

GOERZ OPTICAL COMPANY, INC.

FINAL REPORT

24-INCH CASSEGRAIN-COUDE TELESCOPE

CONTRACT NAS8-20805

TR-2407

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GOERZ OPTICAL COMPANY, INC.

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GOERZ OPTICAL COMPANY, INC.

0.0 INTRODUCTION

This report discusses the design philosophy and checkout procedure for the 24-inch telescope servo system. The mechanical and optical portion of the design have been described in the monthly reports during the course of the contract.

The contract expired before all checkout was completed. The description of the checkout of the polar axis system, which was completed at the Goerz plant, is presented in detail so that NASA personnel may complete the checkout of the declination axis servo system. The polar axis and declination axis servo system are essentially the same.

1.0 GENERAL DESCRIPTION

The telescope control system is composed of a position and rate servo for each axis, safety interlocks and a focusing servo. The operation of the system is divided up into a number of modes which are listed in Table 1.

Selecting one of the modes - Computer, Manual Command, or Sidereal - places that axis in a position servo loop. (See Table 1) The position servo is commanded respectively from a digital computer, console switches or the sidereal clock. The mode Slew puts the axis in a rate servo loop which as incremental commands of three degrees, three minutes and three seconds per second with direction control. The mode Brakes On removes 115 volts from the brake air solenoid, allowing the air brakes to clamp the axis. Also, 28 volts are removed from the coil of the torquer contactors which open the path from power amplifier to torque motor. The Brakes Release mode also removes 28 volts from the torquer contactors, but allows 115 volts on the brake air solenoid. All modes are independent with the exception of Brakes Release which can only be entered from, or exited to Brakes On.

If either axis is driven to a limit, a light is energized at the console and a diode is switched in series with the

1.0 GENERAL DESCRIPTION

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If either axis is driven to a limit, a light is energized at the console and a diode is switched in series with the

torquer. The diode inhibits the polarity of current that would continue to drive the axis into the limit and passes that current which will drive it out of the limit. Also, if either axis exceeds an adjustable rate limit (6-50°/sec), a console light is energized and the system is switched into the Brakes On mode. For Polar axis slow motion, the Fine Adjust air switch is actuated which puts system into Brakes Release mode. Once in Brake Release the Fine Adjust wheel at the base of the telescope can be used to move Polar axis.

Operation of the system usually takes place at the Telescope Control Chassis in the console, but control can be switched to the Remote Control Box by pushing Remote either on the Telescope Control Chassis in the console, but control can be switched to the Remote Control Box by pushing Remote either on the Telescope Control or on the Remote Control Box itself. From the Remote Box all modes described above can be selected, although only one axis at a time. Also, the Remote Control Box contains the focus control resolver, an Initiate button that changes the rate of the Sidereal Clock from 50 Hz to 10 KHz, and a Guiding Control that can vary the DC voltage to the Sidereal VCO.

2.0 OPERATION AND REWORK

2.1 MODES CONTROL

The modes selection circuitry is made up of two relays, an "OR" gate, and a front panel switch (M.R.) for each mode; i.e., 24 relays, 13 OR gates and 13 F.P. switches total. (See Table 2) The F.P. Switch is connected to the coil of the mode relay and the output of the OR gate is connected to the coil of the latching relay (Sketch 1). The latching path of the mode relay is through NC contacts of the latching relay. The gate has an input from every other mode relay. Thus, by pushing a mode switch, all other mode relays are unlatched and the desired mode relay latches through the NC contacts of its unenergized latching relay. The latching of the mode relay controls the system by either providing a closure (Sketch 3) or by generating a DC control voltage (Sketch 2). For a remote mode selection the same circuitry is used except now the momentary contact switch pushed is in the Remote Box (Sketch 1). The final circuitry used to switch control between the Remote Box and Telescope Control is shown in Sketch 4.

NOTES: Direction control of the rate command is supplied by K-17 and K-18 for north-south and K-35 and K-37

for east-west. These direction circuits had to be rewired at checkout to correctly implement a relay flip-flop (Sketch 5). It is worth noting that unless one of the direction relays are latched, the input to the rate divider is a short. Thus, even after pushing "Slew" and "Fast", for example, the rate command is zero volts until a direction is selected. The resistor tree had to be modified also. New resistors and wiring were added providing 8.5 volts, 0.14 volt and 0.003 volt through a 246K for the Fast, Medium and Slow rate commands. Also in the way of rework, a latching path for the Brake Release relay K19, K32, had to be provided and a Brakes ON initialize circuit added (Sketch 6). Since the Remote Box only had one set of mode switches, an exclusive OR arrangement had to be added so that the box could command both axes. The XOR was mechanized by adding a toggle switch to the Remote Box which commanded new relays K40 and K41 in the telescope control chassis. Finally, the Brakes ON relay K1 and K21 started to burn themselves shut after a month of operation. It is recommended that heavier contactors with arc suppression be added to interrupt the inductive brake circuit. The wire from K19 and K32, Pin 5 to K1 and K21, Pin 2, is a redundant wire and should be removed to protect the contacts of K19 and K32.

2.2 SIDEREAL CLOCK

The Sidereal Clock is housed in a chassis labeled Sidereal Clock which also contains the reference electronics for the Inductosyn and all focus servo electronics. Therefore, references to Sidereal Clock are references to the actual clock electronics and not the complete chassis.

The Sidereal Clock is made up of four parts: VCO, Divider Logic, Switching Logic, and Counter and Readout. The VCO is a very stable oven type oscillator that generates 9.73 Mc. at about 4 volts P-P. The DC voltage (from +9 volts to -9 volts) applied to the oscillator is used only as a very fine adjust or calibration per astronomical tracking event. The approximate 10 MHz is divided down to 10 KHz, 100 Kz, 50 Hz. The 100 Hz is the systems strobe rate and is sent from the divider to the strobe electronics housed in the axis readout chassis. One of the two remaining frequencies are gated to the counter. (See Drawing #355-0400) A flip-flop supplies the gating signals and in the "normal" position allows the 50 Hz to clock the counter. When an initiate button is pushed in the Remote Box the F.F. flips and gates through the 10 KHz until the button is released. (Fast Sidereal) The Counter is a 22 bit serial type which has a 22 bit parallel output available at a rear connector as a command to the position servo. The 22 bits are also decoded to octal and displayed as a eight place

octal number. The counter can also be preset to any desired octal number by placing the front panel switch at Preset and placing the desired number in thumb wheel switches on the front panel.

NOTES: The only problem was to implement a fast sidereal gating circuit and clean clock lines of 10 Mc noise which caused the counter to stop periodically.

10KHz REFERENCE: Another of the functions housed in the Sidereal Clock chassis is the reference electronics which consists of a 10 Kc Pc card oscillator and amplifiers. The original card oscillator became inoperative and had to be replaced with a substitute. The second oscillator did not have a stable amplitude so the gain of the following amplifier was increased and the output (10 volts P-P) zenered to about 5 volts P-P. This was double filtered in the readout chassis, amplified (about 8 volts P-P) and drove the rotor of the Inductosyn.

The focus servo electronics were bench checked. The output of a 10 KHz test resolver was used as an input, demodulated, amplified, and drove a resistive 20 ohm load.

	MODE	INTERLOCK
Polar Axis	Computer	CW
	Manual Command	CCW
	Sidereal	Rate Trip
	Slew	Fine Adjust
	Brakes On	
	Brakes Release	
Declination Axis	Computer	CW
	Manual Command	CCW
	Slew	Rate Trip
	Brakes On	
	Brakes Release	

Note: A mode labeled Auto Track has no function; therefore is not listed above.

