OPERATING AND MAINTENANCE MANUAL

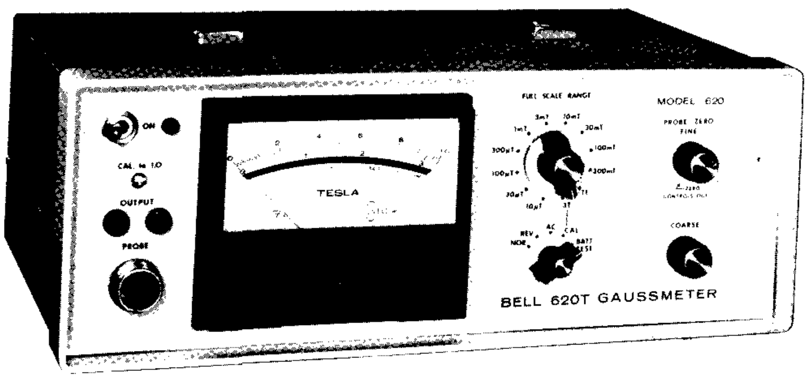
MODEL 620 GAUSSMETER

F.W. BELL

Subsidiary, Magnetics & Electronics, Inc.

F.W. Bell Gaussmeter Model 620
Instruction Manual

MODEL 620
GAUSSMETER
Operating and Servicing Manual



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SECTION I
General Description

I-1 GENERAL

The Model 620 Gaussmeter is a precision magnetic flux measuring instrument, featuring high stability, silicon solid-state construction. It has been designed especially for use with Hall effect magnetic field probes manufactured by F. W. Bell, Inc.

A wide range of standard transverse and axial, as well as special probes, are available including the new high-linearity, temperature compensated Hall-Pak sensors. All probes are directly interchangeable without recalibration. *Factory calibration of probes is carried out with reference to a laboratory standard magnet.* This standard is measured by the Nuclear Magnetic Resonance (NMR) technique and provides traceability to the National Bureau of Standards. The user can then set this calibration into the instrument by the use of the simplified high-accuracy built-in CAL procedure.

Measurement range extends from 1 mG (milligauss) per scale division (100 mG full scale) to 30 kG (kilogauss) full scale. Both dc and ac fields can be measured directly using the 4½ inch panel meter. DC polarity is preserved for direction information when tracing and plotting fields. AC fields of up to 400 Hz are read out as an rms value for sine wave fields.

Output jacks are provided on the front panel. Output voltage is 1 volt full scale and is proportional to the field for dc and ac fields up to 400 Hz. An auxiliary output amplifier is also available, on special order, to provide increased output voltage and power to drive external equipment. To obtain high-accuracy measurements, a high-resolution indicating instrument such as a digital voltmeter can be connected to the output jacks. The internal calibration procedure may also be carried out using this indicating instrument to achieve the best possible accuracy.

Because of automatic change-over to battery operation, the Model 620 is ideal for fixed installations where constant, noninterrupted service is required in spite of power line failure, as well as applications requiring portability. An inexpensive, sealed, high-energy dry battery is used (included with instrument on special order). Also an external dc power input is provided through binding posts on the rear of the cabinet.

Simplicity of operation, wide measurement range and high accuracy make the Model 620 a versatile instrument for measurement in the laboratory or in the field, as well as for production testing and process control.

SECTION II
Specifications

II-1 ELECTRICAL AND PERFORMANCE SPECIFICATIONS

[a] Measurement Ranges:
Measurement of static (dc) or varying (ac to 400 Hz) magnetic field strength in the range of 0.1 gauss full scale to 30,000 gauss full scale in 10 db steps as follows

0.1	3	100	3,000
0.3	10	300	10,000
1.0	30	1,000	30,000

[b] Calibration:
1. Internal calibrating procedure is referenced to a standard NMR magnet traceable to the National Bureau of Standards and to probe deviation curves. Probe deviation curves in accordance with MIL-STD-793-1 (WP) Appendix A.
2. Internal calibration error does not exceed ±0.3%.

[c] Available Standard Probes:
One hundred and ten different Hall effect field probes are available to meet the challenging requirements of virtually any application. Please see the F.W. Bell Gaussmeter Probes literature sheet for probe models and prices. Consult the factory for special probe requirements.

[d] Accuracy:
1. Accuracy is the sum of accuracies of the instrument, the probe and the calibration source. The instrument accuracy is ±0.25% of full scale plus ± 0.02 gauss, and the internal calibration accuracy is ± 0.3% of reading. For example, the 620 guassemter used with the model HTB4-0608 probe calibrated with the internal calibration output: the total accuracy is ± 0.25% of full scale, plus ± 0.02 gauss (instrument), plus ± 0.3% of reading (internal calibration), plus ±1.0% of reading (probe) for a total system accuracy of ± 0.25% of full scale, plus ± 1.3% of reading, plus ± 0.02 gauss. The ± 0.02 gauss is an instrument error. When a 10x probe is used the specification then becomes ± 0.2 gauss.
2. For ac Fields:
0 to 60 Hz: dc field accuracy plus 10% of reading.
60 to 400 Hz: dc field accuracy plus ±10% of reading.
3. Meter Scale Tracking Error:
For dc field meter readout: ±1% of full scale

For ac field meter readout 10 to 400 Hz; ±2% of full scale
4. Improved accuracy obtainable by using probe deviation curves and, at specific tests points, by reference to a known calibration field.

[e] Stability:
1. Line voltage:
Error unmeasureable for ±10% line voltage changes.
2. Temperature effects excluding probe influences:
Approx. ±3% of reading total over the range of —50°C to +70°C (can be removed by using internal calibration feature).
3. Probe temperature effects, 1X sensitivity:
—0.04% of reading per degree C max.
—0.025% of reading per degree C typical. (—20°C to +60°C).
4. Probe temperature effects, 10X sensitivity:
±0.005% of reading per deg. C mean value over —20°C to +60°C
5. Probe temperature effects, zero field influence:
±100 milligauss per deg. C standard probes
±40 milligauss per deg. C high-accuracy probe.

[f] Output Jacks:

1. Output voltage:	1.0 volt dc FS
2. Source impedance:	1 kΩ approx.
3. Maximum ac field frequency:	400 Hz
4. Response time for full scale step input:	0.4 msec approx.
5. RMS Noise:	
0.1 gauss range	25 db below full scale approx.
0.3 gauss range	35 db below full scale approx.
1g to 30 kG range	45 db below full scale approx.

[g] Power Requirements:
1. Line input:

Volts	105-125 V or	210-250 V
Frequency	50-60 Hz	50-60 Hz
Current	0.038 A	0.019 A
Power	4 W	4 W

2. Battery input:
9 V to 18 V at approx. 130 mA, automatic take over in case of failure in line voltage.
3. Internal battery:
12 V dry battery, NEDA 923—Eveready 2780N; automatic take-over in case of failure in line voltage (approx. 100 h life with continuous use)

II-2 PHYSICAL SPECIFICATIONS, CONTROLS AND CONNECTORS

[a] Front Panel:
1. Power Switch:
This toggle switch turns on the primary power to the instrument. The pilot indicates when the instrument is operating on line voltage only, no

indication of battery operation is provided. See cautionary note on Section II-2b4.

2. Range Switch:

The full scale range is set by this switch in 10 db steps marked in the 1, 3, 10 sequence. It covers the range from 0.1 gauss to 30 kG, the full range of the instrument.

3. Function Switch:

This switch selects the mode of operation. It includes the measurement positions for dc fields of both normal and reverse polarities, and for ac fields, the calibration position for internal CAL, and a battery test position to check the internal battery condition or external dc input voltage.

4. Probe Zero Controls:

COARSE and FINE zeroing controls are provided to balance each individual probe for zero output in the absence of a magnetic field. They will also suppress small residual fields up to approximately 30 gauss. By turning the FINE control full CCW past the switch, the zero controls can be disconnected, permitting the instrument to be used with special probes having their own zero controls.

5. CAL FS *Control:*

The screwdriver CAL control is used to calibrate the instrument using the internal calibration feature as well as calibration to a standard magnet. Calibration through external indicating instruments is also possible with connection to the output jacks.

6. Output Jacks:

The black and red front panel jacks will accept a *standard double banana plug* with ¾" spacing. They provide an output voltage proportional to the full-scale field, for use with external instrumentation. The polarity is positive for upscale meter readings and negative for downscale indications. The black jack is grounded to the chassis.

[b] **Rear Panel:**

1. Power Cord Receptacle:

The 3-pin power cord receptacle accepts the detachable power cord. The power cord is equipped with three conductors and is terminated in a three-prong plug recommended by the National Electrical Manufacturers' Association. The round pin is connected to the case, and grounds the instrument case and output terminals when used with the appropriate receptacle. An adapter may be used for *connection to a standard two-contact recep*tacle. The ground is brought out of the adapter by means of a short wire which should be connected to a suitable ground for protection of operating personnel. Only when a ground is supplied by associated equipment should this ground be unused to prevent common ground currents. The Model 620 is normally wired for 117 V nominal 50-60 Hz. To change it to 234 V, the primaries of the power transformer must be changed from parallel to series connection.

2. Fuse:

The fuse holder accepts a standard 3 AG size fuse. For 117 V operation, the fuse should be rated at 1/16 A Slo-Blo. For 234 V operation a 1/32 A Slo-Blo fuse should be used.

3. Battery Input:

An input for external battery power is provided. The yellow and black binding posts are mounted on ¾" centers to accept a standard banana plug or can be tightened directly on to prepared *cable* ends. The instrument will operate satisfactorily for voltages over the range of 9 to 18 volts dc at about 130 mA drain. The yellow post is positive and must be connected to the positive terminal of the dc power source. The black terminal is grounded to the instrument case.

