Model P-3500

Digital Strain Indicator

Instruction Manual

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INSTRUCTION MANUAL

MODEL P-3500

STRAIN INDICATOR

Model P-3500 Strain Indicator

1.0 GENERAL DESCRIPTION

The Model P-3500 Strain Indicator is a portable, battery-powered precision instrument for use with resistive strain gages and transducers. The Model P-3500 will accept full-, half-, or quarter-bridge inputs, and all required bridge completion components for 120-ohm and 350-ohm bridges are provided. Strain gages are normally connected via the front-panel binding posts. Transducers are normally connected via a front-panel transducer connector. Remote-sense capability is provided at the transducer connector to enable full six-wire operation.

The Model P-3500 will accept gage factors of 0.500 to 9.900, and gage factor is settable to an accuracy of 0.001 by a front-panel ten-turn potentiometer. Gage factor is displayed by the front-panel readout.

Operating controls of the Model P-3500 are simple and straightforward. The color-coded push buttons allow the operator to determine the operating mode at a glance. A minimum of operator training is required.

The Model P-3500 is powered by an internal battery pack consisting of six replaceable alkaline “D” cells. Battery life is approximately 200 hours of continuous use. An ac adapter is available for situations in which the unit is in continuous laboratory use.

> CAUTION: When it becomes necessary to clean the Model P-3500, do not use solvents on the front panel or on the information label inside the lid.

2.0 SPECIFICATIONS

All specifications are nominal or typical at 23°C unless otherwise noted. Performance may be degraded in the presence of high-level electromagnetic fields.

RANGE AND DISPLAY: Direct-reading display.

$\pm 19\,999 \mu\epsilon$ at GF <6.000, MULT X1.

$\pm 19\,999 \mu\epsilon \times \frac{6.000}{GF}$ at GF >6.000, MULT X1.

$\pm 199\,990 \mu\epsilon$ at GF <6.000, MULT X10.

$\pm 199\,990 \mu\epsilon \times \frac{6.000}{GF}$ at GF >6.000, MULT X10.

Overload: Indicated by flashing colons.

RESOLUTION: $1\mu\epsilon$ at MULT X1. $10\mu\epsilon$ at MULT X10.

ACCURACY:

±0.1% reading $\pm 3\mu\epsilon$ for Gage Factor ≥1.000, MULT X1, max.

±0.1% reading $\pm 20\mu\epsilon$ for Gage Factor ≥1.000, MULT X10, max.

BALANCE RANGE:

Coarse Balance: ±2000$\mu\epsilon$ ±1%, ±4000$\mu\epsilon$ ±1% (GF=2.000).

Fine Balance: Ten-turn precision potentiometer ±1050$\mu\epsilon$ min (GF=2.000).

Zero position of potentiometer calibrated for zero, ±2$\mu\epsilon$.

Balance is accomplished by electronic voltage injection at the amplifier input.

Balance controls do not load bridge circuit or compromise the measurement range.

GAGE FACTOR:

Range: 0.500 to 9.900
Display Resolution: ± 0.001.

BRIDGE EXCITATION: 2.00 Vdc ±0.1%.

Temperature Stability: ±0.02%/°C. (All readings are fully ratiometric and accuracy not degraded by variation in excitation level.)

AMPLIFIER:

Temperature Effect on Zero: ±1.0μV/°C RTI max.

Temperature Effect on Span: ±0.005%/°C max.

Warm-up Drift: Less than ±3 counts at GF=2.000 from turn-on to ten minutes.

Random Drift at Constant Ambient Temperature:
Less than ±1 count at GF=2.000.

Common-mode Rejection: Greater than 90 dB at 50-60 Hz.

Input Impedance: Greater than 30 megohm differential and common mode.

INPUT CIRCUITS: 60- to 2000-ohm half or full bridge. Internal dummy gages are provided for 120-ohm and 350-ohm quarter bridges. Also, the 120-ohm dummy can be changed to 1000 ohm. (See ***10.2b Bridge Completion and Calibration Components.***)

CALIBRATION: Shunt calibration resistors are provided across internal 120-ohm and 350-ohm dummy gages to simulate 5000$\mu\epsilon$ ±0.05%. Connections are provided for use of an optional internal or external calibration resistor. (See ***5.5 CAL — Orange*** and ***6.1 Input Connections — Transducer***.)

ANALOG OUTPUT:

Linear Output: ±2.50V max; adjustable from 40 μV/$\mu\epsilon$ to 440 μV/$\mu\epsilon$ nominal.

Output Load: 2 KΩ min resistance.

Bandwidth: dc to 4 kHz –3 dB nominal.

Output Noise: Less than 400 μV rms at 40 μV/$\mu\epsilon$ output level.

REMOTE SENSE: Remote sense connections provided at transducer connector.

Remote Sense Error: Less than ±0.001%/ohm of lead resistance.

Recommended Maximum Lead Resistance: 35 ohm.

OPERATIONAL ENVIRONMENT:

Temperature: –10° to +50°C.

Humidity: Up to 90% RH, non-condensing.

POWER: Six alkaline “D” cells. Battery life is approximately 200 hours of continuous use. Power is automatically off when cover is closed.

External adapter for operation from 115/230V 50-60 Hz, 60/30 mA.

CASE: Aluminum, with detachable cover.

The front-panel components of the Model P-3500 should be protected when the instrument is exposed to extremely dusty environments. Plastic bags or dust-tight plastic enclosures will generally provide adequate protection.

SIZE: 9 x 6 x 6 in *(230 x 150 x 150 mm)*.

WEIGHT: 6.3 lb *(2.9 kg)* including battery pack.

3.0 DESCRIPTION OF CONTROLS

3.1 GENERAL

The Model P-3500 has been specifically designed so that the operation of the front-panel controls and push-button switches is straightforward and largely self-explanatory. The push buttons are color-coded and the operating mode can be immediately recognized. In addition, the first six push buttons are mechanically interlocked so that no improper operating mode can be selected. The two right-most push buttons select optional operating modes at the discretion of the user, and are of the alternate-action type.

Model P-3500 Front Panel

The color coding of the push-button switches is such that the colors are displayed when the switches are depressed. The colors referred to in the following descriptions are those displayed when the respective switch is depressed.

The overall result of the color coding scheme is that:

(a) when blue is displayed, the instrument is off;

(b) when orange is displayed, the instrument is in a setup or diagnostic mode;

(c) when green is displayed, the instrument is in the normal measuring mode;

(d) when yellow is displayed, the instrument is in an optional mode of operation; i.e., FULL bridge and/or MULT X10.

3.2 POWER OFF — Blue

When the POWER OFF push button is depressed, primary power (battery pack or dc supply) is removed from all circuits. Power is turned on by depressing any one of the following five interlock push buttons.

3.3 AMP ZERO — Orange

When the AMP ZERO push button is depressed, the S+, S– inputs are disconnected from the bridge circuit and internally connected to signal common. The balance controls (coarse and fine) are also disabled. In this position, the AMP ZERO fingertip knob is adjusted for a ±0000 reading of the output display.

3.4 GAGE FACTOR — Orange

When the GAGE FACTOR push button is depressed, the instrument is configured so that the exact gage factor is displayed. The appropriate gage factor range is selected by the rotary switch adjacent to the gage factor potentiometer. The desired gage factor is set by the gage factor potentiometer and locked mechanically using the potentiometer locking mechanism.

3.5 RUN — Green

When the RUN push button is depressed, the instrument is configured to measure the strain as presented to the input terminals by the externally connected circuit. (See ***5.0 Operating Procedures — Strain Gage Inputs*** for details.)

