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300-FOOT INDUCTOSYN READOUT SYSTEM

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1. Introduction

This report describes the electronics necessary to derive a binary number using the inductosyn readout system, present this data to the H316 computer, and provide a coarse readout independent of the computer.

2. Programming

OCP 550 — This is a system reset; output this command at initialization and periodically while the program is running. The program should wait 300 ms after this command is executed, before trying to read the inductosyn.

OCP 450 — This command holds the inductosyn reading for 2 ms while the computer inputs the data.

INA 1450 — Execute this command to input the inductosyn data. Two data words are required as shown below.

Bit ..	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Word 1	0	2^3	2^2	2^1	2^0	0	0	0	0	0	0	0	0	0	0	0
Word 2	2^{19}	2^{18}	2^{17}	2^{16}	2^{15}	2^{14}	2^{13}	2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4

This count is 0 to 3777777_8 for 360° rotation.

3. Inductosyn

"Inductosyn" is a registered trademark of Inductosyn Corporation for "electrical measurement apparatus". The inductosyn was developed by Mr. C. L. Farrand, Sr., President of Farrand Controls, Inc.

Inductosyn's were first used at NRAO on the 140-ft telescope. Later we used inductosyns on the 45-ft telescope. Impressed by their reliability it was decided to buy an inductosyn for the 300-ft to replace the present optical encoders.

The inductosyn at the 300-ft is different in that the only parts of the inductosyn that we purchased from Farrand were the rotor and stator. The rest of the housing was designed and built by NRAO.

An inductosyn consists of two parts: inductosyn for a fine readout and a resolver for a coarse readout. The fine and coarse reading is combined in the electronics.

4. Resolver to Digital Conversion

Three cards of logic are necessary to derive a coarse and fine binary number using the inductosyn and associated resolver. These three cards were designed by Ron Weimer and are identical to the ones used on the 45-ft telescope. Two of these cards are the same except for some jumper plugs. These plugs should remain with the card slot. These two cards will be referred to as digital cards.

The two digital cards are located in slots 8 and 10. Slot 10 contains the card used by the inductosyn and the other card is used by the resolver. The two jumper plugs select frequency of operation and phasing. The phasing should be adjusted so that with the inductosyn or resolver in "open loop" the error signal should be in phase with the reference. Four test points are provided on the analog card for this adjustment. This adjustment should only be necessary when changing inductosyns.

The other card in this group is referred to as the analog card and is located in slot 9. Both resolver and inductosyn use this card.

The operation of the resolver to digital conversion is quite complicated and I will not attempt to explain it in this report. A brief explanation can be found in EDIR #149, page 8.

5. 300-ft Inductosyn Card

This card (built on a Shalloway card) combines the coarse and fine binary numbers from the resolver to digital converters to form a 20-bit binary number. This number can be indexed for the proper position, then fed to the computer. This card also contains the logic to generate a coarse local readout independent of the computer.

The logic that combines the coarse and fine counts involves the use of adders located in chip locations 11F, 11E, 10E, 9B and 9A. The dip switch in 11C positions 6, 7, and 8 are used to adjust the "crossover" between the coarse and fine count. This adjustment is made by setting the display select switch to separate. The dip switches should be adjusted such that the two middle digits in the display have a difference of four.

Indexing is accomplished by the adders in chip locations 10A, 10B, 10C, 10D and 11D. the dip switches in chip locations 11A, 11B and switches 1, 2, 3, and 4 in 11C are opened or closed to obtain the proper position readout as displayed by the computer.

The logic on pages 2 and 3 of the "300-ft inductosyn card" is used for the readout on the front panel. This logic enables the selection of three possible displays. The three displays that can be selected are separate, combined and indexed. Separate is a display of coarse and fine independent of each other. Combined is a display of fine and coarse added together. Indexed is a display of the combined number with an index number added to it.

5. 300-ft Inductosyn Card (continued):

Pages 4 and 5 contain the logic necessary to convert the indexed number to degrees and tenths of degrees in BCD. The logic function on page 4 is to generate two clocks. The binary clock is generated by dividing a 2 MHz clock by 225_{10}, and the BCD clock is generated by dividing by 256_{10}. These two clocks perform the binary to degree conversion by counting down the binary number while a BCD counter is incrementing. This counting process continues until the binary counter reaches zero. These counters and a latch for the BCD number are located on page 5. Some short time after the binary counter goes to zero a new number will be loaded in the binary counter, and the process starts over. Conversion time depends on the magnitudes of the binary number.

6. Console Display Switch

When this system was originally designed it was planned to have two systems, such as we had with the encoders. After installation of the first system it was decided that only one system with a spare inductosyn was all that was necessary. This card therefore has some unnecessary logic.

This card contains four single-pole double-throw switches whose function was to switch between two inductosyn systems; this function is now not necessary.

The logic that is necessary are the markers. A latch was provided for the markers to help reduce the chatter of the dip relays when the position is on a transition point. Two markers are available -- one every even tenth of degree and one every ten degrees.

7. Balancing the Inductosyn

For optimum performance the drive to the inductosyn and resolver windings must be balanced.

The balancing of the resolver is more straightforward so I will attempt to explain it first. The telescope will have to be moved 45° to balance the resolver, so this should be kept in mind when positioning the telescope as the following describes. First the display select switch must be set to separate. The four digits to the left of the display are the coarse numbers. Position the telescope such that you are on a transition edge of one of the following in the coarse display:

3777-0000	777-1000	1777-2000	2777-3000

When one of these points has been reached, record the fine reading (4 digits to the right). The telescope must now be moved 32 cycles of fine (go through the fine number that was recorded 32 times). Stop on the same fine number the 32nd time. The coarse number should be 400 octal counts from the transition edge selected above. For

example, if the point chosen was 3777-0000 after 32 cycles of fine, it could be reading 377-400 or 3377-3400, depending on which direction the telescope was moved. The resolver adjustment should be adjusted for this number.

The coarse balance of the inductosyn (fine readout system) should be performed when changing inductosyn packages. The fine balance should be checked when changing inductosyn packages or the fine digital card (J10). The fine balance procedure should be attempted on a fairly calm day since wind can affect this procedure.

The coarse balance of the inductosyn requires the use of a digital ohm meter. This meter should be used to read resistance between pins in slot 10 (card removed) as shown below:

J10-3	to J10-4	Fixed resistance.
J10-5	to J10-6	Adjust resistance equal to the resistance measured from J10-3 to J10-4.

The fine balance of the inductosyn (fine readout) will require the use of a chart recorder with the capability to "buck off" 10 V DC. The chart recorder should be connected to the output of the variable speed drive D/A converter. The telescope will have to be doing wobbles at a high rate (we used 130 min/min). The gain of the chart recorder should be such that the AC error component can be displayed. The chart recording should be examined for a periodicity to fit the formula:

$$\frac{42}{\text{wobble rate (min/min)}} = \text{time between peaks in min.}$$

If this period is evident, the balance will have to be adjusted slightly. Observe the chart record carefully for changes of phase, using the direction change edge as a reference point. If this periodicity is still evident, but the phase has changed, the balance point was passed. This adjustment will probably require making a slight adjustment, then observing several wobble cycles. When it is balanced, the AC error component will still be evident but it will not have a periodicity. This error is affected by wind and telescope balance.