4. Battery Line Switch:

This switch selects the input power used by the instrument. *In the line position the* Model 620 will operate on the line power only (117 or 234 V). In the BATT. position the instrument will operate on the internal or external battery by means of the automatic takeover feature if line power is not supplied. NOTE: WHEN THE SWITCH IS IN THE BATT. POSITION THE INSTRUMENT MUST BE TURNED OFF USING THE POWER SWITCH. Merely pulling the plug or turning off *the power source to the line cord* will only cause the instrument to switch over to its internal battery thus shortening the battery life. It is, therefore, suggested that the BATT-LINE switch be left in the LINE position, unless battery power or the automatic takeover feature is desired.

[c] **Overall Dimensions:**

5¾" high x 15" wide x 10 3/8" deep
(14.6 cm high x 38.1 cm wide x 25.72 cm deep)

[d] **Weight:**

Shipping 15 lbs. (6.75 kg)
Net 9 lbs. (4.05 kg.)

SECTION III
Installation and Pre-operation Adjustments

III-1 POWER

[a] Battery Installation:
To install the battery, slide the cover back and off after removing the screws on the rear. Take off the battery mounting clamp strip near the power transformer on the top of the sub chassis. Set the battery on the chassis with its terminal socket facing the power transformer, and slide the battery can lip under the clamp strip riveted near the range switch. Replace the removed strip, clamping the battery lip to the chassis. Connect the red plug to the positive socket and the black plug to the negative socket and replace the cover. The battery used is a 12 volt dry battery NEDA number 923—Eveready 2780N.
For portable operation simply disconnect the power cord (for convenience in handling) and switch to BATT position. The pilot will not operate except on line power.

[b] Power Requirements:
The Model 620 can be operated from any one of three types of power: standard ac line voltage (117 V or 234 V, 50-60 Hz, 4 watts), internal battery (dry battery, 12 volt, NEDA 923—Eveready 2780N) or external dc power (9-18 volts dc at approximately 130 mA drain). The BATT-LINE switch selects either line power-only in line position, or automatic battery takeover in the BATT position. In BATT position the instrument automatically selects the power source on the basis of the following criteria: Power is always drawn from the line when connected to a 117 V (or 234 V) ac source. If line power is not supplied, the instrument will operate from either the internal battery or external dc source, whichever has the higher voltage. Through this action double backup protection for power outages is possible. If the 117 V line fails, the 620 would switch over to the external dc source (it is assumed this source voltage is in excess of the 12 V supplied by the internal battery). In the event of failure of the dc source, the internal battery would take over. Because of the automatic change over, it is important that the instrument always be turned off by the power switch when the BATT-LINE switch is in BATT position. Pulling the plug or turning off the power source will only cause switching over to battery power.

[c] Operation:
Before turning the instrument on, make certain the power to be used matches the voltage and frequency ratings of the gaussmeter. Battery condition or external dc source voltage can be checked prior to turning on by the BATTERY TEST position of the FUNCTION switch.

When the FUNCTION switch is set at BATT TEST position, the meter is connected to the battery and dc input circuitry. The meter monitors either the internal battery or external source whichever has the higher voltage (check above paragraph). The meter must indicate within the range marked BATT with the instrument operating. If the indication is over or under the range, then the voltage is either too high or too low for proper operation. The battery condition can also be checked prior to instrument turn on to monitor the effects of the instrument load on the source.
Connect a probe to the input socket. It is important that the plug is pushed firmly into the panel socket observing the key slot, then the clamp ring screwed on until it is snug. Check the meter mechanical zero by aligning the pointer with its image in the mirror. If necessary adjust the screw on the meter face to bring the pointer to exactly zero reading. Set the panel controls as follows:

RANGE switch to 30 K
FUNCTION switch to NOR

Turn the power switch on and allow a few minutes warm up before making any measurements or calibrating.

III-2 PROBE ZEROING ADJUSTMENTS

To reduce the residual probe output to zero, the probe zero controls are used. Set the FINE control to about mid setting. Rotate the RANGE switch counter clockwise until a reading is obtained on the meter. Adjust the ten-turn COARSE control to bring the reading near zero while reducing the RANGE setting. Below the 1 gauss range, the FINE control may also be used for better resolution of zero adjustment.
Because the earth's magnetic field is well within the measurement capabilities of the gaussmeter, the effects of this and residual fields from other sources on zeroing must be considered, especially when measurements are made on the higher sensitivity ranges (100 gauss and below). Check Section IV-2b for details on types of zeroing.

III-3 CALIBRATION PROCEDURE

[a] General:
The calibration procedure should be carried out before using the instrument for magnetic field measurements. It should also be checked whenever probes are changed. Allow sufficient time for warm up stability before calibrating.
Calibration consists of adjusting the element

control current in accordance with the sensitivity of the probe and gain of the amplifier by using one of the following two methods.

[b] Calibration Against Internal CAL Signal:
Calibration against the internal CAL signal is a simple, easy to apply technique which will, in most cases, produce the best possible accuracy. Calibration against a reference magnet can produce better accuracy only if the reference magnet is better than ±0.3% and the probe linearity curve is known.

The accuracy and stability of the internal calibration signal is dependent only on precision, high stability resistors and the initial factory calibration. Therefore, long-term high stability is characteristic of this technique. It is recommended that, unless a very high accuracy reference magnet and probe linearity data is available, the internal calibration be used.

After the instrument and probe have warmed up (5 min.) set the RANGE switch to the 30 K range and the FUNCTION switch to CAL. Adjust the CAL screwdriver adjustment to obtain a full-scale (1.0) meter reading (or a full-scale reading (1-V range) on any external readout instrument connected to the output jacks). The gaussmeter and probe are then calibrated to the accuracy shown in the specifications is the same for all probes, it is not necessary to recalibrate each time the probe is changed.

[c] Calibration Against a Reference Magnet:
Greater accuracy can be achieved by the use of a reference magnet, provided the magnet has an accuracy of better than ±0.3% and the probe linearity data is known. Deviation error curves can be obtained at a nominal charge for any probe, at the time of purchase or by returning the probe to F.W. Bell, Inc.

The linearity curve is machine drawn using a precision electromagnet and is an error plot for the particular probe measured. It is a plot of the probe's deviation from the true value over the measurement range.

The curve is plotted with actual flux density along the horizontal X-axis and the deviation from true value, in gauss, vertically along the Y-axis. Thus, the locus of deviation errors of, for example, 1% of the actual field, will appear on the sheet as a diagonal line passing through the 1% of value points.

To calibrate using the linearity curve and reference magnet, the following procedure should be used. It is important that the absolute zero procedure be carried out prior to calibration by this method (see Section IV-2b). The Hall probe must be carefully positioned in the field to the correct location and orientation to respond to the correct field magnitude (maximum reading) without alignment errors. Set the RANGE switch to the proper range giving the maximum on-scale meter reading (or external readout instrument reading). Add the reference magnet specified field, in gauss, to the deviation, in gauss, read from the linearity curve at that flux density. Adjust the CAL FS control to obtain a reading equal to the sum. For example, if the reference magnet were specified at 9.8 kG and the deviation from the curve was —10 G, then the adjustment would be made to obtain 9.79 kG on the meter (or external readout instrument if used).

[d] AC Field Calibration
No separate ac field calibration is necessary. If the gaussmeter has been properly calibrated for dc fields, then the ac signal at the output jacks for ac fields will be calibrated to the same accuracy, with the exception of the effects of the frequency response.

The frequency response is essentially flat to 60 Hz. From 60 to 400 Hz the response may vary up to about 10% or 1 db. Above the 400 Hz the response rolls off rapidly and the gaussmeter is unusable for measurements. The reduced accuracy for ac measurements indicated in the specifications is for the panel meter and readout and is a result of the additional errors introduced by the ac detector circuit. These errors are not present in the signal at the output jacks and, therefore, higher accuracy ac measurements can be obtained through the use of high accuracy ac external readout instruments.

SECTION IV
Operating Instructions

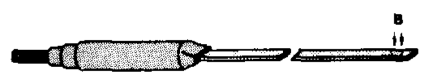
IV-1 THE PROBE

The standard probes are divided into two basic categories depending on field direction response: Transverse and axial. Figure 1 shows the shape and size of the various probes. In addition, special probes of all types can be designed to meet unusual requirements. Contact F.W. BELL, Inc. for information and quotations. Although the probes are quite rugged, reasonable care should be exercised in handling. Avoid excessive shock, pressure, bending or otherwise straining the element mount. The element can be fractured if overstressed since it is brittle as well as rigid. Probes are available with a temperature sensor mounted integrally with the Hall element for temperature compensation. Since the device housing is a good conductor of heat it should be protected and prevented from touching very hot or cold objects.

Note that probes are supplied for various flux measurement ranges. For accurate readings make sure that the probe is being used within its specified range of measurement. When 10 kG probes are used for measurement higher than 10 kG, increased deviation from linear repsonse will result. Such measurements would not be accurate as absolute reading, but might be useful where only a relative indication is sufficient.

AXIAL FLEXIBLE:

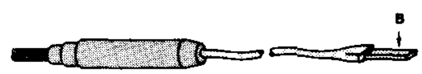
TRANSVERSE PROBE:



REQUIREMENTS	SUGGESTED PROBE CONFIGURATION
general use; durable	HEAVY DUTY
measure flux density in awkward places	FLEXIBLE
measure flux density in a small gap	STANDARD DUTY (laboratory use)
measure homogeneous fields* from 0.001 G to 2G; high sensitivity	MAGNAPROBE
high linearity; low temperature coefficient; accurate field measurement to 150 kG	10X PROBE**
multi-axis field measurement	2-AXIS PROBE; 3-AXIS PROBE
withstand low temperature (down to —270°C)	CRYOGENIC
monitor instantaneous difference between two field points; field mapping, homogeneity testing	DIFFERENTIAL

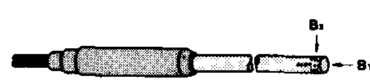
*averages flux density along 9" probe length
**10X probe sensitivity in one-tenth standard probe (1X) sensitivity.

