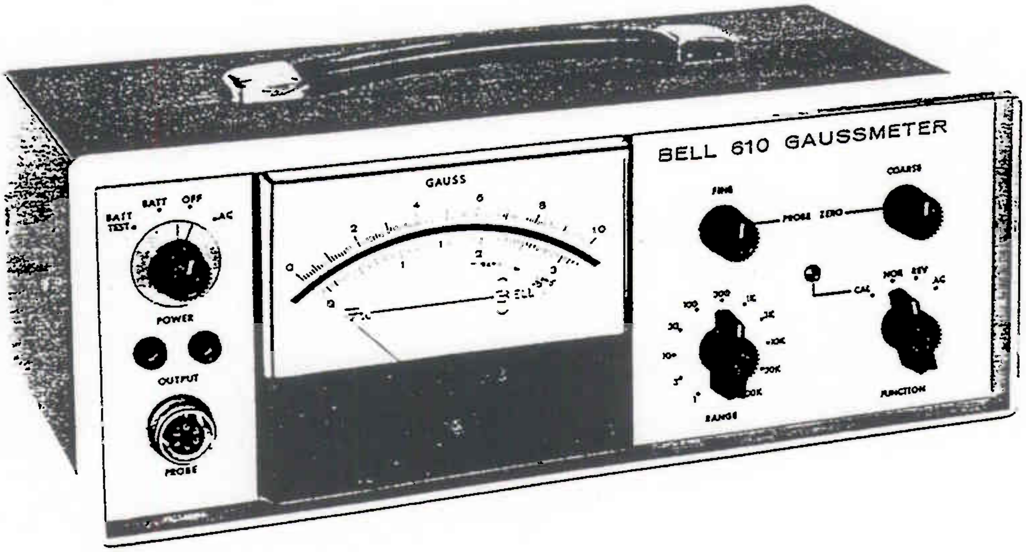
MODEL 610
GAUSSMETER



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SECTION I
General Description

I-1 GENERAL

The Model 610 Gaussmeter is a precision magnetic flux measuring instrument, featuring high stability, 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, is available. All probes are directly interchangeable using a simplified self-calibration technique. 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 which is derived from accepted values of natural physical constants. 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 10 mG (milligaus) per scale division (1 G full scale) to 100 kG (kilogauss) full scale. Both dc and ac fields can be measured directly using the 5½ 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 100 milivolts full scale and is proportional to the field for dc and ac fields up to 400 Hz. 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 overall accuracy.

Because of optional battery operation, the Model 610 is ideal for applications requiring portability, as well as fixed installations. An inexpensive sealed, high energy dry battery is used (included with instrument on special order).

Simplicity of operation, wide measurement range and high accuracy make the Model 610 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 1 gauss full scale to 100,000 gauss full scale in 10 dB steps as follows.

IX probes 1, 3, 10, 30, 100,
300, 1 kG, 3 kG, 10 kG, 30, kG, 100 kG
10X probes 10, 30, 100, 300, 1 kG,
3 kG, 10 kG, 30 kG, 100 kG, 300 kG

[b] Calibration:
1. Internal calibrating procedure is referenced to a standard NMR which is derived from accepted values of natural physical constants.
2. Internal calibration error does not exceed ±0.5%.

[c] Available Standard Probe Types:
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 the accuracies of the instrument, the probe, and the calibration source. The instrument accuracy is ±0.5% of full scale, and the internal calibration accuracy is ±0.5% of reading. For example, assume a 610 Garussmeter used with a model STB1-0402 probe calibrated with the internal calibration output. The total accuracy is ±0.5% of full scale (instrument), plus ± 0.5% of reading (internal calibration), plus ±1% of reading (probe) for a total accuracy of ±0.5% of full scale plus ±1.5% of reading.

2. For Sinusoidal ac Fields (In AC Function):
0 to 60 Hz; ±5% of full scale
60 to 400 Hz; down 3% max, from 60 Hz response

3. Meter Scale Tracking Error:
±1% of full scale max.

4. Improved accuracy obtainable by using probe deviation curves* and, at specific tests points, by reference to a known calibration field.

*Available on special order.

[e] Stability:
1. Line voltage:
Error negligible for ±10% line voltage changes
2. Temperature effects excluding probe influences: Approx. ±3% of reading total over the range of—10° C to +60° C (can be removed by using internal calibration feature)
3. Probe temperature effects:
—0.04% of reading per degree C max.
—0.025% of reading per degree C typical (0° C to +75°C)
4. Probe temperature effects Zero Field Influence:
±100 milligauss per deg. C max. with standard probes.

[f] Output Jacks:

1. Output voltage:	100 millivolts dc FS
2. Source impedance:	10 KΩ approx.
3. ac field frequency response:	See response curve Fig.IV-3
4. Response time for full scale step input:	4 msec approx.
5. RMS Noise:	approx. 40 dB below full scale

[g] Power Requirements:
1. Line input:

Volts	105-125 V	or	210-250 V
Frequency	50-60 Hz		50-60 Hz
Current	0.022 A		0.011 A
Power	2.5 W		2.5 W

2. Internal battery:
12 V dry battery, NEDA 926—Everyready 732 or equivalent. Battery drain 75 mA. Battery life depends on duty cycle. Under normal use, 75 hours or more can be expected.

II-2 PHYSICAL SPECIFICATIONS, CONTROLS AND CONNECTORS

[a] Front Panel:

1. Power Switch:

This rotary switch turns on the primary power to the instrument. The red indicator in the knob window shows when the unit is operating either on line voltage or battery power. The drain on the internal battery is the same in either the Battery or Battery Test positions.

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 1 gauss to 100 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, and the calibration position for internal CAL.

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 dc fields up to approximately 30 gauss.

5. CAL 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 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 receptacle. 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 610 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.

[c] Internal Fuse:

The fuse holder accepts a standard 3 AG size fuse. The fuse should be rated at 1/16 A Slow Blow. It is not necessary to replace the fuse when converting to 234 V operation.

[d] Overall Dimensions:

5¾" high 14" wide 8½" deep

[e] Weight:

Shipping 14 lbs. Net 8 lbs. Add 3½ lbs. for optional battery.

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 strap near the power transformer on the bottom of the sub chassis. Set the battery on the sub chassis with its terminals facing the front of the unit and connect the battery cable with the red lug to the positive(+) battery terminal and black lug to the negative (—). Replace the removed strap, clamping the battery securely to the sub chassis. Replace the cover. The battery used is a 12 volt dry battery NEDA number 926—Eveready 732 or equivalent.

