INSTRUCTION MANUAL

MODEL 7540 STRAIN GAGE INDICATOR
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I. INTRODUCTION

Description: The model 7540 Strain Indicator is an extremely versatile instrument which can be tailored with a variety of options and fill the needs of numerous applications. Options include a dual (2 set point) limit with relay output and a horsepower/R.P.M. unit, as well as both 10,000 and 1,000 count resolution digital displays.

With either readout, polarity selection is automatic, via a minus sign in the readout. Separate plus and minus push button calibrate switches are located on the front panel as well.

Ten turn precision potentiometers equipped with knob locks are located on the front panel for zero and span adjustments. On digital readout units a second set of screwdriver adjust trim pots are used for coarse zero and span. The ten turn pots then become fine controls.

The span adjustment has sufficient range to accommodate transducers with full scale outputs of 0.50 to greater than 7 mV/v while the zero adjustment provides more than \( \pm 100\% \) of full scale assuming a transducer with an output of 2 mV/v. Bridge resistances of 85 to 1000 ohms are acceptable. The excitation voltage is 5 volts at a frequency of 3.28 kHz.

A bi-polar, 1 volt full scale analog output signal and provisions for a calibrate resistor are available on the rear barrier strip. The power input connector used includes a line filter, line cord disconnect, fuse, and 120/240 volt line voltage selector in a single assembly. This unit meets both North American and European standards.

The display response is controlled by an internal slide switch. 4 Hz and 0.4 Hz filter settings are available. The analog output response is also selectable. It is either 300 Hz or else the same as the display response.
SPECIFICATIONS

Input connector: Bendix PTO2E-12-10S
Transducer: 85 to 1000 ohms, full bridge
Input impedance: Greater than 10 Megohms
Common Mode Rejection: Greater than 110 db at 60 Hz.
Display: Two options: No display (LXX), low resolution digital (LX5), and high resolution digital (LX4)
Polarity: Automatic indication with red LED indicator when used with no display. Minus polarity sign displayed with digital displays.
Non-linearity: Maximum of 0.01% of full scale.
Filtering: Active, five pole Bessel phase linear type. Internal. 3 db down at 4 Hz or 0.4 Hz.
Power Requirements: 115/230 VAC, 50/60 Hz, 12 watts, integral line filter and fuse.
Net weight: 8 pounds
Size: 8 ½"x 13½" x 3 3/8" overall. 4" high including bail bar assembly.
Operating temperature: +40°F to 130°F, 5 to 95% R.H.
Bridge balance: ±100% of full scale at 2 mv/v span setting. 10 turn pot with knob and lock. On digital models, coarse-22 turn screw driver adjust, fine-10 turn with knob and lock.
Span adjust: 0.5mv/v to 7 mv/v input for full scale indication. 10 turn pot with knob and lock. On digital models, coarse-22 turn screw driver adjust, fine-10 turn with knob and lock.

Symmetry: Internally adjustable +3% of span.

Analog output: 1 volt D.C. ± 10% adjustment for full scale display indication. 2 ma maximum. Selectable response: 300 Hz, 4.0 Hz; or 0.4 Hz. Short circuit protected, maximum non-linearity 0.01%, noise and spurious response at least 60 db below full scale output.
Applications: The Model 7540 Digital Strain Indicator can be used with virtually any strain gage bridge capable of being operated with 5 volts RMS, 3.2 KHz excitation. Instrument sensitivity is such that it will accommodate full scale transducer outputs from slightly less than 0.5 MV/V to greater than 7 MV/V for full scale indication. In addition, zero offsets of 100% or more, depending upon the output of the transducer, can be effectively suppressed with front panel controls. Strain gage resistance of 85 to 1000 ohms are readily accepted.

The Model 7540 is especially useful with the Lebow 1600 series Rotary Transformer Torque Sensors. This series of transducers employs a rotating transformer system which requires carrier excitation and the Model 7540 is an ideal companion unit in a wide variety of applications - especially those where slip ring-generated noise and minimum maintenance are important considerations.

The single most important advantage in using a carrier excitation system over a DC system is the ability of the carrier system to operate at higher sensitivities while rejecting noise and maintaining acceptable overall stability. A well designed carrier system can operate with five to ten times the overall gain of a DC system in most environments. This allows the user to realize dependable measurements from low output sensors - measurements which might be questionable if other systems were used.

Some precautions must be observed if the advantages of the carrier system are to be fully realized. The most common source of difficulty occurs in the cabling system. It is extremely important the cable conform to specifications outlined in this manual. This is especially true with the Lebow 1600 Series Rotary Transformer Torque Sensors. Failure to observe recommended cabling practice will degrade overall system performance.

For most sensors, other than the 1600 series sensors, with short cable runs (20' or less) and where the temperature is reasonably constant, a four wire cable system can be used with good results. For longer cable runs and/or where substantial temperature variations occur, a six wire cable system is recommended. However, where optimum results are required, a full seven wire cabling system is recommended. This system is essentially independent of cable length and temperature and, more important in systems that depend upon shunt calibration, is free of shunt calibration errors caused by IR drops across the cable.

Relative to the above, bear in mind that if the instrument was supplied as a calibrated system with a transducer and shunt calibration resistor and it is necessary to remove and reinstall the system with different length cable, the seven wire system must be used to assure a valid transfer of calibration data.
When using the Model 7540 with a 1600 series sensor, cabling requirements differ slightly. The 1600 series requires a seven wire system. The seventh wire is connected into the shunt calibration resistor, which in the 1600 series is usually located in the sensor proper. Particularly, note the calibration wire is in a shield by itself and the shield is terminated at the instrument together with all other shields.

Customer application assistance is always available from LEBOW PRODUCTS. Contacting either the factory or your area representative will bring a prompt response (list of representatives appears at rear of this manual).

OPTIONS: Options for use with the Model 7540 are as follows:

* Dual limit (two set point)
* Torque, speed, H.P. readout
* Rack mount adapter (19")
* 1000 Count digital panel meter readout
* 10,000 Count digital panel meter readout
* Calibrated zero and/or span knobs
* Screwdriver zero and/or span adjust with shaft lock
* Special legends
II. INSTALLATION

Safety Information: Your instrument is designed to operate from a single phase power source with one of the current-carrying conductors (the neutral conductor) at earth ground potential. Operation from power sources where both current-carrying conductors are live, with respect to ground, is not recommended since only the line conductor has overcurrent protection inside the instrument.

A 3-wire cord with a 3-terminal polarized plug is supplied for connection to the power source and safety-earth ground. The ground terminal of the plug is directly connected to the metal parts of the instrument. For electric shock protection, insert this plug in a mating outlet with a properly connected safety-earth ground contact. See "Power and Ground Considerations" in this section.

Locating and Mounting: The Model 7540 is half rack size and can be adapted to a variety of mounting configurations such as:

1. As a bench top instrument. The standard unit is equipped with a swing away bail bar which holds the instrument at a convenient operating angle.

