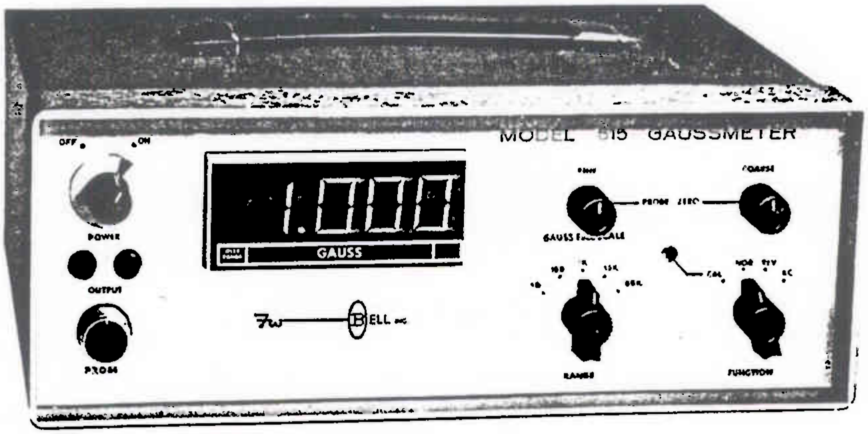
MODEL 615
GAUSSMETER
Operation and Maintenance Manual



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SIMPLIFIED OPERATING INSTRUCTIONS

1. Connect the 615 Gaussmeter to the appropriate power source. Connect the probe to the 615. Turn the instrument on and allow 30 minutes for warm-up.

2. To calibrate the 615 Gaussmeter using its internal calibration feature, set the FUNCTION switch to CAL. The RANGE switch may be in any position. Adjust the CAL screwdriver adjustment to obtain a full-scale (1.000) meter reading or a 100 mV dc reading on any external readout intrument connected to the output jacks.

3. The probe is zeroed using the COARSE and FINE adjustments on the instrument. Set both controls to about mid-setting. Rotate the RANGE switch counterclockwise 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 10 gauss range the FINE control may be used for better resolution of the zero adjustment. See Section IV-2b for details on the effects of the earth's magnetic field and other residual fields on the zero adjustment.

4. The 615 is now ready to measure magnetic fields. For complete details on any of the above procedures consult the appropriate section of the manual which follows.

CONTENTS

SECTION I
General Description

I-1 GENERAL

The Model 615 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 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 100 mG (milligauss) per digit (10 G range) to 1 MG (megagauss) full scale. Both dc and ac fields can be measured directly using the digital 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 mV full scale and is proportional to the field for dc and ac fields up to 2 kHz.

Simplicity of operation, wide measurement range and high accuracy make the Model 615 a versatile instrument for measurement in the laboratory or in the field, as well as for production testing and process control.

615

SECTION II
Specifications

II-1 ELECTRICAL AND PERFORMANCE SPECIFICATIONS

(a) Measurement Ranges:
Measurement of static (dc) or varying (ac to 2 kHz) magnetic field strength in the range of 10 gauss full scale to 1 MG gauss full scale in decade steps as follows:

1X probes	10G, 100G, 1 kG, 10 kG, 100 kG
10X probes	100G, 1 kG, 10 kG, 100 kG, 1 MG

(b) Calibration:

1. Internal calibrating procedure is referenced to a standard NMR magent traceable to the National Bureau of Standards.
2. Internal calibration error does not exceed ±0.5%.

(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 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 615 Gaussmeter 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 accuracy: ±0.1% of reading ±1 digit

4. Improved accuracy obtainable by using probe deviation curves* and, at specific test points, by reference to a known calibration field.
*Available on special order.

(e) Stability

1. Line voltage:
Error negligle 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:
See the F.W. Bell Gaussmeter Probe literature sheet for the specifications for the probe being used.

4. Probe temperature effects Zero Field influence:
See the F.W. Bell Gaussmeter Probe literature sheet for the specifications for the probe being used.

(f) Output Jacks:

1.	Output voltage:	100 millivolts dc FS
2.	Source impedance:	10 kΩ approx.
3.	ac field frequency response:	See 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	.063 A		.032 A
Power	7.2 W		7.2 W

(h) Warm Up Time:
The digital panel meter needs ½ hour of warm up time to insure stable meter readings.

II-2 PHYSICAL SPECIFICATIONS, CONTROLS AND CONNECTORS

(a) Front Panel:

1. Power Switch:
This rotary switch turns on the primary power to the instrument.

2. Range Switch:
The full scale range is set by this switch in decade steps marked in the 1, 10 sequence. It covers the range from 10 gauss to 100 k gauss, 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 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 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 615 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. BCD Output

A rear panel connector provides a positive true, TTL-compatible, BCD output with logic state $1 \geq +2.0$ V into 1kΩ load and logic state $0 \leq +0.5$ V.

(c) Internal Fuse:

The fuse holder accepts a standard 3 AG size fuse. The fuse should be rated at 1/8 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
(14.6 cm)	(35.56 cm)	(21.59 cm)

(e) Weight:

Shipping 14 lbs. (6.35 kg) Net 8 lbs. (3.63 kg.)

SECTION III.
Installation and Pre-Operation Adjustments

III-1. POWER

(a) Power Requirements:

The Model 615 can be operated from standard ac line voltage (117 V or 234 V, 50-60 Hz, 7.2 watts).

(b) Operation:

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

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 is screwed on until it is snug. See the panel controls as follows:

RANGE switch to 100 K
FUNCTION switch to NOR

Turn the power switch on and allow 30 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 counterclockwise 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 10 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 available (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 a 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 (30 min.) set the FUNCTION switch to CAL. The RANGE switch may be in any position. Adjust the CAL screwdriver adjustment to obtain a full-scale (1000) 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. It is an error plot for the particular probe measured. It is a 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 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 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 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.

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 -269° 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

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 measurement would not be accurate as absolute readings, but might be useful where only a relative indication is sufficient.

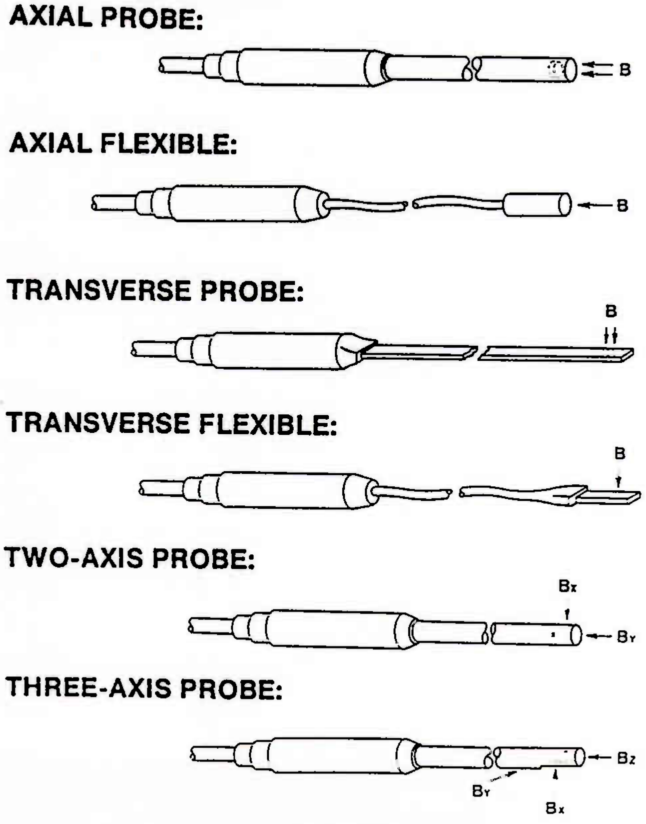


FIGURE IV-1

(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 overstressed 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 -20° C to +60° C range, unless the probe or Hall element was designed for other temperatures.

