VLA TECHNICAL REPORT NO. 65

VLA ANTENNA TILTMETERS

C. Janes and A. Sittler

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TECHNICAL REPORT NO. 65

VLA Antenna Tiltmeters

I. Overview

To measure antenna tilt, sensors are installed on two VLA antennas at this writing, antenna 6 and 22. There are two tilt sensor boxes per antenna, one mounted on each yoke arm. Signals from the boxes pass to the M24 module in Rack B in the Vertex Room, and from there to Data Set 2. The Command and Monitor System accesses the tilt information by addressing the antenna, Data Set 2, and the multiplexer addresses listed later in this report. The tilt signals are proportional to antenna tilt along the elevation axle (y) and perpendicular to the elevation axle (x). The "E" tilts are from the absolute encoder side of the yoke, and the "W" tilts are from the waveguide side of the yoke. VLA Test Memorandum 154 describes the performance of the tilt measuring system.

II. The Tilt Sensor Box

The tilt sensor box includes 2 LSOC-1 Schaevitz inclinometers each mounted on a Klinger tilt table. The tilt table consists of two plates fastened together by a spring hinge at one end. The tilt sensor is mounted on the upper surface of the top plate. The sensor is mounted so that motion of the top plate of the tilt table away from the bottom plate provides a positive tilt signal. The tilt of the top plate may be adjusted with a micrometer. One micron adjustment on the micrometer changes the tilt 2 arcsecond. A heating pad is fastened to the undersurface of each tilt table top plate along with a thermistor. An Oven Industries temperature controller servos the top plate temperature to a set point near 40 C. An Analog devices AD590 temperature sensor also fastened to the top plate provides a temperature signal to the M24 module.

The tilt tables are mounted perpendicularly to each other to permit measuring tilt in two axes. The tables are mounted on a steel plate and housed in a Rose cast aluminum housing. The housing is insulated and mounted on a chromated steel plate on the antenna, with insulating material sandwiched between the box and the mounting plate. Stainless steel bolts hold the housing to the mounting plate.

Two connectors are provided: one for the signals and the DC voltages for the inclinometers; the other provides connection to the 110 VAC for the temperature controllers.

III. The M24 Module

The M24 module houses the AD521 instrumentation amplifiers for the tilt signals, the LM324 operational amplifiers to scale and amplify the tilt sensor temperature signals, and the analog multiplexers to route the selected signal to the analog-to-digital converter (ADC) in the Data Set. The M24 uses a circuit board from the M103 module for uniformity, and thus includes extra unused circuitry. Four extra temperature channels, Temp 5 - Temp 8 are unused as well as 4 of the 6 muxes. Two extra instrumentation amplifiers are also provided. One mux is used for the tilt and temperature signals and the other for the "internals:"

'60	Tilt Ey	(y axis, encoder side)
'61	Tilt Ex	(y axis, waveguide side)
'62	Tilt Wy	(x axis, encoder side)
'63	Tilt Wx	(x asis, waveguide side)
'64	Temp Ey	
'65	Temp Ex	
'66	Temp Wy	
'67	Temp Wx	
'70	-15v/2	
'71	+10v	
'72	+10v	
'73	+15v/2	
'74	+5v	
'75	ground	
'76	ground	
'77	ground	

Only one analog output to the Data Set is permitted at one time, as selected by the addressing lines from the Data Set. The analog output is set up to be a differential signal, but in this application, one side is connected to common through a spare mux. The Data Set is described in a separate report, but includes a 12 bit ADC. The LSB = 5 mv or 0.5 arcseconds for the tilt signal and 0.01 C for the temperature signal. The maximum range is 10 VDC or 1000 arcseconds for the tilt signal. The Data Set output must be multiplied by 100 to provide a reading in arcseconds or by 10 to provide a reading in degrees C.

IV. The Schaevitz LSOC-1 Servo Inclinometer

The purpose of the inclinometer is to provide an analog output proportional to the angle of tilt. In the level (horizontal) position, the DC output is zero. When tilted in one direction, the inclinomter output is 0 to +5 VDC (nominal); and when tilted in the opposite direction, the output is 0 to -5 VDC. A gravity-referenced pendulum in the device tries to move in the direction of the tilt. A position sensor adjacent to the pendulum, senses the motion, and sends a signal to the servo amplifier. The amplifier in turn provides a torque command to a torque motor on the pendulum to prevent the mass from moving. The torque current, which is directly and accurately proportional to tilt, passes through a 16.8 kohm resistor to provide the voltage output. The output is differential, consistent with the input to the instrumentation amplifier on module M24. The device is filled with oil for damping; *maintenance* *personnel are cautioned against opening all ports except the one used for the connector.*

Full range of the device is ±1 degree so that the scaling is 0.72 arcseconds per millivolt. The resolution is 0.001% full scale or 0.072 arcseconds. The scale factor temperature coefficient is 0.019% full scale or 1.368 arcsecond/C, and the noise is 0.002 volts RMS or 1.44 arcseconds. The cross-axis sensitivity is rated in terms of acceleration: 6 arcminutes/g. Acceleration of the sensor during operation (while tracking at a steady velocity) is expected to be quite low. The linearity is 0.05% full scale or 3.6 arcseconds. The frequency response is specified at 3 Hz, but signal output can be observed in the 10's of KHz range. According to the manufacturer, the self-test feature described in the literature, is not available on the models procured for this project.

V. The Oven Industries temperature controller

A full proportional temperature controller provides a maximum power of 480 watts to a heating pad on the tilt table to keep the temperature of the Schaevitz tilt sensor as close to 40 C as possible. 40 C was chosen as the lowest temperature unlikely to be exceeded by ambient temperature at the array. The temperature of the tilt table is sensed by an epoxy-potted model TP30-1 thermistor which feeds back to a wheatstone bridge network in the Model 5CX-207 Oven Industries temperature controller. The difference signal between the sensed signal and the set point pulses a triac into conduction. The triac is pulsed at zero-crossing to eliminate RFI.

The setpoint stability is ±0.005 C/C; the control accuracy is ±0.05 C. The setpoint is adjustable to within ±0.1 C.

VI. The Analog Devices AD521 Instrumentation Amplifier

The AD521 was selected to provide an accurate and equal gain of 7.2 in both sides of the differential input, a high common mode rejection ratio (CMRR) of 110 db, and a high input impedance. The differential inputs are pins 1(+) and 3(-) (figure 1). The 14k resistor across pins 2 and 14 and the 95.3k resistor in series with the 10k trimpot across pins 10 and 13 provide a gain of 7.2. Since the output of the Schaevitz tilt sensor is 1.389 mv per arcsecond, the gain of 7.2 provides an output scaling of 10 mv per arcsecond of tilt. The 10k trimpot across pins 4 and 6 permits adjustment for output offset. Input offset remains a function of the gain, but no separate correction is provided since the gain is constant. The network of two resistors and two capacitors connected to pin 9 is copied from the AD521 specification sheet, and is intended to limit the bandwidth of the output to 1.5 KHz. Analog Devices claims that this circuit is too limited to use for an output bandpass of 3 Hz. Pin 11 is connected to analog ground; and pin 12, the sense feedback, is connected directly to the output, pin 7. Pin 12 can be used in a network to correct for input offset, but that was not done for this application. Capacitors on the power supply connections, pins 8 and 5, decouple power supply noise from the amplifier.

For a gain of 7.2, the AD521K is specified to have a worst case combined input and output offset voltage drift of 185 μv/C, a p-p noise voltage in the signal frequency range 0.1 Hz to 10 Hz of 150 μv, and a linearity of 0.1%. Only the linearity is expected to have any measureable effect on this application; 0.1% of full range, ±10 VDC, is 0.2 arcseconds.

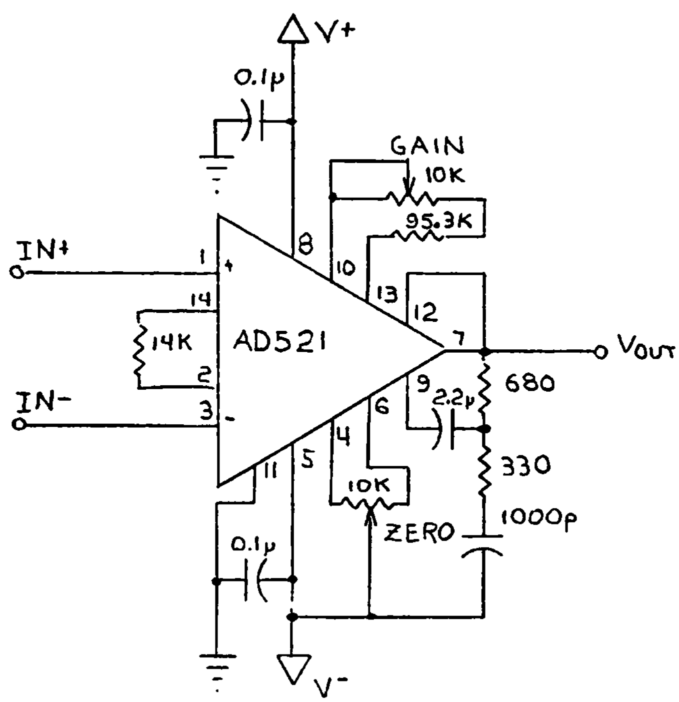


Figure 1.

VII. The Temperature Sensor Circuitry

The conditioning for the temperature signal from the AD590 includes an LM324 operational amplifier used as a summing junction, an amplifier, and a low pass filter (figure 2). The AD590 is a temperature sensitive semiconductor device that will pass 1 μamp of current per degree Kelvin of sensed temperature. To scale the temperature for a convenient op amp output of 0 v = 0° K and 4 v = 40° K, a current equal to 273.2 μamp is produced using a 10v AD581 precision voltage source and two resistors in series, a 35.7k resistor and a 2k trimpot. 10v/36.6k = 273.2 μa. Remember that

273.2 K = 0 C. To hold the (-) impUt at 0 volts, the output voltage of the op amp will change so that the sum of 273.2 μa and the current through the op amp feedback resistor is equal to the current through the AD590 to the -15 VDC supply. For instance, at 40 C, the current through the AD590 must be 313.2 μa by definition. 313.2 μa - 273.2 μa = 40 μa feedback current. A 4 v op amp output voltage dropped across the feedback resistors of 97.6k and the 5k trimpot provides 40 μa to the summing junction. 4v/100k = 40 μa. In that way, the output voltage of the op amp is proportional to the temperature sensed by the AD590.

The 27k resistor leading to the noninverting opamp input (+) is equal to (100k)(36.6K)/(100k + 36.6k), and is intended to offset the input bias current at the inverting input. The 0.1 μf capacitor in the feedback loop limits the frequency bandpass of the op amp.

Since the AD590J is manually calibrated using the trimpots, and since it is used to sense only one temperature, 40 C, the specifications for linearity and absolute calibration don't apply. From this writer's experience, the AD590 can be expected to drift in temperature by several C, though the manufacturer's specification does not mention long term stability. In any case, this temperature is not used in the temperature control loop so that its value is only informational.

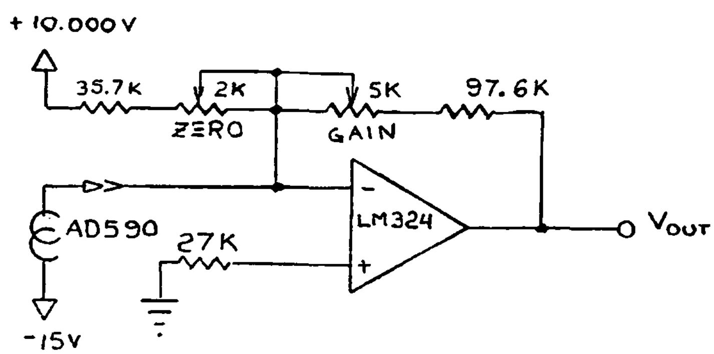
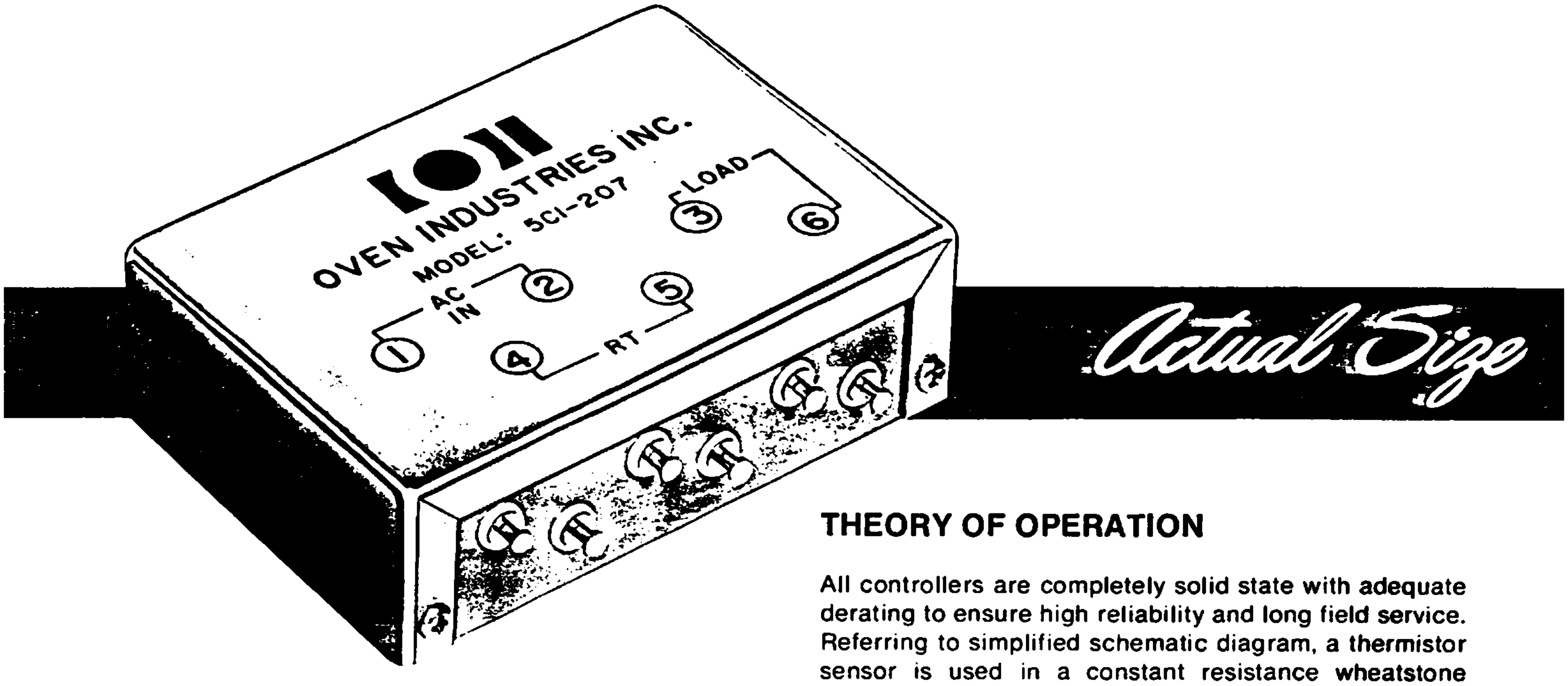


Figure 2.