TRANSVERSE FLEXIBLE:

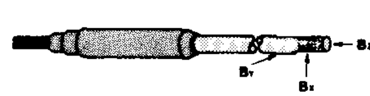


AXIAL PROBE:

TWO-AXIS PROBE:



THREE-AXIS PROBE:



Transverse Probes:
A *transverse probe, as its name implies, has its* flux response direction transverse to the probe handle axis. In figure 1 notice that the flux vector is shown entering the Hall element at right angles (90°) to the plane of the element surface. This is the direction of maximum Hall output. Magnetic fields entering the element at some other angle to the surface cause an output response proportional to the 90° component. That is, the response will be $B \cos\theta$ where B is the field magnitude and θ is the angle of the field to the perpendicular.

The axial probe has its flux response direction parallel and on axis with the probe handle. The element is encapsulated on the end of the probe extension tube. If the field is directed at some angle with respect to the probe axis, only *the axial component will produce an output,* just as the transverse component will only produce output for transverse probes.

IV-2 MEASUREMENT PROCEDURE

[a] General:
After completing the pre-operational adjustments described in Section III, the unit is ready for operation. Allow sufficient time after turn-on for the unit and probe to reach operating temperature (5 min.). It is advisable to position the probe securely in the measurement position using a probe-holding fixture or clamp whenever possible. It may be difficult or impossible to obtain a good field measurement unless the probe is stable. The probe may be *hand-held only when operating on the higher* ranges (100 gauss and above) and the field is fairly uniform over a reasonable area.

When using non-temperature-compensated probes, errors in reading due to temperature changes at the probe can be corrected by using the mean probe temperature coefficient and computing corrections (see Section IV-2e).

[b] Zeroing:
Since Hall probes do not have exactly zero output in a zero field, it is necessary to electrically zero the gaussmeter before taking any readings. Two types of zeroing are possible: Absolute and Relative.

Absolute zero is required whenever it is desired to know the actual field at the probe. As its name implies, the controls are adjusted to give zero reading at zero field. Because of the ever-present earth's field and possible stray fields from other sources, it is necessary to shield the probe to achieve zero field during the time of adjustment. The zero gauss chamber accessory available for the probe is a dual mu-metal can assembly which effectively shunts all external stray fields around the internal volume. By *slipping this chamber over the probe end, a zero field condition is created at the element,* and the gaussmeter is adjusted for zero output by the procedure of Section III-2.

Use care not to place the zero gauss chamber in a strong magnetic field. Also, it must not be allowed to come into direct contact with a magnet, since it may become slightly magnetized and will not provide a true zero. It can be de-magetized by slowly passing the chamber through the ac field of a demagnetizer coil carrying ac line current.

The zero chamber provides a "true" zero reference. Readings taken in the presence of the earth's ambient field will generally have the earth's field, or some component of it, included in the reading of the unknown field. Thus, it may be necessary to subtract the ambient field reading from the total to obtain the value of the unknown field. To avoid this subtraction, the method of relative zeroing may be used. In this case the gaussmeter is zeroed after the probe has been placed in the measurement position, without using the zero gauss chamber. The ambient field is therefore zeroed out electrically in the gaussmeter. This method is successful only if the field to be measured can then be presented to the probe without changing the probe position with relation to the ambient field, and without altering the ambient field at the probe during measurement. The change in field at the probe will be measured by the gaussmeter as an absolute value, and the ambient field excluded from the reading. Since the probe position must remain fixed during the measurement, this method is not always practical. The zero controls are capable of suppressing residual fields of up to about 30 gauss.

Since the ambient field seldom exceeds 1 gauss, the precautions mentioned above apply only when measuring fields less than 500 or 1000 gauss. If a magnet has an iron structure which will modify the ambient field by its presence, it may be necessary to take several measurements in different orientations with respect to the earth's field. Obtain the two extreme values and use the mean value between these as the correct value. The zero adjustments should be checked frequently, if possible, during the course of a measurement particulary when using low ranges. If a change in temperature occurs at the probe, rezeroing may be necessary. Zero drift versus temperature is small and is not compensated. The zero controls are never used to shift the calibration of the gaussmeter.

[c] Calibration Check:
A calibration check can easily be made at any time during a series of measurements without disturbing the probe by using the internal

calibration procedure. Refer to Section III-3b on calibration.

[d] Operation:

1. DC Fields:

For dc field measurements set the FUNCTION switch to NOR and the RANGE switch to a range higher than the expected field. The meter will read up scale if the field direction aligns with the probe sensitivity direction as describ-ed in Section IV-1b. If the meter tends to read below zero, the field direction is reversed and the probe can be turned over or the FUNCTION switch can be set to REV. Switch the RANGE switch to a range which gives the greatest on-scale meter reading. To read the magnitude of the field, adjust the probe for maximum reading. If a desired direction component of a field is to be measured, set the probe so that the sensitive direction aligns with the desired component. The meter will then read the component.

The measured value is determined from the meter reading and RANGE switch setting. The RANGE switch indicates the full scale value in gauss of the meter reading. For example, if the RANGE switch is set on 10 kG and the meter reads 1.0 on the 0 to 1 scale, then the field is 10 kG. If the meter reading were 0.5, then the field would be 5,000 kG. When the RANGE switch is on a 3 range (3 kG, 300 kG, etc.,) the meter reading is taken from the lower Scale. A RANGE switch setting of 300 G and a meter reading of 2 on the lower scale would indicate 200 gauss.

2. AC Fields:

For ac field measurements the FUNCTION switch is set to the AC position. The direction response of the Hall element is the same as for dc fields and alignment of the probe and field direction must be considered as described above. The meter is calibrated to read rms value for sine wave flux. If the field has much harmonic content, the reading will not be the true rms value. The ac detector is an averaging type circuit. For non-sinusoidal wave forms within the 400 Hz bandwidth, the average value can be obtained by multiplying the meter reading by 0.9. The meter reading and RANGE switch setting determine the field measurement just as in the case of dc field measurements.

The frequency response for ac field measurements using the meter is from 10 Hz to 400 Hz. Frequencies outside this range will not indicate correctly on the meter. The amplifier system, however, is capable of operating from dc to 400 Hz, and measurements below 10 Hz can be made by using a dc coupled oscilloscope or low frequency voltmeter connected to the output jacks.

3. Overloading:

Because the amplifying system used in this gaussmeter will amplify ac and dc fields simultaneously, attempting to measure a small ac field in the presence of a large dc field or a small dc field in the presence of a large ac field can overload the amplifier and cause erroneous measurements. When measuring dc fields, especially on the sensitive ranges, check for ac fields by switching to AC. If an ac reading exceeding ⅓ of full scale is encountered, the dc measurement may be in error. Switch to the next less sensitive range. If the dc reading has not changed, the ac component of the field has not overloaded the amplifier. If at any time there is a discrepancy between ranges of more than 2% of full scale on the meter, there is the possiblility that the amplifier is being overloaded, and the above tests should be made.

Also when making ac measurements the component of any dc fields must be kept below 10% of the range in use. This can usually be accomplished by using the zero controls to suppress the small earth's field or residual fields. Relative zeroing as described in Section IV-2b will remove any dc fields up to 30 gauss. If this is not sufficient to prevent overloading, then a less-sensitive-than-normal range must be used to prevent the undesired dc field from overloading the amplifier.

[e] Temperature Effects:

All Hall probes exhibit a certain temperature coeffecient. This value can be found in the specifications for the type of probe being used. If the probe temperature is known relative to the temperature at which it is calibrated, correction for the temperature effects can be applied to the measurement readings. It is recommended, however, that if the probe temperature is not known or rapid varitaions are expected, the temperature-compensated probes be used. They will give greater accuracy in the presence of temperature variations than conventional probes with calculated corrections, and the stability will allow high resolution measurements with external indicating devices.

To correct for temperature influence, non-compensated probes, the following formula can be used:

$$B_a = B_g \quad 1 + (t_{pm} - t_{pc}) \frac{t_c}{100}$$

where:

- B_a = the actual value of the field being meausured (unknown).
- B_g = the value of the field as indicated by the gaussmeter.
- t_{pm} = temperature of probe at time of field measurement in degrees C.
- t_{pc} = temperature of probe at time of cali-

bration in degrees C. (25°C when using internal CAL method.)

t_c = temperature coefficient of probe in % per degree C.

This formula will correct the gaussmeter reading (B_g) to give the actual field (B_a) for measurements under different temperature conditons. This correction need not be applied to the temperature-compensated probes because they exhibit the smallest possible temperature effects. Notice that t_p is a negative number, and the minus sign must be carried into the formula.

IV-3 OUTPUT JACKS

The output jacks provide the electrical output of the instrument. They provide the highest resolution, stability and accuracy possible. The red and black jacks are at the standard ¾" spacing to accept a dual banana plug. The red jack is the output, which is positive for upscale meter readings and the negative for below-scale meter indications. The black jack is the common and is grounded to the gaussmeter case. The voltage available is 1 volt for full scale meter reading and directly proportional to the instantaneous field at the probe, for frequencies from dc to 400 Hz. The source resistance is 1 k and the jacks can be loaded with any desired impedance, thus permitting connection to any type of external indicating instrument.

High resolution and accuracy can be achieved by connecting a digital voltmeter to the output jacks. Set the digital voltmeter to its 1 volt full scale range and calibrate the gaussmeter as described in Section III-3 using the DVM as the readout instrument. By using only the decade ranges (0.1, 1, 10, etc.) on the gaussmeter, the DVM will read directly in gauss with full scale being equivalent to the full scale range setting of the gaussmeter.

Because of the stability (especially with the temperature-compensated probes) and back-up battery power, the Model 620 is ideally suited to long-term field monitoring applications. By connecting a chart recorder or other recording device to the output jacks, the Model 620 becomes a gauss-to-volts transducer for these applications.

IV-4 PROBE DEVIATION CURVES

Machine-drawn error curves can be obtained at a nominal charge for any probe, at the time of purchase or by returning the probe to F.W. Bell, Inc. The use of the probe deviation curves for calibrating is described in Section III-3c.