For portable operation, simply disconnect the power cord (for convenience in handling) and switch to BATT position.

[b] Power Requirements:

The Model 610 can be operated from either of two types of power: standard ac line voltage (117 V or 234 V, 50-60 Hz, 2.5 watts) or internal battery (dry battery 12 volt, NEDA 926—Eveready 732 or equivalent).

[c] Operation:

Before turning the instrument on, make certain the power to be used matches the voltage and frequency ratings of the gaussmeter.

When the POWER switch is set at BATT TEST position, the meter is connected to the battery input circuitry. The meter must indicate within the range marked BATT (upper 40% of meter scale) with a probe connected. If the indication is under the range, then the voltage is too low for proper operation.

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. With power off, 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 100 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 both controls to about mid setting. Rotate the RANGE switch counter clockwise until a reading is obtained on the meter. Adjust the COARSE control to bring the reading near zero while reducing the RANGE setting. On 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 made whenever probes are changed. Allow sufficient time for warm up stability before calibrating.

Calibration consists of adjusting the amplifier gain in accordance with the sensitivity of the probe and the element control current 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 ±0.5% and the probe linearity curve is avialable (supplied on special order). 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 are available, the internal calibration be used.

After the instrument and probe have warmed up (5 min.) set FUNCTION switch to CAL. The RANGE switch may be in any position. Adjust the CAL screwdriver adjustment to obtain a full-scale (1.0) meter reading (or a 100 millivolt dc reading on any external readout instrument connected to the output jacks). The gaussmeter and probe are then calibrated to the accuracy shown in the specifications under Section II-1d. This adjustment must be repeated if the probe is changed. The calibration may be conveniently rechecked at any time by setting the FUNCTION switch to CAL.

[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 ±0.5% and the probe linearity data are 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 the flux density. Adjust the CAL 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).

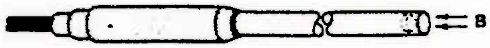
[d] **AC Field Calibration:**
No seperate ac field calibration is necessary. If the gaussmeter has been properly calibrated for dc fields, then the signal at the output jacks for ac fields will be calibrated with the exception of the effects of the frequency response. Figure IV-3 shows the effect of the frequency response on output jack voltage and panel meter reading.

SECTION IV
Operating Instructions

IV-1 THE PROBE

[a] **General:**
The standard probes are divided into two basic categories depending on field direction response; transverse and axial. Figure IV-1 shows the shape and size of various probes. In addition, special probes can be designed to meet unusual requirements. Contact F.W. Bell, Inc. for information and quotations.
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 probes are used for measurement higher than their specified range, increased deviation from linear response will result. Such measurements would not be accurate as obsolute readings, but might be useful where only a relative indication is sufficient.

AXIAL PROBE:



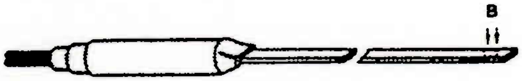
REQUIREMENTS	SUGGESTED PROBE CONFIGURATION
general use; durable	HEAVY DUTY
measure flux density in awkward places	FLEXIBLE
measure flux density in a small gap	STANDARD DUTY (laboratory use)
measure homogeneous fields* from 0.001 G to 2 G; high sensitivity	MAGNAPROBE
high linearity; low temperature coefficient; 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

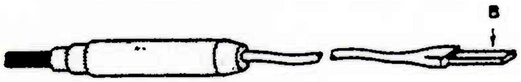
** 10X probe sensitivity is one-tenth standard probe (1X) sensitivity

AXIAL FLEXIBLE:

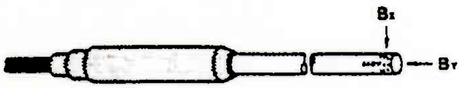
TRANSVERSE PROBE:



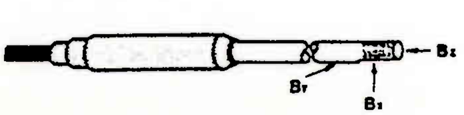
TRANSVERSE FLEXIBLE:



TWO-AXIS PROBE:



THREE-AXIS PROBE:



[b] Probe Handling Precautions:
Reasonable care should be exercised in handling the probe. Avoid excessive shock, pressure, bending or otherwise straining the element mount. The element can be fractured if the mounting is over-stressed since it is brittle as well as rigid. Since the active area is a good heat conductor, it should be protected and prevented from touching very hot or cold objects.
The Hall probes will withstand normal handling without damage. However, it is not indestructible. The following instructions should be followed to insure against breakage.

1. Always select the most durable probe that can be used for the application, to increase the probe service life.

2. Avoid sharp bends in probes in flexible mountings.

3. Do not allow compression or impact forces to strike the Hall element. Rigid mountings are brittle and can be fractured by excessive pressure, shock, or impact forces. A fractured Hall element cannot be repaired—it must be replaced.

4. Do not expose the probe or element to temperatures in excess of the 0° C to +75°C range unless the probe or Hall element was designed for other temperatures.

[c] Transverse Probes:
A transverse probe, as its name implies, has its flux response direction transverse to the probe handle axis. The element is encapsulated on the end of a flexible strip to lessen the chance of breakage due to stressing by the handle.

In figure IV-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 () where B is the field magnitude and () is the angle of the field to the perpendicular.

[d] Axial Probes:
The axial probe has its flux response direction along the axis of 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 only the transverse component will produce the 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.
Errors in readings 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 from F.W. Bell, Inc., 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 demagnetized 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 unkown 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, particularly 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 shown in Figure IV-1. 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 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 measurement, the dc field should first be zeroed out to prevent gaussmeter overload and erroneous readings. Two methods of ac measurement are possible with Model 610.

(a) If a direct reading on the panel meter is desired, the FUNCTION switch must be placed in the AC position. The RANGE switch should be switched to the range giving the highest on-scale meter reading. Probe should be aligned for maximum reading or desired direction component as described in the section on measuring dc field. The meter will indicate ac fields from approximately 10 Hz to 2 kHz. A dc voltage proportional to meter reading (100 mV full scale) will appear at the output jacks and may be used with external dc readout equipment. An ac component will also appear at the output jacks. This ac signal will not generally be useful since its amplitude will be subject to the effects of the output filter and the waveform will appear in full-wave rectified form rather than the waveform of the actual flux field. The gaussmeter panel meter and output jack dc voltage are calibrated to read the rms value for sine wave flux. For non-sinusoidal waveforms, the average value can be obtained by multiplying the meter reading by 0.9. See Figure IV-3 for frequency response.