VIII. Partial Parts List

Schaevitz LSOC-1	$1000
Oven Industries temp controller P/N 5C1-207 with thermistor probe P/N TP30-1	$100
Klinger Tilt Table #TG80	$200
Rose Enclosure, P/N 01.233318	$150



THEORY OF OPERATION

All controllers are completely solid state with adequate derating to ensure high reliability and long field service. Referring to simplified schematic diagram, a thermistor sensor is used in a constant resistance wheatstone bridge network with a precision potentiometer for set temperature adjustment. The sensing bridge signal is fed to a differential amplifier and then to a variable gain preamplifier and power stage. Zero crossing information is combined with the temperature control signal and this combined signal pulses the triac into conduction as the line voltage passes through zero.

These true proportional controllers have the ability to supply fixed power to the load without temperature change at the sensor. Proportioning bandwidth is accomplished by generating a sawtooth signal and summing this signal with the sensor information in a manner which enables the controller to establish the necessary power to the load for each individual time base period. By providing an internal time base of approximately one (1) second, the "on" time is varied as a percent of the total time base which gives the ability to apply as little as one half (½) cycle out of 60. Thus, the controller will proportion the correct number of "on" cycles and "off" cycles out of every individual time base.

The controller's power resolution of 0.8% is further enhanced by its ability to vary the number of "on" cycles in each successive time base period. (i.e. 35 on, 37 on, 34 on, etc.) A mathematical analysis of this type system will conclude that any level of power between 0% and 100% is possible. End item control temperature can be as small as ±0.05° C. with proportional control.

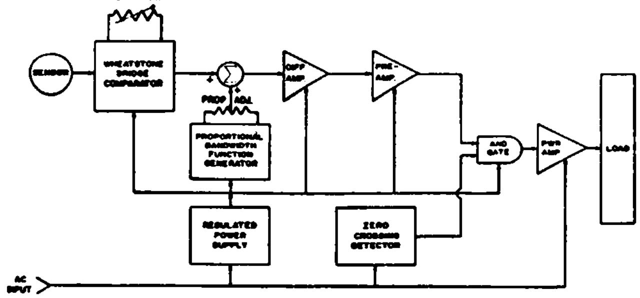
GENERAL DESCRIPTION

This Series of Oven Industries' Temperature Controllers is solid state, non-indicating, full proportional controllers that afford a means to provide excellent control of temperature from a compact package. These controllers were designed for use in the electronics and precision industrial markets. All controller models are capable of maintaining the desired set temperature to ±0.05° C. at the probe. Resistive heaters ranging from 150 milliamperes to 10 amperes may be controlled.

The circuit design employed in this series is insensitive to environmental temperature changes from −20° C. to +70° C. and line fluctuations from 100 to 140 VAC or 200 to 240 VAC. Radio Frequency Interference is virtually eliminated by the zero voltage firing circuit. Users may operate heater loads supplied from AC sources that also supply other sensitive instruments.

Temperature can be adjusted precisely with an internal ten (10) turn cermet potentiometer. Proportional bandwidth is also adjustable with an internal potentiometer. Complete solid state design and rugged mechanical construction insures reliable performance and freedom from shock and vibration damage in either shipping or installation. Optionally, the units may be potted for use in high shock and vibration operating environments.

Simplified schematic diagram:



TYPICAL INDUSTRY APPLICATIONS

- *BLOW MOLDING EQUIPMENT*
- *COLD CONTROL*
- *CONSTANT TEMPERATURE BATHS*
- *CONTROL OF MECHANICAL ASSEMBLY TOLERANCES*
- *COPY MACHINES*
- *DRYERS*
- *ELECTRONIC ENCLOSURES*
- *ENVIRONMENTAL CHAMBERS*
- *FOOD PROCESSING*
- *GLUE DISPENSING SYSTEMS*
- *HEATERS AND HEATER EQUIPMENT*
- *HOT PLATES*
- *INJECTION MOLDING EQUIPMENT*
- *IR DETECTION*
- *LAMINATING PRESSES*
- *LASER CAVITIES*
- *MICROWAVE ASSEMBLIES*
- *OVENS*
- *PHOTOGRAPHIC DEVELOPING PROCESSES*
- *PLASTIC BAG SEALERS*
- *PLASTICS MANUFACTURING*
- *PRINTING PROCESSES AND PRESSES*
- *REFRIGERATION EQUIPMENT*
- *SOLDERING EQUIPMENT*
- *TANK HEATING*
- *VACUUM FORMING MACHINES*
- *VULCANIZING AND RUBBER PROCESSING EQUIPMENT*

TECHNICAL DATA

SET POINT STABILITY

The set point stability of these controllers with respect to controller environment change is ±0.005° C./° C. of ambient change over a −20° C. to +70° C. range. The set point stability with respect to input line change is ±0.0025° C./volt of line change between 100 VAC and 140 VAC. Set point stability can be achieved for any load within the given specifications.

CONTROL ACCURACY

Model 5C1 Series are capable of maintaining temperature at the probe to ±0.05° C. of set point. Model 5CX Series are capable of maintaining temperature at the probe to ± 0.1° C. of set point.

CONTROL TEMPERATURE RANGES

Model 5C1 Series accept any TP Series sensor probes for control temperature ranges between −20° C. and +110° C. (−4° F. to +230° F.). Model 5CX Series accept any TX Series sensor probes for control temperatures between −65° C. and +550° C. (−85° F. to +1000° F.).

ADJUSTABLE SET POINT

An internal ten (10) turn potentiometer permits set point adjustment to within ±0.1° C. at the sensor on both Model Series.

SPECIFICATIONS

ACCURACY: To ±0.05° C. of set point at the probe
*To ±0.1° C. of set point at the probe

CIRCUIT MODE: Full Proportional Zero Voltage Firing

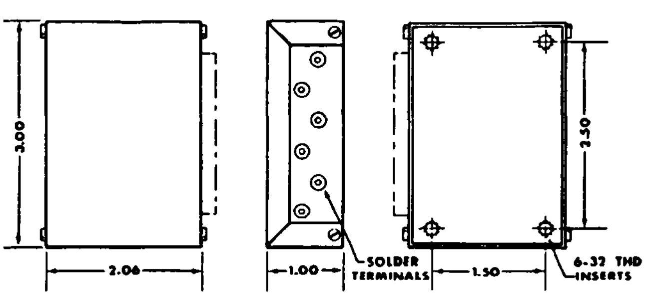
CONTROL RANGE:
From −20° C. to +110° C. (−4° F. to +230° F.)
*From −65° C. to +550° C. (−85° F. to +1000° F.)

VOLTAGE AND POWER RATINGS: Single Phase, 50/60 Hz (For 400 Hz Operation - See Derating Curve)

LINE VOLTAGE	MAXIMUM POWER	MAXIMUM CURRENT	MODEL NUMBER	PRICE	
120 VAC	1.20 kilowatts	10 amperes	5C1-205	~~$76.75~~	83.00
120 VAC	1.20 kilowatts	10 amperes	*5CX-205	~~76.75~~	83.00
208/230 VAC	2.30 kilowatts	10 amperes	5C1-206	~~81.50~~	88.00
208/230 VAC	2.30 kilowatts	10 amperes	*5CX-206	~~81.50~~	88.00
120 VAC	480 watts	4 amperes	5C1-207	~~75.00~~	81.00
120 VAC	480 watts	4 amperes	*5CX-207	~~75.00~~	81.00
208/230 VAC	960 watts	4 amperes	5C1-208	~~79.00~~	85.00
208/230 VAC	960 watts	4 amperes	*5CX-208	~~79.00~~	85.00

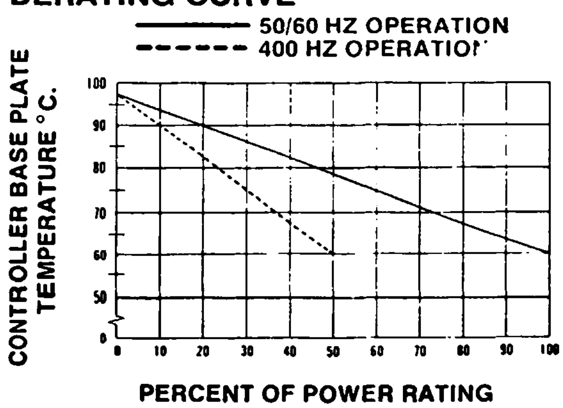
OPEN SENSOR PROTECTION: add suffix "P" to the model number and $10.00 to the price

MECHANICAL CONFIGURATION

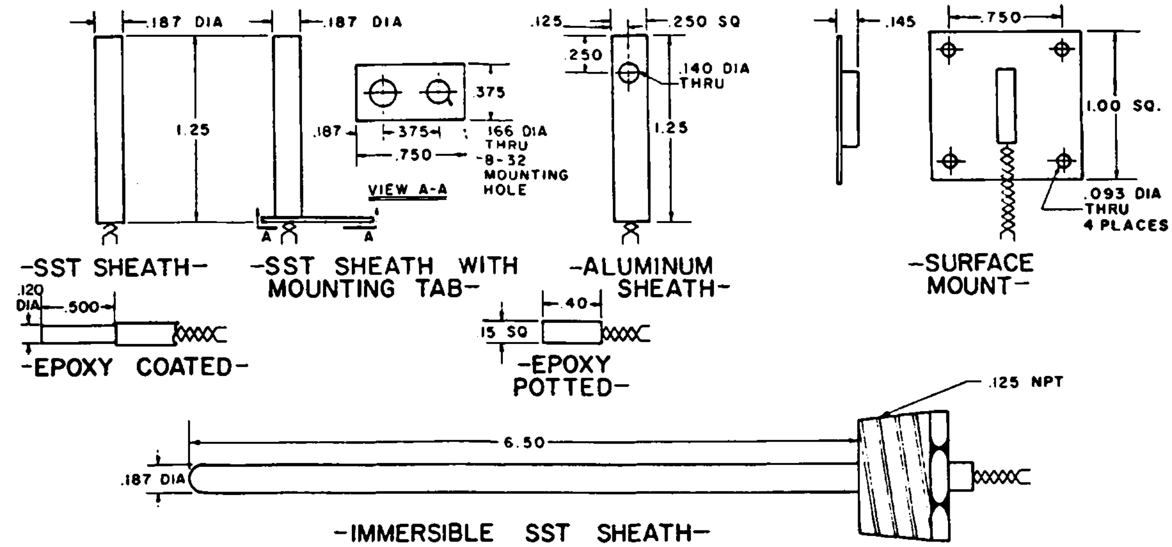


NOTE: (*) Specifications apply to models similarly marked.