2. As a dual bench top unit when paired with another. In this configuration, when factory ordered, it is equipped with a full length swing away bail bar.

3. As a dual unit and when equipped with rack mounting plates, it may be installed in a standard 19" rack panel.

4. It may be combined with another half rack size instrument to form a full width suitable for rack mounting.

The rack mounting plates may be easily installed by removing the normal side plates. Hardware is captive to simplify this change. In addition, the mounting feet may be easily removed for installation in a rack panel.

See instrument outline drawing at end of this section.

NOTE: RACK MOUNTED INSTRUMENTS WILL WITHSTAND NORMAL SHOCK AND VIBRATION INCIDENT TO SUCH USE, BUT RACK MOUNTED INSTRUMENTS SHOULD NEVER BE SHIPPED INSTALLED IN A RACK UNLESS BRACING IS PROVIDED TO SUPPORT THE INSTRUMENT CHASSIS.

Environmental Considerations: The instrument must be located in an indoor location and, ideally, where temperature extremes will not be encountered. Other conditions to avoid, include extreme humidity, corrosive atmospheres, and restricted ventilation. Exposure to corrosive atmospheres and continous high humidity will almost certainly cause permanent damage to the instrument.
The instrument may be operated satisfactorily at any temperature within the specifications noted previously. However, temperature changes during its operation will cause some shift in reading. For example, a 20° F. shift in temperature will cause a 0.03% readout error. Of course, if the instrument is adjusted prior to the reading, the error will be eliminated. Therefore, if the instrument is operated in a reasonable temperature controlled environment, further adjustments are unnecessary and instrument operation is simplified.

Power and Ground Considerations: Either 120 or 240 VAC 50/60 Hz is required to operate the Model 7540 Indicator. As shipped from the factory, it is set up for 120 volt operation.

To change to 240 volt operation, proceed as follows:

1. Remove the line cord from power socket at rear of instrument.

2. Slide clear plastic cover to the left.

3. Remove the fuse by pulling the fuse puller out and to left.

4. Using a pointed instrument, such as a ball point pen, remove the voltage program printed circuit card by engaging the hole in the center and prying outward.

5. Reverse the voltage program circuit card and reinsert so that the 240 volt marking is visible when reinserted in the socket.

6. Replace fuse, slide plastic cover to right and install line cord.

A high quality earth ground, of course, is ideal for operation of the Model 7540 Instrument. Many obscure problems in equipment of this type can be traced to poor or inadequate grounds. Fortunately, the instrument will function reliably with only a modest ground connection such as provided by most wall receptacles. A power line filter is included in the instrument which can effectively suppress most types of transients which are likely to cause interference. Some precautions to observe are:

1. The ground pin on the power plug must be terminated. If the wall plug does not have a ground provision and a three wire to two wire adapter is used, the ground wire usually included must be slipped under a convenient screw at the wall plug and carefully secured.

2. Avoid using power receptacles which have high induc-
itive loads connected to them. Transients generated by this type of load can cause unstable readings in the instrument.

3. In situations where use of a receptacle, described in 2. above, is necessary an isolation transformer can be used between the power receptacle and the instrument. This transformer should have a one to one primary to secondary turns ratio. Time constants in such transformers will normally provide sufficient suppression of transients to assure stable operation. In particularly stubborn cases, it may be necessary to use a transformer with a static shield between windings. In some cases, an additional line filter interfaced between the instrument and the power receptacle will cure transient problems. These are available at most electronic distributors. A one ampere rating is suggested. Careful grounding is important in this instance also.

Transducer Connections: Various cable options are discussed below. The transducer connection drawings at the end of this section should be studied thoroughly. Whichever wiring system is selected, all connections must be very carefully soldered and then inspected for possible adjacent pin shorts. The jumper connections must be completed on the rear of the connector terminating at the instrument. Use of shielded wire is essential. Shield drain wires should be twisted together and connected as shown.

Recommended cable types are as follows:

<table>
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<th>Alpha Part Number</th>
<th>Labow Part Number</th>
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<td>Four wire</td>
<td>8723</td>
<td>6010</td>
<td>597-002</td>
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<tr>
<td>Six wire</td>
<td>N/A</td>
<td>N/A</td>
<td>597-019*</td>
</tr>
<tr>
<td>Seven wire</td>
<td>N/A</td>
<td>N/A</td>
<td>597-019**</td>
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* Green/White and Yellow/White pair not used.
** Yellow/White wire not used.

The Alpha cable shown does not have a color code system compatible with the transducer wiring drawing. If this is used, customer must devise suitable color code. Wires should be paired as follows: Pair 1, + excitation and - excitation; pair 2, + signal and - signal; pair 3, excitation + sense and - sense.
The cable options are as follows. The user should review the three possibilities and decide which is most appropriate for his installation.

**Full Bridge, 4-Wire:** For cable lengths of 20 feet or less under reasonable controlled temperature environment, the 4-wire cable configurations will be satisfactory for use, unless the special accuracy considerations discussed below are pertinent. Note, however, that assurance of optimum accuracy requires the full 7-wire cable system and that all performance specifications are based on the use of the 7-wire cable system.

**Full Bridge, 6-Wire:** This system includes a pair of noncurrent carrying remote sensing leads which allow determination of the precise excitation voltage at the bridge. The instrument is a ratio measuring device and in order to make a precise determination of bridge output (MV/V), it must sense both the signal (MV) and the excitation (V) with great accuracy. Using only a 4-wire system, the excitation sensing must be done through the current-carrying excitation leads. With long cable lengths, the lead resistance can be appreciable and a significant voltage drop can occur. If the cable resistance changes (because of temperature change), or if the current changes due to changes in bridge resistance (because of temperature or strain changes), a variation in excitation voltage is created, of which the instrument can have no knowledge, and erroneous readings result. The effect is small but, in the context of the accuracy capabilities of the instrument, it can become the limiting factor in system accuracy.

**Full Bridge, 7-Wire:** This system adds an additional wire which is used for the purpose of shunting one arm of the bridge with the calibration resistor, without having to make use of a signal lead. Using the 4-wire or 6-wire system, the current drawn by the shunt calibration resistor, located at the instrument, must flow through one of the signal leads creating an additional voltage drop which is additive to the signal and, hence, creates an error in reading during the calibration procedure. Although the effects are small, when it is considered that the instrument is resolving a few micro-volts per-digit, it can be seen that the error can be considerably larger than the combination of all other instrument errors, particularly if the cable length is relatively significant. The effect of the error causes the equivalent input value of a particular calibration resistor to become a function of the cable length or cable resistance. It is important to note that the effect is one of the calibration only, and not of measurement during normal operation. If the system is calibrated (and the calibration resistor determined) with the particular cables in place, and if it is acceptable to associate the calibration resistor with the particular trans-
ducer and cable, then the seventh wire is not necessary. However, if the transducer was calibrated (and the calibration resistor determined) at another location, using a 7-wire system (or a 4-wire or 6-wire system of essentially zero length), and it is necessary to make a valid transfer of that calibration to the new installation, then the seventh wire must be included.

