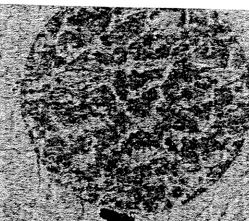
MODEL P–350A



DIGITAL STRAIN INDICATOR

INSTRUCTION MANUAL

VISHAY INSTRUMENTS

A DIVISION OF VISHAY INTERTECHNOLOGY, INC.

63 Lincoln Highway, Malvern, Pennsylvania 19355 ■ (215) 647-5115

INSTRUCTION MANUAL

MODEL P-350A

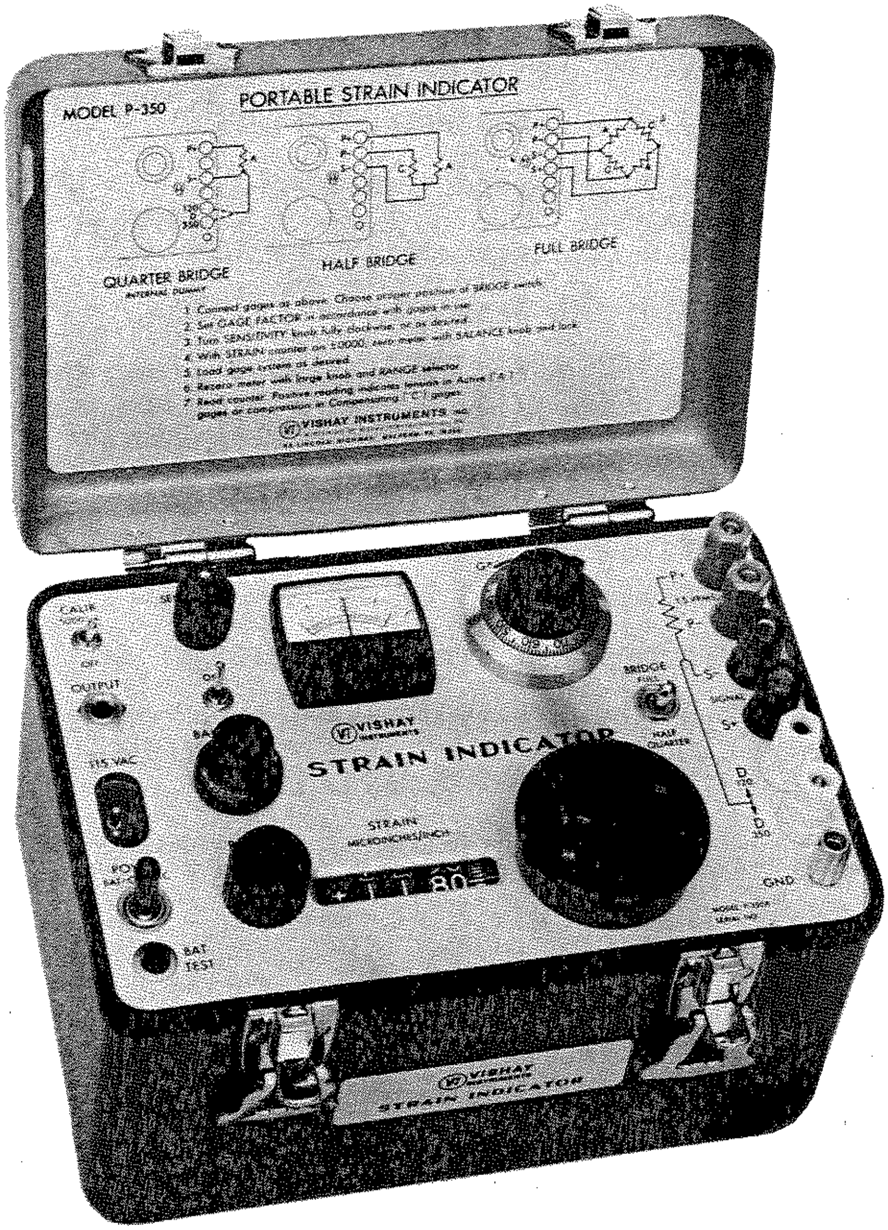
DIGITAL STRAIN INDICATOR

WARRANTY

Vishay Instruments warrants the P-350A to the original purchaser to be free from defects in material and workmanship and to operate within Vishay's specifications for two years from date of shipment under normal conditions of use.

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

August 1973


MODEL P-350
PORTABLE STRAIN INDICATOR
QUARTER BRIDGE
HALF BRIDGE
FULL BRIDGE
VISHAY INSTRUMENTS
OUTPUT
115 VAC
BAT TEST
BRIDGE
STRAIN INDICATOR
STRAIN
GND
STRAIN INDICATOR

1.0 GENERAL DESCRIPTION

The P-350A Digital Strain Indicator is designed primarily for use with resistance-type strain gages or strain gage devices to determine numerically the strain (and thus stress) in a structure or the output of a transducer.

1.1 The P-350A employs the null-balance principle: The operator must center a null galvanometer prior to reading a mechanical digital display. The instrument uses a 1000 Hz carrier; bridge excitation, rebalance circuitry and the null amplifier all operate at this carrier frequency.

1.2 While the P-350A by itself will accept only one input (quarter, half or full bridge), it can be used as the central indicator for a multiple-channel static strain gage data acquisition system when used with Switch and Balance Units; each of the several inputs are manually selected in a sequential manner to obtain the outputs of all channels.

1.3 The principal features of the P-350A are:

...Direct-reading in-line digital display, including sign, to ±49,999με.

...Built-in initial balance control so that the no-load reading is 0000.

...Completely portable: lightweight and rugged, with both self-contained battery and line operation possible with the standard instrument.

...Built-in 120Ω and 350Ω dummies for true quarter bridge operation.

...Wide-range Gage Factor control: 0.10 to 10.0

...Internal shunt-calibration to verify instrument calibration and correct for lead-wire desensitation on quarter bridges, even when the lead resistance is not known.

1.4 The P-350A supercedes the original P-350; normal operation is identical although the following features have been added.

(a) 115 VAC option now standard.

(b) Internal shunt-calibration (5000$\mu\varepsilon$) on quarter bridges.

(c) On-off control on initial BALANCE.

(d) Improved bandpass on 'Scope OUTPUT.