(b) If it is desired to use external ac readout equipment, the FUNCTION switch may be placed in the NOR position. In this operating mode, the voltage at the output jacks will follow the instantaneous polarity and amplitude of the ac field. The gaussmeter panel meter will not provide useful reading. The ac waveform at the output jacks will represent the flux waveform within the limitations of the output frequency response (see Figure IV-3 for output filter frequencey response curve). At higher frequencies where the output is attenuated, do not attempt to switch to a lower range to increase output as this will cause gaussmeter overload and erroneous readings. The correct range is that which gives the highest on-scale reading on the gaussmeter panel meter when the FUNCTION switch is momentarily turned to the AC position, and then retruned to the NOR position.

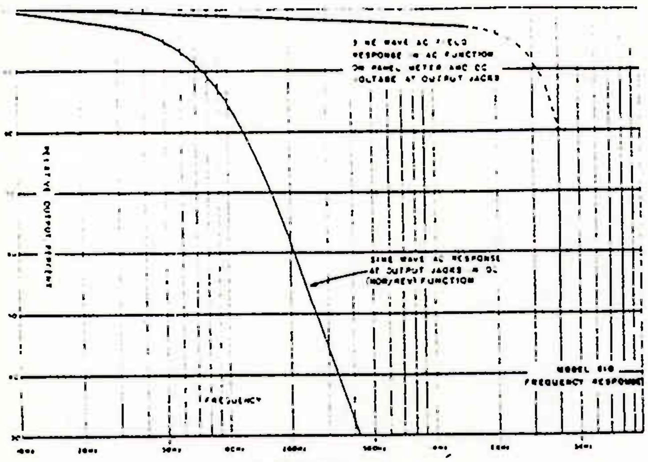


FIGURE IV-3

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 connecting an oscilloscope or ac voltmeter to the output jacks. If an ac reading exceeding 30 mV 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 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 possibility 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 about 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. In the AC FUNCTION, any dc field not properly zeroed out will cause an erroneously high output indication.

[e] Temperature Effects:

All Hall probes exhibit a certain temperature coefficient. 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.

To correct for temperature influence, the following formula can be used:

$$B = B(1-(tpm-tpc)\ tc\ 100)$$

where: B = the actual value of the field being measured (unknown).
B = the value of the field as indicated by the gaussmeter.
= temperature of probe at time of field measurement in degrees C.
= temperature of probe at time of calibration in degrees C (25° C when using internal CAL method).
= temperature coefficient of probe in % per degree C. Typical value is —0.025% per deg. C).

This formula will correct the gaussmeter reading (B_g) to give the actual field (B_a) for measurements under different temperature conditions. Notice that t_c is a negative number, and the monus 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 capability of the Model 610. 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 negative for below zero meter indications. The black jack is the common and is grounded to the gaussmeter case. The voltage available is 100 mV for full scale meter reading and directly proportional to the field at the probe. The source resistance is 10 kΩ. See frequency response Figure IV-3.

High resolution and accuracy can be achieved by connecting a digital voltmeter to the output jacks. Set the digital voltmeter to its 100 mV 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 (1, 10, 100, 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.

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 corrected 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 $\times 10^4$

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 through the area is found by multiplying by the area in question.

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

(Flux) LINES = GAUSS x SQ. INCHES x .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 effective 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 0.003 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 sizes 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

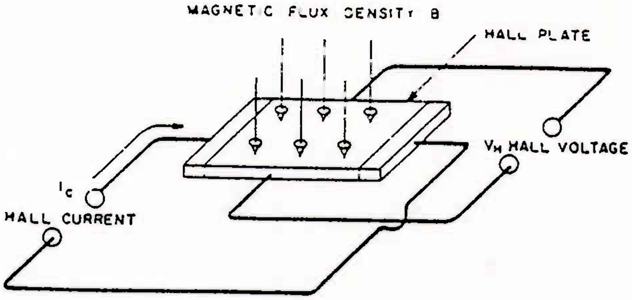
V-1 GENERAL

The basic principle of magnetic flux measurement used in the Model 610 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 and then restored to a flux proportional voltage by the synchronous demodulator without loss to polarity (field direction) information. The demodulator drive the panel meter and output jacks.

If the field is time-varying, the demodulated output will be instantaneously proportional to the flux waveform up to 400 Hz. In the AC function, the demodulator is made self-synchronous to provide a dc output which drives the panel meter and output jacks.

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 retangular wafer of high-purity indium arsenide with 4 leads attached. See Fig V-1.



THE HALL GENERATOR

FIGURE V-1

The application of control current I_c 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 a cathode ray tube.

The resulting build-up 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 .

$$V_H = K_H(\overline{B} \times \overline{I_c})$$

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 for 1X probes.

V-3 CIRCUIT OPERATION

[a] Introduction:

This section describes the overall gaussmeter circuit operation. Check the block diagram and the complete schematic for circuitry detail. Although the circuit design is relatively straightforward, it is recommended that an understanding of the circuit operation be acquired before attempting to service or adjust the instrument.

[b] General Operation Description:

The Hall generator is supplied with an exciting current, I_c from the 5 kHz oscillator and current-regulated amplifier. The Hall output voltage, V_H (the flux modulated carrier signal), is connected to the gaussmeter input summing circuit. At this point, the zeroing voltage from the zero controls is subtracted from the Hall generator output. The difference is amplified depending on the range in use to produce the proper output. The amplifier output feeds the synchronous demodulator which converts the amplified flux-modulated carrier into a flux-proportional output voltage. The output voltage then feeds the output jacks and meter for dc fields. AC fields may be measured by connecting external ac readout equipment to the output jacks. Direct readout of ac fields on the gaussmeter panel meter may be obtained by switching to the AC FUNCTION switch position. In this position, a dc voltage will appear at the output jacks which is proportional to the ac field being measured.

[c] Detailed Operating Description:

1. General:

The circuit is made up of six basic functional sections: the probe, the input section, the amplifier section, the detector and meter, the current-regulated I_c supply, and the power supply. The block diagram shows essential operating functions; however, various circuit details have been eliminated or altered for clarity. Check the complete schematic for all circuit details.

2. The Probe:

The excitation current is supplied to the Hall generator 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 gaussmeter internal calibration voltage to match the sensitivity of the particular Hall generator contained in the probe.

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 resistors R6 and R7 inserted between the halves and a ground to provide points for injecting the zeroing voltage.