(c)Transverse Probes:
A transverse probe, as the 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 $B \cos \Theta$ where B is the field magnitude and Θ 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 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 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 acutal 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 chambers available from F.W. Bell, Inc., are a dual mu-metal can assembly which effectively shunts all external stray fields around the internal volume. It is recommended that a zero gauss chamber Bell Model No. YA-111 is used with standard probes. When using magnaprobes a special zero gauss chamber, Model YA-112, is required. 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 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 admustments 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 versis 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 for 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 10.00, then the field is 10 kG. If the meter reading were 5.00, then the field would be 5 kG 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 the Model 615.

(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 a 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 readings. 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 frequency 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 returned to the NOR position.

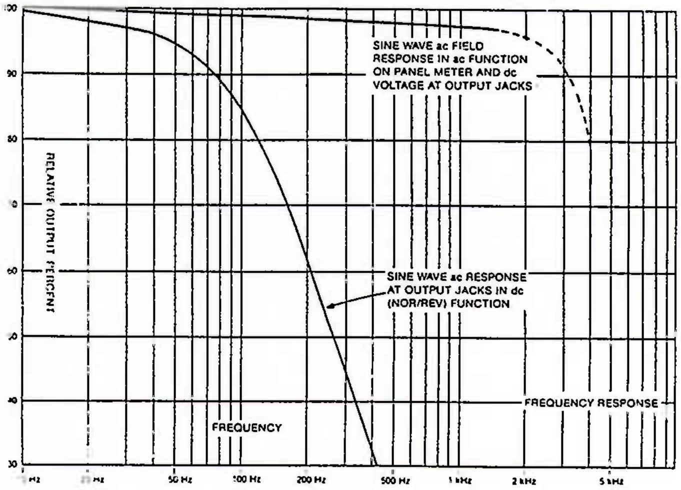


FIGURE IV-3

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:

$$B_a = B_g\,(1 - (t_{pm} - t_{pc})\,\tfrac{t_c}{100})$$

where: B_a = the actual value of the field being measured (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 calibration in degrees C. (25° C when using internal CAL method).

t_c = 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 acutal field (B_a) for measurements under different temperature conditions. Notice that t_c 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 capability of the Model 615. 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.

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 x 10^4
GUASS = 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.

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

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

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 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 615 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 of polarity (field direction) information. The demodulator drives the panel meter and output jacks.

If the field is time-varying, the demodualted 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

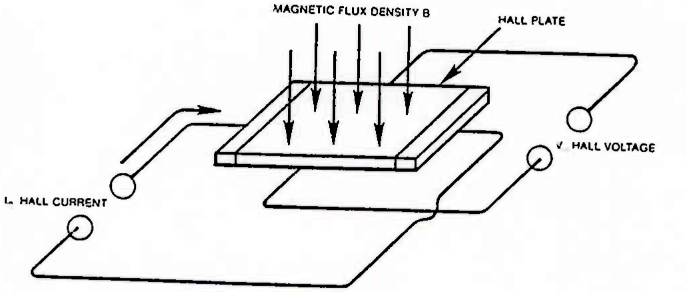
The Hall-Pak generator used for magnetic flux sensing is a semiconductor device operating on the Hall-Effect principle. It consists of a thin rectangular wafer of high-purity indium arsenide with 4 leads attached, Fig. V-1.

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 Lorenx 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.

$$V_H = K_H (\bar{B} \times \bar{I}_c)$$

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, and 0.0075 volt per kG-ampere for 10X probes.



THE HALL GENERATOR

FIGURE V-1

V-3 CIRCUIT OPERATION

(a) Introduction:

This section describes the overall gaussmeter circuit operation. Check the block diagram and the complete schematic for circuitry details. 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. This 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. The 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 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 (1000 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 has two-stages of amplication, plus emitter-follower direct-coupled circuitry with ac and dc feedback for stablization. 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 10 times attenuation.

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.

7. Power Supply:

The power to all circuits is supplied from the power regulator which provides +7 Vdc. 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 615 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 615 Gaussmeter:

(a) A high-impedence 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 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 ⅛ A 3AG Slow Blow.
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 100K
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, 0.063 A nominal
at 234 V line, 0.032 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 jack should be 100 millivolts dc for full-scale meter reading (1000).

(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 10 G range.
2. Set the RANGE switch to the 100 gauss range.
3. Rotate the COARSE zero control over its range.
4. A total of about 60 gauss adjustment range should be obtained.

(e) Detector Zero Test:

1. Again zero the instrument on the 10 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 0.1 mV dc.

(f) Noise Check:

1. With the zero gauss chamber in place and a good zero on the 10 G range, switch the FUNCTION switch to AC.
2. The residual meter reading should be less than 3% of full scale on the 10 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 615 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) Power Supply Voltage Adjustment:
Adjust R106 on the circuit board to obtain +7 Vdc across C104.

(b) Oscillator Feedback Adjustment:
Adjust R113 to obtain 150 mV dc across CR 106.

(c) Control Current (I_c) Adjustment:
Adjust R110 to obtain 100 mV ac across R11.

(d) Detector Zero Adjustment:
Place the probe in the zero gauss chamber and zero the gaussmeter down to the 10 gauss range. Switch

to the 100 K range and adjust R143 to obtain zero dc voltage on the meter.

(e) 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 10 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 the coaxial wire with the yellow color tape on the circuit board. Residual signal should be below 15 mV with the CAL control set to max clockwise. If it is higher 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.
3. The probe input socket J1 wiring adjustment has been altered or has loosened due to hard useage.

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 input 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 red wire may be shifted from its position to adjust quadrature.

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 Bell Item Numbers are parts designed for the Model 615 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
ABBREVIATIONS

Cer	Ceramic	MF	Metal Film
Cerm	Cermet	μ	Micro or 10^{-6}
CF	Carbon Film	MME	Molded miniature epoxy
EM	Electrolytic miniature type	PLY	Polystyrene
F	Farad	Ω	ohm
FOP	Fact. adj. for opt. perf.	p	Pico or 10^{-12}
HM	Hot molded	V	Working volts
k	Kilo or 10^3	Var	Variable
M	Meg or 10^4	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 boards.