8. Credits

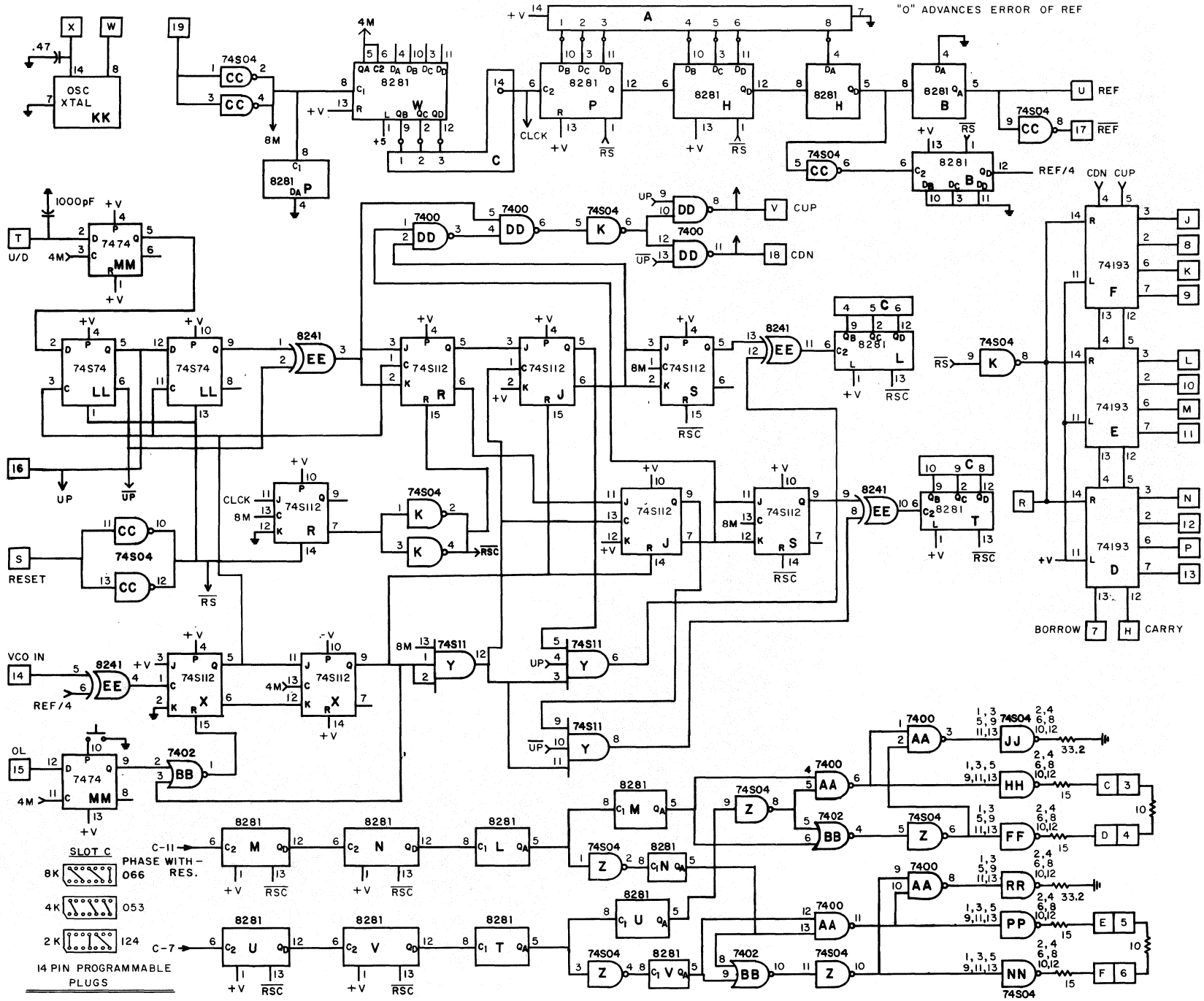
Credit should be given to the following people:

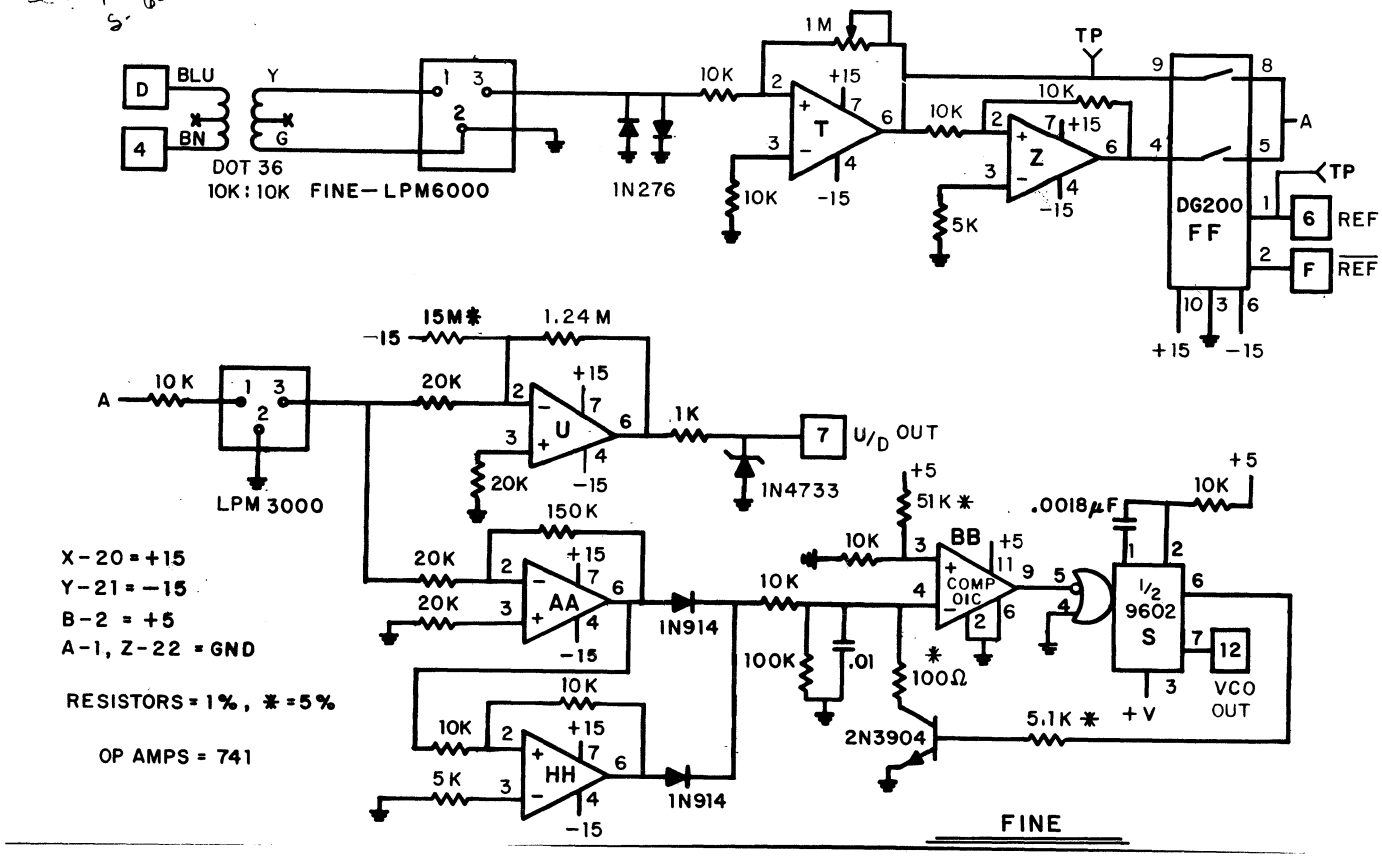
Ron Weimer for the design of the resolver to digital converter cards and the balancing procedure.