3.6 CAL — Orange

When the CAL push button is depressed, the internal calibration resistors are connected across the 120-ohm and 350-ohm dummy gages. Also, a contact closure is provided by pins G and H of the transducer connector. This contact closure may be used to implement various calibration arrangements; i.e., shunt active gage, shunt half-bridge, transducer shunt calibration, etc. Care should be exercised, however, to insure that the relative merits or limitations of each arrangement are thoroughly understood.

NOTE: The resistors may also be placed on the PC board if desired. See Fig. 2, page 12.

3.7 BR EXCIT OFF — Orange

When the BR EXCIT OFF push button is depressed, bridge excitation is removed from P+, and the P+ terminal is connected directly to P–. The balance controls (coarse and fine) are also disabled. This position is not normally used if the remote-sense leads are connected. (See ***6.6 BR EXCIT OFF — Orange***.)

3.8 MULT X1/X10 — Yellow

When the MULT push button is depressed, the full-scale range of the instrument is increased to ±199 990$\mu\epsilon$. The displayed reading must be multiplied by ten to obtain the correct numerical value. This button is not interlocked, and is therefore selectable at the option of the user.

NOTE: The MULT push button has no effect on the displayed reading when GAGE FACTOR push button is depressed.

3.9 BRIDGE FULL/ 1/4-1/2 — Yellow

When this push button is depressed, the internal half bridge is disconnected, and the instrument is in the FULL-bridge mode. This button is not interlocked, and is therefore selectable at the option of the user.

3.10 AMP ZERO Control

The AMP ZERO control is used to set the electrical zero of the amplifier when the AMP ZERO push button is depressed. The setting must not be changed during a reading or in any other operating mode. The control is operated by pressing lightly with the fingertip and rotating until displayed reading is ±0000. The AMP ZERO must be set with the MULT push button in the X1 position.

3.11 GAGE FACTOR Range Switch

The GAGE FACTOR range is selected by setting the rotary switch to the desired position. When gage factors of approximately 2.000 are being used, the 1.7 to 2.5 range will result in the optimum settability.

3.12 GAGE FACTOR Control

The exact value of gage factor is set by the ten-turn gage factor potentiometer. The locking mechanism provides a means to mechanically lock the knob in place. Once the GAGE FACTOR and BALANCE controls are set, it is recommended that the knobs be locked in position to prevent accidental rotation; these knobs utilize a lever which must first be pulled *away* from the panel and then rotated clockwise. The knob can be unlocked simply by rotating the lever back to the counterclockwise stop.

3.13 BALANCE Range Switch

The BALANCE range is selected by setting the rotary switch to the desired position. The switch may be set to the zero position, in which case only the BALANCE potentiometer is active. Switch positions of ±2000$\mu\epsilon$, ±4000$\mu\epsilon$, and 0 are provided.

3.14 BALANCE Control

The BALANCE is set by the ten-turn BALANCE potentiometer. The potentiometer is locked in place by the locking mechanism. Once the GAGE FACTOR and BALANCE controls are set, it is recommended that the knobs be locked in position to prevent accidental rotation; these knobs utilize a lever which must first be pulled *away* from the panel and then rotated clockwise. The knob can be unlocked simply by rotating the lever back to the counterclockwise stop.

3.15 ANALOG OUTPUT

The ANALOG OUTPUT is accessible via the front-panel BNC connector. (See ***2.0 Specifications*** for output specifications.)

3.16 ANALOG OUTPUT Level Control

The ANALOG OUTPUT level is variable over an 11:1 range by the fingertip adjustable level control. The control is operated by pressing lightly with the fingertip and rotating until the desired level is obtained.

3.17 INPUT CONNECTOR — dc Power

The female connector from the ac adapter plugs into the male receptacle in the upper-left corner of the instrument.

3.18 BATTERY Indicator

Battery condition is monitored (when the instrument is on) by the BATTERY indicator. If the meter deflects to the white area, the batteries are in satisfactory condition. When the meter falls to the white-red transition, battery charge is approximately 90% depleted and batteries should be replaced as soon as practical. **Do not leave discharged batteries in the instrument for prolonged periods. Leakage can result in costly damage!**

3.19 BINDING POST Connectors

Strain gages are normally connected to the binding posts. (See ***5.0 Operating Procedures — Strain Gage Inputs*** for details.)

3.20 TRANSDUCER Connector

Transducers are normally connected to the Model P-3500 via the front-panel TRANSDUCER connector. In addition to the excitation and signal leads, remote-sense leads and connections for a remote calibration resistor are provided at this connector.

4.0 OPERATING PROCEDURES — General

The Model P-3500 is designed for ease of operation — the push-button switches and front-panel controls are arranged such that the proper set-up procedure generally follows a straightforward left-to-right sequence. The steps outlined below are applicable to the use of the instrument as either a strain gage or transducer indicator. Specific details are covered in ***5.0 Operating Procedures — Strain Gage Inputs*** and ***6.0 Operating Procedures — Transducers.***

4.1 Select FULL or 1/4-1/2 position of BRIDGE push button as required.

4.2 Select X1 position of MULT push button.

4.3 Connect strain gage(s) or transducer to binding posts or TRANSDUCER connector. (See instructions inside instrument cover or refer to ***5.0*** and ***6.0***.)

NOTE: In applications where the Model P-3500 and/or the input wiring may be subjected to high-level EMI (electromagnetic interference) and/or ESD (electrostatic discharge), shielded cabling should be used to help preserve data integrity as well as prevent permanent damage to the instrument. For additional protection, the external bridge sensor(s) should also be shielded. The shield should be connected to either the **GND** binding post or Pin F of the TRANSDUCER input connector; the **GND** binding post should also be connected to a good "earth ground".

4.4 Depress AMP ZERO push button. Allow instrument to warm up for a minimum of two minutes. Set AMP ZERO control for a readout display of ±0000. This adjustment must be made with MULT in X1 position.

4.5 Depress GAGE FACTOR push button. Set GAGE FACTOR range switch and GAGE FACTOR potentiometer to display the desired gage factor.

4.6 Depress the RUN push button. Set the BALANCE switch and the BALANCE potentiometer for reading of ±0000. This setting must be made with the MULT in the X1 position. **NOTE:** A reading of ±0000 with flashing colons indicates an off-scale condition that is usually caused by improper input wiring or a defective strain gage installation.

4.7 Depress the CAL push button and verify calibration of the instrument. (See ***5.5*** and ***6.5 CAL — Orange***.)

4.8 Select the X1 or X10 MULT position as required.

4.9 Depress the RUN push button. Load the strain gage or transducer system and record the reading.

5.0 OPERATING PROCEDURES — Strain Gage Inputs

The operating procedures described in this section are intended for use with resistive strain gage inputs. The procedures in ***4.0 Operating Procedures — General*** are also applicable and should be consulted in conjunction with the procedures in this section.

5.1 INPUT CONNECTIONS — Strain Gage

Resistive strain gages are normally connected at the binding posts on the front panel. These binding posts are color-coded in accordance with conventional practice, and are clearly labeled. Input connections for full-, half-, and quarter-bridge configurations are shown on the inside cover of the instrument and also in Fig. 1.

Connect the strain gage leadwires to the binding posts. Select the desired bridge configuration using the BRIDGE push button. Set the MULT push button to X1 position.

5.2 AMP ZERO — Orange

Depress the AMP ZERO push button. Allow the instrument to warm up for at least two minutes. Rotate the AMP ZERO finger-tip control for a reading of ±0000. [To save time, instrument may be left in AMP ZERO position while gage(s) are being connected.]