DERATING CURVE



STANDARD SENSORS



NOTE: All sensor leads are nominally 18 inches long

TP PROBE SERIES

MODELS & PRICE LIST									
TEMPERATURE RANGE DEGREES C.	TEMPERATURE RANGE DEGREES F.	BASE MODEL	COATED STANDARD	POTTED −1	SURFACE −2	SST SHEATH −3	SHEATH W/TAB −4	ALUMINUM −6	IMMERSIBLE −7
−20 to +10	−4 to +50	TP10	$9.25	$16.80	$12.20	$12.20	$13.25	$12.20	$22.60
0 to +30	+32 to +86	TP20	9.25	16.80	12.20	12.20	13.25	12.20	22.60
+20 to +50	+68 to +122	TP30	9.25	16.80	12.20	12.20	13.25	12.20	22.60
+40 to +70	+104 to +158	TP40	9.25	16.80	12.20	12.20	13.25	12.20	22.60
+60 to +90	+140 to +194	TP50	9.25	16.80	12.20	12.20	13.25	12.20	22.60
+80 to +110	+176 to +230	TP60	9.25	16.80	12.20	12.20	13.25	12.20	22.60

TX PROBE SERIES

MODELS & PRICE LIST									
TEMPERATURE RANGE DEGREES C.	TEMPERATURE RANGE DEGREES F.	BASE MODEL	SST SHEATH STANDARD	COATED −1	SURFACE −2	POTTED −3	SHEATH W/TAB −4	ALUMINUM −6	IMMERSIBLE −7
−65 to +25	−85 to +77	TX0A	$9.75	$16.80	$12.60	$16.80	$10.75	$9.75	$22.60
−40 to +120	−40 to +248	TX0	9.75	16.80	12.60	16.80	10.75	9.75	22.60
−10 to +150	+14 to +302	TX1	9.75	16.80	12.60	16.80	10.75	9.75	22.60
+80 to +260	+176 to +500	TX2	11.00	16.80	14.70	16.80	12.10	11.00	22.60
+150 to +550	+300 to +1000	TXX	-	-	-	-	-	-	-

INSTALLATION NOTES:

Mount the controller to an appropriate heat sinking surface. Avoid mounting the controller to a thermal insulating surface which may cause excessive internal temperatures and damage the unit. Attach a means of measuring temperature at the point where control is desired. It is very important to mount the sensor probe as close to the heater as possible to reduce the thermal time constant between the sensor and the heater.

Adjust the set temperature adjustment to the approximate center of its rotation. Turn the bandwidth control full counterclockwise and then clockwise approximately ⅛th turn. Connect a lamp or other voltage indicating device across the load. Apply power to the unit and observe that the load is energized. The load voltage will be uninterrupted until the load temperature approaches the controller's set temperature. Proportional control operation near the set temperature is indicated by the load voltage being turned on and off by the controller approximately once every second. Longer on or off periods indicate the need for wider bandwidth adjustment (clockwise) until the controller is in complete proportional control of the load.

Optimum setting of the bandwidth control is that point which reduces temperature excursion of the load to a minimum. Observe the temperature of the load. If temperature excursions are noted, gradually increase (clockwise) the bandwidth setting until the smallest load temperature excursion is obtained. NOTE: Full counterclockwise setting may be optimum, if no temperature excursions are noted.

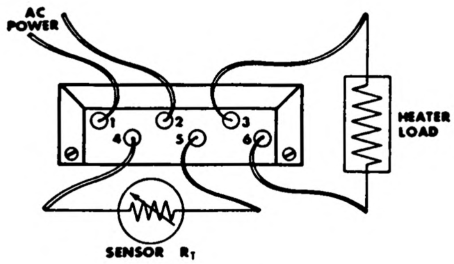


Figure 1
NORMAL INSTALLATION CONNECTIONS

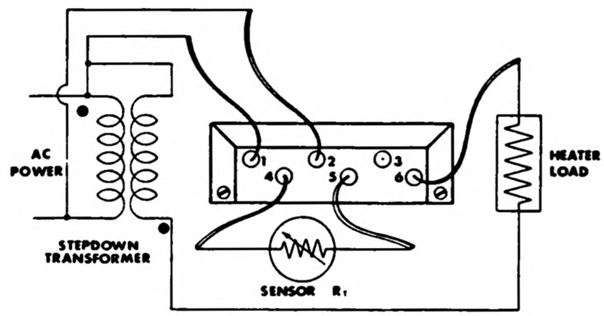
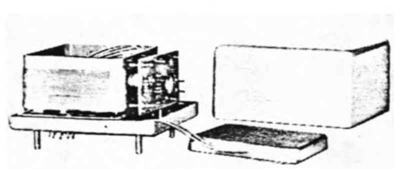


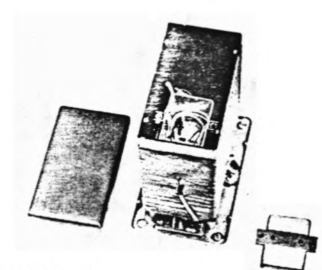
Figure 2
LOW VOLTAGE HEATER INSTALLATION CONNECTIONS

OVEN INDUSTRIES MANUFACTURES MANY OTHER TEMPERATURE CONTROL DEVICES, SUCH AS......

Model 3C2-50
DC PROPORTIONAL CONTROLLER



Model 3147-11
SMALL COMPONENT OVEN



Model 3269
HIGH STABILITY OVEN

GENERAL INFORMATION

Terms: Net 30 days
FOB Mechanicsburg, Pennsylvania
Code Identification Number: 21302

WARRANTY: All units are warranted to be free from defects and to operate within specifications for one year from date of shipment, if the controller is not subjected to misuse and has not been tampered with. Please contact the factory or your area representative for shipping instructions on warranty units prior to returning.

PRICES & INFORMATION ON OTHER MODELS ARE AVAILABLE FROM OUR REPRESENTATIVE IN YOUR AREA:

We make every effort to keep prices as accurate as possible, however, we reserve the right to change prices and specifications without notice.

OVEN INDUSTRIES, INC.
INDUSTRIAL CONTROLS DIVISION
P.O. BOX 290, 207 HEMPT ROAD, MECHANICSBURG, PA. 17055, PH. (717) 766-0721

Model No LSOC-1

SN-24127

Operating Instructions, Installation Information, and Calibration Certificate for Servo Inclinometers

schaevitz

Schaevitz Engineering
U S [illegible] & Union Avenue
[illegible] NJ 08110
Tel [illegible] 8000

3M-4801A

3M 6-85 DLI

schaevitz

The Name in Transducer Technology

ZERO OFFSET

This is defined as the voltage-signal-output with no intentional input components along the sensitive axis and is caused by a small residual spring force. The resultant offset voltage adds to the output signal for one direction of applied tilt and subtracts for the other. This generally is limited to ±0.05% of full scale; that is, ±0.005 volts for a ±5 volt instrument.

SCALE FACTOR TEMPERATURE COEFFICIENT

This is a measure of the change in output voltage due to a change in temperature. It is defined as the change in output voltage (for any input angle) per degree ~~Fahrenheit~~ C divided by the output voltage (x 100 to convert to percentage).

$\frac{\Delta V}{V} \times 100 :$

.019%

.019%

NULL TEMPERATURE COEFFICIENT

This is a measure of the change in output at zero input due to temperature. It is defined as the change in output per degree ~~Fahrenheit~~ C divided by full scale output (10 volts for a 5 volt full range output) (x 100 to convert to percentage).

$\Delta V = \frac{V \times .019\%}{100}$

$= .19\ \mu V$ mV/°C

$\cancel{= .34\ \mu V / mV/°C}$

±5V = ±1°

10V = 2°

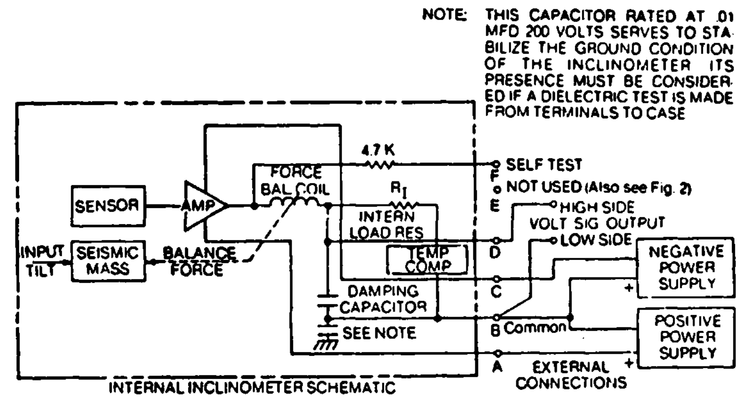
$\frac{\Delta V/°C \times 100}{FS} = .035\%$

$\Delta V = \frac{.035\% (10V)}{100} = .0035\ V/°C = \cancel{6.3\ mV/°C}$

= 2.5 mV

HOW TO USE THE INCLINOMETER

In the most common configuration, a dual power source is used, and a VOLTAGE OUTPUT SIGNAL is available. In this configuration, the force-balance current flows through a low-temperature-coefficient internal resistor R_I which returns the current to the midpoint of the dual power supply. This operating mode is shown in Figure 1.



ACTUAL FULL RANGE OUTPUT AVAILABLE DEPENDS ON LOAD RESISTANCE THE RECEIVING CIRCUIT IMPOSES. LET R_E REPRESENT THIS RESISTANCE. MULTIPLY RATED SCALE FACTOR BY:

$$\frac{R_E}{R_I + R_E}$$

FIGURE 1. VOLTAGE SIGNAL OUTPUT WITH INTERNAL LOAD AND TEMPERATURE COMPENSATION

When temperature compensation is not required, the return path for R_I is made externally as shown in Figure 2.

In this mode, CURRENT ANALOG operation may be selected instead of VOLTAGE ANALOG operation. The proper connections are illustrated in Figure 2. The full-range current is available to flow through the external circuit if it is of relatively low resistance (resistance of 50% or less of the internal resistance of the inclinometer). Note that

A = +15
B = Common
C = -15
D = Signal (w/ Temp Comp)

E = N/C
F = self test

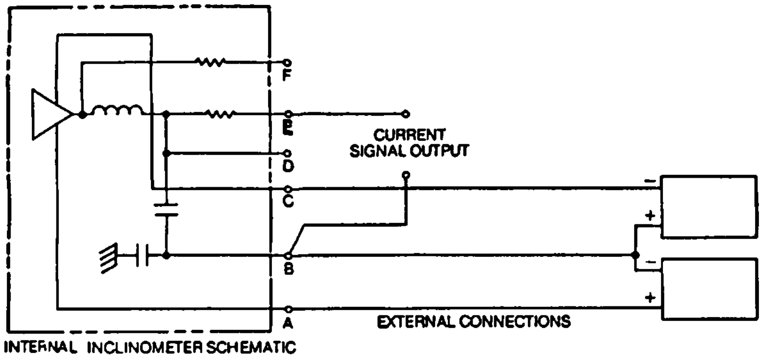


FIGURE 2. CURRENT SIGNAL OUTPUT WHEN TEMPERATURE COMPENSATION IS OMITTED

the INTERNAL RESISTANCE is recorded on the inclinometer's individual data sheet. If current output is not wanted, an external jumper must be connected from Pin E to Pin B. This completes the force balance current path. If the control or indicating circuit has relatively low DC resistance, so that it would load the output, it is possible to use it instead of R_l to complete the force balance current path. By connecting the load circuit between Pin D and Pin B, instead of the jumper mentioned above, the internal resistance R_l is bypassed. The voltage scale factor will then be related to the stated scale factor by the following:

$$\text{New Scale Factor} = \text{Stated Scale Factor} \times \frac{\text{External DC Resistance}}{\text{Stated } R_l}$$

In no case must the external DC resistance be greater than 1.5 R_l. For this limiting value, full range output would be 7.5 volts which is a maximum permitted. It is desirable that the external load resistance be the same or close to R_l.

R_l = 16.5kΩ

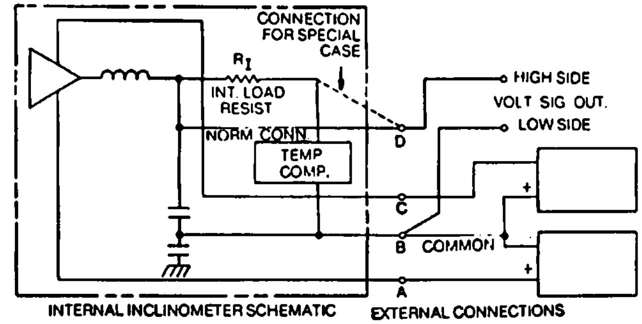


FIGURE 3. VOLTAGE SIGNAL OUTPUT WITH INTERNAL LOAD AND TEMPERATURE COMPENSATION (4 TERMINALS)

Some types of inclinometers have only four terminals: connections are shown in Figure 3. Note that SELF TEST is not available. In special cases, where arrangements have been requested in advance, Pin D may be a current output terminal (shown by dotted line identified as SPECIAL CONNECTION in Figure 3). The same restriction for Figure 2 applies, that is, the external circuit cannot exceed 50% of stated R_l. The feature of substituting an external load for the internal load is not available for this special case because the normal voltage signal point, the junction of the force balance coil and R_l (see Figure 1), is not available to the user. Note also that temperature compensation is not available in the special case.

A final mode of operation is SELF TEST, also known as current-forcing. This is illustrated in Figures 4A and 4B.