2.0 SPECIFICATIONS

2.1	RANGE & DISPLAY	±50,000 microstrain (με): 10,000με on the primary balance knob. Polarity and range extension on the range extender knob. Total reading in single digital display.
2.2	SENSITIVITY	Variable: Null meter deflects from zero to full scale with 40 to 4000με (nominal at GF=2).
2.3	READABILITY	1με.
2.4	ACCURACY	±0.1% of reading or 5με, whichever is greater, for R=120Ω and GF=2. ±0.3% of reading or 5με, whichever is greater, for R=120Ω, GF=1.5-4.5. ±0.5% of reading or 5με, whichever is greater, for R=50-2000Ω, GF=1.5-4.5.
2.5	CALIBRATION	Self-contained shunt-calibration across internal 120Ω and 350Ω dummy gages. Simulates +5000με (±0.1%) on quarter bridge operation regardless of lead-wire resistance (GF=2).
2.6	INPUT CURCUITS	50-2000Ω half or full bridge; internal dummy gage provided for 120Ω and 350Ω 3-wire quarter bridges.

		All bridge completion resistors are standard self-temperature-compensated strain gages bonded to 2024 aluminum.
2.7	BALANCE	10-turn lock knob provides approximately ±2000 microstrain (GF=2, quarter and half bridge or 120Ω full bridge) for zeroing the digital readout prior to load application. On-off switch provided.
2.8	BRIDGE EXCITATION	1.5 volts RMS, 1000 Hz square wave.
2.9	LEAD WIRE CAPACITANCE EFFECT	Typically less than .05% loss of accuracy with .005 microfarads. Negligible effect with 500 feet of lead wire.
2.10	AMPLIFIER	AC transistorized.
2.11	GAGE FACTOR	Continuously variable from 0.10 to 10.00 (calibrated between 1.50 and 4.50 only).
2.12	OSCILLOSCOPE OUTPUT	Linear range ±250 mv DC. Sensitivity variable from approximately 0.2 to 20 $\mu\varepsilon$/mv Bandpass approx. DC to 60 Hz (±5%).
2.13	GALVANOMETER OUTPUT	Full scale ±1/2 ma unfiltered DC. Sensitivity variable from approximately 80 to 8000$\mu\varepsilon$/ma.

2.14	POWER	Internal batteries: 9V (6 "D" cells). Life approx. 200 hrs. External Power: 105-125V 50-60 Hz standard. (210-250V optional)
2.15	CASE	Aluminum - dust and spray tight.
2.16	SIZE & WEIGHT	9 x 6 x 6 inches [230 x 150 x 150 mm] 7.5 pounds [3.4 kg] including batteries.

3.0 DESCRIPTION OF CONTROLS

3.1	CALIB Switch	Shunts both the 120Ω and 350Ω internal dummies to read 5000με at GF=2. Thus can be used either to verify instrument accuracy or to compensate for lead-wire desensitization on quarter bridge operation.
3.2	OUTPUT Jack	Two DC outputs available; requires 3-circuit plug (provided). "Shank" connection used as ground return for both. Disconnects Null Meter when used. Scope output ("ring" connection): Provides filtered DC for observing dynamic signals with high-impedance scope or recorder (source impedance 7,000Ω). Linear range 0±250 millivolts with sensitivity variable (using SENSITIVITY Control) from approx. 0.2 to 20 mv/με. Noise and ripple approx. 3με + 1mv. Flat ±5% DC to 60 Hz. Galvo output ("tip" connection): Provides unfiltered DC current to an external null meter or oscillograph galvanometer. (Meter must highly reject 1kHz carrier components.) Suggested external meter: ±1/2 ma, 100Ω resistance. SENSITIVITY control adjusts sensitivity from approx. 0.08 to 8με/μa.

3.3	115 VAC Receptacle	Receives the female end of the detachable 3-wire line cord. (Not used on BAT operation.)
3.4	POWER Switch	The only On-Off switch on the instrument. Pushed to the left, the instrument will operate on the internal battery. Pushed to the right, it will operate on the AC power supply. On battery operation, the unit is automatically shut off when the lid is closed.
3.5	BAT TEST Pushbutton	With the POWER switch on BAT, depressing this pushbutton will deflect the Null Meter to indicate battery condition. Although a weak battery does not directly affect accuracy, the Null Meter may become somewhat insensitive.
3.6	SENSITIVITY Control	A gain control for the amplifier driving the Null Meter. The control can vary the sensitivity of the meter by a factor of approx. 100:1. Normally this control is turned fully clockwise to yield a Null Meter sensitivity of approximately 40 microstrain full-scale in either direction. At lower settings of the control the Null Meter itself can be used for direct strain

readout of static or dynamic signals up to 1 Hz.

The SENSITIVITY Control is also used in conjunction with the OUTPUT jack for true dynamic measurements.

3.7	BALANCE Switch	Used to disconnect the initial BALANCE circuit if desired. Usually kept in ON position.
3.8	BALANCE Control	Used to compensate for the initial unbalance in a gage circuit (up to 2000με) to read 0000 at no load. Subsequent readings then are direct-reading "Indicated Strain". The control should be locked after adjusting on a given strain gage installation.
3.9	RANGE EXTENDER	Used to change sign (for tension or compression readings) and to extend the range of the STRAIN counter in increments of 10,000με.
3.10	Null Meter	A zero-center galvanometer used to determine instrument balance in adjusting the BALANCE and Rebalance knobs. Normally all readings are taken with the pointer on "0", although other applications exist (see paragraph 3.6). It is also used to check the condition of the internal battery.

3.11	Rebalance Knob & STRAIN Counter	Used to bring the Null Meter to "0" in making a strain measurement - the Counter then displays the strain in micro-inches per inch (microstrain or $\mu\varepsilon$). The knob mechanism has a range of 10,000 micro-strain. The basic calibration assumes a single active strain gage.
3.12	GAGE FACTOR Dial	A 10-turn locking control used to set the appropriate Gage Factor. This control can be varied from nominally 0.10 to 10.00.
3.13	BRIDGE Selector	Used to switch the internal dummy half bridge into the circuit for quarter and half bridge applications.
3.14	Binding Posts	For attachment of lead-wires to the strain gage(s) or transducer. The hook-up for a single gage is marked on the panel. Other typical arrangements are shown on a brief instruction plate attached to the inside of the instrument cover.

4.0 OPERATING PROCEDURE

4.1 Static Measurements ("Null Balance"):

4.1.1 Connect the gage(s) as shown on the plate inside the lid.

4.1.2 Select the proper position of the BRIDGE selector, FULL OR HALF/QUARTER.

4.1.3 Set the GAGE FACTOR dial as desired for the particular gage and/or application and lock. (On quarter bridge operation, the CALIB switch use is described in Section 4.4.)

