GOULD BRUSH

MANUAL PART NO.
13-804615-30-1

D.C. BRIDGE
PREAMPLIFIER
MODEL 13 4615 30

The information contained herein is the exclusive property of Gould Inc., except as otherwise indicated and shall not be reproduced, in whole or part, without explicit written authorization from the company. The distribution of this material outside the company may occur only as authorized by the company in writing.

PRINTED JULY, 1976

Gould Inc., Instrument Systems Division
3631 Perkins Avenue-Cleveland, Ohio 44114

2nd PRINTING
PRINTED IN U.S.A.

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

SECTION I

GENERAL INFORMATION

1.1 INTRODUCTION

The Gould Model 13-4615-30 D.C. Bridge Preamplifier (Figure 1-1) is a high gain preamplifier designed to work with resistive transducers, including strain gages and strain gage based transducers. It is designed for use with Gould 2000 series recorders, and receives its operating power from a companion pendrive amplifier located in the same analog channel of the recorder.

This single channel preamplifier module expands measurement capability of the recorders to include strain gages, strain gage based transducers, resistance temperature devices and low-level DC input signals. Common mode rejection of 130db at dc and 100db at 60Hz permits operation in noisy industrial environments.

Calibrated Zero Suppression is provided with four voltage ranges, each of which has a resolution of one part per thousand. The attenuator position can be altered without readjusting the zero suppression control.

Both the input circuit and the dc excitation supply are fully floating, which permits the preamplifier to be operated at potentials up to 500 volts off-ground. A variable sensitivity (CALIBRATE) control has a continuous pre-calibrated range from 1 to 10, and a maximum resolution of one part per thousand. This calibrated sensitivity control provides known amplifier gain settings for each of the 6 fixed gain ranges, assuring precise direct calibration for all types of signal inputs.

Internal switching is provided for selection of ±5 or ±10 volt dc excitation, positive or negative shunt calibration, and bridge excitation polarity reversal. Low-pass output filtering is internally selectable to eliminate objectionable high frequency signal components.

a. **Important Features of the D.C. Preamplifier**

1. Ten turn calibrate dial for calibration to a known transducer sensitivity or gage factor.
2. Shunt Cal pushbutton to set calibrate dial to a known load in conjunction with the shunt trim pot.
3. Zero suppression to ±0.1 volt.
4. Zero suppression vernier for setting suppression between zero volts and maximum range.
5. Bridge balance pot.
6. Either ±5 volts or ±10 volts excitation, switch selectable.
7. Internal terminals for bridge completion resistors, calibration resistors, or "+" or "–" cal. selection.

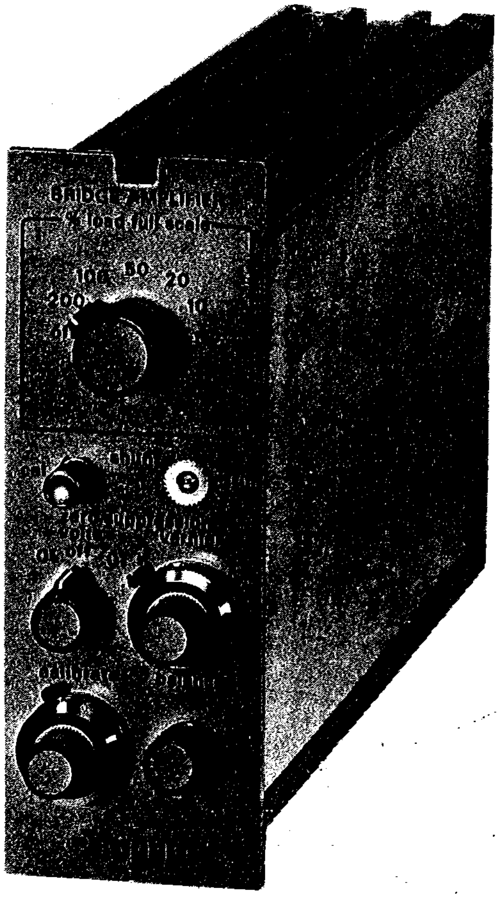


FIGURE 1-1 GOULD MODEL 13-4615-30 D.C. BRIDGE PREAMPLIFIER

1.2 SPECIFICATIONS

All operating specifications are based on 5 volts excitation, 350 ohms across input and a sensitivity (gage factor) of 2.0 mv/volt unless otherwise stated.

Signal Input

Circuit	Differential.
Impedance	50K ohms
Measurement Range	250 microvolts full scale to 100 millivolts full scale
Maximum Sensitivity	25 microinch/inch full scale with 4 active arm bridges (gage factor of 1).
Sensitivity Steps	5, 10, 20, 50, 100 and 200% of load full scale and off.
Maximum Safe Voltage	50 volts peak-either input terminal to common. 500 volts peak-common to chassis.

Signal Output

Circuit	Single ended to common.
Voltage:	
Linear Range	+5.0 volts into 2 K ohms or greater.
Minimum Load Resistance	Zero ohms (Short circuit proof).
Calibration Inaccuracy (at 25° C and nominal line voltage)	±0.1% of full scale in the 100% of load setting with the calibration dial set to 2.
Attenuator Accuracy	±0.5% of calibrated step.
Non-Linearity	±0.1% of full scale.
Impedance	Less than 5 ohms.
Instability	At a calibration setting of 2 and attenuator setting of 5% of load full scale, after 15 minutes warmup.
Zero with Time	±25 mv/24 hours. (±0.5% of full scale/24 hours.)
Zero with Line	±10mv for a 10% line change (±0.2% full scale for a 10% line change).
Zero with Temp	±10mv/° C (±0.2% of full scale/° C).
Gain with Temp	±0.05%/24 hours after 15 minute warmup.
Gain with Line	±0.1% for ±10% line change.
Gain with Temp	±0.03%/° C.

Frequency Response	
Without Filter	d-c to 100Hz ±0.5% (Less than 3 dB down at 5 kHz)
With Internal 5 Hz Filter	3 dB down at 5 Hz ±10%
Filter Rolloff	12 dB/octave or 40 dB/decade
Noise	Less than 1% of full scale from dc to 100Hz.
Common Mode Rejection:	
Common to Chassis	Greater than 100db from dc to 60Hz at 100 ohm unbalance.

Bridge Excitation

Voltage	5 or 10 volts dc, ±0.1% internally selectable. 100 ma capacity. Normal or reverse polarity internally selectable.
Noise	0.1% peak-to-peak from dc to 1KHz.
Stability (after 15 minute warmup)	
Temperature	±0.05%/° C
Time	±0.05%/24 hours.
Line	±0.1% for ±10% line change.

Zero Suppression

Range	-.1, -.01, off, +.01, +.1 volts.
Inaccuracy	±0.5%
Non-Linearity	±0.3%
Resolution	±0.1% of suppression range.
Stability (after 15 minutes warmup)	
With Time	±0.2%/week.
With Temp	±0.05%/° C.
With Line	±0.02% for ±10% line change.
Noise	±0.05% of suppression range.

Environment

Temperature:	
Storage	-40° C to +70° C.
Operating	0° C to +50° C.
Humidity, Non-Condensing:	
Operating	95% relative humidity; 0° C to 30° C. Less than 95% relative humidity; 30° C to 50° C.

Physical Characteristics

Dimensions	Refer to Figure 2-3 Outline Dimensions
Weight	3.6 lbs (1.5kg)
Mounting	Retained from Rear.
Finish	Molded Front Panel, Color: Light Parchment.

Controls

Front Panel:

% Lead Full Scale	Selects % of load for a full scale output.
Shunt: Cal	Push button switch that connects shunt CAL R, trim pot, or both across one arm of bridge.
Trim	Multi turn pot for calibrating bridge.
Zero Suppression (-volts+)	Selects range and polarity of suppression voltage.
Zero Suppression (Vernier)	Provide calibrated setting of suppression voltage from 0% to 100%.
Calibrate	Sets mv/v sensitivity of preamplifier.
Balance	Multi-turn pot to balance bridge.

NOTE: No Pen Position Control

Internal:

Input Zero	15 turn pot to set zero of input amplifier.
Output Zero	Single turn pot to set zero of output amplifier.
Input Bal	Single turn pot to balance inputs 1 and 2 to common.
.1V CAL	15 turn pot to set accuracy of .1 volt suppression.
.01V CAL	15 turn pot to set accuracy of .01 volt suppression.
5V CAL	15 turn pot to set accuracy of 5 volt bridge excitation.
10V CAL	Single turn pot to set accuracy of 10 volt bridge excitation.

Normal-Reverse Switch	Slide switch to reverse the polarity of the excitation voltage.
+CAL, −CAL	Terminals provided for jumper to produce either a positive or negative voltage when the CAL R, is placed across one arm of the bridge.
5Hz Filter	Terminals and capacitors provided to permit adding an active filter.

Rear Panel:

Input	Guarded Multi-pin Connector (Proprietary). Mating Connector 11-5407-03 supplied.
Output	Card edge mates with AMP 582140-5 or equivalent.

Power Input From Recorder

Voltage DC	±15 volts, ±0.6 volts @ 100ma.
Line and Load Regulation	±.5%
Ripple	5mv max.
Voltage AC	13 vrms @ 200ma.

System Specifications When used with Series 2000 Recorders

Gain Accuracy	±0.7% of full scale.
Non-Linearity	±0.45% of full scale.

Instability (at 2mv/v cal setting and 5% of load full scale).

Zero with Time	± 0.6% of full scale/24-hours.
Zero with Temp	±0.3% of full scale/° C.
Zero with Line	±0.3% of full scale for a 10% line change.
Gain with Time	±0.15% /24 hours.
Gain with Line	±0.6%for a 10% line change.
Gain with Temp	±0.08%/° C.
Frequency Response	Refer to Specifications, 2000 Series Recorder Manual.
Noise	Less than 1% of full scale peak-to-peak.
Maximum Safe Input	±50 volts peak, inputs 1 and 2 to common.
Common Mode Rejection	Refer to Specifications, page 1.3 of this manual.

Accessories

* *Extender Card and Cable Assembly	887291
*Balance Resistor	1-265469-15001
*Calibration Resistor:	
15K ohm (120 ohm bridge)	1-265969-15001
50K ohm (350 ohm bridge)	1-265969-50001
* *Bridge Completion Resistor:	
120 ohm	242879-121
350 ohm	10-240368-350R0
*Input Connector	11-5407-03

*Supplied with Preamplifier
* *Ordered Separately

SECTION II

INSTALLATION

2.1 GENERAL

This section describes inspection checks to be made upon receipt of the Gould D.C. Bridge Preamplifier, Model 13-4615-30 with a 2000 Series Recorder. It covers installation procedures, signal input connections, and outline dimensions.

2.2 INITIAL INSPECTION

Prior to attempting any electrical connections or operation visually examine the unit for broken or loose knobs, dented or nicked panels and broken or chipped rear connectors.

2.3 INSTALLATION

Preamplifier Model 13-4615-30 may be mounted in Gould 2000 Recorder frames, or mounted separately in a Gould rack adapter kit or portable carrying case.

a. Insertion

To install the preamplifier into its appropriate slot:

1. Slide the preamplifier into the enclosure until the rear output card edge connector is engaged.
2. Tighten the rear retaining screw. This locks the preamplifier into the enclosure.
3. Connect the plastic input signal connector and secure it by turning the threaded plastic locking ring clockwise.

b. Removal

1. Disconnect the input connections with a counterclockwise turn and pull.
2. Loosen the rear retaining screw. The preamplifier will move forward about 1/8 of an inch.
3. Carefully slide the entire preamplifier out of the Gould 2000 enclosure.

2.4 SIGNAL CONNECTIONS

a. General

Gould preamplifier Model 13-4615-30 is a direct coupled differential input amplifier. Input and output are isolated from chassis, but there is no isolation between input and output.

b. Signal Input Connections

NOTE: For signal input connections, use the special connector provided with the preamp (Gould part number 11-5407-03). (See installation drawing at end of this section).

1. Connections to the preamplifier are made at the rear. (Figure 2-1). A four wire, double foil shielded signal cable (Gould P/N 232956) should be used.

NOTE: The cable from the transducer to the preamplifier should be one continuous length. Splices are not permitted, but mating low level signal connectors may be used if necessary.

2. Connect the double shielded signal cable pair to the preamplifier signal input connector pins 1 and 2, and the inner shield to the guard ring (Figure 2-2).

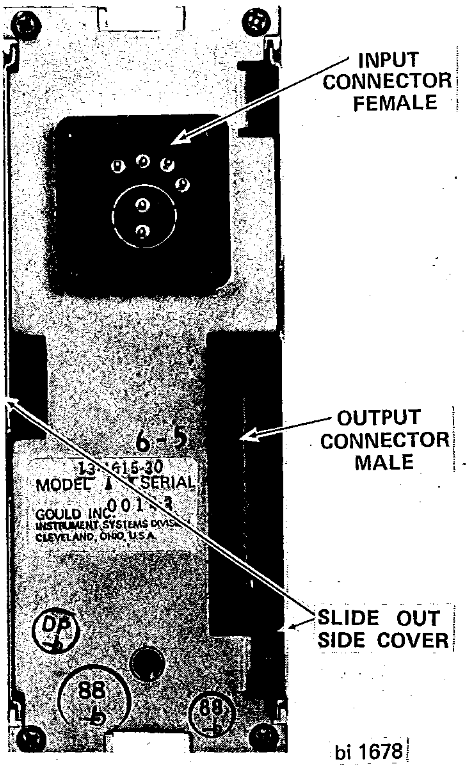


FIGURE 2-1 REAR VIEW

3. Connect the transducer excitation pair to connector pins 6 and 7, and the outer shield to the sensor enclosure and to the guard ring.

NOTE: Detailed instructions for connecting one, two or four arm gages is given in Section III, Operation.

c. Grounding

1. For most applications, with both the sensor and sensor enclosure floating, both dotted jumpers shown in Figure 2-2 should be in place.

2. If either the bridge or the sensor enclosure is grounded, the jumper from AMPLIFIER COMMON to CHASSIS GROUND must be removed.

3. If the bridge is to be operated off-ground at a potential (500 volts maximum) the jumper from AMPLIFIER COMMON to CHASSIS GROUND must be removed.

4. Both jumpers must be removed if the Preamp is to be used as a DC amplifier with a grounded signal source configuration. Observe good grounding practice; make certain that the shield is tied to earth ground at one point and one point only.

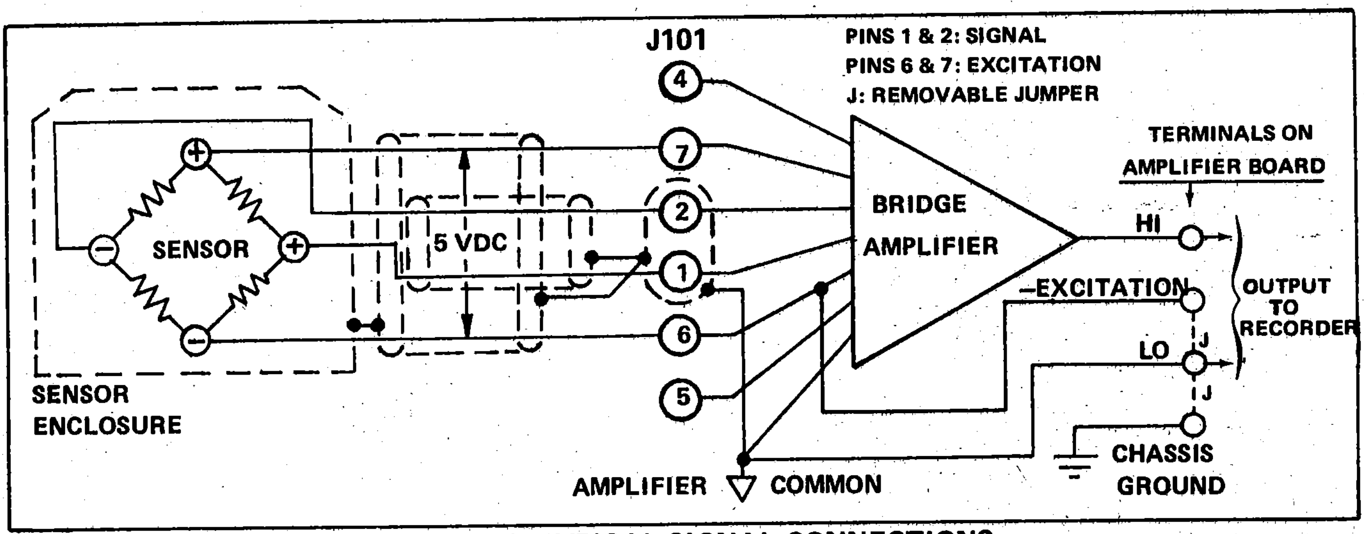


FIGURE 2-2 TYPICAL SIGNAL CONNECTIONS

Need [illegible]!