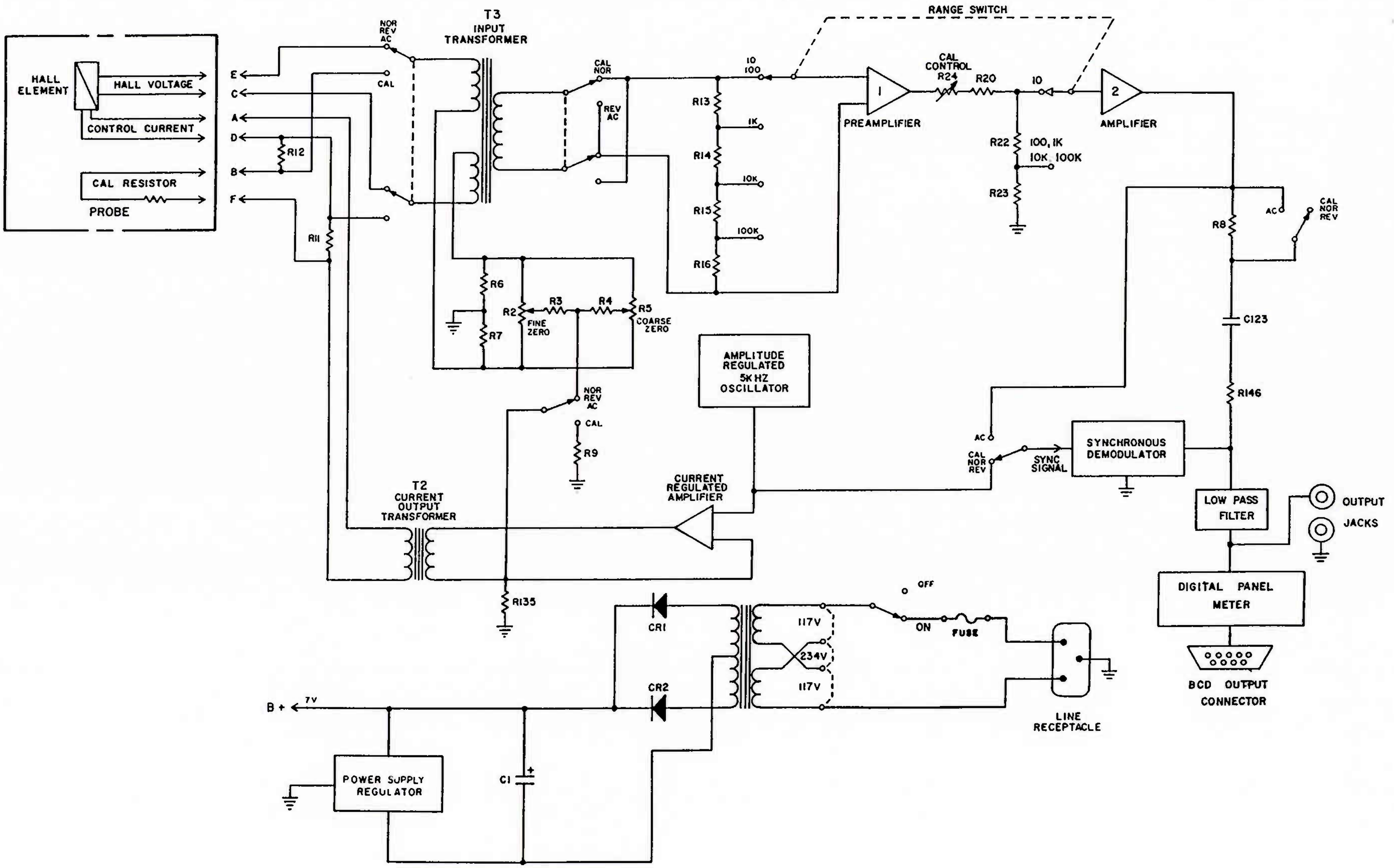
Schematic Ref.	Value		Spec.	Type		Bell Item No.
R1	10Ω	¼W	5%	CF	Fixed	311475
R2	5kΩ			HM	Var	321170
R3	270kΩ	¼W	5%	CF	Fixed	311591
R4	5.6kΩ	¼W	5%	CF	Fixed	311551
R5	250Ω			HM	Var	321180
R6	5.1Ω	2W	5%	WW	Fixed	319880
R7	5.1Ω	2W	5%	WW	Fixed	319880
R8	105Ω	¼W	1%	MF	Fixed	315792
R9	5.6kΩ	¼W	5%	CF	Fixed	311551
R10	26.7kΩ	¼W	1%	MF	Fixed	316520
R11	2Ω	1/10W	1/10%	WW	Fixed	318360
R12	2Ω	1/10W	1/10%	WW	Fixed	318360
R13	45kΩ	1/8W	¼%	MF	Fixed	314730
R14	4.5kΩ	1/8W	¼%	MF	Fixed	314710
R15	450Ω	1/8W	¼%	MF	Fixed	314680
R16	50Ω	1/8W	¼%	MF	Fixed	314650
R20	9.09kΩ	1/8W	¼%	MF	Fixed	314700
R22	909Ω	1/8W	¼%	MF	Fixed	314670
R23	101Ω	1/8W	¼%	MF	Fixed	314660
R24	20kΩ				Var	321680
R25	1MΩ	¼W	5%	CF	Fixed	311605
RX	FOP	¼W	5%	CF	Fixed	
R101	47kΩ	¼W	5%	CF	Fixed	311573
R102	1kΩ	¼W	5%	CF	Fixed	311553
R103	1kΩ	¼W	5%	CF	Fixed	311553
R104	2.7Ω	¼W	5%	CF	Fixed	311461
R105	8.2kΩ	¼W	5%	CF	Fixed	311555
R106	2kΩ	½W	10%	Cerm	Var	322045
R107	3kΩ	¼W	5%	CF	Fixed	311544
R108	180Ω	¼W	5%	CF	Fixed	311515
R109	2kΩ	¼W	5%	CF	Fixed	311540
R110	2kΩ	½W	10%	Cerm	Var	322045
R111	2.4kΩ	¼W	5%	CF	Fixed	311542
R112	62kΩ	¼W	5%	CF	Fixed	311576
R113	1kΩ		10%	Cer	Var	322044
R114	1.6kΩ	¼W	5%	CF	Fixed	311538
R115	22Ω	¼W	5%	CF	Fixed	311483
R116	3.9kΩ	¼W	5%	CF	Fixed	311547
R117	150kΩ	¼W	5%	CF	Fixed	311585
R118	301Ω	¼W	1%	MF	Fixed	315880
R119	1.3kΩ	¼W	1%	MF	Fixed	316090
R120	240Ω	¼W	5%	CF	Fixed	311518
R121	8.2kΩ	¼W	5%	CF	Fixed	311555
R122	5.1kΩ	¼W	5%	CF	Fixed	311550
R123	10kΩ	¼W	5%	CF	Fixed	311557
R124	16kΩ	¼W	5%	CF	Fixed	311562
R125	27kΩ	¼W	5%	CF	Fixed	311567
R126	22kΩ	¼W	5%	CF	Fixed	311565
R127	62kΩ	¼W	5%	CF	Fixed	311576
R128	2.4kΩ	¼W	5%	CF	Fixed	311542
R129	120Ω	¼W	5%	CF	Fixed	311511
R130	5.1kΩ	¼W	5%	CF	Fixed	311550
R131	510Ω	¼W	5%	CF	Fixed	311526
R132	510Ω	¼W	5%	CF	Fixed	311526
R133	2.7Ω	¼W	5%	CF	Fixed	311461
R134	2.7Ω	¼W	5%	CF	Fixed	311461
R135	4.7Ω	2W	5%	WW	Fixed	319860
R136	820Ω	¼W	5%	CF	Fixed	311531
R137	1.8kΩ	¼W	5%	CF	Fixed	311539
R138	62kΩ	¼W	5%	CF	Fixed	311576
R139	3.9kΩ	¼W	5%	CF	Fixed	311547
R140	470Ω	¼W	5%	CF	Fixed	311525
R141	10Ω	¼W	5%	CF	Fixed	311475
R142	470Ω	¼W	5%	CF	Fixed	311525
R143	1kΩ	½W	10%	Cerm	Var	322044
R144	470Ω	¼W	5%	CF	Fixed	311525
R145	1Ω	2W	5%	WW	Fixed	319800
R146	453Ω	¼W	1%	MF	Fixed	315910
R147	536Ω	¼W	1%	MF	Fixed	315940
R148	15kΩ	¼W	5%	CF	Fixed	311561
R149	15kΩ	¼W	5%	CF	Fixed	311561
R150	5kΩ	½W	10%	Cerm	Var	322046
R151	13kΩ	¼W	5%	CF	Fixed	311560
R152	47kΩ	¼W	5%	CF	Fixed	311573
R153	12kΩ	¼W	5%	CF	Fixed	311559
R154	301Ω	¼W	1%	MF	Fixed	315880
R155	62kΩ	¼W	5%	CF	Fixed	311576
R156	13kΩ	¼W	5%	CF	Fixed	311560
R157	20kΩ	¼W	1%	MF	Fixed	316490
R158	2kΩ	¼W	5%	CF	Fixed	311540
R159	5.1kΩ	¼W	5%	CF	Fixed	311550
R160	5.6kΩ	¼W	5%	CF	Fixed	311551
R161	1kΩ	¼W	5%	CF	Fixed	311533
R162	330Ω	¼W	5%	CF	Fixed	311521
R163	127Ω	¼W	1%	MF	Fixed	316650
R164	47kΩ	¼W	5%	CF	Fixed	311573
R165	16kΩ	¼W	5%	CF	Fixed	311562
R166	174Ω	¼W	1%	MF	Fixed	315820
R167	12kΩ	¼W	5%	CF	Fixed	311559
R168	62kΩ	¼W	5%	CF	Fixed	311576
R169	54.9kΩ	¼W	1%	MF	Fixed	316590
R170	1.8kΩ	¼W	5%	CF	Fixed	311539
R171	5.1kΩ	¼W	5%	CF	Fixed	311550
R172	5.1kΩ	¼W	5%	CF	Fixed	311550
R173	22Ω	¼W	5%	CF	Fixed	311483
R174	22Ω	¼W	5%	CF	Fixed	311483
R175	120Ω	¼W	5%	CF	Fixed	311511
R176	62Ω	¼W	5%	CF	Fixed	311504
R177	6.8Ω	¼W	5%	CF	Fixed	311553
R178	75kΩ	¼W	5%	CF	Fixed	311578
R179	6.8kΩ	¼W	5%	CF	Fixed	311553
R180	75kΩ	¼W	5%	CF	Fixed	311578
R181	6.8kΩ	¼W	5%	CF	Fixed	311553
R182	75kΩ	¼W	5%	CF	Fixed	311578
C1	1200μF		15V		EM	323240
C2	82pF	1000V	10%		Cer	325360
C101	10μF		6V		EM	322930
C102	0.015μF	200V	10%		MME	324500
C103	10μF		6V		EM	322930
C104	1000μF		10V		EM	323050
C105	100μF		12V		EM	323160
C106	100μF		12V		EM	323160
C107	10μF		6V		EM	322930
C108	10μF		6V		EM	322930
C109	10μF		6V		EM	322930
C110	0.0033μF		200V	10%	MME	324430
C111	0.0033μF		200V	10%	MME	324430
C112	10μF		6V		EM	322930
C113	0.015μF		200V	10%	MME	324500