4.1.4 Turn the SENSITIVITY knob fully clockwise (for maximum meter sensitivity).

4.1.5 Turn the large rebalance knob counterclockwise to a STRAIN counter reading of "0000".

4.1.6 Turn the RANGE EXTENDER knob to "+" (without digit).

4.1.7 Push the POWER switch to BAT or AC. The latter will require installation of the 115 VAC line cord.

4.1.8 Turn toggle switch above the BALANCE Control to ON.

4.1.9 With a No-Load condition on the test specimen turn the BALANCE knob to null (zero) the Null Meter (clockwise to move the pointer to the right). Lock the knob.

> If it is impossible to null the Meter using the BALANCE Control, lock the control in any position and use the large Rebalance knob to obtain the null in accordance with paragraph 4.1.11. Record the STRAIN Counter sign and reading of this NO-LOAD condition. Resume instructions with paragraph 4.1.10.

4.1.10 Load the test specimen as desired.

For the procedures that follow it is assumed that the Null Meter has been nulled with the strain counter at +0000 prior to the application of a load.

4.1.11 Meter deflects left: Rotate the large Rebalance knob clockwise until the Meter comes to null. Read the STRAIN counter and sign.

> If the Meter remains to the left at full counter reading, rotate the RANGE EXTENDER knob clockwise until the Meter pointer moves to the right, then rotate the large Rebalance knob counterclockwise to null.

Meter deflect right: turn the RANGE EXTENDER switch counterclockwise until the Meter pointer moves to the left. Then rotate the large Rebalance knob clockwise to obtain a Meter null. Read the STRAIN counter and sign.

4.1.12 The STRAIN Counter reading (meter nulled) is the "Indicated Strain." A "+" quantity indicates tension in the "Active" gages, a "-" quantity indicates compression.

> For those No-Load cases where the Null Meter could be nulled only by use of the large Rebalance knob, a pretest STRAIN counter sign and reading were obtained for zero load. The test load should now be applied and the Meter nulling procedures repeated using the Rebalance knob. Under these conditions, the "Indicated Strain" is determined from the following with due regard to signs:
>
> Indicated Strain = (Final Reading) - (No-Load Reading).

4.2 Low-Frequency Measurements (Static to 1 Hz)

Occasionally there are situations in which a strain level is fluctuating at a slow rate, but too rapidly for an operator to maintain null on the Null Meter. In these cases a simple technique is available to obtain data without additional equipment. (Accuracy better than 5 percent.)

4.2.1 Under static conditions (by use of a separate gage installation, if static output of active gage cannot be achieved), turn the SENSITIVITY Control to approximately 10 o'clock position.

4.2.2 Bring the Null Meter to exact null with the initial BALANCE and/or large Rebalance knobs. Note the

STRAIN reading and sign.

4.2.3 Rotate the Rebalance knob (in either direction) that number of microstrain from the noted reading which you desire to represent full scale on the Meter (usually a round number, such as 500).

4.2.4 Adjust the SENSITIVITY Control so that the Meter deflects precisely to the full scale mark.

4.2.5 Return to the original STRAIN Counter setting and re-zero using the BALANCE Control, if necessary.

4.2.6 If readjustment was necessary in 4.2.5, return to the full scale setting and refine the SENSITIVITY Control to give an exact full scale indication.

4.2.7 The Null Meter is now calibrated so that strain readings can be taken directly from the Null Meter (in the example, each meter division now represents 50 microstrain). The strain level representing zero meter deflection (needle pointing at "0") can be adjusted with the Rebalance knob.

This system is limited to frequencies of less than 1 Hz because of meter damping and visual limitations.

4.3 Dynanic Measurements (Static to 60 Hz)

For higher frequency dynamic measurements the Portable Strain Indicator is used in conjunction with an oscilloscope or high-input-impedance oscillograph. The approximate frequency response of the scope OUTPUT is shown on the following page. Note that the indicated output is about one-half the true strain at about 350 Hz; the general usefulness of this output for frequencies above 100 Hz will depend on the nature of the test.

Since the source impedance of the scope OUTPUT is approximately 7,000 ohms, it is recommended that the oscilloscope or oscillograph input impedance be above 100K, preferably 1 megohm.

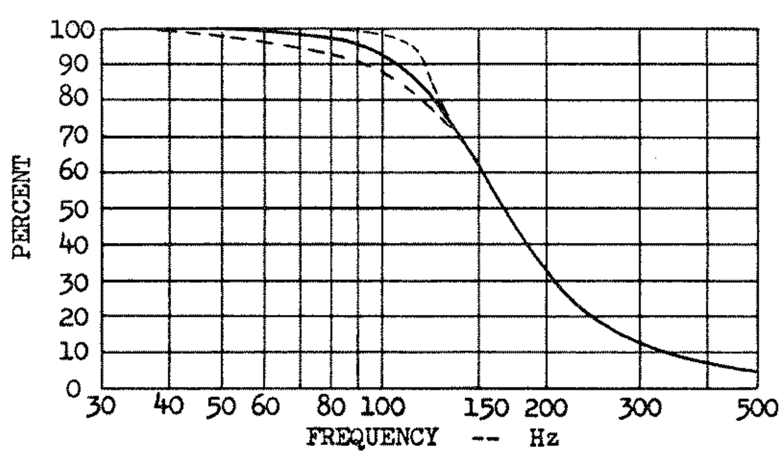
Connections: Using the standard 3-circuit plug provided, connect the scope ground to the "shank" connection and the signal input to the "ring" connection.

While the maximum output of the scope OUTPUT is approximately ±500 millivolts, it preferably should be used to only ±250 millivolts to maintain good linearity (approx. ±2%).

Depending on the setting of the SENSITIVITY Control, the scale factor for the scope OUTPUT can be varied from approximately 0.2 to 20 microstrain per millivolt. This range provides adequate flexibility for measuring low or high amplitude dynamic strains.

The output can be used for measuring small dynamic strains superimposed on large static strains. In this case the static level is balanced out with the Indicator using the large Rebalance knob and RANGE EXTENDER until the dynamic trace of the strain is displayed symmetrically about the zero DC output level of the Scope OUTPUT.

Calibration of the scope OUTPUT can be achieved with either shunt calibration across the active strain gage(s) or by use of the large Rebalance knob on the Indicator. Shunt calibration is somewhat more accurate but not as convenient.