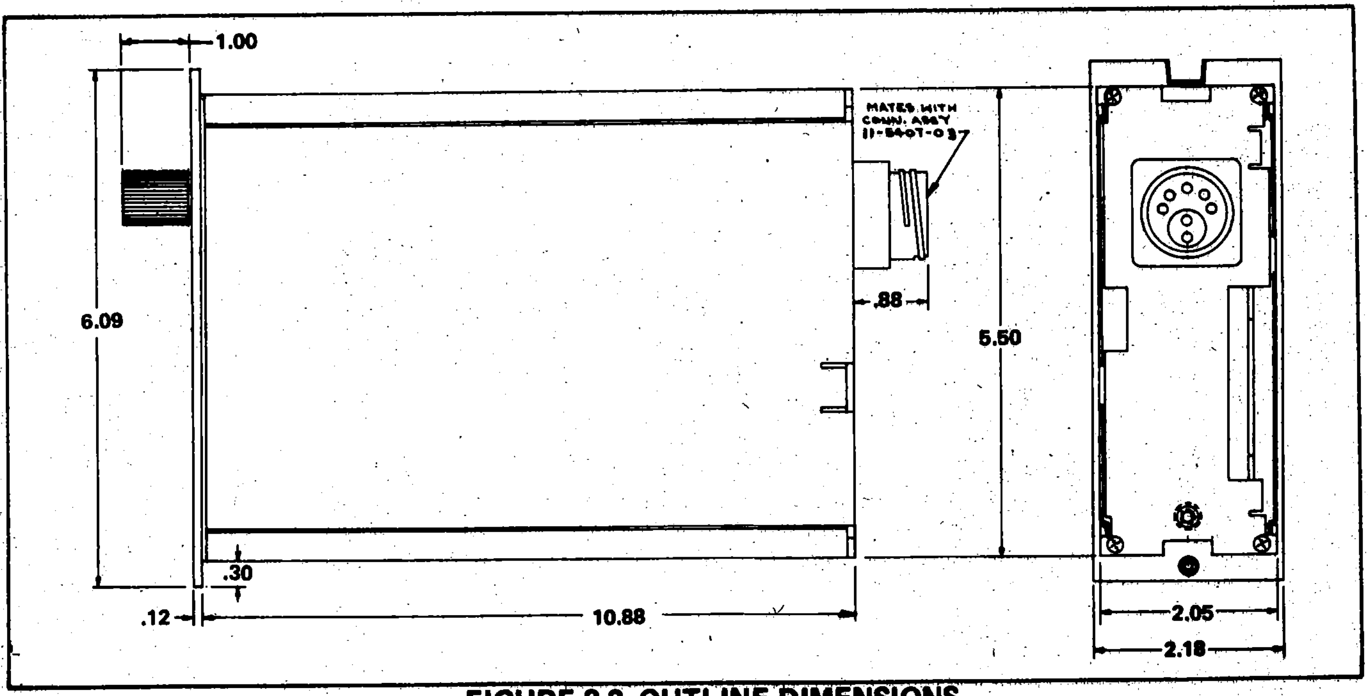


FIGURE 2-3 OUTLINE DIMENSIONS

d. Output and Power

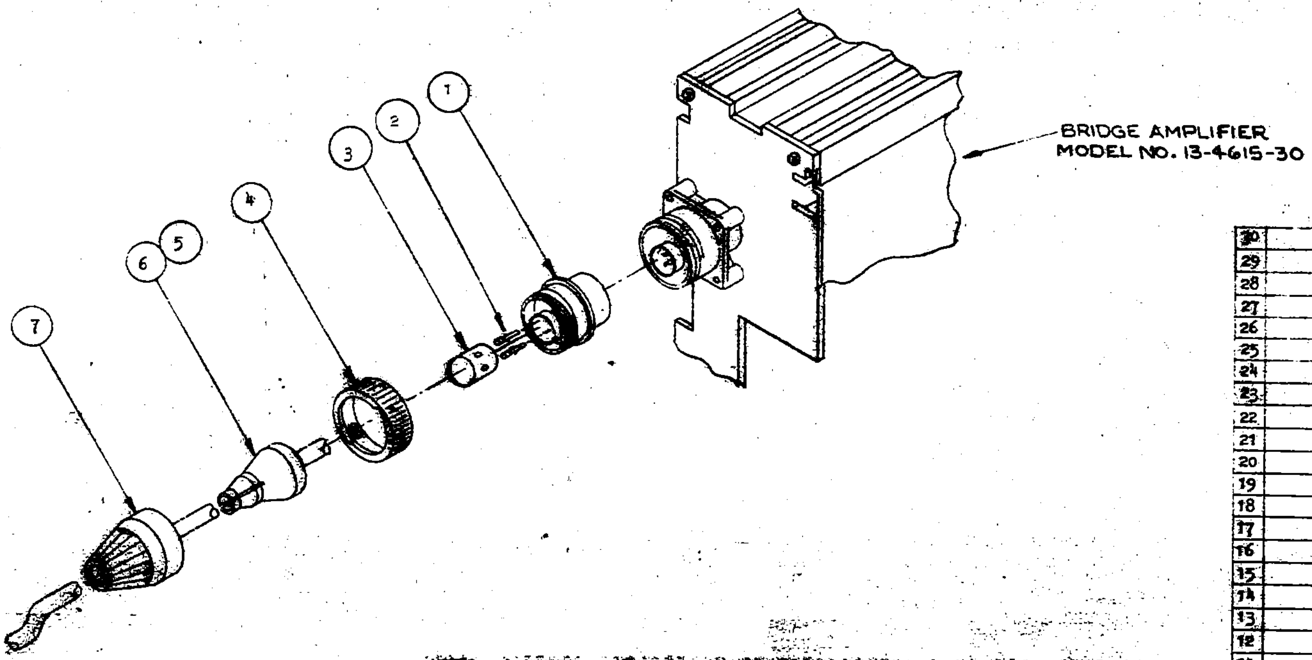
The amplifier is designed to operate on + and —15 volt 100ma regulated supplies, and 13vrms, 60Hz sine wave at 200 ma current. Output and power connections are provided through an 8 pin card edge connector on the rear of the preamp. (Figure 2-1). The mating connector is located in the recorder chassis.

The preamplifier provides a 5 volt full scale signal to the recorder.

2.5 OUTLINE DIMENSIONS

Refer to Figure 2-3 for outline dimensions.

REPRODUCED
MAY 30 1974



NOTES:
1. NUMBERS IN CIRCLES INDICATE ITEM NUMBERS.
2. MOUNT ITEM-4 TO ITEM-1 BY [illegible] OF ITEM-4 OVER SHOULDER OF [illegible]
3. [illegible] OR CABLE SHIELD OVER [illegible]
4. WIRE CONNECTIONS:
  A. USING ITEM-3:
    A. INSTALL ITEM-3 OVER CABLE & CRIMP OR SOLDER WIRES TO ITEM-2 & INSERT INTO ITEM-1, PIN 1+, PIN 2-, PIN 4 CAL.1, PIN 5 CAL.2, PIN 6 EXCITATION [illegible]
    B. SOLDER SHIELD WIRE TO ITEM-3 AND [illegible] SHIELD OF ITEM-1.
  B. WITHOUT ITEM-3.
    A. CRIMP OR SOLDER WIRES TO ITEM-2 AND INSERT [illegible] PIN 4 CAL.1, PIN 5 CAL.2 PIN 6 EXCITATION [illegible]
    B. SOLDER SHIELD WIRE TO SHIELD OF ITEM-1.
5. SECURE ITEM-7 ALONG WITH ITEM-5 OR ITEM-6 TO ITEM-4.

30			
29			
28			
27			
26			
25			
24			
23			
22			
21			
20			
19			
18			
17			
16			
15			
14			
13			
12			
11			
10			
9	[illegible]		
8	[illegible]	[illegible]	
7	385548-1	[illegible]	
6	385548-4	WEDGE, [illegible]	
5	385548-3	WEDGE, STRAIN RELIEF	1
4	385548-2	RING, LOCKING	1
3	385402	[illegible]	1
2	385309-1	CONTACT, FEMALE	[illegible]
1	[illegible]	CONNECTOR, [illegible]	

386571

THIS DRAWING IS USED
BY OTHER GOULD DIVISIONS
AND/OR LOCATIONS. A F

SECTION III

OPERATION

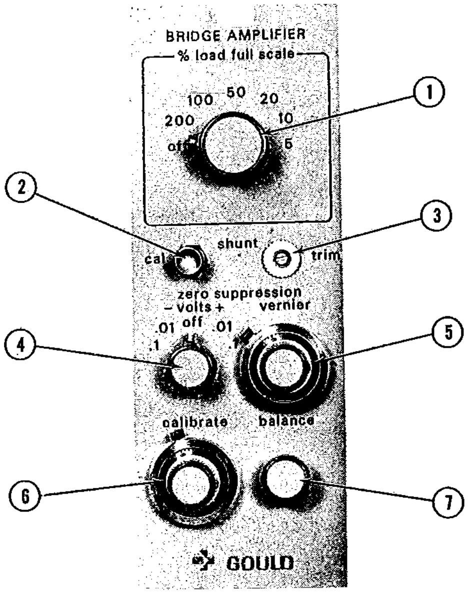
3.1 GENERAL

This section describes and illustrates the controls of the D.C. Bridge Preamplifier, Model 13-4615-30 and provides operating instructions.

3.2 CONTROL DESCRIPTION

Item numbers listed below correspond to circled number in Figure 3.1.

ITEM	CONTROL	DESCRIPTION
1	%Load Full Scale	A seven position rotary switch selects a full scale sensitivity from 5% to 200% of rated load of transducers, plus OFF.
2	Cal, Shunt	Pushbutton switch to place a calibration resistor, pot, or both across 1 arm of bridge.
3	Trim, Shunt	Multiturn pot for trimming calibration resistor.
4	Zero Suppression (Range, – volts +)	Selects suppression voltage and polarity.
5	Zero Suppression (Vernier)	10 turn potentiometer allows calibrated setting of suppression from 0 to 100 millivolts.
6	Calibrate	Provides calibrated sensitivity adjustment from a gage factor of 1 to 10 or 1 mv/v to 10mv/v for transducers.
7	Balance	Multiturn pot to correct bridge imbalance.



bi 1679

FIGURE 3-1 FRONT PANEL CONTROLS

3.3 INTERNAL CONNECTIONS

The Model 13-4615-30 D.C. Bridge Amplifier is designed to offer the user the maximum in options for convenience.

3.3.1 Excitation Voltage

1. The excitation voltage can be conveniently selected to be 5 or 10 volts by means of slide switch S202 located on the amplifier board.

NOTE: 5 volt excitation is assumed in the following instructions unless otherwise noted. When used, the 10 volt setting will double the effective sensitivity of the signal source. Signal to noise ratio will also be improved by a factor of 2 to 1. Make certain the gage specifications will permit 10 volt operation. Also be aware that increased voltage means increased power disapation in the transducer with resultant self heating. This in turn could introduce excessive drift.

2. Polarity is reversible by means of slide switch S201 located on the amplifier board. This is especially convenient should the transducer be wired to opposite polarity. It is unnecessary to reverse wiring, simply change the polarity of the excitation voltage.

3.3.2 Bal R

The standard 15K ohm bridge balance resistor located on the amplifier board can easily be changed (all the terminals are spring loaded) to vary the range of the front panel BALANCE knob. Lowering the resistance of the Bal R will give the BALANCE control more effect. Make certain that a balance resistor is installed between E13 and E14 on the amplifier board.

3.3.3 Cal R

1. The bridge amp is prewired such that when a Cal R is placed between E1 and E2 (on the amplifier board) it is in series with the shunt trim pot, R101. See Figure 3-2. Jumpers must be in place between terminals E3 and E4, and also between E12 and E13. With the front panel CAL pushbutton depressed, the trim pot may be adjusted to give a convenient amount of pen deflection. This allows simulation of a known load on the transducer which may be referred to by simply depressing CAL.
2. If the fixed CAL R is exactly the right value so that trimming is not required, place a jumper between E1 and E3. FOR EXAMPLE, IF A SPECIFIC CALIBRATION RESISTOR IS SUPPLIED WITH THE TRANSDUCER WHICH IS SUPPOSED TO GIVE A CERTAIN PERCENT OF FULL SCALE DEFLECTION, THE TRIM POT MUST BE OUT OF THE CIRCUIT. This is accomplished by jumpering E1 to E3. Also see Section 3.8, operation with calibration resistors external to the preamplifier.

3.3.4 +Cal, −Cal

With a jumper from E12 to E13, the bridge amp is prewired such that when a calibration resistor is placed from the "+" input to the "+" excitation terminal, the amplifier produces a positive output voltage.

To produce a negative output voltage for the same condition, remove the jumper between E12 and E13 and place it between E12 and E11.

NOTE: To use external calibration resistors or calibration resistors which are part of the transducer, see paragraph 3.8, Operation with Calibration Resistors External to Preamplifier.

3.3.5 Optional Filter

For noisy environments an optional 5Hz, 2 pole filter is provided by means of inserting C204 into terminals E5 and E6, and C205 into terminals E8 and E9 (see Figure 3-2).

For frequencies other than 5Hz, C204 & C205 values in microfarads may be calculated using the following formulas:

$$C204 = \frac{(.8\text{ufd})\ (5\text{ Hz})}{\text{New Frequency}}$$

$$C205 = \frac{(.02\text{ufd})\ (5\text{ Hz})}{\text{New Frequency}}$$

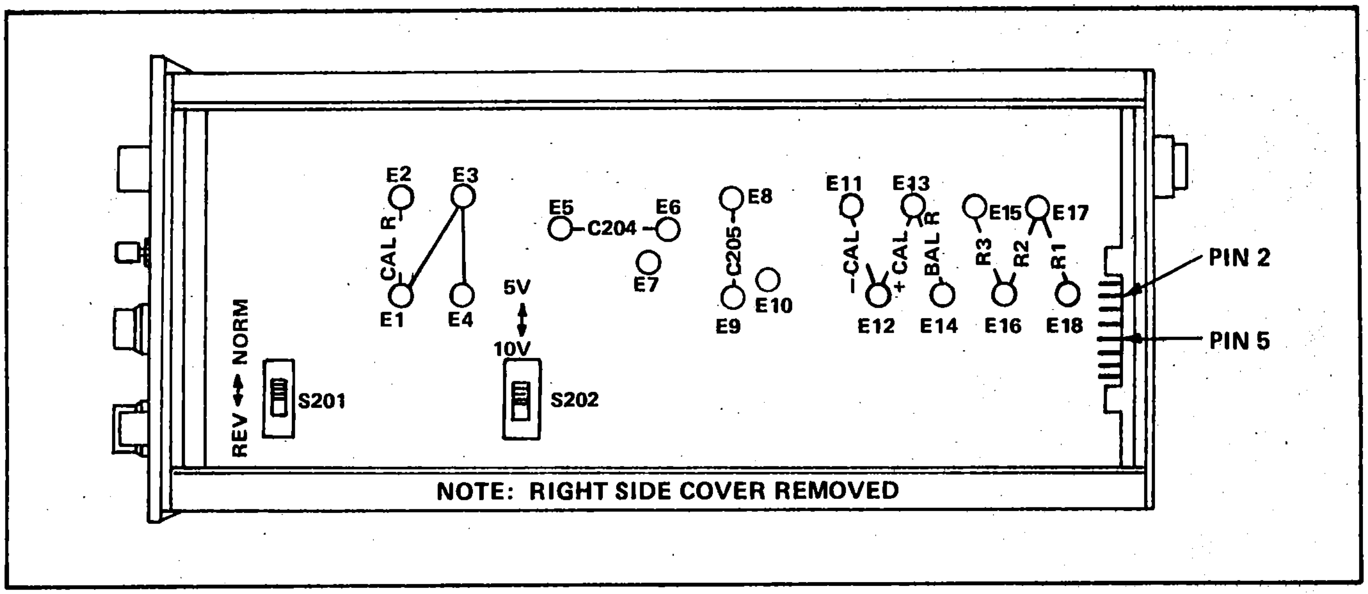


FIGURE 3-2a AMPLIFIER BOARD TERMINALS

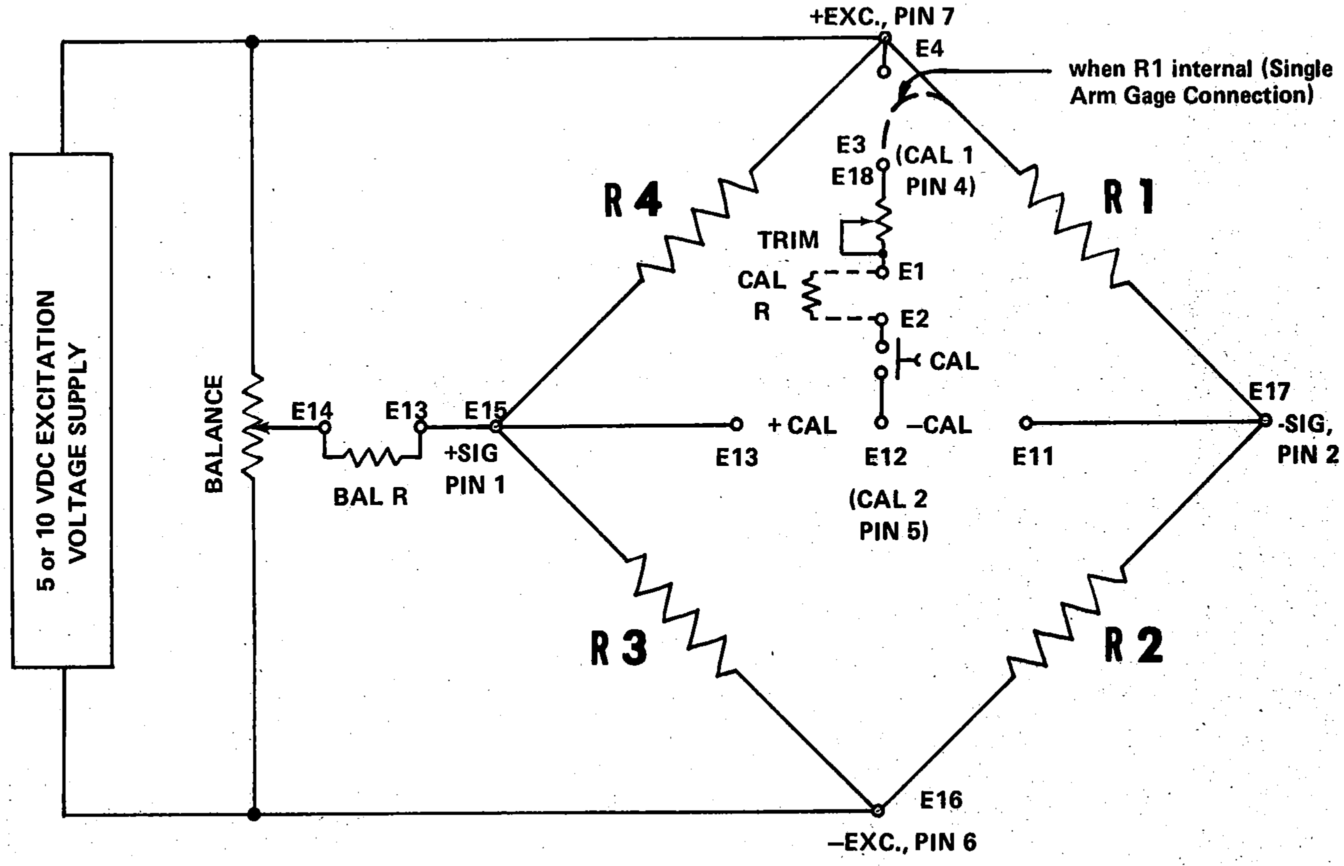


FIGURE 3-2b BRIDGE CONNECTION SCHEMATIC

3.4 INPUT CONNECTIONS AND OPERATION

Input connections and operating procedures vary slightly depending on the number of active arms in the strain gage. The paragraphs below cover four, two, and single arm sections.

Figure 3-2 should be helpful when making bridge connections. Figure 3-2a pictorally shows the amplifier board terminals used for convenient jumper and resistor connections. Figure 3.2b is a schematic of the bridge connections.

When using the amplifier in conjunction with the recorders, operate the chart at a moderate speed during setup and calibration.

NOTE: Make all signal connections with the connector provided with the preamplifier. Use Gould P/N 232956 cable or equal.

NOTE: 5 volt excitation is used in the following instructions unless otherwise stated.

3.4.1 Four Arm Gage (Figure 3-3)

CONNECTION

a. Connect Negative excitation lead to pin 6 and Positive lead to pin 7 of the preamp input connector.

b. Connect Positive signal lead to pin 1 and Negative signal lead to pin 2 of the input connector.

c. Connect outer cable shield to sensor enclosure. Connect both cable shields to input connector guard ring. See section 2.4.c for grounding instructions.

d. Check to be sure a balance resistor is installed between E13 and E14 on amplifier board assembly.

NOTE: To take advantage of the many options available with the internal jumpers and switches refer to paragraph 3.3, Internal Connections.