MODES AND INTERLOCKS

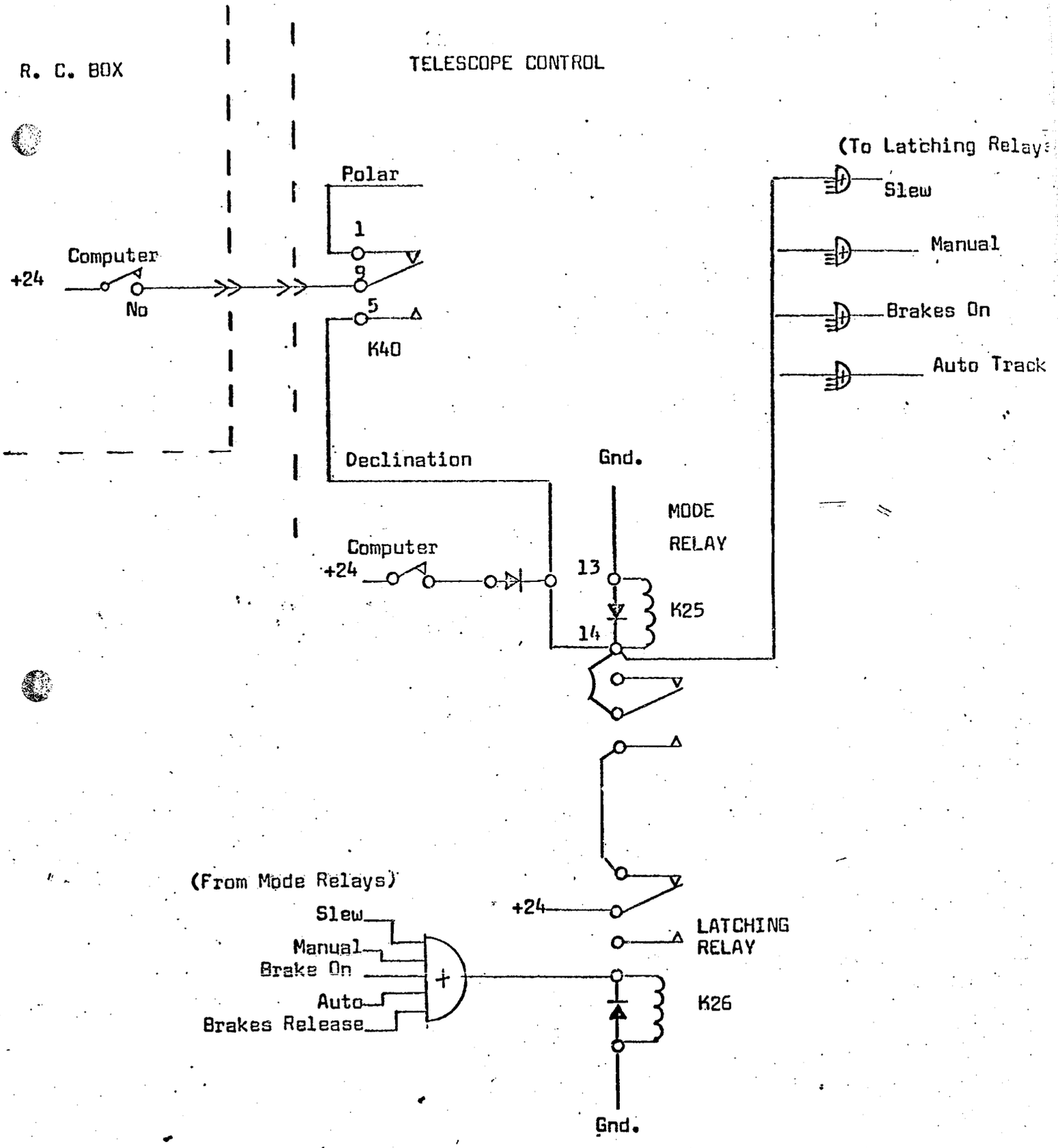
Table 1

		MODE RELAY	LATCHING RELAY
Polar Axis			
	Computer	K5	K6
	Manual	K7	K8
	Sidereal	K11	K12
	Slew	K3	K4
	Brakes On	K1	K2
	Brakes Release	K19	(None)
	*Auto Track	K9	K10
Declination Axis			
	Computer	K25	K26
	Manual	K27	K28
	Slew	K23	K24
	Brakes On	K21	K22
	Brakes Release	K32	(None)
	*Auto Track	K29	K30

*Performs no function in the current configuration.