Rotary Transformer Cabling: All of the preceding information concerning cabling systems applies to the rotary transformer sensor with one exception. Rotary transformer sensors use a slightly different shunt calibration scheme. The calibrate resistor is located within the sensor and one lead of the resistor is brought out through the cable and is connected to either + or - excitation by the front panel calibrate switch. This wire must be shielded independently of all other wires and the shield terminated at the 7540 Instrument. See appropriate drawing at the end of this section for details.

Half Bridge Use: If half bridge operation with the Model 7540 is desired, the other half of the bridge must be completed. These resistors can be installed at or near the active legs. The resistors chosen must be of high quality such as a noninductive wire-wound type. A resistance of 1,000 ohms can be used regardless of the resistance of the strain gage. However, it is very important that the resistors be very carefully matched - within 1 ohm or better. Otherwise, the zero control in the instrument may not have sufficient range to balance out the circuit. One-half watt size will be adequate. Do not use composition resistors even though they may be matched. Their temperature coefficient could cause serious drift problems and should be avoided for this reason.

ANALOG OUTPUT: The analog output voltage is available on the rear barrier strip of the instrument. The terminals are marked "analog". The terminal marked "C" is connected to circuit common.

The analog output is internally adjustable from 0.9 to 1.1 volts for full scale on the display. Maximum current is 2 ma.

One precaution to observe deals with the possibility of ground loops when connecting foreign instruments to the 7540 Instrument. A ground loop can be generated if substantial current should flow through the shield wire as a result of uncommon grounds between the 7540 Instrument and the foreign instrument. If excessive noise appears on the analog output signal or if the 7540 Instrument display is unstable, a ground loop can be suspected. The cure is to be sure that all associated instruments are connected to a common ground point. Other possible arrangements include the lifting of all grounds except one in the instrument grouping. Experience will dictate the best arrangement.
III. SET-UP AND OPERATION

WARNING: IN ORDER TO PERFORM SOME OF THE SET-UP STEPS, THE INSTRUMENT COVER MUST BE REMOVED. DANGEROUS VOLTAGES ARE PRESENT AT SEVERAL POINTS INSIDE THE INSTRUMENT. TO PREVENT ELECTRICAL SHOCK, DO NOT TOUCH EXPOSED CONNECTIONS OR COMPONENTS WHEN THE INSTRUMENT IS OPERATED WITH THE COVER REMOVED.

Digital display: For information on the operation of the digital display option, consult the display instruction manual.

Calibration procedure: After the load cell, torque pick-up or other transducer has been connected to the instrument, turn on the AC power switch and allow a 15-minute warm-up period.

Rotate knob lock slightly counterclockwise and set the span and zero controls five full turns from their full counterclockwise position (each has ten turns of total travel).

With zero mechanical input to the transducer, adjust the zero control for zero display reading and tighten knob lock.

Span setting can be accomplished in one of two ways depending upon whether the instrument was shipped as part of a precalibrated system or as an instrument only.

If the instrument has been precalibrated with a particular transducer, a calibration resistor and calibration number will usually be provided. The calibration resistor should be installed on the rear apron of the instrument at the terminals marked "CAL". With the calibration resistor in place, push the + "CAL" switch on the front panel and adjust the span control to the equivalent calibration number supplied. Lock the span control with the knob lock.

Release the + "CAL" switch and note the display reading. If it is not exactly zero, correct the reading with the zero control. Recheck the span by operating the + "CAL" switch, note the reading and make corrections as necessary. Recheck zero.

If the load cell was calibrated for both tension and compression or torque pick-up for clockwise and counterclockwise use, two separate calibration numbers may have been supplied. Whichever is the case, depress the - "CAL" switch and note the reading. If it does not match the calibrate number supplied, it may be necessary to adjust symmetry pot P-20.

Note: When the control knob locks are operated, the display should be observed to be sure the zero and span adjustments are not disturbed.

If a calibration number is not available, a precisely known mechanical input must be applied to the transducer in order to establish calibration. If this method is chosen, proceed as follows:
With zero mechanical input to transducer, set instrument zero as detailed previously. Apply a mechanical input to the transducer at or about the anticipated operating region and adjust the span control until the display indicates the input value. Recheck zero with zero mechanical input. Recheck span.

If the transducer is bidirectional, apply an opposite mechanical input to the transducer and note reading. If an exact reading is not noted, it may be necessary to adjust symmetry pot P-20.

To obtain a calibration number for future checks of the system, it is necessary to place a resistor across the "CAL" terminals on the rear of the instrument. This resistor should be a precision non-inductive wire-wound type with a low temperature coefficient. The exact value is not critical but it should be such that the instrument will provide an indication of somewhere around 70% of full scale display reading upon actuating the "CAL" switch. See appendix I at end of this section.

The calibration resistor, then, merely simulates a mechanical input to the transducer by electrically unbalancing the strain gage bridge to produce an equivalent electrical output signal. If the calibrate resistor is determined as noted in the paragraph above, the resistor should be preferably left in place or the terminals provided or carefully preserved together with the calibration number noted.

Capacitive Balance: The excitation system in the Model 7540 has a very high degree of differential symmetry which virtually eliminates the need for a front panel capacitive balance control. However in the event that transducer connecting cable other than specified is used with a sensor, it may be necessary to make minute adjustments to reduce quadrature voltage to near zero. Potentiometer P-7 located on the main printed circuit board may be adjusted while observing test point TP-IN to achieve capacitive balance. With the sensor connected to the instrument with the cable to be used and no mechanical input to the sensor, observe TP-IN with an oscilloscope and iterate between potentiometer P-7 and the front panel zero control for a maximally flat trace. It should be possible to get practically a straight line with a vertical scope sensitivity of 1 mv/cm.

ANALOG OUTPUT: The amplitude of the bipolar analog voltage appearing on the terminals on the rear apron of the instrument is adjustable by means of a potentiometer on the main circuit card. Amplitude increases with clockwise rotation. With the control fully counterclockwise, the output level will be approximately 0.9 volt with a full scale reading on the display and will be approximately 1.1 volts at the other rotational extreme. Voltage polarity will be as indicated by the display polarity sign. Refer to maintenance section for details.
If a particular application for the analog output voltage requires heavy filtering, the user may select filtered output for the analog voltage by means of a switch located on the main (lower) printed circuit card located in the 7540 instrument. In the "on" position, the analog output voltage is filtered to either 4 or .4 Hertz depending upon the setting of the adjacent display switch (see "Filter Switch" section below). In the "off" position, the analog voltage response is 300 Hertz regardless of the position of the display switch.

FILTER SWITCH: A selectable filter is included in the 7540 instrument. It is a multipole active pass type with cutoff frequencies of either 4 or .4 Hertz. The selector switch is located on the printed circuit card. If substantial low frequency variations exist in the transducer signal, it should be set to the .4 Hertz position.

