INSTRUCTION BOOK FOR

MODEL 4391
MULTI-PURPOSE
THRULINE® WATTMETER
RF POWER ANALYST®

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MODELS COVERED IN THIS INSTRUCTION BOOK

4391

USER INFORMATION NOTICE

This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class B Computing Device pursuant to Subpart J of Part 15 of FCC Rules.

INSTRUCTION BOOK

multi-purpose Thruline® Wattmeter RF Power Analyst®

MODEL 4391

BIRD

Electronic Corporation

30303 Aurora Road, Cleveland (Solon), Ohio 44139-2794

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INTRODUCTION

GENERAL

The Model 4391 is a multi-purpose Radio Frequency wattmeter designed around a microcomputer. A fairly extensive program stored in permanent memory controls the operation of the instrument at all times, permitting the detection and correction of various error sources and the refinement of the raw data produced by the directional detectors. Thus the instrument can compute VSWR, amplitude modulation, and various decibel variables reducing the odds of error and making such measurements consistent or repeatable regardless of who is making the measurement.

Other benefits include extended range using standard elements in some modes of operation, continuous monitoring of maximum and minimum readings, a peaking aid, and error messages.

Because of its complexity, the proper use of the 4391 is not always obvious. For this reason it is strongly advised that this manual be read in its entirety before using the device.

PURPOSE AND FUNCTION

The 4391 RF Power Analyst™ is an insertion type digital RF Directional THRULINE® Wattmeter designed to measure peak or average power flow, load match, and amplitude modulation in 50 ohm coaxial transmission lines. It is intended for use with CW, AM, FM, SSB TV and Pulse modulation envelopes. The instrument directly reads PEP or CW power in watts, milliwatts, or kilowatts in 9 ranges from 2.5 to 1000 full scale forward power of 0.25 to 100 full scale reflected power depending on the Plug-in Element. In addition it reads SWR directly over the range of 1.00 to 99.99, percent modulation directly over the range of .0 to 99.9, and return loss over the range of 0 to 36.1dB. For convenience, forward and reflected CW power can be displayed in dBm (dB above 1 milliwatt) from 6dB above to 24dB below nominal element range.

Power range and frequency band are determined by the Plug-in Elements used. Two switches on the front panel of the instrument are set by the user to correspond to the nominal power range of the forward element. The reflected element is assumed to have a nominal range one tenth that of the forward element.

In any of the modes of operation described, the instrument can recall from memory the lowest or highest reading taken or tell the operator whether the newest reading is less than, equal to, or greater than the previous reading.

DESCRIPTION

The instrument is housed in an aluminum calculator style case approximately 4⅜" high by 9⅝" deep by 6¼" wide (110mm x 244mm x 159mm) including connections. See Figure 1. The line section is contained in the case and is not intended for removal. At each end of the line section are Bird Quick-Change type RF connectors which may be easily interchanged with any other Bird QC connector. See Section 5, Parts List for types available.

Operating power is derived from rechargeable nickel-cadmium batteries inside the unit or from a 115/230V AC power source connected to the unit through the power cord supplied with the unit.

SPECIFICATIONS

Specifications for the Power Analyst are given in Table 1. Refer to Figure 1 for outline dimensions.

Table 1. Specifications

Measuring Medium	RF transmission in 50 ohm lines.
RF Power Range[1]	100mW to 10kW full scale using Bird Plug-in Elements. Accuracy not guaranteed with components not supplied by Bird.
Usable Over-Range	To 120% of scale on CW, PEP, SWR and return loss functions. To 400% of scale (PEP) on dBm and % modulation.
Frequency Range[1]	450kHz to 2.3GHz
Sampling Range	2-3 readings per second
Settling Time	10 seconds (worst case)[3]
Accuracy	
Power Readings	±5% of full scale
SWR	±10% of reading
% Modulation	±5%[2]
Return Loss	±0.3dB to corresponding SWR value
Impedance	50 ohms
Insertion SWR	1.05 max to 1000MHz
Pulse Parameters (square pulses)	
Pulse Width	0.8 u sec min.[4]
Repetition Rate	25 pps min.
Duty Cycle	0.01% min.
RF Line Connections	Bird Quick Change "QC"
Standard	Female N
Optional	Any standard AN "QC" type
Temperature Range	
Operating	+10°C to +45°C
Storage	−20°C to +45°C
Input Power Requirements	
Voltage	100-130/200-230 VAC (switch selectable) or 7.5V DC (internal battery)
Frequency	50-60 Hz
Power	6 watts
Batteries	6-1.25V Nicad. C size
Battery Life	(Rechargeable) 8 hours approx.
Weight	5¾ lb. (2.6 kg)

[1]Frequency band and power range is determined by Plug-in Element selected. See Bird Catalog for availability. Some modes require two elements in a 10:1 power ratio.