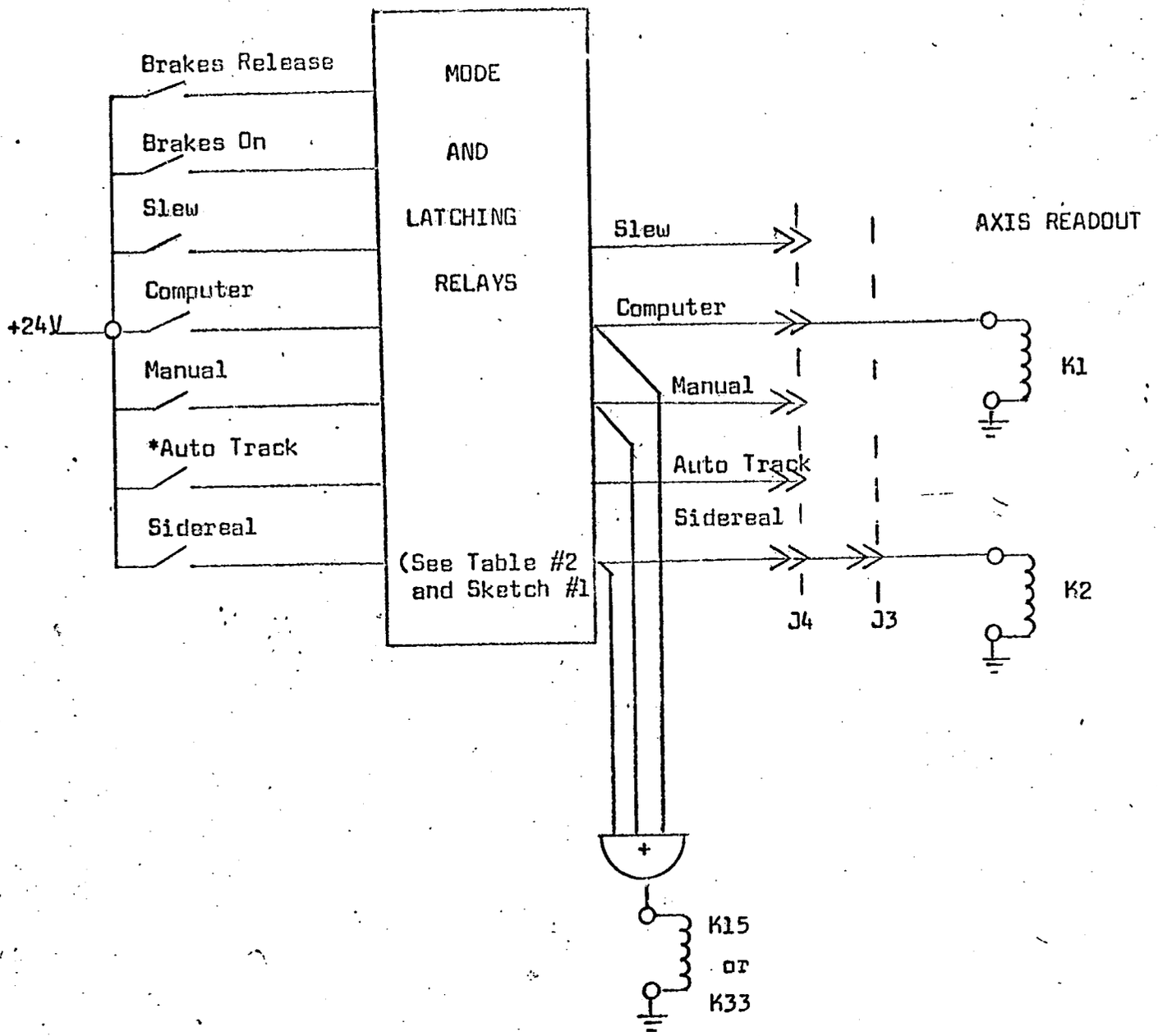
MODE SELECTION RELAYS

Table 2

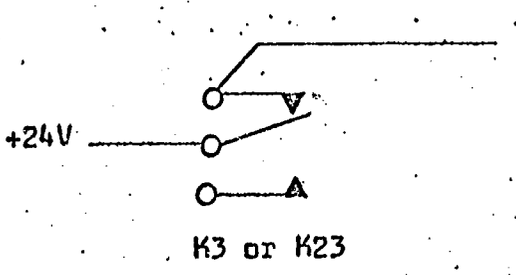


EXAMPLE OF MODE SELECT CIRCUITRY SKETCH #1

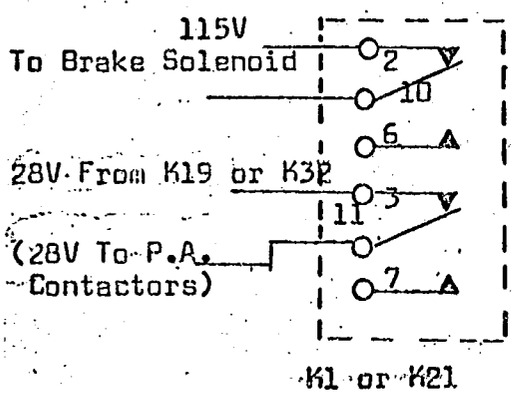
TELESCOPE CONTROL CHASSIS



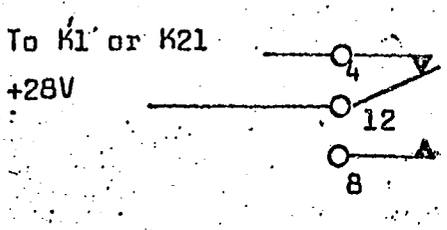
MODE DC CONTROL VOLTAGES SKETCH #2



SLEW



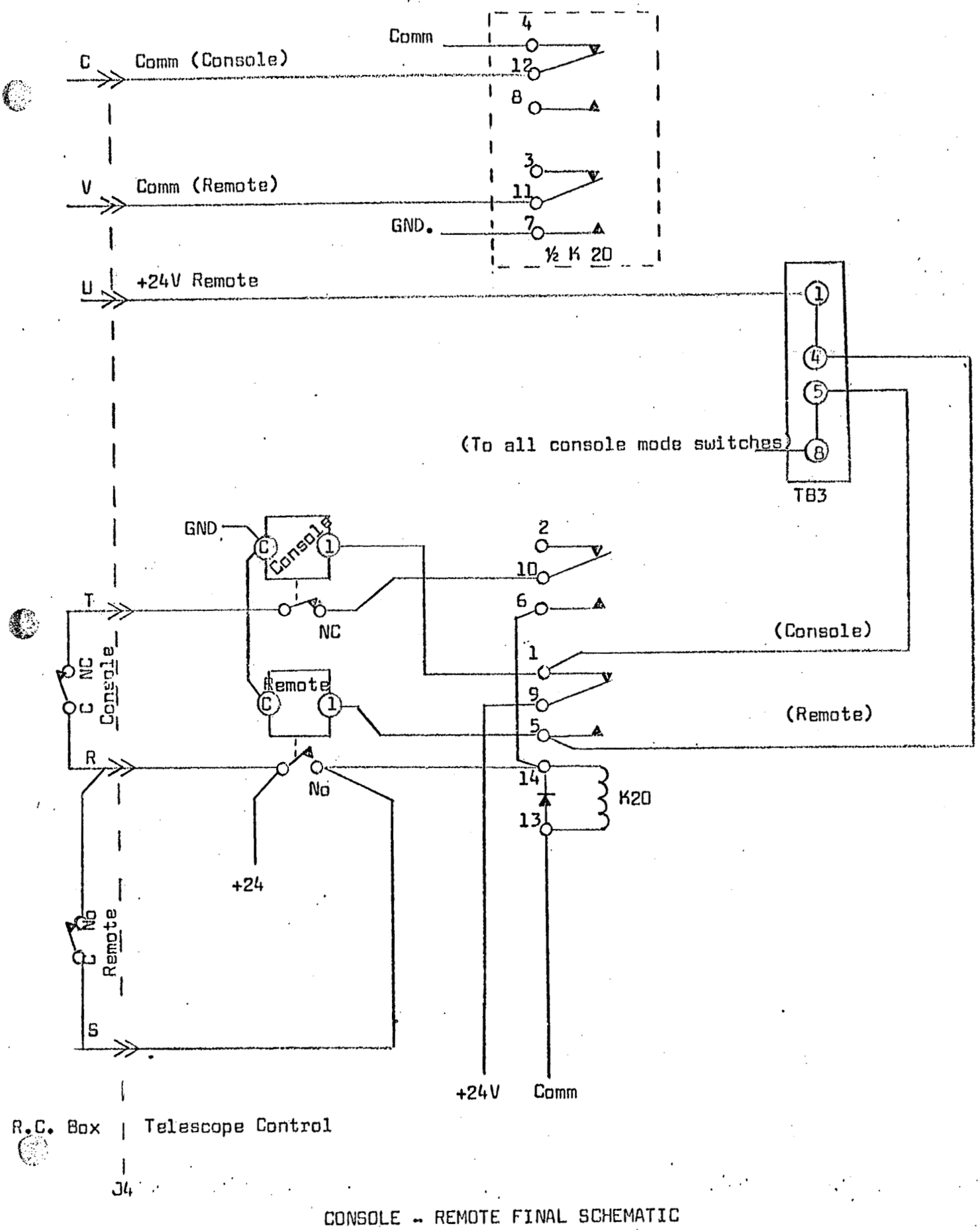
BRAKES ON



BRAKES RELEASE

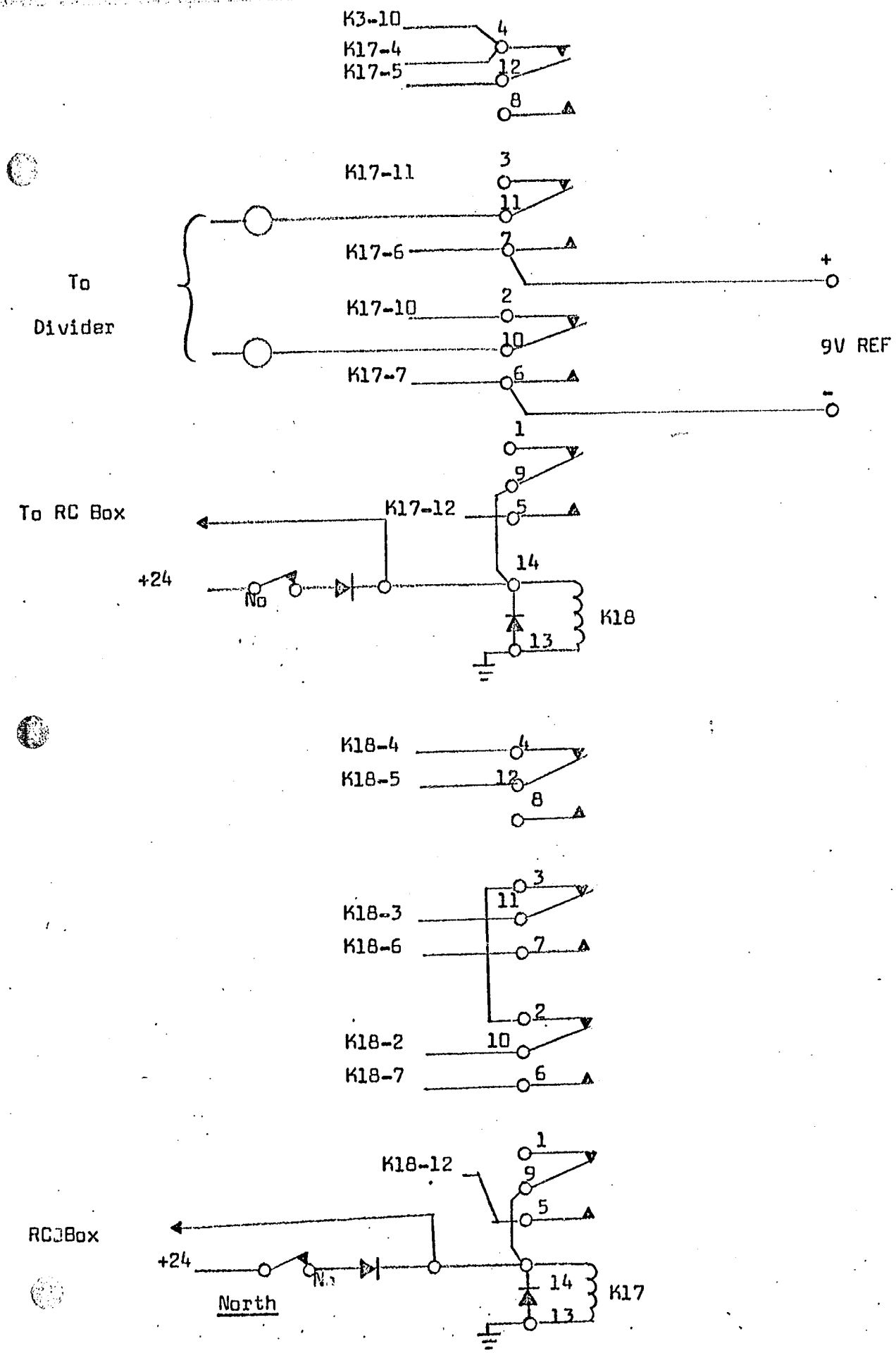
MODE CONTROL CLOSURES

SKETCH #3



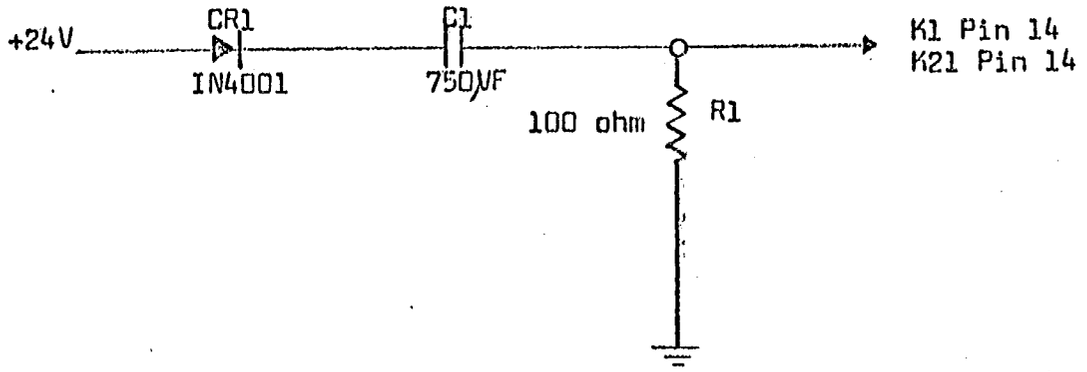
CONSOLE - REMOTE FINAL SCHEMATIC

SKETCH #4

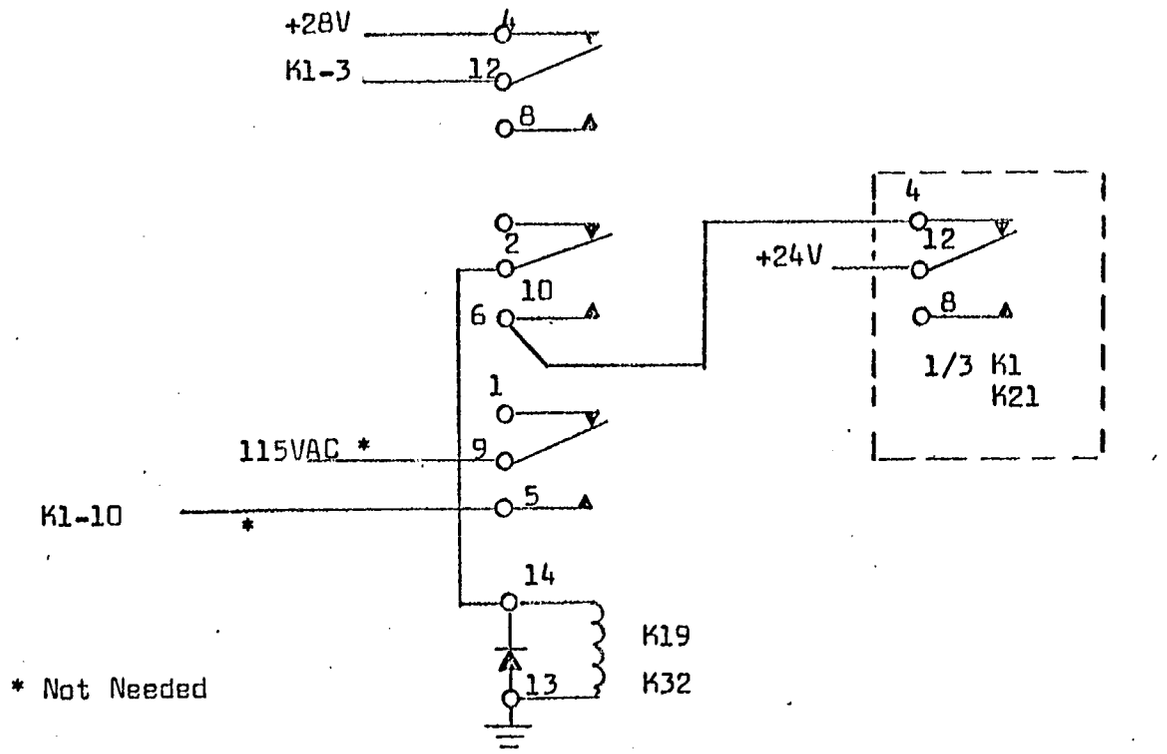


DIRECTION CONTROL

SKETCH #5



BRAKES ON INITIALIZE



BRAKES RELEASE LATCH

SKETCH #6

2.3 AXIS READOUT AND ENCODERS

The Polar and Declination readout chassis are identical and each contains the following:

1. 512:1 Follow up Servo
2. Position Command Gating
3. Strobe Generator
4. Eight Digit Octal Readout

In the way of theory, the follow-up servo has already been discussed in an earlier report. The generation of axis position is explained under Encoder Hardware considerations and the remaining readout logic is straightforward and its operation can easily be determined from the study of Drawing #355-0240 Sheets 1.2.3.

NOTES: Both Polar and Declination readout chassis had a logic oscillation in the area of cards A18, A19, and A20. The oscillation was stopped by running separate 5V lines to the above cards. The wiring and the time relationship of the strobe and sample pulses are shown on Sheet 3 of Drawing #355-0240.

SHAFT ENCODERS: The Polar Axis shaft encoders were set to zero with axis in vertical position then synchronized. They appeared

to be operating properly, although accuracy was not determined. The Declination shaft encoders were not synchronized since the fine encoder was not received from factory repair until two days before shipment of Telescope.

SYNCHRONIZATION: Synchronization of the coarse-fine encoders is defined as a command from the fine to the coarse encoder to switch brushes at a transition when all lines of both encoders are high (4.5V) and the 13 lines of the fine go low (0V). That is, when the readout displays 17777777_8 at the next .31 arc sec movement of the axis the fine encoder goes from 7777_8 to 0000_8 and tells the coarse encoder to go from 1777_8 to 0000_8. Following are instructions for encoder synchronization and vendor specifications:

ENCODER SYNCHRONIZING INSTRUCTIONS

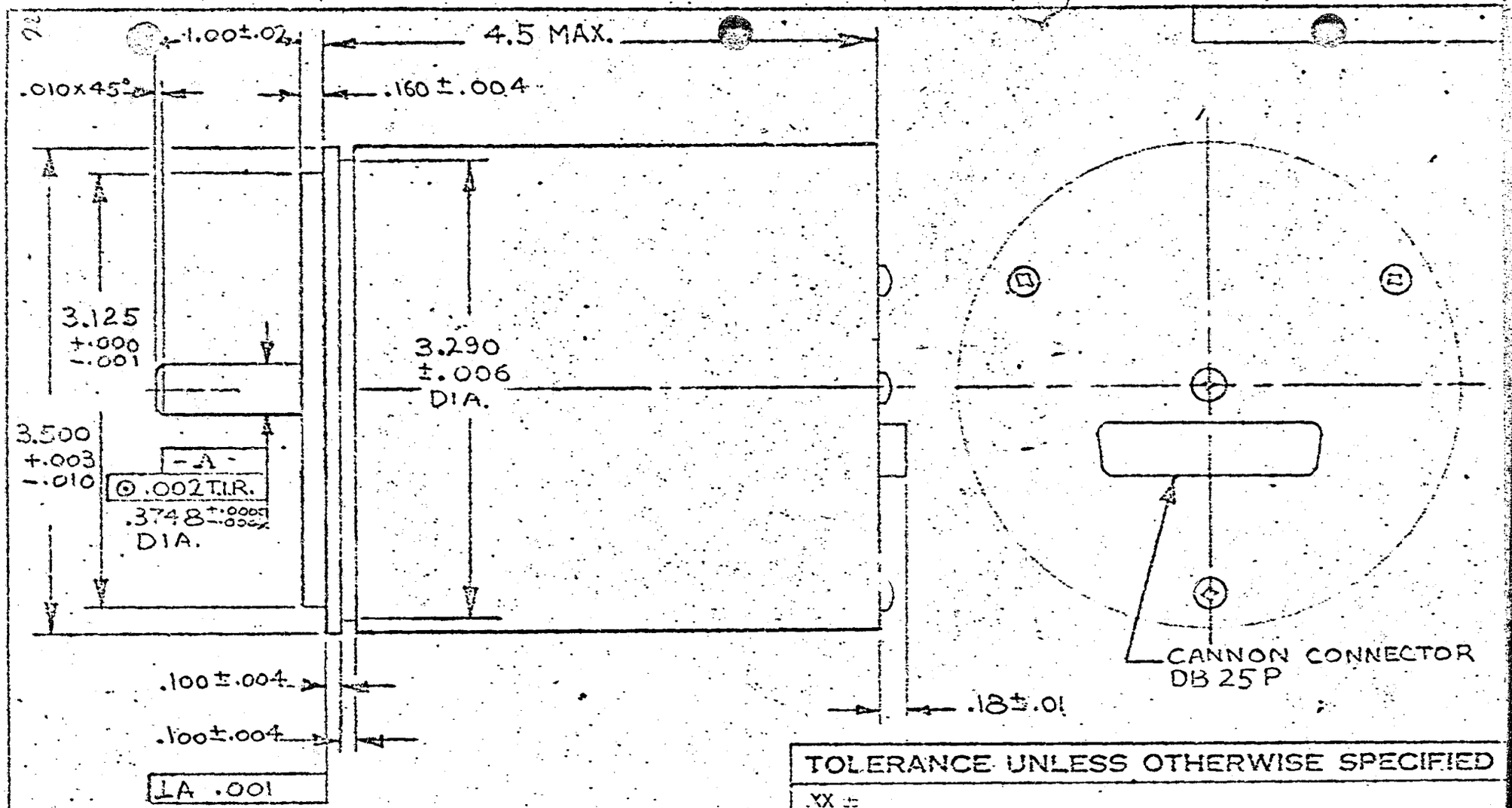
1. Take rear cover off of axis. Also, pull out readout chassis at console.
2. Put axis in Brake Release mode and move axis by hand. Check that the shafts of both encoders are rotating in the <u>same</u> direction with respect to the encoders. If rotations are opposite reverse one set of stator wires on follow-up servo resolver (Readout Chassis).
3. Position axis to desired orientation for zero position.
4. Decrease tension on coarse encoder drive band with axis stationary, move shaft of coarse encoder using drive wheel until readout displays 1776 xxxxx. Engage encoder by tightening drive band.

5. In readout chassis, loosen resolver back screws. Turn resolver until readout displays 17777777. Tighten resolver lock screws.
6. Move axis ±.31 arc sec. readout display should go from 17777777 to 17777776 or 00000000.

ENCODER HARDWARE CONSIDERATIONS: The coarse encoder, Litton Model E-AD35-10L4, is a 10 bit shaft encoder whose "1st bit" (Pin 10) is the MSD and whose "10th Bit" (Pin 1) is actually an input which when high causes brushes to be switched and the output transition of 111111111 to 000000000. The fine encoder, Litton Model AD35-12L4, is a 13 bit shaft encoder whose "13th Bit" (Pin 1) is the LSD and whose "1st Bit" (Pin 13) is displayed and is inverted and sent to C.E. Pin 1 as sync command. Thus, 9 bits from C.E. and 13 bits from F.E. are displayed providing a 22 bit position readout of axis. (See Drawing #355-0240 Sheet 2).

POSSIBLE DECLINATION READOUT WIRING ERROR

On the Declination Readout the MSD display should be 1 or 0. Only 1st Bit of C.E. (MSD of 22 Bit position word) is being displayed. If, say, 7 and 5 are displayed, pins of that tube have to be rewired. (Jumpers and wire) The wiring should be made identical to that of Polar Readout MSD. Nixie tube literature is enclosed.



Follow-up
SERVO

SYSTEM FINE ENCODER

① MACHINING CENTERS PERMISSABLE

NOTES:

TOLERANCE UNLESS OTHERWISE SPECIFIED

.XX ±
.XXX ± .010 ANGLES ±

LITTON PRECISION PRODUCTS, INC.
ENCODER DIVISION CHATSWORTH, CA. 91311

DRAWN 3-27-81	SCALE NONE	REVISIONS	DATE
CHECKED			
APPROVED			
DATE 3/27/81			

TITLE MODEL AD35-12L4 ENCODER.

NO. E-AD35-12L4

SHEET 1 OF 3 19

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

2.2.4

PIN #	FCN
1	13th bit (LSD)
.	
.	
.	
13	*1th bit (MSD)
14	Signal Ground
15	
.	Spare
.	
.	
21	
22	Case Ground
23	Power Ground
24	-6.3 VDC
25	+6.3 VDC

* This bit is displayed but; also, is inverted (sync. bit) and goes to Pin 1 of coarse encoder.

2.3 ACCURACY ± 1/2 bit

2.4 ENVIRONMENTAL

2.4.1	Temperature Operating	0° ⟶ 55°C
2.4.2	Temperature Storage	-40 ⟶ +65°C
2.4.3	Altitude 50,000 feet	50,000 feet
2.4.4	Vibration	Meets MIL-E-5400
2.4.5	Humidity	98% relative with no condensation.

REVISION:

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

MODEL AD35-12L4 ENCODER

1.0 GENERAL DESCRIPTION

A continuous reading 2^{13} natural binary parallel output size 35 optical encoder with the most significant digit used as the least significant digit of an AD35-10L-1 encoder.

2.0 PRELIMINARY SPECIFICATION

2.1 MECHANICAL

2.1.1 Size	35
2.1.2 Weight	48 oz.
2.1.3 Starting Torque	.5 in oz.
2.1.4 Running Torque	0.25 in. oz.
2.1.5 Max Angular Acceleration	50,000 rad/sec^2
2.1.6 Max Slew Speed	5000 RPM
2.1.7 Moment of Inertia	.273 oz. in^2
2.1.8 *Rotation	CCW
2.1.9 Bearing Life	50 x 10^6 rev @ shaft speeds 3000 PRM
2.1.10 Mounting Position	any

2.2 ELECTRICAL

2.2.1 Power input	+6.3VDC±5% @ 700 ma max -6.3VDC±5% @ 500 ma max
2.2.2 Signal Output-Bin "1"	4.5VDC±.5VDC
Bin "0"	0VDC±.5VDC