To use the curves to correct the field measurements, locate the field value as indicated on the gaussmeter on the horizontal axis of the curve. Use the right half of the curve for positive or normal direction fields and the left half for negative or reverse direction fields. Read the deviation in gauss from the curve. If the deviation is positive (above the axis), the probe output is high and the error is to be subtracted from the indicated value. Negative probe deviations are added to the readings to obtain the correct value.

IV-5 TOTAL FLUX DETERMINATION

The Hall-effect sensing device is inherently responsive to magnetic flux density and not to total flux lines. It is not dependent on rate-of-change of flux as is a search coil.

From the basic definitions:

GAUSS = WEBERS PER SQUARE METER X 10

GAUSS = LINES PER SQUARE INCH X .1550

The Hall probe is equally useful in homogenous, uniform low-gradient fields and in high-gradient fields, although the low-gradient fields are capable of more accurate measurement. If the flux density is uniform and unidirectional over a given area, the total flux though the area is found by multiplying by the area in question.

$$\text{(Flux) WEBERS} = \text{GAUSS X SQ. METERS X } 10^{-4} = \text{GAUSS X SQ. CM X } 10^{-8}$$

$$\text{(Flux) LINES} = \frac{\text{GAUSS X SQ. INCHES}}{.1550}$$

When the Hall generator is moved in a plane, the component of flux normal to this plane will be indicated. If the field varies in magnitude over the area, it is necessary to integrate the values of flux density over the area in question. The flux density value indicated by the Hall probe output is the effctive value over the active area of the Hall generator. Fortunately, the Hall-Pak devices have extremely small active area. The standard transverse probe active area is only about 0.030 square inch, and sensitivity is essentially uniform over this area.

Absolute measurements of total flux of magnets having odd shape or high length-to-diameter ratio are best made using the search coil and standard fluxmeter methods. In many cases, however, valuable data are obtained by air-gap flux density measurements when the magnet is mounted in its working structure. Also, accurate comparison data can be obtained on almost all magnets of various sized and shapes using a Hall probe to measure pole face density in comparison to a magnet selected as a standard of reference.

SECTION V
Theory of Operation

V-1 GENERAL

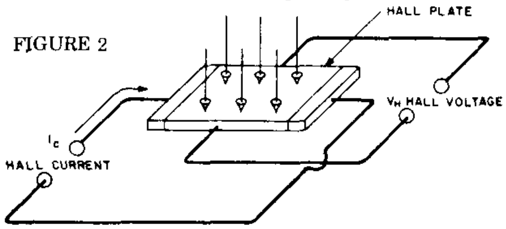
The basic principle of magnetic flux measurement used in the Model 620 Gaussmeter may be described as a flux-modulated carrier-amplifier system. A locally generated ac carrier signal is fed as an exciting current to the Hall element. The flux to be measured at the probe modulates the ac carrier within the Hall sensor, producing an ac output voltage which is accurately proportional to flux density. The flux-modulated ac carrier output is amplified by the carrier amplifier an then restored to a flux-proportional voltage by the synchronous demodulator wihtout loss of polarlity (field direction) information. The demodulator drives the panel meter and output jack.

If the field is time-varying, the demodulated output will be instantaneously proportional to the flux waveform up to 400 Hz. A separate ac detector is connected to the synchronous demodulator output to produce a dc meter reading for ac fields.

V-2 THE SENSING ELEMENT

The Hall-Pak generator used for magnetic flux sensing is a semiconductor device operating on the Hall-effect principle. It consists of a thin rectangular wafer of high-purity indium arsenide with 4 leads attached.

FIGURE 2



THE HALL GENERATOR

The application of control current I to the Hall generator results in a flow of charge carriers through the semiconductor material in the direction of its long dimension. When the Hall generator is placed in a magnetic field, the Lorenz force, acting on the moving charges, deflects them at right angles to the direction of their motion through the Hall plate. This is the same force that deflects the electron beam in the cathode ray tube.

The resulting build-ip of charge carriers along the sides of the wafer produces the Hall voltage, and this voltage appears as an output at connections made on each side of the element. Hall voltage V_H is directly proportional to the flux density B and to the magnitude of control current I_c.

$$V_H = K_H(B \times I_c)$$

The three factors V_H, I_c, and B are mutually perpendicular. If the magnetic flux vector B is not perpendicular to the face of the Hall Generator, the Hall output will be proportional to the component of B that is perpendicular to the element. The constant of proportionality K_H is called the Hall sensitivity constant, and is approximately 0.075 volt per kG-ampere, depending on the probe.

V-3 CIRCUIT OPERATION

[a] Introduction:

This section describes the overall gaussmeter circuit operation. Check the simplified block diagram, Fig. 3; the detailed block diagram, Fig. 4; and the complete schematic, Fig. 5. Because of the unique circuit design it is recommended that a thorough understanding of the circuit operation be aquired before attempting to service or adjust the instrument.

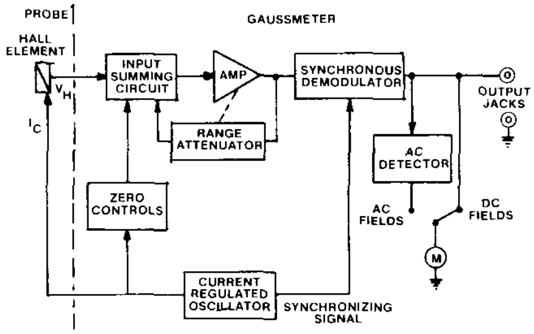
[b] General Operation Description:

The Hall element is supplied with exciting current, I_c from the 5 kHz current-regulated oscillator, Fig. 3. The Hall output voltage, V_H, (the flux-modulated carrier signal) is connected to the gaussmeter input summing circuit. At the summing circuit the zeroing voltage from the zero controls and the feedback voltage from the range attenuator are subtracted from the Hall output. The difference is amplified to produce the proper output depending on the range in use. The amplifier output feeds the range attenuator which sets the proper gain, and controls and stabilizes the amplifier by means of overall loop feedback. The zeroing voltage is obtained from the zero control circuit which adjusts and attenuates a sample of the control current. The amplifier output feeds the synchronous demodulator which converts the amplified flux-modulated carrier into a flux-proportional output voltage. This output voltage then feeds the output jacks and meter for dc fields. For meter reading of ac fields, the ac detector is connected between the output and meter to convert the flux proportional ac output to dc.

[c] Detailed Operating Description:

1. General

The circuit is divided into 6 basic functional groups: the probe, the input section, and the amplifier section, the detector and meter, the current-regulated oscillator, and the power supply. Fig. 4, the complete block diagram, shows all essential operating functions. However, various circuit details have been eliminated or altered for clarity. Check the complete schematic, Fig. 5, for all circuit details.



MODEL 620
SIMPLIFIED BLOCK DIAGRAM

FIGURE 3

2. The Probe:
The excitation current is supplied to the element through pins A and D of the probe plug and the Hall output voltage is connected to the gaussmeter through pins C and E. A calibrating resistor, mounted in the probe plug across pins B and F, accurately programs the amplifier gain to the proper value according to the sensitivity of the particular Hall element.

3. Input Section:
The FUNCTION switch, in the operating positions, connects the Hall voltage output directly to the input transformer. The primary winding of the transformer is split with the two resistors R3 and R4 inserted between the halves and grounded, to form a balance-to-ground summing point. The input transformer, in effect, sees the difference between the Hall input voltage and the summing point voltage. The summing point voltage consists of the feedback voltage from the range attenuator and the zero injection voltage from the zero controls. Also shunting across R3 and R4 is the calibrating resistor or network in the probe. By varying this CAL resistor, the feedback factor of the range attenuator is adjusted, and the overall amplifier gain is programmed very accurately for proper calibration.

The zero injection voltage from the zero controls is obtained by sampling the element control current. The controls adjust and attenuate the voltage obtained from the current sensing transformer T201. Because the Hall sensor zero and residual field field output is proportional to control current, and the zero injected voltage is derived from the current, cancellation of the zero field voltage is maintained even under the condition of current changes. Highest possible zero stability is, therefore, achieved.
During calibration the FUNCTION switch connects the internal gain programming resistor R2 in place of the resistor in the probe and disconnects the zero controls. The internal gain calibrating resistor programs the gain to the proper value for the nominal Hall element sensitivity (0.075 V/kG-A).
The input is switched from the probe output a resistor R1 in series with the control current to the element which is calculated to produce a voltage equal to 10, 10 kG field (full scale (1.0) on the 30 kG range). The CAL control which varies the current is then adjusted to give full scale output (1.0). By this method of adjustment, any amplifier gain errors are compensated for by the control current adjustment, providing an internal calibration which is dependent only on the accuracy of the resistors R1, R2, R3, and R4 and the initial factory calibration which determines the probe calibrating resistor.

4. Amplifier Section:
The input transformer secondary connects to the first attenuator which operates on the middle three ranges (30G, 100G, 300G) to keep the input below the saturation level of the first amplifier. The first amplifier is a two-stage plus emitter follower direct coupled circuit with ac and dc feedback for stabilization. The voltage gain is 46 db at the carrier frequency and is attenuated at all other frequencies by the synchronous filter. The filter consists of two transistor switches operating in synchronism with the carrier frequency and two RC filter networks inserted in the feedback network of the amplifier section. The action is that of a very narrow band pass filter synchronized to the carrier frequency. Very high rejection of noise and spurious signals is achieved, and easy alteration of band width is possible by changing the RC network.
The first amplifier feeds the second attenuator which operates in the lowest ranges (.3, 1, 3, and 10 G) to prevent overloading the second amplifier. The second amplifier is indentical to the first and gives another 46 db gain at the carrier frequency with synchronous filtering. Again the output feeds an attenuator which operates on the highest 4 ranges, (1kG, 3kG, 10kG, 30kG).
A third 46 db filter amplifier feed a dual complementary unity gain output amplifier which drives the output transformer. The output transformer has two center tapped outputs, one for the range attenuator and the other for the synchronous demodulator. The 500Ω range attenuator connects the output back to the summing point across R3 and R4, giving about a 40 db feedback factor for high gain stability, high input impedance and high linearity.
The range attenuator consists of four 500Ω"0" pads switched in a binary sequence (1, 2, 4, 4), to give 10 db steps to 110 db total attenuation. Also connected to the range attenuator switch are the three dividers between the amplifiers which also operate in 10 db steps to maintain the 40 db feedback factor.