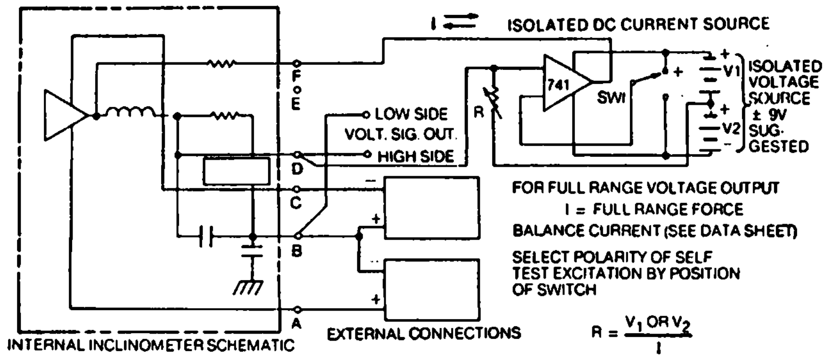


FIGURE 4A. DC SELF TEST

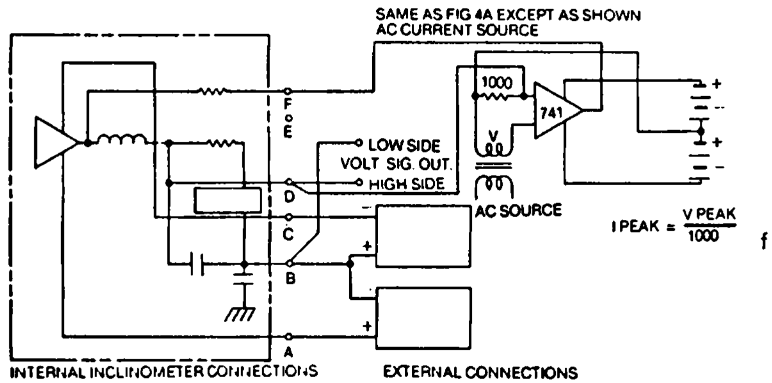


FIGURE 4B. AC SELF TEST

Preferably, the isolated current source should be of high-impedance, 100,000 ohms or higher. In the circuit shown using an operational amplifier current source, it is higher than 10 megohms. If the inclinometer is operating properly, servo-action will cause it to develop a current in the force-balance coil equal and opposite to the injected current. The net effect is that the current will be forced through the internal load resistor just as if it were being developed by an applied tilt. Rated current injected will result in rated signal-voltage-output. Once the self-test source has been set up to produce this response, any failure to achieve rated signal-voltage-output is an indication that the inclinometer is not operating properly. Direct-current self-testing is shown in Figure 4A. A high-impedance isolated ac source shown in Figure 4B may be employed if the frequency response characteristic is to be examined.

Since this method of self-testing verifies proper operation of the inclinometer, it is obvious that it can also verify the operation of a control system fed by the inclinometer. If it is desired only to check the operation of a control system, a simpler method is possible, illustrated in Figure 5.

$$R_{SE}\,(\text{OHMS}) = \frac{\text{POSITIVE OR NEGATIVE POWER SOURCE} - \text{RATED VOLTAGE SIGNAL}}{\text{RATED FORCE BALANCE CURRENT}}$$

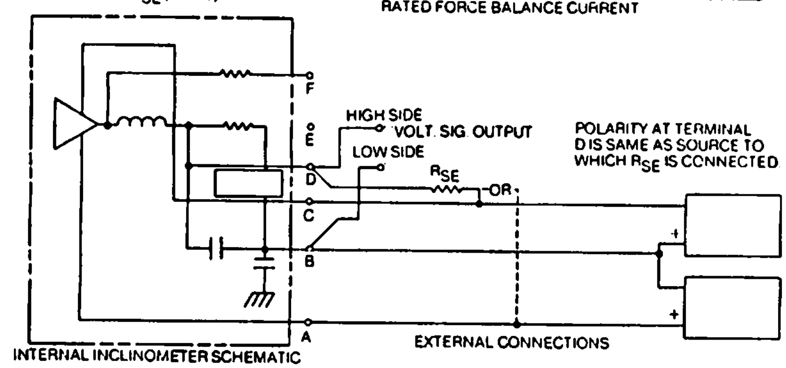


FIGURE 5. ALTERNATE SELF TEST

INTRODUCTION

The LS series of inclinometers are solid-state, dc, closed-loop, force-balance tilt sensors with accuracy, stability and reliability several orders of magnitude greater than open-loop types. They are ideally suited for use in the construction industry for setting tilt of road grading and paving machines; in the geophysics field for tilt and strong motion studies; in the civil engineering field for evaluation of tilt of supporting walls in dams and other structures; and other applications where high-accuracy measurement of tilt is required.

DESCRIPTION

The Schaevitz inclinometer is fully self-contained and designed to operate from a standard DC power source. Its output is an analog DC signal directly proportional to the sine of the angle of tilt. In level (horizontal) position, the DC output is zero. When tilted in one direction, the inclinometer output is 0 to +5V DC full scale. When tilted in the opposite direction, the output is 0 to -5V DC full scale. The heart of this closed-loop, gravity-referenced sensor is a flexure-supported torque-balance system, rugged enough to withstand severe shock and vibration and still maintain excellent accuracy. The solid-state electronics and sensor are enclosed within the sealed housing, permitting operation in hostile environments.

PRINCIPLES OF OPERATION (Refer to Figure 1)

As inclinometer tilts angle "θ", paddle "A" tries to move in direction of tilt (due to force of gravity). Any resultant motion is converted by sensor B to a signal input to the electronic amplifier whose current output is applied to the torque motor C. This develops a torque equal and opposed to the original so the pendulous mass no longer moves, but assumes a position minutely different from its original to provide the required error signal. The torque motor current is directly and accurately proportional to tilt, and by allowing it to flow through stable resistor Ro, an equally accurate output voltage is developed.

Stops are provided on both sides of the paddle to limit its travel when not powered. When powered, the paddle automatically moves to its null position.

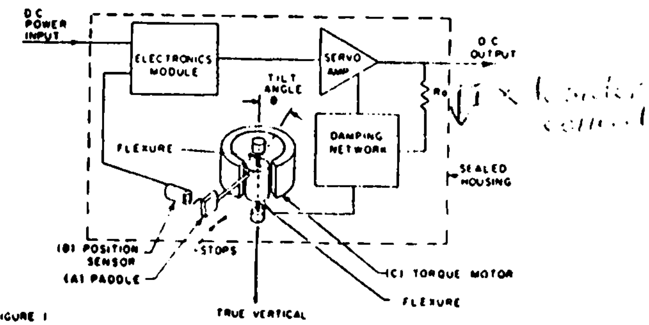


FIGURE 1

This method provides a signal to a control system but note that it does not always verify proper operation of the inclinometer.

Figure 6 illustrates operation of the inclinometer from a single power source. Note that in this configuration the power source cannot have a terminal common to the signal return.

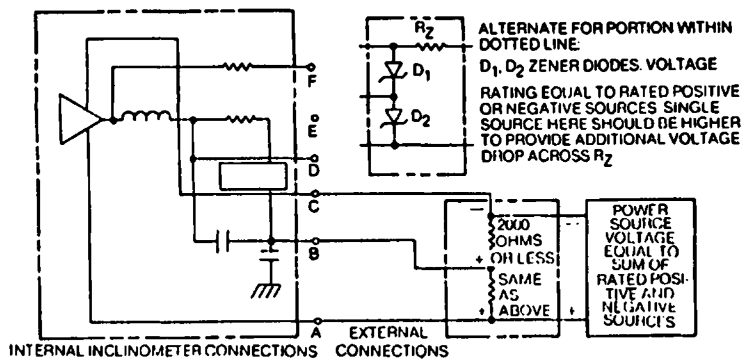


FIGURE 6. OPERATION FROM SINGLE POWER SOURCE

INSTALLATION

The inclinometer should be installed on a mounting surface known to be flat and in one plane. The simplest way of verifying qualitative operation of the inclinometer is to connect it in accordance with one of the diagrams and place it at rest in the position in which it is to be installed. For most the sensitive axis will be horizontal. The ZERO OFFSET output should appear in either the measuring or control systems being fed by the inclinometer. Tilt the inclinometer up and down by hand; the readout system should display a periodic output

INCLINOMETER DATA SHEET

DATE		TESTED BY:	WDY6J
MODEL NO.	L50C-1	APPROVED BY:	G.M.
SERIAL NO.	24137	CUSTOMER INSP.	
CUSTOMER		GOVT. INSP.	
SALES NO.			

CONNECTIONS - SCHAEVITZ DRAWING NO.	P6.7	
POWER SUPPLY VOLTAGE(S)	±15	volts
POWER SUPPLY CURRENT	+10-14	ma
FREQUENCY RESPONSE (-3db)	3	cps
RANGE	1	degrees
FULL RANGE OUTPUT	4.984	volts
CROSS AXIS SENSITIVITY	.500	volts/g
NOISE	.002	volts rms
LINEARITY	0.05	%
OUTPUT IMPEDANCE	16.8	K ohms
ZERO OFFSET	+.033	volts
SCALE FACTOR TEMPERATURE COEFFICIENT	.09	%/°F C
NULL TEMPERATURE COEFFICIENT	.035	%FS/°F C
TILT APPLIED SO THAT CONNECTOR END IS LOWER CAUSES OUTPUT VOLTAGE TO BECOME MORE	Pos.	
MOUNTING DIMENSIONS	3255-0070-003	

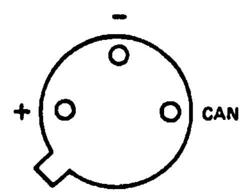
Two-Terminal IC Temperature Transducer

AD590*

FEATURES

Linear Current Output: $1\mu A/K$
Wide Range: -55°C to +150°C
Probe Compatible Ceramic Sensor Package
Two-Terminal Device: Voltage In/Current Out
Laser Trimmed to ±0.5°C Calibration Accuracy (AD590M)
Excellent Linearity: ±0.3°C Over Full Range (AD590M)
Wide Power Supply Range: +4V to +30V
Sensor Isolation from Case
Low Cost

AD590 PIN DESIGNATIONS



BOTTOM VIEW

PRODUCT DESCRIPTION

The AD590 is a two-terminal integrated circuit temperature transducer which produces an output current proportional to absolute temperature. For supply voltages between +4V and +30V the device acts as a high impedance, constant current regulator passing $1\mu A/K$. Laser trimming of the chip's thin film resistors is used to calibrate the device to $298.2\mu A$ output at 298.2K (+25°C).

The AD590 should be used in any temperature sensing application below +150°C in which conventional electrical temperature sensors are currently employed. The inherent low cost of a monolithic integrated circuit combined with the elimination of support circuitry makes the AD590 an attractive alternative for many temperature measurement situations. Linearization circuitry, precision voltage amplifiers, resistance measuring circuitry and cold junction compensation are not needed in applying the AD590.

In addition to temperature measurement, applications include temperature compensation or correction of discrete components, biasing proportional to absolute temperature, flow rate measurement, level detection of fluids and anemometry. The AD590 is available in chip form making it suitable for hybrid circuits and fast temperature measurements in protected environments.

The AD590 is particularly useful in remote sensing applications. The device is insensitive to voltage drops over long lines due to its high impedance current output. Any well-insulated twisted pair is sufficient for operation hundreds of feet from the receiving circuitry. The output characteristics also make the AD590 easy to multiplex: the current can be switched by a CMOS multiplexer or the supply voltage can be switched by a logic gate output.

*Covered by Patent No. 4,123,698

PRODUCT HIGHLIGHTS

1. The AD590 is a calibrated two terminal temperature sensor requiring only a dc voltage supply (+4V to +30V). Costly transmitters, filters, lead wire compensation and linearization circuits are all unnecessary in applying the device.
2. State-of-the-art laser trimming at the wafer level in conjunction with extensive final testing insures that AD590 units are easily interchangeable.
3. Superior interference rejection results from the output being a current rather than a voltage. In addition, power requirements are low (1.5mW's @ 5V @ +25°C). These features make the AD590 easy to apply as a remote sensor.
4. The high output impedance ($>10M\Omega$) provides excellent rejection of supply voltage drift and ripple. For instance, changing the power supply from 5V to 10V results in only a $1\mu A$ maximum current change, or 1°C equivalent error.
5. The AD590 is electrically durable: it will withstand a forward voltage up to 44V and a reverse voltage of 20V. Hence, supply irregularities or pin reversal will not damage the device.

10

SPECIFICATIONS (@ +25°C and V_S = 5V unless otherwise noted)

Model	AD590J Min	AD590J Typ	AD590J Max	AD590K Min	AD590K Typ	AD590K Max	Units
ABSOLUTE MAXIMUM RATINGS							
Forward Voltage (E + to E −)			+44			+44	Volts
Reverse Voltage (E + to E −)			−20			−20	Volts
Breakdown Voltage (Case to E + or E −)			±200			±200	Volts
Rated Performance Temperature Range[1]	−55		+150	−55		+150	°C
Storage Temperature Range[1]	−65		+155	−65		+155	°C
Lead Temperature (Soldering, 10 sec)			+300			+300	°C
POWER SUPPLY							
Operating Voltage Range	+4		+30	+4		+30	Volts
OUTPUT							
Nominal Current Output @ +25°C (298.2K)		298.2			298.2		μA
Nominal Temperature Coefficient		1			1		μA/K
Calibration Error @ +25°C			±5.0			±2.5	°C
Absolute Error (over rated performance temperature range)							
Without External Calibration Adjustment			±10			±5.5	°C
With +25°C Calibration Error Set to Zero			±3.0			±2.0	°C
Nonlinearity			±1.5			±0.8	°C
Repeatability[2]			±0.1			±0.1	°C
Long Term Drift[3]			±0.1			±0.1	°C
Current Noise		40			40		pA/$\sqrt{Hz}$
Power Supply Rejection							
$+4V \le V_S \le +5V$		0.5			0.5		μA/V
$+5V \le V_S \le +15V$		0.2			0.2		μA/V
$+15V \le V_S \le +30V$		0.1			0.1		μA/V
Case Isolation to Either Lead		10^{10}			10^{10}		Ω
Effective Shunt Capacitance		100			100		pF
Electrical Turn-On Time		20			20		μs
Reverse Bias Leakage Current[4] (Reverse Voltage = 10V)		10			10		pA
PACKAGE OPTION[5]							
TO-52 (H-03A)		AD590JH			AD590KH		
Flat Pack (F-2A)		AD590JF			AD590KF		

NOTES

[1] The AD590 has been used at −100°C and +200°C for short periods of measurement with no physical damage to the device. However, the absolute errors specified apply to only the rated performance temperature range.