5.3 GAGE FACTOR — Orange

Set the GAGE FACTOR switch to the desired gage factor range and depress the GAGE FACTOR push button. The gage factor will be displayed on the readout. Rotate the GAGE FACTOR potentiometer for the exact desired gage factor, and lock the control in place.

Normally this will be the gage factor given by the manufacturer on the engineering data sheet supplied with the strain gages. However, in some cases, the operator may calculate an "adjusted" gage factor to be used to compensate for the resistance of the leads connecting the strain gage to the Model P-3500.

Example: 350-ohm active gage, connected in three-wire quarter-bridge configuration.

Leadwire resistance is 3 ohms in each lead. See Fig. 1.

Gage Factor listed on package = 2.08.

$$\text{Corrected Gage Factor} = \frac{350}{350 + 3} \times 2.08 = 2.062.$$

The Gage Factor should be set to 2.062.

This procedure may be done automatically by using the GAGE FACTOR control in conjunction with the CAL push button as explained in ***5.5 CAL — Orange***.

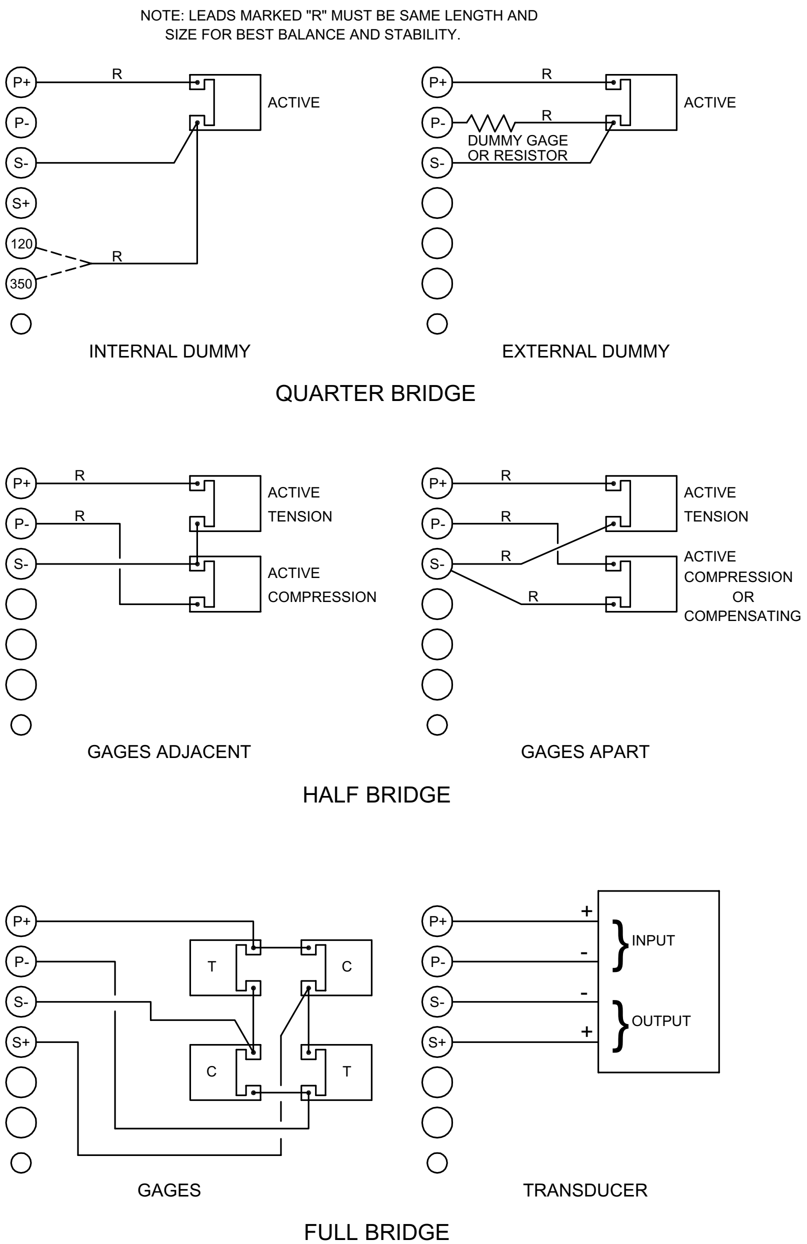


Fig. 1 — Input Connections

5.4 RUN — Green

Select the X1 or X10 MULT position as required and depress the RUN push button. In this position all internal circuitry is configured to make an actual strain measurement. Set the BALANCE range switch and rotate the BALANCE potentiometer to obtain a reading of ±0000 with no load on the test structure. **NOTE:** A reading of ±0000 with flashing colons indicates an off-scale condition that is usually caused by improper input wiring or a defective strain gage installation.

The test structure may now be loaded and the reading recorded.

5.5 CAL — Orange

The Model P-3500 incorporates shunt calibration resistors across the internal 120-ohm and 350-ohm dummy gages. The calibration resistors simulate 5000$\mu\epsilon$ at a gage factor of 2.000. If the dummy gage (quarter bridge) is being used, depress the CAL push button. If lead resistance is negligible, the displayed reading will be:

$$5000\mu\epsilon \text{ x } \frac{2.000}{\text{GF Setting}} \pm 0.05\%$$

NOTE: If unit has been modified to provide a 1000-ohm dummy (located at the 120-ohm binding post), R5 must be changed to 99 500 ohm to simulate 5000$\mu\epsilon$ on a 1000-ohm bridge.

The shunt calibration resistors can be changed by the user to a value other than 5000$\mu\epsilon$ if desired. These resistors are insertable into turrets on the bottom of the main PC board. (See Fig. 2 for details.)

When using quarter-bridge configuration, the CAL position can also be used in conjunction with the GAGE FACTOR control to compensate for leadwire resistance. This procedure is as follows:

(a) Depress CAL push button.

(b) Calculate $\frac{2.000}{\text{Pkg. Gage Factor}}$ x 5000$\mu\epsilon$ = calibration number.

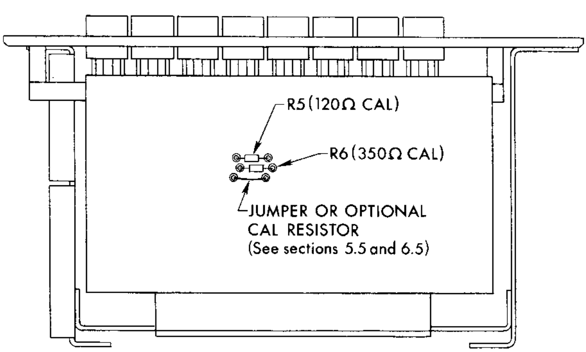


Fig. 2

(c) Adjust GAGE FACTOR control to give reading of calibration number.

(d) Lock GAGE FACTOR control in place.

The Model P-3500 is now compensated for leadwire resistance. This is essentially the same procedure as explained in ***5.3 Gage Factor — Orange***.

As previously noted (***3.6 CAL — Orange***), the Model P-3500 provides a contact closure at pins G and H of the transducer connector for use in implementing various calibration arrangements. If an alternate calibration arrangement is desired, these connections are wired through the transducer plug to the appropriate points. The calibration resistor may be located external to the Model P-3500 or it may be installed on the PC board as shown in Fig. 2. The location of the calibration resistors which shunt the dummy 120-ohm and 350-ohm gages is also shown in Fig. 2.

5.6 BR EXCIT OFF — Orange

If measurement appears noisy or unstable, depress BR EXCIT OFF push button. If the interference disappears, it is most likely of a mechanical or load-related nature. If the interference is still present, it is most likely of an electrical nature; i.e., induced electrical noise, poor grounding or thermally induced offsets.