5. Detector and Meter:
The synchronous demodulator consists of two switching transistors driven by the sync. signal from the carrier oscillator. When the FUNCTION switch is in the REV postion, the output transformer signal polarity is reversed which changes the polarity of the demodulated output. The output jacks are connected to the demodulator through the ripple filters R53, R54 and C1.
The meter is connected through the R49 calibrating resistor for dc fields and CAL. For ac fields the meter is switched to the ac detector. The detector consists of a diode bridge connected in the current feedback loop of a two-stage amplifier. High linearity ac-to-dc conversion of the flux-proportional demodulated output is, therefore, achieved. For battery test, the meter is switched to the attenuator formed by R50 and R51 fed from the diodes which select the higher voltage, battery or external dc input.

6. Current regulated Oscillator:
The element control current is supplied from the 5 kHz square wave current oscillator. The oscillator consists of an astable multivibrator driving a pair of push-pull output transistors into the output transformer. The output current amplitude is controllable by a dc control signal. This control signal is obtained from a dc amplifier with positive feedback for infinite gain. The input to the amplifier is then obtained from the current-sensing transformer T201 through a zener reference diode. By means of this feedback loop, the control current is regulated to obtain a high stability element excitation current.
The current is adjustable by the CAL control which varies the secondary load on the current sensing transformer. The current-sensing transformer also feeds the zeroing controls.
7. Power Supply:
The power to all circuits is supplied from the power regulator which provides + 7 V dc. The input to the regulator is obtained from the power transformer, rectifier diodes, and filter capacitor. At 117 V ac line voltage (or 234 V) the unregulated dc voltage is about 20 V. Because the internal battery and external input are less than 20 volts, the diodes in series with these power sources are reverse biased and no power is drawn from them. Therefore, if the ac line power fails, the external or internal battery will automatically take over, when the LINE-BATTERY switch is in the Batt. position.

SECTION VI
Maintenance

VI-1 INTRODUCTION

This section contains the necessary instructions and diagrams for maintaining the Model 620 Gaussmeter. In addition to the schematic diagram, a block diagram showing typical voltage levels, is provided to aid in trouble-shooting. Also included are circuit board layouts.
Repair and adjustment of the instrument should be attempted in the field only where adquate test equipment and qualified personnel are available. Refer to the warranty page for the procedure to be followed should factory repair service be required.

VI-2 TEST EQUIPMENT

The following test equipment is required to test and adjust the Model 620 Gaussmeter:
(a) A high impedance dc voltmeter having 2% or better accuracy.
(b) A high impedence ac voltmeter having 2% or better accuracy. The meter should be an average reading circuit, calibrated in rms for sine wave voltages. A true rms reading meter will not read the same voltages because of the square wave forms.
(c) A high quality oscilloscope having response to dc.

VI-3 COVER REMOVAL

CAUTION—Always disconnect power cord from power line when removing or replacing cover.
To remove cover, it is necessary only to remove the four screws on the rear of the unit and slide the cover off.

VI-4 PERFORMANCE TESTS

This paragraph describes a rapid overall series of tests for proper operation. IF difficulty still is encountered, proceed to paragraph VI-5.

[a] **Preliminary:**
1. Make sure power cord is properly connected and fully seated in the receptical on instrument.
2. Check fuse for burnout. Correct fuse is:
1/16 A 3AG slow-blow for 117 V operation.
1/32 A 3AG slow-blow for 234 V operation.
3. Inspect the probe for damaged element or cable, or poor plug contacts.
4. Check meter mechanical zeroing.
5. Set controls as follows:
RANGE switch to 30 K
FUNCTION switch to CAL
6. Plug securely in front panel socket.
[b] Line Current Check:
1. Connect to rated power source. Line current

after warmup should be:
at 117 V line, 0.038 A nominal.
at 234 V line, 0.019 A nominal.

[c] Calibration Check:

1. With the instrument operating the meter should read near full scale.
2. Adjust the CAL control. A full-scale meter reading should be obtainable with a small adjustment leeway on each side.
3. Voltage at output jacks should be 1 volt dc for full-scale meter reading.

[d] Zero Test:

1. Switch the FUNCTION switch to NOR. Adjust the zero controls to obtain zero meter reading with the zero gauss chamber over the probe on the 0.1 G range.
2. Set the RANGE switch to the 100 G range.
3. Rotate the COARSE ZERO control over its range, switching the FUNCTION switch to REV when below-zero meter indications are obtained.
4. A total of about 60 gauss adjustment range should be obtained.

[e] Detector Zero Test:

1. Again zero the instrument on the 0.1 G range with the FUNCTION switch at NOR.
2. Switch to the 30 K range and measure the dc voltage at the output jacks. It should be less than 1 mV dc.

[f] Noise Check:

1. With the zero gauss chamber in place and a good zero on the 0.1 G range, switch the FUNCTION switch to AC.
2. The residual meter reading should be less than 10% of full scale on the 0.1 G range.

VI-5 ADJUSTMENT AND ALIGNMENT PROCEDURE

IMPORTANT—None of the adjustments described in this section should be disturbed unless the instrument is malfunctioning and the tests indicate adjustment is necessary. These tests and adjustments are designed to assure correct overall performance. Before making any adjustments, the Model 620 should be turned on for at least one hour with the cover in place. Line voltage should be at rated value (117 V or 234 V).

[a] Meter Mechanical Zero:
For this test the meter terminals may be short-circuited with a jumper wire, or the instrument turned off, allowing a few seconds for complete discharge of all capacitors. The instrument must be in the normal horizontal operating position. Read the meter accurately by aligning the pointer with its image in the mirror. If necessary, adjust the screw on the meter face to bring the pointer to exactly zero.

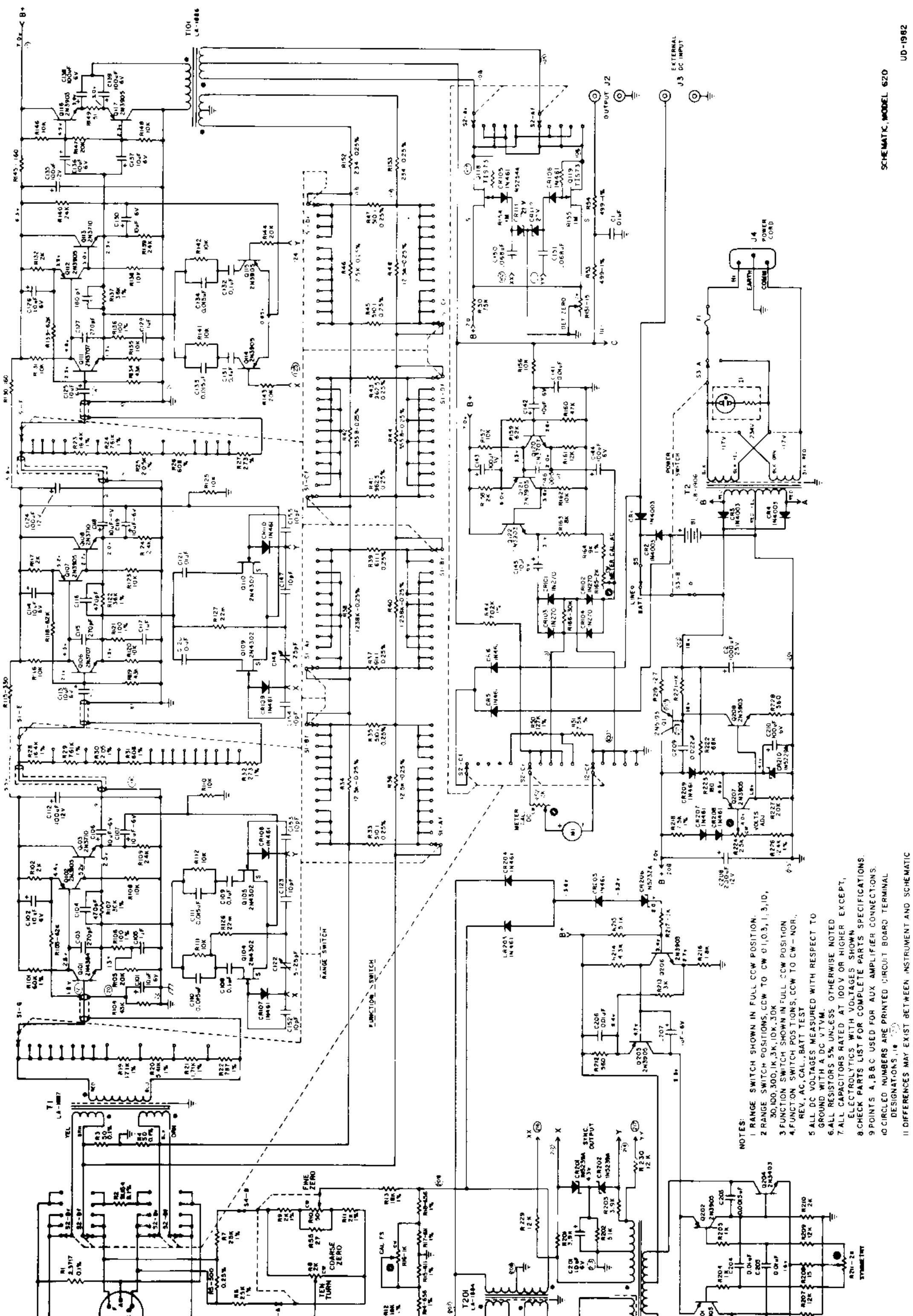
[b] Power Supply Voltage Adjustment:
Adjust R224 on the oscillator power supply circuit board to obtain +7 V dc between terminal 206 and ground.