Schematic Ref.	Value	Spec.	Type	Bell Item No.
C114	100μF	12V	EM	323160
C115	100μF	12V	EM	323160
C116	100μF	12V	EM	323160
C117	100μF	12V	EM	323160
C118	0.001μF 1000V	20%	Cer	325510
C119	10μF	6V	EM	322930
C120	0.001μF 1000V	20%	Cer	325510
C121	100μF	12V	EM	323160
C122	100μF	12V	EM	323160
C123	1μF 100V	10%	PLY	324930
C124	0.047μF 200V	10%	MME	324530
C125	0.047μF 200V	10%	MME	324530
C126	10μF	6V	EM	322930
C127	0.68μF 100V	10%	PLY	324990
C128	270pF 1000V	20%	Cer	325470
C129	180pF 1000V	10%	Cer	325400
C130	10μF	6V	EM	322930
C131	10μF	6V	EM	322930
C132	10μF	6V	EM	322930
C133	100μF	12V	EM	323160
C134	10μF	6V	EM	322930
C135	10μF	6V	EM	322930
C136	1μF 100V	10%	PLY	324930
C137	270pF 1000V	20%	Cer	325470
C138	10μF	6V	EM	322930
C139	10μF	6V	EM	322930
C140	100μF	12V	EM	323160
T1	LB-1931		Power Transf	326310
F1	Fuse 1/8 A. SB		307	330680
T2	Output Transformer			326330
T3	Input Transformer			326320
M1	Meter Digital			310675*
S1	Power Switch			334290
S2	Range Switch Ass. Sub-A			201110
S3	Function Swit. Ass. Sub-A			201163
Q101	2N3403	Transistor		328910
Q102	2N508A	Transistor		328920
Q103	2N508A	Transistor		328920

Schematic Ref.	Value	Spec.	Type	Bell Item No.
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	PN4917	Transistor		329150
Q117	2N4401	Transistor		329130
Q118	2N3707	Transistor		328990
Q119	2N4917	Transistor		329150
Q120	2N2430	Transistor		328910
Q121	2N2706	Transistor		328930
Q122	2N4126	Transistor		329080
Q123	2N4126	Transistor		329080
Q124	2N4126	Transistor		329080
CR1	1N4003	Diode		328090
CR2	1N4003	Diode		328090
CR101	1N270	Diode		327990
CR102	1N270	Diode		327990
CR103	1N5230	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

NOTE: Connector that will mate with J6 the rear BCD output connector is Cinch #57-30240 (item #331944)

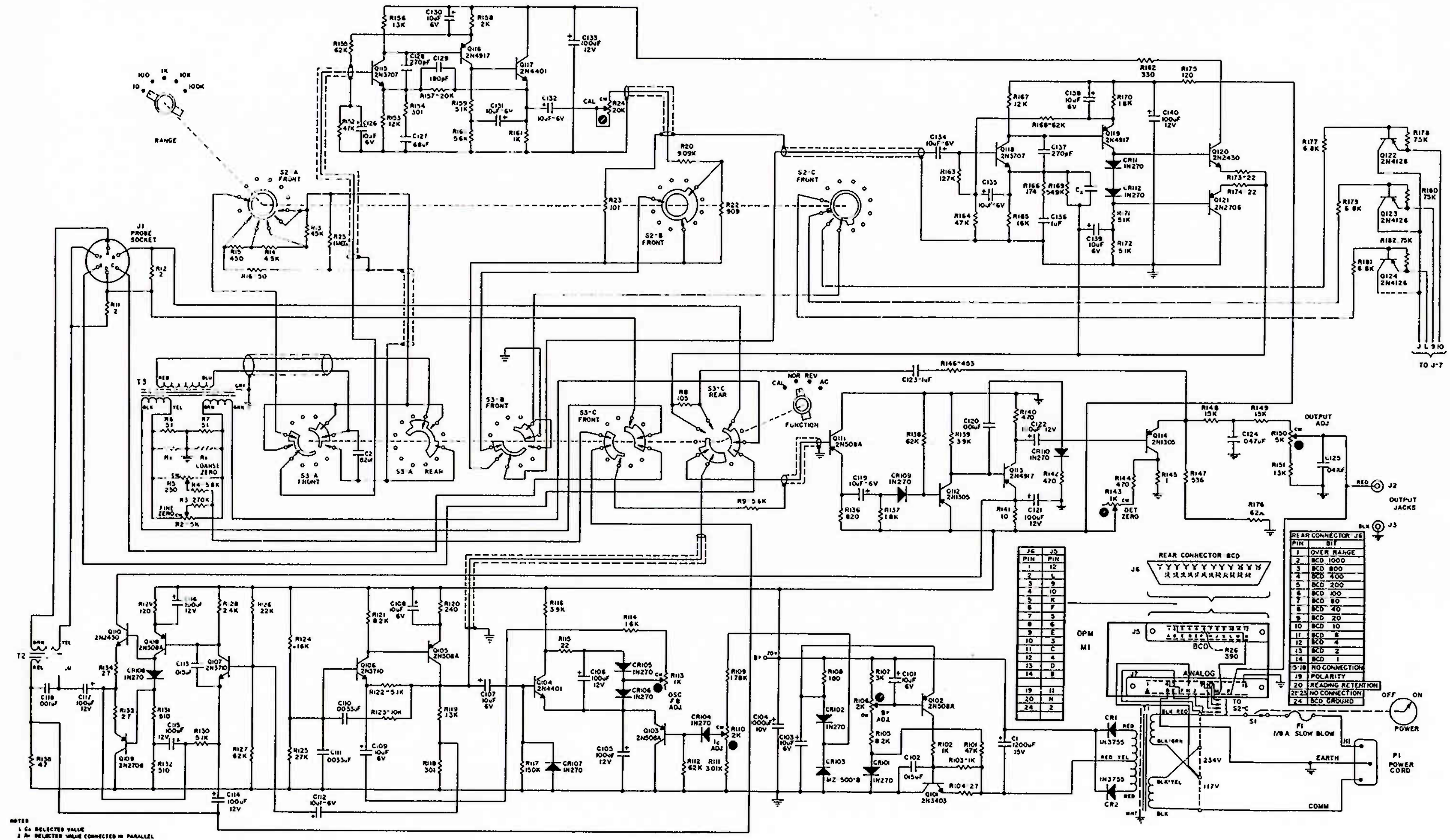
*Item #310675 is used for serial numbers 161456 and above. For serial numbers 161455 and below use item #310672.