The zero injection voltage is obtained by sampling the element control current. The zero controls adjust and attenuate the voltage obtained from the current-sensing resistor R135. Because the Hall sensor zero and residual field output is proportional to control 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 input transformer primary across R12 to obtain a reference voltage for adjusting amplifier gain. The zero controls are disconnected in the CAL position. Since the output voltage of both the Hall generator and the calibrating resistor are proportional to the excitation current, I_c the effects of changes in I_c are removed in the calibration procedure. The reference voltage is adjusted by the CAL control to produce a full scale indication (1.0 on the meter and 100 mV dc at the output jacks). The internal calibration is dependent only on the accuracy of resistors R11 and R12 and the initial factory calibration which determines the probe calibrating resistor.

4. Amplifier Section:
The signal appearing on the input transformer secondary is applied to the first range switch attenuator section. Each step on this section produces an additional 10 times attenuation of the signal applied to the preamplifier. The preamplifier is a two-stage plus emitter follower direct coupled circuit with ac and dc feedback for stabilization. Voltage gain at the 5 kHz carrier frequency is approximately 70.
The preamplifier output is attenuated by the CAL control and fed to the second section of the range switch attenuator. Each step on this section produces 10dB ($\sqrt{10}$ times) attenuation. R17 and R18 on the 1 G range and R18 on the 3 G range are added to the attenuator shunt leg to compensate for amplifier loading.
The second amplifier section contains two direct coupled stages plus a complementary emitter follower to drive the detector circuit. The amplifier voltage gain at 5 kHz is approximately 300.

5. Detector and Meter:
The synchronizing signal which is taken either from the 5 kHz oscillator or the second amplifier output (depending on FUNCTION switch position) is shaped into a square wave which is used for switching the demodulator transistor Q114.
Q114 acts as a shunt switch, permitting the amplified flux-modulated carrier signal to be applied to the meter and output filter network only during the half cycle that Q114 is cut off by the synchronizing signal.

6. Regulated Oscillator-Current Amplifier:
The Hall generator exciting current (I_c) is supplied from an amplitude-regulated 5 kHz Wein bridge oscillator driving a current-regulated amplifier. Q106 and Q105 form the oscillator with regulator transistor Q104 controlling the current through CR105 and CR106 and thus the bridge feedback impedance. The reference for Q104 is derived from a zener diode by Q103. The current-regulated amplifier employs negative current feedback to supply a constant exciting current to the Hall generator essentially independent of circuit impedance.

6. 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, and input filter capacitor or from the optional internal battery. Q102 is referenced to zener diode CR103 and maintains a constant 7 V output by controlling the voltage drop across Q101.

SECTION VI
Maintenance

VI-1 INTRODUCTION

This section contains the necessary instructions and diagrams for maintaining the Model 610 Gaussmeter. In addition to the schematic diagram, a block diagram is provided to aid in troubleshooting. Also included is a circuit board layout.

Repair and adjustment of the instrument should be attempted in the field only where adequate test equipment and qualified personnel are available. Refer to the warranty section 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 610 Gaussmeter:
(a) A high impedance dc voltmeter having 2% or better accuracy.
(b) A high impedance ac voltmeter such as Hewlett-Packard 400H having 2% or better accuracy.
(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 only necessary to remove the four screws on the rear of the unit and slide the cover off.

VI-4 PERFORMANCE TESTS

This list describes a series of rapid overall tests for proper operation. If difficulty is encountered, proceed to paragraph VI-6 and, if necessary, VI-5.

[a] Preliminary:
1. Make sure power cord is properly connected and fully seated in the receptacle on instrument
2. Check fuse for burnout. Correct fuse is 1/16 A 3AG Slow Blow.
3. Inspect the probe for damaged element or cable, or poor plug contacts.
4. Check meter machanical zeroing.
5. Set controls as follows:
   RANGE switch to 100 K
   FUNCTION switch to CAL
   ZERO controls approximately mid-setting
6. Plug probe securely into front panel socket.

[b] Line Current Check:
1. Connect to rated power source. Turn power switch to AC. Line current after warmup should be: at 117 V line, 0.022 A nominal
   at 234 V line, 0.011 A nominal

[c] Calibration Check:
1. With the instrument operating, the front panel CAL control should be capable of adjusting the meter to read full scale.
2. Voltage at output jacks should be 100 millivolts 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 1 G range.
2. Set the RANGE switch to the 100 gauss 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 1 G range with the FUNCTION switch at NOR.
2. Switch to the 100 K range and measure the dc voltage at the output jacks. It should be less than 0.3 mV dc.

[f] Noise Check:
1. With the zero gauss chamber in place and a good zero on the 1 G range, switch the FUNCTION switch to AC.
2. The residual meter reading should be less than 15% of full scale on the 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 610 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 R106 on the circuit board to obtain +7 V dc across C104.

[c] Oscillator Feedback Adjustment:
Adjust R113 to obtain 170 mV dc across CR106.

[d] Control Current [I_c] Adjustment:
Adjust R110 to obtain 100 mV ac across R11.

[e] Detector Zero Adjustment:
Place the probe in the zero gauss chamber and zero the gaussmeter down to the 1 gauss range. Switch to the 100 K range and adjust R143 to obtain zero dc voltage at the output jacks. Use the highest sensitivity voltage at the output jacks. Use the highest sensitivity voltmeter range.

[f] Output Calibration:
Make certain the meter mechanical zero is correct. Turn the FUNCTION switch to CAL. Adjust the CAL control to obtain exactly full scale reading on the upper meter scale (1.0). Adjust R150 to obtain exactly 100 mV dc at the output jacks. The more accurate the dc VTVM used, the more accurate the setting of 100 mV output for full scale.

[g] Quadrature Adjustments:
An excessive residual reading with the FUNCTION switch in AC could indicate a large quadrature signal. To check, set the RANGE switch to 1 G and FUNCTION switch to REV. Place probe in zero gauss chamber and carefully adjust the COARSE and FINE zero controls to obtain zero meter reading on the panel meter. Connect the oscilloscope between the output of the second amplifier and chassis. The amplifier output is a coaxial wire with yellow color tape on the circuit board. Residual signal should be below 150 mV with the CAL control set to max clockwise. If it is higher than than this, it means that:

1. The probe quadrature adjustment (in probe connector) has been disturbed, or
2. The probe cables have been overstressed or cable wires shifted at probe or connector end due to loosening of the strain relief, or
3. The probe input socket J1 wiring adjustment has been altered or has loosened due to hard usage.

