national accelerator laboratory

TM-506
0210

REMOTE CONTROL UNIT FOR SORENSEN DCR 20-250 POWER SUPPLIES

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July 12, 1974

Summary

An improved control package has been developed which makes it possible to operate the Sorensen hihg-current power supplies in a current mode from a remotely located voltage source. This source may be a dc, low frequency ac or d/a converter with corresponding characteristics.

The essential characteristics of the new package are:

1. Improved performance because of improved handling of the low-level signals.
2. Ease of troubleshooting and maintenance obtained by component layout and selection.
3. Simplified installation procedure.
4. The local/remote switch can be operated with the circuit breakers on.

This note describes the operational features, circuits and installation procedure of the control package.

Background

The purpose of this development was to make it possible to operate the Sorensen DCR series and other similar power supplies from a remote voltage source in an improved manner. Large number of this type of power supply has been purchased by Fermilab because these power supplies satisfy the basic requirements, are readily available and the price is reasonable. The remote control of these power supplies, however, presents a problem because the output current and voltage are controlled by varying a resistance in the input

amplifier. Motor driven variable resistors and other variable resistance schemes have been devised with various degrees of success. The use of a separate amplif' , described in this note, bypasses most of the Sorensen circuitry.

The Linac preaccelerator uses a number of Sorensen DCR series power supplies to energize quadrupoles on the 700-kV transport line. These supplies have been controlled from the Control Room using D/A converter and remote control units developed during early stages of accelerator construction. From purely circuit point of view, these control units were satisfactory; however, operating difficulties have been encountered due to long runs of cables, aging and noise pickup associated with the millivolt level signals. The effort required to modify the original power supplies for remote operation has been excessive and it was desirable to simplify and ease this effort.

Description of the Remote Control Package

a. Physical Characteristics

The remote control package consists of 3 parts: an electronic assembly, relay assembly and a SPDT toggle switch. The electronic assembly housed in a steel box 5 x 2½ x 12" and shown in Figure 1, contains a pc card and ± 15V power supply. This box is attached to the rear, upper left-hand side of the Sorenson power supply with 120V, 60 Hz power connector on the bottom, and the input, output and the remote control connectors on the top of the box. For inspection and test purposes, the top cover is easily removable.

The relay assembly also seen in Figure 1, consists of 3 high-reliability relays mounted on a bracket which is attached to the rear top of the Sorensen power supply using 2 8-32 screws. These relays select the SCR driving signal from local or from the remote amplifier in response to the front panel mounted switch, provide a latching function, so that once the mode selection, local or remote, is made, the subsequent

operation of the local remote switch has no effect until 480V breaker is actuated. These relays also provide a set of relay contacts which close in the DC ON condition. The modification work on the Sorensen supply necessary to mount these relays consists of drilling 2 8-32 holes.

A SPDT switch is mounted on the front panel of the Sorensen supply; however, its only function is to operate the relays and not to switch the low-level signals as was done previously. The 10 pin M S connector used in the previous design has been retained for remote status indication.

b. Circuit Characteristics, Figures 2 and 3

The purpose of the electronic unit is to compare the reference signal with an amplified current sensor signal and amplify the resulting error signal to a level sufficient to drive the SCR driver transistor Q7, in constant current mode.

The current is sensed by a 50 Mv/300A manganin resistor (shunt) and transmitted from this resistor by a 2 conductor shielded cable, through a 3-pin connector J2, Bendix Pigmy PC06A-8-3S (SR)/PC02A-8-3P connectors, through the pins 2 and 3 of the pc card connector to IC-1. The shield is carried through and connected to the power supply common terminal on the pc card. IC-1 is connected as a non-inverting differential amplifier with a gain of 100. Since this stage is critical, a low drift type, high quality amplifier, Analog Devices AD-504M, is used with an offset adjusting resistor R-5 and ±0.01% resistors for high common mode rejection. The IC-2, National Semiconductor LM301-A, is connected as an inverting single-ended amplifier with a dc gain variable between 1 and 3. In addition to dc amplification, this amplifier filters the amplified signal to attenuate the ac signals above 0.1 Hz and to provide an adjustable zero offset, using R-10. The output of IC-2 is connected through pins A and B of J-4 (MS312DE10-6S/MS3126F10-6P) for remote monitoring (A/D) and directly to IC-3 for comparison with the reference signal (D/A).

The reference signal (D/A) comes in on J-4 pins D and E, pc connector pins 12 and 18, through turn-on protection switch Q-1 to IC-3. Q-1 is an N-channel FET transistor which bypasses the reference signal to power supply common until the -15V supply is on.

The difference between the positive going reference signal and the negative going feedback signal (error signal) is amplified by IC-3. The IC-3 is connected as an inverting amplifier with a dc gain of approximately 40, and a frequency attenuation of 20 db/decade beginning at 0.005 Hz. The output is limited to -3.6V using IN5227 Zener diode.

c. Relay Switching Circuits, Figures 4 and 5

To provide the necessary switching and protection functions, 3 dc relays, Potter-Brumfield type R-10, are used. The details are:

1. In the REMOTE position of the Local/Remote switch, the base of Q-7 is connected to the output of the error amplifier IC-3 through normally closed contacts 5 and 6 of K5, and normally open contacts 15 and 16 of K3.

2. The second function of relays K-3 and K-4 is to provide a latching function so that when the 480V, 3-phase circuit breaker is ON, accidental tripping of the LOCAL/REMOTE switch will not product disasters. This latching function is obtained as follows:

Assume that while the C.B. is in the OFF position, the LOCAL/REMOTE mode switch is switched to the REMOTE position. When the C.B. is switched to ON position, the relay K-3 is energized from +34V dc line through K-4 contacts 9 and 8, through the K-3 coil 4 and 1, to the common side of +34V dc line. When K-3 is energized, its coil latches through contacts K-3/6-7 to +34V and the LOCAL/REMOTE switch is no longer effective as long as the 480V circuit breaker is ON.

When the LOCAL/REMOTE switch is in the LOCAL MODE, relay K-4 latches with similar results.

3. The purpose of K-5 relay is to enable the operation of thermal overload lamp (DS1) in case of cooling water loss to the quads when the power supply is operating in REMOTE CONTROL mode.

a.) This is realized by wiring the coil of K-5, 12V (R10-E1-L4-V185) between the junction wire of 2 fault lamps DS1 and DS4 and terminal #33 on pc board.

b.) In LOCAL operation, a positive voltage, approximately 34V is fed from terminal #23 (AH) on the pc board through the S1-S2-S3 overload relay contacts S1-S3, through the K5 relay coil 4, 1 to emitter of Q-14.

c.) In case of LCW failure, the circuit between J1 terminals I and J is shorted, thus lighting DS1 and energizing K-5.

d.) When K-5 becomes energized, the normally closed contacts, 9 and 10 open, shutting off the SCR's and thus turning off the output current.

Remote indication of power ON is by a set of contacts K-4-13/12 and K-3-13/12, which close when the 480V, 3-phase circuit breaker is ON. The remote indication of LOCAL position of the LOCAL/REMOTE switch is by means of closed contacts K-4-16/15.