LEGEND: If the Model 7540 Instrument is supplied with a transducer as a system, the correct legend will be supplied. Otherwise, a sheet of legends are included such as pounds, pound-feet, kilograms, etc. The user may select an appropriate legend to suit his needs.

If the top cover was removed during set-up, it must be replaced to insure safe, drift-free operation of the instrument.

OPERATION: After the above procedures have been completed, the instrument will operate with a particular transducer without further attention other than zero adjustments to compensate for tare loads on the transducer or substantial changes in ambient temperatures. However, it is good practice to check zero and span adjustments periodically to insure valid readings. Zero shifts can be caused by changes in tare loading on the transducer, extreme changes in ambient temperature, transducer damage and accidental changes of instrument control settings. After checking zero, operate the (+) calibrate switch and verify calibration numbers making minute adjustments as required with fine span control.

After first applying power to the instrument, zero shift errors will be introduced if readings are made immediately. As mentioned previously, a 15-minute warm-up period is recommended to allow the circuitry time to thermally stabilize.

1600 Rotary Transformer Torque Sensor Operation: The Model 7540 instrument is designed to operate in conjunction with the 1600 series sensors and, when used as the basis of a torque measuring system (or horsepower when this option is employed), optimum results are assured.

Since shunt calibration has long been a standard calibration procedure, this feature has been retained with the 1600 product line. However, direct access to the strain gage bridge with the calibration resistor is very difficult. Therefore, a special resistor network has been devised which provides this feature. Essentially it consists of a star bridge, temperature compensated shunting resistor and phase correction resistance/capacitance circuit. The shunt calibration resistor network is located directly on the 1600 connector block to minimize operation problems.
Because of the internal calibration network, no calibrate resistor is required on the rear of the Model 7540. The cable connections to the instrument rear connector are such that the calibrate resistor terminals are bypassed.

Cables which interconnect the 1600 series sensors with signal conditioning equipment require careful consideration. For best all-around results, it is recommended that only Lebow part number 597-019 cable be used. Extensive testing has demonstrated the superiority of this cable for 1600 series sensor use. It is extremely important that cable diagrams located elsewhere in this manual be consulted before constructing new cables. Any variations in shield termination, pairings, etc. will almost certainly lead to operational problems.

For more information on the rotary transformer, see the Theory of Operation section.
APPENDIX 1

Shunt Calibration: Shunt calibration is a method of setting and checking instrument sensitivity with a given strain gage transducer. Essentially, the process consists of shunting a value of resistance across one or two legs of a transducer bridge circuit. This simulates a mechanical input to the transducer by unbalancing the bridge and produces a proportional electrical output. The instrument used for readout thus displays this arbitrary quantity in whatever units of measurement being used such as pounds, inch-pounds, pounds per square inch, etc.

In most shunt calibrate systems the absolute value obtained is not important. Generally, the value lies in the range of 50% to 100% of the full scale output of the transducer.

The usual method of obtaining the shunt calibrate value is as follows:

1. With the transducer connected to the instrument, a full scale mechanical input is applied.

2. The instrument's span (sensitivity) control is adjusted to indicate the mechanical input quantity.

3. The mechanical input is removed and the shunt calibrate resistor placed across the bridge as described earlier.

4. The instrument display is read and noted.

5. The calibrate resistor, the number noted in 4. above and the transducer are now matched and form the basis of a transferable calibration.

It is possible to use this transducer with any suitable indicator as a calibrated system by first connecting the transducer to the indicator and then adjusting the span control with the calibrate resistor in place until the previously determined calibrate number is displayed. In addition, the calibrate number can be used to periodically verify system calibration.

As can be seen in the above explanation, the actual value of the calibrate number is not of significance. What is important is the relative calibrate number obtained when a particular resistor is used with a particular transducer.

A formula exists which can determine the value of the resistor re-
quired for a given electrical output. The formula is:

\[ Rs = Rb \left( \frac{1000}{4s} - \frac{1}{2} \right) \]

Where: \( Rs \) = Shunt calibrate resistor in ohms.
\( Rb \) = Strain gage resistance in ohms.
\( s \) = Bridge output in mv/v.

Example 1. A shunt calibrate resistor value is to be determined for a transducer of 350 ohms resistance and with an output of 2 mv/v full scale.

Calculation: \( Rs = 350 \times \left( \frac{1000}{4 \times 2} - \frac{1}{2} \right) \)

\[ Rs = 43,575 \text{ ohms} \]

The value of \( Rx \) calculated will provide a calibrate value of 100% of full scale. If a lesser calibrate number is desired, multiply the full scale mv/v (\( s \) in the above formula) by the percent of full scale desired prior to substituting in the formula. For example, assume a 70% value is desired:

2 mv/v x 70% = 1.4 mv/v

\[ Rs = 350 \times \left( \frac{1000}{4 \times 1.4} - \frac{1}{2} \right) \]

\[ Rs = 62,325 \text{ ohms} \]

Example 2. A shunt calibrate resistor with a value of 60,000 ohms is to be used with a 350 ohms transducer. The relative output it produces can be calculated by the following:

\[ s = \frac{1000 Rb}{4(Rc + Rb)^{1/2}} \]

\[ s = \frac{1000 \times 350}{4(60,000 + 350)^{1/2}} \]

\[ s = 1.4541 \text{ mv/v} \]

Obviously, the results of these calculations are dependent upon the strain gage bridge resistance. Transducers of some manufacturers can vary in resistance as much as 1 to 2% or more. This, of course, has considerable effect on the value of the calibrate resistor or the output resulting from a given shunt calibrate resistor.
Fortunately, this is of small consequence since only relative values are important in most applications as discussed earlier.

One further point merits discussion and this concerns the actual calibrate resistor. The resistor must be of high quality. Important parameters are low temperature coefficient (under 10 parts per million per °F.), good long term stability (25 parts per million per year) and adequate wattage rating.

The preceding is subject to some error in carrier systems since the effects of stray reactance (capacitive and inductive) have not been considered. These effects are generally negligible if close attention is paid to physical symmetry of the circuit and inductive shunt calibrate resistors are not used. In carrier systems, noninductive wire-wound units are used for this reason.

The above formulas are not applicable to the 1600 series Lebow rotary transformer torque sensors. These units have a special shunt calibration circuit built-in consisting of a star network, phase shift capacitor and temperature compensating network together with the shunt calibration resistor. Refer to the appropriate 1600 Instruction Manual for more details.
# IV. MAINTENANCE

**WARNING:** THE MAINTENANCE INSTRUCTIONS CONTAINED IN THIS SECTION ARE FOR USE BY QUALIFIED PERSONNEL ONLY. TO AVOID ELECTRIC SHOCK, DO NOT PERFORM ANY MAINTENANCE OPERATIONS UNLESS YOU ARE QUALIFIED TO DO SO.

**Adjustments:** A number of adjustments are provided on the main printed circuit card in the 7540 instrument. Normally these adjustments are precisely set at the factory and will not require attention for extended periods of time. Unless component changes are necessary, these adjustments should not be disturbed unless the user is certain a problem exists.