The quadrature (90° phase shifted) signals generated in the gaussmeter input are the result of mutual inductive coupling between the probe control current pair and the Hall output pair. These pairs are tightly twisted except at interconnecting tie points and where wires are positioned and cemented to minimize quadrature. These lead placement adjustments are made at the imput socket J1 rear and inside the probe connector. Before attempting quadrature adjustment, make certain that the signal cannot be further reduced with the zero controls. Socket J1 adjustment should be changed only if a probe is used that is known to be good and correctly adjusted. Perhaps the most likely point to change would be in the probe due to handling. If several probes are used, all should be checked to insure interchangeability. Extremely small changes in the position of one of the current leads with respect to one of the Hall leads will make a noticeable change in quadrature output. Loosen the cable plug housing and carefully unscrew the housing. The approximately 1" long piece of solid wire (with tubing) may be shifted from its central position to adjust quadrature, then resealed with cement.

VI-6 TROUBLE SHOOTING

The following suggestions and procedures are recommended when difficulty is encountered in operating the instrument:

(a) The probe should be checked whenever erratic operation is obtained, particularly at low levels. A fractured probe element will produce unstable and erratic operation, and the zero adjustment on low ranges will become particularly unstable. Check the cable also for poor contact or wire breakage. Light finger pressure against the probe element should produce only small temporary effect.

(b Make the preliminary performance tests, most of which can be made without auxiliary test equipment. The source of trouble should be localized, in general, with these tests.

(c) Refer to the circuit diagrams and to the parts lists, by using schematic reference symbols, to obtain detailed information on parts used.

(d) It is important to replace parts with the same type and electrical value as originally used. Parts having F.W. Bell, Inc. part numbers are parts designed especially for the Model 610 and should be obtained directly from the factory.

(e) Use care in replacing diodes and transistors; do not apply excessive heat to the leads. A heat sink is recommended, such as gripping with pliers on the lead between the body of the component and the soldering iron.

(f) If necessary to return this instrument to the factory for repair, refer to WARRANTY section.

VI-7 PARTS LIST

Schematic Ref.	Value	Spec.		Type		Item Number
R1	10 Ω	½W	5%	Comp	Fixed	312570
R2	5 kΩ			HM	Var	321170
R3	270 kΩ	½W	5%	Comp	Fixed	313580
R4	5.6 kΩ	½W	5%	Comp	Fixed	313180
R5	250 Ω			HM	Var	321180
R6	5.1 Ω	2W	5%	WW	Fixed	319880
R7	5.1 Ω	2W	5%	WW	Fixed	319880
R8	105 Ω	¼W	1%	Film	Fixed	314466
R9	5.6 kΩ	½W	5%	Comp	Fixed	313180
R10	26.7 kΩ	¼W	1%	Film	Fixed	316520
R11	2 Ω	1/10W	1/10%	WW	Fixed	318360
R12	2 Ω	1/10 W	1/10%	WW	Fixed	318360
R13	45 kΩ	1/8 W	¼%	Film	Fixed	314730
R14	4.5 kΩ	1/8 W	¼%	Film	Fixed	314710
R15	450 Ω	1/8 W	¼%	Film	Fixed	314680
R16	50 Ω	1/8 W	¼%	Film	Fixed	314650
R17	56 Ω	½ W	5%	Comp	Fixed	312710
R18	6.2 Ω	½ W	5%	Comp	Fixed	312560
R19	6.838 kΩ	1/8 W	¼%	Film	Fixed	314720
R20	2.162 kΩ	1/8 W	¼%	Film	Fixed	314700
R21	683.8	1/8 W	¼%	Film	Fixed	314690
R22	216.2 Ω	1/8 W	¼%	Film	Fixed	314672
R23	100 Ω	1/8 W	¼%	Film	Fixed	314660
R24	20 kΩ			HM	Var	321190
R25	1 MΩ	½ W	5%	Comp	Fixed	313650
RX	FOP	½ W	5%	Comp	Fixed	
R101	47 kΩ	½W	5%	Comp	Fixed	313400
R102	1 kΩ	½ W	5%	Comp	Fixed	313000
R103	1 kΩ	½ W	5%	Comp	Fixed	313000
R104	2.7 Ω	½ W	5%	Comp	Fixed	312530
R105	8.2 kΩ	½ W	5%	Comp	Fixed	313220
R106	2 kΩ	½W	10%	Cerm	Var	322045
R107	3 kΩ	½ W	5%	Comp	Fixed	313110
R108	180 Ω	½ W	5%	Comp	Fixed	312820
R109	2 kΩ	½ W	5%	Comp	Fixed	313070
R110	2 kΩ	½W	10%	Cerm	Var	322045
R111	2.4 kΩ	½ W	5%	Comp	Fixed	313090
R112	62 kΩ	½ W	5%	Comp	Fixed	313430
R113	1 kΩ	½W	10%	WW	Cerm	322044
R114	1.6 kΩ	½ W	5%	Comp	Fixed	313050
R115	22 Ω	½ W	5%	Comp	Fixed	312610
R116	3.9 kΩ	½ W	5%	Comp	Fixed	313140
R117	150 kΩ	½ W	5%	Comp	Fixed	313520
R118	300 Ω	½ W	5%	Comp	Fixed	312870
R119	1.3 kΩ	½ W	5%	Comp	Fixed	313030
R120	240 Ω	½ W	5%	Comp	Fixed	312850
R121	8.2 kΩ	½ W	5%	Comp	Fixed	313220
R122	5.1 kΩ	½ W	5%	Comp	Fixed	313170
R123	10 kΩ	½ W	5%	Comp	Fixed	313240
R124	16 kΩ	½ W	5%	Comp	Fixed	313290
R125	27 kΩ	½ W	5%	Comp	Fixed	313340
R126	22 kΩ	½ W	5%	Comp	Fixed	313320
R127	62 kΩ	½ W	5%	Comp	Fixed	313430
R128	2.4 kΩ	½ W	5%	Comp	Fixed	313090
R129	120 Ω	½ W	5%	Comp	Fixed	312790
R130	5.1 kΩ	½ W	5%	Comp	Fixed	313170
R131	510 Ω	½ W	5%	Comp	Fixed	312930
R132	510 Ω	½ W	5%	Comp	Fixed	312930
R133	2.7 Ω	½ W	5%	Comp	Fixed	312530
R134	2.7 Ω	½ W	5%	Comp	Fixed	312530
R135	4.7 Ω	2 W	5%	WW	Fixed	319860
R136	820 Ω	½ W	5%	Comp	Fixed	312980
R137	1.8 kΩ	½ W	5%	Comp	Fixed	313060
R138	62 kΩ	½ W	5%	Comp	Fixed	313430
R139	3.9 kΩ	½ W	5%	Comp	Fixed	313140
R140	470 Ω	½ W	5%	Comp	Fixed	312920
R141	10 Ω	½ W	5%	Comp	Fixed	312570
R142	470 Ω	½ W	5%	Comp	Fixed	312920
R143	1 kΩ	½W	10%	Cerm	Var	322044
R144	470 Ω	½ W	5%	Comp	Fixed	312920
R145	1 Ω	2 W	5%	WW	Fixed	319800
R146	453 Ω	¼ W	1%	Film	Fixed	315910
R147	536 Ω	¼ W	1%	Film	Fixed	315940
R148	15 kΩ	½ W	5%	Comp	Fixed	313280
R149	15 kΩ	½ W	5%	Comp	Fixed	313280
R150	5 kΩ	½W	10%	Cerm	Var	322046
R151	13 kΩ	½ W	5%	Comp	Fixed	313270
R152	47 kΩ	½ W	5%	Comp	fixed	313400
R153	12 kΩ	½ W	5%	Comp	Fixed	313260
R154	301 Ω	¼ W	1%	Film	Fixed	315880
R155	62 kΩ	½ W	5%	Comp	Fixed	313430
R156	13 kΩ	½ W	5%	Comp	Fixed	313270
R157	20 kΩ	¼ W	1%	Film	Fixed	316490
R158	2 kΩ	½ W	5%	Comp	Fixed	313070
R159	5.1 kΩ	½ W	5%	Comp	Fixed	313170
R160	5.6 kΩ	½ W	5%	Comp	Fixed	313180
R161	1 kΩ	½ W	5%	Comp	Fixed	313000
R162	330 Ω	½ W	5%	Comp	Fixed	312880
R163	127 kΩ	¼ W	1%	Film	Fixed	316650
R164	47 kΩ	½ W	5%	Comp	Fixed	313400
R165	16 kΩ	½ W	5%	Comp	Fixed	313290
R166	174 Ω	¼ W	1%	Film	Fixed	315820
R167	12 kΩ	½ W	5%	Comp	Fixed	313260
R168	62 kΩ	½ W	5%	Comp	Fixed	313430
R169	54.9 kΩ	¼ W	1%	Film	Fixed	316590
R170	1.8 kΩ	½ W	5%	Comp	Fixed	313060
R171	5.1 kΩ	½ W	5%	Comp	Fixed	313170
R172	5.1 kΩ	½ W	5%	Comp	Fixed	313170
R173	22 Ω	½ W	5%	Comp	Fixed	312610
R174	22 Ω	½ W	5%	Comp	Fixed	312610
R175	120 Ω	½ W	5%	Comp	Fixed	312790
C1	1200 µF	15 V		EM		323240
C2	82 pF	1000 V	10%	Cer		325360
C101	10 µF	6 V		EM		322930