2.2.3 Signal output configuration:

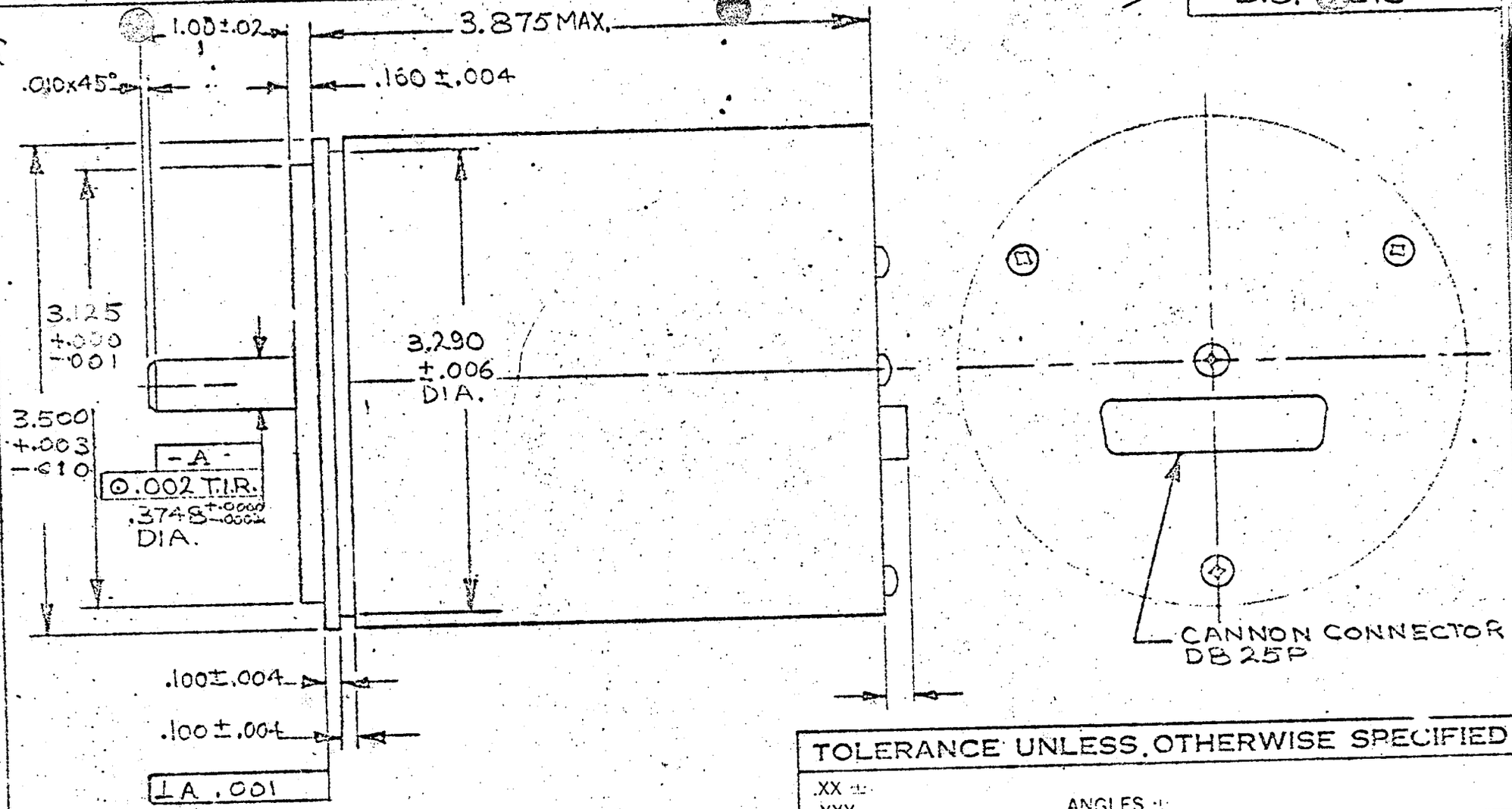


*CW available on special order.

REVISION:

ENCODER DIVISION CHATSWORTH, CALIFORNIA	TITLE: MODEL AD35-12L4 ENCODER	DOCUMENT NO.: E-AD35-12L4

S.O. [illegible]215



TELESCOPE AXIS

SYSTEM COARSE ENCODER

① MACHINING CENTERS PERMISSABLE

NOTES:

TOLERANCE UNLESS OTHERWISE SPECIFIED

.XX ±
.XXX ±
ANGLES ±

LITTON PRECISION PRODUCTS, INC.
ENCODER DIVISION CHATSWORTH, CA. 91311

		REVISIONS	DATE
DRAWN [illegible] 3-11-88	SCALE NONE		
CHECKED [illegible]			
APPROVED J. D.			
DATE MAR. 29 '88			

TITLE MODEL AD35-10L4 ENCODER

NO. E-AD35-10L4

SHEET 1 OF 3

22

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

MODEL AD35-10L4 ENCODER

Note: 10th Bit is incoming sync. bit. *

1.0 GENERAL DESCRIPTION

A continuous reading 2^{10} natural binary parallel output size 35 optical encoder in which the least significant digit is obtained from an AD35-12L4 encoder.

2.0 PRELIMINARY SPECIFICATION

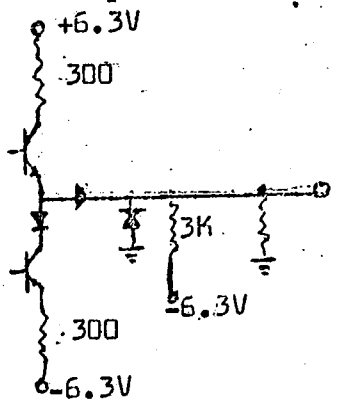
2.1 MECHANICAL

2.1.1	Size	35
2.1.2	Weight	48 oz.
2.1.3	Starting Torque	.5 in-oz.
2.1.4	Running Torque	0.25 in-oz.
2.1.5	Max. Angular Acceleration	50,000 rad/sec^2
2.1.6	Max. Slew Speed	5000 RPM
2.1.7	Moment of Inertia	.273 oz-in.^{2}
2.1.8	*Rotation	CCW
2.1.9	Bearing Life	50 x 10^6 rev. @ shaft speeds < 3000 RPM
2.1.10	Mounting Position	any

2.2 ELECTRICAL

2.2.1	Power input	+6.3VDC ± 5% @ 700 ma max -6.3VDC ± 5% @ 500 ma max
2.2.2	Signal Output Bin "1"	4.5VDC ± .5VDC
	Bin "0"	0 VDC ± .5 VDC

2.2.3 Signal output configuration

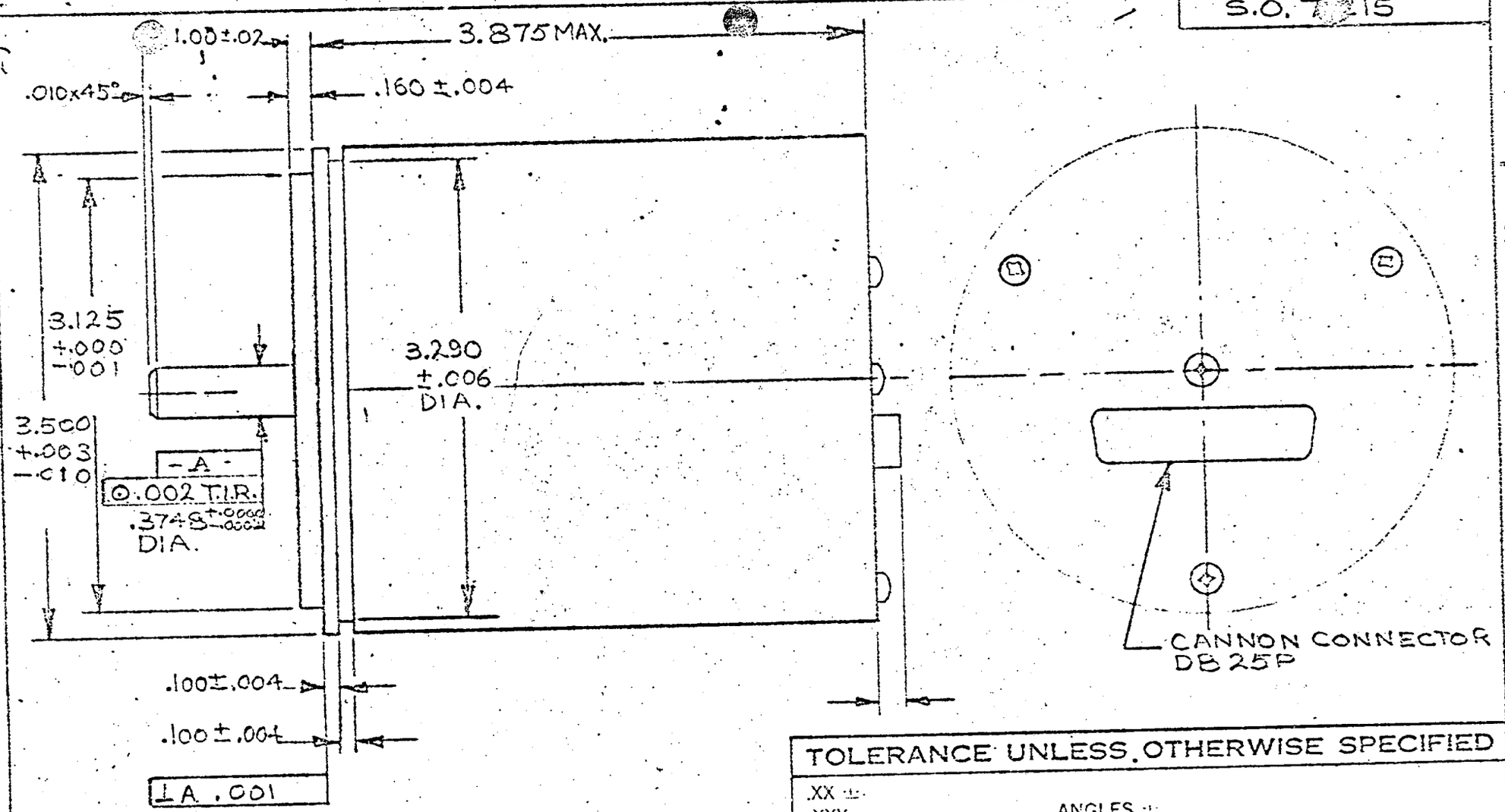


* CW available on special order.