Offsets (thermal or other) may be measured as follows:

(a) Set the coarse BALANCE switch to 0.

(b) Set the fine BALANCE potentiometer to exactly 5.00.

(c) Depress BR EXCIT OFF push button.

(d) The displayed reading is the result of the extraneous offset. (If remote-sense leads are being used, see ***6.6 CAL — Orange***.)

5.7 MULT (X10 — Yellow)

The MULT push button extends the measurement range of the instrument to ±199 990$\mu\epsilon$ when in the X10 position. The operator selects the desired range in accordance with the expected strain reading.

AMP ZERO and BALANCE adjustments must be made with the MULT push button in the X1 position.

5.8 BRIDGE (Full — Yellow)

The BRIDGE push button configures the internal circuitry for FULL or 1/4-1/2 operation. The operator selects the desired position in accordance with the bridge configuration currently in use.

In addition to providing transducer excitation voltage, and conditioning of the transducer output signal, the Model P-3500 incorporates specially designed remote-sense capability. The remote-sense circuitry varies the reference voltage to the A/D converter so as to give an accurate readout regardless of fluctuations in leadwire resistance. Remote-sense is activated by connecting pins J and K of the front-panel transducer plug to the plus and minus excitation terminals ***at the transducer***.

The Model P-3500 also provides a separate contact closure for remote shunt calibration. Wiring connections for the input connector are shown in Fig. 3.

If desired, transducers may be connected to the front-panel binding posts. However, remote-sense and remote calibration connections are accessible only at the transducer connector.

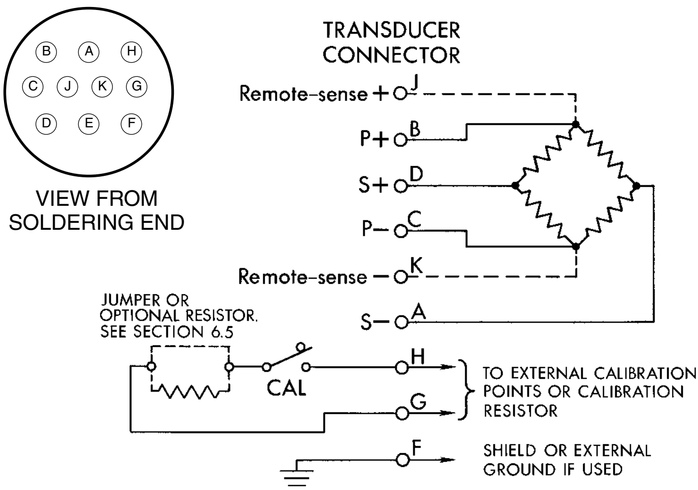


Fig. 3 — Transducer Input Plug Pin Arrangement and Wiring Connections.

6.1 INPUT CONNECTIONS — Transducer

Set the BRIDGE push button to the FULL position. Connect the transducer to the instrument using the input plug. Spare plugs may be ordered from the Vishay Micro-Measurements (see ***12.0 Replacement Parts***).

Remote-sense connections are available at pins J and K of the input connector. If remote-sense is not to be used, these connections are not completed.

A contact closure from the CAL push button is also accessible at the transducer input connector. A remote resistor can be connected in series with pin G or H to facilitate calibration of the transducer according to the transducer manufacturer's recommendations. It is also possible to install the calibration resistor on the Model P-3500 circuit board. (See Fig. 2 for details.)

6.2 AMP ZERO — Orange

Select the X1 MULT position and depress the AMP ZERO push button. Allow the instrument to warm up at least two minutes. Rotate the AMP ZERO fingertip control for a reading of ±0000.

6.3 GAGE FACTOR — Orange

When using transducers, the gage factor may be set to give a readout in engineering units. The appropriate gage factor setting is calculated as follows:

Sensitivity of transducer, $\frac{mV}{V}$

FS = full-scale rating of transducer expressed in engineering units (psi, pounds, etc.)

GF = gage factor to be set on Model P-3500

$$GF = \frac{4000 \times \frac{mV}{V}}{FS}$$

The usable gage factor range of the Model P-3500 is 0.500 to 9.900. At gage factors <1.000 the readings may appear somewhat more unstable due to the high resolution. Therefore, it is recommended that the highest gage factor consistent with the required resolution be used. The examples below illustrate this procedure.

Example 1: Transducer sensitivity, 3.60 mV/V

Full-scale transducer rating is 20 000 psi

$$GF = \frac{4000 \times 3.6}{20\,000} = 0.720$$

The setting of 0.720 will operate satisfactorily, but the reading may appear unstable due to the low gage factor setting.

If a resolution of 10 psi is acceptable, the gage factor may be set to 7.20 and the readout will be 2000 counts. The reading must be multiplied by ten to obtain the correct result in engineering units.

Example 2: Transducer sensitivity, 1.80 mV/V

Full-scale transducer rating is 500 psi

$$GF = \frac{4000 \times 1.80}{500} = 14.40$$

A gage factor setting of 14.40 is not possible with the Model P-3500. Therefore, the gage factor would be set to 1.440 and the display would indicate 5000 counts. The resolution is, therefore, 0.1 psi. If this resolution is not required, the MULT push button may be set to X10 and the readout will be 500 counts, with a resolution of 1 psi.

Table 1 shows gage factor settings for several popular transducer sensitivities. If the gage factor is set for a displayed reading of greater than 6.000, the range restrictions must be considered. (See ***2.0 Range and Display***.)

Calculate the gage factor setting for the transducer in use.

Depress the GAGE FACTOR push button. Set the GAGE FACTOR switch to the appropriate range.

Rotate the GAGE FACTOR control for the exact desired gage factor, and lock the control in place.

TABLE 1
GAGE FACTOR vs TRANSDUCER SENSITIVITY

FULL SCALE COUNTS	GF SETTING* Transducer Sensitivity in mV/V		
	1.5 mV/V	2.0 mV/V	3.0 mV/V
1000	6.000	8.000	12.000
1200	5.000	6.667	10.000
1500	4.000	5.333	8.000
2000	3.000	4.000	6.000
2500	2.400	3.200	4.800
3000	2.000	2.667	4.000
4000	1.500	2.000	3.000
5000	1.200	1.600	2.400
6000	1.000	1.333	2.000
7000	0.857	1.143	1.714
8000	0.750	1.000	1.500
9000	0.667	0.889	1.333
10 000	0.600	0.800	1.200
12 000	0.500	0.667	1.000
15 000	0.400	0.533	0.800
20 000	0.300	0.400	0.600

$$FS = \frac{4000 \times \frac{mV}{V}}{GF} \qquad GF = \frac{4000 \times \frac{mV}{V}}{FS}$$

*See ***6.3 Gage Factor — Orange*** for recommendations relative to gage factors of less than 1.000 or greater than 9.990.

6.4 RUN — Green

Depress the RUN push button. Rotate the BALANCE potentiometer for a display of ±0000. If necessary, adjust the BALANCE range switch to obtain this reading. **NOTE:** A reading of ±0000 with flashing colons indicates an off-scale condition that is usually caused by improper input wiring or a defective transducer.

6.5 CAL — Orange

As noted in ***6.1 Input Connections — Transducer***, a contact closure from the CAL push button is available at terminals G and H of the transducer connector. This feature will normally be used to implement shunt calibration of the transducer according to the transducer manufacturer's recommendation. The manufacturer will generally specify exactly how a specific value of shunt calibration resistor is to be connected. In some cases, the manufacturer may also supply leadwires, integral to the transducer assembly, which are to be used for this purpose. In any case, the transducer manufacturer's recommendations should be followed. The calibration resistor may be connected external to the Model P-3500 if desired, or in some cases where the Model P-3500 is essentially dedicated to the readout of a particular transducer, the calibration resistor may be installed on the PC board. (See Fig. 2 for details.)