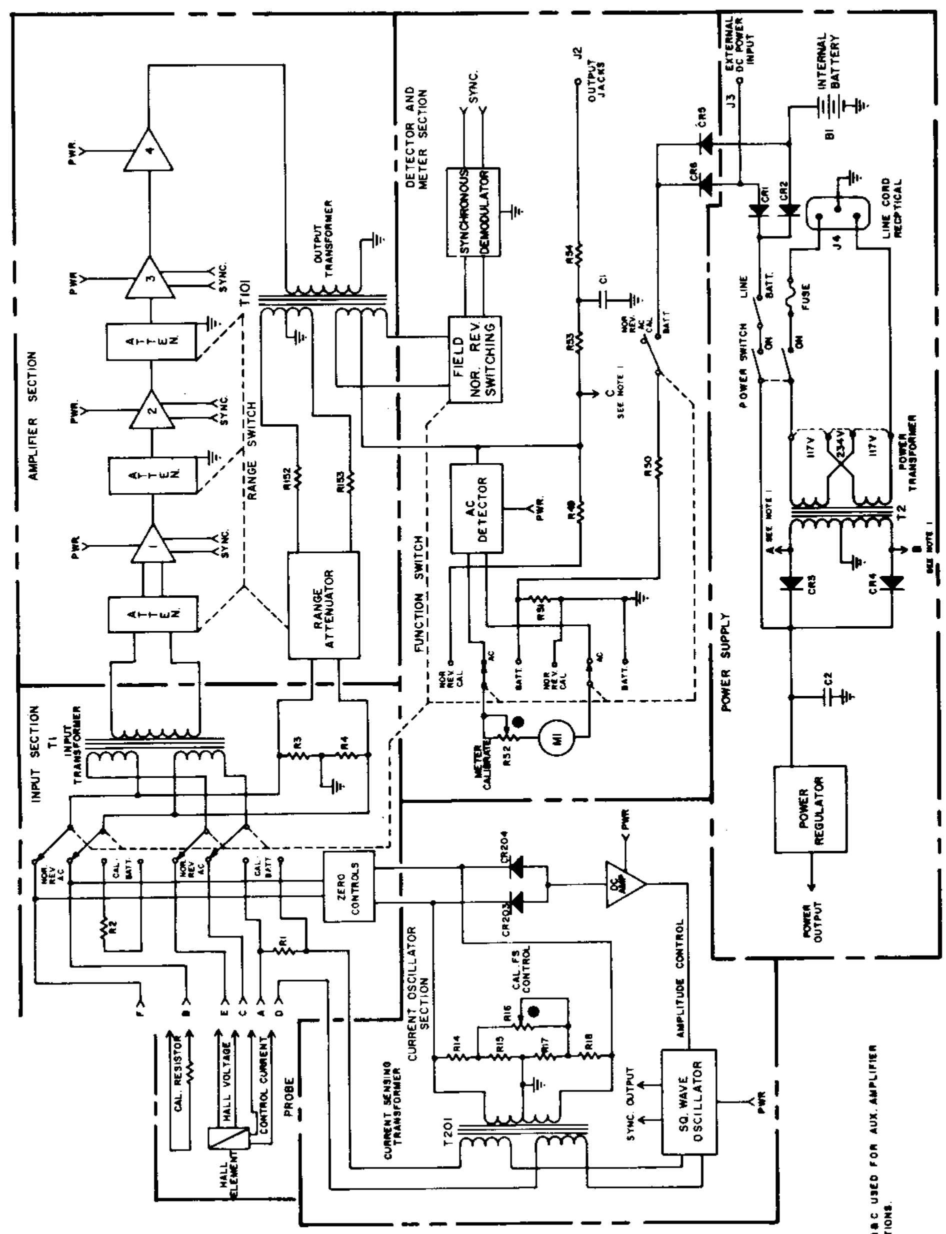
[c] Oscillator Symmetry Adjustment:
Connect the oscilloscope to terminal 212 and ground on the oscillator power supply board and adjust R211 on that board for a symmetrical square wave. Use the largest scope trace possible.

[d] Detector Zero Adjustment:
Place the probe in the zero gauss chamber and zero the gaussmeter down to the 0.1 gauss range. Switch to 30K range and adjust R151 on the amplifier board to obtain zero dc voltage at the output jacks. Use the highest sensitivity voltmeter range.

[e] Meter Calibration dc:
For dc fields switch the RANGE switch to 30 K and the FUNCTION switch to CAL. Adjust the CAL F.S. control to obtain exactly 1 volt at the ouput jacks using the dc VTVM. Adjust the potentiometer R52 on the circuit board on the back of the meter to obtain exactly full-scale meter reading. The more accurate the dc VTVM used, the more accurate the setting of 1 volt output for full scale.

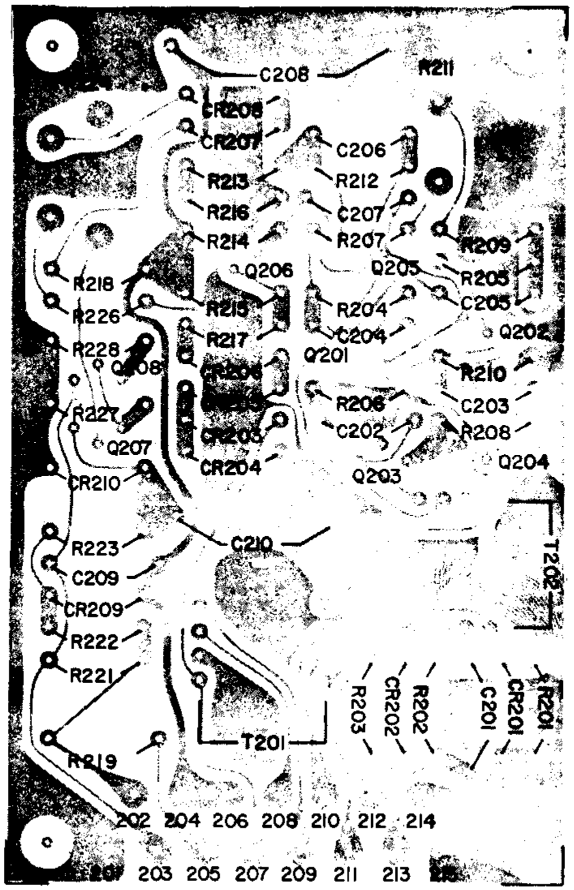
[f] Meter Calibaration ac:
Connect the ac VTVM to the front panel output jacks and place the probe in a source of ac field about 60 Hz. This field can be generated by any method: The external field of a power transformer, a coil operating from line power, etc. No particular accuracy is necessary, but a field of about 10 gauss would be easy to use. Mount the probe in the field using a holding fixture. Zero the dc field, if any, using the zeroing controls and on the range which gives about 1 volt reading on the ac VTVM. Adjust the probe to provide exactly 1 volt on the ac VTVM and adjust R165 on the amplifier board to obtain exactly full scale on the Gaussmeter with the FUNCTION switch on AC. It is recommended that the ac field used be above the 1 gauss range because stray dc fields will not be as apt to cause difficulty. Be sure there is no dc field reading in the NOR or REV positions of the FUNCTION switch as these could cause errors. (See Section IV-2d3).


SCHEMATIC, MODEL 620
UD-1982
NOTES:
1 RANGE SWITCH SHOWN IN FULL CCW POSITION.
2 RANGE SWITCH POSITIONS, CCW TO CW 0.1,0.3, 1, 3, 10, 30, 100, 300, 1K, 3K, 10K, 30K
3 FUNCTION SWITCH SHOWN IN FULL CCW POSITION
4 FUNCTION SWITCH POSITIONS, CCW TO CW - NOR., REV., AC, CAL., BATT TEST
5 ALL DC VOLTAGES MEASURED WITH RESPECT TO GROUND WITH A DC VTVM.
6 ALL RESISTORS 5% UNLESS OTHERWISE NOTED
7 ALL CAPACITORS RATED AT 100V OR HIGHER EXCEPT, ELECTROLYTICS WITH VOLTAGES SHOWN
8 CHECK PARTS LIST FOR COMPLETE PARTS SPECIFICATIONS.
9 POINTS A, B & C USED FOR AUX AMPLIFIER CONNECTIONS.
10 CIRCLED NUMBERS ARE PRINTED CIRCUIT BOARD TERMINAL DESIGNATIONS, ie
11 DIFFERENCES MAY EXIST BETWEEN INSTRUMENT AND SCHEMATIC AS A RESULT OF CHANGES MADE DURING FINAL CHECKOUT AND ALIGNMENT.

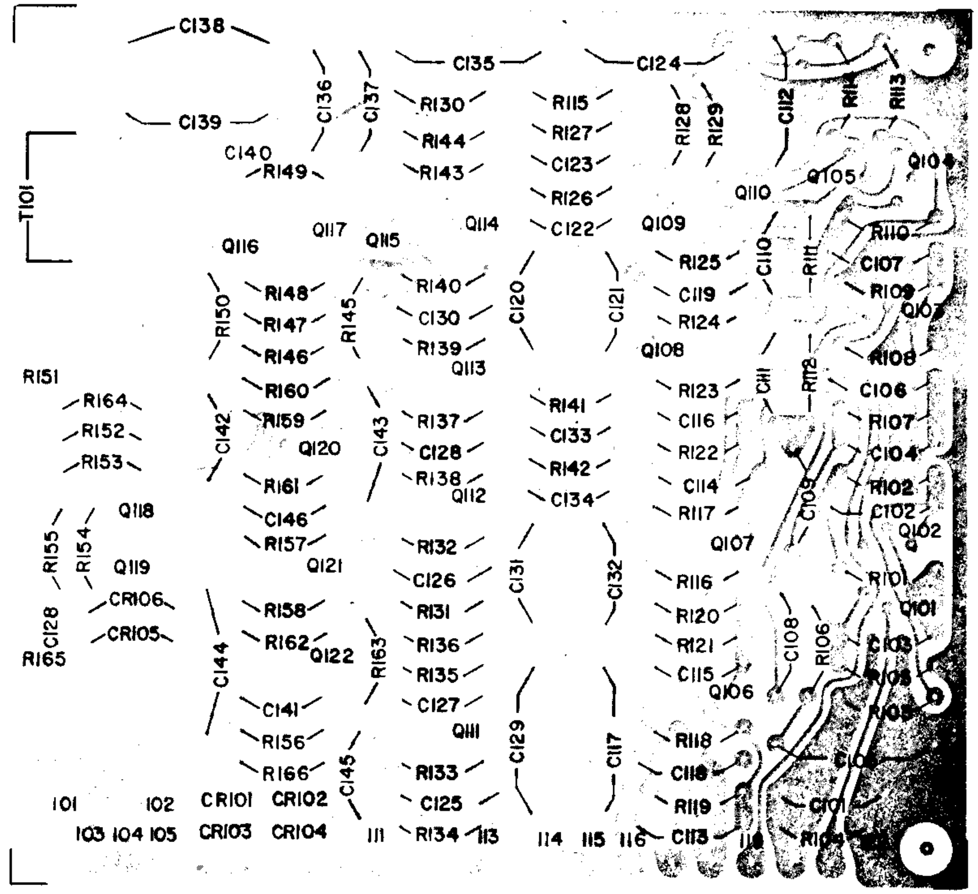


NOTES:
1 POINTS A,B&C USED FOR AUX. AMPLIFIER CONNECTIONS.