[2] Maximum deviation between +25°C readings after temperature cycling between −55°C and +150°C; guaranteed not tested.

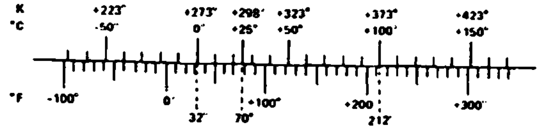
[3] Conditions: constant +5V, constant +125°C; guaranteed, not tested.

[4] Leakage current doubles every 10°C.

[5] See Section 16 for package outline information.

Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.



TEMPERATURE SCALE CONVERSION EQUATIONS

$$°C = \frac{5}{9}(°F - 32) \qquad K = °C + 273.15$$

$$°F = \frac{9}{5}°C + 32 \qquad °R = °F + 459.7$$

Model	AD590L Min	AD590L Typ	AD590L Max	AD590M Min	AD590M Typ	AD590M Max	Units
ABSOLUTE MAXIMUM RATINGS							
Forward Voltage (E+ to E−)			+44			+44	Volts
Reverse Voltage (E+ to E−)			−20			−20	Volts
Breakdown Voltage (Case to E+ or E−)			±200			±200	Volts
Rated Performance Temperature Range[1]	−55		+150	−55		+150	°C
Storage Temperature Range[1]	−65		+155	−65		+155	°C
Lead Temperature (Soldering, 10 sec)			+300			+300	°C
POWER SUPPLY							
Operating Voltage Range	+4		+30	+4		+30	Volts
OUTPUT							
Nominal Current Output @ +25°C (298.2K)		298.2			298.2		μA
Nominal Temperature Coefficient		1			1		μA/K
Calibration Error @ +25°C			±1.0			±0.5	°C
Absolute Error (over rated performance temperature range)							
Without External Calibration Adjustment			±3.0			±1.7	°C
With +25°C Calibration Error Set to Zero			±1.6			±1.0	°C
Nonlinearity			±0.4			±0.3	°C
Repeatability[2]			±0.1			±0.1	°C
Long Term Drift[3]			±0.1			±0.1	°C
Current Noise		40			40		pA/$\sqrt{Hz}$
Power Supply Rejection							
$+4V \le V_S \le +5V$		0.5			0.5		μA/V
$+5V \le V_S \le +15V$		0.2			0.2		μA/V
$+15V \le V_S \le +30V$		0.1			0.1		μA/V
Case Isolation to Either Lead		10^{10}			10^{10}		Ω
Effective Shunt Capacitance		100			100		pF
Electrical Turn-On Time		20			20		μs
Reverse Bias Leakage Current[4] (Reverse Voltage = 10V)		10			10		pA
PACKAGE OPTION[5]							
TO-52 (H-03A)		AD590LH			AD590MH		
Flat Pack (F-2A)		AD590LF			AD590MF		

ANALOG DEVICES

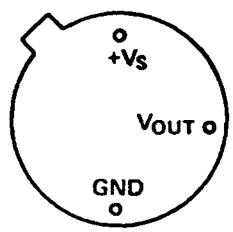
High Precision 10V IC Reference

AD581*

EATURES

- aser-Trimmed to High Accuracy:
  - 10.000 Volts ±5mV (L and U)
- Trimmed Temperature Coefficient:
  - 5ppm/°C max, 0 to +70°C (L)
  - 10ppm/°C max, -55°C to +125°C (U)
- xcellent Long-Term Stability:
  - 25ppm/1000 hrs. (Noncumulative)
- egative 10 Volt Reference Capability
- ow Quiescent Current: 1.0mA max
- 0mA Current Output Capability
- -Terminal TO-5 Package

AD581 FUNCTIONAL BLOCK DIAGRAM



TO-5
BOTTOM VIEW

RODUCT DESCRIPTION

e AD581 is a three-terminal, temperature compensated, onolithic band-gap voltage reference which provides a preise 10.00 volt output from an unregulated input level from 2 to 30 volts. Laser Wafer Trimming (LWT) is used to trim th the initial error at +25°C as well as the temperature efficient, which results in high precision performance preously available only in expensive hybrids or oven-regulated nodules. The 5mV initial error tolerance and 5ppm/°C guarnteed temperature coefficient of the AD581L represent the st performance combination available in a monolithic volte reference.

The band-gap circuit design used in the AD581 offers several dvantages over classical Zener breakdown diode techniques. ost important, no external components are required to hieve full accuracy and stability of significance to low power systems. In addition, total supply current to the device, including the output buffer amplifier (which can supply up to 10mA) typically 750µA. The long-term stability of the band-gap esign is equivalent or superior to selected Zener reference odes.

The AD581 is recommended for use as a reference for 8-, 10- r 12-bit D/A converters which require an external precision reference. The device is also ideal for all types of A/D converters p to 14 bit accuracy, either successive approximation or integrating designs, and in general can offer better performance than that provided by standard self-contained references.

he AD581J, K, and L are specified for operation from 0 to 70°C; the AD581S, T, and U are specified for the -55°C to +125°C range. All grades are packaged in a hermetically-sealed three-terminal TO-5 metal can.

PRODUCT HIGHLIGHTS

1. Laser trimming of both initial accuracy and temperature coefficient results in very low errors over temperature without the use of external components. The AD581L has a maximum deviation from 10.000 volts of ±7.25mV from 0 to +70°C, while the AD581U guarantees ±15mV maximum total error without external trims from -55°C to +125°C.
2. Since the laser trimming is done on the wafer prior to separation into individual chips, the AD581 will be extremely valuable to hybrid designers for its ease of use, lack of required external trims, and inherent high performance.
3. The AD581 can also be operated in a two-terminal "Zener" mode to provide a precision negative 10 volt reference with just one external resistor to the unregulated supply. The performance in this mode is nearly equal to that of the standard three-terminal configuration.
4. Advanced circuit design using the band-gap concept allows the AD581 to give full performance with an unregulated input voltage down to 13 volts. With an external resistor, the device will operate with a supply as low as 11.4 volts.

overed by Patent Nos. 3,887,863; RE 30,586

SPECIFICATIONS (@ V_{IN} = +15V and 25°C)

Model	AD581J Min	AD581J Typ	AD581J Max	AD581K Min	AD581K Typ	AD581K Max	AD581L Min	AD581L Typ	AD581L Max	Units
OUTPUT VOLTAGE TOLERANCE (Error from nominal 10.000V output)			**±30**			**±10**			**±5**	mV
OUTPUT VOLTAGE CHANGE Maximum Deviation from +25°C Value, T_{min} to T_{max}			**±13.5**			**±6.75**			**±2.25**	mV
(Temperature Coefficient)			30			15			5	ppm/°C
LINE REGULATION 15V ≤ V_{IN} ≤ 30V			**3.0**			**3.0**			**3.0**	mV
			(0.002)			(0.002)			(0.002)	%/V
13V ≤ V_{IN} ≤ 15V			**1.0**			**1.0**			**1.0**	mV
			(0.005)			(0.005)			(0.005)	%/V
LOAD REGULATION 0 ≤ I_{OUT} ≤ 5mA		200	**500**		200	**500**		200	**500**	µV/mA
QUIESCENT CURRENT		0.75	**1.0**		0.75	**1.0**		0.75	**1.0**	mA
TURN-ON SETTLING TIME TO 0.1%[1]		200			200			200		µs
NOISE (0.1 to 10Hz)		50			50			50		µV p-p
LONG-TERM STABILITY		25			25			25		ppm/1000 hrs
SHORT-CIRCUIT CURRENT		30			30			30		mA
OUTPUT CURRENT Source @ +25°C	**10**			**10**			**10**			mA
Source T_{min} to T_{max}	**5**			**5**			**5**			mA
Sink T_{min} to T_{max}	**5**			**5**			**5**			µA
Sink −55°C to +85°C	–			–			–			mA
TEMPERATURE RANGE Specified	**0**		**+70**	**0**		**+70**	**0**		**+70**	°C
Operating	−65		+150	−65		+150	−65		+150	°C
PACKAGE OPTION[2] TO-5 (H-03B)		AD581JH			AD581KH			AD581LH		

Model	AD581S Min	AD581S Typ	AD581S Max	AD581T Min	AD581T Typ	AD581T Max	AD581U Min	AD581U Typ	AD581U Max	Units
OUTPUT VOLTAGE TOLERANCE (Error from nominal 10.000V output)			**±30**			**±10**			**±5**	mV
OUTPUT VOLTAGE CHANGE Maximum Deviation from +25°C Value, T_{min} to T_{max}			**±30**			**±15**			**±10**	mV
(Temperature Coefficient)			30			15			10	ppm/°C
LINE REGULATION 15V ≤ V_{IN} ≤ 30V			**3.0**			**3.0**			**3.0**	mV
			(0.002)			(0.002)			(0.002)	%/V
13V ≤ V_{IN} ≤ 15V			**1.0**			**1.0**			**1.0**	mV
			(0.005)			(0.005)			(0.005)	%/V
LOAD REGULATION 0 ≤ I_{OUT} ≤ 5mA		200	**500**		200	**500**		200	**500**	µV/mA
QUIESCENT CURRENT		0.75	**1.0**		0.75	**1.0**		0.75	**1.0**	mA
TURN-ON SETTLING TIME TO 0.1%[1]		200			200			200		µs
NOISE (0.1 to 10Hz)		50			50			50		µV p-p
LONG-TERM STABILITY		25			25			25		ppm/1000 hrs
SHORT-CIRCUIT CURRENT		30			30			30		mA
OUTPUT CURRENT Source @ +25°C	**10**			**10**			**10**			mA
Source T_{min} to T_{max}	**5**			**5**			**5**			mA
Sink T_{min} to T_{max}	**200**			**200**			**200**			µA
Sink −55°C to +85°C	**5**			**5**			**5**			mA
TEMPERATURE RANGE Specified	**−55**		**+125**	**−55**		**+125**	**−55**		**+125**	°C
Operating	−65		+150	−65		+150	−65		+150	°C
PACKAGE OPTION[2] TO-5 (H-03B)		AD581SH			AD581TH			AD581UH		

NOTES
[1]See Figure 7
[2]See Section 13 for package outline information.
Specifications subject to change without notice.

Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

ABSOLUTE MAX RATINGS

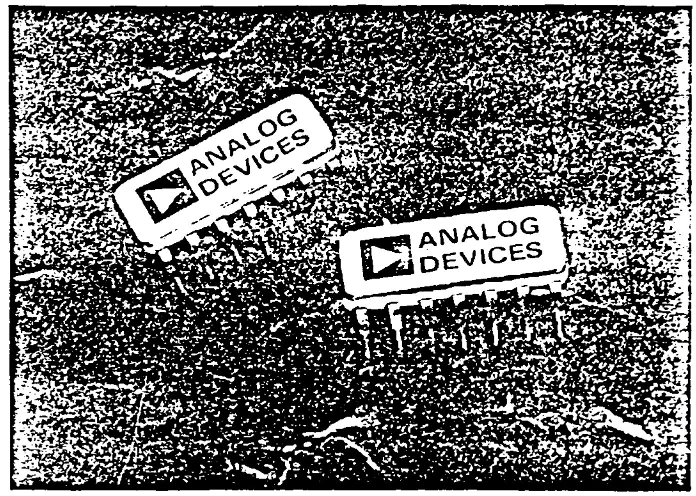
Input Voltage V_{IN} to Ground . . . . [illegible]
Power Dissipation @ +25°C . . . . [illegible]
Operating Junction Temperature Range . . . −55°C to [illegible]
Lead Temperature (Soldering 10sec) . . . . [illegible]
Thermal Resistance
Junction-to-Ambient . . . . 150°C/[illegible]

ANALOG DEVICES

Integrated Circuit Precision Instrumentation Amplifier

FEATURES

Programmable Gains from 0.1 to 1000
Floating Differential Inputs
High CMRR: 110dB min
Complete Input Protection, Power ON and Power OFF
Functionally Complete with the Addition of Two Resistors
Internally Compensated
Gain Bandwidth Product: 40MHz
Output Current Limited: 25mA
Extremely Low Cost



PRODUCT DESCRIPTION

The AD521 is the second generation, low cost, monolithic IC instrumentation amplifier developed by Analog Devices. A true instrumentation amplifier, the AD521 is a controlled gain block with differential inputs and an accurately programmable input/output gain relationship.

The AD521, like its predecessor the AD520, should not be confused with an operational amplifier, even though several manufacturers (including Analog Devices) offer op amps that can be used as building blocks in variable gain instrumentation amplifier circuits. An op amp is merely a high gain component requiring the addition of external feedback to complete the amplification function. Because of the limitations of resistor matching in the external feedback circuit and the relatively low input impedance resulting from the input resistors, an instrumentation amplifier circuit designed around op amps frequently provides less than satisfactory performance. Since the AD521 is a complete amplification circuit which does not depend upon external resistor matching for input/output isolation it maintains its high CMRR (110dB min) in any application. In addition, the high impedance inputs are fully protected against over voltages up to 15V greater than the supply voltage.