P-350A Oscilloscope Output Frequency Response

4.4 CALIB Circuit

The internal calibration circuit only functions when using the internal dummy on 120Ω or 350Ω on quarter bridge operation.

It can be used to (1) verify instrument calibration, (2) accurately set the GAGE FACTOR Control over a range of 0.2 to 10.0, and (3) compensate for lead-wire desensitization on quarter bridge operation, even when the lead resistance is not known.

4.4.1 Instrument Calibration

a. Connect any accurate (±0.1% or better) non-inductive 120Ω or 350Ω strain gage or resistor in standard quarter-bridge manner. Lead resistance must be negligible (less than 0.05Ω, 0.02Ω preferable).

b. Set GAGE FACTOR at exactly 2.000.

c. With STRAIN counter at +0000, adjust initial BALANCE Control as usual.

d. Turn CALIB Switch On.

e. Turn large Rebalance Knob to obtain null. Reading should be +5000 ±5 at 75°F.

Note: With a perfect external circuit, the tolerance of internal components should yield a reading of ±1με. However, the span of the P-350A is adjusted to "bracket" errors as best as possible over the range of the instrument. Conceivably it could have been set to read +5με at 5000με because other readings tended to be negative up to 0.1%. Thus a relatively large error at +5000με does not necessarily mean that the instrument is not properly calibrated.

4.4.2 To accurately set GAGE FACTOR.

Due to inherent linearity limitations on the GAGE FACTOR Control, settings other than 2.000 cannot be guaranteed very precisely; this is especially true below 1.500. The following procedure is independent of potentiometer linearity.

a. Connect any accurate (±0.1% or better) non-inductive 120Ω or 350Ω strain gage or resistor in standard quarter bridge manner. Lead resistance must be neglibible (unless the circuit is the one to be tested - in which case this procedure eliminates the effect of this lead resistance).

b. Set GAGE FACTOR at approximately the desired value.

c. With the STRAIN counter at +0000, adjust initial BALANCE Control as usual.

d. Turn CALIB Switch On.

e. Set STRAIN counter at calculated value:

$$\text{STRAIN} = \frac{10{,}000}{\text{GF}} \qquad (4\text{-}1)$$

f. If Null Meter is not at "0", adjust GAGE FACTOR Control slightly to get "0". Lock GAGE FACTOR.

g. Turn CALIB Switch OFF.

4.4.3 To compensate for lead wire resistance:

As discussed in paragraph 6.2.1, even modestly long lead wires can affect the accuracy of strain measurements. The traditional solution is, knowing the lead-wire resistance, to calculate a special "Gage Factor" for the instrument. The unique CALIB circuit in the P-350A provides a variant of this procedure for which the lead-wire resistance need not be known: it is only applicable on quarter bridge circuits using the internal dummies provided.

a. Connect the gage to the P-350A as usual (3-lead circuit).

b. With the STRAIN counter at +0000, adjust initial BALANCE as usual.

c. Turn CALIB Switch On.

d. Set STRAIN counter at exactly +5000$\mu\varepsilon$.

e. Adjust GAGE FACTOR CONTROL to center the Null Meter.

f. Read GAGE FACTOR Control and calculate deviation from 2.000.

g. Apply this calculated deviation to the Gage Factor on the strain gage package; set this new value into the GAGE FACTOR control and perform the desired tests.

   Example: In (f) above, reading was 1.965,
   or a deviation of -0.035.
   Suppose GF from package was 2.080;
   Set GAGE FACTOR at:
   2.080 - 0.035 = 2.045

4.5 Detachable Cover

The instrument as supplied is equipped with hinges which will allow removal of the cover. To effect removal, bend the open-sided portion of the cover hinge upwards far enough to clear the center section of the body hinge. If you prefer a permanently attached cover, please disregard these instructions.