BLOCK DIAGRAM

MODEL 615

UD-3104 REV. A



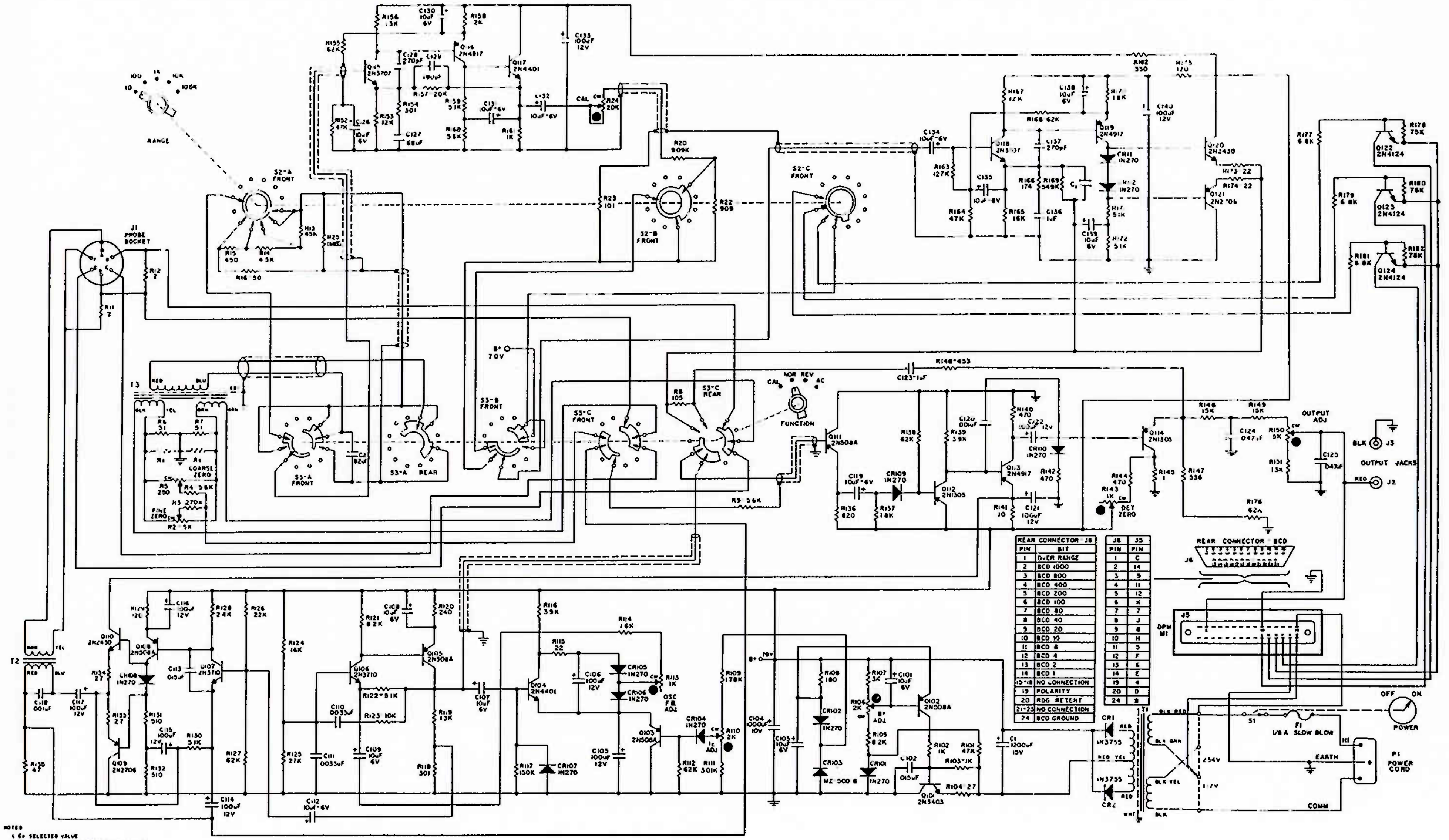
J6 PIN	J5 PIN
1	12
2	L
3	9
4	10
5	K
6	F
7	5
8	6
9	E
10	3
11	C
12	4
13	D
14	B
19	11
20	N
24	2

REAR CONNECTOR J6	
PIN	BIT
1	OVER RANGE
2	BCD 1000
3	BCD 800
4	BCD 400
5	BCD 200
6	BCD 100
7	BCD 80
8	BCD 40
9	BCD 20
10	BCD 10
11	BCD 8
12	BCD 4
13	BCD 2
14	BCD 1
15-18	NO CONNECTION
19	POLARITY
20	READING RETENTION
21-23	NO CONNECTION
24	BCD GROUND

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 615 GAUSSMETER
SERIAL NO'S. 16455 AND BELOW

UD-3103 REV. G



REAR CONNECTOR J6	
PIN	BIT
1	OVER RANGE
2	BCD 1000
3	BCD 800
4	BCD 400
5	BCD 200
6	BCD 100
7	BCD 80
8	BCD 40
9	BCD 20
10	BCD 10
11	BCD 8
12	BCD 4
13	BCD 2
14	BCD 1
15-18	NO CONNECTION
19	POLARITY
20	RDG RETENT
21-23	NO CONNECTION
24	BCD GROUND

J6	J5
PIN	PIN
1	C
2	14
3	9
4	11
5	12
6	K
7	7
8	J
9	6
10	H
11	5
12	F
13	6
14	E
19	4
20	D
24	B

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 615 GAUSSMETER
SERIAL NO'S. 16456 AND ABOVE

UD-3919 REV. A

INSTRUCTION MANUAL

MODEL 615/488 GAUSSMETER

Operation and Maintenance Manual

CONTENTS

I. GENERAL DESCRIPTION

The Model 615/488 Gaussmeter is a standard model 615 gaussmeter that has been modified to accept a basic talker IEEE-488-1978 Interface. Operation of the 615 gaussmeter is unchanged by the 488 interface. The 488 interface accepts data from the 615 digital panel meter and relays the information over the 488 bus. Range and/or functional setting of the 615 gaussmeter are not selectable via the 488 interface. These selections must be done manually.

II. PHYSICAL CONTROLS

A. REAR PANEL

IEEE-488-1978 Interface connector replaces BCD output connector on 615 rear panel.

B. ADDRESS

Switch (S1), located inside the 615 gaussmeter, selects the instrument address and operation mode. Refer to Section IIIB for address (S1) selection and operation.

III. OPERATING INSTRUCTIONS

A. PROGRAMMING

The 615/488 Interface can be configured by the bus controller to operate in one of two different modes. These are the "triggered" mode and the "read" mode.

1. **Triggered:** In this mode the controller initializes the interface as described in IEEE-488-1978 specifications. When data is then desired from the instrument, the controller triggers the instrument via the trigger command. The 488 Interface reads the data from the 615 gaussmeter and formats the data as selected by the address (S1) and transmits the data over the 488 bus to the controller.
2. **Read:** In this mode the controller initializes the interface as described in IEEE-488-1978 specifications. When the controller desires data from the instrument, the controller sends an "X" to the interface. The 488 interface then reads the data from the 615 gaussmeter, formats the data as selected by the address switch (S1) and sends a service request to the controller.

   The interface will then wait until the service request is acknowledged before sending the data (status request read by controller). After service request is granted, data is sent to the controller.

   The difference between the operating modes is that in the "read" mode, the 488 interface allows the controller to cause a data reading to take place without interrupting the bus. This allows the controller to do something else while this reading is taking place, then actually receive the data from the instrument 488 interface when it so desires. Refer to flow charts for Active Service and Power On software description. **The End of Identity (EOI) character for the interface is a Line Feed (LF). Data are terminated by Carriage Return/Line Feed (CR/LF).**

B. ADDRESS SWITCH (S1)

Address Switch (S1), located on the main logic board inside the 615 gaussmeter, selects the instrument's talker and listener address. Four bytes of address are given, allowing up to 16 different instruments to be connected to the IEEE-488 bus.