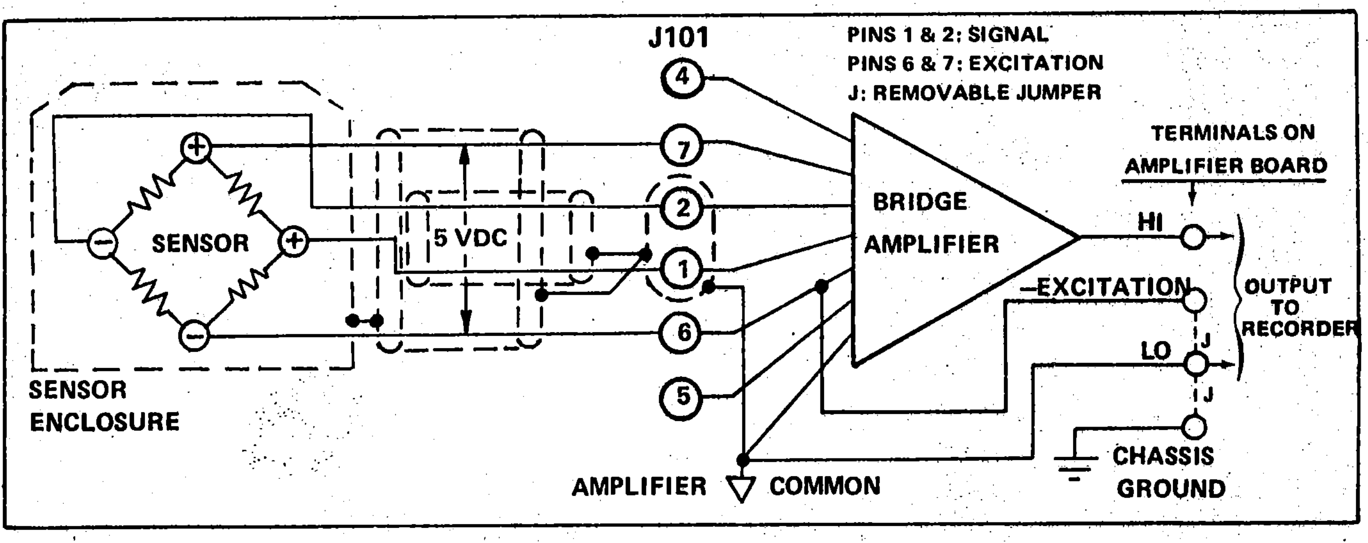


FIGURE 3-3 CONNECTING FULL-BRIDGE SENSORS

OPERATION

a. Set gage sensitivity/factor on the CALIBRATE dial, or set 2.00 if not known.

NOTE: The setting on the CALIBRATE dial should never be less than 1.00.

b. Set % LOAD FULL SCALE switch to the OFF position.

c. Center the pen trace on the chart, using POSITION control located on the recorder.

d. Be certain that the gage is not stressed (in no load condition).

e. Set the % LOAD FULL SCALE to the 200% position and use the BALANCE control to keep the pen at chart center (zero position).

f. Continue to rotate the % LOAD FULL SCALE switch through each position, keeping the pen trace at chart center with the BALANCE control, until a balance is achieved at the 5% position. If the balance control does not have enough range, reduce the resistance of the Bal R (E13 to E14). See Figure 3-2.

g. Return % LOAD FULL SCALE switch to the OFF position. Position pen to right chart edge (chart zero for + input signal) using POSITION control located on the recorder. Amplifier is now balanced and calibrated, provided an accurate sensitivity factor was used in setting the CALIBRATE dial.

h. If the gage sensitivity/factor is unknown, but the calibrated resistance is given, then proceed with steps j and k.

j. Set the % LOAD FULL SCALE switch to 100% and put the CAL R resistor in place between terminals E1 and E2. Place a jumper between terminals E1 and E3.

k. Depress the CAL pushbutton on the front panel and adjust the calibrate dial until the proper pen deflection is achieved. Lock the CALIBRATE dial and record the setting for future use.

m. A gage or transducer may also be calibrated by applying a full load condition to the sensor and adjusting the CALIBRATE dial for full scale (edge-to-edge) pen deflection. This should be done with the % LOAD FULL SCALE set to 100%.

3.4.2 Two Arm Gage (Figure 3-4)

CONNECTION

a. Connect Positive excitation lead to pin 7 of the preamp input connector.

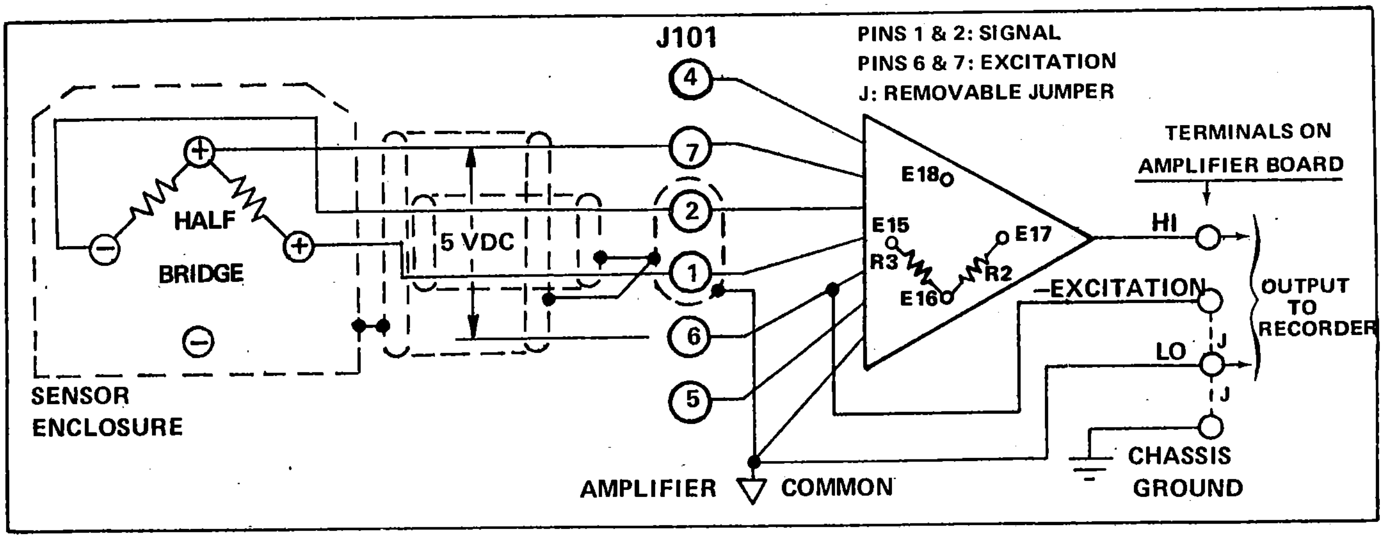


FIGURE 3-4 TWO ARM GAGE CONNECTIONS

b. Connect Positive signal lead to pin 1 and Negative signal lead to pin 2 of the input connector.

c. Connect outer cable shield to sensor enclosure. Connect both cable shields to input connector guard ring. See section 2.4.c for grounding instructions.

d. Check to be sure a balance resistor is installed between E13 and E14 on amplifier board assembly.

e. Install bridge completion resistors R2 and R3 between terminals E16 and E17, and E15 and E16 on the amplifier board assembly. (See Para. 1.2 Specifications, under Accessories, page 1.6).

NOTE: Bridge completion resistors must be low TC metal film or wire wound types of the same resistance value as the active arms of the bridge (±.1%, 1 watt).

OPERATION

a. Operation is identical with that of a four arm gage with the following exceptions due to the sensitivity being half that of the four arm gage.

b. All % LOAD FULL SCALE settings must be multiplied by 2 to get actual readings if the gage factor is dialed directly.

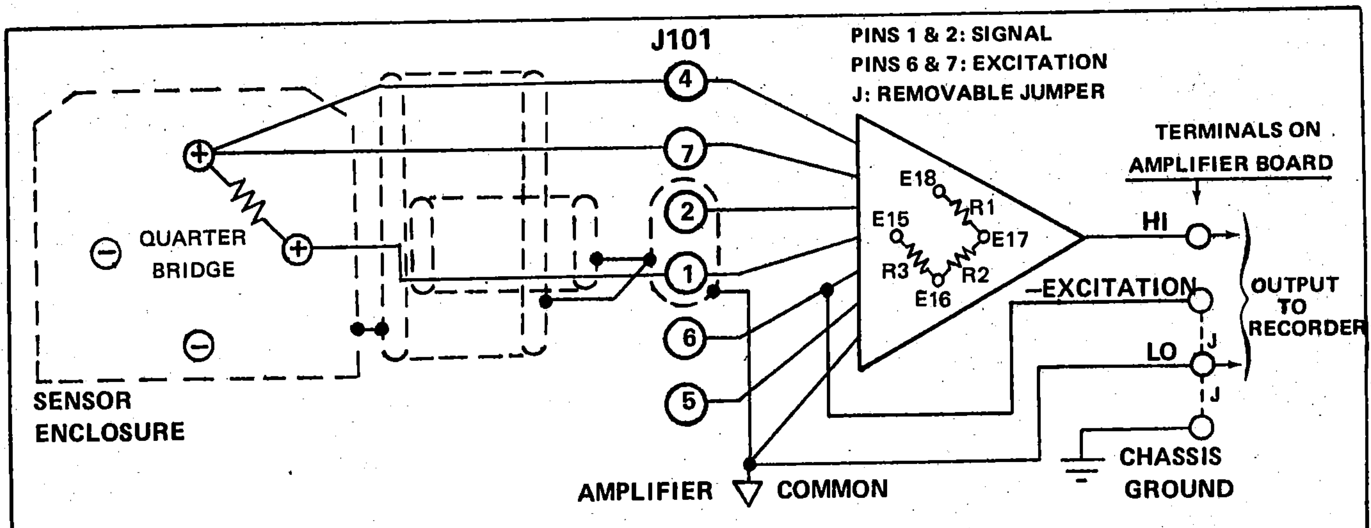
c. Step m from Four Arm Gage operation, above, is changed to read: A two arm gage or transducer may also be calibrated by applying a full load to the sensor and adjusting the CALIBRATE dial for full scale (edge-to-edge) pen deflection with the % LOAD FULL SCALE control set to 50%.

NOTE: The setting of the CALIBRATE dial must never be less than 1.00. Therefore, if the gage factor is 2.00 or greater, the CALIBRATE dial can be set to one-half the gage factor and the % LOAD FULL SCALE control can be used directly as in the four arm gage procedure. Alternately, 10 volt excitation may be used (if the gage permits), which also will allow direct use of the % LOAD FULL SCALE control.

3.4.3 Single Arm Gage (Figure 3-5)

CONNECTION

a. Connect Positive signal lead to pin 1 of the input connector.



NOTE: Internal jumper from E3 to E4 must be removed.

FIGURE 3-5 SINGLE ARM GAGE CONNECTIONS, SHOWN WITH TEMPERATURE COMPENSATION

b. Connect Positive excitation lead to pin 7 of the Preamp input connector. For temperature compensation, as illustrated in Figure 3-5, connect a third lead going from the positive excitation terminal of the gage to pin 4 and remove the jumper between E3 and E4. The extra input lead required must be an integral part of the input cable. Refer to paragraph 6.10, Temperature Compensation.

c. Connect outer cable shield to sensor enclosure. Connect both cable shields to input connector guard ring. See 2.4.c for grounding instructions.

d. Check to be sure 15 Kohm balance resistor is installed between E13 and E14 on amplifier board assembly.

e. Install bridge completion resistors R1, R2 and R3 between E17 and E18, E16 and E17, and E15 and E16 on the amplifier board assembly. (See Para. 1.2 Specifications, under Accessories, page 1.6).

NOTE: Bridge completion resistors must be low TC metal film or wirewound types of the same resistance value as the active arm of the bridge (±.1%, 1 watt).

OPERATION

a. Operation is identical with that of a four arm gage with the following exceptions due to the sensitivity being one-fourth that of the four arm gage.

b. All % LOAD FULL SCALE settings must be multiplied by 4 to get actual readings if the gage factor is dialed directly.

c. Step m from Four Arm Gage operation, above, is changed to read: A one arm gage may also be calibrated by applying a full load to the gage and adjusting the CALIBRATE dial for half scale (center-to-edge) pen deflection, with the LOAD FULL SCALE control set to 50%.

NOTE: If the gage factor is 4.00 or greater, the CALIBRATE dial can be set to one-fourth the gage factor and the % LOAD FULL SCALE control can be used directly as in the four arm gage procedure.

3.5 EVALUATING STRAIN IN MICRO INCHES PER INCH

This section tabulates full scale sensitivities in micro inches (uin) per inch for different settings of the % LOAD FULL SCALE switch. Examples of sensitivities for several settings of the CALIBRATE control are also given.

ATTENUATOR SETTING (% LOAD FULL SCALE)	FULL BRIDGE OPERATION	HALF BRIDGE OPERATION	QUARTER BRIDGE OPERATION
5%	50 uin./in	100 uin/in	200 uin/in
10%	100 uin/in.	200 uin/in	400 uin/in
20%	200 uin/in.	400 uin/in	800 uin/in
50%	500 uin/in	1000 uin/in	2000 uin/in
100%	1000 uin/in	2000 uin/in	4000 uin/in
200%	2000 uin/in	4000 uin/in	8000 uin/in

Gage factor (CALIBRATE Control) set at gage factor of gage as specified by strain gage manufacturer (must be between 1.0 and 10.0). Excitation voltage set to 5 volts.

TABLE 3-1 TYPICAL FULL SCALE SENSITIVITIES

Examples of changing full scale sensitivity by varying the setting of the CALIBRATE Control (Attenuator @ 100% F.S.):

	CALIBRATE Control Setting	SENSITIVITY in uin/in F.S.
Full Bridge operation with gage factor of gage equal to 2.1	2.1 (matching gage) 4.2 (Double) 8.2 (Quadruple)	1000 2000 4000
Half Bridge operation with gage factor of gage equal to 2.3	2.3 (matching gage) 4.6 (Double) 6.9 (Triple)	2000 4000 6000
Quarter Bridge operation with gage factor of gage equal to 3.5	3.5 matching gage) 7.0 (Double)	4000 8000

TABLE 3-2 EFFECT OF CALIBRATE CONTROL

3.6 OPERATION AS A DC AMPLIFIER

The DC Bridge Preamplifier can be satisfactorily used as a sensitive DC amplifier. Remove the Bal R (the 15 K ohm resistor) from terminals E13 and E14. Remove the shorting link from between terminals E12 and E13. Also remove all bridge completion resistors (R1, 2, and 3).

The following list indicates % LOAD FULL SCALE switch settings and corresponding voltage sensitivity for various CALIBRATE dial settings.

Connect the input signals to pins 1 and 2 and the shield to the guard ring. See section 2.4c for grounding information.

D-C Amplifier Operation – Typical Ranges – Full Scale Sensitivity in Millivolts

Attenuator Setting (% Load Full Scale)	Calibrate Vernier Setting (Gage Factor or Millivolts Per Volt)			
	1.00	2.00	5.00	10.00
5%	0.250mV	0.500mV	1.25mV	2.50mV
10%	0.500mV	1.00mV	2.50mV	5.00mV
20%	1.00mV	2.00mV	5.00mV	10.0mV
50%	2.50mV	5.00mV	12.5mV	25.0mV
100%	5.00mV	10.0mV	25.0mV	50.0mV
200%	10.0mV	20.0mV	50.0mV	100.0mV

3.7 USING CALIBRATED ZERO SUPPRESSION

Zero suppression permits the steady-state component of a complex signal (load) to be suppressed allowing the dynamic portion to be amplified and recorded in greater detail.

Zero suppression can be used either in strain gage applications or those where the Bridge Preamp is used strictly as an amplifier.

3.7.1 Application No. 1: Using Zero Suppression with a Strain Gage

1 — 2
2 — 3
4 — 5
6 4
7 — 1
SH 6 + SHELL

a. Set up the bridge as described in paragraph 3.4.

b. Turn ZERO SUPPRESSION (VERNIER) to full counterclockwise position.

c. Apply a load to the strain gage and rotate the % LOAD FULL SCALE control until the pen approaches chart edge.

d. Set the ZERO SUPPRESSION (range, –VOLTS+) control to the appropriate range and polarity.

NOTE: For calculating output of bridge, refer to paragraph 3.10,"Computing Calibration Resistance and Calibration Deflection".

e. Advance ZERO SUPPRESSION (VERNIER) dial clockwise until pen approaches chart zero.

f. Advance % LOAD FULL SCALE control clockwise until desired sensitivity is reached, keeping pen to chart zero with ZERO SUPPRESSION (VERNIER).

g. The load now may be varied around the static portion to obtain more useful information.

3.7.2 APPLICATION NO. 2: Using Zero Suppression with a D.C. Signal

a. Set % LOAD FULL SCALE control to the OFF position.

b. Set CALIBRATE dial to desired sensitivity.

c. Connect signal to the input leads.

d. Center pen trace on chart using POSITION control located on chart recorder.

e. Turn the ZERO SUPPRESSION (VERNIER) dial fully counterclockwise.

f. Rotate the % LOAD FULL SCALE control clockwise until pen approaches chart edge.

g. Set the ZERO SUPPRESSION (Range, –VOLTS+) control to the appropriate range and polarity.

h. Advance the ZERO SUPPRESSION (VERNIER) dial clockwsie until the pen reaches chart center.

j. Advance the % LOAD FULL SCALE control until the dynamic portion of the signal approaches the chart edge.

k. Read the static portion of the signal directly from the ZERO SUPPRESSION (VERNIER) dial.

3.8 OPERATION WITH CALIBRATION RESISTORS EXTERNAL TO THE PREAMPLIFIER

Transducers which contain a built-in shunt resistor to give a % of full scale calibration signal can easily be used with the preamplifier. (Refer to transducer manufacturer's instructions for connections.)

Transducers of this type fall into 2 major types:

A) those with the calibration resistor connected to the negative excitation terminal of the bridge.

B) those with the calibration resistor connected to the negative output terminal of the bridge.

If the transducer is type A, to obtain a positive calibration place a jumper between terminals E12 and E11. Remove the jumper between E3 and E4 and place between E3 and E2. Connect lead from the free end of the resistor to pin 4 (CAL 1) of the input connector. Depressing the "CAL" pushbutton on the front panel places the resistor across one arm of the bridge. To obtain a negative calibration, place the jumper between E12 and E13 instead of E12 and E11.

If the transducer is type B, to obtain positive calibration, place a jumper from E12 to E16. Place jumpers between E2 and E3. Remove all others. Connect free end of resistor to pin 4 (CAL 1) of the input connector. Depress the "CAL" pushbutton on the front panel to obtain a deflection.

To obtain a negative calibration, place jumpers between E2 and E3, and E3 and E4. Remove all other jumpers. Connect free end of resistor to pin 5 (CAL 2) of the input connector. Depress the "CAL" pushbutton on the front panel to obtain a deflection.

3.9 CALCULATING OUTPUT OF A STRAIN GAGE BRIDGE

Calculate the output of the bridge by:

$e_o = KE\epsilon$ where:

a. e_o = Output voltage in microvolts

b. K = Gage factor

c. $\epsilon = \dfrac{\epsilon_1 - \epsilon_2 + \epsilon_3 - \epsilon_4}{4}$ = Average strain in microinches/inch.

d. E = Bridge excitation in volts.

NOTE: Use signs (+) for tension, (–) for compression and zero (0) for inactive arms.

The expression for e_o holds good for any number of active arms of a bridge as long as zero (0) is substituted for inactive arms in formula c.

3.10 COMPUTING CALIBRATION RESISTANCE AND CALIBRATION DEFLECTION

The formula for calculating the calibration resistance is:

$$Rc = \frac{Rg \times 10^6}{KN\epsilon} - Rg$$

For calculations of simulated strain it is:

$$\epsilon = \frac{Rg \times 10^6}{KN\,(R_c + R_g)}$$

Rg = Resistance of each active gage

K = Gage factor or voltage sensitivity of transducer.

N = Number of active gages

Rc = Resistance of calibration resistor.

ϵ, = $\left(\frac{\Delta L}{L}\right)$ = Simulated strain (microinches/inch)

OR

$\left(\frac{\Delta L}{L}\right)$ = Simulated calibration load for any transducer.