In addition to the above, additional functions are brought out in the connector J-1 for status monitoring:

J1-F = 50mV/250A Shunt Output (+)

J1-E = 50mV/250A Shunt Output (-)
J1-H = +20V
J1-I = +34V
J1-J = Thermal Overload
A, B = Wear/Remote Signal from K-4
C, D = Current Overload Signal from K-5

Results

The measurements on 1 modified Sorensen power supply indicate that the pickup and noise output in the REMOTE mode is somewhat lower than in the LOCAL mode. The long-term drift, of course, depends on the stability of the remote reference being used. The amount of current ripple is determined by the filtering within the Sorensen supply and the nature of the load being used. Experience with the modified power supply to-date indicates that the original objectives have been achieved.

Acknowledgements

Many people contributed to the end results. The initial work was done by Bob Featherstone, Chuck Sharp and Bill Skeens. Curt Owen, Cy Curtis and Jim Griffin made the present effort possible. Frank Cilyo supplied the key ideas, directed the actual effort and wrote this note. Dave Huffman made the tests, performed many modifications, designed the relay latch circuit and prepared many sketches. John Reid handled the pc card while Ray Hren and Joe Davis contributed during early stages of the project.

LIST OF FIGURES

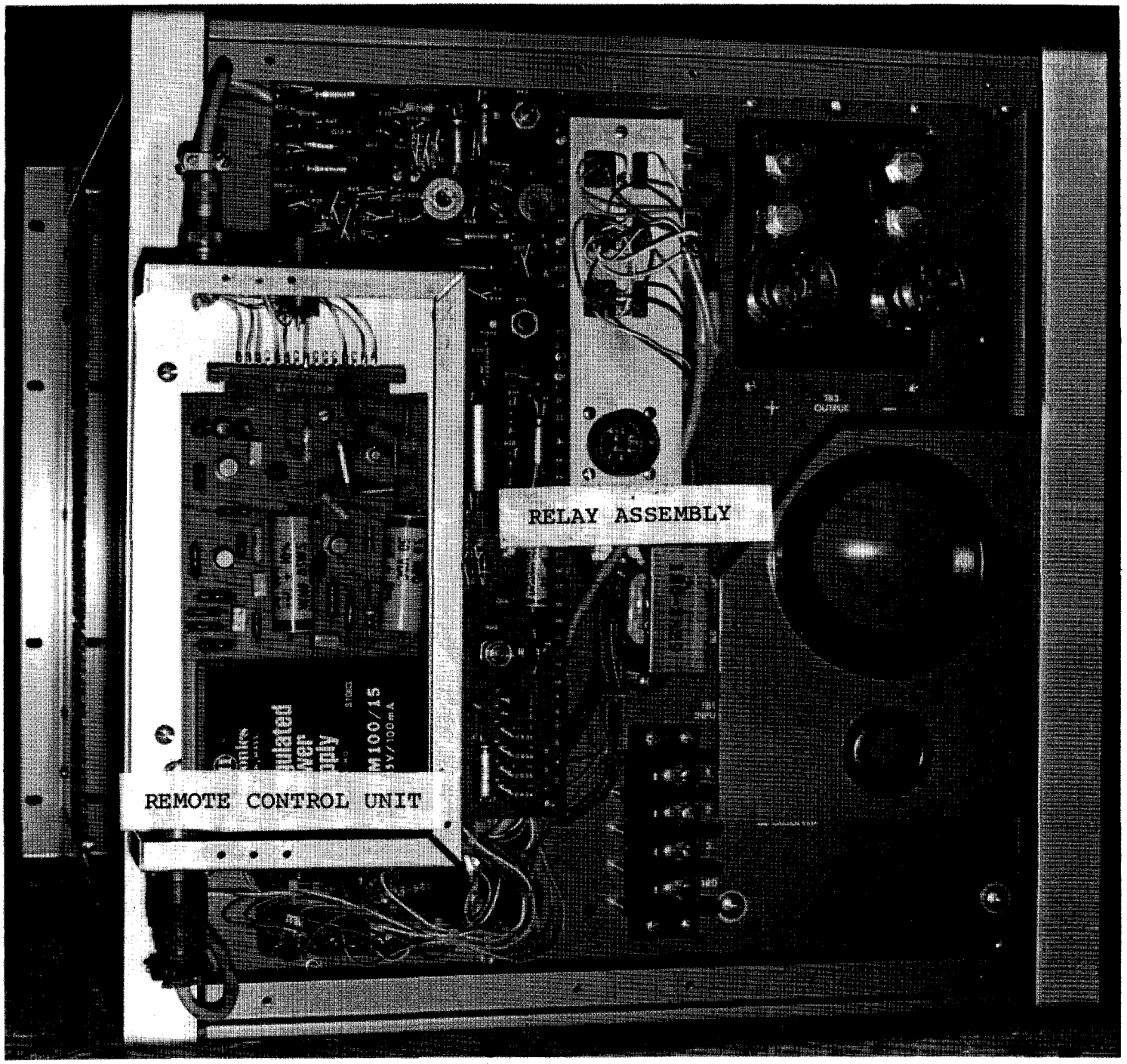
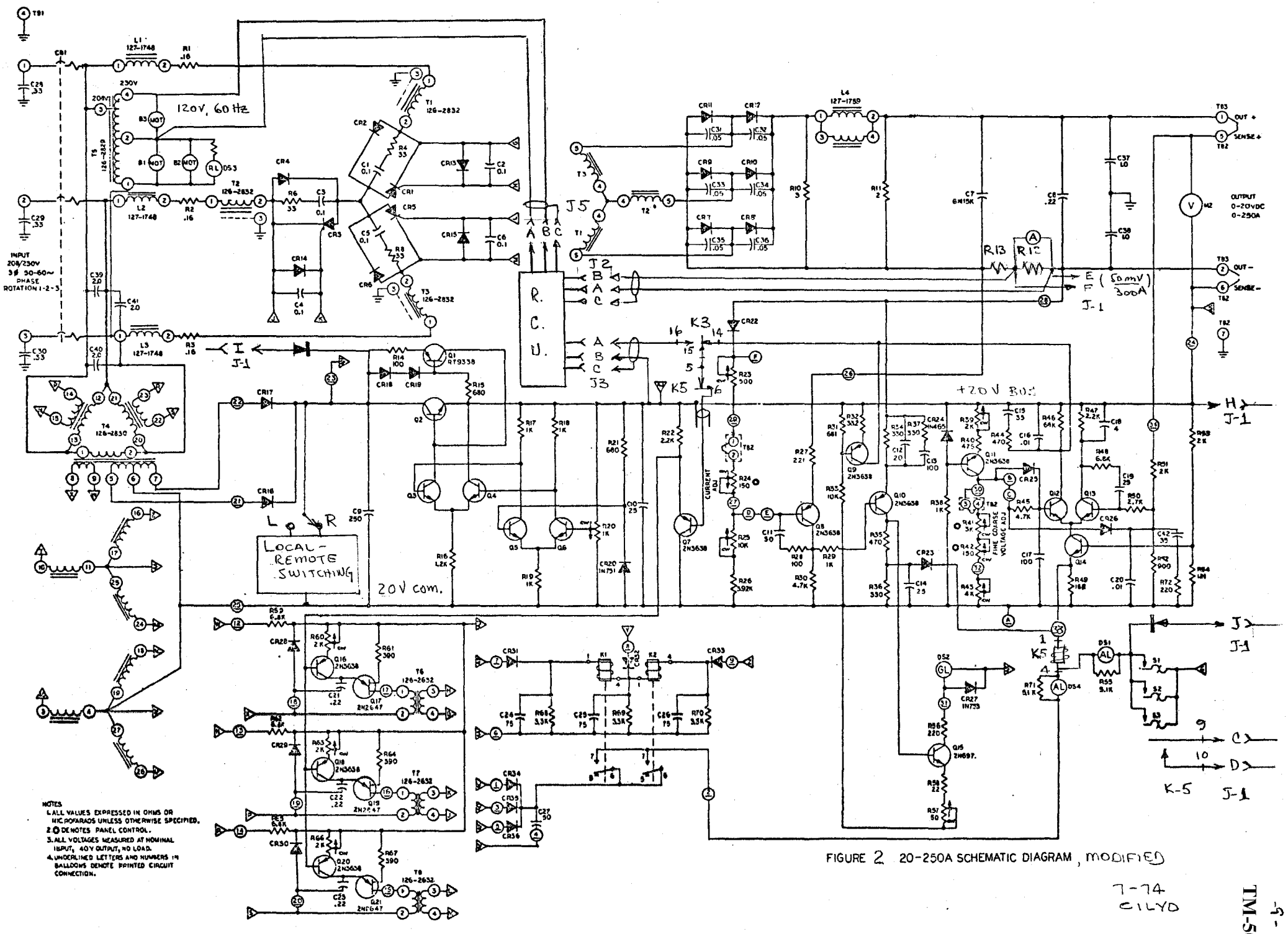