BLOCK DIAGRAM FIG. 4



POWER SUPPLY—CURRENT OSCILLATOR CIRCUIT BOARD



AMPLIFIER—DETECTOR CIRCUIT BOARD

ABBREVIATIONS

Cer	Ceramic	k	Kilo or 10^3
Comp	Composition	μ	Micro or 10^6
EC	Electrolytic can type	MME	Milded miniature epoxy
EM	Electrolytic miniature type	Ω	ohm
F	Farad	p	Pico or 10^{12}
Film	Metal film	V	Working volts
Fixed	Fixed	Var	Variable
FOP	Factory adjusted for optimum performance	W	Watt
HM	Hot molded	WW	Wire wound

PARTS LIST MODEL 620

Schematic Ref.	Value	Spec.		Type		Bell Part No.
R1	2.3717Ω	1/10 W	1/10%	WW	Fixed	18370
R2	91.154Ω	1/10 W	1/10%	WW	Fixed	18420
R3	50Ω	1/10 W	1/10%	WW	Fixed	18400
R4	50Ω	1/10 W	1/10%	WW	Fixed	
R5	500Ω	1/8W	¼%	Film	Fixed	15240
R6	25kΩ	½ W	1%	Film	Fixed	17900
R7	25kΩ	½ W	1%	Film	Fixed	17900
R8	2 kΩ			WW	Var	22150
R9	2 kΩ	½ W	1%	Film	Fixed	17660
R10	50Ω			HM	Var	21140
R11	2kΩ	½ W	1%	Film	Fixed	17660
R12	18 kΩ	½ W	1%	Film	Fixed	17880
R13	18 kΩ	½ W	1%	Film	Fixed	17880
R14	656Ω	½ W	1%	Film	Fixed	17590
R15	611Ω	½ W	1%	Film	Fixed	17570
R16	1 kΩ			HM	Var	21130
R17	611Ω	½ W	1%	Film	Fixed	17570
R18	656Ω	½ W	1%	Film	Fixed	17590
R19	17.1 kΩ	1/8 W	1%	Film	Fixed	16470
R20	5.41 kΩ	1/8 W	1%	Film	Fixed	16260
R21	1.71 kΩ	1/8 W	1%	Film	Fixed	16130
R22	796Ω	1/8 W	1%	Film	Fixed	
R23	16.4 kΩ	1/8 W	1%	Film	Fixed	16460
R24	7.61 kΩ	1/8 W	1%	Film	Fixed	16310
R25	2.05 kΩ	1/8 W	1%	Film	Fixed	16160
R26	608Ω	1/8 W	1%	Film	Fixed	15960
R27	273Ω	1/8 W	1%	Film	Fixed	15870
R28	16.4 kΩ	1/8 W	1%	Film	Fixed	16460
R29	7.61 kΩ	1/8 W	1%	Film	Fixed	16310
R30	2.05 kΩ	1/8 W	1%	Film	Fixed	16160
R31	608Ω	1/8 W	1%	Film	Fixed	15960
R32	273Ω	1/8 W	1%	Film	Fixed	15870
R33	510.1Ω	1/8 W	¼%	Film	Fixed	15250
R34	12.5 kΩ	1/8 W	¼%	Film	Fixed	15290
R35	510.1Ω	1/8 W	¼%	Film	Fixed	15250
R36	12.5 kΩ	1/8 W	¼%	Film	Fixed	15290
R37	611.1Ω	1/8 W	¼%	Film	Fixed	15260
R38	1.238 kΩ	1/8 W	¼%	Film	Fixed	15280
R39	611.1Ω	1/8 W	¼%	Film	Fixed	15260
R40	1.238 kΩ	1/8 W	¼%	Film	Fixed	15280
R41	962.5Ω	1/8 W	¼%	Film	Fixed	15270
R42	355.8Ω	1/8 W	¼%	Film	Fixed	15230
R43	962.5Ω	1/8 W	¼%	Film	Fixed	15270
R44	355.8Ω	1/8 W	¼%	Film	Fixed	15230
R45	510.1Ω	1/8 W	¼%	Film	Fixed	15250
R46	12.5 kΩ	1/8 W	¼%	Film	Fixed	15290
R47	510.1 Ω	1/8 W	¼%	Film	Fixed	15250
R47	510.1Ω	1/8 W	¼%	Film	Fixed	15250
R48	12.5 kΩ	1/8 W	¼%	Film	Fijxed	15290
R49	7.02 kΩ	½ W	1%	Film	Fixed	17770
R50	127 kΩ	¼ W	1%	Film	Fixed	16650
R51	7.5 kΩ	¼ W	1%	Film	Fixed	16300
R52	2 kΩ			WW	Var	22150
R53	500Ω	½ W	1%	Film	Fixed	15240
R54	500Ω	½ W	1%	Film	Fixed	15240
R55	27Ω	½ W	5%	Comp	Fixed	12630
C1	0.1μF	200 V		MME	Fixed	24550
C2	1000μF	25 V		EC	Fixed	23930

Transistors & Diodes

CR1	IN2069	28090
CR2	IN2069	28090
CR3	IN2069	28090
CR4	IN2069	28090
CR5	IN461	28010
CR6	1N461	28010
Q1	2N3740	

Transformers

T1	Input Tansformer	26260
T2	Power Tansformer	26270

Switches

S1	Range Switch	34240
S2	Function Switch	34260
S3	Power Switch	33770
S4	Zero Out Switch Part of Fine Zero Control	
S5	Batt-Line Switch	33690

Meter

M1	0-100μ A Meter	10540
	Battery	35870

The following parts are on the amplifier circuit board assembly, YP-01-003

Schematic Ref.	Value	Spec.		Type		Bell Part No.
R101	10 kΩ	¼ W	1%	Film	Fixed	15435
R102	2 kΩ	½ W	5%	Comp	Fixed	13070
R103	62 kΩ	½ W	5%	Comp	Fixed	13430

Schematic Ref.	Value	Spec.		Type		Bell Part No.
R104	43 kΩ	½ W	5%	Comp	Fixed	13390
R105	10 kΩ	½ W	5%	Comp	Fixed	13240
R106	100Ω	¼ W	1%	Film	Fixed	15790
R107	36 kΩ	¼ W	1%	Film	Fixed	16550
R108	10 kΩ	½ W	5%	Comp	Fixed	13240
R109	2.4 kΩ	½ W	5%	Comp	Fixed	13090
R110	10 kΩ	½ W	5%	Comp	Fixed	13240
R111	13 kΩ	½ W	5%	Comp	Fixed	
R112	13 KΩ	½ W	5%	Comp	Fixed	
R115	330 Ω	½ W	5%	Comp	Fixed	12880
R116	10 kΩ	½ W	5%	Comp	Fixed	13240
R117	2 kΩ	½ W	5%	Comp	Fixed	13070
R118	62 kΩ	½ W	5%	Comp	Fixed	13430
R119	43 kΩ	½ W	5%	Comp	Fixed	13390
R120	10 kΩ	½ W	5%	Comp	Fixed	13240
R121	100 Ω	¼ W	1%	Film	Fixed	15790
R122	36 kΩ	¼ W	1%	Film	Fixed	16550
R123	10 kΩ	½ W	5%	Comp	Fixed	13240
R124	2.4 kΩ	½ W	5%	Comp	Fixed	13090
R125	47 kΩ	½ W	5%	Comp	Fixed	13400
R126	13 kΩ	½ W	5%	Comp	Fixed	
R127	13 kΩ	½ W	5%	Comp	Fixed	
R128	43 kΩ	½ W	5%	Comp	Fixed	13390
R129	43 kΩ	½ W	5%	Comp	Fixed	13390
R130	160 Ω	½ W	5%	Comp	Fixed	12810
R131	10 kΩ	½ W	5%	Comp	Fixed	13240
R132	2 kΩ	½ W	5%	Comp	Fixed	13070
R133	62 kΩ	½ W	5%	Comp	Fixed	13430
R134	43 kΩ	½ W	5%	Comp	Fixed	13390
R135	10 kΩ	½ W	5%	Comp	Fixed	13240
R136	100Ω	¼ W	1%	Film	Fixed	15790
R137	36 kΩ	¼ W	1%	Film	Fixed	16550
R138	10 kΩ	½ W	5%	Comp	Fixed	13240
R139	2.4 kΩ	½ W	5%	Comp	Fixed	13090
R140	47 kΩ	½ W	5%	Comp	Fixed	13400
R141	13 kΩ	½ W	5%	Comp	Fixed	
R142	13 kΩ	½ W	5%	Comp	Fixed	
R143	43 kΩ	½ W	5%	Comp	Fixed	13390
R144	43 kΩ	½ W	5%	Comp	Fixed	13390
R145	160 Ω	½ W	5%	Comp	Fixed	12810
R146	10 kΩ	½ W	5%	Comp	Fixed	13240
R147	20 kΩ	½ W	5%	Comp	Fixed	13310
R148	10 kΩ	½ W	5%	Comp	Fixed	13240
R149	51Ω	½ W	5%	Comp	Fixed	12700
R150	7.5 kΩ	½ W	5%	Comp	Fixed	13210
R151	15Ω			WW	Var	22100
R152	234Ω	¼ W	¼%	Film	Fixed	15220
R153	234Ω	¼ W	¼%	Film	Fixed	15220
R154	7.5 kΩ	½ W	5%	Comp	Fixed	13210
R155	7.5 kΩ	½ W	5%	Comp	Fixed	13210
R156	10 kΩ	½ W	5%	Comp	Fixed	13240
R157	10 kΩ	½ W	5%	Comp	Fixed	13240
R158	2 kΩ	½ W	5%	Comp	Fixed	13070
R159	62 kΩ	½ W	5%	Comp	Fixed	13430
R160	47 kΩ	½ W	5%	Comp	Fixed	13400
R161	12 kΩ	½ W	5%	Comp	Fixed	13260
R162	10 kΩ	½ W	5%	Comp	Fixed	13240
R163	1.8 kΩ	½ W	5%	Comp	Fixed	13060
R164	9 kΩ	¼ W	1%	Film	Fixed	16330
R165	2 kΩ			WW	Var	22150