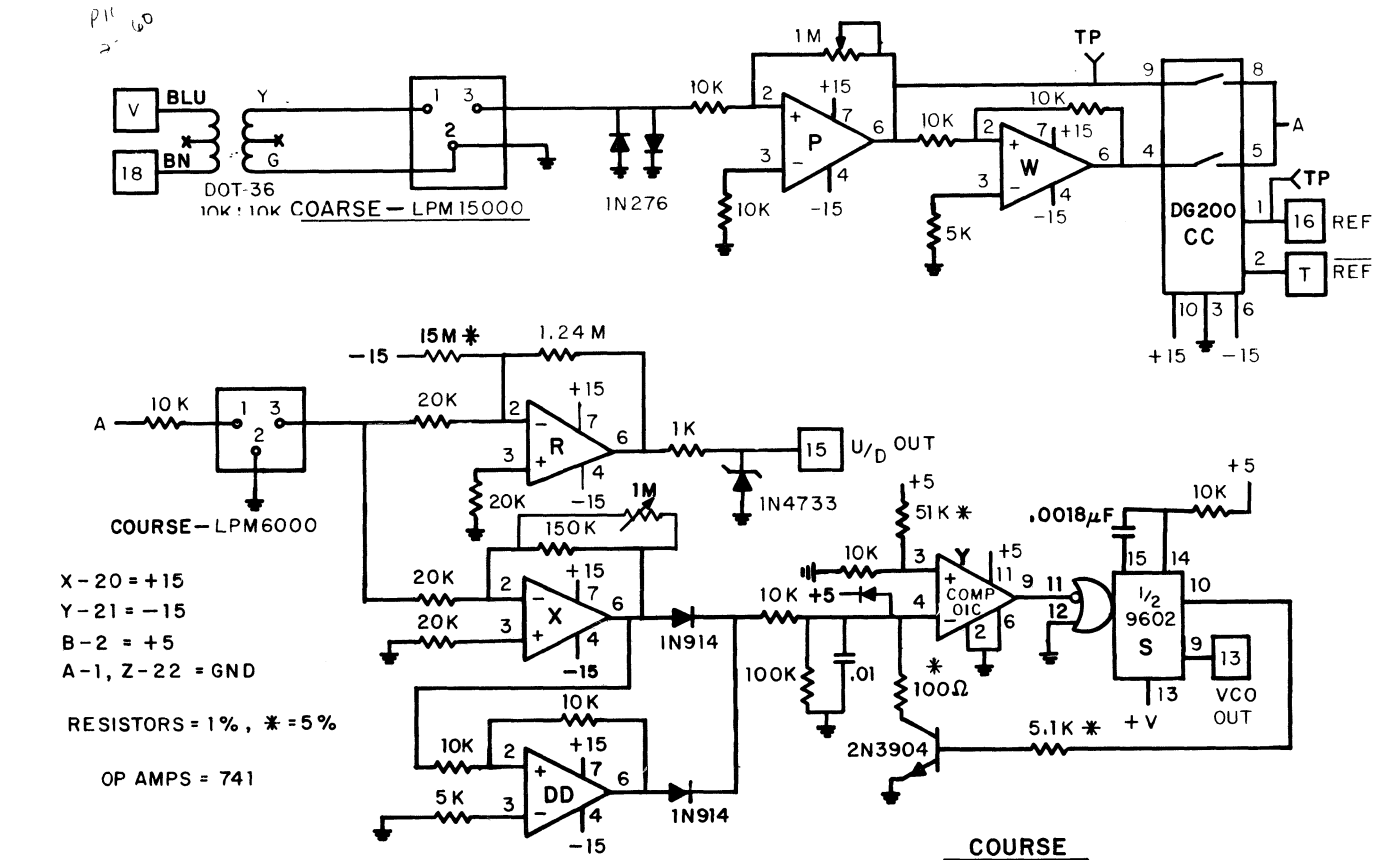
Engineering for the design of all the hardware for the inductosyn housing and mounting the inductosyn to the telescope.

Machine Shop for all the precision machine work necessary for the inductosyn.

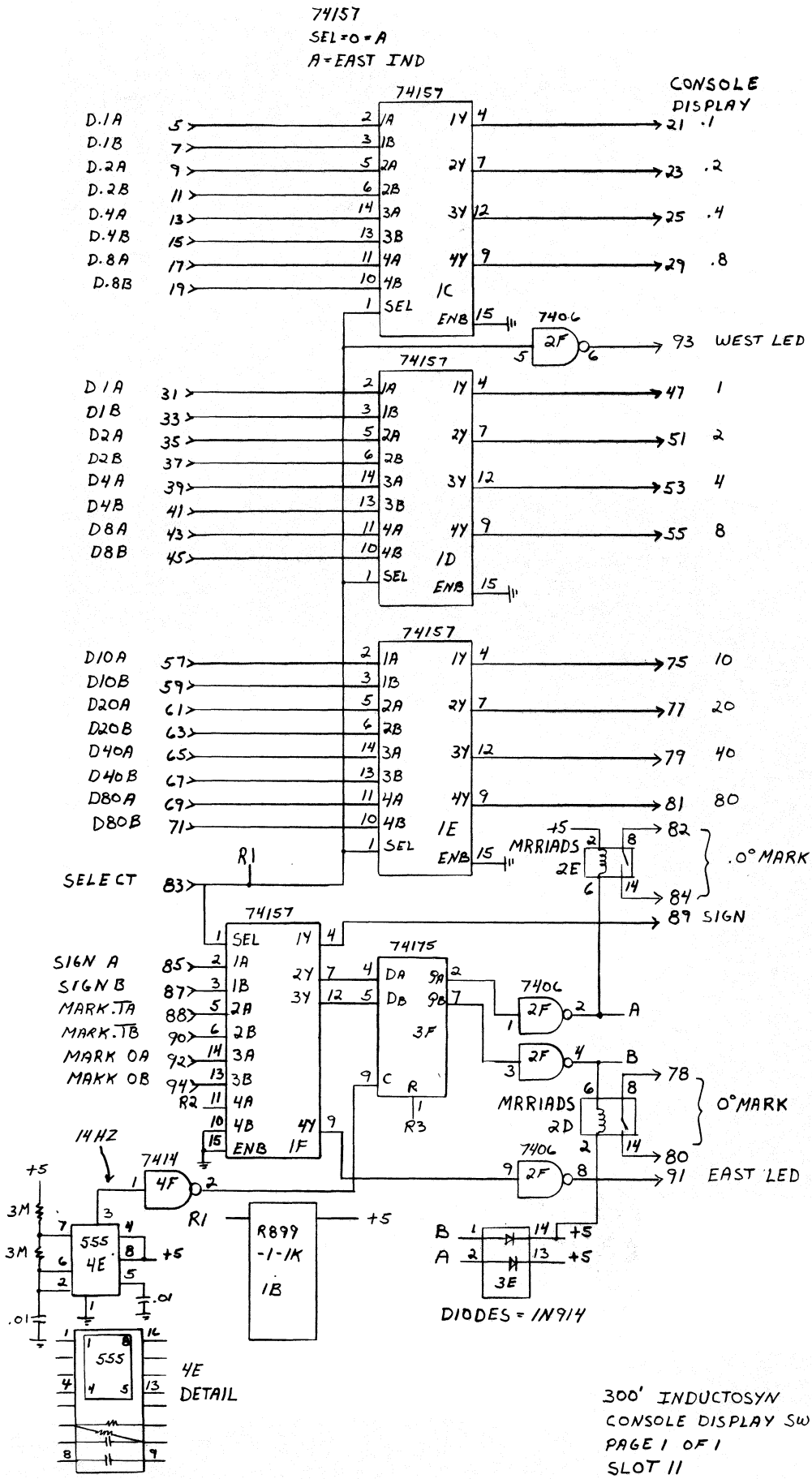
Jerry Turner for wiring the digital chassis for this project.