FIG. 1: REMOTE CONTROL UNIT INSTALLED



NOTES
1. ALL VALUES EXPRESSED IN OHMS OR MICROFARADS UNLESS OTHERWISE SPECIFIED.
2. ⊙ DENOTES PANEL CONTROL.
3. ALL VOLTAGES MEASURED AT NOMINAL INPUT, 40V OUTPUT, NO LOAD.
4. UNDERLINED LETTERS AND NUMBERS IN BALLOONS DENOTE PRINTED CIRCUIT CONNECTION.

FIGURE 2 20-250A SCHEMATIC DIAGRAM, MODIFIED

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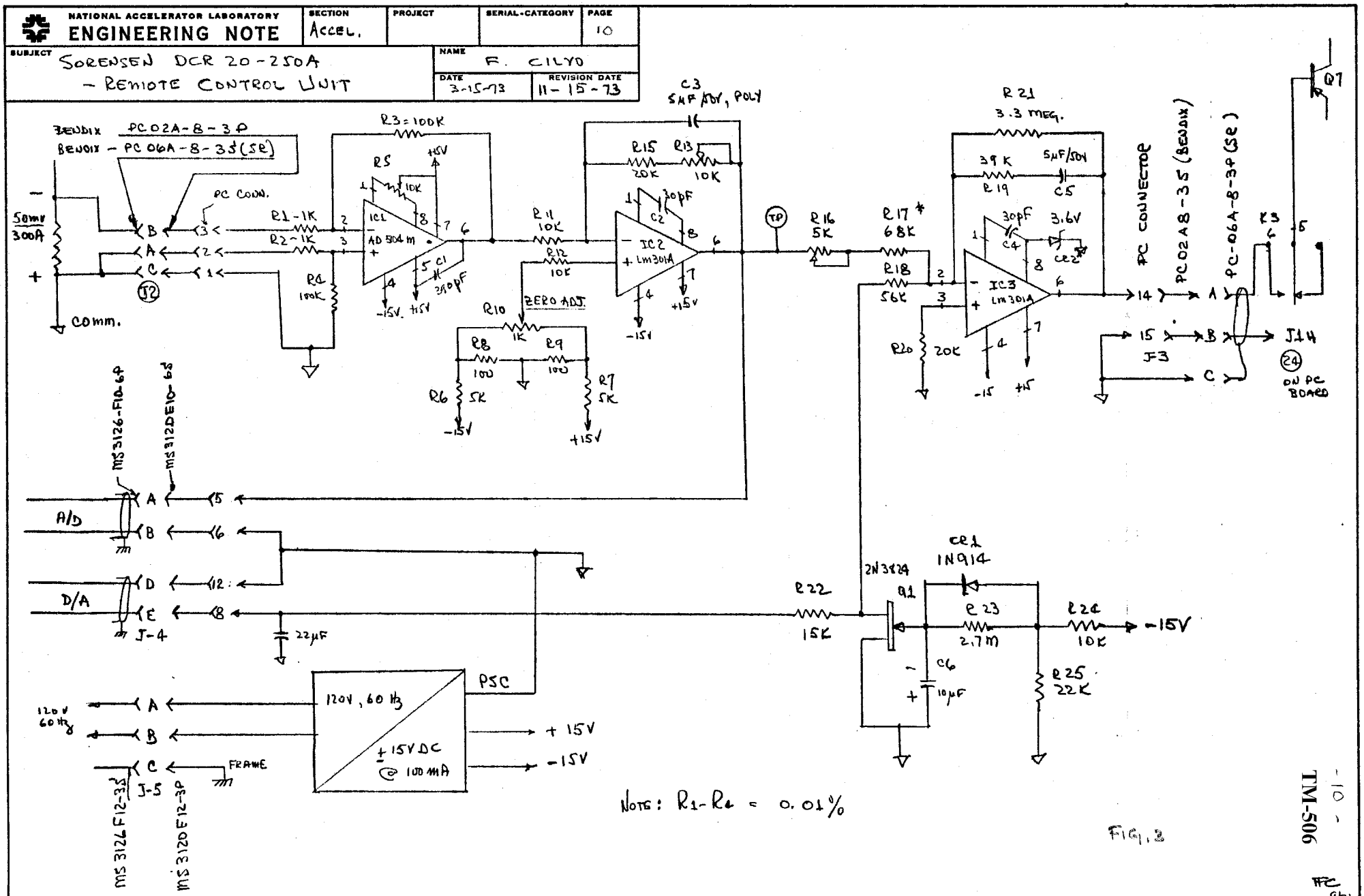
ENGINEERING NOTE