The analog output span adjust is an exception to the above. It may be necessary to re-adjust this pot to conform to the users requirements.

Refer to assembly drawing D-26780 for test point and adjusting potentiometer locations.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>TEST POINT</th>
<th>DESCRIPTION</th>
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</thead>
<tbody>
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<td>P-1</td>
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<td>R-COMMON MODE</td>
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<td></td>
<td></td>
<td>EAR-SCAN</td>
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<tr>
<td></td>
<td></td>
<td>SYMMETRY</td>
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<tr>
<td>P-2</td>
<td>Conn. 1(3)</td>
<td>C-COMMON MODE</td>
</tr>
<tr>
<td>P-3</td>
<td>IN</td>
<td>ANALOG OUT SPAN</td>
</tr>
<tr>
<td>P-4</td>
<td>ANALOG OUT</td>
<td>COARSE SPAN</td>
</tr>
<tr>
<td>P-5*</td>
<td>**</td>
<td>EXCITATION PHASE</td>
</tr>
<tr>
<td>P-6</td>
<td>BL</td>
<td>C-BALANCE</td>
</tr>
<tr>
<td>P-7</td>
<td>**</td>
<td>DAP-3b OFFSET</td>
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<tr>
<td>P-8</td>
<td>SD</td>
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</tr>
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<td>P-15</td>
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<td>EXCITATION PHASE BAL.</td>
</tr>
<tr>
<td>P-16</td>
<td>BL</td>
<td>NOT USED</td>
</tr>
<tr>
<td>P-17</td>
<td>**</td>
<td>COARSE ZERO</td>
</tr>
<tr>
<td>P-18*</td>
<td>-21-</td>
<td>IM 306</td>
</tr>
</tbody>
</table>
P-19  
P-20  
P-21  
P-22  
P-23  
P-24  
P-25*  
P-26  
P-27  
P-28  
P-29  
P-30  

* LOCATED ON FRONT PANEL

S-1  
S-2  

** SEE PROCEDURE

To enable a precise calibration, the following equipment is required:

1. Transducer simulator. Lebow model 7905-103
2. Oscilloscope Min sensivity 1 MV/DIV., 1 M Hz.
3. D.V.M. Resolution: 1 part in 10,000 D.C., 1 part in 5000 A.C.
4. Frequency Counter. Resolution: ± 0.1 Hz at 3.2768 KHz.
5. Transducer simulator cable. 6 Wire system.
6. Voltage divider as shown on the far right side of schematic D-26787. Resistors with a tolerance of .1% or better must be used.

Calibration Procedure:

IMPORTANT: When done properly, this procedure allows you to adjust the instrument to its original performance specifications. Any trouble you find during the procedure should be corrected before continuing. See section on Diagnosing Trouble.
1. Remove top cover.

2. Remove option boards.

3. If a horsepower or limit option board was removed, solder the jumper pad located next to conn. 3.

4. On digital models, remove solder from rear section of Bar/sym solder jumper and solder the front section. (Located near conn 2 in the front corner of the main circuit board.)

5. Set S-1 to the 4 Hz position and S-2 to the out position.

6. Connect the model 7540 to the transducer simulator.

7. Turn on the model 7540 and test equipment and allow ½ hour warm up time.

**Excitation Alignment**

8. Connect the frequency counter lo lead to circuit common (lead of C-6) and the hi lead to TP + EXC.

9. Adjust P-23 for a counter reading of 3.2768 kHz ± 1 count. (Allow at least 10 seconds after adjusting pot before reading last digit on counter.

10. Connect one clip of the voltage divider to TP + EXC. and the other clip to TP- EXC. Connect the scope low input lead to circuit common and the high lead to TP-BL (center of the divider).

11. Set the scope sensitivty to 2 MV/DIV and the sweep to 1 MS/DIV. Adjust P-16 for a minimum amplitude sine-wave.

12. Adjust P-6 for a minimum thickness trace. It will be necessary to readjust P-16 and P-6 several times to obtain the flatest trace.

13. Connect the scope high lead to TP-ED. Set the scope sensitivty to 200 MV/DIV and the sweep to 100 MS/DIV. Adjust P-9 for a wave form as shown below:

   ![Diagram of wave form](image)

   Equal gaps

   Touching line

14. Disconnect the scope and connect the D.V.M. lo lead to TP-EX and the high lead to TP + EX. Adjust P-24 for a D.V.M. reading of 5.000 VAC + 1 MV.

15. Re-check steps 11 thru 13. Repeat if necessary.

   Remove voltage divider.
Front-end alignment

16. Using a jumper lead, short the pos. and neg. signal leads together on the transducer simulator. Connect the scope lo lead to circuit common and the high lead to TP-Z.

17. Set the scope sensivity for 2 MV/DIV and the sweep for .1MS/DIV. Adjust the front panel zero control and P-7 for minimum amplitude on the scope.

18. Move the scope high lead to TP-IN. Note the amplitude of the signal. Connect the junction of + sig and - sig to + Exc. on the transducer simulator.

19. Adjust P1 and P3 alternately for the lowest possible amplitude on the scope.

20. Move the junction of + Sig and - Sig to - Exc. The amplitude on the scope should be equal to the amplitude in step 19. If it is not, re-adjust P1 while moving the jumper lead back and forth between + Exc. and - Exc. until there is no difference in the readings. The final amplitude should be within ± 1 MV of the amplitude on TP-IN with the excitation jumper lead disconnected.

21. Remove the jumper leads from the Sig and Exc. terminals of the transducer simulator. Re-adjust the front panel zero control and P-7 for minimum amplitude on the scope.

Band Pass and Demodulator Alignment

22. Connect scope high lead to TP-SD and set sensitivity for 2 MV/DIV. Set sweep for .1MS/DIV. Adjust P-7 until line segments on the scope are paralleled as shown below:

```
--- ---
```

23. Adjust P-8 until parallel line segments join to form a continuous unbroken line.

24. Set the scope sensitivity to 50 MV/DIV. and then press the + 2 MV/V button on the transducer simulator. Adjust P-19 to obtain a symmetrical wave form on the scope as shown:

```
--- ---
- --- Equal gaps
--- --- Touching line
```

-24-
25. With the same set-up as in step 24, adjust P-28 so that
the sections of the wave form are all connected.

\[ \text{Equal height} \]
\[ \text{Sharp points} \]

26. Set the transducer simulator back to zero MV/V and set the
scope sensitivity to 2 MV/DIV. Repeat steps 22 and 23 if
necessary so that the line segments form a straight line.
If steps 22 and 23 were repeated then steps 24 and 25
should be checked.