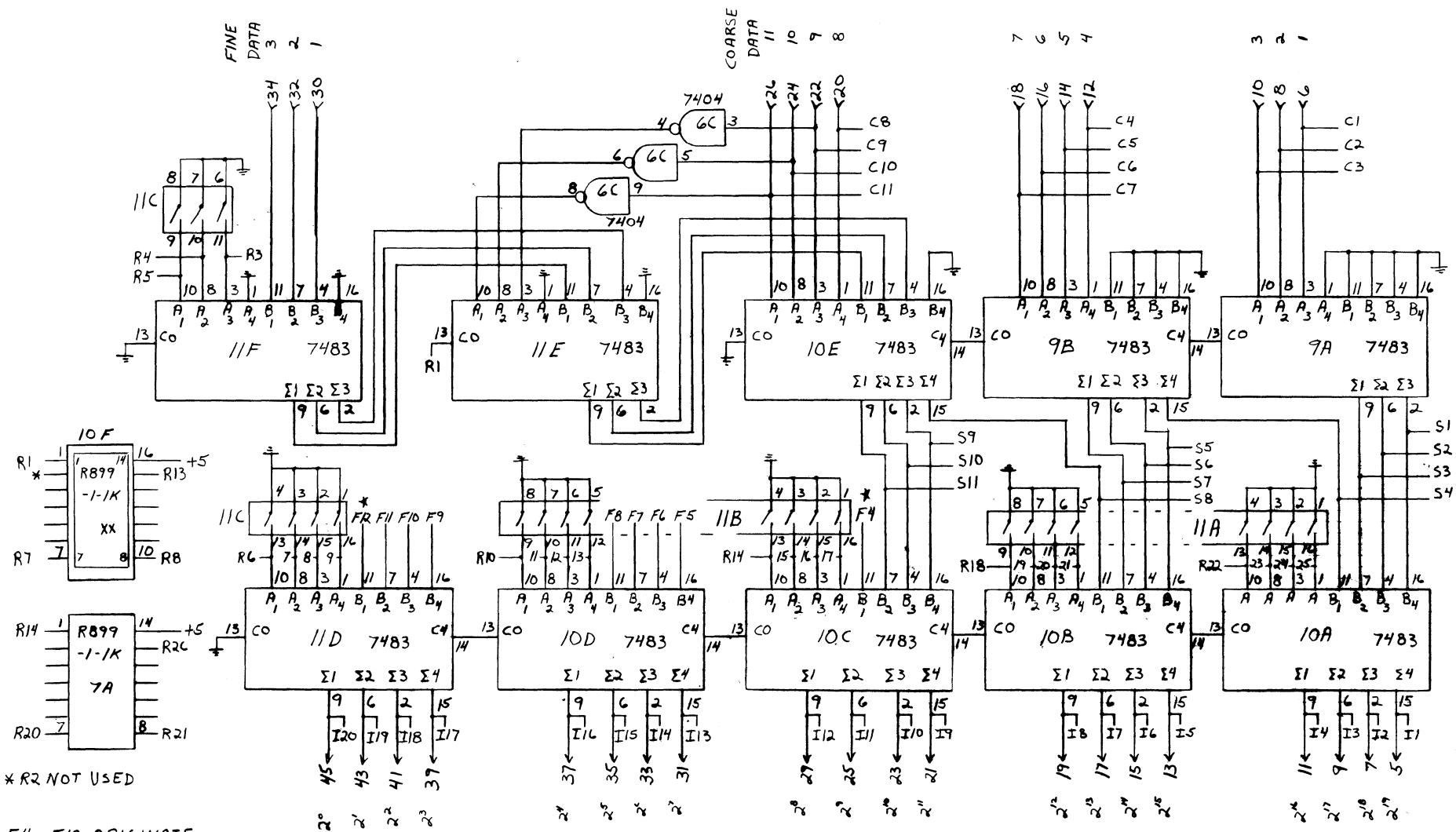

"0" ADVANCES ERROR OF REF
OSC XTAL KK
74S04
4M
8M
8281
A
B
P
H
W
C
CLCK
REF
REF/4
CDN CUP
1000pF
U/D
7474 MM
74S74 LL
8241 EE
74S112 R
74S112 J
74S112 S
74S112 X
74S112 Y
74193 F
74193 E
74193 D
UP
RESET
VCO IN
OL
7402 BB
7400 DD
7400 AA
74S11 Y
74S04 Z
74S04 K
74S04 JJ
74S04 HH
74S04 FF
74S04 RR
74S04 PP
74S04 NN
BORROW
CARRY
SLOT C
8K
4K 053
2K 124
14 PIN PROGRAMMABLE PLUGS
C-11 PHASE WITH-RES. 066
C-7
COURSE — SLOT 8
FINE — SLOT 10
POSITION READOUT, RESOLVER TO DIGITAL CONVERVTER
DIGITAL COUNTER/DRIVER CIRCUITS