6.6 BR EXCIT OFF — Orange

Depressing the BR EXCIT OFF push button removes excitation from the transducer. Any residual reading will be the result of thermal or electrical offsets in the system. If it is desired to measure such offsets, proceed as follows:

(a) Set coarse BALANCE switch to 0.
(b) Set fine BALANCE control to 5.00.
(c) Depress BR EXCIT OFF push button.
(d) The displayed reading is the result of the offset.

If remote-sense leads are connected, the displayed reading must be corrected by a factor directly related to the total resistance in the P+ and P– leadwires.

Example: Transducer is a 350-ohm full bridge with full-scale reading of 5000 psi.

Total resistance in P+ and P– leadwires is 8 ohms.

Displayed reading is 100 psi when BR EXCIT OFF push button is depressed.

Correction factor is $\frac{350 + 8}{350} = 1.023$

Actual equivalent offset = 100 x 1.023 = 102.3 psi.

This correction applies only to the measurement of thermal or other extraneous offsets with BR EXCIT OFF and REMOTE-SENSE leads connected. During a measurement procedure, all existing offsets are cancelled by the setting of the balance controls.

7.0 USE WITH SEMICONDUCTOR STRAIN GAGES

The Model P-3500 is not specifically intended for use with semiconductor strain gages. However, the versatility of the instrument will allow it to be used satisfactorily in many cases.

The gage factor for most semiconductor strain gages is between 50 and 200, and is beyond the immediate range of the Model P-3500 gage factor controls. However, when the MULT push button is set to the X10 position, the gage factor range is effectively multiplied by ten, giving a range of 5.000 to 99.00. In this case, the readout is directly in microstrain with a resolution of 1$\mu\epsilon$.

For gage factors greater than 99.00 the following procedure may be used:

(1) Set the MULT push button to the X10 position.

(2) Mentally divide the desired gage factor by 100 and set the GAGE FACTOR controls for this value. Example: The gage factor is 180. Set the GAGE FACTOR controls for 1.800.

(3) The readout is now directly in microstrain with a resolution of 0.10$\mu\epsilon$; i.e., the actual reading is the displayed reading divided by ten.

Note that the full-scale range of the instrument is now ±1999.9$\mu\epsilon$.

The range restrictions as specified in ***2.0 Range and Display***, apply to both the above cases. If the GAGE FACTOR control is set for a displayed gage factor greater than 6.000, this restriction must be considered.

The BALANCE range of the Model P-3500 will generally not be adequate for semiconductor strain gages. The user will sometimes find it desirable to provide external bridge completion components and external balance networks. Consult the semiconductor strain gage manufacturer for recommendations.

8.0 ANALOG OUTPUT

The Model P-3500 is equipped with an analog output accessible via the BNC connector on the front panel. The output level is 40 μV/$\mu\epsilon$ (or 40 μV/count if using transducers) when the output level control is set at minimum. This level can be increased to a maximum of 440 μV/$\mu\epsilon$ with output level set to maximum.

The analog output is intended primarily to allow monitoring of the signal using an oscilloscope or recorder. Bandwidth is dc to 4 kHz –3 dB.

The analog output level is always linearly related to the digital display. Therefore, it is possible to simulate any desired level of output for strain or transducer measurements by using the BALANCE control. Using this procedure, the balance controls are used to obtain a digital display of the desired reading. Subsequently, the ANALOG OUTPUT level control and/or the input level control of the external readout device are used to obtain the desired display on the external readout device. This procedure will work equally well with external oscilloscopes, strip chart recorders, digital voltmeters, peak reading voltmeters, etc.

9.0 OPTIONAL ACCESSORIES

9.1 AC ADAPTER

An ac adapter is available for operation from the ac power line. When the cord from the adapter is plugged into the front-panel connector of the Model P-3500, the internal battery pack is automatically disconnected. The bench-top style adapter (dc power supply) with an IEC-320 compatible line cord can be ordered using the Vishay Micro-Measurements Accessory Model Number shown below:

Adapter Input Voltage	Accessory Number
115/230V, 50/60 Hz	P-3500-A72

Note: If the batteries are not used for extended periods of time, or become discharged, they should be removed as a precaution to avoid *costly* battery-acid damage. (See paragraph 10.1.)

When the ac adapter is used, it is advisable to use a good quality ac line filter and/or isolation transformer. This practice will minimize ac line interference when making very low-level strain readings.

9.2 TRANSDUCER CONNECTOR

The input plug for mating to the transducer connector may be ordered from the Vishay Micro-Measurements or an electronic parts distributor.

Vishay Micro-Measurements Part Number	12X300515
Bendix	PT06A-12-10P(SR)

9.3 USE OF MODEL SB-10 WITH MODEL P-3500

The Vishay Micro-Measurements Model SB-10 Switch and Balance Unit can be used to switch up to ten separate channels to the Model P-3500 input terminals. This is accomplished by connecting the front-panel binding posts of the Model P-3500 to the corresponding front-panel binding posts of the Model SB-10.

Note: The operating characteristics of Vishay Micro-Measurements switch and balance units of earlier design, e.g., SB-1, SB-1L, and SB-1K, are generally the same as SB-10.

When using the Model SB-10 with the Model P-3500, the following considerations must be applied:

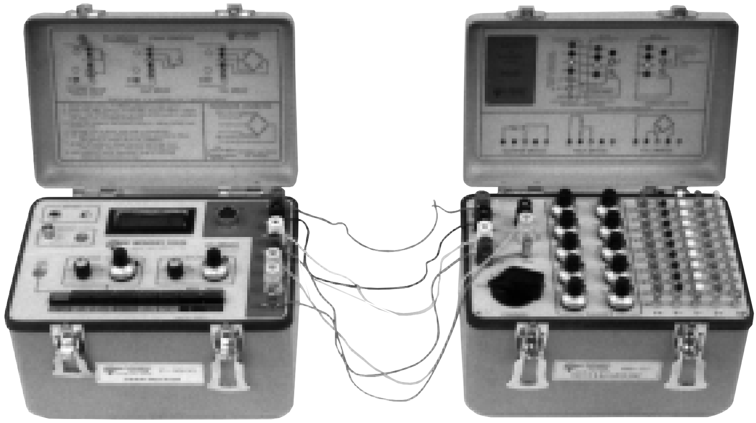
(a) When intermixing 120-ohm and 350-ohm quarter bridges, the interconnecting leadwire from the SB-10 “D EXT” terminal must be manually moved to the appropriate dummy binding post on the Model P-3500.

(b) When intermixing full bridges with half or quarter bridges, the BRIDGE push button on the Model P-3500 must be switched to the appropriate position for the respective input configuration.

(c) When using the Model SB-10, the coarse BALANCE switch of the Model P-3500 must be set to 0, and the fine BALANCE control of the Model P-3500 must be set to 5.00. The balance controls of the Model SB-10 are used for initial bridge balance.

Figure 4 shows the interconnections between the Model P-3500 and the Model SB-10.

NOTE: More detailed instructions for use of the Model SB-10 are given in the separate instruction manual supplied with that instrument.