Filter and Scaling Stage Alignment

27. Connect D.V.M. lo lead to circuit common and the high
to TP-LD. Adjust P-10 for a D.V.M. reading of zero ± .1MV

28. Move D.V.M. high lead to TP-SK and adjust P-11 for a
reading of zero ± .1MV.

29. Move D.V.M. high lead to TP-LP. (S-1 in 4 Hz position)
Adjust P-13 for a reading of zero ± .1MV.

30. Set S-1 to the .4 Hz position. Adjust P-29 for a
reading of ± .1MV. Return S-1 to the 4 Hz position.

31. With the D.V.M. still connected to TP-LP, set the
transducer simulator for 2 MV/V. Adjust the front panel
span controls for a D.V.M. reading of .7350 V.D.C.± .1MV.
Return transducer simulator to 0 MV/V.

32. Move the D.V.M. high lead to the analog output. Adjust
P-12 for a D.V.M. reading of 0 ± .1 MV. Set the
transducer simulator for+2 MV/V. Adjust P-4 for a D.V.M.
reading of 1.0 V.D.C. ± .1MV.

33. Re-check the analog output zero and repeat step 32 if
necessary.

Absolute Value and Symmetry Alignment

34. Connect the D.V.M. high lead to TP-PT. Adjust P-14 for a
negative D.V.M. reading. Next, turn P-14 back until the
D.V.M. reading starts to swing positive (aprox. reading
+ .3 V.D.C.).

35. Connect the D.V.M. high lead to TP-NT. Adjust P-15 for
a positive D.V.M. reading. Next, turn P-15 back until the
D.V.M. reading starts to swing negative (aprox. reading
- .3V.D.C.).
36. Move the D.V.M. high lead to the analog output. Adjust the front panel zero for a D.V.M. reading of zero ± .1MV.

37. Set the transducer simulator for + 2 MV/V. Adjust the front panel span for a D.V.M. reading of 1 V.D.C. ± .1MV.

38. Set the transducer simulator for -2MV/V. Adjust P-20 for a D.V.M reading of -1 V.D.C. ± .1MV.

39. Move the D.V.M. high lead to Pin 3 of Conn 1. Set the transducer simulator for +2 MV/V. Note this reading.

40. Set the transducer simulator for -2 MV/V. Adjust P-2 until the D.V.M. reading is equal to the one in step 39.

41. This completes the calibration. If solder jumpers were changed at the beginning of the procedure, return them to their original state. Replace option boards and top cover.
Diagnosing Trouble: When operated within specifications, the Model 7540 Instrument will provide years of trouble-free use. All components were carefully selected with reliability of prime importance. If difficulty should arise, the following checklist may assist in isolating the fault quickly. Refer to block diagram C-26545, schematic diagram D-26787 and assembly drawing D-26780.

1. AC Power

*Power switch on (LED Indicator)?
*Line voltage selector properly set (see Section II)?
*Fuse ok?
*Power cord connected between instrument and live outlet?

2. DC Power

*Operating voltage present?
±11 VDC
±12 VDC
±5 VDC
Excitation

3. Set-up

*Analog output filter select set? (S-1)
*Display filter select set? (S-2)
*Analog output voltage span set? (P-4)

4. Input/Output

*Transducer and cabling properly connected and excitation present?
*Shunt calibrate resistor in place and proper value?
*If digital display; scale multiplier, inert zero and decimal point selector switches set properly?

The block diagram at the beginning of Section V can be very useful in isolating problems to a section, stage or circuit of the instrument. Referring to this drawing (C-26545), it is evident that some signal paths are serial while others are parallel. For example, the instrumentation amplifier section consisting of QAP-1d, b and c is common to both instrument outputs - analog voltage output and display. Thus, problems in this stage will be apparent in both of these areas.

If the analog output voltage appears normal but the display is not, the problem is likely in either the low pass filter (depend-
ing upon position of switch S-1), absolute value amplifier (QAP-3 b and c) or the display itself.

The basic idea of troubleshooting this instrument as well as almost any electronic circuit, is to correlate visual symptoms and identify the general area of difficulty; use available test equipment (voltmeter, scope, etc.) to pin-point the specific stage and, finally, the defective component(s). By referring the block diagram and schematic diagrams, it should be possible to quickly isolate most circuit defects.
V. THEORY OF OPERATION

See block diagram C-26545 and schematic diagram D-26787 for circuit details.

EXCITATION POWER SUPPLY

The 7540 uses a loop-stabilized approach to regulate amplitude and a ceramic resonator to generate the undivided, unshaped carrier frequency.

Outside the loop is the oscillator composed of DIC-2 (oscillator/divider) C11, R94, R95, C33, CR-1 (approx. 209KC Ceramic Resonator) and P-23 (used to fine tune oscillator so that the divided down output from DIC-2 is exactly 3.2768KC).

Also outside the loop is a precision DC reference (V ref) used in conjunction with P-24, to adjust excitation amplitude, and a reference buffer AP-5 who's output is 1 of 2 inputs to the error amplifier QAP-5 (b). The second input to QAP-5 (b), and also outside the loop, is from DIC-3 (2/3), which is used as a precision full wave rectifier. It is controlled by the phase-shifter to be described later. AP - 8 along with C43, R96, R79, and R80, filters the output of DIC-3 (2/3) before it goes to QAP-5 (b) (error-amp).

Inside the loop is the error-amp QAP-5 (b) which along with R48, R50, R46, R45 and C32 sets the loop gain to approximately 90.8. This stage in turn feeds the direction/gain modifier stage QAP-5 (c) which, for an increase in excitation, say due to drift, reduces it's output to DIC-3 (1/3). DIC-3 (1/3) functions as a mux to multiply divided oscillator frequency (3.2768KC) and the output of QAP-5 (c) to produce a regulated square wave input for the notch filter. It is composed of QAP-5 (d), C39, C40, C41, R12, R13, R38 and R98. QAP-5 (d) outputs drives the phase-splitter pair QAP-4 (b) (+exc) and QAP-5 (c) (-exc) containing R35, R36, R37, and C36 (+exc) and R41, R42, R43 and C37 (-exc) as their stage components. The feedback and -exc sense control is provided by QAP-4 (a) and QAP-4 (b). -Exc sense control is provided by QAP-4 (d) and QAP-4 (c). BF-1 is a current buffer and drives +exc from QAP-4 (b). Likewise -exc is driven by BF-2 running off QAP-4 (c). P-6 and C29 in conjunction with AP-8 allows precise phase balancing (Exactly 180' out) of +exc to -exc. P-16 allows precise amplitude balance, about ground, of + and - excitation.
INSTRUMENTATION AMPLIFIER

The instrumentation amplifier section is composed of a differential pair QAP-1 (d) and QAP-1 (c); their summer QAP-1 (b); and the zero/fine C-bal injection AMP QAP-1 (a). The differential pair is phase-balanced by P3 (C-C mode) and the instrument AMP trio is amplitude balanced by P-1 (R-C mode) which in combination provide excellent, common-mode rejection and minimum phase delay through this stage. The zero un-bal injection AMP provides an isolated method of zeroing and C-balancing independant of the bridge. The gain of this stage is low (approx. 6.7) to prevent EMI-RFI saturation.