REVISION:

ENCODER DIVISION LITTON PRECISION PRODUCTS, INC. CHATSWORTH, CALIFORNIA	TITLE: MODEL AD35-10L4 ENCODER	DOCUMENT NO.: E-AD35-10L4

S.O. T-215



TELESCOPE AXIS

SYSTEM COARSE ENCODER

① MACHINING CENTERS PERMISSABLE

NOTES:

TOLERANCE UNLESS OTHERWISE SPECIFIED

.XX ±
.XXX ±
ANGLES ±

LITTON PRECISION PRODUCTS, INC.
ENCODER DIVISION CHATSWORTH, CA. 91311

		REVISIONS	DATE
DRAWN 3-11-68	SCALE NONE		
CHECKED			
APPROVED			
DATE Mar 29 68			

TITLE MODEL AD35-10L4 ENCODER

NO. E-AD35-10L4

SHEET 1 OF 3

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REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

"Coarse-Fine" Synchronization Bit from Fine Encoder (13 Bit)

2.2.4

PIN #	FCN
1	10th bit (from AD35-12L4) (Input) *
2	9th bit Fastest Changing Bit (LSD)
.	
.	
10	1st bit
11	Signal Ground
12	
.	
.	Spare
.	
21	
22	Case Ground
23	Power Ground
24	-6.3 VDC
25	+6.3 VDC

2.3 ACCURACY ± 1/2 bit

2.4 ENVIRONMENTAL

2.4.1	Temperature Operating	0° ——→ 55°C
2.4.2	Temperature Storage	-40 ——→ +65°C
2.4.3	Altitude	50,000 feet
2.4.4	Vibration	Meets MIL-E-5400
2.4.6	Humidity	98% relative with no condensation

REVISION:

ENCODER DIVISION
CHATSWORTH CALIFORNIA

TITLE: MODEL AD35-10L4 ENCODER

DOCUMENT NO.: E-AD35-10L4

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

BULLETIN NO. 1120
December 15, 1967

BCD NIXIE® TUBE DECODER/DRIVER
(With Integrated Circuits)

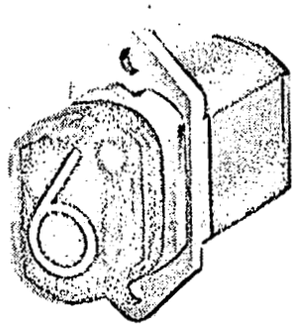
TYPES
BIP-8804-1
BIP-8804-2

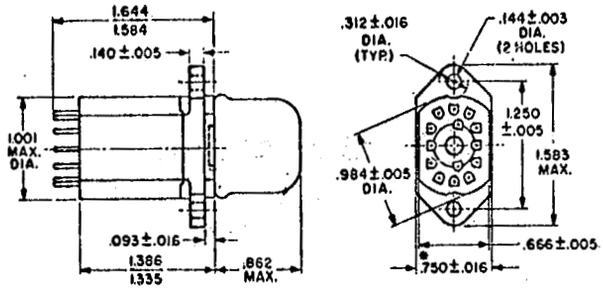
The BIP-8804 series integrated circuit decoder/drivers accept 4-line 8-4-2-1 BCD input from DTL and TTL circuitry, and provide decimal readout on integrally mounted NIXIE tubes. The BIP-8804-1 drives a standard rectangular "0-9" NIXIE tube, type 8422 (B-5591). The BIP-8804-2 drives the B-59956 standard rectangular NIXIE tube "0-9 with a decimal point."

These modules are non-latching in that they require a continuously available BCD information input.

The modules feature a socket pack construction, i.e., the socket and decoder are an integral unit. Height and width dimensions are those of the socket itself, permitting 0.8" center to center spacing of multi-digit displays. By mounting the integrated circuit as close to the NIXIE tube as possible, the undesirable effects of switching transients are minimized. A decoupling capacitor, C1, is used to bypass power supply transients.

Refer to Bulletin 616 for typical NIXIE tube applications and theory of operation. Bezel assemblies for multi-tube displays are described in Bulletin 1020.





*VIEW OF SOCKET WITHOUT NIXIE TUBE
DIMENSION WITH NIXIE TUBE IS .790 MAX.

Figure 1. OUTLINE DRAWING

ELECTRICAL SPECIFICATIONS

INPUT REQUIREMENTS — 4 line 8-4-2-1 BCD (Note 1)
- Logic "0" (E_L) ..... −0.5V to +0.85V
- Logic "1" (E_H) ..... 2.0V to 6.0V

INPUT CURRENT
- Logic "0" present ..... 1.5 mA max. (Note 2)
- Logic "1" present ..... 10 μA max. Note (3)

DECIMAL POINT DRIVE REQUIREMENTS
- V off ..... 60V to 140V
- V on ..... 0 to 2V
- I off ..... 30 μA max. (Note 4)
- I on ..... 0.5 mA max. (Note 9)

POWER REQUIREMENTS
- Positive High Voltage ..... +200V dc ±10V (Note 6)
- Positive Low Voltage ..... 5V dc ±0.25V
- Current at 200V ..... 2.8 mA typ.; 4.0 mA max. (BIP 8804-2)
  2.3 mA typ.; 3.5 mA max. (BIP 8804-1)
- Current at 5.0V ..... 60 mA max.

MECHANICAL SPECIFICATIONS

- Connector ..... 12 pin rectangular base (Note 10)
- Receptacle ..... Sk-169 (Fig. 4) (Note 7)
- Mounting Diagram ..... Figure 5 (Note 8)
- Outline Drawing ..... Figure 1
- Terminal Connections ..... Table 1
- Weight with tube ..... 1.5 oz. max.
- Temperature
  - Operating (Free Air) ..... 0°C to +75°C
  - Non-operating ..... −55°C to +85°C

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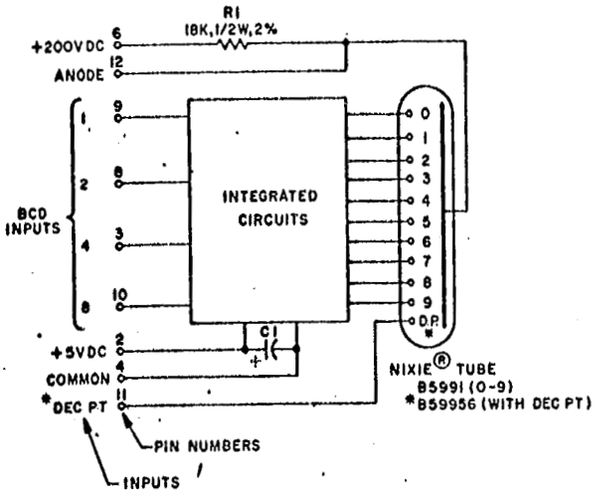


Figure 2. BLOCK DIAGRAM

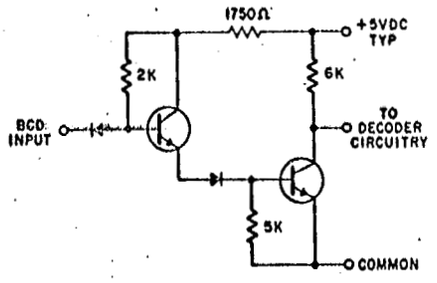


Figure 3. MODULE INPUT CIRCUIT

TERMINAL	INPUT
1	N.C.
2	+ 5V dc
3	BCD 4
4	Common
5	N.C.
6	+ 200 Vdc
7	N.C.
8	BCD 2
9	BCD 1
10	BCD 8
11	Decimal Point* Not Normally Used

* When using the BIP-8804-1 (B-5991 NIXIE tube) terminal 11 must be left open.