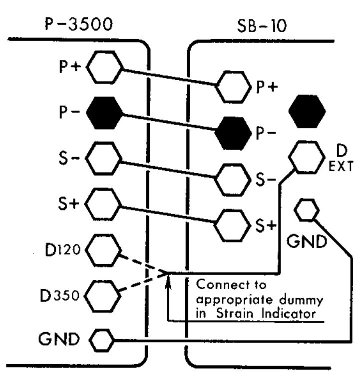


Fig. 4

10.0 MAINTENANCE AND CIRCUIT DESCRIPTION

10.1 BATTERY REPLACEMENT

Battery condition is monitored by the miniature front-panel meter when the Model P-3500 is "on". The pointer will normally indicate in the white region. When the pointer falls to the red/white transition, the batteries are approximately 90% depleted and should be replaced as soon as practical. To replace the batteries, proceed as follows:

(1) Remove the four screws from the bottom of the case and remove the instrument from the case.

(2) Place the battery compartment so that the two screws that retain the circuit board are accessible, and remove both screws.

(3) Note battery polarity. Remove old batteries and replace with new batteries. OBSERVE CORRECT POLARITY.

(4) Reassemble in the reverse order.

10.2 CIRCUIT DESCRIPTION

The following circuit description and the attached schematic diagram are intended to aid the technician in the diagnosis and repair of the Model P-3500.

10.2a POWER AND EXCITATION CIRCUITS

The Model P-3500 is powered from the 9 Vdc battery pack through the dc input connector J9. When the external ac adapter is used, it is also connected through J9 and the battery pack is automatically disconnected. Voltage from connector J9 is applied to the power switch, S1A. When S1A is on, voltage is applied to the front-panel battery indicator through R24 and CR1, and to the stable reference source U4. The output of U4 is 2.500V ±0.025V at TP1, and this output is used as a stable reference source for U5 and U6. U5 is a 723 type regulator that supplies +5 Vdc to all operational amplifiers. The output of U6 is adjusted by R30 for 2.000V at TP2. This voltage is the regulated P+ excitation supply for the instrument. The P– lead is connected to the negative side of the battery and to the chassis ground.

The +5V supply is also used to power the digital panel meter, Z1. The digital panel meter has a built-in positive-to-negative converter which provides –5 Vdc at pin A15. This converter is reinforced by another positive-to-negative converter, U3, which operates from the +5V supply. The –5 Vdc outputs from U3 and the digital panel meter are combined to provide the –5V supply for the operational amplifiers. (The –5V supply will actually measure –4.8 to –4.9V.) Capacitors C8, C9 and C10 are filter capacitors to reduce noise from the input power supply and the internal positive-to-negative converters.

10.2b BRIDGE COMPLETION AND CALIBRATION COMPONENTS

Bridge completion components R2 and R4, located on the bridge completion gage block, make up the 350-ohm internal half bridge. When half- or quarter-bridge operation is selected by S1-H, the center point of R2 and R4 is connected to S+. In the full-bridge position, this center point is disconnected and the half bridge has no effect on the operation of the instrument. R1 and R3 are the 120-ohm and 350-ohm internal dummy gages.

NOTE: Model P-3500's starting with serial number 83203 provide 1000 ohm quarter-bridge capability. For this mode, the 120-ohm dummy is converted to a 1000-ohm dummy by removing a shunt from a factory-installed Vishay 880-ohm precision resistor (R77) in series with the internal 120-ohm dummy gage (R1). To make this conversion, the user must cut a wire shunt parallel to R77. (See Fig. 5.)

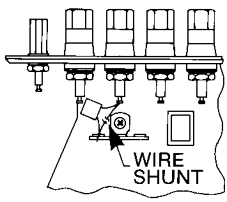


Fig. 5

R5 and R6 are internal shunt calibration resistors. These resistors are shunted across the internal dummy gages whenever the CAL switch is depressed. If desired, a calibration resistor may be connected through contacts G and H of the transducer connector. All calibration resistors are connected to turrets on the bottom side of the main switchboard, and can be easily changed by the user to accommodate specific requirements.

10.2c INPUT AMPLIFIER

The input amplifier consists of dual operational amplifier U1, and single operational amplifier U2. In the AMP ZERO mode, the inputs are connected directly together and to P– through R7 and R8. In this mode, AMP ZERO control R45 is adjusted for an exact ±0000 reading on the display.

Gain of the amplifier is determined by the setting of the MULT push button; R13 determines the gain on X1 setting; R14 determines the gain on X10 setting. U2 is the common-mode amplifier, and has a nominal gain of 1.12 to give an adequate overall adjustment range for the instrument. Potentiometer R21 is adjusted for maximum common-mode rejection at 60 Hz. The network composed of R24, R25, and R26 provides span adjustment of the instrument.

The output of the amplifier is applied to the input of the digital panel meter through the gage factor push button switch. This output is applied to the digital panel meter at all times except in the GAGE FACTOR mode.

10.2d GAGE FACTOR AND BALANCE

Excitation voltage is applied to an isolation amplifier consisting of U11A and U11B. The output of this amplifier is applied to the balance network consisting of R46 through R56. Switch S3 is the coarse BALANCE switch, and potentiometer R54 is the ten-turn fine balance control.

The outputs from the balance network are fed through two additional isolation amplifiers, U10A and U10B. The outputs of U10A and U10B are fed through R9, R10, R11 and R12 to the inverting inputs of the input amplifier. R42 is used to correct the output of the balance network for any offset voltages in U10 or U11. R45 is the front-panel AMP ZERO control.

The outputs of U11A and U11B are also applied to U11C. U11C removes any existing common-mode component so that the output of U11C is referenced to P– (battery negative and chassis ground). This output is used to drive the gage factor network consisting of R63 through R70 and the GAGE FACTOR control, R71. When the GAGE FACTOR push button is depressed, the full output from U11C is applied to the reference input of the digital panel meter.

The output from the wiper of GAGE FACTOR control R71 is applied to the analog-high input of the digital panel meter. The voltage level at the wiper of R71 is determined by the setting of GAGE FACTOR range switch S2, and the setting of the GAGE FACTOR control. The digital panel meter will indicate the gage factor with the decimal point properly positioned.

When any push button other than GAGE FACTOR is depressed, the reference input of the digital panel meter is fed from the wiper of the GAGE FACTOR control, and the analog-high input of the digital panel meter is fed from U2.

10.2e ANALOG OUTPUT

The analog output from the input amplifier is fed from the junction of R25 and R26 to the input of an active low-pass filter, U12. The output of U12 is fed to a non-inverting follower amplifier U13. The output of U13 can be adjusted over an 11 to 1 range by the front-panel control R74. The analog output appears at the front-panel BNC connector, J10.

11.0 ADJUSTMENT PROCEDURE

Adjustment of the Model P-3500 is most easily accomplished using the Vishay Micro-Measurements Model 1550A Strain Indicator Calibrator. A digital voltmeter with accuracy of approximately ±0.01% and a resolution of at least 100 μV on a 2V scale is also required.

The Model P-3500 is specified to a basic accuracy of ±0.05%. Since the Model 1550A is specified to an accuracy of ±0.02%, the tolerances outlined in the following procedure are reduced to ±0.03% to allow for the errors in a Model 1550A that meets its published accuracy specification.

If the Model 1550A is not available, other types of mV/V calibrators may be used. The user is cautioned, however, that it is necessary to understand both the mV/V calibrator, and the ratiometric nature of the measurement made by the Model P-3500, before attempting to adjust the instrument.

In the adjustments and checks to follow (and in normal instrument use), much care must be used when setting the GAGE FACTOR control, particularly when large readings are involved; this is because the resolution of the GAGE FACTOR *display* is finite: 1 in 2000 (0.05%) at a gage factor setting of 2.000. To check for accuracy and linearity, best results can be obtained by first trimming (if necessary) the GAGE FACTOR control to get the correct reading at the highest level to be tested prior to performing the checks. (In normal instrument use, shunt calibration can be used to obtain sufficient output level to set the span accurately.)