Example No. 1: Strain gage bridge with four active arms each 120 ohms. Gage factor of 2.00, with a 15K ohm calibration resistor.

$$\epsilon = \frac{120 \times 10^6}{(2.00)\quad(4)\quad(15000 + 120)}$$

$$= \frac{120}{.12096}$$

$$= 992$$

= 992 micro strain

= 99.2% of full scale

The general formula CAL deflection for a 120 ohm bridge with four active arms, using a 15K ohm calibration resistor is:

$$\%\text{ full scale} = \frac{198.4}{\text{gage factor}}$$

Example No. 2: 1000 lb load cell with 350 ohm bridge & 4 active arms. Sensitivity factor 2.00 millivolts/volt of excitation, using 50K ohm calibration resistor.

$$\left(\frac{\Delta L}{L}\right) = \frac{350 \times 10^6}{(2.00)\quad(4)\quad(50{,}000 + 350)}$$

$$= \frac{350}{.4028}$$

= 869 lbs.

= 86.9% of full scale

The general formula for CAL deflection for a 350 ohm bridge with four active arms, using 50K ohm calibration resistor is:

$$\%\text{ full scale} = \frac{173.8}{\text{gage factor}} \text{ or } \frac{173.8}{\text{sensitivity factor.}}$$

SECTION IV

THEORY OF OPERATION

4.1 GENERAL

The Gould D.C. Bridge Preamplifier, Model 13-4615-30 consists of a differential input amplifier with variable calibrated gain, a stepped attenuator, an output amplifier, and a regulated, isolated D.C. power supply which provides excitation voltage to the transducer. In addition, the amplifier has calibrated zero suppression and selectable filtering for noisy environments. See Block Diagram, Figure 4.1.

4.2 INPUT AMPLIFIER

The input amplifier consists of dual transistors Q201 and op amp U201 with associated circuitry. The transistors are low bias current, low voltage drift types and are supplied with a constant current source comprised of Q202, CR201, CR202, R209 and R210. To keep voltage drift to a minimum, the collector resistors are low TC wirewound types. U201 provides additional gain to maintain gain accuracy. Multiturn pot R206 zeroes the amplifier.

R203 is a gain balance pot to set common mode rejection. The gain of the amplifier is determined by the setting of the front panel "calibrate" potentiometer R103, and varies from 52.5 to 262.5. The output of U201 is connected to attenuator S203, "% load full scale" control.

4.3 ATTENUATOR

The output of U201 is connected across resistor string R212 through R217 to common. The resistor ratio's determine the percentage of full scale deflection from 5% to 200%. The attenuator is connected to the output amplifier U202.

4.4 OUTPUT AMPLIFIER

The output of the attenuator is applied to U202, the output amplifier, which provides further gain for the transducer signal.

4.5 DC POWER SUPPLY

The power supply is operated from the secondary of an isolated transformer. The AC is rectified by full wave bridge CR207 and filtered by C208. Q205 and U203 provide a regulated supply for transducers. The supply is selectable for either 5V or 10V by S202. The polarity is reversible by means of S201.

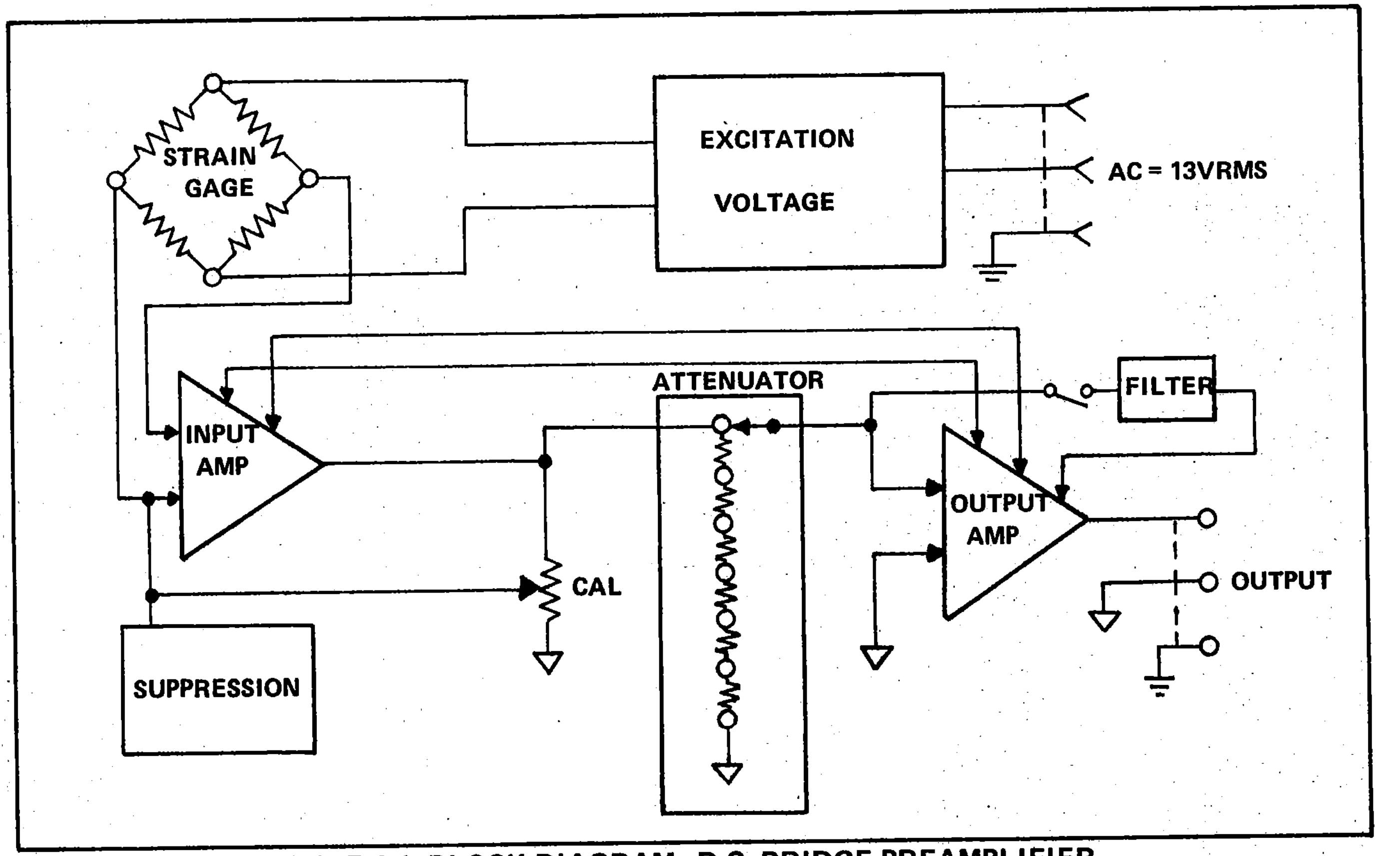


FIGURE 4-1 BLOCK DIAGRAM—D.C. BRIDGE PREAMPLIFIER

4.6 ZERO SUPPRESSION

A stable reference voltage is provided by zener diode CR203 in conjunction with the current sources formed by Q203 and Q204. A plus or minus reference is provided depending upon which end of the zener is connected to common. It is then divided down to provide either .01 volts or .1 volts suppression full scale.

The amount of suppression is variable by means of front panel potentiometer R104. The output of the control is applied to R224 and summed into the inverting input of the input amp.

4.7 OPTIONAL FILTER

For noisy environments an optional 5Hz, 2 pole filter is provided by means of inserting C204 and C205 into the terminals provided. This does not behave as a true 2 pole filter due to the gain configuration. It rolls off at -12db/octave until approximately -30db and then becomes a single pole filter with -6db/octave attenuation.

Formulas for calculating C204 and C205 for frequencies other than 5 Hz:

$$C204 = \frac{(.8\ \text{ufd})\ (5\ \text{Hz})}{\text{New Frequency}}$$

$$C205 = \frac{(.02\text{ufd})\ (5\ \text{Hz})}{\text{New Frequency}}$$

SECTION V

CALIBRATION

5.1 GENERAL

In addition to detailed calibrate procedures, this section contains paragraphs on troubleshooting and maintenance.

5.2 CALIBRATION

a. General

The Gould D.C. Bridge Preamplifier, Model 13-4615-30 has been accurately calibrated before shipment from the factory and should give long trouble free service. Should recalibration be required, it should be performed by qualified technical personnel only.

NOTE: Performance checks in this section specify limitations based on optimum "new-equipment" values. Should any results be unacceptable, please see the troubleshooting section of this manual or your Gould Service Representative.

b. Test Equipment Required

Proper test equipment is essential for accurate calibration. Use the equipment specified below or its equal.

1. Digital Multimeter, AC/DC. Fluke Model 8100A.
2. Oscilloscope. Tektronix Series 530 with 1A7A plug-in.
3. AC Source. ±.05% accuracy (or settability and stability).
4. DC Source. ±.05% accuracy: Fluke Model 343A.
5. Power Supplies ±15V @ 150ma, ±5% accuracy.
6. Auto Transformer. Variac W5MT3AE.
7. Extender Card and Cable Assembly: Gould P/N 887291.
8. 2000 Series Recorder.

c. Preliminary Procedure

1. Set Front Panel Controls as follows:

%LOAD FULL SCALE	off
SUPPRESSION (–VOLTS+)	off
VERNIER DIAL (SUPPRESSION)	Remove
VERNIER DIAL (CALIBRATE)	Remove
SHUNT (CAL)	N/A
SHUNT (TRIM)	N/A
BALANCE	N/A

2. Load Output with a 2Kohm resistor. (pins 2 & 5)
3. Remove right side cover from preamp (Figure 5-1).

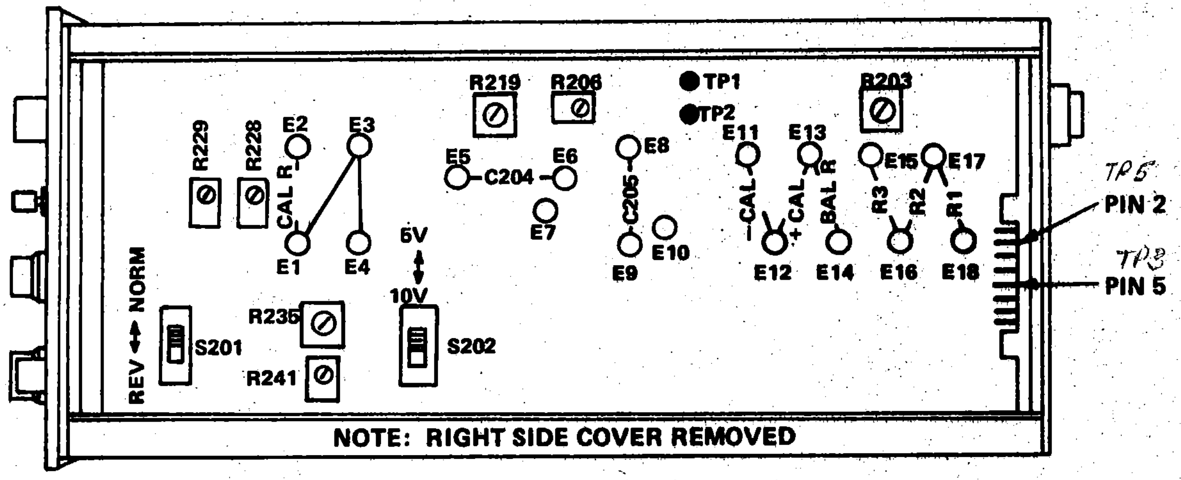


FIGURE 5-1 CALIBRATION COMPONENT LOCATIONS

4. Connect input to power source: ±15Vdc and 13Vrms or power from a series 2000 recorder.

5. Measure voltage at TP1 to Pin 5 (common). It should be approximately 10 Volts (Figure 5-1).

6. Measure voltage at TP2 to common. It should be approximately 10 volts. (Figure 5-1).

7. Make certain that capacitors C204 & C205 are not in the circuit. (Not connected to E6 or E9.)

8. Check that there are no oscillations on output.

9. Allow unit to warm-up for 15 minutes.

d. Amplifier Calibration

1. Short inputs to common (E11 & E13 to pin 5) and set front panel controls as described in paragraph 5.2c.

2. Connect voltmeter to the output (pins 2 & 5). Set the output to zero (0) volts ±5mv with R219 (Figure 5-1).

3. Set the front panel CALIBRATE pot approximately 1.5 turns from the extreme counter-clockwise position.

4. Set the % LOAD FULL SCALE switch to the 5% position and use R206 to set the output to zero (0) volts ±50mv. (Figure 5-1).

5. Tie the "+" and "-" inputs (E11 & E13) together and apply a 10 volt peak-to-peak 60Hz signal between the inputs and common (pin 5). Connect an oscilloscope to the output (pins 2 & 5) and adjust R203 for a minimum output. (Figure 5-1).

6. Remove signal generator. Short input to common as in step 1 and set % LOAD FULL SCALE switch to the 100% position.

7. Set the front panel CALIBRATE turns counting dial to 2.00, and lock it in this position. Apply a 10.0 mv DC signal to the input. Adjust the CALIBRATE pot (Slot under plastic knob) with a screwdriver for 5.00 vDC ±5 mv on the output. Secure the turns coutning dial to the shaft.

e. Bridge Excitation Voltage

1. Set %LOAD FULL SCALE switch to the OFF position. Short inputs to common.

2. Place a 100 ohm, 2 watt resistor between pins 6 and 7 of the input connector. Connect a voltmeter across the resistor (Hi to pin 7). Connect as oscilloscope with "Hi-Cutoff" at 1KHz across the resistor.

3. Set the 5-10 volt switch, S202, to the 5V position and the Normal-Reverse switch, S201, to the NORMAL position. Use R241 to adjust the voltage to +5.0V ±5mv. Noise should be less than 5mv peak-to-peak (See Figure 5-1).

4. Change S201 to the REVERSE position. Voltmeter should read -5.0V ±5mv. Noise should be less than 5 mv peak-to-peak. Return to the NORMAL position.

5. Set S202 to the 10.0V position. Use R235 to set the voltage to +10.0V ±10mv. Noise should be less than 10 mv peak-to-peak (See Figure 5-1).

6. Change S201 to the REVERSE position. Reading should be -10.0V ±10mv. Noise should be less than 10mv peak-to-peak.

f. Suppression Voltage

1. With inputs shorted to Common (E11 & E13 to pin 5) set the % LOAD FULL SCALE switch to 100. Set the CALIBRATE dial to 2.0.

2. Take remaining vernier turns counting dial and set to 00.0 and lock. Adjust the ZERO SUPPRESSION—VERNIER pot (slot under plastic knob) with a screwdriver fully counter-clockwise. Place the dial on the shaft and secure in place with set screw provided.

3. Monitor the output (pins 2 & 5) with a voltmeter. Be sure output reads zero volts ±5 mv. Adjust R219 as required (See Figure 5-1).

4. Turn SUPPRESSION VERNIER to 10.0 and lock. Apply a +10.0mv ±0.05% DC signal to the input (E11/E13). Set the —VOLTS+ switch to the +0.01 position and use R228 (Figure 5-1) to set the output to read 0.00 Volts ±5 mv.

5. Switch the input to -10mv and the —VOLTS+ switch to -0.01 position. The output should read 0 volts ±25mv.

6. Apply a +100.0 mv ±0.05% DC signal to the input. Set the —VOLTS+ switch to +0.1 and use R229 (Figure 5-1) to set the output to read 0.00 Volts ±50mv.

7. Switch the input to -100.0mv and change the —VOLTS+ switch to the -0.1 position and check to see that the output reads 0 Volts ±100mv.

8. Remove the input and return the —VOLTS+ switch to the OFF position.

9. Return the SUPPRESSION VERNIER dial to 00.0 and lock.

g. Amplifier Zero Check

1. Set controls as follows:

% LOAD FULL SCALE	OFF
NORMAL/REVERSE Switch	NORMAL
Bridge Voltage Switch (S202)	5V

2. Short inputs to common.

3. Connect voltmeter to the output. Check for 0 ±5 mv. If not zero see step 5.2.d, above, for calibration.

4. Set the %LOAD FULL SCALE switch to the 5% position. Check for 0 ±50 mv as in preceeding step.

TABLE 5-1 INPUT/OUTPUT VOLTAGES FOR % LOAD FULL SCALE SETTINGS

%FULL SCALE SETTING	D.C. INPUT ±.05%	OUTPUT	ERROR
5	+.25 mv	+2.5V	25mv
10	+.50mv	+2.5V	25 mv
20	+1.0mv	+2.5V	12.5 mv
50	+2.5mv	+2.5V	12.5 mv
100	+5.0 mv	+2.5V	5.0 mv
200	+10.0mv	+2.5V	12.5 mv

h. Amplifier Accuracy Check

Table 5-1 lists the input and output voltage for each setting of the % LOAD FULL SCALE switch. The error at each setting should be with in the limit listed. If errors exceed those in table, repeat step 5.2.d. If still excessive, see paragraph 5.2.a.

j. Common Mode Rejection Check

1. During the common mode rejection check remove the 15K ohm balance resistor from terminals E13 & E14.

2. Connect a 100 Ohm resistor between + and - input (pins 11 & 13). Set the CALIBRATE dial to 2.00 and the % LOAD FULL SCALE switch to 5%.

3. Apply a 10 Volt peak-to-peak 60Hz sinewave between common (pin 5) and chassis ground. Monitor the output with a scope and connect (—) input to common. The output should be less than 1 Volt peak-to-peak.

4. Remove (-) input from common and connect the (+) input. The output should be less than 1 Volt peak-to-peak.

k. Frequency Response

1. Set % LOAD FULL SCALE switch to 100% and CALIBRATE dial to 2.00.

2. Apply a 7.0 mvrms, 60Hz sinewave to the input. Monitor the output and increase frequency to 1KHz. Output should not decrease more than 40mv below the 60Hz reading.

3. Switch frequency to 3Hz. Monitor output with an oscilloscope (DC coupled). Set amplitude on output to be approximately 10V peak-to-peak.

4. Place plug-in capacitors C204 and C205 in the circuit by inserting in terminals E5 and E6, and E8 and E9. (See Figure 5-1).

5. Increase frequency until output decreases to 7 volts peak-to-peak. Frequency at this point should be between 4.5 and 5.5Hz.

6. Remove input signal and remove capacitors (C204 and C205) from circuit by inserting them in E5 and E7, and E8 and E10.

m. **Amplifier Noise**

1. Short inputs to common (E11 & E13 to pin 5). Set CALIBRATE dial to 2.00 and the % LOAD FULL SCALE switch to 5%.

2. Observe output with the oscilloscope "Hi-Cut-off" frequency set to 100Hz. Noise should be less than 100 mv peak-to-peak.

3. Set "Hi-Cutoff" to 1KHz. Noise should be less than 150mv peak-to-peak.

n. **Bridge Excitation Voltage Noise Check**

1. Recheck the noise levels per step 5.2.e to make certain they are within the specified limits.

p. **Suppression Voltage Check**

(If any of the following voltages are not as specified, repeat the Suppression Voltage calibration per step 5.2.f.)

1. With inputs shorted to common, set the % LOAD FULL SCALE switch to 100. Set the CALIBRATE dial to 2.0.

2. Monitor the output with a voltmeter. Be sure output reads zero volts ±5 mv.

3. Apply +10.0mv ±.05% dc to the input. Set the –VOLTS+ switch to OFF. The output should be 5.0V ±10mv.

4. Turn the VERNIER SUPPRESSION dial to 0.0 and set the –VOLTS+ switch to +.01. The output should be the same as in step 3 above.