SECTION	PROJECT	SERIAL-CATEGORY	PAGE
Accel.			10

SUBJECT: SORENSEN DCR 20-250A – REMOTE CONTROL UNIT

NAME: F. CILYO

DATE: 3-15-73 | REVISION DATE: 11-15-73



NOTE: R1-R4 = 0.01%

FIG. 3

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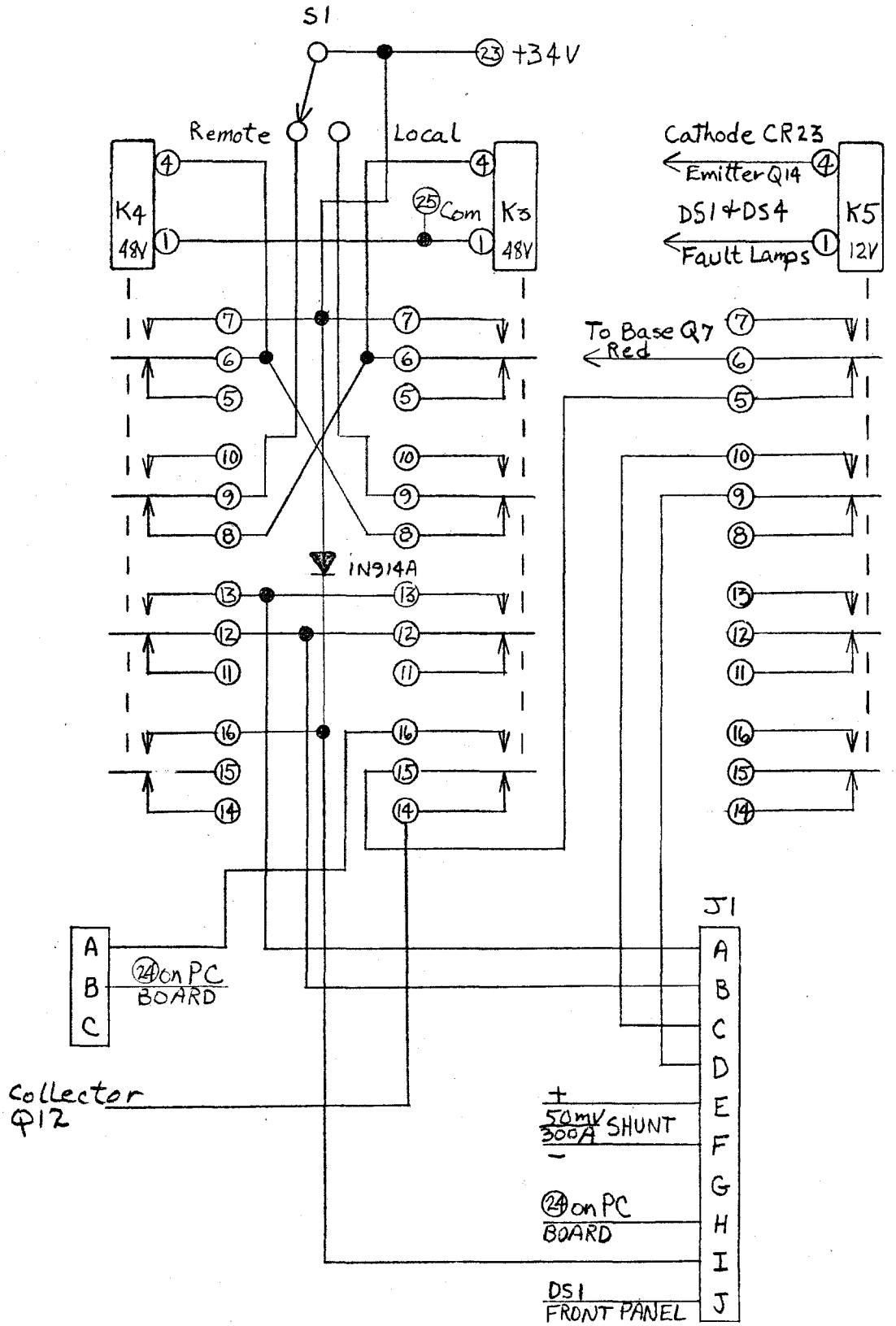

S1
23 +34V
Remote
Local
Cathode CR23
Emitter Q14
DS1+DS4
Fault Lamps
K4
48V
25 Com
K3
48V
K5
12V
To Base Q7
Red
IN914A
J1
A
B
C
24 on PC
BOARD
Collector
Q12
+
50mV
300A SHUNT
−
24 on PC
BOARD
DS1
FRONT PANEL
D
E
F
G
H
I
J