The following procedure assumes that there are no functional problems and the primary purpose is to perform basic dc adjustments and to verify proper operation of the instrument.

11.1 PRELIMINARY PROCEDURE

Remove the Model P-3500 from its case. Verify that the battery is in satisfactory condition, and that the instrument is functional in all basic operating modes.

Remove the battery pack by removing the four retaining screws in the side panels. Position the battery pack to permit access to the circuit boards.

Connect the 350-ohm section of the Model 1550A to the Model P-3500 binding posts in the full-bridge configuration. Use 20AWG [0.032 in *(0.813 mm)*] or larger wire diameter and keep all leads less than one foot in length. Set the Model 1550A to 350 ohm and the polarity to "+". In the following procedure, a reading from the digital voltmeter (DVM) is specifically referred to as "DVM reading". A reading from the Model P-3500 display is specifically referred to as "a reading of XXXX".

Locations of controls referenced in Fig. 6 are described on the next page.

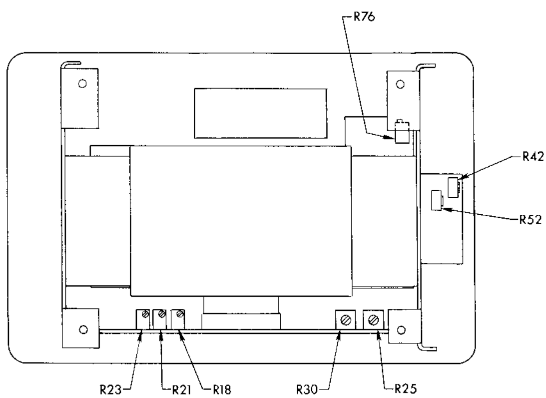


Fig. 6

11.2 EXCITATION

(a) Depress AMP ZERO push button.

(b) Connect DVM from P+ to P– terminals of Model P-3500.

Adjust R30 for DVM reading of 2.0000 ±0.1 mV.

11.3 ZERO ADJUSTMENTS

(a) Connect DVM from pin 1 to pin 7 of U10.

Set AMP ZERO control to mid-scale.

Adjust R42 for DVM reading of 0000 ±10 μV.

Remove DVM.

(b) Depress GAGE FACTOR push button.

Adjust GAGE FACTOR control for reading of 2.000.

Lock GAGE FACTOR control in place.

(c) Depress AMP ZERO push button.

Set MULT push button to X10.

Adjust R23 for reading of 0000 ±0.

(d) Set MULT push button to X1.

Adjust R18 for a reading of 0000 ±0.

(e) Repeat (c) and (d) until there is no change in reading when MULT is switched between X1 and X10.

(f) Connect DVM directly across Analog Output, J10.

Set MULT push button to X1.

Set OUTPUT level control to maximum CCW position.

Adjust R76 for a DVM reading of 0000 ±10 μV.

Remove DVM.

(g) Short the S+ to the S– binding post of the Model P-3500. (Leave the Model 1550A connected.) Use a 20 AWG [0.032 in *(0.813 mm)*] or larger wire diameter and tighten binding posts securely.

Depress RUN push button. Set BRIDGE push button to FULL.

Set BALANCE switch to 0 position.

Set BALANCE control to exactly 5.00 and lock in place.

Adjust R52 for a reading of 0000 ±1.

Remove S+, S– short.

11.4 SPAN ADJUSTMENTS

(a) Depress AMP ZERO push button. Adjust AMP ZERO control for a reading of 0000 ±0.

(b) Depress GAGE FACTOR push button. Verify that gage factor is exactly 2.000 by setting the GAGE FACTOR control to *exactly* halfway between the 1.999 and 2.001 transition. Lock GAGE FACTOR control in place.

(c) Set 1550A to 000$\mu\epsilon$.

(d) Depress RUN push button. Adjust BALANCE control for a reading of 0000 ±1. Lock BALANCE control in place.

(e) Set MULT push button to X1 position.

Set Model 1550A to 19 900$\mu\epsilon$.

Adjust R25 for a reading of 19 900 ±6.

(f) Set MULT push button to X10. Set Model 1550A to 60 000$\mu\epsilon$. Reading should be 6000 ±3.

(g) If the readings of (e) and (f) above do not track properly, it will be necessary to determine which gain position (X1 or X10) is too ***low*** and to increase that gain accordingly.

Pads are provided on the bottom of the PC board directly under gain-determining resistors R13 (X1) and R14 (X10). After determining which gain position is ***low***, connect a padding resistor across the appropriate gain-determining resistor. If a padding resistor is required, it will normally be in the 500K to 2 megohm range. Use only low-temperature-coefficient (<100 ppm/°C) resistors. After the gain is changed, repeat steps (e) and (f) until tracking is accurate.

11.5 FINAL CHECKS

(a) Set MULT push button to X1.

Perform the following checks:

Model 1550A Setting ($\mu\epsilon$)	**Reading**	**Tolerance***
0000	0000	±2
100	100	±2
500	500	±2
1000	1000	±2
5000	5000	±4
10 000	10 000	±5
19 000	19 000	±8

**Tolerances are computed to be ±0.03% reading ±2 counts.*

(b) Set MULT push button to X10.

Perform the following checks:

Model 1550A Setting ($\mu\epsilon$)	**Reading**	**Tolerance***
0000	0000	±1
20 000	2000	±2
40 000	4000	±2
60 000	6000	±3
80 000	8000	±3
90 000	9000	±4

**Tolerances are computed to be ±0.03% reading ±1 count.*

(c) Set MULT push button to X1. Set Model 1550A to 18 000$\mu\epsilon$.

Vary the gage factor settings as per the table below and check readings.

Gage Factor	**Reading $\mu\epsilon$**	**Tolerance***
2.000	18 000	±8
3.000	12 000	±6
4.000	9000	±5
6.000	6000	±4
8.000	4500	±3
9.000	4000	±3