5. Set the VERNIER SUPPRESSION dial to 5.0. The output should be +2.50V ±25mv.

6. Set the VERNIER SUPPRESSION dial to 10.0. The output should be 0.0V ±25mv.

7. Change the input to +100.0mv. Turn the -VOLTS+ switch to +.1. The output should be 0.0V ±50mv.

8. Change the input to -100 mv. Turn the -VOLTS + switch to -.1. The output should be 0.0V ±100mv.

9. Change the input to -10MV. Set the -VOLTS+ switch to -.01. The output should be 0.0V ±25 mv.

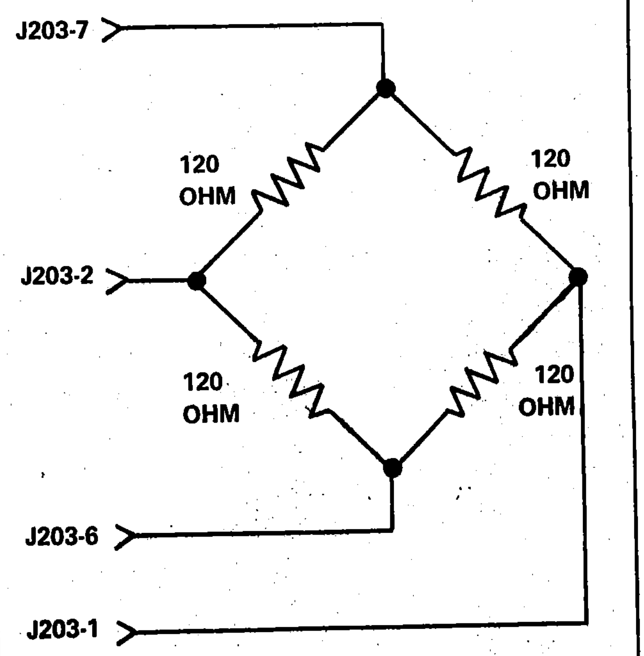
10. Turn the -VOLTS+ switch to OFF.

q. **Final Check**

1. Set the front panel CALIBRATE dial to 2.00 and lock. Check the zero in the OFF position: ±5mv. Check the zero in the 5% position: ±50mv. If tolerances exceeded, return to step 5.2.d. Return the % LOAD FULL SCALE switch to the OFF position.

2. Excitation voltage switch, S202, should be on 5 volt.

3. Connect a 4-arm 120 Ohm bridge to the amplifier as shown in Figure 5-2.



RESISTORS SHOULD BE .25%, 1 WATT METAL FILM.

FIGURE 5-2 INPUT BRIDGE

4. Place a 15K ohm resistor between the CAL R terminals (E1-E2) and a 15K ohm resistor between BAL R terminals (E13-E14) on the P.C. board (see Figure 5-1).

5. Place a jumper between E1 and E3, between E3 and E4, and between E12 and E13.

6. Connect a voltmeter to the output and increase the sensitivity step by step from 200% to 5% keeping the output to zero ±50mv with the BALANCE control.

7. Return the % LOAD FULL SCALE switch to the 100% position.

8. Depress the front panel SHUNT CAL pushbutton. The output should read approximately +4.9 volts.

9. Remove the jumper between E12 and E13 and insert between E11 and E12. (This jumper determines the direction of pen movement when CAL button is pressed. Depress the SHUNT CAL pushbutton. Output should read approximately -4.9 volts. Replace the jumper between E12 and E13.

10. Change S201 (Figure 5-1) to the REVERSE position and repeat Step 7. Output should read approximately -4.9 volts. Return S201 to the NORMAL position.

11. Set S202 to the 10V position. Repeat Step 7. The output should be approximately +9.8 volts. Return S202 to the 5 V position.

12. Remove the jumper between E1 and E3.

13. With the SHUNT CAL pushbutton depressed, use a screwdriver to rotate the front panel SHUNT TRIM Pot from the extreme counterclockwise position to the extreme clockwise position (approx. 4½ turns). The output should read approximately +4.9 volts (CW) to +1.8 volts (CCW). Return the TRIM pot to its center position, approximately +2.7 volts on the output.

14. Remove test bridge and turn % LOAD FULL SCALE switch to OFF.

5.3 SYSTEM CALIBRATION CHECK (PREAMP PLUS RECORDER)

Install preamplifier into Gould 2000 Series Recorder, and perform the following procedures:

NOTE: In order for these steps to have any significiance, the 2000 Series Recorder must be properly calibrated.

a. Gain Accuracy

1. Turn recorder on and run at 5 mm/sec. Use Pen POSITION to set trace to CENTER ZERO.

2. Apply DC voltages to all ranges as listed in Table 5-2. Deflection should be within limits listed. On the 5% and 10% of % LOAD FULL SCALE settings it may be necessary to use the Pen POSITION adjustment on the recorder to re-zero the trace.

TABLE 5-2 VOLTS APPLIED/RECORDER DEFLECTION FOR % LOAD FULL SCALE SETTINGS

% OF LOAD FULL SCALE	VOLTS APPLIED	RECORDER DEFLECTION
5	± 0.25 mV	Full scale ±0.7%
10	± 0.5 mV	Full scale ±0.7%
20	± 1.0 mV	Full scale ±0.7%
50	± 2.5 mV	Full scale ±0.7%
100	± 5 mV	Full scale ±0.7%
200	± 10 mV	Full scale ±0.7%

b. Linearity

1. Set the "% Load Full Scale" switch to 100.
2. Set the line voltage to 90% of normal and the chart speed to 5mm/sec. Apply a 1 Hz triangular wave from a function generator. Adjust the amplitude and pen zero for full scale deflection on the chart.
3. Increase the chart speed to 200 mm/sec. and run approximately 500 to 600 mm of chart paper. Measure the variation from a straight line of a positive and negative going waveform. The maximum error should be less than 0.45% of full channel width.
4. Set the line voltage to 100% of normal and repeat Step 3. Error should be the same as in Step 3.

c. Zero with Line

1. Set the line voltage to nominal and the chart speed to 5 mm/sec. Short the input to the preamp and set the pen to zero.
2. Decrease the line voltage to 90%. the zero should shift less than 0.3% of full channel width.
3. Set the line voltage back to nominal and recheck the zero. Increase the voltage to 110%. The zero should shift less than 0.3% of full channel width.

d. Noise

Short the input to the preamp lifter and set the chart speed to 5mm/sec. Position the pen on the zero line. Run the chart at 200 mm/sec. for approximately 300mm.

The trace width should be less than 1% of full channel width.

5.4 TROUBLESHOOTING

Troubleshooting may be performed in conjunction with the schematic (located behind the parts section) and the bench equipment listed in paragraph 5.2. When the preamplifier is used with a Gould 2000 Series Recorder, refer to the troubleshooting table in Section V of the recorder manual.

5.5 MAINTENANCE

a. General

Maintenance on the preamplifier is limited to cleaning only.

CAUTION

1) Before attempting to clean preamplifier, turn OFF power and remove from enclosure.

2) Avoid use of chemical cleaning agents which might damage plastic or printed surfaces. Do not use chemicals which contain toluene, Cellusolve, acetone or similar solvents.

EXTERIOR

Remove loose dust with a soft cloth or small paint brush. Dirt which remains can be removed with a soft cloth dampened in a mild detergent and water solution. DO NOT USE ABRASIVE CLEANERS.

INTERIOR

Dust in the interior should be removed occasionally due to its electrical conductivity under high humidity conditions. Blow off accumulated dust with dry low pressure air. Remove any dirt which remains with a soft paint brush or a soft cloth dampened in a mild detergent and water solution. A cotton-tipped applicator is useful for cleaning in narrow spaces and/or printed circuit boards.

SECTION VI

APPLICATIONS

6.1 AN INTRODUCTION TO STRAIN

Strain is a fundamental physical phenomenon. It exists in solids at all times, due either to loads or to the weight of the material itself. The terms "strain" and "physical deformation" are synonymous. In engineering strain refers to the change in any linear dimension of a body which is due to the application of either internal or external forces.

"Strain" as defined above refers to total strain, but we are primarily interested to "unit strain" which has much greater significance. Average unit strain is the total deformation of a body in a given direction divided by the original length in that direction. Unit strain as determined by a strain gage is expressed in microinches per inch.

$$\text{Strain} = \frac{\text{Change in Length}}{\text{Original Length}} \text{ (microinches)}$$

or

$$\varepsilon = \frac{\Delta L}{L}$$

The word "strain" (or "micro-strain") when used alone normally refers to "unit strain." Engineers and scientists have attempted for centuries to measure strain accurately, but only the last two decades has seen outstanding advancement in the art of strain measurement, made possible by the development of the bonded resistance strain gage.

6.2 WHY MEASURE STRAIN?

The measurement of strain can be beneficial to anyone in industry who is interested in developing or producing a superior product. During the past two decades strain measurement has opened up an entirely new branch of engineering called "experimental stress analysis." The strain gage has been used so extensively and so successfully in the aircraft industry that it can safely be said that without it aircraft performance and safety factors would be far below their high present day levels. Today, the bonded strain gage is finding its way into all heavy industries. From strain gage data, engineers can produce better machine designs which provide superior performance and reliability, weigh less and cost less to build. Strain gages are used in hundreds of industrial applications from strain analysis of smoke stacks to metal distortion in turbine blades, and from the flight of an arrow to the flight of an airliner. The only limit of strain gage applications appears to be the imagination of the user.

6.3 ACCURACY

Strain gages are electromechanical transducers that

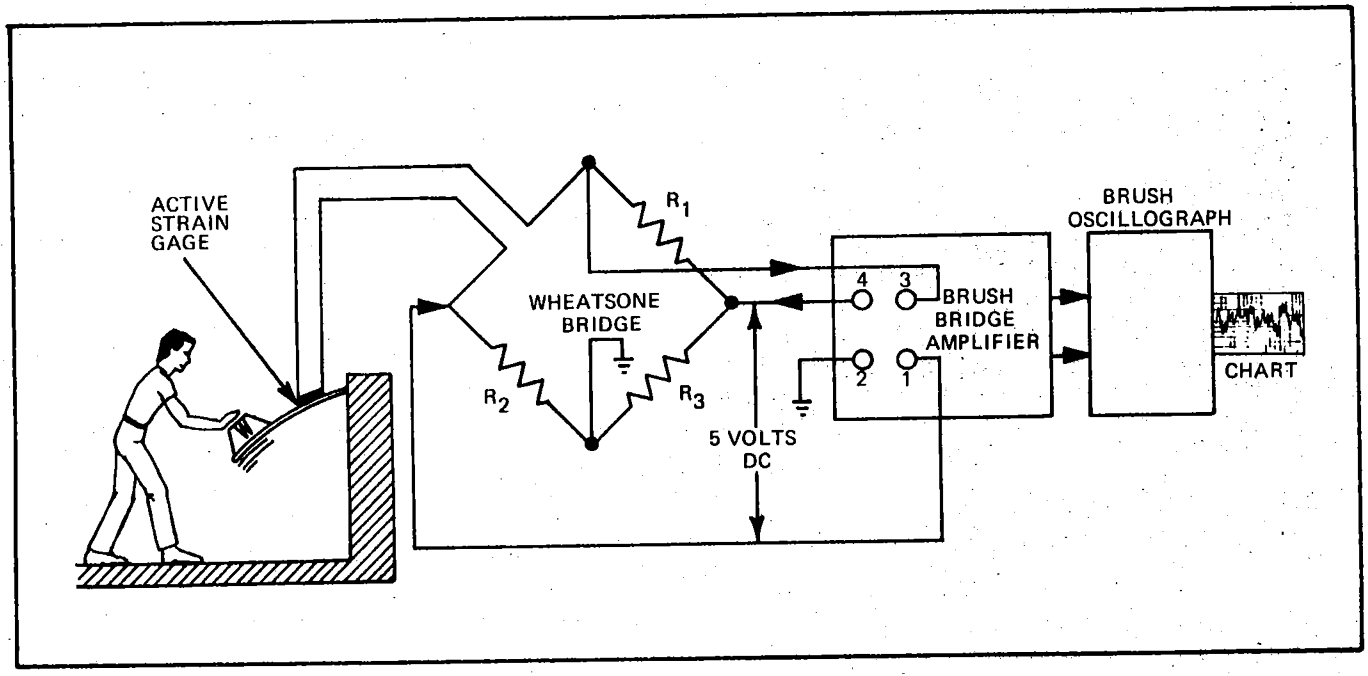


FIGURE 6-1 BASIC STRAIN RECORDING

are applied to the surface of the material. The strain gage exhibits a change of electrical resistance with a change in strain. The change is linear, and may be measured with suitable instrumentation. The method, although indirect, is precise. Accuracies of 1% are obtained with standard equipment, properly applied and operated with reasonable care. Accuracies up to 0.1% can be achieved by experts working with special apparatus. (Figure 6-1)

6.4 SENSITIVITY

Sensitivity of a strain gage is determined by the electrical conductivity of the sensing element material and its configuration. It is predetermined by the manufacturer. "Gage factor" is a measure of strain gage sensitivity. All commercial resistance strain gages have a positive gage factor. This means that an increase in strain produces an increase in strain gage resistance. Strain (ϵ) has been defined as the change in the length (ΔL) divided by the original length (L). The unit change in resistance that the strain produces is defined as the change in resistance (ΔR) divided by the original resistance (R).

Gage factor (G_f) is defined as the unit resistance change divided by the unit strain. That is:

$$G_f = \frac{\Delta R/R}{\Delta L/L}$$

The measured gage factor stated on each strain gage package should be used in all instrument calibrations.

6.5 AREA OF STRAIN MEASUREMENT

In use, each portion of the strain gage is intimately bonded to the member being tested and accurately follows its movements in both tension and compression. It measures the average of strains all along the gage length. If strain is localized in a small area, a short length gage must be used. Gages only 1/64" long are available for use when working space is limited.

For measuring large strains up to 10% elongation special "post yield" strain gages are available.

6.6 ROSETTES FOR COMPLEX STRAIN MEASUREMENTS

Single-element strain gages are designed to measure only those strains that are parallel to the strain gage axis. Transverse-axis sensitivity of a single-element gage is usually less than 2% of the normal "strain—axis" sensitivity and has negligible effect on output.

Where strain directions are not known, it is necessary to use multiple array strain gages called rosettes. The individual elements in a rosette gage are arranged to facilitate later calculation of both the magnitude and direction of the principal strains. Three separate channels are required to measure or record the strain data from a three-gage rosette.

The two most common types are the rectangular rosette which has gages oriented at 0°, 45° and 90° and the delta rosette with gages oriented at 0°, 60° and 120°. When the direction of principal strain is known approximately, the rectangular rosette is used so that the center gage can be oriented in the estimated direction of the principal strain. When the direction of the principal strain is completely unknown, the delta rosette should be used.

6.7 DURATION AND FREQUENCY OF STRAIN

Three general classes of strain work are encountered. The first is long-term measurement of static or slowly changing forces. This requires gages which provide consistent output under changing environmental conditions. The conventional strain gages used with proper temperature compensated strain gages, are both available for these long term, drift-free measurements.

The second class of strain work deals with rapidly varying strains of high magnitude. This work requires gage grid materials of high fatigue resistance. Isoelastic wire gages were developed specifically for this type of application, but they create difficult problems in temperature compensation.

The third class of strain work deals with a combination of static and dynamic strains plus transient temperature conditions. The new temperature-compensated foil gages are quite satisfactory for this class of work.

6.8 DESIRABLE CHARACTERISTICS OF STRAIN GAGES

An ideal universal strain gage would contain the following characteristics:

1. Ability to measure strains accurately under static or dynamic conditions.
2. Small size, light weight and negligible thickness.

3. Suitable for remote observation and recording.
4. Unaffected by temperature, vibration, humidity or other ambient conditions.
5. Easy to install on member being analyzed.
6. Good stability and negligible hysteresis.
7. Large linear output in response to strain.
8. Inexpensive.
9. Dependable and not subject to aging or fatigue.
10. Capable of operation as an individual strain gage or in multiple rosettes.

6.9 ETCHED FOIL STRAIN GAGES

Today the "etched foil" strain gage contains practically all of the foregoing features. Several hundred different types and sizes are commercially available from a number of sources. Bonded resistance strain gages are available today that will satisfy most engineering requirements.

Etched foil strain gages offer significant improvement over the earlier wire-grid gages in both electrical and mechanical performance, along with better application flexibility. Each grid element is many times wider than its thickness, providing a large bonding area. The end loops of the grid reduce transverse sensitivity of the gage and also reduce creep and hysteresis. Very thin gages are available in which the total thickness is less than 0.002 inches, allowing extreme flexibility and close contact to the mounting surface.

Etched foil gages have strain sensitivities from 5% to 20% greater than equivalent bonded wire strain gages.

a. Transverse Sensitivity

Etched foil gages are designed for minimum transverse strain sensitivity. Relatively low resistance in the loop ends, which join adjacent grid elements, results in very low transverse sensitivity factors of between 0.5% and 2.0%, providing greater accuracy in two-directional stress fields such as torque measurements.

b. Hysteresis and Strain Limits

Actual tests show the combined hysteresis and zero shift obtained with etched foil gages during strain reversals of ±1500 microinches per inch, to be less than 0.1% of the total strain excursion. Accurate strain measurements can be made up to 5% elongation with properly selected standard self-compensated foil strain gages. Special high elongation foil gages are available for large strains up to 15% elongation.

c. Fatigue Life

Many of the larger epoxy resin backed etched foil gages operated at a reversed cyclic strain level of ±1500 microinches per inch, will have a service life greater than 3,000,000 cycles. Increasing the strain level to ±2000 microinches per inch will reduce the strain gage life expectancy by a factor of 10 to 100, depending on environmental conditions.

d. Operating Temperatures

Etched foil gages are available which will operate from -320^{o}F to $+1200^{o}$F for static measurements or $+1800^{o}$F for dynamic work. It is not practical to cover this entire range with a single gage.

e. Physical Construction and Versatility

Foil strain gages have a distinct advantage in their thin flat form which places the strain-sensitive grid close to the material under test and conforms accurately to surface contours. Flexible construction is achieved by using very thin fiberglass laminates and epoxy base carrier materials. These thin gages are excellent for contour fitting and fast curing applications for use at normal room temperature.

6.10 TEMPERATURE COMPENSATION

Temperature compensation is one of the most important and one of the most frequently over-looked factors in the field of strain measurement. It is possible to start out to measure strain and end up measuring ambient temperature changes. One large company had to scrap more than a million dollars worth of strain data because adequate temperature compensation was not achieved by conventional "dummy" gage compensating techniques. Any strain gage will respond to all strains in the test material whether the strains are thermally induced or produced by an external force or load. If you wish to record strain and not temperature changes, it is urged that you pay special attention to the temperature compensated bridge circuits, temperature compensated strain gages and temperature compensated lead wire systems which will be described later.

a. Self-Temperature-Compensated Gages

The terms ''self-compensated'', ''temperature-compensated'', or "self-temperature-compensated" are applied to strain gages intended for use on materials having a related thermal coefficient of expansion. The gage alloy is so processed that the combined effects of thermal coefficient of resistance in the gage and thermal coefficient of expansion in the mounting surface result in essentially zero resistance change due to temperature. This results in a very low value of "apparent" or "temperature-induced" strain.

When transient temperature conditions are encountered, best accuracy will be obtained by using temperature-compensated strain gages, available from several sources.