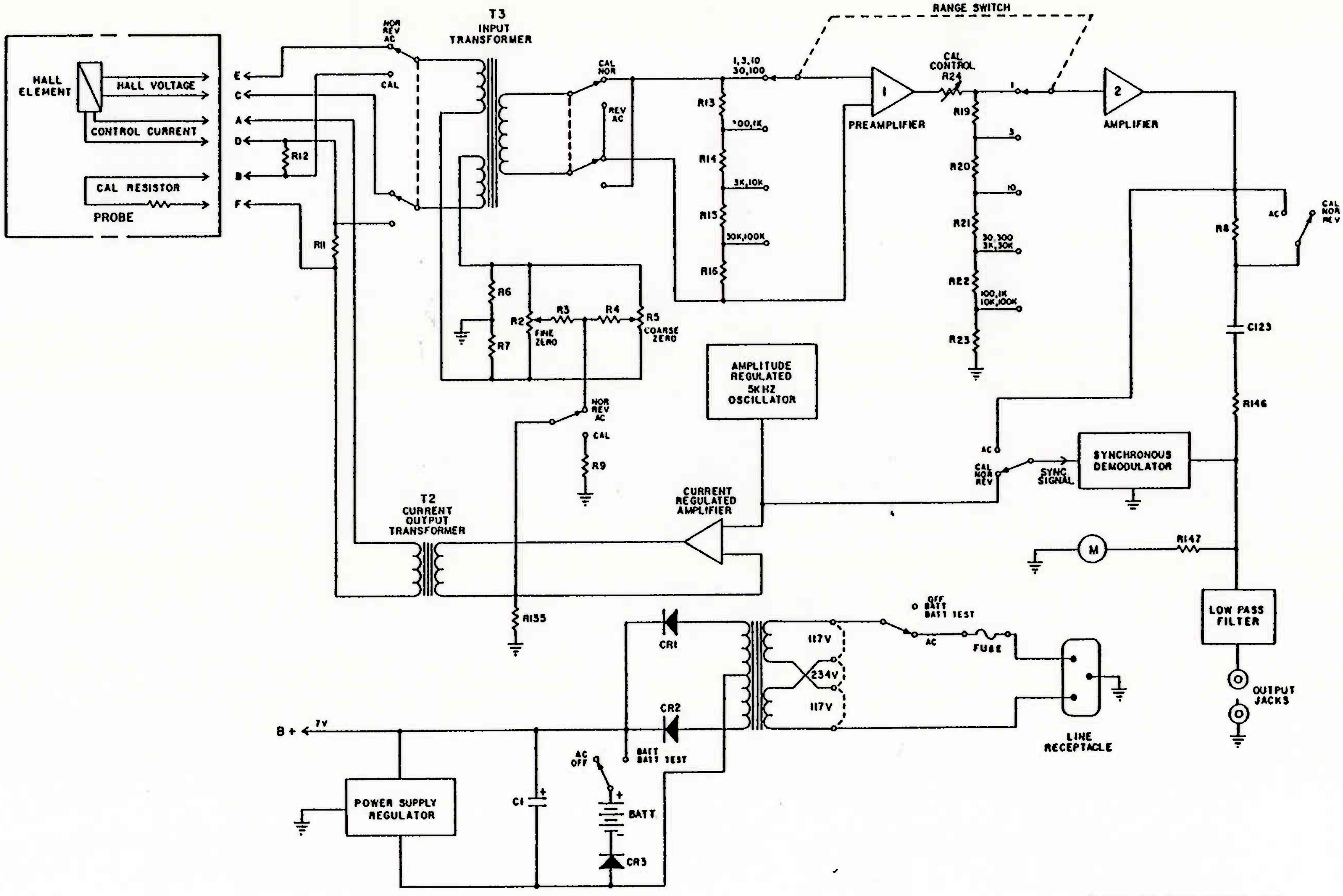
Schematic Ref.	Value	Spec.	Type	Item Number
C102	0.015µF	200 V 10%	MME	324500
C103	10µF	6 V	EM	322930
C104	1000µF	10 V	EM	323050
C105	100µF	12 V	EM	323160
C106	100µF	12 V	EM	323160
C107	10µF	6 V	EM	322930
C108	10µF	6 V	EM	322930
C109	10µF	6 V	EM	322930
C110	0.0033µF	200 V 10%	MME	324430
C111	0.0033µF	200 V 10%	MME	324430
C112	10µF	6 V	EM	322930
C113	0.015µF	200 V 10%	MME	324500
C114	100µF	12 V	EM	323160
C115	100µF	12 V	EM	323160
C116	100µF	12 V	EM	323160
C117	100µF	12 V	EM	323160
C118	0.001µF	1000 V 20%	Cer	325510
C119	10µF	6 V	EM	322930
C120	0.001µF	1000 V 20%	Cer	325510
C121	100µF	12 V	EM	323160
C122	100µF	12 V	EM	323160
C123	1µF	100 V 10%	PLY	324930
C124	0.047µF	200 V 10%	MME	324530
C125	0.047µF	200 V 10%	MME	324530
C126	10µF	6 V	EM	322930
C127	0.68µF	100 V 10%	PLY	324990
C128	270 pF	1000 V 20%	Cer	325470
C129	180 pF	1000 V 10%	Cer	325400
C130	10µF	6 V	EM	322930
C131	10µF	6 V	EM	322930
C132	10µF	6 V	EM	322930
C133	100µF	12 V	EM	323160
C134	10µF	6 V	EM	322930
C135	10µF	6 V	EM	322930
C136	1µF	100 V 10%	PLY	324930
C137	270 pF	1000 V 20%	Cer	325470
C138	10µF	6 V	EM	322930
C139	10µF	6 V	EM	322930
C140	100µF	12 V	EM	323160
T1		Power Transformer		326310
T2		Output Transformer		326330