Bits 1 thru 4 select the binary address of the instrument. Bit 5 of the address switch selects the data format to be sent to the controller. The first format is BCD and is formatted as follows:

BCD: Sign 0/1 . X X X E X

Data — Sign 0/1 . X X X

Range — X

2 = 100 G Range
3 = 1000 G Range
4 = 10 kG Range
5 = 100 kG Range

Data is sent in ASCII form.

The second format is Binary and is sent as a 16-bit two's compliment ASCII hexidecimal format, and is formatted as follows:

X X X X , X
( )—Two's Compliment ASCII Hexidecimal Data
(,)——"Comma" Delimeter
(X)——Range
2 = 100 G Range
3 = 1000 G Range
4 = 10 kG Range
5 = 100 kG Range

In both formats, if the 615 gaussmeter is overranged, the 488 interface will send an overrange message "OVERRANGE" in ASCII.

Bit 6 in the address switch (S1) places the 488 interface in a remote or local operation mode. In the local mode, the 488 interface in disconnected from the bus and does not participate in bus activity. In the remote mode, the interface is an active participant on the bus. The interface, however, does not respond to a local lockout message from the controller.

Table 1 is a summary of the address switch (S1) operation.

TABLE 1 Switch Position
OFF = 1, ON = 0

Bits
1 2 3 4 5 6 7 8
7 8 — Spare
6 — Remote/Local (1 = Remote 0 = Local)
5 — Binary BCD (1 = Binary 0 = BCD)
4 — MSB Address — Talker/Listener Address
1 — LSB Address — Talker/Listener Address

NOTE: Factory instrument settings are: Address 5. Remote mode. BCD Data Format.

IV. THEORY OF OPERATION

A. GENERAL

The 615/488 interface is comprised of three printed circuit board assemblies. The first printed circuit board is the meter interface board. This board plugs onto the back of the 615's digital voltmeter and provides a connection path from the DVM to the 488 interface CPU. In addition to providing a connection path, the meter board contains a 32 x 8 ROM that converts the range switch position to the correct decimal point information needed by the DVM and provides range information to the CPU.

The second, and largest, board is the 488 CPU. The CPU board receives the DVM and the range information from the meter interface board and processes the data as required by the 488 interface mode and program instructions.

Located on the CPU board is a 2 k x 8 EPROM that stores all the program instructions required by the interface. The CPU located on the CPU board processes the data according to the position of the mode switch (S1) and the relevant instructions contained in the EPROM.

Also connected to the CPU board is the bus interface board. This board contains a bus controller IC and two line driver/receiver IC's. Its function is to provide all necessary interconnection and control between the actual 488 bus and the CPU.

B. CIRCUIT DESCRIPTION

1. CPU Board

Power for the entire interface is derived from Transformer T1. A full wave rectifier converts the ac voltage into a dc voltage of approximately 6.8 Vdc which is filtered and regulated to 5.0 Vdc. The Microprocessor IC101 (8048) has an 8 bit data bus that connects the program ROM (IC104) and meter buffers (IC102 and IC103) to the 488 bus interface. The internal clock period of the CPU is approximately 2.44 microseconds. IC106 uses the Advanced Latch Enable (ALE) clock to demultiplex the lower address from the data bus. IC105 memory maps the I/O devices onto the data bus at the appropriate address locations. The interrupt input to the CPU is used by the 488 bus interface IC to signal the CPU when it desires service. I/O port P1 is used to input the address switch to the CPU. The lower half of P2 is used as a high order address for the program ROM. The upper I/O pins of P2 are used to input decimal point information. The clock output is used as a clock driver to the bus interface. Timer input T1 is used as a data valid flag from the digital panel meter. Transistor Q1 inverts the reset signal for the 488 bus interface.

2. 488 Bus Interface Board

IC201 is a special purpose IC designed to accept and provide all of the hand shaking and message handling requirements of the 488 bus standard. Data to and from this IC are handled as if it were eight successive memory locations. Data read and written to IC201 is sent over the CPU 8-bit data bus. Service requests required by the interface are signaled via the interrupt input to the CPU. IC's 202 and 203 are simply bus transceivers that provide the necessary bus terminations and interface to the 488 bus system controller.

PROGRAM EXAMPLES FOR HP 86/87

Triggered Mode

```
10 Trigger 705......... !Trigger Device to Read
20 Enter 705 Using "%K" ; A$ ... !Transfer Data
                                   to Controller
30 Disp A$..................... !Display Data.
```

Read Mode

```
10 Output 705 Using "A,/" ; "X" ......... !Send
                          Command to Gaussmeter
20 Enable Intr 7;8 .................... !Enable
                            Controller Interrupt
30 On Intr 7 Goto 50 ...............!Check for
                           Gaussmeter Interrupt
40 Goto 30.................... !Loop to Check
50 ! Gaussmeter Service Routine
60 S = Spoll (705) ..... !Serial Poll Gaussmeter
70 If Bit (S,6) = 1, Then Goto 90..... !Check if
                                 Service Request
80 Goto 60 ! SRQ Register Bit 6 Not Active
90 Enter 705 Using "K%" ; Y$
100 Print "Data Received From G.M."
110 Print "Input From G.M. Is" ; Y$
120 End
```

V PARTS LIST MODEL 615/488

Note: Components with schematic reference numbers: in 100's are located on Processor printed circuit board, in 200's are located on Buss Interface printed circuit board and 300's are located on Meter printed circuit board.

Ref.	Description	F.W. Bell Item No.
R101	Res. CF, ¼W, 5%, 10 kΩ	312280
R102	Res. CF, ¼W, 5%, 10 kΩ	312280
RN101	8 Pack Pullup, 10k	322764
RN301	7 Pack Pullup, 10k	322745
C101	Capacitor, Ceramic, 33 pF, 50 V	325535
C102	Capacitor, Ceramic, 33 pF, 50 V	325535
C103	Capacitor, Tan., 2.2 μF, 16 V	325568
C104	Capacitor, Elec., 4700 μF, 16 V	322785
C105	Capacitor, Tan., 2.2 μF, 16 V	325568
C201	Capacitor, Tan., 2.2 μF, 16 V	325568
C301	Capacitor, Tan., 2.2 μF, 16 V	325568
D101	Diode, IN4003	328090
D102	Diode, IN4003	328090
IC101	Microprocessor, 80C48	329700
IC102	Buffer, 74NCT541	330118
IC103	Buffer, 74NCT541	330118
IC104	ROM, JA-953	330095
IC105	Decoder, 74HCT138	330110
IC106	Latch, 74HCT573	330119
IC107	Voltage Regulator, LM2940C	330048
IC201	Bus Controller, 8291A	330101
IC202	Bus Interface, 8293A	330102
IC203	Bus Interface, 8293A	330102
IC301	ROM, JA-952	329820
IC302	Optoisolator, MTC-6	330066
IC303	Optoisolator, MTC-6	330066
J101	Connector, 26 Pin	332024
J102	Connector, 26 Pin, Right Seq.	332006
P201	Connector, 26 Pin	332137
P202	Connector, 26 Pin	332024
P301	Connector, PCB	332136
P302	Connector, Ribbon	332023
P303	Connector, 26 Pin, Female	332007
Q101	Transistor, VN10KN	329132
SW101	Switch, Dip 8 Pos.	334580
T101	Transformer	326625
	Jack Screws, 488 Connector	341487
	Connector, 24 Pin, 488 Bus	332299
	Connector, 26 Pin, Female	332007
	Cable, 26 Conductor, Ribbon	352237