Self-temperature-compensated strain gages are designated by an extra letter and digit in their type number which indicate the expansion coefficient of the material for which the gage is designed. For example, C6 in the Budd Company type number, or S6 in a Baldwin type number, would indicate that the strain gage is designed for use on materials which have a thermal expansion of 6 parts per million per degree Fehrenheit (6 PPM/^{o}F).

b. Temperature Compensation in Lead Wires

Lead wire resistance and capacitance also change with temperature. Therefore, lead wires from strain gages to the amplifier must also be temperature compensated.

Many people make the mistake of connecting a single strain gage to the Wheatstone bridge with only two lead wires. Variation in ambient temperature introduces a variable resistance in one leg of the bridge, causing the measuring instrument to see a strain that is not there. Compensation for temperature variation in the leads can be provided by using the "Siemens" three-lead method shown in Figure 6-2. In this three-lead method, two of the leads are in adjacent legs of the bridge which cancels their resistance changes and does not disturb the bridge balance. The third lead is in series with the power supply and is, therefore, independent of bridge balance. The four-wire lead systems described in paragraph 6-11 are also temperature compensated.

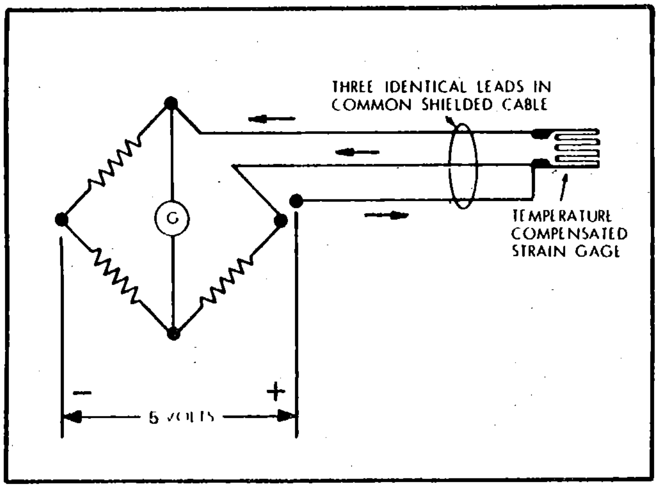


FIGURE 6-2 TEMPERATURE COMPENSATED THREE-LEAD WIRE SYSTEM

Each lead wire between the strain gages and the amplifier should be made exactly the same length and the same size of copper wire so that each lead wire will have exactly the same resistance. The three (or four) lead wires should be run in the same cable or laced snugly together so that all three are subjected to the same ambient temperature conditions. Changes in ambient temperature along the lead wire cable will not affect the strain measurements if the temperature is uniform at any cross-section along the cable. For long runs the size of the copper lead wires should be sufficiently large so that lead wire resistance is small when compared to the resistance of the Wheatstone bridge circuit. In strain gage work, never use the shield as a conductor.

6.11 LATERAL DEFORMATION (Figure 6-3)

Another possible source of errors in strain measurement is lateral deformation as produced by a given longitudinal deformation. In a specimen of uniform cross-section, this relationship is known as Poisson's Ratio.

By definition, Poisson's Ratio is the ratio of the transverse contraction per unit dimension in a bar of uniform cross-section to its elongation per unit length, when subjected to a tensile stress. When the material is subjected to compression, an equal and opposite effect takes place. For cold-rolled steel, for example, the Poisson's Ratio is 0.278; for various aluminum alloys it is 0.330 to 0.334. Poisson's Ratio must be taken into account whenever a temperature-compensating strain gage is mounted directly on the test specimen in simple tension or compression at right angles to the active strain gage. The single gage output will be increased directly in accordance to Poisson's Ratio for the material involved.

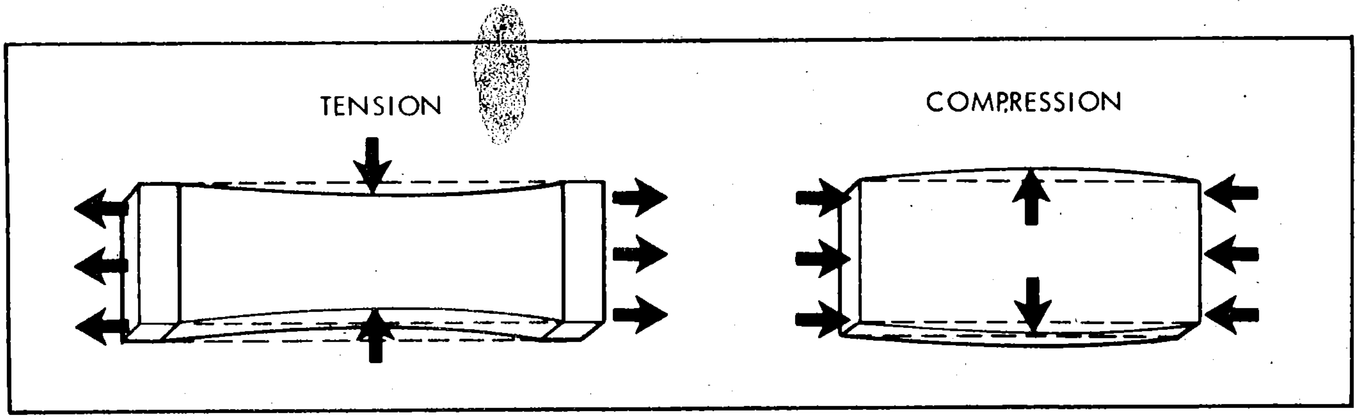


FIGURE 6-3 TYPICAL DEFORMATION OF A RECTANGULAR BAR UNDER TENSION AND COMPRESSION TESTS

6.12 BASIC STRAIN RECORDING CIRCUITS

The Wheatstone bridge circuit can be made up with one active strain gage and three fixed resistors, two active strain gages and two fixed resistors or four active strain gages. A basic Wheatstone bridge circuit is shown in Figure 6-4 with one active strain gage (R_g) and three fixed resistors (R_1,R_2, and R_3). Potentiometer (R_b) is used to balance the bridge with no load applied to active strain gage (R_g). Variable resistor (R_v) provides an adjustment of bridge excitation and thereby adjusts the bridge output.

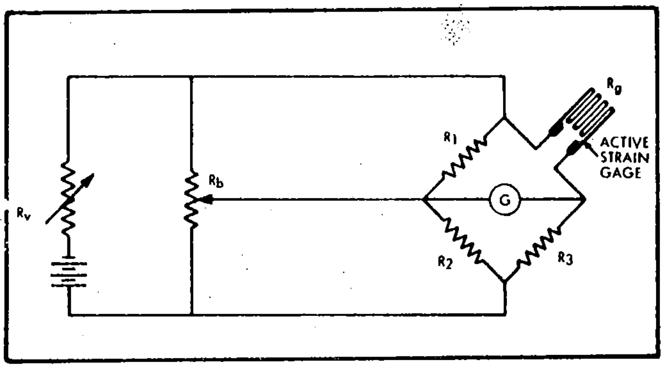


FIGURE 6-4 BASIC WHEATSTONE BRIDGE CIRCUIT

During normal strain measurements, the change in resistance (ΔR) of a resistance strain gage is so small in comparison to the unstressed resistance of the strain gage (R), that bridge linearity remains excellent. Bridge output can be considered directly proportional to changes in strain gage resistance as long as the strain gage receives constant current excitation.

When connecting the strain gages in a bridge circuit it is important to remember that the Wheatstone bridge output will be directly proportional to the difference of resistance changes in any two adjacent arms. Also, in any two opposite arms, the Wheatstone bridge output will be directly proportional to the sum of the resistance changes.

Until a few years ago, A.C. carrier frequencies were used almost exclusively for the excitation of passive type transducers because they worked much better than anything else that was available. Now solid-state electronics have permitted the development of appropriate D.C. amplifiers that have the necessary sensitivity, stability and noise rejection characteristics which makes them satisfactory for most applications.

D.C. Excitation Features

1. Frequency response is limited only by the characteristics of the amplifier selected.
2. Operating simplicity is achieved by elimination of reactive balance, phase adjustment and the balance/operate control.
3. Instrument versatility is improved since universal D.C. amplifiers are also used for many other applications.
4. Longer lead lengths can be used. Reactive transmission losses are eliminated.
5. Cross-talk interference with other circuits is minimized by eliminating the higher A.C. frequencies.
6. It is not necessary to synchronize adjacent D.C. amplifiers to eliminate "beating" because the higher carrier frequencies have been eliminated.

a. Assumed Circuit Conditions

Performance of the strain recording circuits illustrated on the following pages is based on these assumptions:

1. Constant current strain gage excitation, (I_C).
2. Minor changes in the modulus of elasticity (E) of the material due to temperature changes are neglected.
3. In Figures 6-10 and 6-11 transverse effects are neglected.
4. All the bridge circuits on the following pages receive excitation from the Brush Amplifier.

b. One Active Strain Gage

When one active strain gage is used, a Brush strain recording system is normally calibrated for a sensitivity of four microinch per inch of strain per chart division. The internal calibration system in most Brush strain amplifiers permits adjustment of amplifier gain so that this sensitivity may be obtained for any 100 to 1000 ohm strain gage with a gage factor of 2.0 or higher. If desired, the system may be calibrated for a lower sensitivity.

c. One · Active Gage Without Temperature Compensation

The simplest but least accurate method of strain measurement employs only one active strain gage as shown in Figure 6-5. The inactive arms of the bridge circuit are completed with precision wire-would resistors or unstressed mounted gages of the same resistance value as the active gage.

With one active strain gage mounted and connected in a Wheatstone bridge circuit as indicated in Figure 6-5, the output of the bridge will be:

1. Proportional to the change in bending load, or...
2. Proportional to the change in axial load, or...
3. Proportional to the algebraic sum of the two above loads.
4. Also proportional to temperature changes.

Since this arrangement does not provide temperature compensation, it is not acceptable for accurate static measurements. It is useful only in the laboratory where temperature is closely controlled, for dynamic measurements where it is not necessary to measure static strain or where the static strain is of such short duration that temperature change effects are slight.

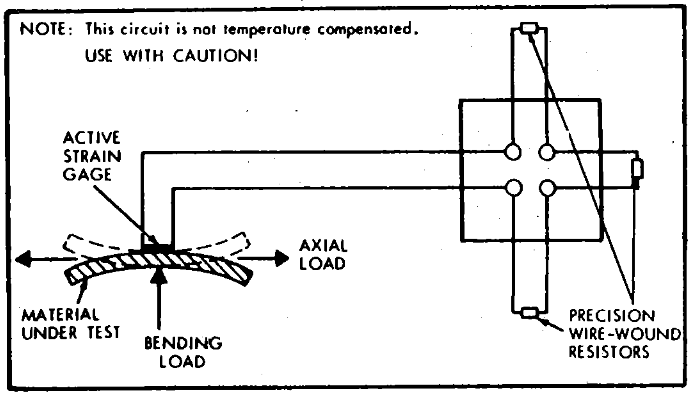


FIGURE 6-5 ONE ACTIVE STRAIN GAGE CONNECTED TO BRIDGE

d. One Active Temperature-Compensated Gage

One of the most popular techniques for securing temperature-compensation is to use a temperature-compensated strain gage which exhibits a very low temperature coefficient when mounted on the proper material. The bridge circuit, shown in Figure 6-6 should be completed with three unstressed, temperature-compensated gages mounted on the proper material. This arrangement performs well for both gradual changes in ambient temperature and transient temperature changes.

Temperature compensation in the lead wires is accomplished by using the "three-wire lead system" shown in Figure 6-6.

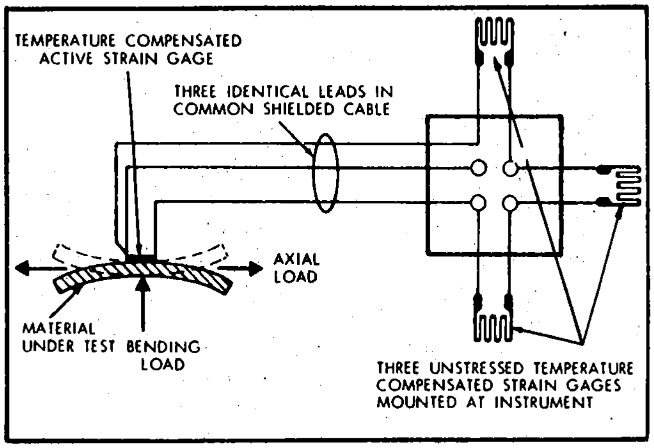


FIGURE 6-6 STRAIN GAGE CONNECTED TO WITH THREE WIRE LEAD

With one temperature-compensated strain gage, mounted and connected in a Wheatstone bridge circuit as indicated in Figure 6-6, the output of the bridge will be:

1. Directly proportional to the change in bending load, or ...
2. Directly proportional to the change in axial load, or ...
3. Directly proportional to the algebraic sum of the two above loads.
4. Independent of temperature changes.

This arrangement is used only when axial loading remains constant during the measurement of bending loads or where bending load remains constant during the measurement of axial loads, or where the algebraic sum is desired.

e. One Active Gage and One Compensating Gage

One method to compensate for temperature changes in the material being tested is to apply a second strain gage to material of same composition, same head transfer characteristics and in the same temperature zone as material under test, but not subjected to strain. The temperature-compensating gage is connected in the bridge arm adjacent to the active strain gage.

Both the active gage and the compensating gage should be identical. This not only means identical resistance, gage factor, type and manufacturer, but from the same lot number of package and applied to the surface in exactly the same manner. The bridge should be completed with two identical precision wire-wound resistors or two identical unstressed gages mounted on a common plate or heat sink at the instrument.

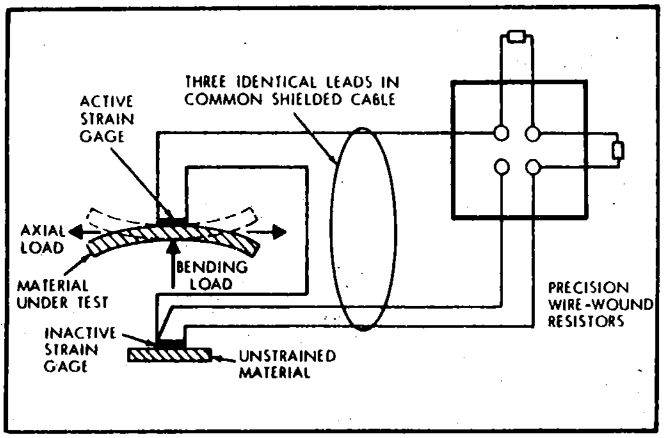


FIGURE 6-7 ONE ACTIVE AND ONE INACTIVE STRAIN GAGE CONNECTED

When one active strain gage and one temperature-compensating gage are mounted and connected in a Wheatstone bridge circuit as indicated in Figure 6-7, the output of the bridge will be:

1. Directly proportional to the change in bending load, or ...
2. Directly proportional to the change in axial load, or ...
3. Directly proportional to the algebraic sum of the two above loads.
4. Independent of temperature changes as long as these prevail uniformly at active and compensating gages.

This arrangement is subject to the same limitations as the previous circuit of Figure 6-6. Temperature compensation in the lead wires is achieved by running three identical leads in a common shielded cable.

f. Two Active Gages

Most Brush strain recording systems, using two active strain gages, can be calibrated to a sensitivity of two microinch per inch of strain per chart division, or twice that of a one-gage system.

g. In Adjacent Arms of the Bridge

An excellent strain recording circuit is achieved when two active strain gages are connected in adjacent arms of the bridge and subjected to strains of equal magnitude but of opposite sign. The bridge circuit is completed at the instrument with two identical precision wire-wound resistors or two identical unstressed gages mounted on a common plate or heat sink.

With two active strain gages mounted and connected in a Wheatstone bridge circuit as indicated in Figure 6-8, the output of the bridge will be:

1. Directly proportional to the change in bending load.
2. Independent of axial loads.
3. Independent of torsion.

4. Independent of temperature changes as long as these take place uniformly throughout the material.

5. Twice as large as the output from a single gage.

This arrangement is an easy method of achieving temperature compensation and determining the bending stresses in a member independent of axial thrust or tension. Temperature compensation in the lead wires is accomplished by using the three wire lead system.

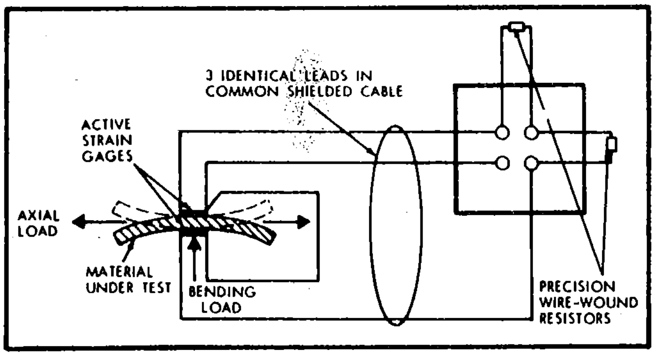


FIGURE 6-8 CONNECTING TENSION AND COMPRESSION STRAIN GAGES

h. In Opposite Arms of the Bridge

To obtain the sum of two separate strains install two active temperature-compensated gages and connect to opposite arms of the bridge. In this case temperature compensation in the lead wires is secured by using a separate three-wire lead system for each active gage.

i. Four Active Gages

Most Brush strain recording systems using four active strain gages can be calibrated to a sensitivity of one microinch per inch of strain per chart division, or four times that of a one-gage system. Satisfactory temperature compensation in the lead wires will be achieved by connecting all four strain gages to a terminal block in the vicinity of the gages, with identical jumpers. Then run four identical leads in a common shielded cable to the amplifier.

With four active strain gages mounted and connected in a Wheatstone bridge circuit as indicated in Figure 6-9, the output of the bridge will be:

1. Directly proportional to the change in bending load.

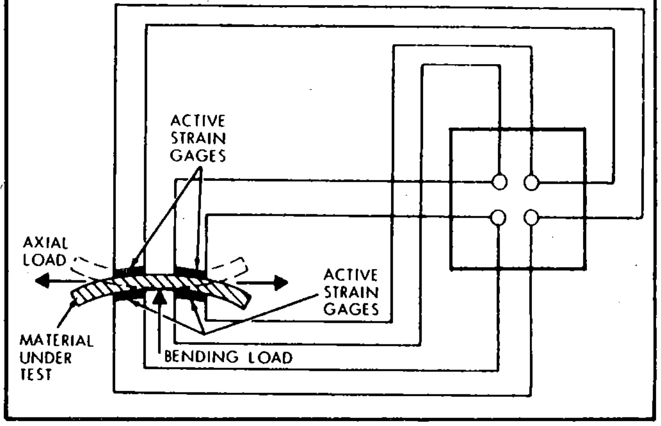

NOTE Connect Strain Gages to terminal block in vicinity and run four identical leads in common shielded cable to amplifier

FIGURE 6-9 CONNECTING TWO TENSION AND TWO COMPRESSION STRAIN GAGES

2. Independent of axial loads.

3. Independent of torsion.

4. Independent of temperature changes as long as these take place uniformly throughout the material.

5. Four times as large as the output from a single gage.

This arrangement is often used for the following reasons:

1. Temperature compensation is achieved without difficulty.

2. Bending stresses can be measured independent of axial thrust or tension.

3. The bridge circuit produces maximum output.

j. Two Active Gages and Two Compensating Gages

This Poisson's (P_r) arrangement of strain gages is frequently used to measure strain produced by axial thrust, load or tension by mounting four gages directly on the material under test. Two active gages are mounted parallel to the center line (axial) but on opposite sides of the member. The two temperature compensating gages are moutned at right angles to the two active gages. As shown in Figure 6-10, the two active gages are connected in opposite arms of the bridge to add their output and each of the other gages is connected adjacent to an active gage which not only provides temperature compensation, but increases the bridge output in accordance with Poisson's Ratio (P_r) for the material involved.