BAND PASS AND DEMODULATOR CIRCUITS

The band pass stage is comprised of the amplifier DAP-3 (a); R66, R109, R49, C21, C22, and R114 and it's unity-gain inverter DAP-3 (b); R22, R23, R62 and R5 (which provides the inverting function necessary to drive the synchronous demodulator DIC-1a(1/3). P19 controls the center-freq. and P8 matches DC outputs of DAP-3 (a) and DAP-3 (b).

The demodulator stage contains two sections. The demodulator itself and the phase-shifter. The phase-shifter is composed of DAP-1 (a) and DAP-1 (b) and their components R25, R24, C18, C28 and R99. It's function is to provide a stable phase-relationship to excitation that is adjustable by P-9 in harmony with C20 to drive both the control arm of the signal demodulator and the excitation demodulator. The range of this adjustment is approx. +45° (Ref. to +exc.).

DAP-1 (b) is the comparator stage that "squares-up" the "Phase-Shifted" sine-wave and P-28 is used to precisely set duty-cycle to 50%. This adjustment allows exact "chopping" of the fundamental at its midpoint to produce a "perfect full-wave rectified" signal. This output in turn is filtered @ 300Hz by AP-6, and components R53, R52, R71, R123, C47 and C19 with a gain of 4 and 2 poles @ Fc. Zeroing is accomplished by P-10.

SCALING AND DISPLAY FILTER

From the output of AP-6 the signal is routed to front-panel span controls P-25 (fine- if used) and P-5 (coarse span). From there it proceeds to Conn-3 pins 1 and 2 where any right-hand option is fed and outputs back to the sallen and key/span-buffer stage (AP-2). This is a 2-pole; 300 Hz; gain of four stage composed of AP-2, R125, R124, R73, C9 and C26. Zeroing is achieved using P-11. This stage also contains the symmetry mux. (DIC-1 (2/3 and 3/3)). This mux, in conjunction with R72, R115 and P20 works as a fine - span to correct transducer span assymetry. P-20 is used for this adjustment and has an authority of + 3%. This mux can be solder-jumped to sign-bit polarity control (DPM) or #1 polarity detector (bar-scan).

The output of AP-2 drives two stages. The .4/4Hz lowpass and, if S-2 is in the "out" position the analog output. The display lowpass is a 5-pole; bessel-function sallen and key composed of AP-7 (3-poles _); AP-4 (2-poles) and their associated components.
S-1 selects the rolloff frequency of either 0.4Hz or 4Hz (-3db @ F). The output of AP-4 drives the display-option selected as well as the IN stage and the analog output (if S-2 is in the "IN" position). Zeroing of 4Hz position is done using P-13. Zeroing of 0.4Hz is done with P29.

ANALOG OUTPUT

The analog output is a gain-settable stage implemented by AP-3, R85, R81, R83, R86 and C8. This stage is adjustable from 0.9 to 1.1 volts with a full scale instrument display. It can be routed through the display lowpass via S-2 in which case rolloff is whatever S-1 is set for. In the "out" position of S-2, rolloff is system rolloff (300 Hz). The zeroing is accomplished with P-12.

ABSOLUTE VALUE AMPLIFIER AND POLARITY DETECTOR

The absolute value amplifier is an auto-reverse, unity gain, stage providing a uni-polar output to drive a bar-scan display option or external analog meter. QAP-3 (b) acts as the inverting full-wave rectifier with components D-5, D6, R31, R19 and P-2. P-14 is used to set the negative cross-over point of this stage. QAP-3 (c) acts as the non-inverting full-wave half with components R32, R34, D7 and D8. P-15 is used to set the positive cross-over point. P-2 (mentioned earlier) is used to adjust bar-scan symmetry.

The polarity detector utilizes the snap-action of QAP-3 (b) and QAP-3 (c) and their components through zero to provide a jitter-free, true "zero crossing" detector. R-107 provides a small amount of hysteresis to reject any noise on low-level signals. This detector is composed of QAP-3 (d) R30, R33, (R-107 mentioned earlier) and drive-components R59, R29, D3 and Q1. Q1 drives the "rev" led-2 on the front-panel (bar-scan display or no display only). Q2, R120 and R110 provide Symm. control when programmed for bar-scan operation.

CALIBRATION

Calibration is a bridge-shunt type implemented by S3-A (-cal) or S3-B (+cal) in union with either a rear apron mounted cal resistor (supplied with transducer)or through the cable to transducer connector (for rotary transformer type transducers-containing their own cal resistor). AP-1 works as a "parking" place for this cal resistor that takes into account any bridge imbalance and keeps 0 current flow through this resistor when not in use.
POWER SUPPLIES (D.C)

All power supplies necessary to run the basic instrument and any option are "Resident". These are +5v @ .5A, +12v @ .5A, +11v @ .2A (analog), +12v @ .1A (excitation), approx. +16v @ 2A (B+) and on rear board either +170v (digital) or +235v (bar-scan)- jumper programmable.

The +5v is composed of REG-4, input filter C44, output filter C5 and bridge BR-3.

The +12v output is composed of REG-3, input filter cap C-1, output filter cap C4 and bridge BR-1. This +12v is also available (fused) at the rear apron with the purchase of the HP, RPM right hand option.

The +11v power-supply is made up of reg-1 (pos.) and reg-2 (minus), pos. input filter C2, neg. input filter C3, pos. output filter C6, neg. output filter C7, tracking resistor R93 and voltage set resistors R15 (pos.), R129 and R18 (neg.). As indicated by R93's description, this is a tracking supply. BR-2 is the bridge.

The +12v excitation supply is non-tracking, and is used to provide current limiting and thereby short-CKT-protection for excitation buffers BF-1 and BF-2. Reg-5 is the positive regulator with output filter C-48. Reg-6 is the minus regulator with output filter C-49. This supply runs off of BR-2 also.

The B+ (approx. +16v) supply is tapped off of the input to reg-3 and is used to power led's, relays and the v-ref. heater.

The +170v or +235v high voltage supplies are used to power the gas discharge display (+170v) or glow-transfer (bar-scan) neon display (+235v). BR-1 along with C2 and R1 (bleeder) produce the DC which, by moving the tap on T-1 via solder-jumper and shorting or not shorting Dz-3 provide the +170v or +235v. R2, Dz-1, Dz-2 and Dz-3 provide the regulation.

Finally all these supplies are driven by multi-wound transformer T-1 (which also has dual primaries and faraday shielding). USF-1 acts a 120/240 vac programmer, line fuse and RF-1 filter. C-1 provides analog common to chassis common noise bypass while maintatining isolation.
1600 Rotary Transformer Torque Sensor Operation: This series of torque sensors is unique in many respects. Therefore, an understanding of its basic operating principles is very helpful in attaining best performance. In this connection, the Model 7540 Instrument is designed to operate in conjunction with the 1600 series sensors and, when used as the basis of a torque measuring system (or horsepower when this option is employed), optimum results are assured.