Schematic Ref.	Spec.	Type	Item Number
T3	Input Transformer		326320
M1	Meter 0 500µA		310550
S1	Power Switch Ass'y	Sub Ass'y	201164
S2	Range Switch Ass'y	Sub Ass'y	201161
S3	Function Switch Ass'y	Sub Ass'y	201163
Q101	2N3403	Transistor	328940
Q102	2N508A	Transistor	328920
Q103	2N508A	Transistor	328920
Q104	2N4401	Transistor	329130
Q105	2N508A	Transistor	328920
Q106	2N3710	Transistor	329000
Q107	2N3710	Transistor	329000
Q108	2N508A	Transistor	328920
Q109	2N2706	Transistor	328930
Q110	2N2430	Transistor	328910
Q111	2N508A	Transistor	328920
Q112	2N1305	Transistor	328780
Q113	2N4917	Transistor	329150
Q114	2N1305	Transistor	328780
Q115	2N3707	Transistor	328990
Q116	2N4917	Transistor	329150
Q117	2N4401	Transistor	329130
Q118	2N3707	Transistor	328990
Q119	2N4917	Transistor	329150
Q120	2N2430	Transistor	328910
Q121	2N2706	Transistor	328930
CR1	1N3755	Diode	328130
CR2	1N3755	Diode	328130
CR3	1N3755	Diode	328130
CR101	1N270	Diode	327990
CR102	1N270	Diode	327990
CR103	1N5230A	Zener Diode	328440
CR104	1N270	Diode	327990
CR105	1N270	Diode	327990
CR106	1N270	Diode	327990
CR107	1N270	Diode	327990
CR108	1N270	Diode	327990
CR109	1N270	Diode	327990
CR110	1N270	Diode	327990
CR111	1N270	Diode	327990
CR112	1N270	Diode	327990

ABBREVIATIONS

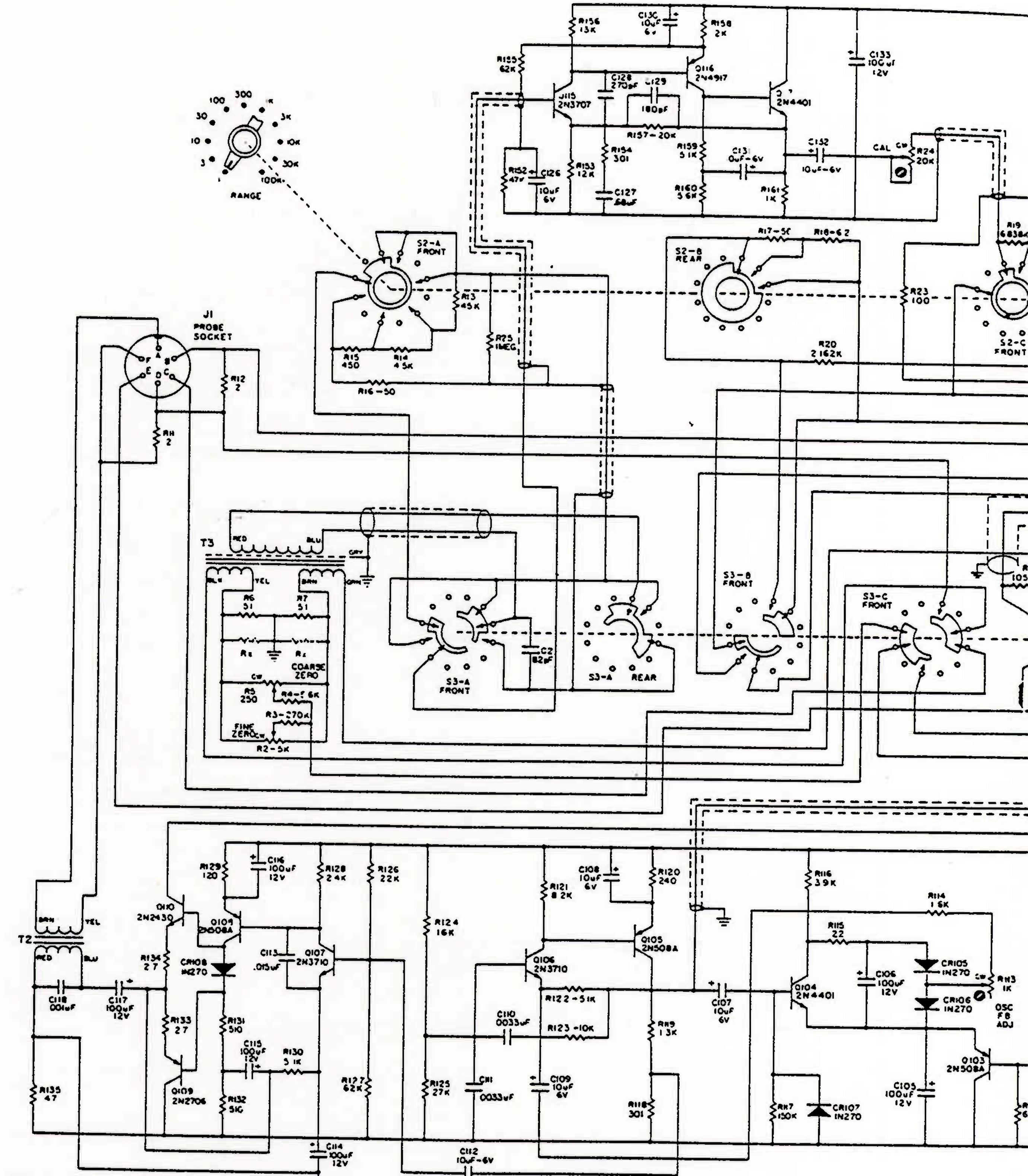
Cer	Ceramic
Cerm	Cermet
Comp	Composition
EM	Electrolytic miniature type
F	Faraf
Film	Metal film
FOP	Factory adjusted for optimum performance
HM	Hot molded
K	Kilo or 10^3
M	Meg or 10^6
µ	Micro or 10^{-6}
MME	Molded miniature epoxy
PLY	Polystyrene
Ω	ohm
p	Pico or 10^{-12}
V	Working volts
Var	Variable
W	Watt
WW	Wire wound