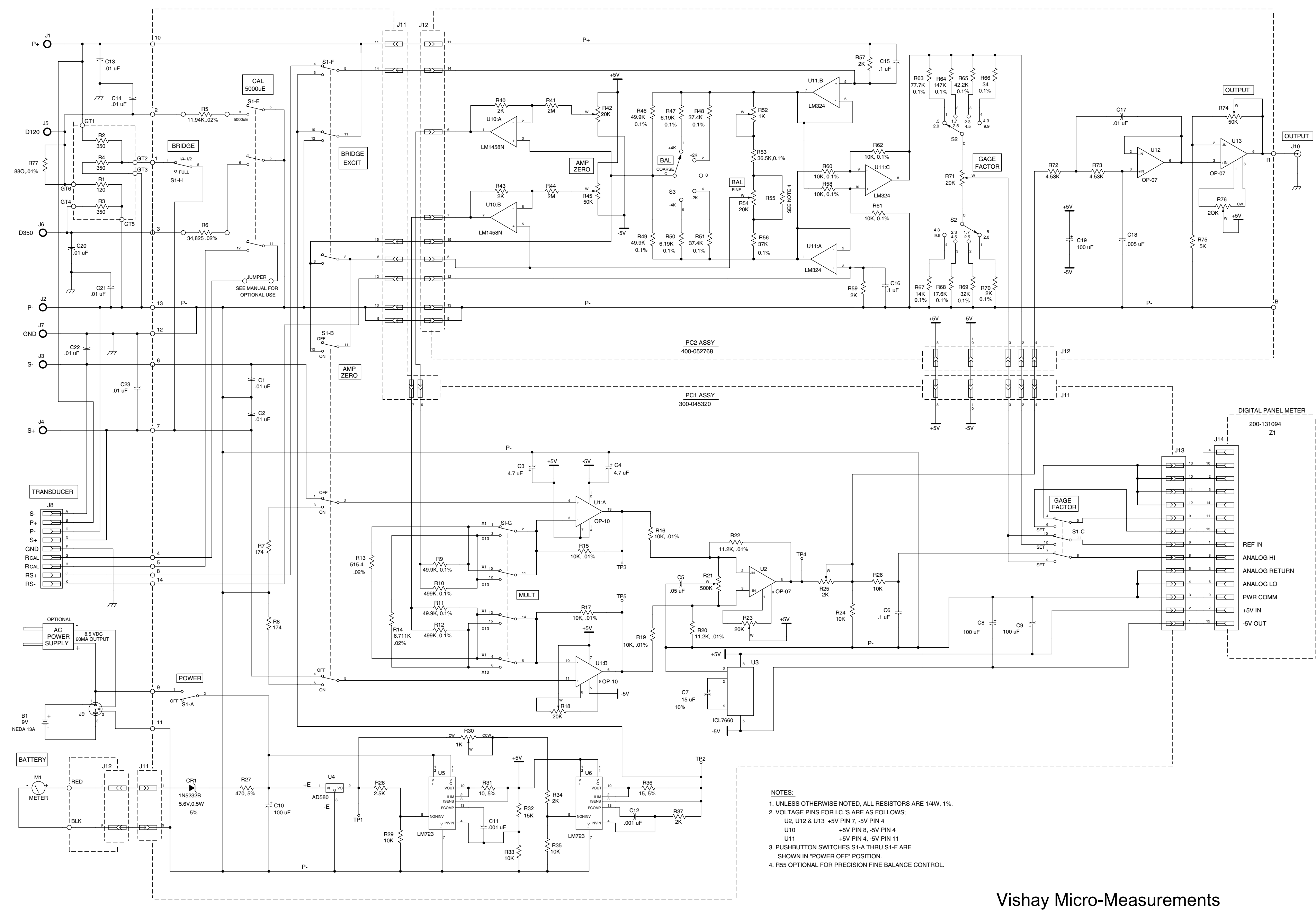
**Tolerances are computed to be ±0.03% reading ±2 counts.*

(d) Depress POWER push button. Disconnect Model 1550A. Reassemble instrument.

Schematic Designation	Description	MG Part Number
U1	Dual Matched Amplifier, LT1002ACN, Linear Technology	14X700100
U2, U12, U13	Amplifier, OP-07DP, Analog Devices	14X700087
U3	Voltage Converter, ICL7660CPA, Intersil	14X700101
U4	Voltage Reference, AD580JH, Analog Devices	14X700070
U5, U6	Voltage Regulator, LM723CN, National Semiconductor	14X700040
U10	Amplifier, LM1458N, National Semiconductor	14X700055
U11	Quad Amplifier, LM324N, National Semiconductor	14X700068
B1	Batteries, Alkaline D cells, NEDA 13A, Panasonic AM1 or equal (six required)	23X300001
Z1	LCD Digital Meter (standard replacement meter)	200-131994*
	LED Digital Meter Conversion Kit (converts to LED Display)	200-131398*
	Transducer Input Plug (male) Model P-3500-A50 Bendix PT06A-12-10P(SR)	12X300515
	AC Adapter, 115/230 Vac, 50/60 Hz without line cord	100-122261

*Part numbers for digital meters/kits are appropriate *only* for units with serial numbers above 55850.

If other replacement parts are required, they may be obtained by specifying the instrument model number, serial number, part description and schematic designation. Contact Vishay Micro-Measurements Applications Engineering if assistance is required.



Vishay Micro-Measurements

400-052775L

SCHEMATIC
DIGITAL STRAIN INDICATOR
P-3500

WARRANTY

Vishay Micro-Measurements, warrants all instruments it manufactures to be free from defect in materials and factory workmanship, and agrees to repair or replace any instrument that fails to perform as specified within three years after date of shipment. Coverage of computers, cameras, rechargeable batteries, and similar items, sold in conjunction with equipment manufactured by Vishay Micro-Measurements and bearing the identifying name of another company, is limited under this warranty to one year after the date of shipment. The warranty on nonrechargeable batteries and similar consumable items is limited to the delivery of goods free from defects in materials and factory workmanship. This warranty shall not apply to any instrument that has been:

i) repaired, worked on or altered by persons unauthorized by the Vishay Micro-Measurements in such a manner as to injure, in our sole judgment, the performance, stability, or reliability of the instrument;

ii) subjected to misuse, negligence, or accident;

or

iii) connected, installed, adjusted, or used otherwise than in accordance with the instructions furnished by us.

At no charge, we will repair, at our plant, or an authorized repair station, or at our option, replace any of our products found to be defective under this warranty.

This warranty is in lieu of any other warranties, expressed or implied, including any implied warranties of merchantability or fitness for a particular purpose. There are no warranties which extend beyond the description on the face hereof. Purchaser acknowledges that all goods purchased from Vishay Micro-Measurements are purchased as is, and buyer states that no salesman, agent, employee or other person has made any such representations or warranties or otherwise assumed for Vishay Micro-Measurements any liability in connection with the sale of any goods to the purchaser. Buyer hereby waives all rights buyer may have arising out of any breach of contract or breach of warranty on the part of Vishay Micro-Measurements, to any incidental or consequential damages, including but not limited to damages to property, damages for injury to the person, damages for loss of use, loss of time, loss of profits or income, or loss resulting from personal injury.

Some states do not allow the exclusion or limitation of incidental or consequential damages for consumer products, so the above limitations or exclusions may not apply to you.

The Purchaser agrees that the Purchaser is responsible for notifying any subsequent buyer of goods manufactured by Vishay Micro-Measurements of the warranty provisions, limitations, exclusions and disclaimers stated herein, prior to the time any such goods are purchased by such buyer, and the Purchaser hereby agrees to indemnify and hold Vishay Micro-Measurements harmless from any claim asserted against or liability imposed on Vishay Micro-Measurements occasioned by the failure of the Purchaser to so notify such buyer. This provision is not intended to afford subsequent purchasers any warranties or rights not expressly granted to such subsequent purchasers under the law.

The Vishay Micro-Measurements reserves the right to make any changes in the design or construction of its instruments at any time, without incurring any obligation to make any change whatever in units previously delivered.

The Vishay Micro-Measurement's sole liabilities, and buyer's sole remedies, under this agreement shall be limited to the purchase price, or at our sole discretion, to the repair or replacement of any instrument that proves, upon examination, to be defective, when returned to our factory, transportation prepaid by the buyer, within the applicable period of time from the date of original shipment.

Return transportation charges of repaired or replacement instruments under warranty will be prepaid by Vishay Micro-Measurements.

The Vishay Micro-Measurements is solely a manufacturer and assumes no responsibility of any form for the accuracy or adequacy of any test results, data, or conclusions which may result from the use of its equipment.

The manner in which the equipment is employed and the use to which the data and test results may be put are completely in the hands of the Purchaser. Vishay Micro-Measurements, shall in no way be liable for damages consequential or incidental to defects in any of its products.

This warranty constitutes the full understanding between the manufacturer and buyer, and no terms, conditions, understanding, or agreement purporting to modify or vary the terms hereof shall be binding unless hereafter made in writing and signed by an authorized official of Vishay Micro-Measurements.