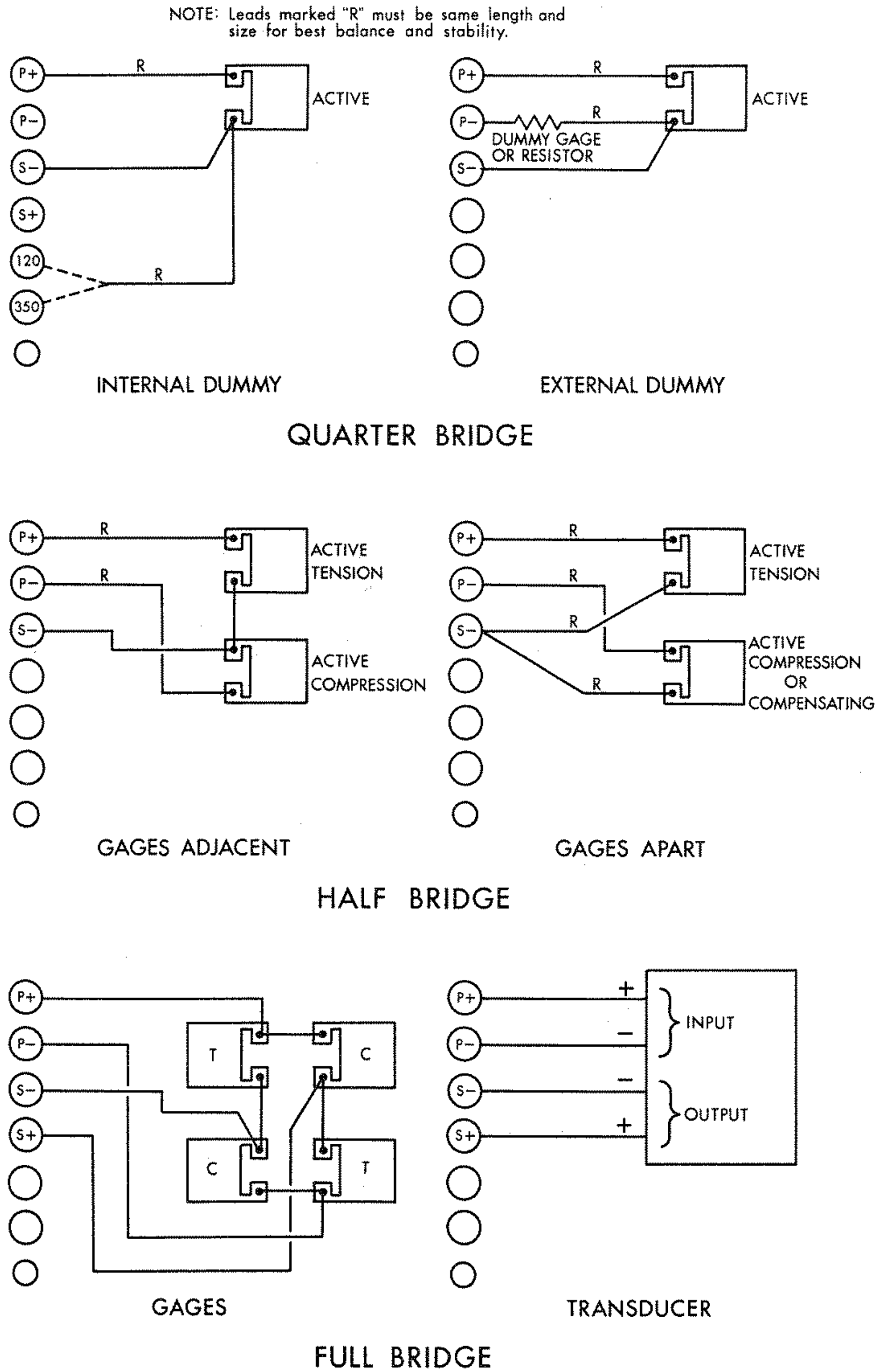


FIGURE 1: INPUT CONNECTIONS

5.0 INPUT CONNECTIONS

5.1 The P-350A readily adapts to various bridge circuits, but it is important to note that a basic condition for proper operation requires that the instrument must always have a four-arm bridge (internal or external) at the input and this bridge must have certain symmetry. Some forms of this bridge are theoretically linear but most are non-linear, although the non-linearity can usually be neglected.

The most common forms of bridge hook-up for strain measurements are shown in Figure 1.

5.2 In quarter bridge (single gage) operation good strain gage practice dictates the use of the three-wire circuit. However, the P-350A can be used with two-wire circuits: Short together terminals S- and D at the Indicator.

Due to the high temperature coefficient of resistance of copper wire, ambient temperature changes on the lead wires can give a large false indication of strain when only two lead wires are used. (Using 10 feet [3 meters] of twisted-pair AWG #30 [0.25 mm dia.] wire to a 120Ω gage, the apparent zero could shift almost 200 microstrain for a 10°F [5.6°C] change. Even using AWG #20 [0.81 mm dia.] wire in this situation, the shift would be about 18$\mu\varepsilon$.) The recommended three-wire system puts half of the temperature-induced lead wire resistance change in series with the dummy gage while the other half remains in series with the active gage. Equal changes in lead resistances in these adjacent arms then do not effect the strain measurement.

The best approach is to get in the habit of ALWAYS using three leads -- don't guess it doesn't matter in a particular test and then get erratic data.

5.3 For quarter bridge operation it is suggested that the Strain Indicator be at approximately the same ambient temperature as the active gage and test structure. This is because the "dummy" gage in the Indicator is also a standard strain gage and produces the normal apparent strain (due to non-ideal temperature compensation.) For "room temperature" testing between 60° and 100°F [15° and 40°C], the residual apparent strain caused by a temperature difference between the "active" and "dummy" gages can generally be neglected, but where either gage is below 60°F [15°C], best zero stability will be achieved by either (1) being certain that both the active gage and Indicator are close to the same temperature or, (2) use of a true unstrained "compensating" gage in the environment of the active gage.

6.0 GAGE FACTOR EQUATIONS

6.1 Definition - Gage Factor is a term used to relate the electrical sensitivity of a strain gage to strain; specifically it is the percent change in resistance for a percent change in length (or "strain"). For example, a GF of 2.00 means the gage changes 2 micro-ohms per ohm of initial resistance for a strain of 1 microinch per inch. Generally, the GAGE FACTOR dial on the Indicator should be set at the exact Gage Factor given by the manufacturer for the particular gage in use.

6.2 The GAGE FACTOR dial can be used to compensate for certain situations not directly defined as Gage Factor.

6.2.1 DESENSITIZATION

Care must be taken in strain gage work to avoid excessively long fine-gage lead wires. The resistance of the leads appear in the strain gage bridge and this resistance does not change with strain. As a result the overall bridge circuit is desensitized. The following equation can be used to compute a corrected gage factor taking this desensitization into consideration:

$$GF_i = \left(\frac{R_g}{R_L + R_g}\right) GF \qquad (6\text{-}1)$$

where: GF_i = the corrected "GAGE FACTOR" to be used on the Indicator

R_g = the nominal gage resistance

R_L = the lead-wire resistance (see below)

GF = the original gage factor (from package)

For a two-wire quarter bridge installation, R_L is the total lead-wire resistance; but for three-wire quarter bridge circuits it is the resistance of <u>one</u> lead only.

NOTE: An alternate procedure to calculate GF_i using the CALIB circuit on the P-350A is given in Paragraph 4.4.3.

6.2.2 HALF BRIDGE CORRECTION

The GAGE FACTOR dial can also be used in Half Bridge circuits where a "Compensating" gage is placed at right angles to the "Active" gage in a uniaxial stress field. In this situation the "Compensating" gage will be partially active due to Poisson's Ratio and will cause the Indicator to read higher strains. The following equation can be used to compute the composite gage factor:

$$GF_c = GF\ (1 + \mu) = GF_i\ (1 + \mu) \qquad (6\text{-}2)$$

where: GF_c = the COMPOSITE "GAGE FACTOR" to be used on the Indicator.

GF and GF_i = (defined in equation 6-1)

μ = Poisson's Ratio for the particular material on which the gage(s) are installed (typically 0.25 to 0.35 in metals)

6.2.3 CANTILEVER COMPENSATION

If there are two gages in a half bridge configuration bonded to opposite sides of a cantilever beam, the Indicator will read twice the strain seen by either gage. To determine the single average strain of one side, the Indicator reading may be divided by 2, or, alternately, the "Composite Gage Factor", GF_c may be used:

$$GF_c = GF \times 2 \qquad (6\text{-}3)$$

In this case the instrument will then read directly the average strain indicated by each gage. Symbols are defined as above.

6.2.4 FULL BRIDGE CORRECTION

In full-bridge circuits GF_c may be calculated for four active arms (double value from 6.2.2) or for two right angle pairs (double value from 6.2.3).

6.2.5 TRANSDUCER READOUT

Using transducers, the span is generally expressed in "millivolts per volt". This is the output in millivolts for an input of 1 volt at full rated mechanical input.