NOTE: Components with schematic reference numbers below 100 are located in the chassis wiring; numbers above 100 are located on the circuit board.

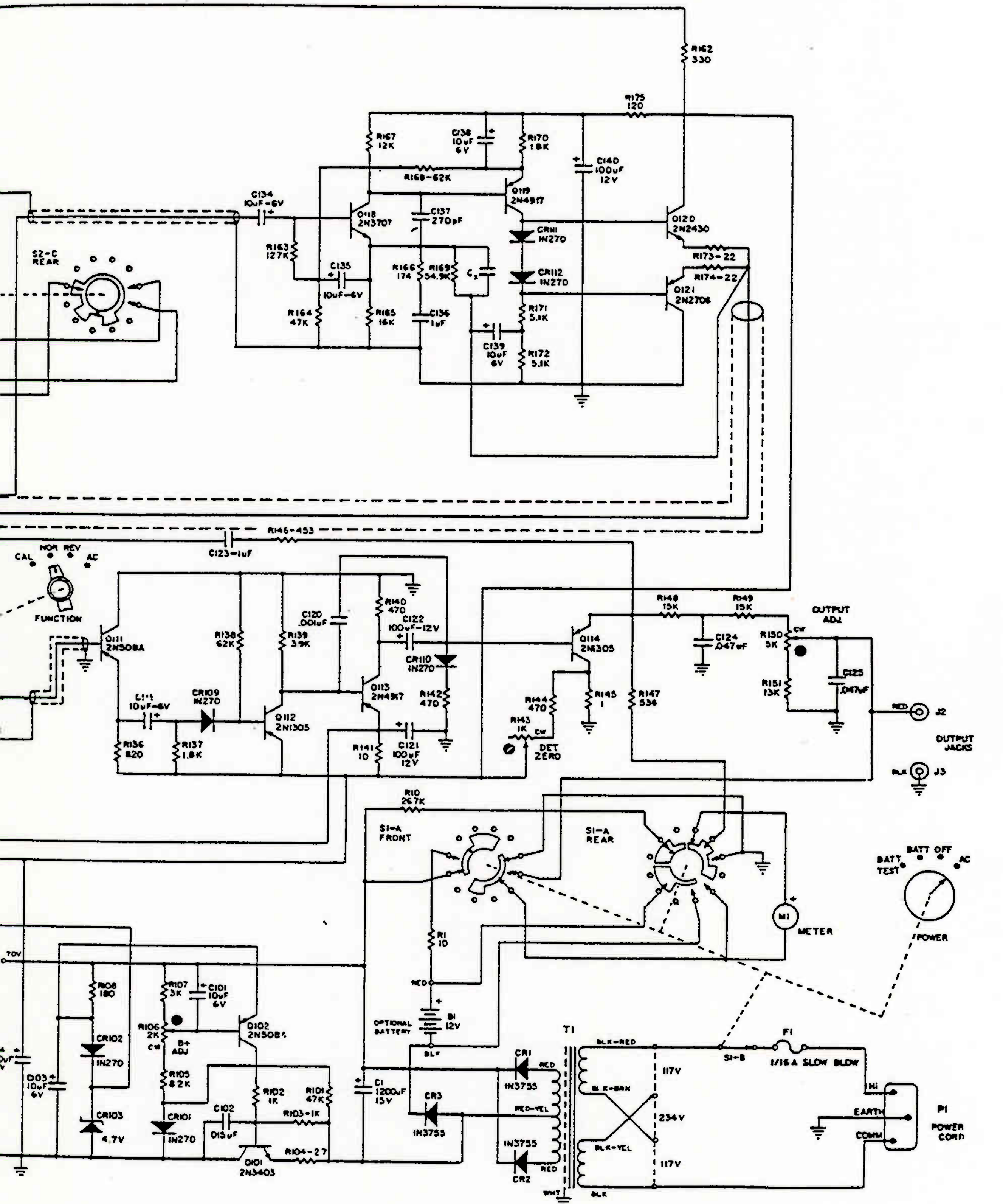


BLOCK DIAGRAM, MODEL 610
UC-2034

FIGURE VI-1



NOTES.
1 Cx SELECTED VALUE
2 Rx SELECTED VALUE CONNECTED IN PARALLEL WITH R6 OR R7
3 SEE PARTS LIST FOR COMPLETE COMPONENT SPECIFICATIONS



SCHEMATIC , MODEL 610

UD-2020