FIG. 4

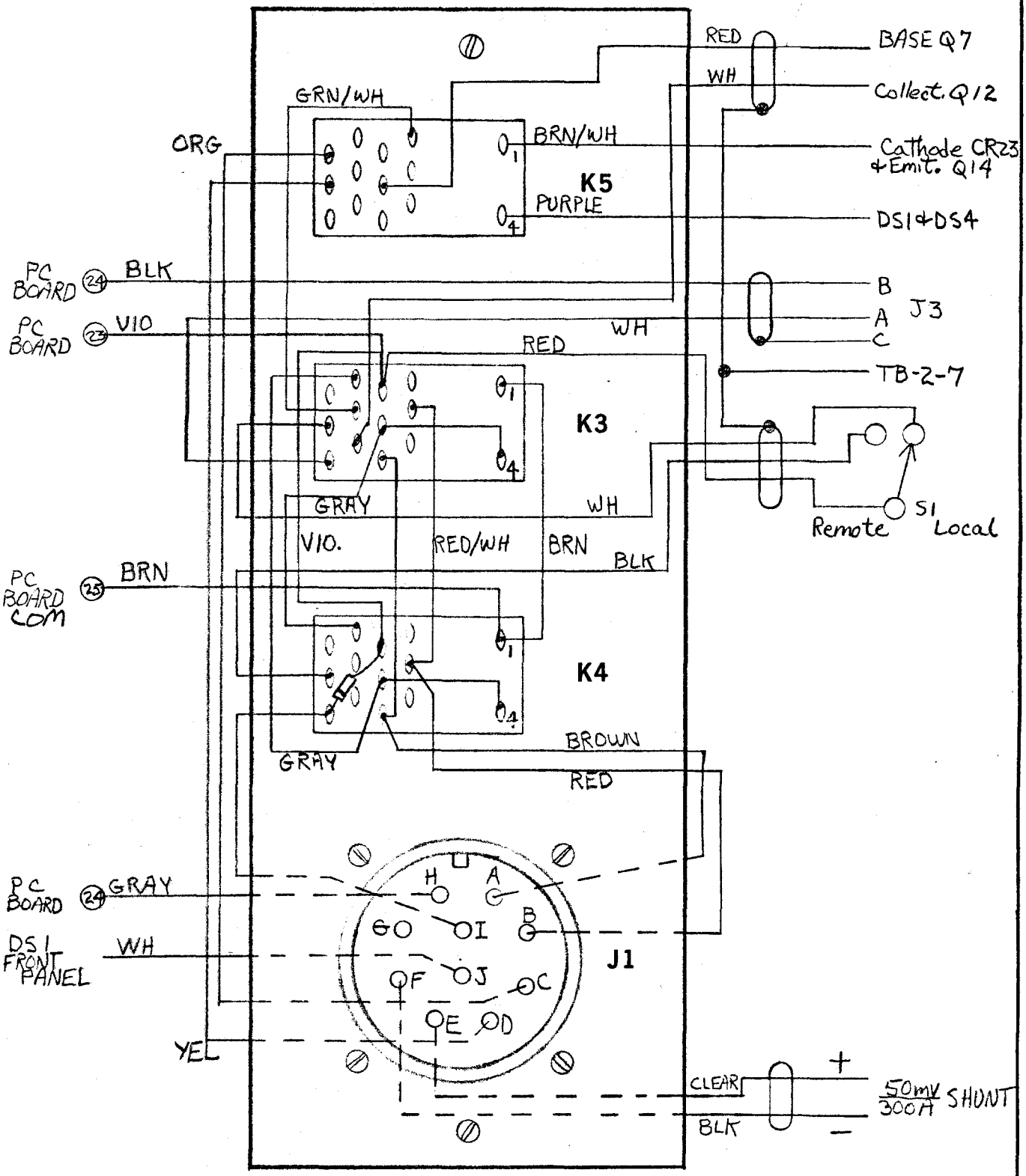
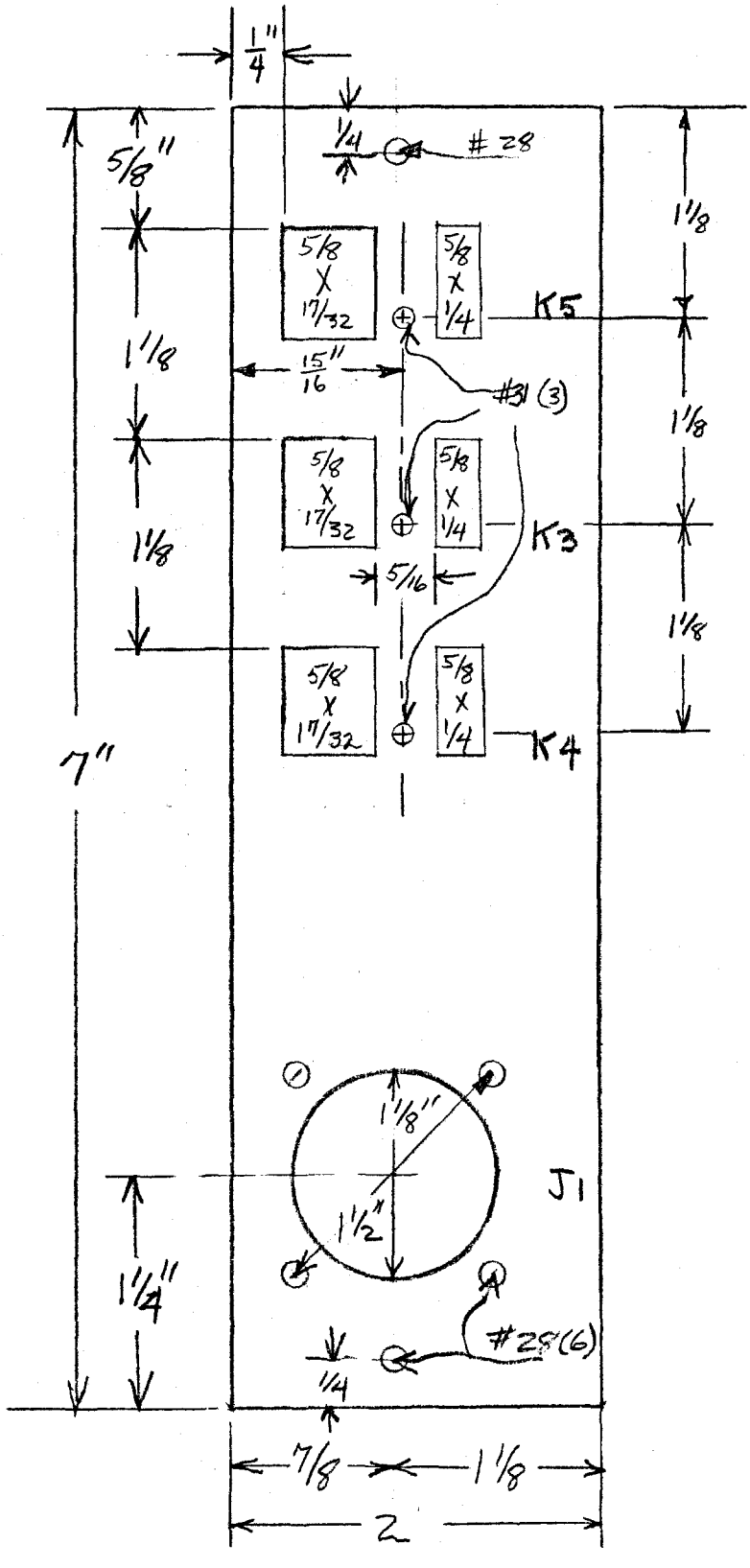
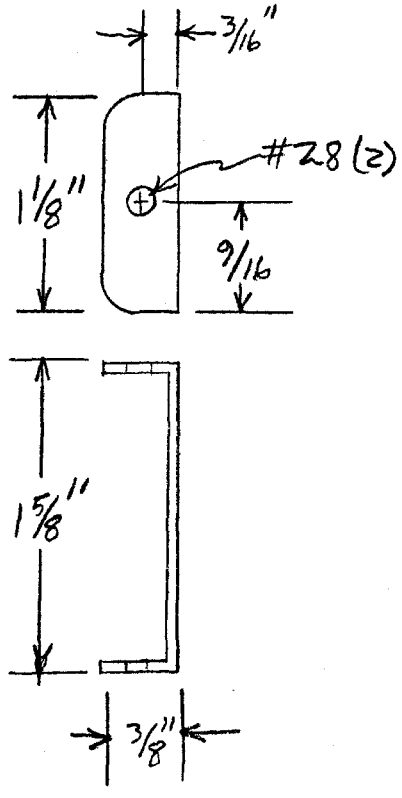

RED
BASE Q7
WH
Collect. Q12
GRN/WH
ORG
BRN/WH
Cathode CR23
& Emit. Q14
K5
PURPLE
DS1 & DS4
PC BOARD 24 BLK
B
A
C
J3
PC BOARD 23 VIO
WH
RED
TB-2-7
K3
GRAY
WH
Remote
S1
Local
VIO.
RED/WH
BRN
BLK
PC BOARD COM 25 BRN
K4
BROWN
GRAY
RED
PC BOARD 24 GRAY
H
A
B
G
I
DS1 FRONT PANEL WH
J1
F
J
C
E
D
YEL
CLEAR
+
50mV 300A SHUNT
BLK
-

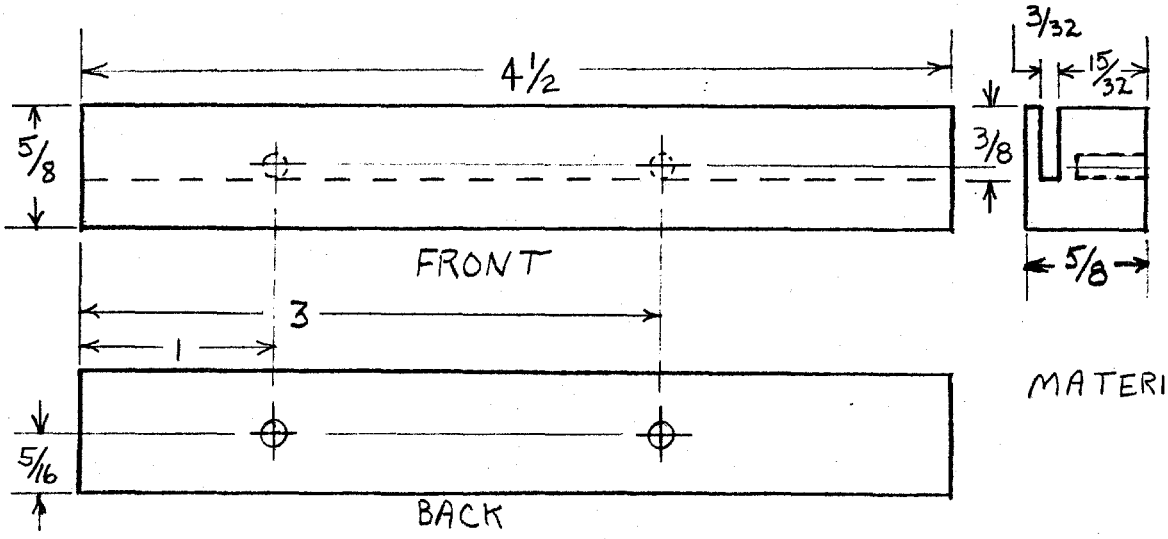
FIG. 5

$\frac{3}{32}$" Aluminum





Relay Bracket Support (2)