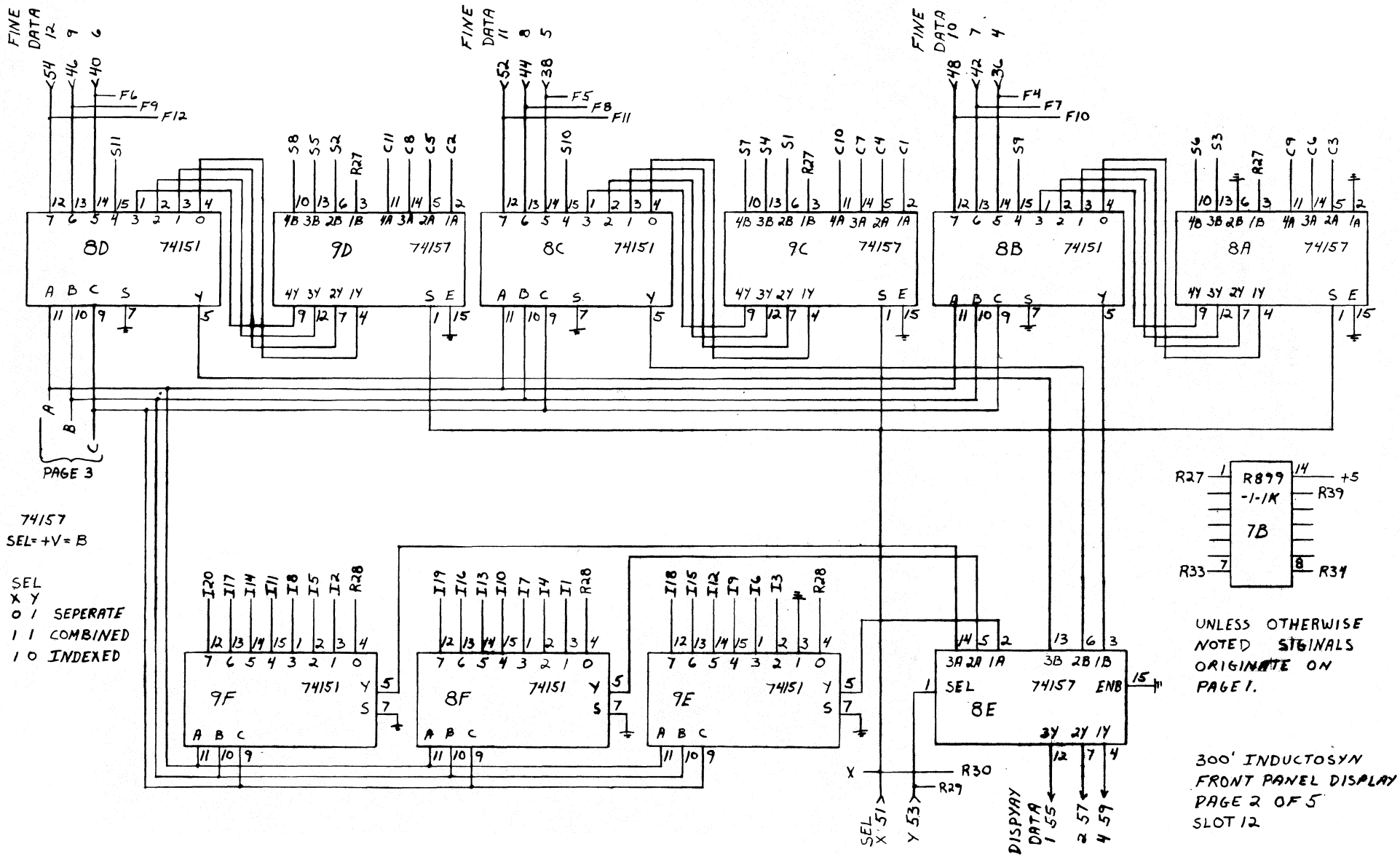
POSITION READOUT, RESOLVER TO DIGITAL COMPUTER
ANALOG CIRCUITS / SYNC. DET. / ERROR AMP. / VCO SLOT 9

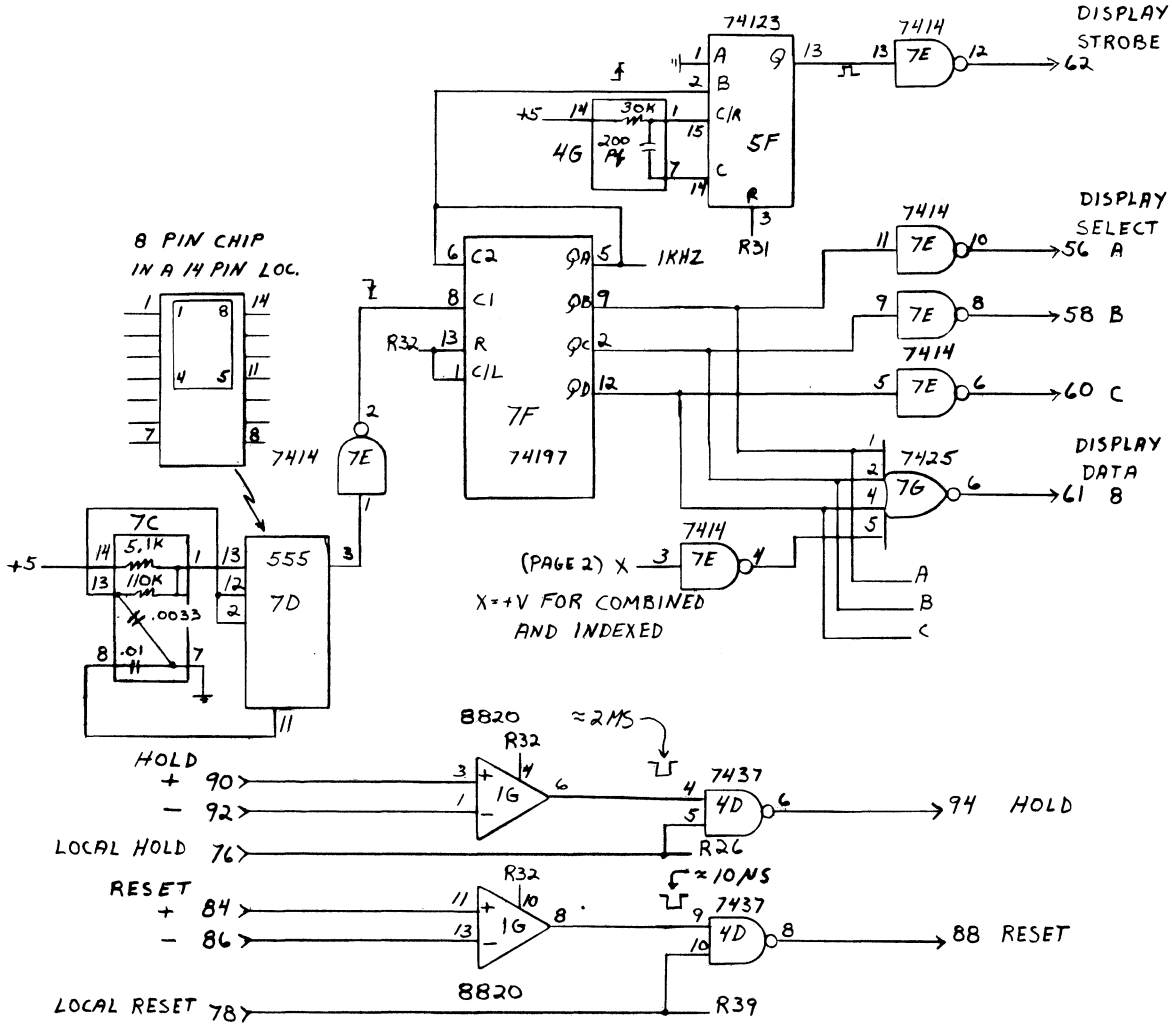

74157
SEL=0=A
A=EAST IND
CONSOLE DISPLAY
D.1A
D.1B
D.2A
D.2B
D.4A
D.4B
D.8A
D.8B
74157
1A
1B
2A
2B
3A
3B
4A
4B
SEL
ENB
1Y
2Y
3Y
4Y
1C
7406
2F
93 WEST LED
D1A
D1B
D2A
D2B
D4A
D4B
D8A
D8B
1D
D10A
D10B
D20A
D20B
D40A
D40B
D80A
D80B
1E
MRRIADS 2E
.0° MARK
SELECT
R1
89 SIGN
74175
DA
DB
3F
SIGN A
SIGN B
MARK .TA
MARK .TB
MARK 0A
MAKK 0B
R2
R3
7406
2F
A
B
78
MRRIADS 2D
0° MARK
80
91 EAST LED
14HZ
7414
4F
+5
3M
555
4E
.01
R899
-1-1K
1B
DIODES = IN914
4E DETAIL
300' INDUCTOSYN
CONSOLE DISPLAY SWITCH
PAGE 1 OF 1
SLOT 11