The corrected gage factor for direct transducer readout is computed as follows:

$$GF_T = 4000 \frac{k}{T_R} \qquad (6\text{-}4)$$

where: GF_T = the Transducer GAGE FACTOR to be used on the Indicator

4000 = a constant

k = the transducer sensitivity in mv/v

T_R = Transducer Rated capacity (pounds, psi, etc.)

Set GF_T, calculated above, to three significant figures on the GAGE FACTOR dial in the range from 0.10 to 9.99. Make the appropriate decimal placement at readout.

EXAMPLE:

Transducer: A 200,000 pound tension link with a 2 mv/v output at rated full load.

$$GF_T = 4000 \frac{k}{T_R}$$

$$GF_T = 4000 \frac{2}{200,000}$$

$$GF_T = 0.04$$

Therefore, either 0.40 or 4.00 could be set on the GAGE FACTOR dial and the STRAIN Counter reading multiplied by 10 or 100 respectively to yield pounds directly. Using GF_T = 0.40, full load would give a STRAIN counter indication of 20,000, giving best sensitivity and readability. Using GF_T = 4.00, full load indication is 2000 counts.

The corrected gage factor for direct transducer readout can also be experimentally determined; the following method may be found more accurate since it does not depend on exact linearity of the GAGE FACTOR Control:

With the transducer installed in an experimental apparatus and connected to the P-350A adjust the SENSITIVITY control full clockwise.

Set the GAGE FACTOR dial at 2.00.

With the STRAIN Counter at +0000, null the meter with the BALANCE control.

Apply a fixed (but unknown) load or input to the transducer.

Rebalance using the large Rebalance Knob.

Note the reading.

Then:

$$\text{LOAD} = \frac{\text{STRAIN READING}}{2 \times k} \times T_R \times 10^{-3} \qquad (6\text{-}5)$$

Calculate the LOAD value.

Reset the STRAIN counter to indicate calculated LOAD.

With this load still applied, set the GAGE FACTOR control as required to null the Meter.

The system is now calibrated.

7.0 INSTRUMENT CALIBRATION

The P-350A calibration is performed with accurately calibrated strain gage networks. Since the calibration is functionally related to the resistance values of few stable components the instrument's accuracy is insured for many years of normal usage.

7.1 Should there be any question of accuracy, the standard technique of checking the instrument is shunt-calibration.

The simplest procedure is to use the internal CALIB circuit described in Paragraph 4.4.1. However, the following more general procedure is provided to obtain more general data. It should be noted that the determined accuracy will only be as good as the components used. The 1kHz square-wave excitation must be considered in this selection.

7.1.1 Set up the 120-ohm half-bridge circuit shown by Figure 2:

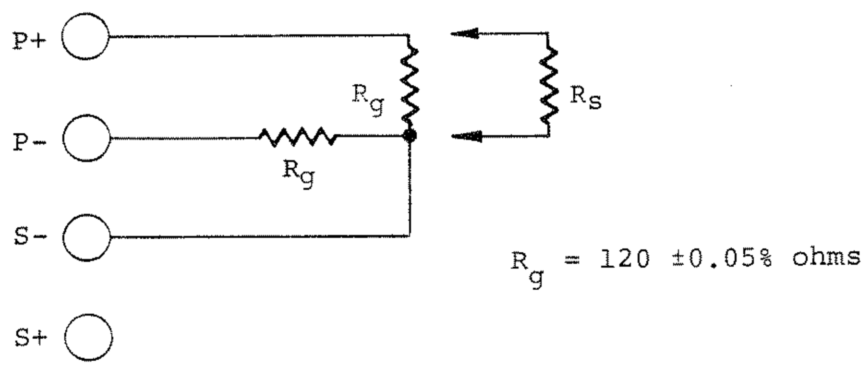


FIGURE 2: CALIBRATION CIRCUIT

7.1.2 With the STRAIN Counter set at +0000, zero the Null Meter using the BALANCE Control knob.

7.1.3 Shunt R_g with R_s as shown.

7.1.4 Using the large Rebalance knob, re-zero the Null Meter and note the sign and reading on the STRAIN counter. Compare this reading with the following computed reading:

$$\varepsilon_i = \frac{-2R_g}{GF_i \; (2R_s + R_g)} 10^6$$

where: ε_i = the indicated strain (microstrain in compression)

R_g = the nominal gage resistance in ohms

R_s = the shunt resistance in ohms

GF_i = the GAGE FACTOR set into the Indicator

The Indicator STRAIN Counter reading and the computed reading should agree within the specified accuracy limits.

7.1.5 To compute R_s for a desired STRAIN Counter reading, the above may be rearranged to:

$$R_s = \frac{-R_g \times 10^6}{GF_i \times \varepsilon_i} - \frac{R_g}{2} \quad (7\text{-}2)$$

7.2 It may be noticed that the latter equation is similar to the standard "shunt-calibration" equation often used to simulate a given strain in a gage (the same circuit applying), viz:

$$R_c = \frac{R_g \times 10^6}{GF_g \times \varepsilon_s} - R_g \quad (7\text{-}3)$$

where: R_c = the shunt "calibration" resistor in ohms

R_g = the gage resistance in ohms

GF_g = the Gage Factor of the specific strain gage

ε_s = the desired simulated strain in $\mu\varepsilon$.

The distinction between equations (7-2) and (7-3) is that the second simulates the action of an ideal strain gage under compressive strain, whereas the first refers to the reading on the Indicator.

While it would be desirable that the results of these equations be the same, this is unfortunately not practical with a commercial Indicator employing fixed bridge excitation. The errors introduced are generally small compared to other experimental errors in typical applications. (The resistors in the internal CALIB circuit in the P-350A are calculated in accordance with equation (7-2) and thus are for Indicator calibration rather than true strain simulation.)

7.3 An expression can be developed to compute this error:

$$\varepsilon_g = \varepsilon_i\left(\frac{1}{1 - \left(\frac{GF}{2} \quad \varepsilon_i \times 10^{-6}\right)}\right) \qquad (7\text{-}4)$$

where: ε_g = the strain at the gage in microstrain

ε_i = the Indicated STRAIN from the counter (retain sign)

GF = the Gage Factor of the strain gage and the GAGE FACTOR value to be set into the Indicator.

This error does not occur in bridge circuits where the current in each leg is kept constant; i.e.: fully active half bridge and full bridge circuits.

8.0 USE WITH SEMICONDUCTOR GAGES

While the P-350A Indicator is not designed for use with semi-conductor gages, it is possible to use these gages if certain corrections are made.