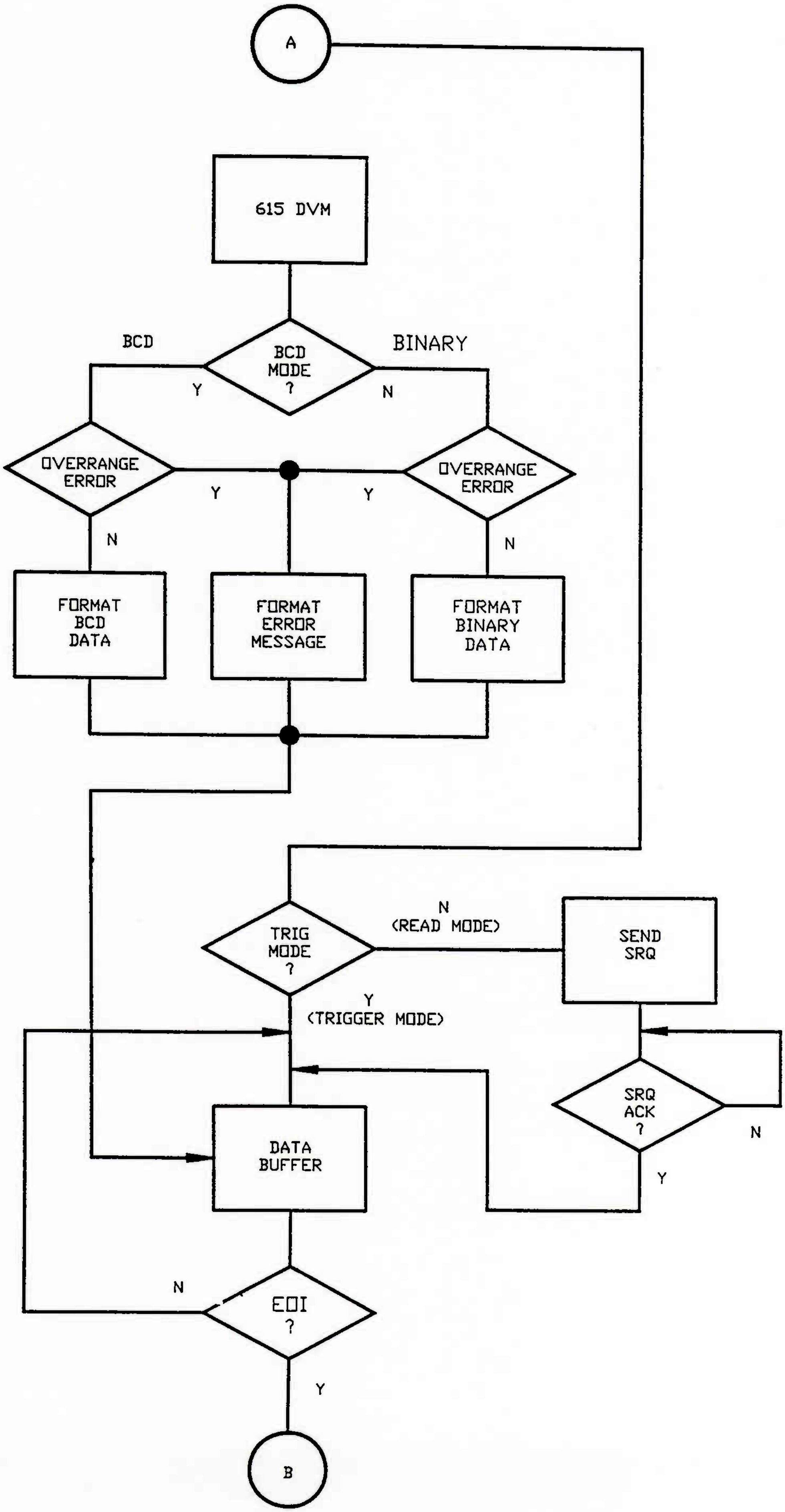
VI INTERFACE SPECIFICATIONS
615/488

615 INTERFACE: Meets requirements for ANSI/IEEE STD 488-1978 for talker.

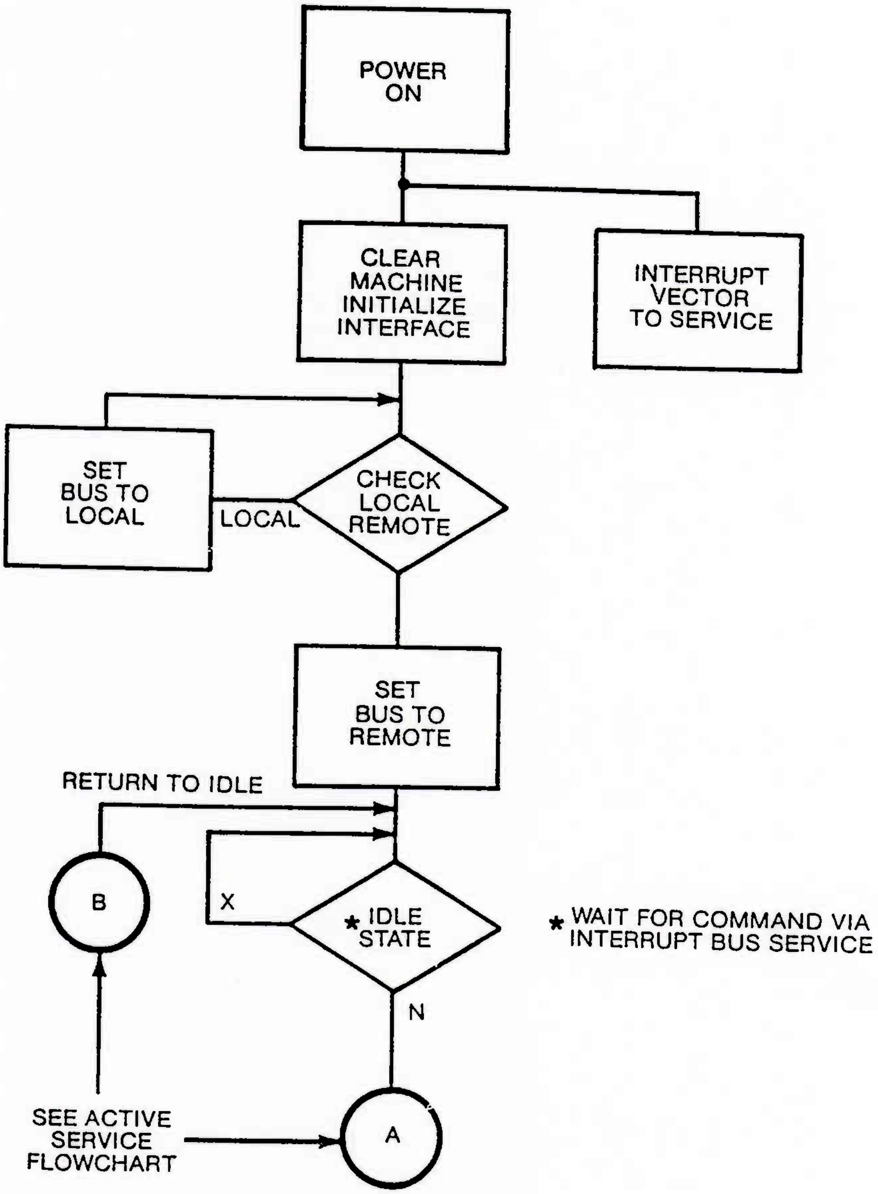
DEVICE RESPONSE: The device can be triggered to make a measurement or the device can be programmed to make a measurement. The programmed response will generate a Service Request (SRQ) when data are ready.