Table 1. TERMINAL CONNECTIONS

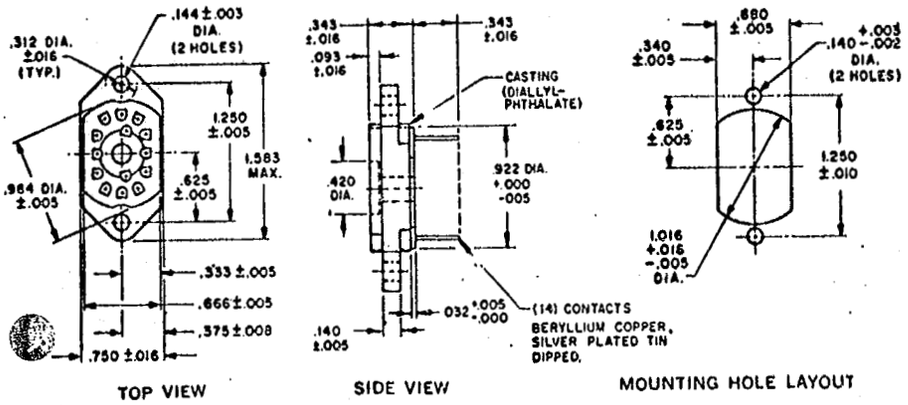


Figure 4. RECEPTACLE SK-169 (Note 7)

NUMERAL	CODE			
	8	4	2	1
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1

Table 2. TRUTH TABLE

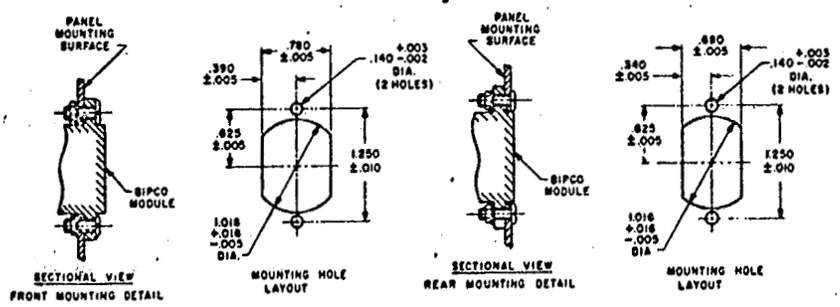


Figure 5. MOUNTING DIAGRAM (Note 8)

NOTES

1. All voltages given are referenced to terminal 4.
2. This is the current out of the module when E_0 is 0.45V.
3. This is the current into the module when E_1 is 4.0V.
4. This is the current out of the module when Von is 60V.
5. When using the BIP-8804-2, the decimal point input is directly connected to the decimal point (See Figure 2). Appropriate high voltage driver circuits must be externally provided.
6. The absolute maximum rating for the positive high voltage is 300V. This rating applies for a maximum pulse width of 100 mS at a maximum duty cycle of 10%.
7. The SK-169 receptacle is not included as part of the module and must be ordered separately.
8. Modules may be mounted either in front of, or behind panel (Figure 5). Front mounting should be employed only when there is no back lighting. Rear mounting may be used whether or not back lighting is present. Following this rule will eliminate light showing through the panel.
9. This is current out of the module.
10. A polarizing pin is added to the connector. This pin is not internally connected and mates with pin 14 of receptacle SK-169.

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2.4 DIGITAL SUBTRACTOR AND CONVERTER

The Metric Digital Subtractors are supplied with two 22 bit words (Command-Master and Position-Slave) and a 100 PPS strobe signal. The output to the control system is a DC voltage, 0 to ±7.9 volts, which is the position error signal. The theory of these units is completely described in the Metric Systems Manuals, but basically a difference of 0 to 8 bits (LSB's) generates the ramp 0 to ±7.9 volts, and any difference greater than 8 bits generates the constant, ±7.9 volts.

NOTES: The subtractors were checked out and calibrated according to the Metric recommended procedure. The Polar Subtractor operated per specification; i.e., the unit subtracted properly and zero and gain adjustments brought Analog Out to proper values (see manual). The declination subtractor gain adjustment did not bring output down to +7.963 volts, although this unit did subtract properly. It was noticed that the problem was isolated to the connections of the Trimpots on the D/A PC card.

2.5 POLAR POSITION AND RATE SERVOS

POSITION SERVO CHECK-OUT NOTES:

The original Servo Compensation had to be discarded since possible bandwidth was only approximately half of that needed due to structural resonances as low as 25 cps. Also, real inertia of Polar was about 1800 slug-feet^2 instead of 600 and friction was unsymmetric at about 10 foot-pound CW and 20 foot-pound CCW.

In Sidereal, there was a following error of about 10 arc seconds due to friction of the bearing. (for component values see drawing # 355-0390)

RATE SERVO NOTES: No problems other than Tach noise which was filtered out with .22 uf at buffering amplifiers. All rates and direction commands appeared to be working smoothly but rates were never calibrated.

2.6 DECLINATION POSITION AND RATE

The declination rate servo is identical to the polar rate servo in construction. Again, rates and direction commands worked smoothly, but rates were not calibrated. The declination position servo was never operated as a closed loop since the fine encoder on the follow-up servo only came back from factory repair two days before shipment of the system.

2.7 SERVO DESIGN PHILOSOPHY

The original proposed servo configuration was abandoned due to bandwidth limitations caused by low frequency structural resonances. The servos, as delivered, were optimized to provide the highest possible bandwidth consistent with the load dynamics. The procedure followed for setting up each servo was as follows:

A. Polar and Declination Rate Servos

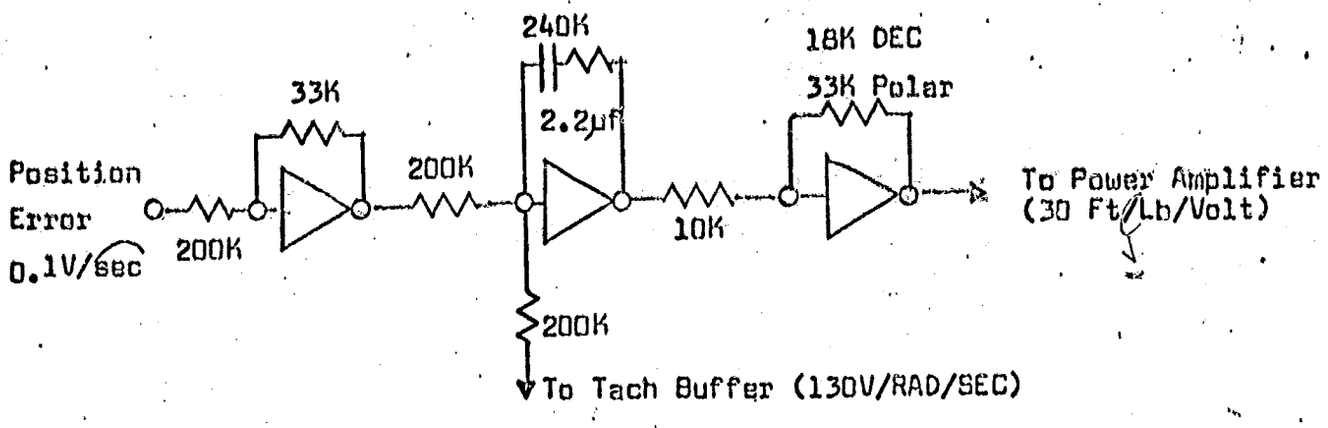
1. In the rate mode all lag capacitors were removed and the forward DC gain was gradually raised until oscillation occurred. The gain was then backed off and servo response tested. This procedure provides a measure of allowable AC (high frequency) gain and bandwidth. The bode plot of the servo is shown in Sketch 8.
2. The rate servos were then stiffened by adding an integration in the loop with a stop at 15 to 20db before crossover. (See bode plot) This step provides a maximum rate servo stiffness li d only by the open loop gain of the compensation amplifier.

B. Polar and Declination Position Servos

1. The position servo gains were set by increasing the position loop gain until oscillations occurred and then backed off until a stable situation was achieved.
2. Actual Circuit Values

   Sketch 7 shows the actual servo compensation used for each axis.

SERVO COMPENSATION



Polar Inertia = 1800 Slug FT^2

Declination Inertia = 600 Slug FT^2

APPROXIMATE RATE SERVO TRANSFER FUNCTIONS

$$G(S) \cong \frac{20\,(S/2+1)}{S^2}$$

SKETCH #7

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR.

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Sketch 8: Approximate Rate Servo Bode Plots