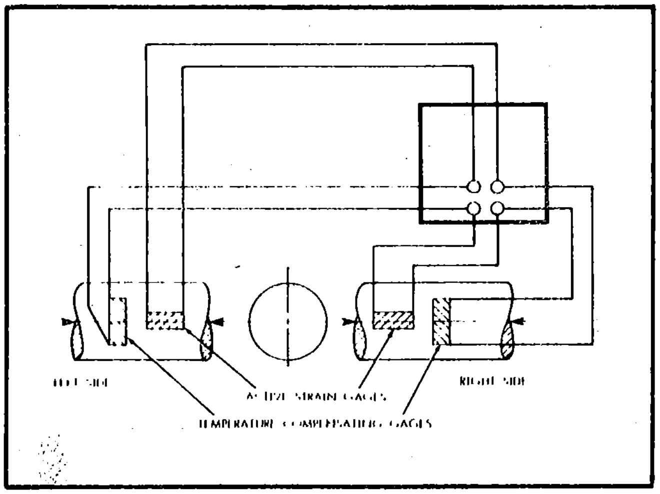


FIGURE 6-10 CONNECTING STRAIN AND COMPENSATING GAGES TO MEASURE THRUST, LOAD OR TENSION

When the four gages are mounted on a member of uniform cross-section and connected in the four arms of a Wheatstone bridge as indicated in Figure 6-10, the output of the bridge, for a change in axial thrust, load or tension will be:

1. Directly proportional to the change in applied load.
2. Independent of bending.
3. Independent of temperature changes as long as these take place uniformly throughout the material.
4. Independent of torsion.
5. $2(1 + P_r)^* = 2(1 + 0.287) = 2.574$ times as large as the output from a single gage.

***(P_r) Poisson's Ratio is discussed in paragraph 6.11, Lateral Deformation. Poisson's Ratio (P_r) for cold rolled steel is 0.287.**

Temperature compensation in the lead wires is achieved by connecting strain gages to an adjacent terminal block with identical leads and running a shielded cable containing four identical color coded leads from the terminal block to the amplifier. This arrangement is frequently used in applications where the principal strain occurs in only one direction.

k. Four Active Gages for Recording Torque

When a cylindrical shaft is subject to torsion, the principal axes of strain on the surface will be inclined at 45° to the axis and the magnitude of these strains will be equal but in opposite directions.

Measurement of torsion or torque can be accomplished quite easily by mounting two active gages on a shaft at right angles to one another and oriented as indicated in Figure 6-11. Under these conditions, one gage is in tension while the other gage is in compression so they are connected in adjacent arms of the bridge. A similar pair of active gages is installed on the opposite side of the specimen from the first pair in order to double the bridge output and provide a measurement which is independent of bending.

When the four strain gages are mounted on the shaft and connected in a Wheatstone bridge circuit as indicated in Figure 6-11, the output of the bridge will be:

1. Directly proportional to the applied torque.
2. Independent of bending.
3. Independent of temperature changes as long as these take place uniformly throughout the shaft.
4. Independent of axial loading.

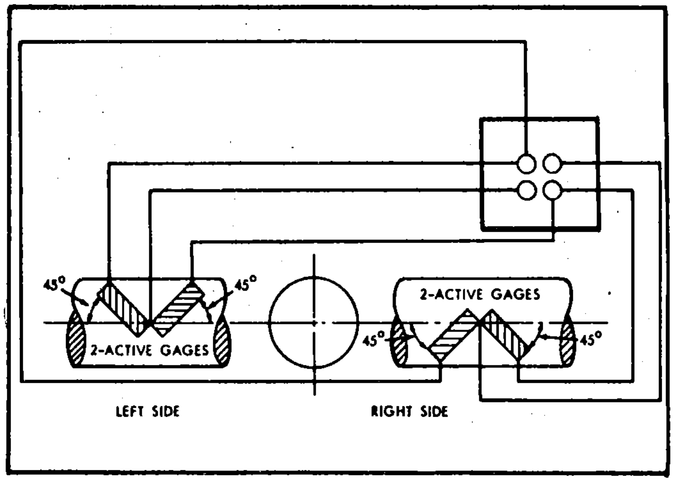


FIGURE 6-11 CONNECTING STRAIN GAGES TO MEASURE TORQUE

5. Four times as large as the output from a single strain gage.

Temperature compensation in the lead wires is achieved by connecting strain gages to an adjacent terminal block with identical leads and running a shielded cable containing four identical color coded leads from terminal block to amplifier.

The output from the bridge circuit may be taken off a rotating shaft by appropriate slip rings. Both the slip rings and brushes must be of high quality and in good state of repair so that variable resistances are not introduced into the circuit. Torque can also be measured with two active strain gages mounted at right angles to each other and connected to adjacent arms of the bridge. This is NOT independent of bending and has half the output of the previous circuit. Temperature compensation in lead wires is automatically accomplished by using the conventional three-wire lead system.

6.13 ELIMINATION OF ERRORS IN WHEATSTONE BRIDGE CIRCUITS

a. Avoiding Variable Contact Resistance and Thermocouple Effects

All connections in the Wheatstone bridge circuit must be low resistance joints in order to secure accurate recordings. Difficulties from contact resistance can be avoided by soldering, fusing, welding or by using good compression type connectors. The usual "banana plug" type of connector must be avoided, but a tight screw-down connection on clean, tinned copper wire is quite acceptable. For d-c excited bridge circuits thermocouple effects can be minimized by placing both strain gage lead wire junctions close together physically, in the same temperature zone and encasing them with cement on a common piece of metal or other form of "heat-sink."

b. Provide Adequate Lead Wire Support

If strain gage leads are allowed to hang freely from great heights, the strains produced in the leads, by their own weight, will change the lead wire resistance and cause strain measurements to vary. The movement of leads can also cause capacity changes in the lead wires, which will produce a capacity unbalance in the bridge circuit. A good example of this is where lead wires are allowed to flop against a metallic column or pipe or are allowed to hang loosely in a large vertical conduit. It is most desirable to lace a lead together in a single cable and tie down the cable firmly so that the strain gage readings are not modulated by the swinging of the lead wires.

6.14 RECORDING FROM STRAIN GAGE BASED TRANSDUCERS

The great versatility of the strain gage has now been realized through its use as the heart of the precision bridge type sensing elements employed in many pre-packaged transducers.

a. Commercially Available Types

Typical of the many transducers now available are the various types of load cells, pressure gages, torque meters, accelerometers, flow meters, and load beams. Each is precision built and calibrated to handle a large range of variables encountered in scientific, military and industrial fields. These not only include complex applications like measuring the flow of fuel to rocket engines and recording its torque or acceleration against time, but common every-day tasks such as automatically weighing packages of sugar or regulating the coal feed in an electric power plant.

b. Use Either Bonded or Unbonded Type Transducers

There are two basic types of strain gage based transducers which are widely used. These are the bonded type and the unbonded type. The bonded type gage usually takes the form of a flat grid which is cemented directly to the sening element. Four strain gages, connected in a conventional Wheatstone bridge are generally used for the sensing circuit. Temperature compensation, linearity, hysteresis and moisture resistance all receive special consideration during the design and manufacture of the transducer.

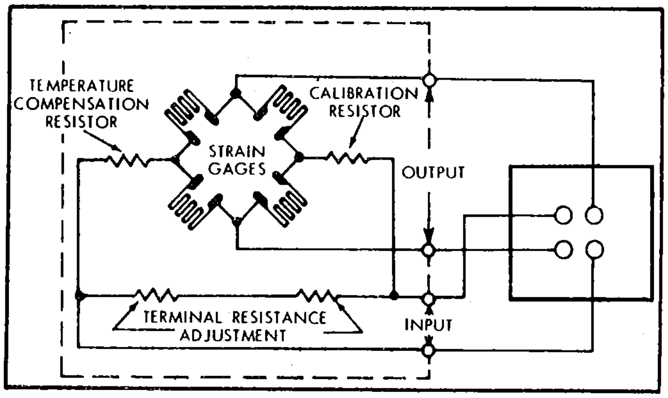


FIGURE 6-12 CONNECTING TYPICAL LOAD CELL

The unbonded strain gage consists of a stationary frame which supports a moveable armature through thin cantilever plates. The strain-sensitive wire is strung under tension between pins located on the frame of the transducer and pins located on the moveable armature.

Four filaments are normally used in each transducer, connected in a conventional Wheatstone bridge, which makes up the sensing circuit. As the armature is moved longitudinally by an external force, the resistance increases in one pair of filaments and decreases in the other. This provides a bridge output that is directly proportional to the longitudinal movement or the force applied. The choice between bonded or unbonded strain gage based transducers depends on the specific application and the personal preference of the user.

Brush Bridge Amplifiers can be used with strain gage based transducers with resistance values from 100 to 1000 ohms. These amplifiers can be used with almost any of the commercially available strain gage based transducers. Most of these devices contain four active gages and may be connected to the Bridge Amplifier in exactly the same manner as shown for the Typical Load Cell in Figure 6-12. Four identical (low resistance) leads in a common shielded cable will provide adequate lead wire temperature compensation. Strain gage based transducers having less than four active gages may also be used by following the appropriate procedure outlined in the use of individual strain gages.

SECTION VII

PARTS IDENTIFICATION

7.1 GENERAL

This instrument has been accurately calibrated and adjusted before shipment from the factory and should give long, trouble-free service. For servicing beyond the scope of the instructions contained in this manual or the technical equipment available, contact your nearest Gould Service Engineer listed on the warranty card shipped with the instrument.

The following parts lists and schematic diagrams are designed to assist in servicing and repairing the instrument.

NOTE: Check to be sure the schematic number and revision letter stamped on the rear of the instrument agree with the number and revision letter on the schematic contained in this section.

To assure prompt and satisfactory delivery of replacement parts, include the following with the purchase order:

1. Name, model number, and serial number of the instrument.

   For Example: DC Bridge Preamplifier Model 13-4615-30 Serial Number ______________

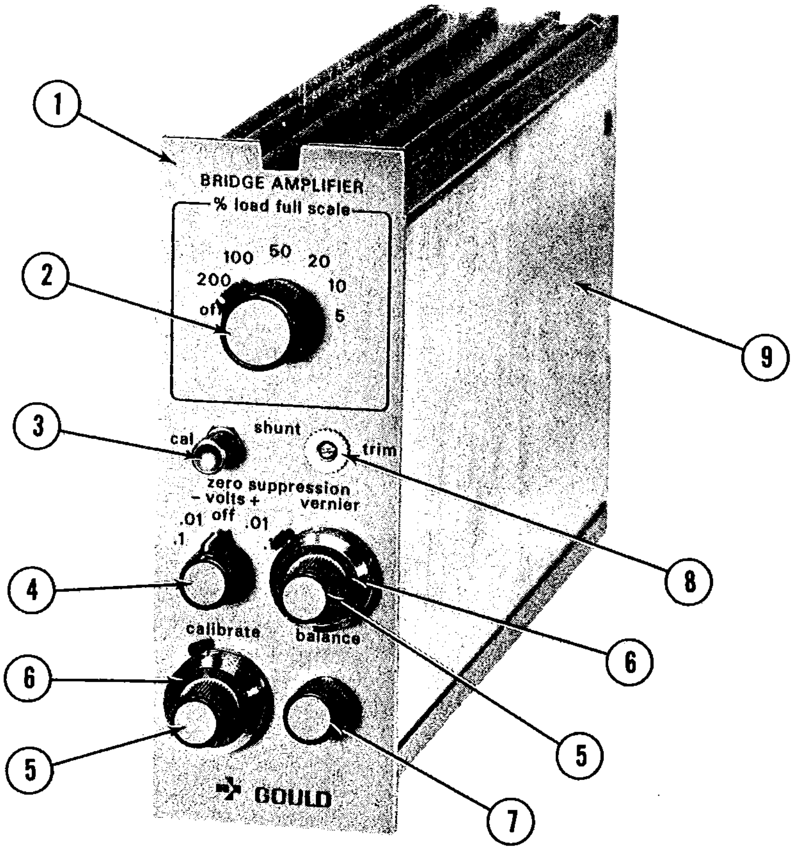
2. Description of the part as listed in the manual.

3. Gould part number.

NOTE: Do not use the SYMBOL NUMBER from the parts list for identifying desired parts on the order.

GOULD D.C. BRIDGE PREAMPLIFIER
MODEL 13-4615-30
FIGURE 7-1

ITEM NO	PART NUMBER	DESCRIPTION	SYMBOL NO
1	786750	Front Panel Assembly	
2	285652-2	Knob	
3	668024	Button	
4	285652-1	Knob	
5	285650	Knob	
6	284990	Knob, Turns Counting	
7	285651-3	Knob	
8	286318	Bushing, Adapter	
9	285943	Cover, Right Side	
10	230048	Switch, Pushbutton	S101
11	286467	Nut, Adapter	
12	1-286417-253	Resistor, Variable	R101
13	286151-2	Switch, Rotary	S102
14	230050-102	Resistor, Variable	R104
15	230050-103	Resistor, Variable	R103
16	1-286417-103	Resistor, Variable	R102
17	386712	Panel, Sub	
18	9-281501-12	Connector	P201
19	9-281501-8	Connector	P202
20	281506-1	Contact, Elec(Not shown, Part of items 18, 19 and 26).	
21	685944-1	Frame, Top or Bottom	
22	886838	Amplifier Board Assembly (See Fig. 7-2)	
23	785946	Panel Assembly, Rear	
24	686775	Connector, Female	J101
25	285303-1	Contact (Not shown, Part of item 24)	
26	9-281501-8	Connector	P203
27	686421	Cover Assembly, Left side	
28	11-5407-03	Connector, Male (Not shown, Mates with J101)	P101



bi 1677

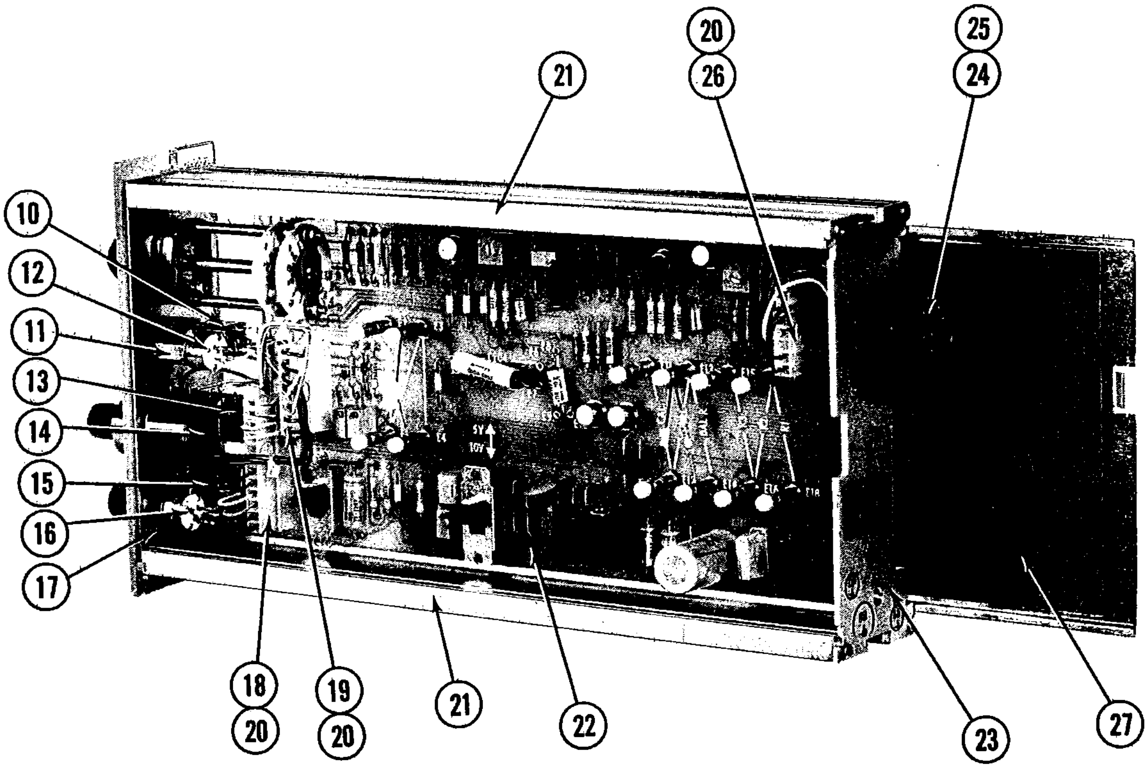


FIGURE 7-1 D.C. BRIDGE PREAMPLIFIER

GOULD D.C. BRIDGE PREAMPLIFIER, MODEL 13-4615-30
ELECTRICAL PARTS LIST
AMPLIFIER BOARD ASSEMBLY (886838)
FIGURE 7-2 (2 Sheets)

SYMBOL NO	PART NUMBER	DESCRIPTION
C201, C202	262585-106	Capacitor
C203	240352-201	Capacitor
C204	10-241145-804	Capacitor
C205	10-241145-203	Capacitor
C206	231922-256	Capacitor
C207	281344-203	Capacitor
C208	281509-507	Capacitor
C209,C210	243006-205	Capacitor
C211	281344-203	Capacitor
CR201, CR202	231869	Semiconductor, 1N816
CR203	280435-2	Semiconductor, 1N823
CR204, CR205	249747	Semiconductor, 1N752
CR206	270508	Semiconductor, 1N4454
CR207	286018-1	Bridge Rectifier
E1 thru E4	269082-1	Terminal
E5 thru E10	265154	Contact, Elec.
E11 thru E18	269082-1	Terminal
J201	281711-12	Connector
J202, J203	281711-8	Connector
Q201	268929	Transistor, 2N4044
Q202	245752	Transistor, 2N1711
Q203	242323	Transistor
Q204	247149	Transistor
Q205	230058-1	Transistor, 2N4918
S	269182	Heat Sink
Bal R	1-265969-15001	Resistor
R201	25-265969-25001	Resistor
R202	25-265969-60002	Resistor
R203	284878-503	Resistor, Variable
R204	25-265969-25001	Resistor
R205	5-241111-101	Resistor
R206	269085-104	Resistor, Variable
*Cal R	1-265969-15001	Resistor
*Cal R	1-265969-50001	Resistor

*Supplied with Preamplifier, but not shown.