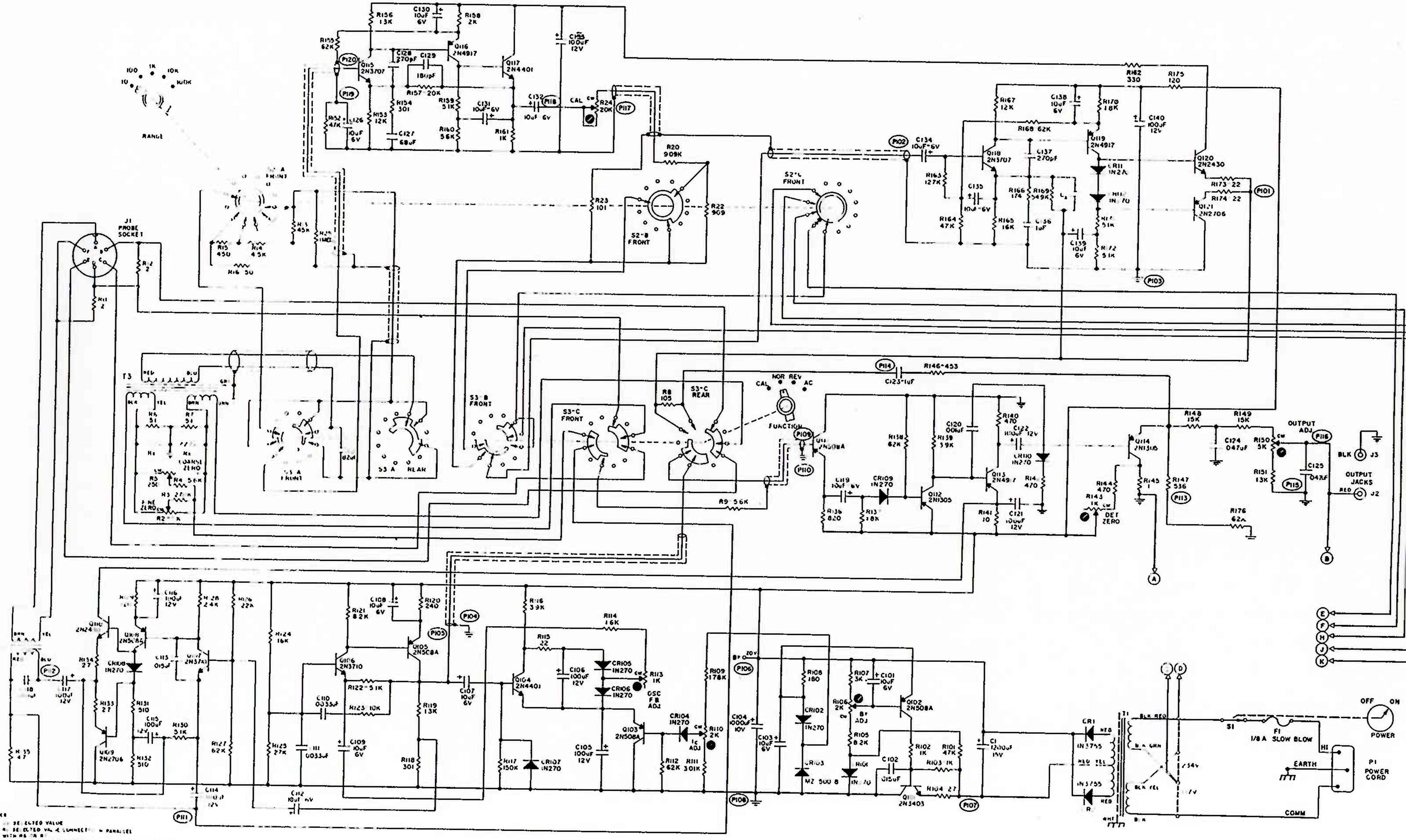
DATA FORMAT: The data can be sent to the controller using BCD Floating Point Format, or the data can be sent using 2's complement ASCII Hexidecimal Format.

488 BUS/615
ACTIVE SERVICE



488 BUS/615
POWER ON



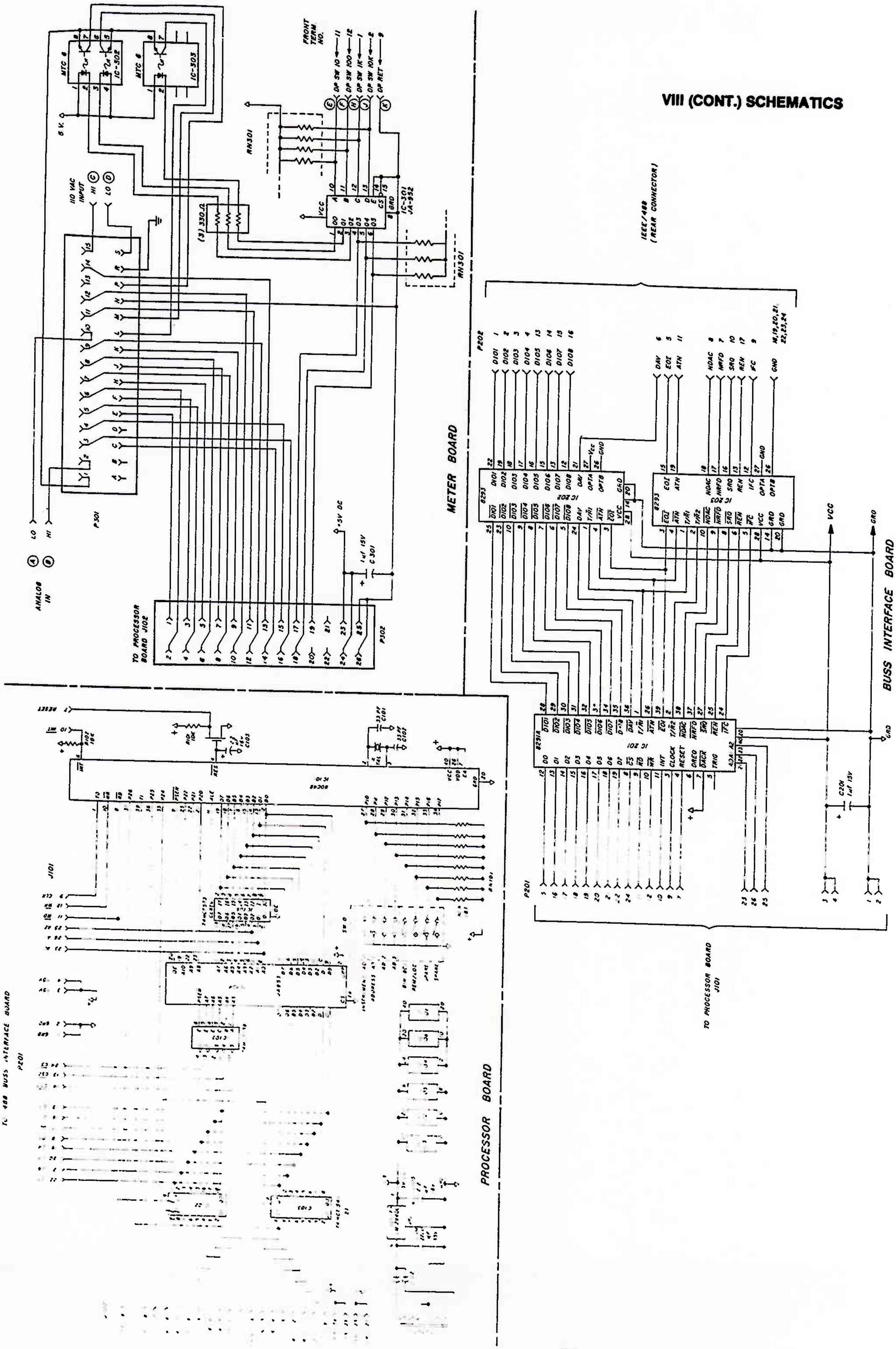


SELECTED VALUE
SELECTED VALUE CONNECTED IN PARALLEL
WITH R6 OR R7
SEE PARTS LIST FOR COMPLETE COMPONENT SPECIFICATIONS
NUMBERS ARE PRINTED CIRCUIT BOARD TERMINAL DESIGNATIONS I.E. (P101)

SCHEMATIC IEEE/488-615

UD-4349
SHEET 1

VIII (CONT.) SCHEMATICS



UD-4349
SHEET 2