300 INDUCTOSYN
COMBING + INDEXING
PAGE 1 OF 5

SLOT 12


FINE DATA 12
FINE DATA 11
FINE DATA 10
F6
F9
F12
F5
F8
F11
F4
F7
F10
8D 74151
9D 74157
8C 74151
9C 74157
8B 74151
8A 74157
PAGE 3
74157
SEL=+V=B
SEL
X Y
0 1 SEPERATE
1 1 COMBINED
1 0 INDEXED
9F 74151
8F 74151
9E 74151
8E 74157
SEL
ENB
R27
R899
-1-1K
7B
R39
R33
R34
+5
UNLESS OTHERWISE NOTED SIGNALS ORIGINATE ON PAGE 1.
300' INDUCTOSYN
FRONT PANEL DISPLAY
PAGE 2 OF 5
SLOT 12
R30
R29
SEL X 51
Y 53
DISPYAY DATA 1 55
2 57
4 59



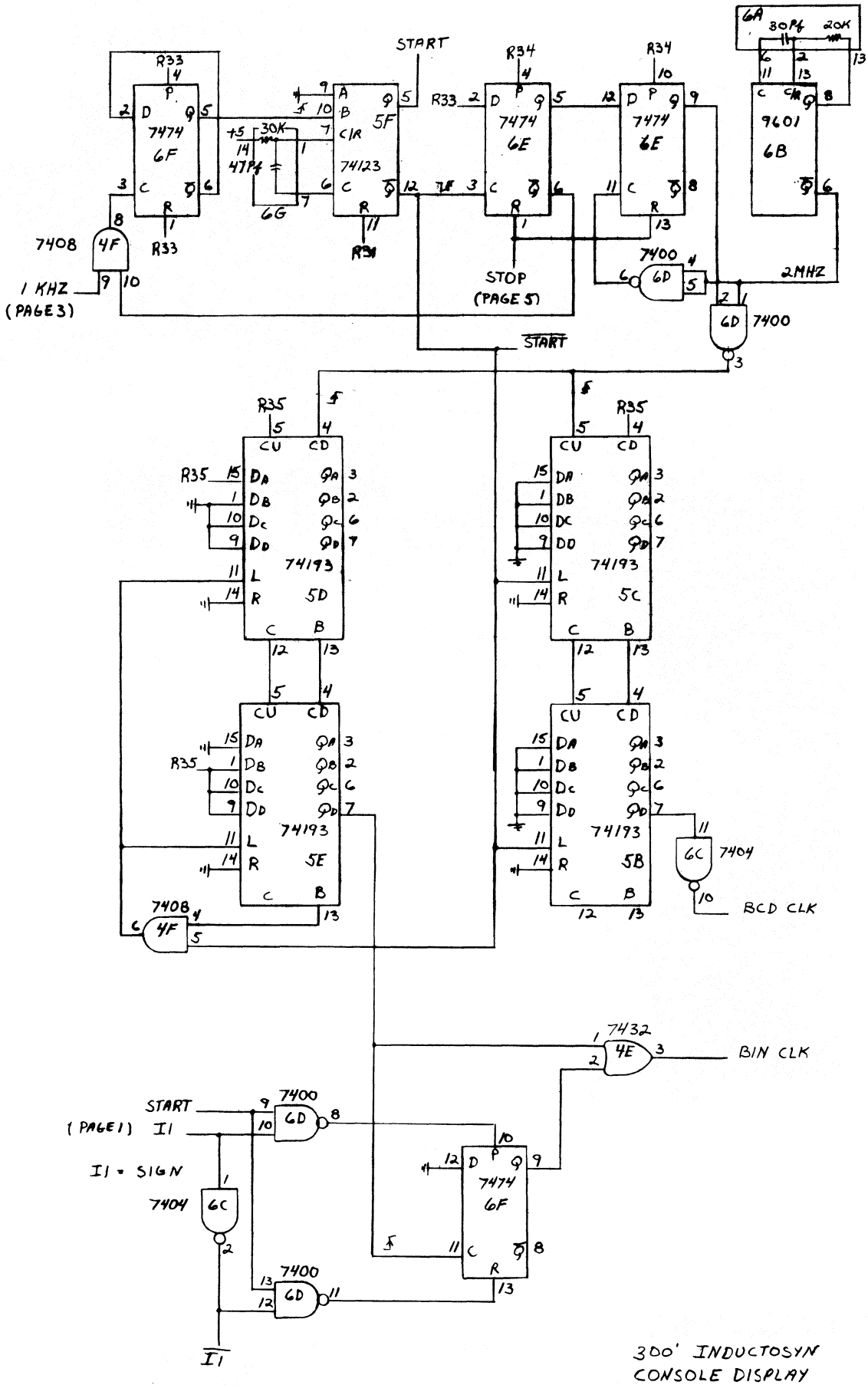
DISPLAY MULTIPLEXING

	SEPERATE					COMBINED					INDEXED				
	8	4	2	1		8	4	2	1		8	4	2	1	
COUNT AT 74151	0	0	0	C1	C2	1	1	1	1		1	1	1	1	
	1	0	C3	C4	C5	0	0	S1	S2		0	0	I1	I2	
	2	0	C6	C7	C8	0	S3	S4	S5		0	I3	I4	I5	
	3	0	C9	C10	C11	0	S6	S7	S8		0	I6	I7	I8	
	4	0	S9	S10	S11	0	S12	S13	S11		0	I9	I10	I11	
	5	0	F4	F5	F6	0	F4	F5	F6		0	I12	I13	I14	
	6	0	F7	F8	F9	0	F7	F8	F9		0	I15	I16	I17	
	7	0	F10	F11	F12	0	F10	F11	F12		0	I18	I19	I20	