The AD521 can be operated at gains from 0.1 to greater than 1000 with the addition of only two programming resistors. Excellent dc characteristics are realized through the device's inherently low offset and gain drift and optional one-pot nulling. Dynamic performance is also outstanding with a gain bandwidth product of 40MHz, full peak response of 100kHz and a 10V/μs slew rate.

The AD521 IC instrumentation amplifier is available in three different versions, depending on accuracy and operating temperature range: the economical "J" specified from 0 to +70°C, the low drift "K", also specified from 0 to +70°C and the "S", guaranteed over the full MIL-temperature range, -55°C to +125°C. All versions are packaged in a 14 pin DIP.

PRODUCT HIGHLIGHTS

1. The AD521 is a true instrumentation amplifier in integrated circuit form, offering the user performance comparable to many modular instrumentation amplifiers at a fraction of the cost.
2. The AD521 is functionally complete with the addition of two resistors. Gain can be preset from 0.1 to more than 1000.
3. The AD521 is fully protected for input levels up to 15V beyond the supply voltage and 30V differential at the inputs.
4. Internally compensated for all gains, the AD521 also offers the user the provision for limiting bandwidth.
5. Offset nulling can be achieved with an optional trim pot.
6. The AD521 offers superior dynamic performance with a gain bandwidth product of 40MHz, full peak response of 100kHz (independent of gain) and a settling time of 5μs to 0.1% of a 10V step.
7. Every AD521 is baked for 40 hours at +150°C and temperature cycled ten times from -65°C to +150°C.

SPECIFICATIONS (typical @ V_S = ±15V, R_L = 2kΩ and T_A = 25°C unless otherwise specified)

MODEL	AD521J	AD521K	AD521S
GAIN			
Range (For Specified Operation, Note 1)	1 to 1000	*	*
Equation	$G = R_S/R_G$ V/V	*	*
Error from Equation	(±0.25 − 0.004G)%	*	*
Nonlinearity (Note 2)			
1≤G≤1000	0.1% max	*	*
Gain Temperature Coefficient	±(3 ±0.05G)ppm/°C	*	±(15 ±0.4G)ppm/°C
OUTPUT CHARACTERISTICS			
Rated Output	±10V, ±10mA min	*	*
Output at Maximum Operating Temperature	±10V @ 5mA min	*	*
Impedance	0.1Ω	*	*
DYNAMIC RESPONSE			
Small Signal Bandwidth (±3dB)			
G = 1	>2MHz	*	*
G = 10	300kHz	*	*
G = 100	200kHz	*	*
G = 1000	40kHz	*	*
Small Signal, ±1.0% Flatness			
G = 1	75kHz	*	*
G = 10	26kHz	*	*
G = 100	24kHz	*	*
G = 1000	6kHz	*	*
Full Peak Response (Note 3)	100kHz	*	*
Slew Rate, 1≤G≤1000	10V/μs	*	*
Settling Time (any 10V step to within 10mV of Final Value)			
G = 1	7μs	*	*
G = 10	5μs	*	*
G = 100	10μs	*	*
G = 1000	35μs	*	*
Differential Overload Recovery (±30V Input to within 10mV of Final Value) (Note 4)			
G = 1000	50μs	*	*
Common Mode Step Recovery (30V Input to within 10mV of Final Value) (Note 5)			
G = 1000	10μs	*	*
VOLTAGE OFFSET (may be nulled)			
Input Offset Voltage (V_{os_I})	3mV max (2mV typ)	1.5mV max (0.5mV typ)	**
vs. Temperature	15μV/°C max (7μV/°C typ)	5μV/°C max (1.5μV/°C typ)	**
vs. Supply	3μV/%	*	*
Output Offset Voltage (V_{os_O})	400mV max (200mV typ)	200mV max (30mV typ)	**
vs. Temperature	400μV/°C max (150μV/°C typ)	150μV/°C max (50μV/°C typ)	**
vs. Supply (Note 6)	0.005V_{os_O}/%	*	*
INPUT CURRENTS			
Input Bias Current (either input)	80nA max	40nA max	**
vs. Temperature	1nA/°C max	500pA/°C max	**
vs. Supply	2%/V	*	*
Input Offset Current	20nA max	10nA max	**
vs. Temperature	250pA/°C max	125pA/°C max	**
INPUT			
Differential Input Impedance (Note 7)	3×10^9Ω‖1.8pF	*	*
Common Mode Input Impedance (Note 8)	6×10^{10}Ω‖3.0pF	*	*
Input Voltage Range for Specified Performance	±10V	*	*
Maximum Voltage without Damage to Unit, Power ON or OFF Differential Mode (Note 9)	30V	*	*
Voltage at either input (Note 10)	V_S ±15V	*	*
Common Mode Rejection Ratio, DC to 60Hz with 1kΩ source unbalance			
G = 1	70dB min (74dB typ)	74dB min (80dB typ)	**
G = 10	90dB min (94dB typ)	94dB min (100dB typ)	**
G = 1000	100dB min (104dB typ)	104dB min (114dB typ)	**
G = 1000	100dB min (110dB typ)	110dB min (120dB typ)	**
NOISE			
Voltage RTO (p-p) @ 0.1Hz to 10Hz (Note 10)	$\sqrt{(0.5G)^2 + (150)^2}$ μV	*	*
RMS RTO, 10Hz to 10kHz	$\sqrt{(1.2G)^2 + (30)^2}$ μV	*	*
Input Current, rms, 10Hz to 10kHz	15pA(rms)	*	*
REFERENCE TERMINAL			
Bias Current	3μA	*	*
Input Resistance	10MΩ	*	*
Voltage Range	±10V	*	*
Gain to Output	1	*	*
POWER SUPPLY			
Operating Voltage Range	±5 to ±18	*	*
Quiescent Supply Current	5mA max	*	*
TEMPERATURE RANGE			
Specified Performance	0 to +70°C	*	−55°C to +125°C
Operating	−25°C to +85°C	*	−55°C to +125°C
Storage	−65°C to +150°C	*	*

*Specification same as AD521J.
**Specification same as AD521K.

Specifications and prices subject to change without notice.

NOTES:

1. Gains below 1 and above 1000 are realized by simply adjusting the gain setting resistors. For best results, input voltage should be restricted to ±10V for gains equal to or less than 1.

2. Nonlinearity is defined as the ratio of the deviation from the "best straight line" through a full scale output of ±9 volts to 18 volts. With a combination of high gain and ±10 volt output swing, distortion may increase to as much as 0.3%.

3. Full Peak Response is the typical frequency below which the amplifier will produce full output swing.

4. Differential Overload Recovery is the time it takes the amplifier to recover from a pulsed 30V differential input with 15V of common mode voltage, to within 10mV of final value. The test input is a 30V, 10μs pulse at a 1kHz rate. (When a differential signal of greater than 11V is applied between the inputs, transistor clamps are activated which drop the excess input voltage across internal input resistors. If a continuous overload is maintained, power dissipated in these resistors causes temperature gradients and a corresponding change in offset voltage, and an added thermal time constant, but will not damage the device.)

5. Common Mode Step Recovery is the time it takes the amplifier to recover from a 30V common mode input with zero volts of differential signal to within 10mV of final value. The test input is 30V, 10μs pulse at a 1kHz rate. (When a common mode signal greater than V_S - 0.5V) is applied to the inputs, transistor clamps are activated which drop the excessive input voltage across internal input resistors. Power dissipated in these resistors causes temperature gradients and a corresponding change in offset voltage, and an added thermal time constant, but will not damage the device.)

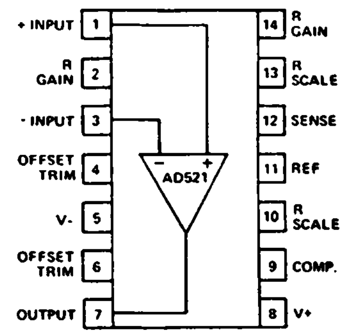
6. Output Offset Voltage versus Power Supply Change is a constant 0.005 times the unnulled output offset per percent change in either power supply. If the output offset is nulled, the output offset change versus supply change is substantially reduced.

7. Differential Input Impedance is the impedance between the two inputs.

8. Common Mode Input Impedance is the impedance from *either* input to the power supplies.

9. Maximum Input Voltage (differential or at either input) is 30V when using ±15V supplies. A more general specification is that neither input may exceed either supply (even when V_S = 0) by more than 15V and that the difference between the two inputs must not exceed 30V. (See also Notes 4 and 5.)

10. 0.1Hz to 10Hz Peak-to-Peak Voltage Noise is defined as the maximum peak-to-peak voltage noise observed during 2 of 3 separate 10 second periods with the test circuit of Figure 6.



TOP VIEW

Figure 1. AD521 Pin Configuration

TO-116

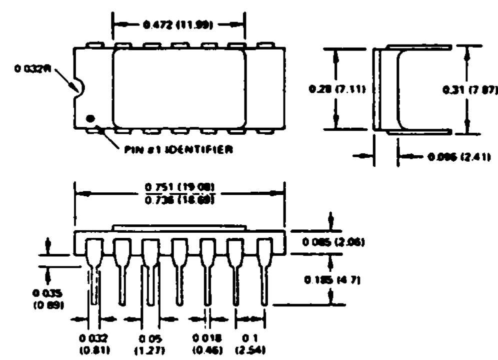


Figure 2. Physical Dimensions. Dimensions shown in inches and (mm).

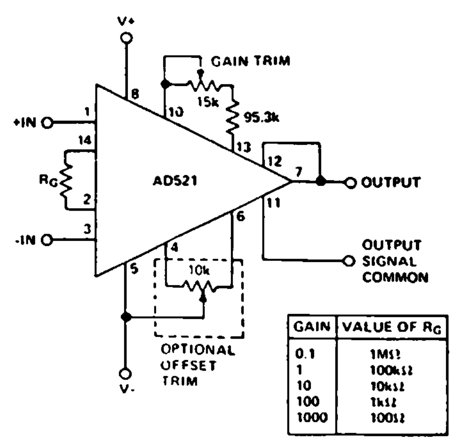


Figure 3. Operating Connections for AD521

INPUT OFFSET AND OUTPUT OFFSET

When specifying offsets and other errors in an operational amplifier, it is often convenient to refer these errors to the inputs. This enables the user to calculate the maximum error he would see at the output under any gain or circuit configuration. An op amp with 1mV of input offset voltage, for example, would produce 1V of offset at the output in a gain of 1000 configuration.

In the case of an instrumentation amplifier, where the gain is controlled in the amplifier, it is more convenient to separate errors into two categories. Those errors which simply add to the output signal and are unaffected by the gain, can be classi-

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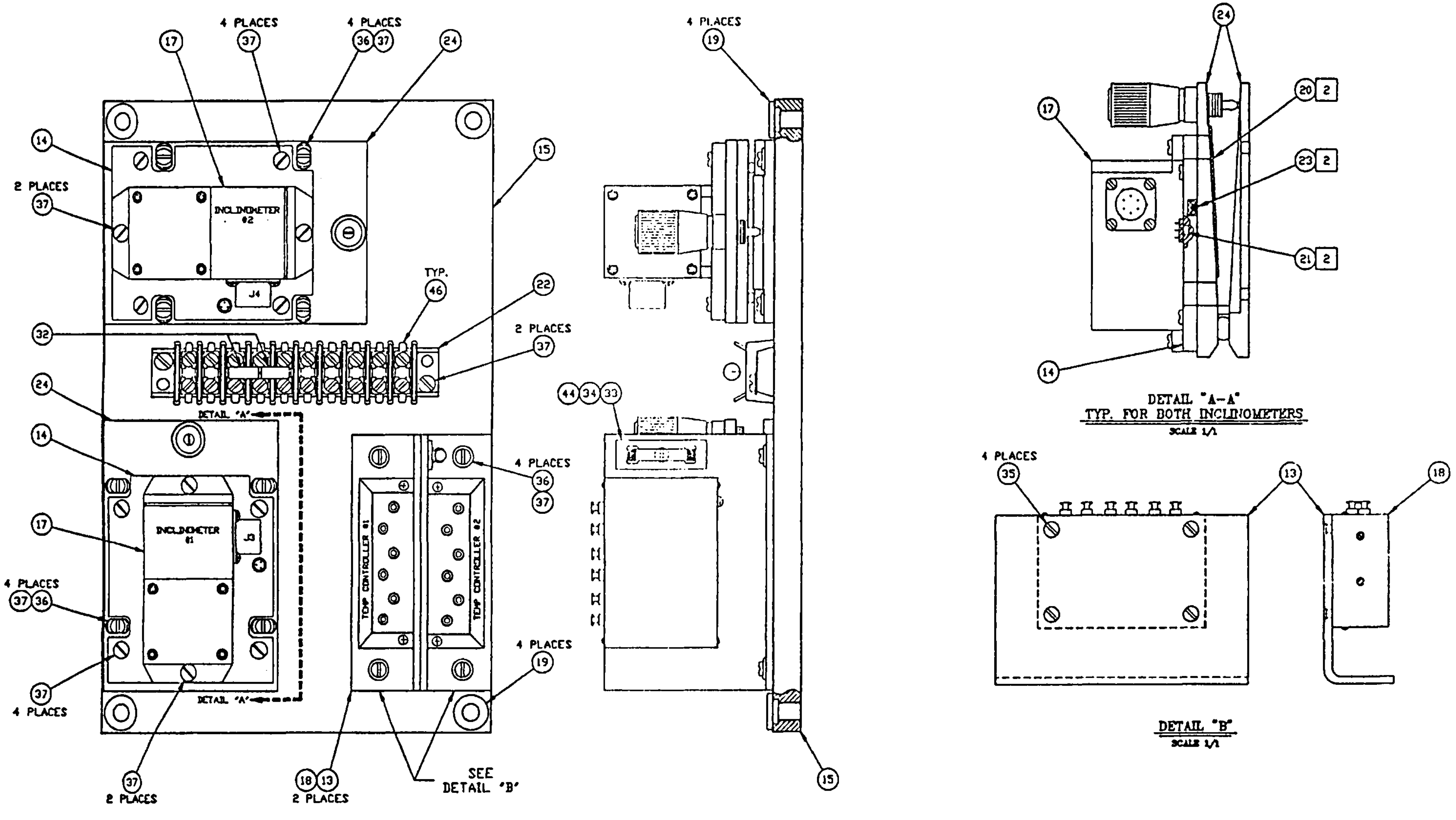

BASEPLATE ASSEMBLY
SCALE 1/1

NOTES :

1. APPLY HEAT SINK COMPOUND BETWEEN THE TILT TABLE AND THE INCLINOMETER MOUNTING BASE AND BETWEEN THE INCLINOMETER MOUNTING BASE AND THE INCLINOMETER.