GOULD D.C. BRIDGE PREAMPLIFIER, MODEL 13-4615-30
ELECTRICAL PARTS LIST (continued)
AMPLIFIER BOARD ASSEMBLY (886838)
FIGURE 7-2 (2 Sheets)

SYMBOL NO	PART NUMBER	DESCRIPTION
R207, R208	R1-246659-45002	Resistor
R209	1-265969-35001	Resistor
R210	1-265969-82000	Resistor
R211	5-241111-101	Resistor
R212	25-265969-50000	Resistor
R213	25-265969-25000	Resistor
R214	25-265969-15000	Resistor
R215	25-265969-500R0	Resistor
R216, R217	25-265969-250R0	Resistor
R218	25-265969-25001	Resistor
R219	284878-103	Resistor, Variable
R220	25-265969-10003	Resistor
R221	25-265969-27001	Resistor
R222	25-265969-12503	Resistor
R223	1-265969-500R0	Resistor
R224	25-265969-12503	Resistor
R225	1-265969-90000	Resistor
R226	1-265969-100R0	Resistor
R227	25-265969-13850	Resistor
R228	269085-502	Resistor, Variable
R229	269085-501	Resistor, Variable
R230	1-265969-300R0	Resistor
R231	5-241111-222	Resistor
R232	1-265969-300R0	Resistor
R233	5-241111-222	Resistor
R234	25-265969-51000	Resistor
R235	284878-201	Resistor, Variable
R236	25-265969-51000	Resistor
R237	5-241111-202	Resistor
R238	5-241111-151	Resistor
R239	5-241111-102	Resistor
R240	25-284694-15000	Resistor
R241	269085-202	Resistor, Variable
R242	25-284694-44000	Resistor
R243	5-241111-3R3	Resistor
S201, S202	247432	Switch
S203	286882	Switch, Rotary
U201	230062-1	Integrated Circuit, 301A
U202	281287	Integrated Circuit
U203	280439	Voltage Regulator
----	267235	Jumper

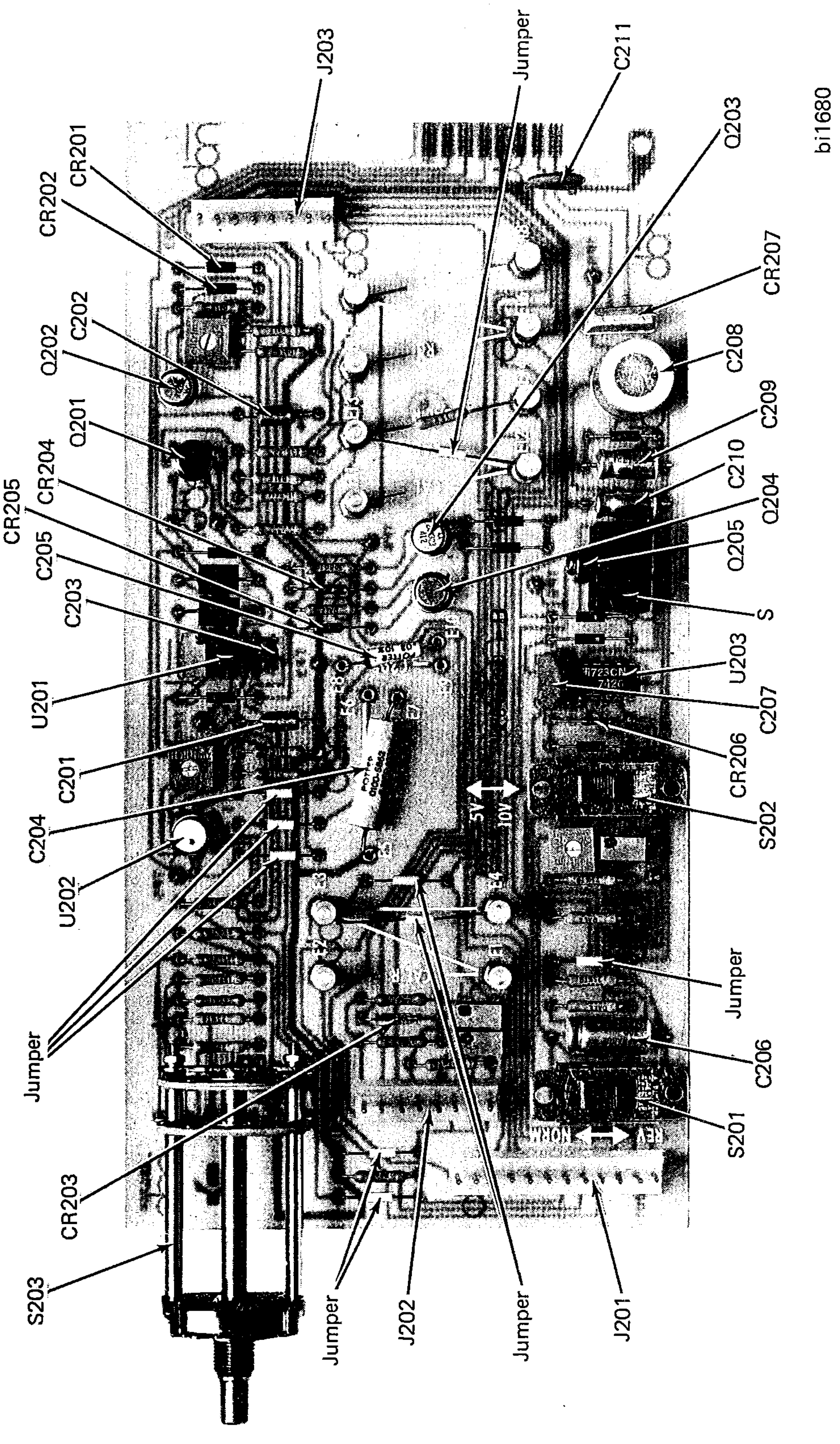


FIGURE 7-2 AMPLIFIER BOARD ASSEMBLY 886838 (Sheet 1 of 2)

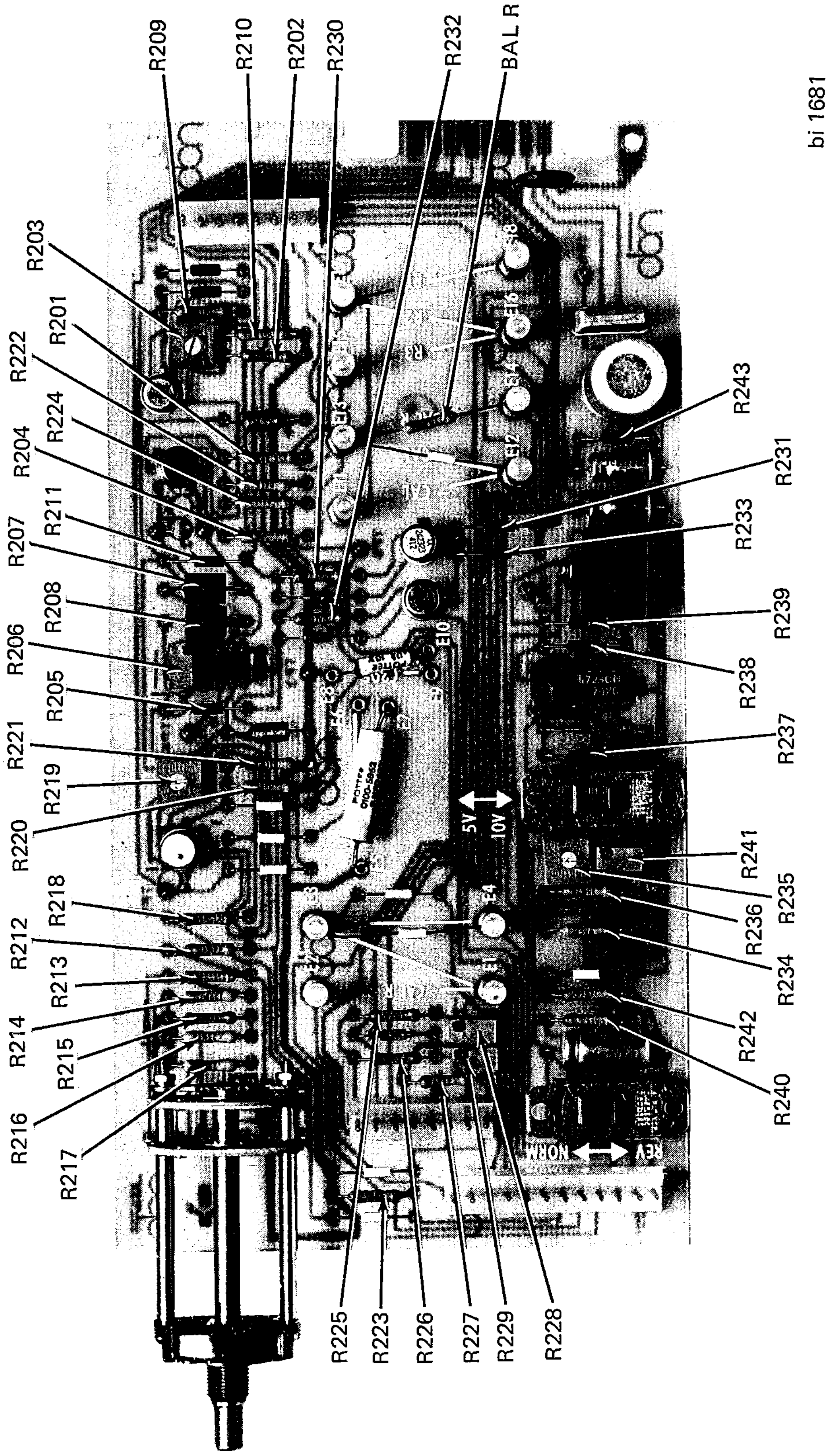
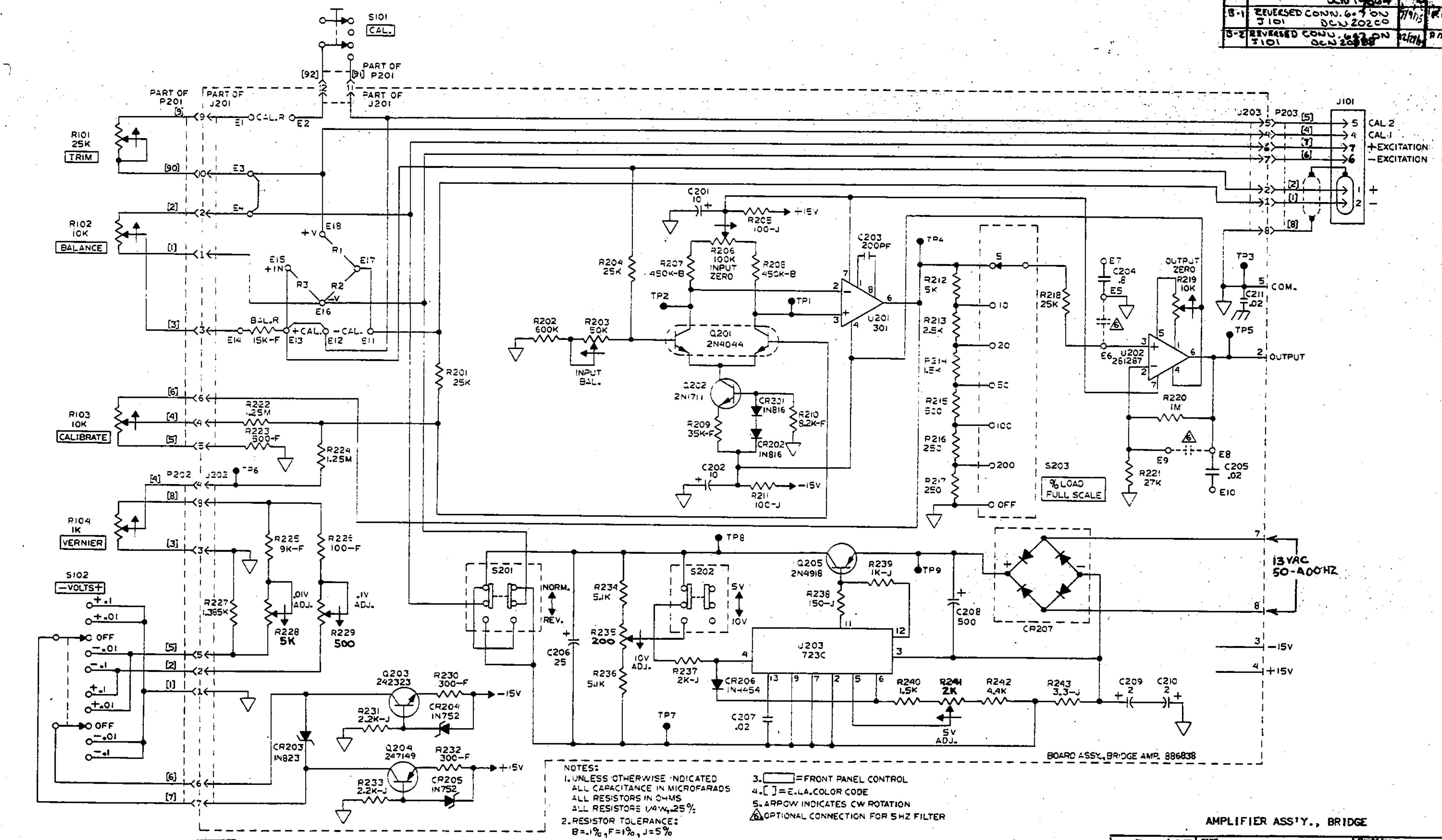


FIGURE 7-2 AMPLIFIER BOARD ASSEMBLY 886838 (Sheet 2 of 2)

REVISIONS			
	DESCRIPTION	DATE	APPROVAL
A-1 A-2	R235 WAS: 100 R241 WAS: 1K DCN 19864	1/30/7?	CZECH
B-1	REVERSED CONN. 6-7 ON J101 DCN 20200	7/9/75	R.M.
B-2	REVERSED CONN. 6&7 ON J101 DCN 20388	12/21/7?	R MILLER



NOTES:
1. UNLESS OTHERWISE INDICATED
ALL CAPACITANCE IN MICROFARADS
ALL RESISTORS IN OHMS
ALL RESISTORS 1/4W, .25%
2. RESISTOR TOLERANCE:
B=.1%, F=1%, J=5%
3. ☐ = FRONT PANEL CONTROL
4. [ ] = E.I.A. COLOR CODE
5. ARROW INDICATES CW ROTATION
⚠6 OPTIONAL CONNECTION FOR 5HZ FILTER

THIS DRAWING IS USED
BY OTHER GOULD DIVISIONS
AND/OR LOCATIONS. A F

AMPLIFIER ASS'Y., BRIDGE

BY	DATE	NAME	
D. CZECH	11-12-74	SCHEMATIC MODEL NO. 13-4615-30	Gould Inc. Instrument Systems Division Cleveland, Ohio 44114 U.S.A.
	11/21/74	CODE IDENT. 96795	DWG. NO. 286380
F.E. Nagel	11-21-74	ISSUE 6	

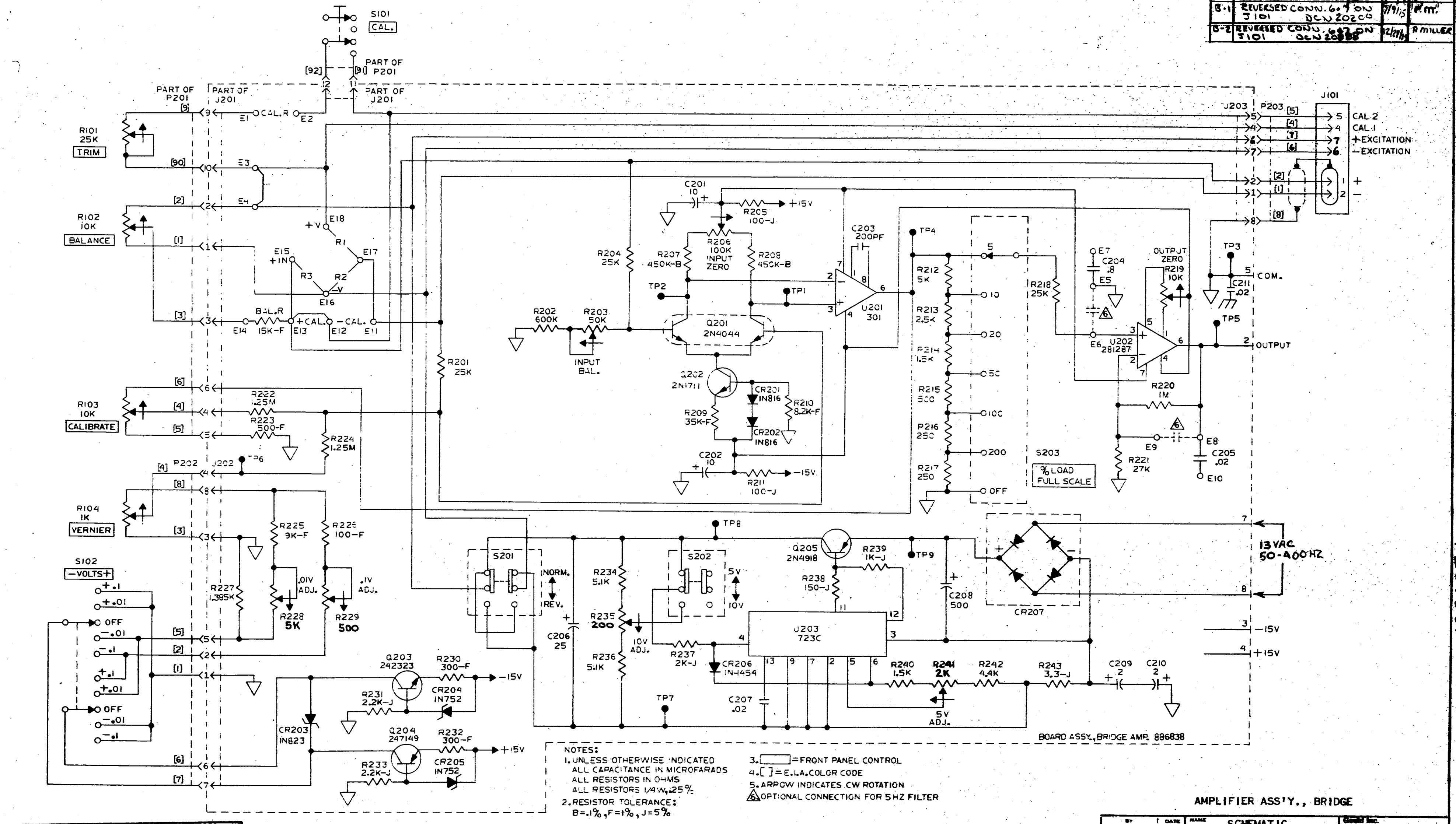
286380

76

75

REVISIONS

SYM.	DESCRIPTION	DATE	APPROVAL
A-1 A-2	R235 WAS: 100 R241 WAS: 1K DCN 19864	1/30/24	CZECH
B-1	REVERSED CONN. 6+7 ON J101 DCN 20200	7/9/75	F.M.
B-2	REVERSED CONN. 6+7 ON J101 DCN 20888	12/29/	A MILLER



NOTES:
1. UNLESS OTHERWISE INDICATED
ALL CAPACITANCE IN MICROFARADS
ALL RESISTORS IN OHMS
ALL RESISTORS 1/4W, .25%
2. RESISTOR TOLERANCE:
B=.1%, F=1%, J=5%
3. ☐ = FRONT PANEL CONTROL
4. [ ] = E.I.A. COLOR CODE
5. ARROW INDICATES CW ROTATION
6. OPTIONAL CONNECTION FOR 5HZ FILTER

THIS DRAWING IS USED BY OTHER GOULD DIVISIONS AND/OR LOCATIONS. A F

AMPLIFIER ASS'Y., BRIDGE

BY	DATE	NAME	
DR. D. CZECH	11-12-74	SCHEMATIC MODEL NO. 13-4615-30	Gould Inc. Instrument Systems Division Cleveland, Ohio 44114 U.S.A.
CHK.	11/21/74	CODE IDENT. 96795	ISSUE 6
APP. J. E. Nagel	11-21-74		DWG. NO. 286380

76