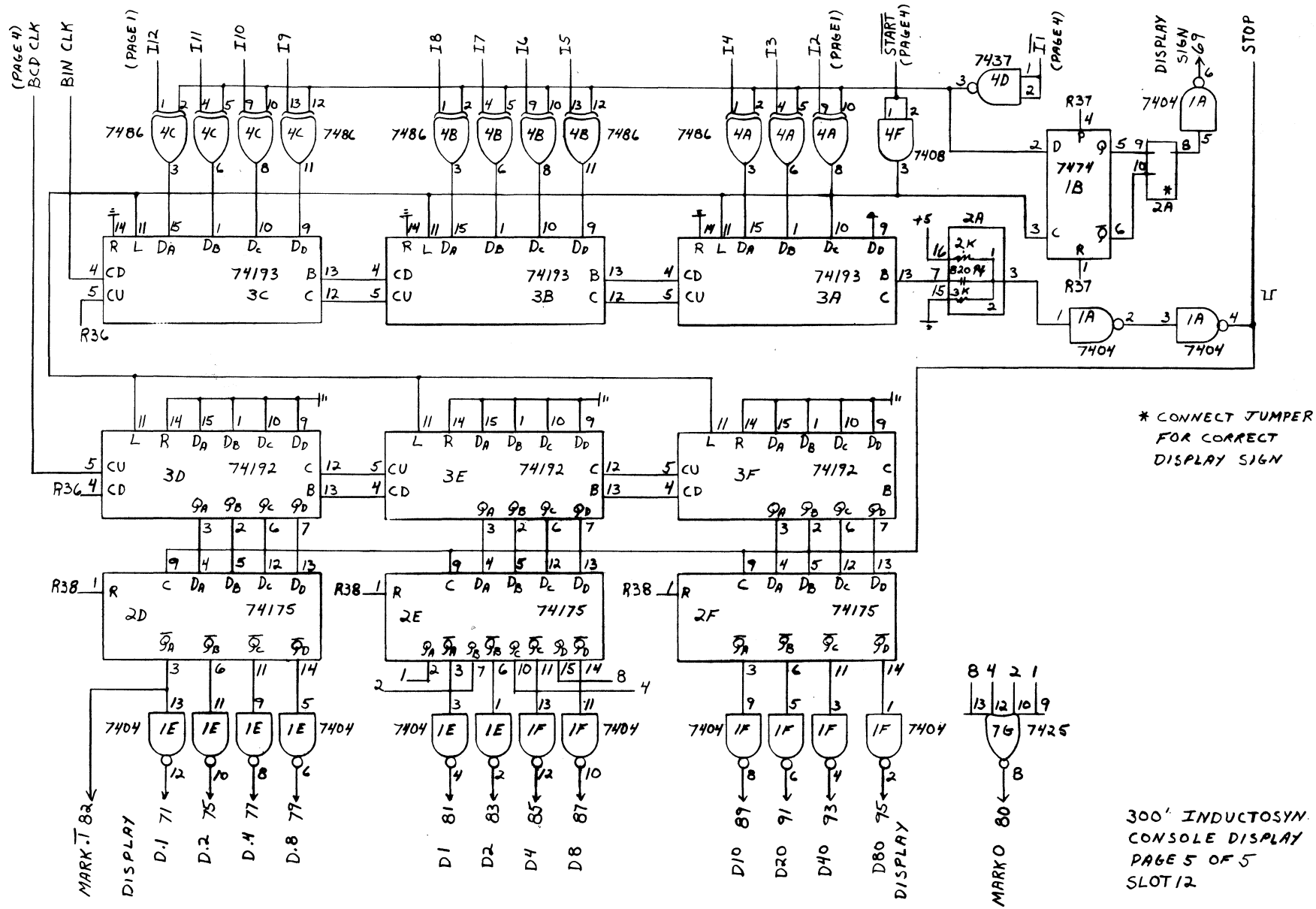
0	1	2	3	4	5	6	7

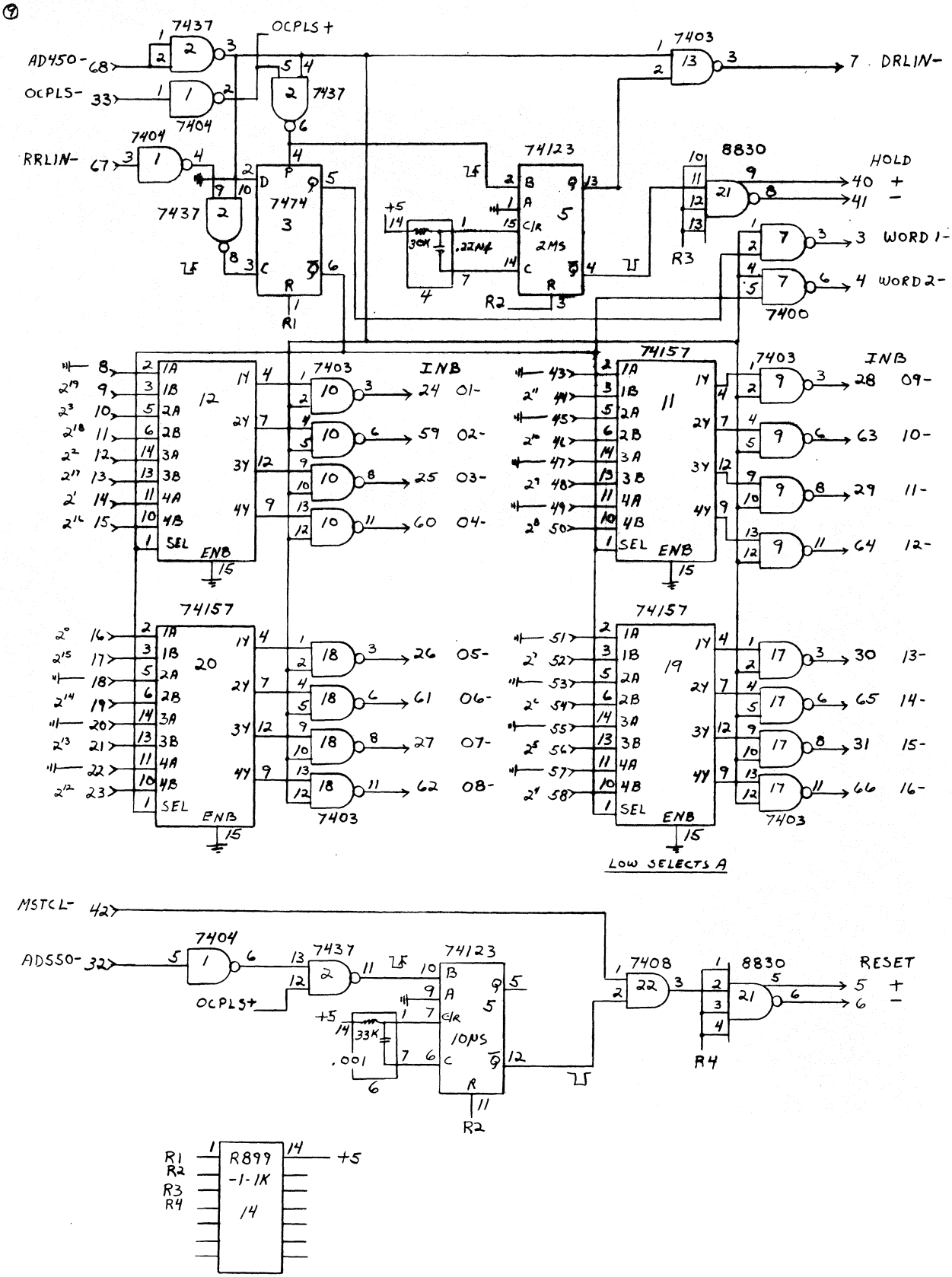
DISPLAY

300' INDUCTOSYN
FRONT PANEL DISPLAY
PAGE 3 OF 5
SLOT 12

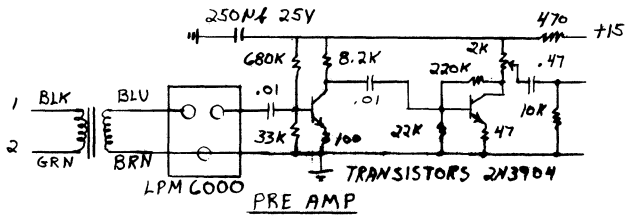


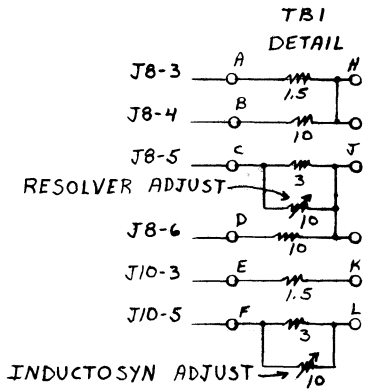
300' INDUCTOSYN
CONSOLE DISPLAY
PAGE 4 OF 5
SLOT 12