8.1 Gage Factor - The Gage Factor of semi-conductor gages is usually between 50 and 200, far beyond the range of the P-350A's GAGE FACTOR control. It is possible, however: to divide the actual GF_g by a "scaling ratio" of 5, 10, or 20; to use this new GF_i as the GAGE FACTOR setting; and to divide the final result by the original scaling ratio.

8.2 Non-linearity - Due to the very high Gage Factor of semi-conductor gages, installations with a single active gage become quite non-linear. The following equation can be used to correct this error:

$$\varepsilon_g = \frac{\varepsilon_i}{s} \frac{1}{1 - \left(\frac{GF_i}{2} \quad \varepsilon_i \times 10^{-6} \right)} \qquad (8\text{-}1)$$

where: ε_g = the calculated strain at the strain gage in microstrain

ε_i = the microstrain sign and reading from the Indicator's STRAIN counter.

s = the "scale ratio" (see para. 8.1)

GF_i = the GAGE FACTOR used on the Indicator, $= \frac{GF_g}{s}$

GF_g = the Gage Factor of the specific strain gage.

Equation (8-1) assumes linear operation of the semi-conductor strain gage, which is not always the case.

9.0 MAINTENANCE

Within the warranty period, the only maintenance procedure which does not void the instrument warranty is the periodic battery replacement. In the event of an electronic or mechanical malfunction during this period contact your Vishay Sales Representative or the Vishay Instruments plant in Malvern, Pa.

9.1 BATTERY REPLACEMENT

Remove the four screws from the underside of the case and remove the instrument from its case. Each tube contains 3 standard "D" cells (flashlight batteries) and they must be all in the same direction in each tube. The two tubes are installed in opposite directions; the "+" ends of each tube must point toward the red plastic clip.

9.2 If BAT TEST checks good (Null Meter must deflect to right with RANGE EXTENDER on "+") yet the Indicator is totally inoperative:

9.2.1 Check for the 1.5 AC voltage between Terminals P+ and P-. If not present, turn POWER Switch off and on several times, pausing 5 seconds in OFF each time; occasionally the oscillator is difficult to start, especially in cold weather. If this fails, replace Oscillator transistors Q5 and Q6, the positions of which are shown in Figure 3. If there is still no AC, replace Regulator transistor Q7.

9.2.2 If AC voltage is present at P+ and P- but the Null Meter does not deflect, check that the "normally closed" contacts on the OUTPUT jack are making electrical contact.

9.2.3 If the Null Meter still does not deflect or is poor in sensitivity, replace Amplifier transistors Q1, Q2, Q3, and/or Q4.

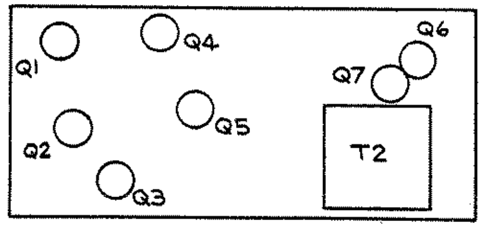


FIGURE 3

TRANSISTOR LOCATIONS ON PRINTED CIRCUIT BOARD

9.3 Adjustments: There are four screw-driver adjustments in the P-350A. Two affect calibration and should not be altered except in extreme cases. The other two can be adjusted at will to achieve a more satisfactory instrument.

9.3.1 Span Adjustment: This is a 25-turn Vishay trim potentiometer near the large 5K 10-turn pot; it adjusts the overall span of the P-350A and has a total range of about 3%. (If the instrument is out more than 0.25% in spite of age, look for source of trouble before touching this adjustment.)

9.3.2 Span Symmetry (R26 on p.c. board): Used to adjust reading at -5000με to equal reading at +5000με. Range about ±15με.

9.3.3 Gain (R10 on p.c. board): Used to adjust sensitivity of Null Meter with SENSITIVITY at maximum. May have to be reset if transistors Q1, Q2, Q3, or Q4 are changed.

9.3.4 Demodulator Balance (R19 on p.c. board): Adjust to maintain exact "0" on Null Meter as SENSITIVITY is changed. Should not require adjustment unless diodes are changed.

9.4 If the large Rebalance knob tens to slip in driving the STRAIN Counter, loosen the two set screws in the hub of the large gear on the potentiometer shaft, then slide the gear to the desired frictional contact with the rubber-tired roller on the Rebalance knob shaft. To maintain accuracy tighten the gear set screws with the Rebalance knob mechanical stop and a STRAIN Counter reading of 0000 at exact coincidence.

9.5 A schematic of the P-350A is provided on Page 35.

9.6 Most electrical parts in the P-350A are standard parts commercially available. Vishay will supply any part required, although the prudent approach is to return the instrument to our plant for factory service and calibration.

The following specific problems may be encountered in any major field repair:

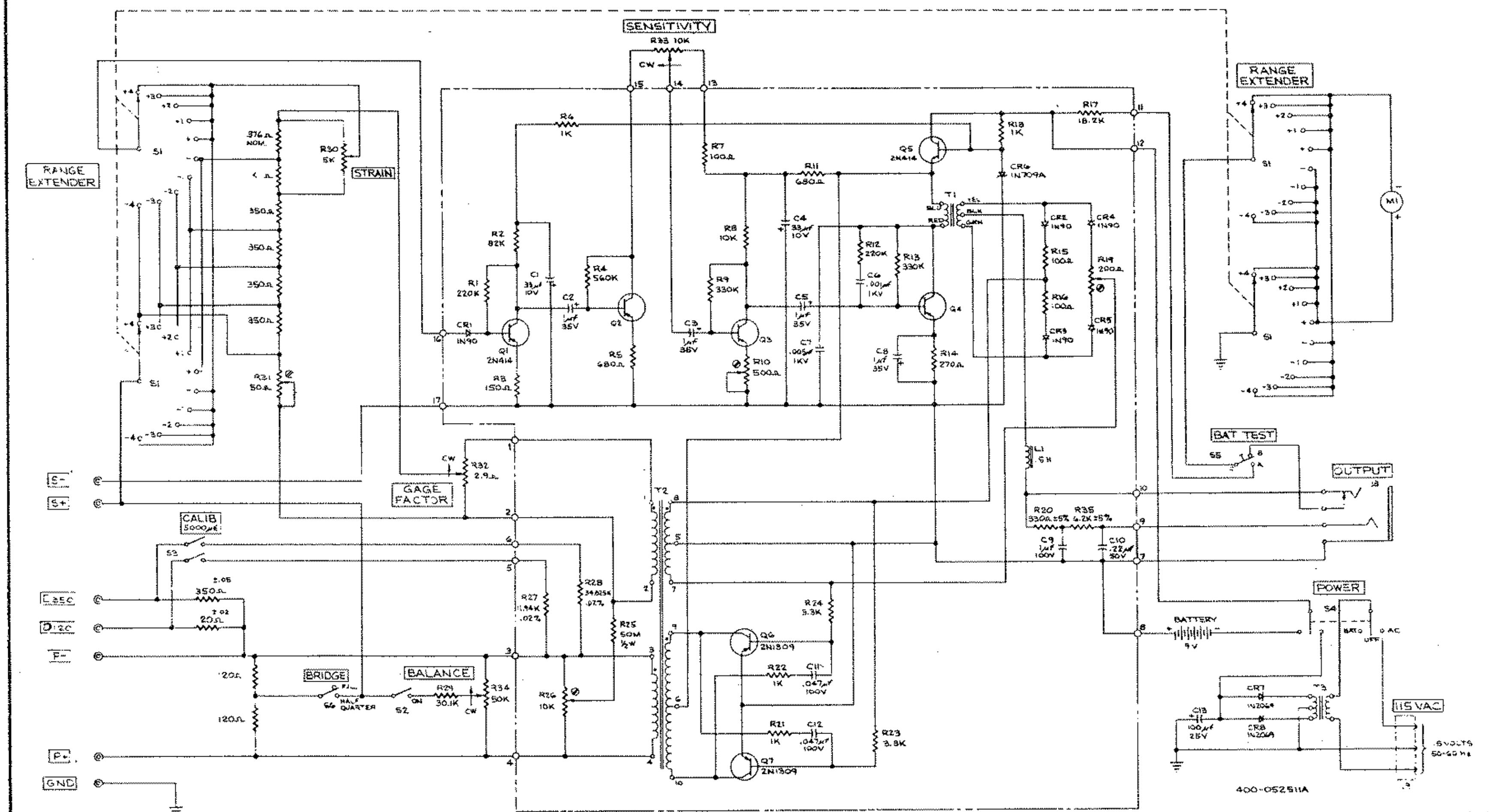
(a) The GAGE FACTOR dial probably does not read 000 at the CCW stop. This is intentional and is carefully adjusted for each GAGE FACTOR potentiometer. For this and other reasons, replacement of this potentiometer will almost certainly affect calibration.

(b) The 5K STRAIN potentiometer cannot be replaced without affecting calibration; the 1Ω and 376Ω resistors in the RANGE EXTENDER circuit are trimmed to each individual STRAIN potentiometer.

9.7 The following abbreviated parts list includes repair parts which may be required and which do not affect instrument calibration:

Description	Vishay Part No.
AC line cord (Belden 17258)	21x900039
OUTPUT plug (Switchcraft 260)	12x700088
OUTPUT jack (Switchcraft 13B)	12x700017
Null Meter	152-012774

Description	Vishay Part No.
Transistors:	
Q1, 5(RCA 2N414)	14x200007
Q2, 3, 4, (Fairchild 2N3638A)	14x200115
Q6, 7 (2N1309)	14x200045
Power Transformer (T1)	
115V primary	200-130318
230V primary	200-130319
Balance Potentiometer (R34)	24x400057
Power Switch (Switchcraft 13037L)	10x700012



NOTES:
1. UNLESS OTHERWISE SPECIFIED; ALL TRANSISTORS ARE 2N3638A, ALL RESISTORS ARE ¼W, ±10%.

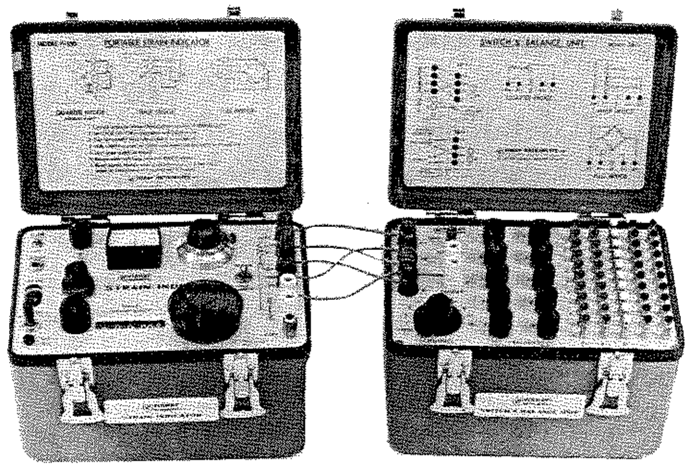
SCHEMATIC P-350A
PORTABLE STRAIN INDICATOR

10.0 ACCESSORIES & COMPANION INSTRUMENTS

10.1 COUNTING BALANCE KNOB KIT (MODEL A2-P-350)

A concentric-dial counting knob is available for the BALANCE control on the P-350A replacing the standard lock knob. This accessory facilitates repeat settings of this control for measurements taken at different times on the same strain gage installations. Part No. 120-000745

10.2 SWITCH AND BALANCE UNIT (MODEL SB-1)



P-350A WITH SB-1 SWITCH AND BALANCE UNIT

A 10-point Switch and Balance Unit is available as a companion instrument in a similar case which provides for 10 separate strain-gage channels (quarter, half, or full bridges) with individual initial-balance controls for each channel and a selector switch to select the desired channel. Quick-connect gold-plated "Push-Posts" are used for gage connections. Any number of Switch and Balance Units can be connected in parallel to the same P-350A.
Part Number 120-000584.

10.3 SWITCH AND BALANCE UNIT (MODEL SB-2)

This unit is electrically identical to the Model SB-1 Switch and Balance Unit and operation is the same, but the input connections are a gold-flashed, screw terminal type and they are located on a panel at the rear of the instrument. The controls and output terminals have also been rearranged.

The alternate arrangements provide a greater choice for our customers who may have test setup requirements that would be better satisfied by one configuration than by the other. For example, the SB-1 Unit, with its push-post connectors, might be the choice of those whose test setup requires frequent changing of input channel connections, whereas the SB-2 instrument might be the choice of those whose testing involves a relatively permanent type of setup. Personal preference for one control arrangement instead of the other also might be a consideration.

10.4 SWITCH UNIT (MODEL S-1)

A 10-point Switch Unit is also available. It is an economy version of the Model SB-1 or SB-2. Initial-balance controls are not provided and gage connections are made on screw-type terminals. Quality and accuracy are equal to those of the Model SB-1, but it is not as convenient to use.

Part Number 300-042918