MATERIAL - G-10

2 HOLES DRILL & TAP 6-32
DRILL 3/8" DEEP
TAP 1/4" DEEP

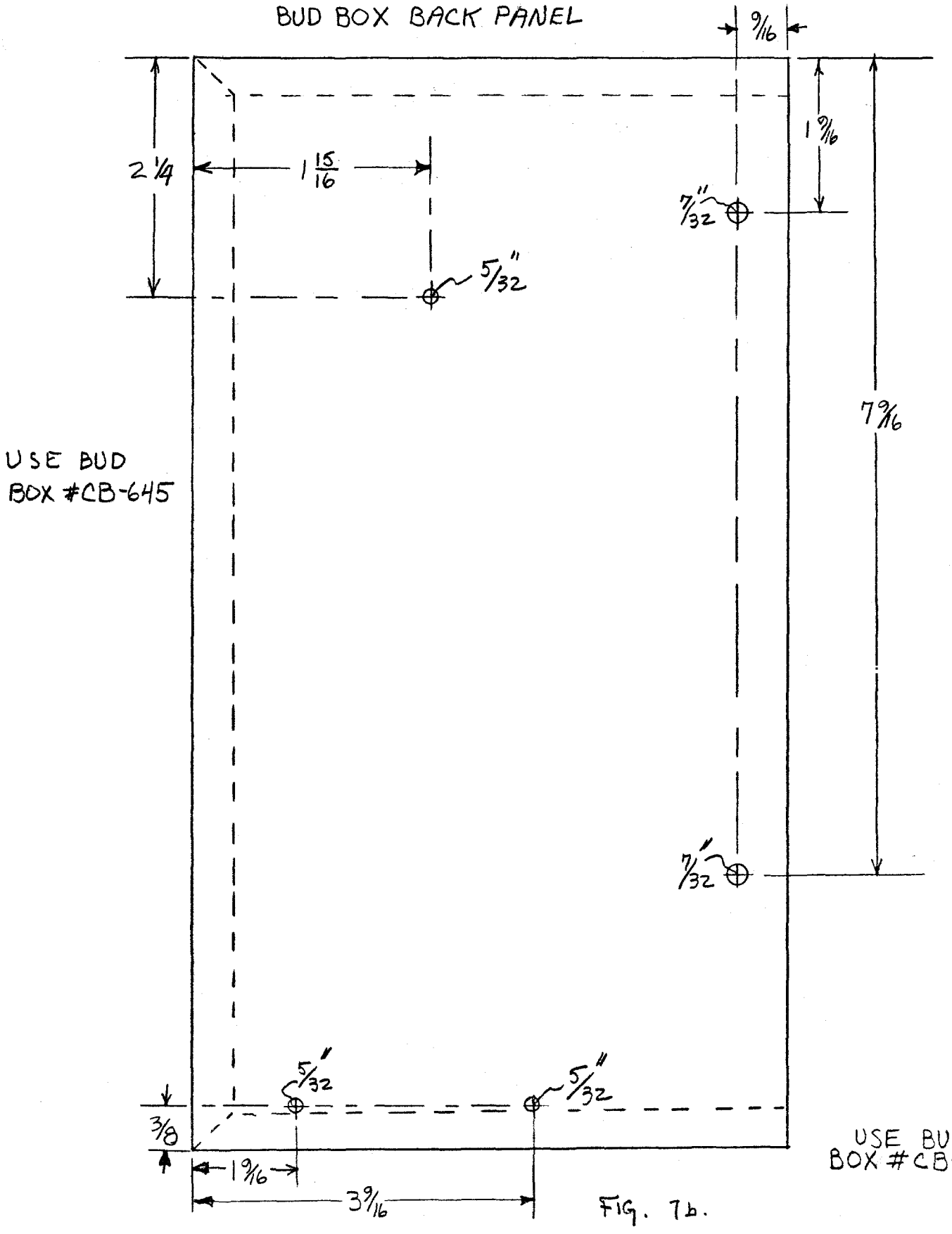
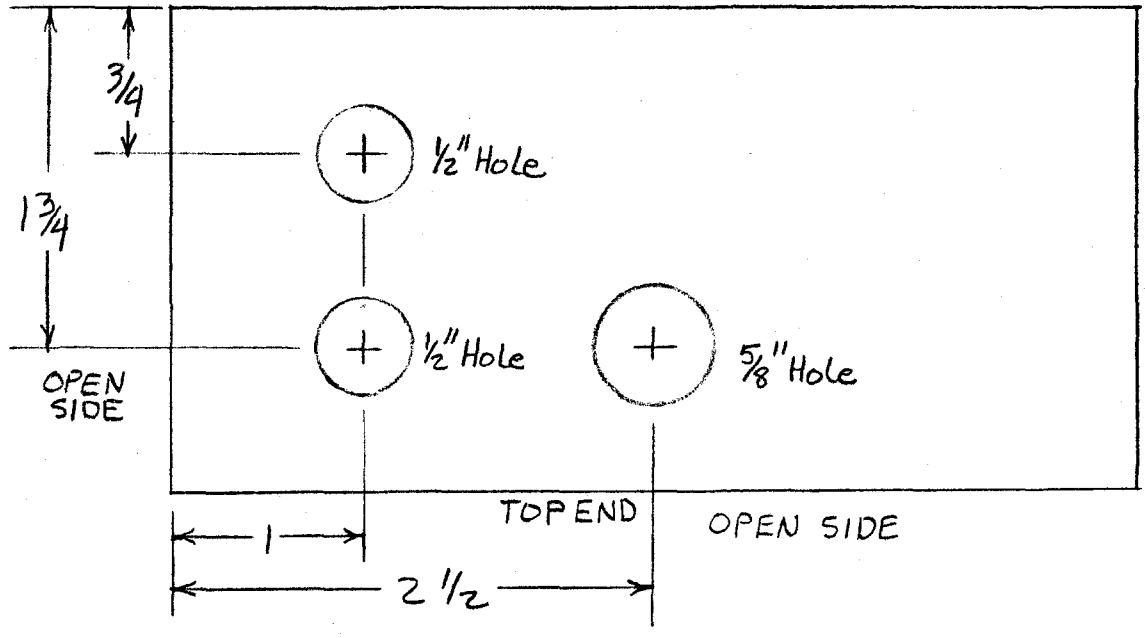
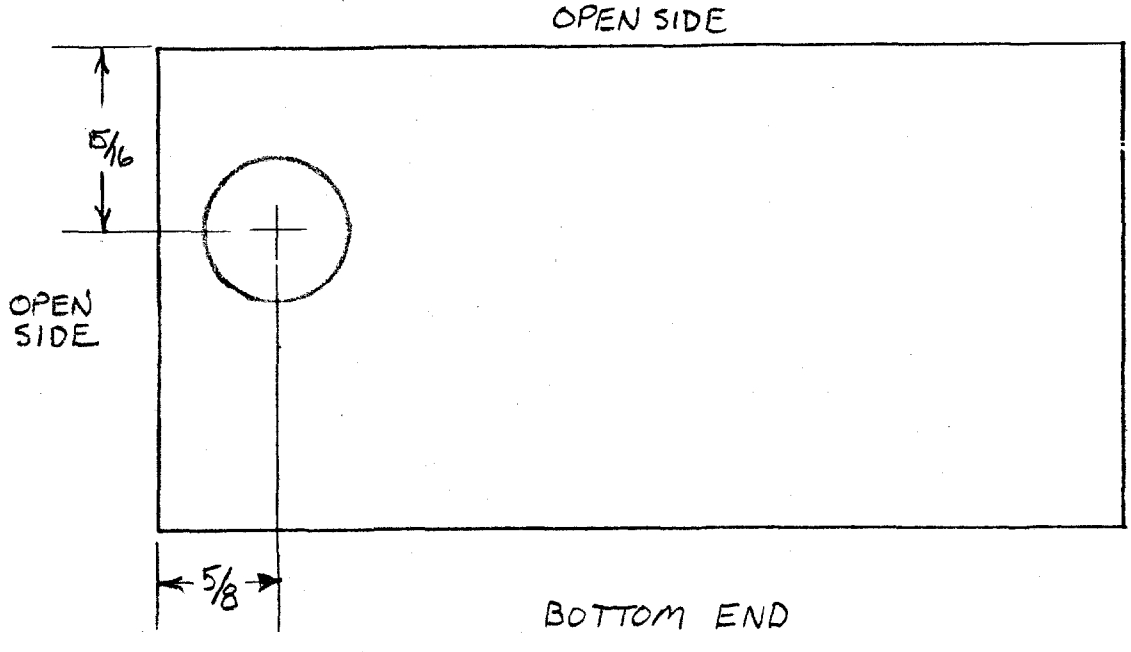