2. USE MINCO #6 RUBBER ADHESIVE TO INSTALL HEATERS (INSTRUCTIONS ENCLOSED) AND TEMP SENSORS.

BOM : #A13721Z08

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ANGLES ±
3 PLACE DECIMALS (.XXX) ±
2 PLACE DECIMALS (.XX) ±
FRACTIONS (1/X) ±

MATERIAL:

FINISH:

VLA PROJECT: TILTMETER

TITLE: TILTMETER MOUNT ASSEMBLY

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801

DRAWN BY — DATE 10-87
DESIGNED BY — DATE 10-87
APPROVED BY — DATE

SHEET NUMBER 1 of 2 | DRAWING NUMBER D13721P08 | REV A | SCALE 1/1

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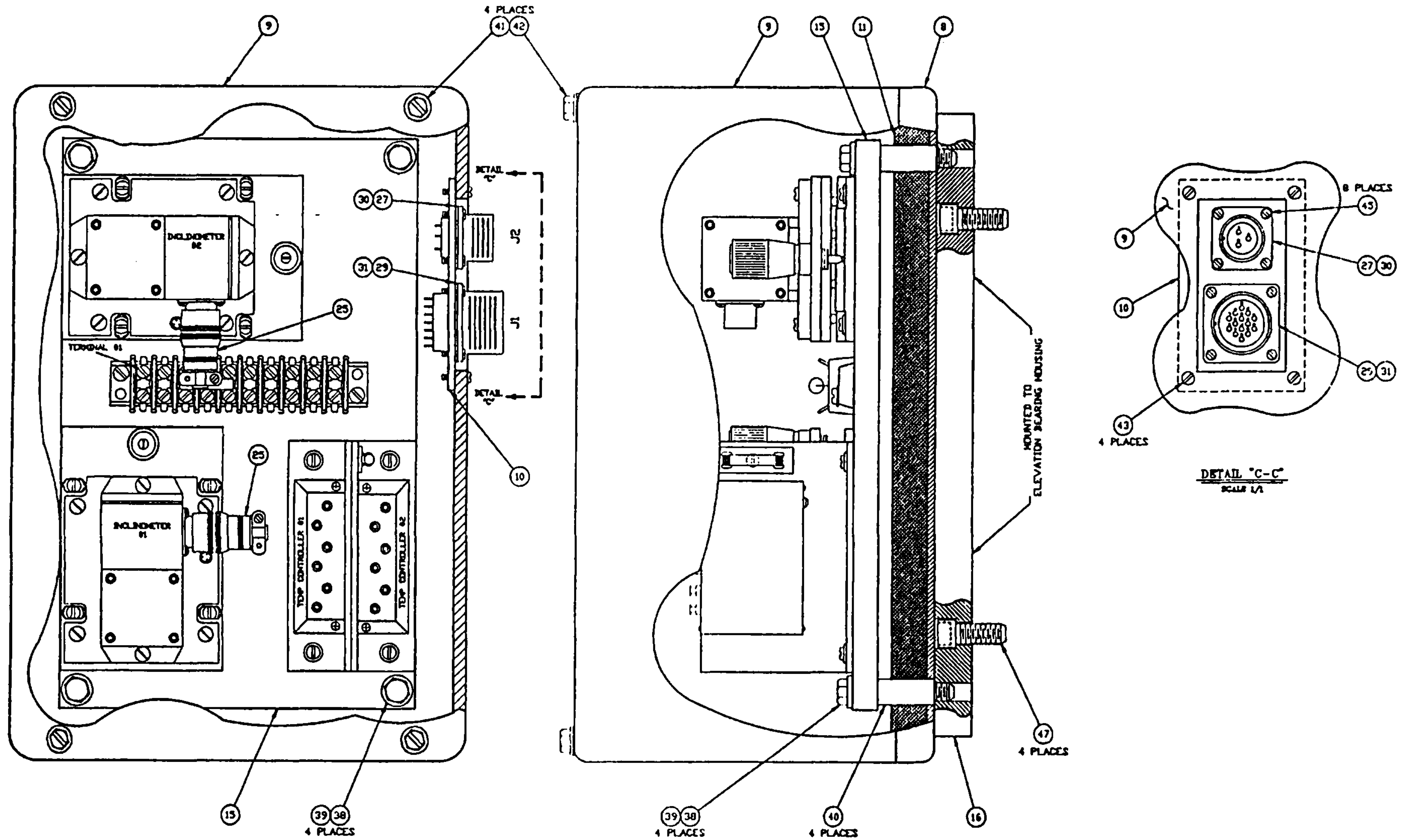

BOM : #A13721Z08

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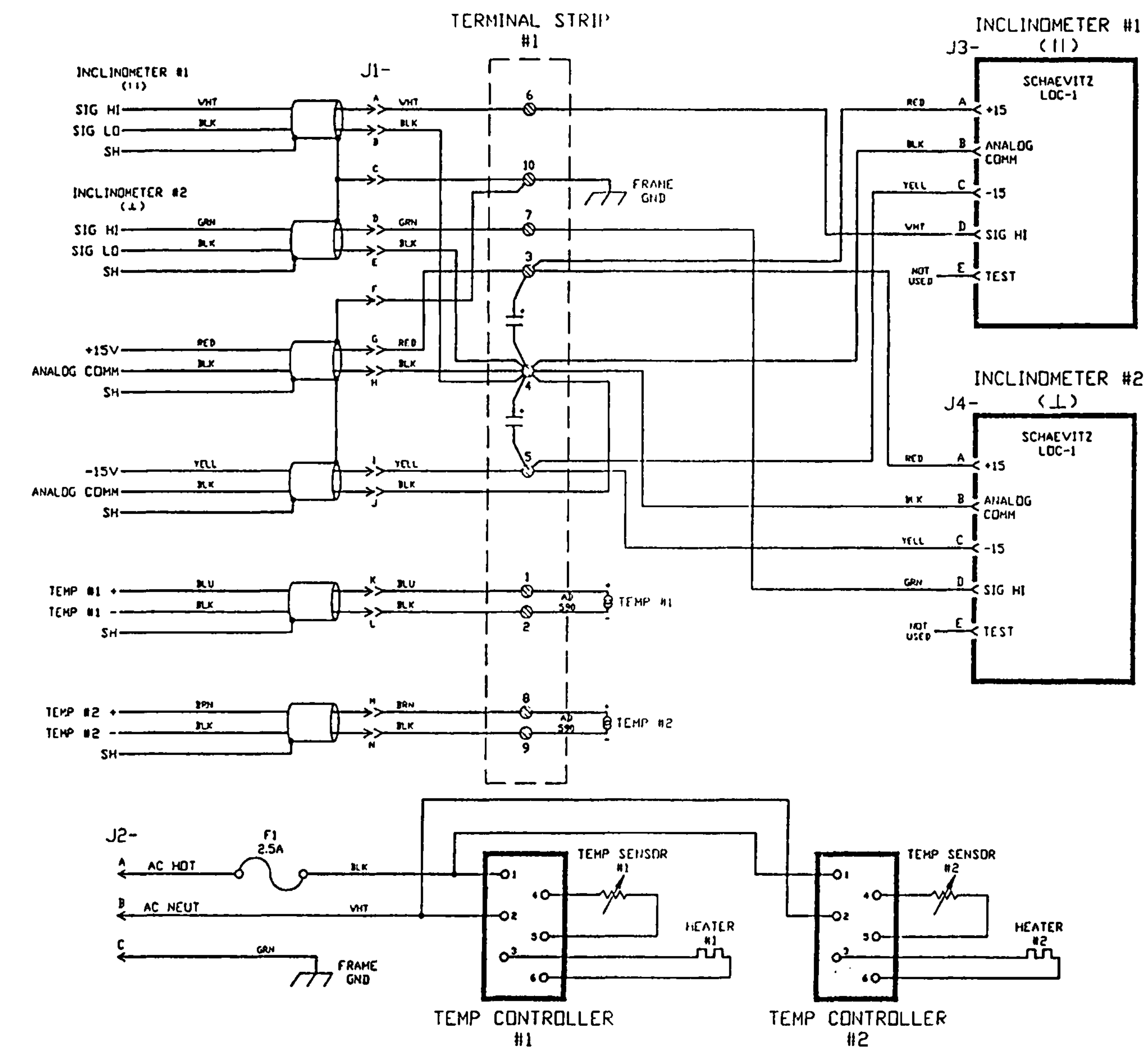
MATERIAL:	TITLE: TILTMETER MOUNT ASSEMBLY	DRAWN BY — DATE 10-87 DESIGNED BY — DATE 10-87 APPROVED BY — DATE
FINISH:	SHEET NUMBER 2 of 2 — DRAWING NUMBER D13721P88	REV A — SCALE 1/1



ACAD : INCLSKEM

NEXT ASSY	USED ON

UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX) ±
2 PLACE DECIMALS (.XX) ±
1 PLACE DECIMALS (.X) ±

MATERIAL:

FINISH:

PROJECT: VLA

TILTMETER

TITLE: TILTMETER SCEMATIC

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801

DRAWN BY	DATE 12-88
DESIGNED BY	DATE 11-88
APPROVED BY	DATE

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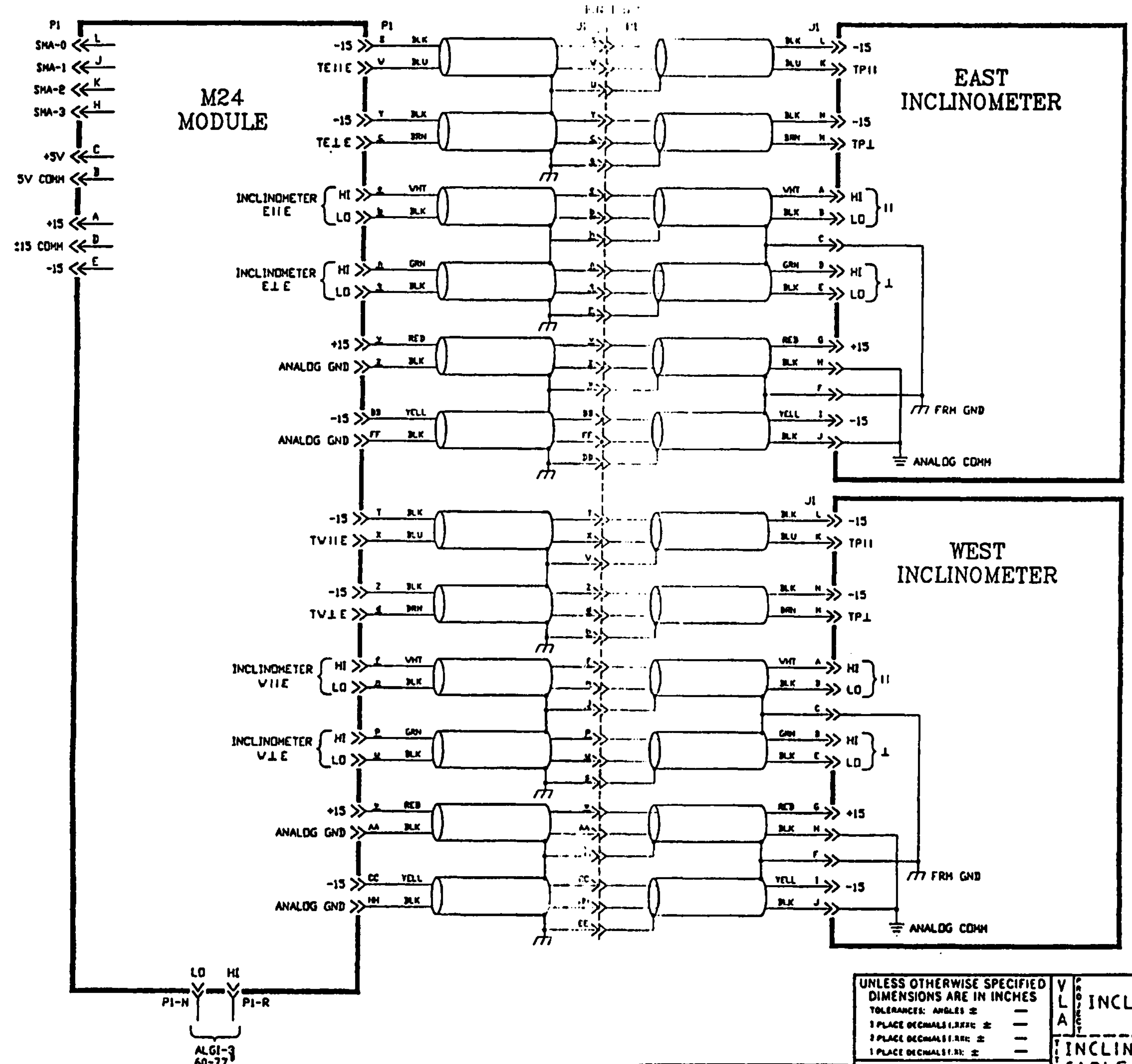