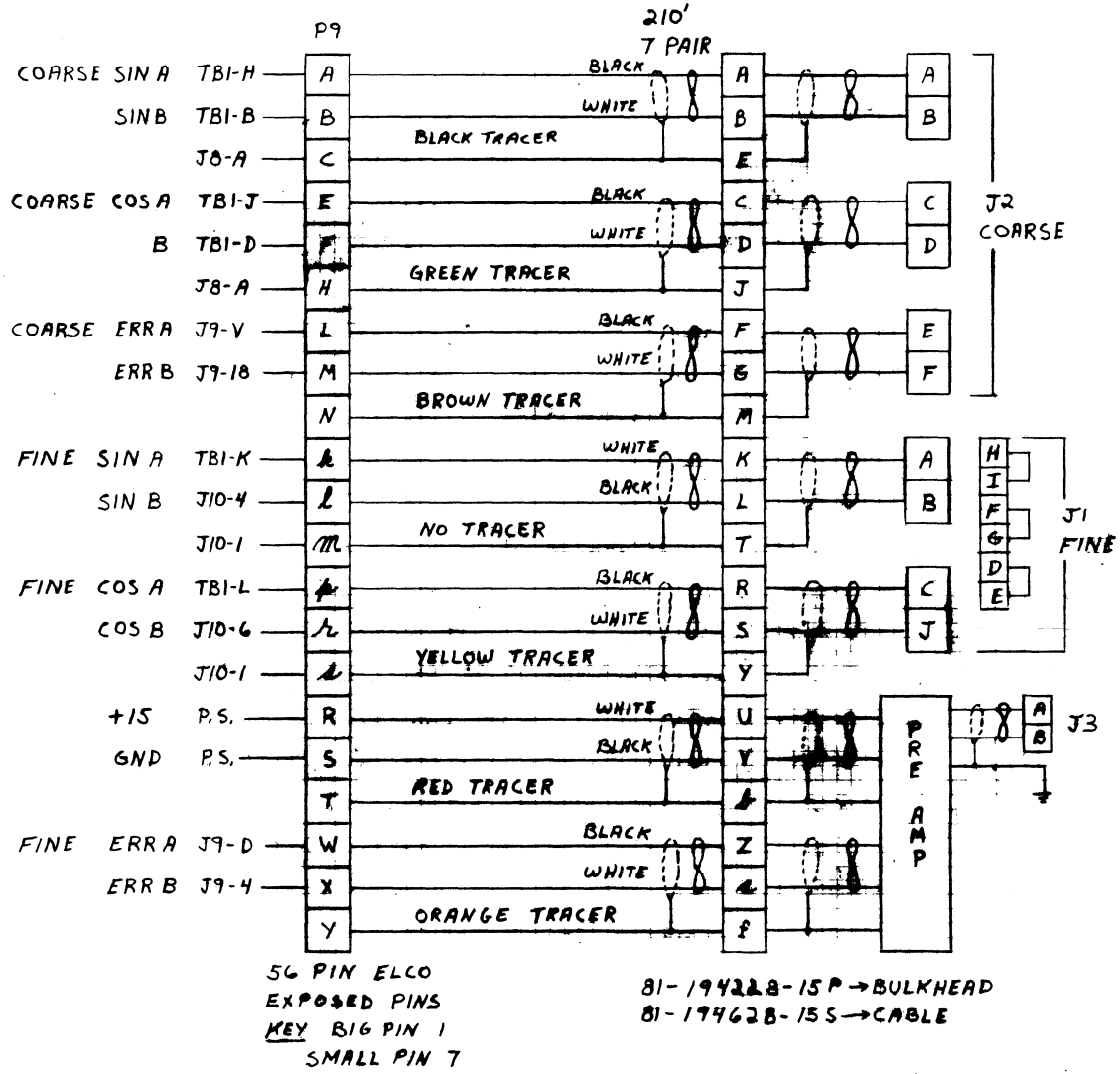

(PAGE 4) BCD CLK
BIN CLK
(PAGE 1) I12
I11
I10
I9
I8
I7
I6
I5
I4
I3
I2 (PAGE 1)
START (PAGE 4)
7437 4D
I1 (PAGE 4)
DISPLAY SIGN 69
STOP
7486 4C
7486 4B
7486 4A
7408 4F
7474 1B
7404 1A
74193 3C
74193 3B
74193 3A
R36
R37
2A
2K
820
3K
+5
74192 3D
74192 3E
74192 3F
74175 2D
74175 2E
74175 2F
R38
7404 1E
7404 1F
MARK T 82
DISPLAY
D.1 71
D.2 75
D.4 77
D.8 79
D1 81
D2 83
D4 85
D8 87
D10 89
D20 91
D40 93
D80 95
DISPLAY
MARK 0 80
8 4 2 1
74 25
* CONNECT JUMPER FOR CORRECT DISPLAY SIGN
300' INDUCTOSYN CONSOLE DISPLAY PAGE 5 OF 5 SLOT 12



INDUCTSYN H31C INTERFACE
PAGE 1 OF 1
H31C SLOT 11


250MF 25V
470
+15
680K
8.2K
2K
.47
220K
.01
.01
10K
1
BLK
BLU
33K
100
22K
47
2
GRN
BRN
LPM 6000
TRANSISTORS 2N3904
PRE AMP


TBI
DETAIL
J8-3
A
H
1.5
J8-4
B
10
J8-5
C
J
RESOLVER ADJUST
3
10
J8-6
D
10
J10-3
E
K
1.5
J10-5
F
L
3
INDUCTOSYN ADJUST
10


P9
210'
7 PAIR
COARSE SIN A
TBI-H
SIN B
TBI-B
J8-A
COARSE COS A
TBI-J
B
TBI-D
J8-A
COARSE ERR A
J9-V
ERR B
J9-18
FINE SIN A
TBI-K
SIN B
J10-4
J10-1
FINE COS A
TBI-L
COS B
J10-6
J10-1
+15
P.S.
GND
P.S.
FINE ERR A
J9-D
ERR B
J9-4
BLACK
WHITE
BLACK TRACER
GREEN TRACER
BROWN TRACER
NO TRACER
YELLOW TRACER
RED TRACER
ORANGE TRACER
J2
COARSE
J1
FINE
J3
PRE AMP
56 PIN ELCO
EXPOSED PINS
KEY BIG PIN 1
SMALL PIN 7
81-19422B-15P → BULKHEAD
81-19462B-15S → CABLE
300' INDUCTOSYN
EAST CABLE