BUD BOX BACK PANEL
9/16
2 1/4
1 15/16
5/32"
1 9/16
7/32"
7 9/16
USE BUD
BOX #CB-645
5/32"
5/32"
3/8
1 9/16
3 9/16
USE BUD
BOX #CB-645

FIG. 7b.





USE BUD
BOX # CB-645

Fig. 7c

Fig. 8
VOLTAGE GAIN VS. FREQUENCY OF THE FEEDBACK SIGNAL PRE-AMPLIFIER.

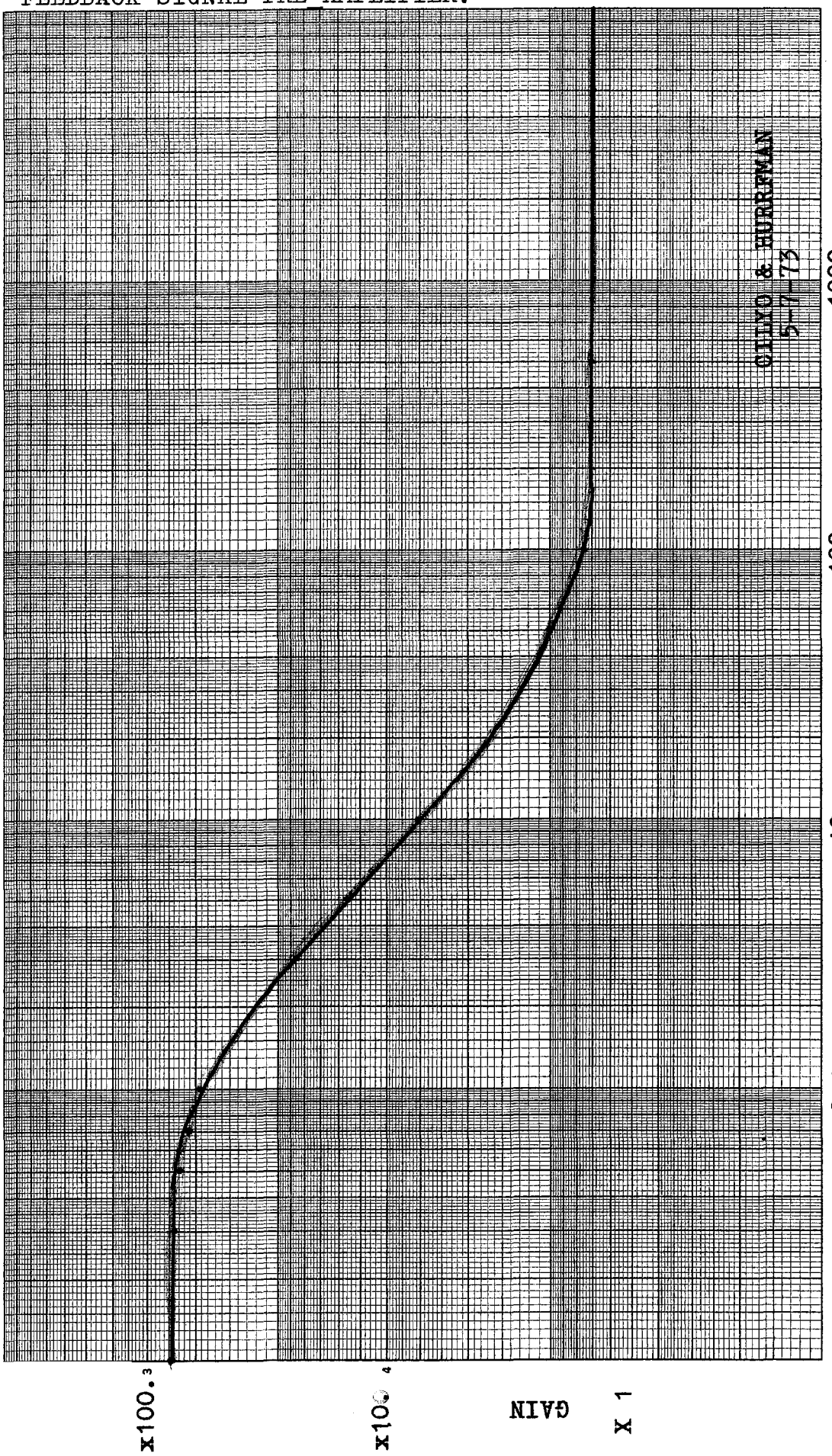
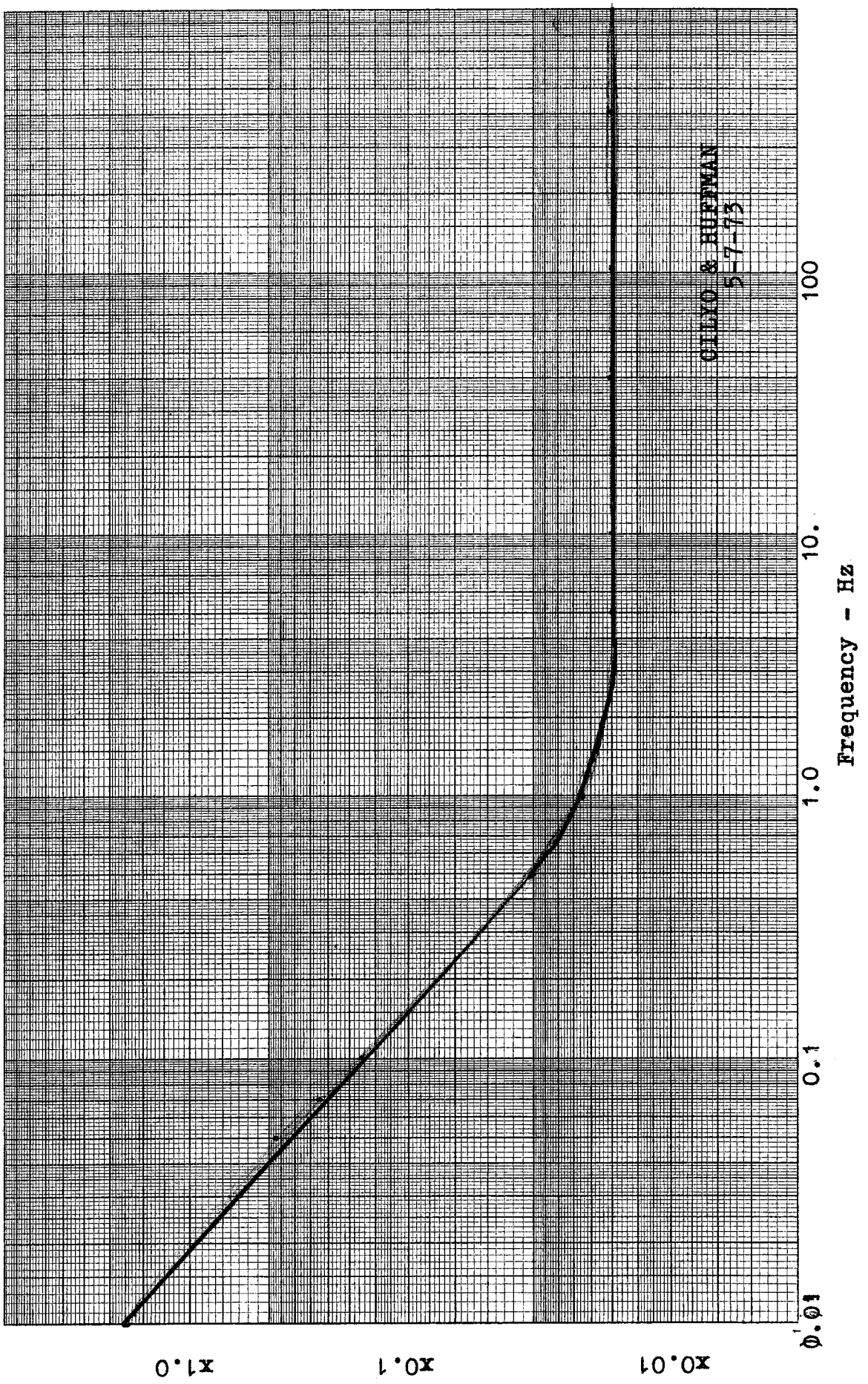