The 1600 series transducer employs a strain gaged sensor as might a typical slip ring type sensor. However, coupling between the rotating portion and the stationary portion is via electromagnetic induction. This is accomplished by using two separate transformers - each transformer with a primary and a secondary winding. Cup core construction is employed utilizing ferrite material machined to exacting tolerances. One transformer functions as the excitation source and the other as the signal source. Thus, the rotating portion of the excitation transformer functions as the secondary while the rotating portion of the signal transformer functions as the signal primary. Conversely, the stationary portion of the excitation transformer is the excitation primary while the stationary portion of the signal transformer is the signal secondary.

Core geometry is determined by the sensor type. A sophisticated computer program was written to produce optimum transformer design. A series of iterations results in the selection of magnet wire size, inductance and turn ratio. Carrier frequency is fixed at 3.28 KHz or 12 KHz depending upon the type of sensor. Generally speaking, the higher carrier frequency results in superior bandwidth. Under average conditions, bandwidth is considered to be approximately 10% of the carrier frequency. Sideband energy extends considerably beyond this figure but with increasing attenuation.

The instrumented sensor section is temperature compensated for zero and span separately. Then the entire sensor assembly including the transformer is temperature compensated for span by means of a precision thermistor trimmed with parallel resistance. This second temperature compensation is necessitated by thermal effects on the copper wire used in the transformer construction. Other second order effects are also eliminated via this technique.

Since shunt calibration has long been a standard calibration procedure, this feature has been retained with the 1600 product line. However direct access to the strain gage bridge with the calibration resistor is very difficult. Therefore, a special resistor network has been devised which provides this feature. Essentially it consists of a star bridge, temperature compensated shunting resistor and phase correction resistance/capacitance circuit.
The shunt calibration resistor network is located directly on the 1600 connector block to minimize operational problems. Even though extraordinary care is used in designing the transformer, real world limitations result in compromised specifications dealing with overall transfer function of the device. However, with proper signal processing equipment, these effects are minimized. The more important characteristics are listed below:

1. The phase angle of the output signal lags the excitation phase by approximately 12 to 18° depending upon the sensor model.

2. The phase angle of the output signal shifts by as much as ±2° with a temperature change of 75°F.

3. Although phase corrected at room temperature, the shunt calibration signal phase angle will differ by as much as ±2° relative to the normal mode signal output over a 75°F temperature change.

4. Inductance of the signal secondary is in the order of 10 to 20 millihenries depending upon the transducer model. Shunting effects of interconnecting cable capacitance causes a signal amplitude enhancement of 5 to 10% between a short cable, say 10 feet and a long cable, say 300 feet. The effect is identical for both normal mode signals and shunt calibration signals and is in essence due to approaching resonance. (Transformer coil inductance and cable capacitance).

5. The shunt calibration star bridge parallels the normal mode signal leads. As the bridge is offset during shunt calibration, the common mode point also shifts. If the excitation source has imperfect differential symmetry, the instrument will perceive the common mode voltage as a zero-like shift and asymmetry in the calibration signal will result. This effect becomes greater as cable length increases (greater capacitance to the shield or ground). The net effect is to invalidate a particular calibration when attempting to substitute a cable of differing length.

Most carrier based excitation strain gage instrumentation systems have two additional controls when compared with DC systems. One or both may be front panel accessible. These controls commonly called capacitive balance and phase peak must be carefully considered when used with any strain gage sensor including the Model 1600 series rotary transformer torque sensors.

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The capacitive or "C" balance control is required to null out quadrature voltages present due to imperfect capacitive balance between the sensor output or signal wires and the cable shield. Under small signal conditions, it is possible that using high gain, amplifier saturation will occur due to high quadrature voltages. The C balance control then nulls out quadrature voltages and assures that the amplifier will have unrestricted dynamic range. Some carrier signal processing equipment get around this problem in another way. The cable shield is removed from direct ground and driven by operational amplifier with a neutral voltage input. This technique greatly reduces capacitive currents flowing through the cable shield. Thus smaller quadrature voltages appear at the input to the signal processing equipment. This approach, though effective, suffers the disadvantage of the cable shield not being at DC ground.

Neither of these approaches unfortunately, address the problem directly. The basic problem is the fact that most carrier excitation systems do not have perfect differential symmetry about ground or common. If they did, the need for C balance controls would be limited only to those systems where very small signals are present and very high gain is required.

Almost all carrier based signal processors employ a phase sensitive demodulator (PSD) to obtain a DC analog of the strain gage signal. The output of the PSD - also called a synchronous demodulator or rectifier - is essentially the product of the input signal and a unity amplitude square wave. This technique produces a bi-polar DC output which can be analogous to CW or CCW torque and tension or compression force for example.

Maximum output from the PSD occurs when the reference signal and input signal have identical phase relationships. The phase peaking control mentioned earlier is employed to shift the phase of the reference signal such that it matches the input signal phase. The signal phase can be and usually is different from excitation by varying amounts. Signal phase is effected by cable parameters (length, capacity per unit length, shields, wire size, and even insulation) and sensor parameters (inductive effects, capacitive effects). In addition, changes in ambient temperature produce effects on all of the above.

The phase peaking control is used to eliminate the phase shift anomalies noted above and provide maximized output from the PSD. It is important to note however, that linearity errors do not necessarily result in the PSD output due to phase angle errors at the input. Phase angle errors result in only a decrease in amplitude at the PSD output. Essentially the DC output = \( \frac{2}{P_1} E_s \cos \theta \). Thus at any angle greater or less than 0, (or 180°) the cosine will be less than 1 and a decrease in output will be observed.
The PSD is responsive to odd harmonics of the carrier frequency. In general, the third is the only troublesome one and steps must be taken to reduce its effect. A bandpass or low pass filter preceding the PSD is sufficient to minimize such problems. Being imperfect, the 1600 series sensors can generate harmonic distortion on the strain gage signal and unless steps are taken in the signal processing equipment, linearity errors can be produced under some conditions.

One final word concerning the phase peaking control and its use when a 1600 series sensor is employed. Most carrier instrumentation manufacturers recommend peaking this control for maximum output with a given sensor under loaded conditions. When using a 1600 sensor with a Lebow 7535 or 7540 instrument, a different approach is recommended. The Lebow carrier instruments mentioned are phase peaked at the factory with a resistive network connected directly to the instrument transducer input connector. No further adjustment should be made under most circumstances. This uniformity of adjustment between instruments will allow shunt calibration transfer between not only instruments of the same model but also cables of varying lengths. It is entirely practical to obtain a calibration transfer within 0.25% of original calibration between a given sensor, any instrument of the same model number and cable lengths of 10' up to 300' or more.

Cables which interconnect the 1600 series sensors with signal conditioning equipment require careful consideration. For best all around results, it is recommended that only Lebow part number 597-019 cable be used. Extensive testing has demonstrated the superiority of this cable for 1600 series sensor use. It is extremely important that cable diagrams located elsewhere in this manual be consulted before constructing new cables. Any variations in shield termination, pairings etc. will almost certainly lead to operational problems.
VI. DOCUMENTATION

Assembly Drawings

Schematic Diagram