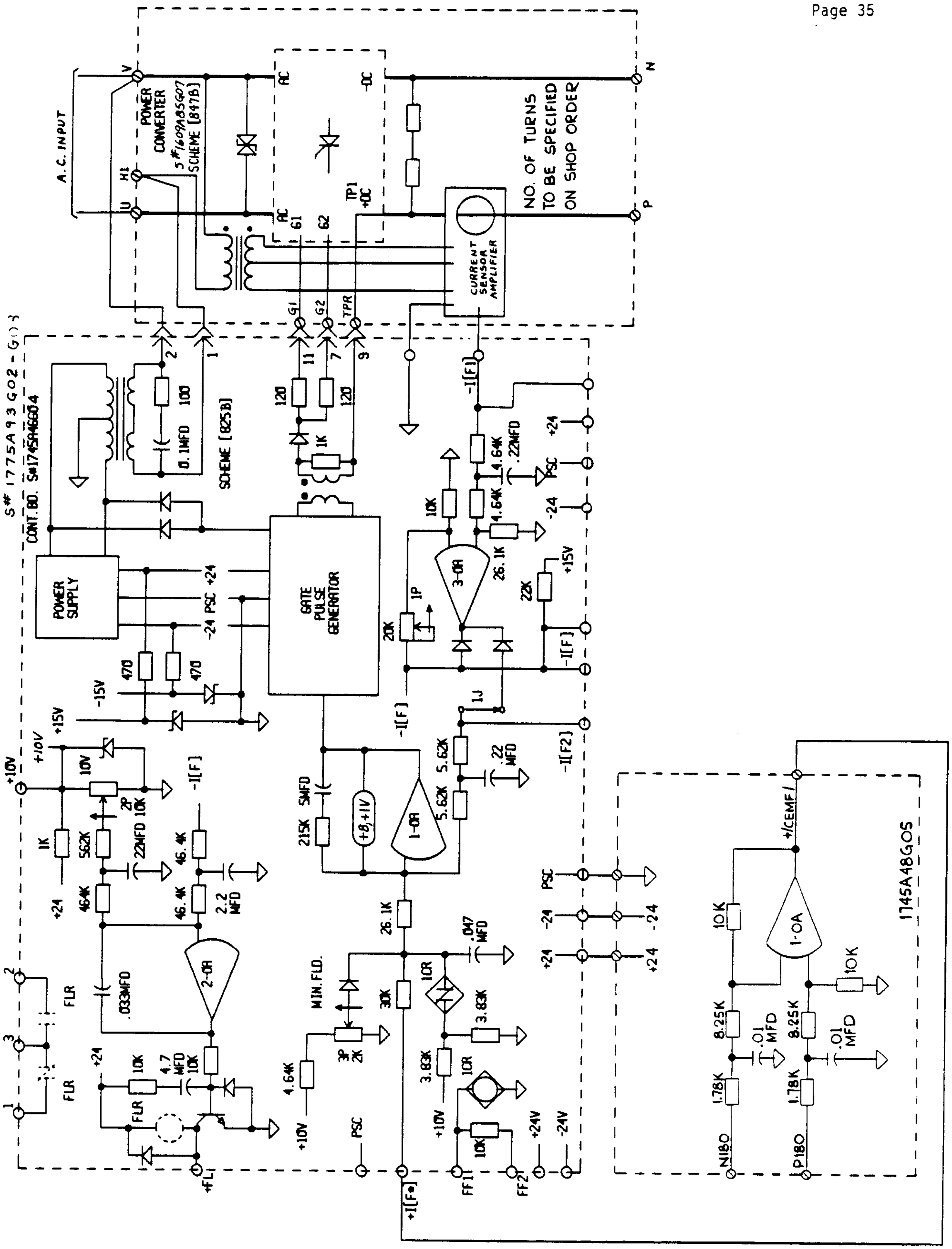
C. Differential Input Isolation

If required, a differential input isolation circuit can be used with the isolated field exciter described in I.L. 16-800-392. A simplified schematic of the total assembly with the differential input package is shown in Figure 5C1.



GROUP NO.	NO. OF TURNS	MAX I_F
G02, G03	4	15-25A
G04	3	20-30A
G05	5	12-20A
G06	8	8-12A
G07	12	5-8A
G08	20	3-5A

ISOLATED FIELD PACKAGE S#1775A93G__
FIGURE 5B1



ISOLATED FIELD PACKAGE WITH DIFFERENTIAL INPUT ISOLATION
FIGURE 5C1