ACAD : INCLCABL

REV	DATE	DRAWN BY	APPROVED BY	DESCRIPTION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES: ANGLES ±
3 PLACE DECIMALS (.XXX) ±
2 PLACE DECIMALS (.XX) ±
1 PLACE DECIMALS (.X) ±

MATERIAL:

FINISH:

NEXT ASSY | USED ON

VLA PROJECT: INCLINOMETER

TITLE: INCLINOMETER CABLE WIRE DIAGRAM

NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801

DRAWN BY | DATE 4-89
DESIGNED BY | DATE 4-89
APPROVED BY | DATE

SHEET NUMBER 1 OF 1 | DRAWING NUMBER C13720530 | REV | SCALE -

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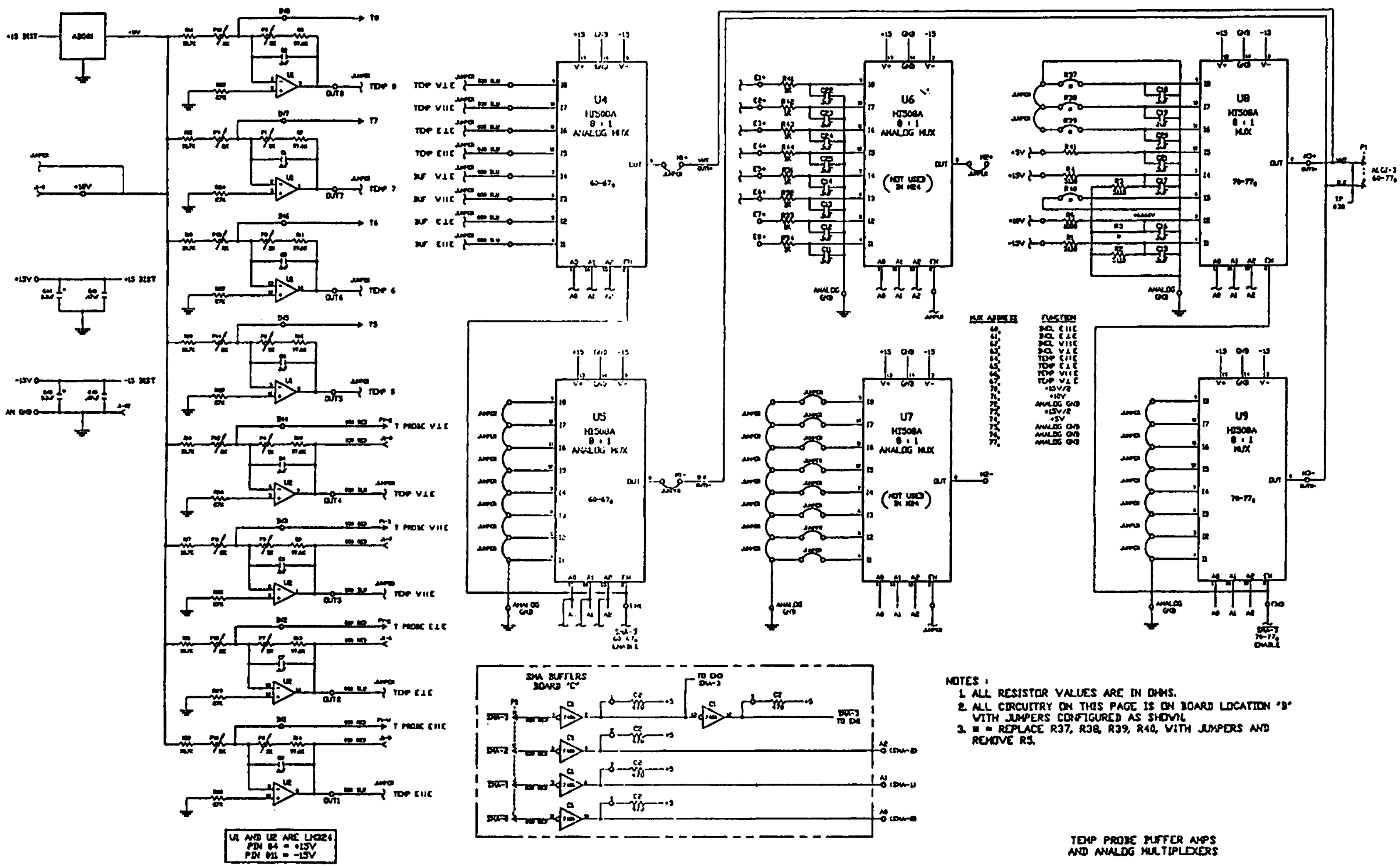


NOTES :
1. ALL RESISTOR VALUES ARE IN OHMS.
2. ALL CIRCUITRY ON THIS PAGE IS ON BOARD LOCATION "B" WITH JUMPERS CONFIGURED AS SHOWN.
3. * = REPLACE R37, R38, R39, R40, WITH JUMPERS AND REMOVE R5.

TEMP PROBE BUFFER AMPS AND ANALOG MULTIPLEXERS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES: ANGLES ± —
3 PLACE DECIMALS (.XXX) ± —
2 PLACE DECIMALS (.XX) ± —
FRACTIONS (1/X) ± —

MATERIAL: ______

FINISH: ______

VLA PROJECT: M24 INCLINOMETER INTERFACE

TITLE: M24 INCLINOMETER INTERFACE SCHEMATIC

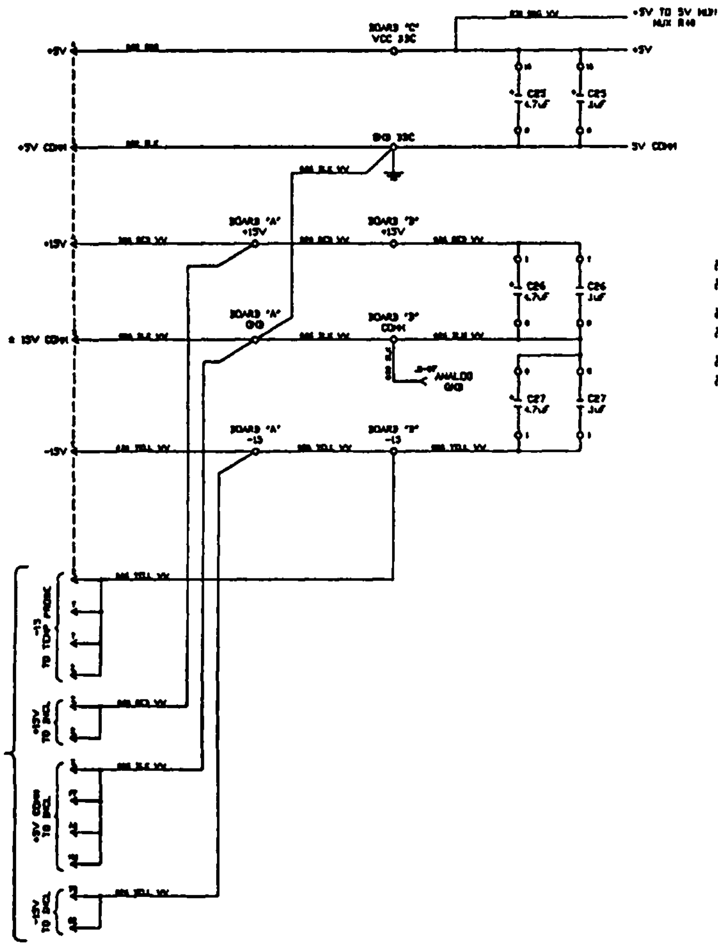
NATIONAL RADIO ASTRONOMY OBSERVATORY
SOCORRO, NEW MEXICO 87801

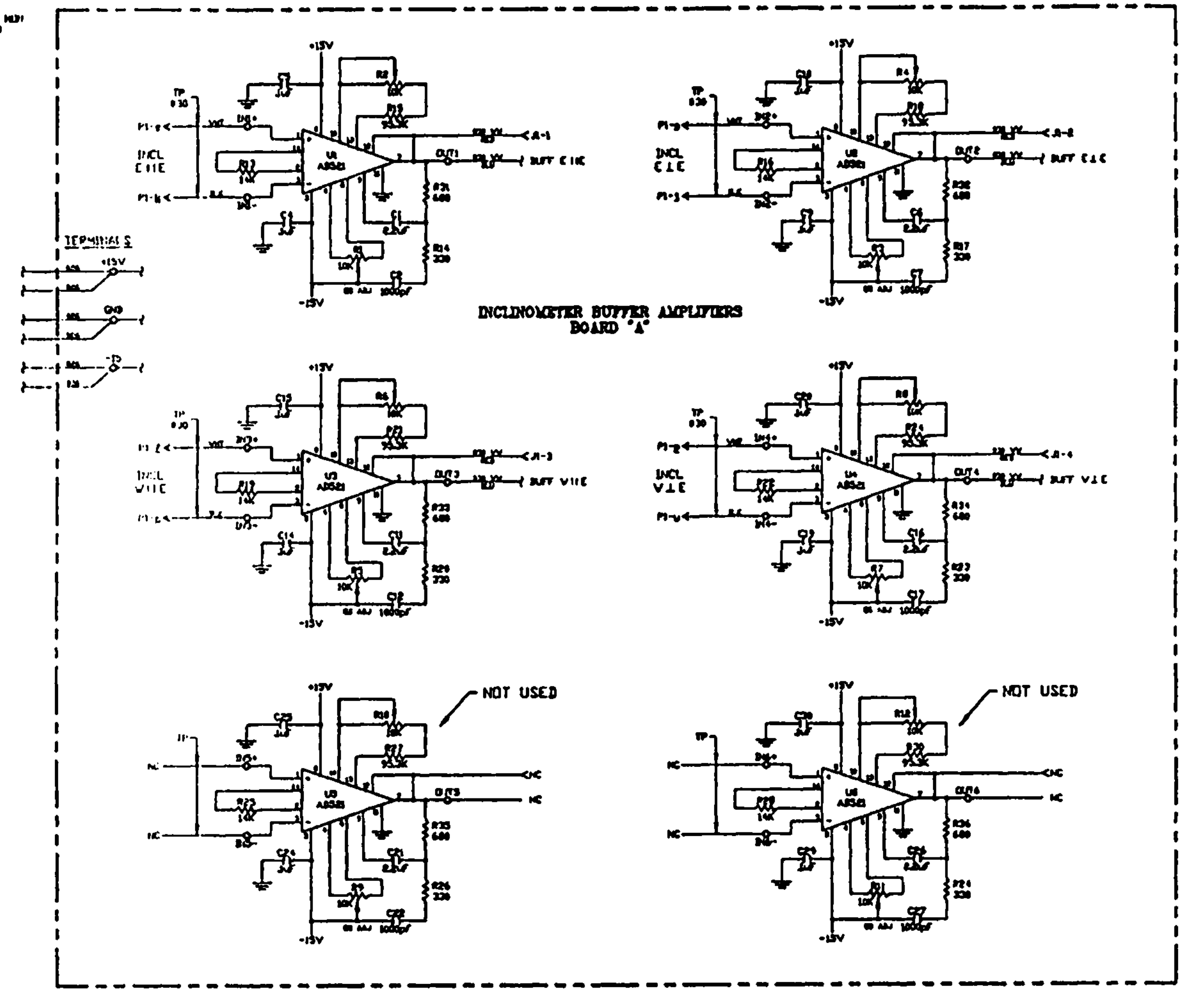
DRAWN BY	DATE 3-89
DESIGNED BY	DATE 3-89
APPROVED BY	DATE

SHEET NUMBER 1 of 2 | DRAWING NUMBER D13720S29 | REV. A | SCALE —

REV	DATE	DRAWN BY	APPRV'D BY	DESCRIPTION
A	12-89			REDRAWN WITH ACAD;

POWER DITRUBUTION WIRING





INCLINOMETER BUFFER AMPLIFIERS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES	VLA	PROJECT: M24 INCLINOMETER INTERFACE	NATIONAL RADIO ASTRONOMY OBSERVATORY SOCORRO, NEW MEXICO 87801
TOLERANCES: ANGLES ± ——; 3 PLACE DECIMALS (.XXX) ± ——; 2 PLACE DECIMALS (.XX) ± ——; FRACTIONS (1/X) ± ——		TITLE: M24 INCLINOMETER INTERFACE SCHEMATIC	DRAWN BY — DATE 3-89
MATERIAL:			DESIGNED BY — DATE 3-89
FINISH:			APPROVED BY — DATE
		SHEET NUMBER 2 of 2; DRAWING NUMBER D13720S29	REV. A; SCALE ----