Fig. 9
VOLTAGE GAIN VS. FREQUENCY OF THE ERROR AMPLIFIER.



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PARTS LIST

FIGURE 10

The following special parts are required to modify each Sorenson SCR-20-250A supply:

1	3 pin Connector PC02A83S Bendix
1	3 pin Connector PC02A83P Bendix
1	6 pin Connector MS3126F Bendix
1	6 pin Connector MS3120E Bendix
1	3 pin Connector MS3126F12-3S Cannon
1	3 pin Connector MS3120E12-3P Cannon
1	3 pin Connector PC06A83P Bendix
1	3 pin Connector PC06A83S Bendix
1	SPDT Toggle Switch (JBT Type JMT-123)
1	±15Vdc Power Supply Intronics SM100/15
1	PC Card for Remote Control Unit (Fermilab Design)
1	9½ x 5 x 2½ Metal Box (Bud #CB-645)
1	15 pin PC Card Socket (Cinch #50-15A-20M)
1	Relay Bracket (See Figure 6)
2	Relay Bracket Supports (See Figure 6)
2, K3, K4	Relay, 4PDT, 48Vdc P. B. R10-E1-L4-V.2.5K with Socket
1, K5	Relay, 4PDT, 12Vdc P.B. #R10-E1-L4-V185 with Sockets
1	Cable for Shunt Input Signal - Belden #8208
1	Cable for the Output Signal - Braided Shield Twisted Pair
1	Cable for A/D - Belden #8208
1	Cable for D/A - Belden #8208
1	Cable for 120V, 60Hz

SORENSON DCR 20-250A REMOTE CONTROL UNIT

PARTS LIST - P.C. BOARD

C_1	-	390pf ±5% 500 WVDC Silvered Mica Type CM05
C_2	-	27pf ±5% 500 WVDC Silvered Mica Type CM05
C_3	-	5 µf ±10% 90 WVDC
C_4	-	Same as C_2
C_5	-	Same as C_3
C_6	-	10 µf ±10% 20 WVDC Elect.
C_7	-	22 µf ±10% 20 WVDC Elect.
CR_1	-	IN914A 75 PRV 1.0 VF
CR_2	-	IN749 4.3V Zener
I_{C_1}	-	AD504M (Analog Devices)
I_{C_2}	-	LM301A(National Semiconductor)
I_{C_3}	-	Same as I_{C_2} = LM301A
P.S.1		±15V, 100ma, Intronics Model #S1083
Q_1	-	2N 3824
R_1	-	1K Ω ±.01%
R_2	-	Same as R_1
R_3	-	100K Ω ±.01%
R_4	-	Same as R_3
R_5	-	10K Ω Pot. Trimming Helipot
R_6	-	5.1K Ω ±5% ½W, Metal Film (MF)
R_7	-	Same as R_6, MF

R_8 - 100 Ω ±5% ½W, MF
R_9 - Same as R_8
R_{10} - 1K Ω Pot. Trimming Helipot
R_{11} - 10K Ω ±5% ½W, MF
R_{12} - Same as R_{11}
R_{13} - Same as R_5
R_{15} - 20K mF
R_{16} - 5K Ω Pot. Trimming Helipot
R_{17} - 68K Ω ±5% ½W, MF
R_{18} - 56K Ω ±1%, MF
R_{19} - 39K Ω ±5% ½W, MF
R_{20} - 20K Ω ±5% ½W, MF
R_{21} - 3.3M Ω ±5% ½W, MF
R_{22} - 15K Ω ±5% ½W, MF
R_{23} - 2.7M Ω ±5% ½W
R_{24} - 10K Ω ±5% ½W
R_{25} - 22K Ω ±5% ½W

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SORENSEN REMOTE CONTROL UNIT

FIGURE 11

A. Final Tests of a Modified Power Supply
208V 3ϕ Power Off, Use Separate 120V Power

1. Short the input at terminals A-B - use shorting plug.
   a. Adjust R5 until the output of IC1 is zero.
   b. Adjust R10 until IC2 output as read at A/D connector pins AB = Zero.

2. Connect an input signal = 25 mV (150A) to terminals A-B (shunt signal).
   a. Read and record the output of IC-1 - it should read 2.5V.
   b. Adjust R13 (10K pot) until the IC-2 output at A/D connector (A-B) is $\frac{25}{1000}$ x 100 x 2.4 = 6.0V.

B. 208V 3ϕ Operation (Internal 120V Connection)

3. Connect the remote control unit for normal operation. Adjust D/A signal input to zero volts. Observe and photograph the A/D output. It should be nearly zero.

4. Set the D/A Signal to:
   a. 3V = 75A
   b. 6V = 150A
   Adjust R16 until D/A = A/D. On screen 136 gauss/cm = 50A; 272 G = 100A, etc.