Schematic Ref.	Value	Spec.		Type		Bell Part No.
R166	30 kΩ	½ W	5%	Comp	Fixed	13550
C101	10μF		6 V	EM	Fixed	22930
C102	10μF		6 V	EM	Fixed	22930
C103	270pF		1 kV	Cer	Fixed	25470
C104	470pF		1 kV	Cer	Fixed	25500
C105	1μF		100 V	MME	Fixed	24930
C106	10μF		6 V	EM	Fixed	22930
C107	10μF		6 V	EM	Fixed	22930
C108	0.1μF		200 V	MME	Fixed	24550
C109	0.1μF		200 V	MME	Fixed	24550
C110	0.033μF		200 V	MME	Fixed	24520
C111	0.033μF		200 V	MME	Fixed	24520
C112	100μF		12 V	EM	Fixed	23160
C113	10μF		6 V	EM	Fixed	22930
C114	10μF		6 V	EM	Fixed	22930
C115	270μF		1 kV	Cer	Fixed	25470
C116	470μF		1 kV	Cer	Fixed	25560
C117	1μF		100 V	MME	Fixed	24930
C118	10μF		6 V	EM	Fixed	22930
C119	10μF		6 V	EM	Fixed	22930
C120	0.1μF		200 V	MME	Fixed	24550
C121	0.1μF		200 V	MME	Fixed	24550
C122	0.033μF		200 V	MME	Fixed	24520
C123	0.033μF		200 V	MME	Fixed	24520
C124	100μF		12 V	EM	Fixed	23160
C125	10μF		6 V	EM	Fixed	22980
C126	10μF		6 V	EM	Fixed	22930
C127	270 pF		1 kV	Cer	Fixed	25250
C128	180 pF		1 kV	Cer	Fixed	
C129	1μF		100 V	MME	Fixed	24930
C130	10μF		6 V	EM	Fixed	22930
C131	0.1μF		200 V	MME	Fixed	24550
C132	0.1μF		200 V	MME	Fixed	24550
C133	0.033μF		20o V	MME	Fixed	24520
C134	0.033μF		200 V	MME	Fixed	24520
C135	100μF		12 V	EM	Fixed	23160
C136	10μF		6 V	EM	Fixed	22930
C137	10μF		6 V	EM	Fixed	22930
C138	100μF		6 V	EM	Fixed	22980
C139	100μF		6 V	EM	Fixed	22980
C140	220 pF		1 kV	Cer	Fixed	25440
C141	0.01μF		200 V	MME	Fixed	24490
C142	10μF		6 V	EM	Fixed	22930
C143	100μF		3 V	EM	Fixed	22800
C144	100μF		6 V	EM	Fixed	22980
C145	10μF		6 V	EM	Fixed	22930

Transistors and Diodes

CR101	1N270	27990
CR102	1N270	27990
CR103	1N270	27990
CR104	1N270	27990
CR105	1N461	28010
CR106	1N461	28010
CR107	1N461	28010
CR108	1N461	28010
Q101	2N4384	29120
Q102	2N3905	29040
Q103	2N3710	29000
Q104	2N4302	29100

Schematic Ref.	Value	Spec.	Type	Bell Part No.
Q105		2N4302		29100
Q106		2N3707		28990
Q107		2N3905		29040
Q108		2N3710		29000
Q109		2N3905		29040
Q110		2N3905		29040
Q111		2N3707		29990
Q112		2N3905		29040
Q113		2N3710		29000
Q114		2N3905		29040
Q115		2N3905		29040
Q116		2N3903		29030
Q117		2N3905		29040
Q118		2N3905		29040
Q119		2N3905		29040
Q120		2N3707		28990
Q121		2N3905		29040
Q122		2N3903		29030

Transformer

T101	Output Transformer	26250

The following parts are on the power supply—current oscillator circuit board assembly YP-01-004

R201	3.9 kΩ	½ W	5%	Comp	Fixed	13140
R202	5.1 kΩ	½ W	5%	Comp	Fixed	13170
R203	3.9 kΩ	½ W	5%	Comp	Fixed	13140
R204	1 kΩ	½ W	5%	Comp	Fixed	13000
R205	1 kΩ	½ W	5%	Comp	Fixed	13000
R206	2 kΩ	½ W	5%	Comp	Fixed	13070
R207	12 kΩ	½ W	5%	Comp	Fixed	13260
R208	15Ω	½ W	5%	comp	Fixed	12590
R209	12 kΩ	½ W	5%	Comp	Fixed	13260
R210	2 kΩ	½ W	5%	Comp	Fixed	13070
R211	2 kΩ			WW	Var	22150
R212	560Ω	½ W	5%	Comp	Fixed	12940
R213	3 kΩ	½ W	5%	Comp	Fixed	13110
R214	4.3 kΩ	½ W	4%	Comp	Fixed	13150
R215	5.1 kΩ	½ W	5%	Comp	Fixed	13170
R216	1.8 kΩ	½ W	5%	Comp	Fixed	13060
R217	2 kΩ	½ W	5%	Comp	Fixed	13070
R218	7.5 kΩ	¼ W	1%	Film	Fixed	16300
R219	2.7Ω	2 W	5%	WW	Fixed	19830
R221	1 kΩ	½ W	5%	Comp	Fixed	13000
R222	68 kΩ	½ W	5%	Comp	Fixed	13440
R223	510Ω	½ W	5%	Comp	Fixed	
R224	2.5 kΩ			WW	Var	22160
R225	110Ω	½ W	5%	Comp	Fixed	12780
R226	16 kΩ	¼ W	1%	Film	Fixed	
R227	20 kΩ	½ W	5%	Comp	Fixed	13310
R228	560Ω	½ W	5%	Comp	fixed	12940
C201	10μF		6 V	EM	Fixed	22930
C202	0.0015μF		200 V	MME	Fixed	24410
C203	0.0015μF		200 V	MME	Fixed	24410
C204	0.01μF		200 V	MME	Fixed	24490
C205	0.01μF		200 V	MME	Fixed	24490
C206	0.01μF		200 V	MME	Fixed	24490
C207	1μF		6 V	EM	Fixed	22910
C208	200μF		12 V	EM	Fixed	23170

Schematic Ref.	Value	Spec.	Type		Bell Part Number
C209	0.022μF	200 V	MME	Fixed	24510
C210	100μF	6 V	EM	Fixed	22980

Transistors and Diodes

CR201	1N713	
CR202	1N713	
CR203	1N461	28010
CR204	1N461	28010
CR205	1N461	28010
CR206	1N708	
CR207	1N461	28010
CR208	1N461	28010
CR209	1N461	28010
CR210	1N704	
Q201	2N3905	29040
Q202	2N3905	29040
Q203	2N3403	28940
Q204	2N3403	28940
Q205	2N3905	29040
Q206	2N3903	29030
Q207	2N3905	29040
Q208	2N3903	29030

Transformers

T201	Current Sensing Transformer	26240
T202	Current Output Tansformer	26300

WARRANTY

F.W. BELL, INC. warrants each instrument of its manufacture to be free from defects in material and workmanship. Our oblication under this warranty is limited to servicing or adjusting any instrument returned to our factory for that purpose, and to replacing any defective parts thereof (excluding electron tubes, batteries, transistors and probe sensing elements, which parts are covered by a standard EIA 90-day warranty). This warranty covers instruments which, within one year after delivery to the original purchaser, shall be returned with transportation charges prepaid by the original purchaser, and which upon examination shall disclose to our satisfaction to be defective. If it is determined that the defect has been caused by misuse or abnormal conditons of operation, repairs will be billed at cost after submitting an estimate to the purchaser.

F.W. BELL, INC. reserves the right to make changes in design at any time without incurring any obligation to install same on units previously purchased.

This warranty is expressly in lieu of all other obligations or libialities on the part of F.W. BELL, INC., and F.W. BELL, INC. neither assumes nor authorizes any other person to assume for them any other liability in connection with the sales of F.W. BELL, INC. instruments.

DAMAGE IN SHIPMENT

The instrument should be examined and tested as soon as it is received. If it does not operate properly, or is damaged in any way, immediately file a claim with the carrier. The claim agent will provide report forms. A copy of the completed form should be forwarded to us. We will then make the necessary arrangements for repair or replacement. All correspondence concerning this instrument should include model and serial numbers.

SHIPPING INSTRUCTIONS

Always use the original shipping carton and inserts, if possible, or pack the instrument in a sturdy container and surround the entire instrument with two or three inches of shock-absorbing material.

F.W. BELL

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