[2]For CW power levels greater than one third of full scale, accuracy of the % modulation mode is ±5% from 0 to 90% and +10% from 90 to 100%. Modulation frequency is 25 to 100,000 Hz; except for "A" and "B" elements: 25 to 20,000 Hz; and "H" elements: 25-10,000 Hz.

[3]VSWR and return loss functions settle in less than 1 second.

[4]For "A" & "B" elements the min. pulse width is 1.5 microseconds. For "H" elements the min. pulse width is 15 microseconds.

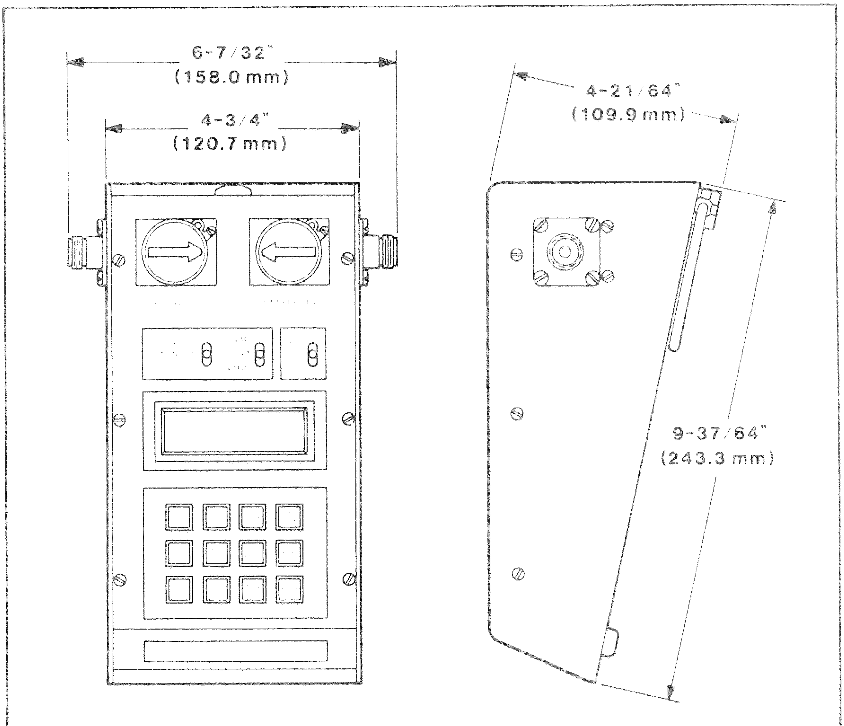


Figure 1. Configuration and Size.

SAFETY PRECAUTIONS

CAUTION

Never apply RF power to the 4391 unless both line section sockets are filled with either an element or a dust plug. If an element is used it is advisable to place the element with the arrow at a 90° angle to the coaxial line.

CAUTION

Always disconnect AC power before opening the 4391 enclosure. Removal of at least one battery cell is also recommended when servicing the instrument.

CAUTION

The 4391 contains MOS integrated circuits which may be damaged by static electricity. Open the housing only when sure that there are no static producing materials such as carpeting or styrofoam where the work is to be done. Work on a conductive, grounded work surface touching it frequently to discharge static from your body. If a part is to be stored or shipped, wrap it in aluminum foil.

SECTION 1
INSTALLATION

1-1. GENERAL

1-2. The Power Analyst Model 4391 is completely portable and very suitable for field or laboratory use. Its power is derived from rechargeable nickel-cadmium batteries inside the unit or from an AC outlet via the power cord supplied with the device. Always make sure that the "115/230V" selector switch on the rear panel is set correctly to the voltage supplied.

1-3. CONNECTIONS

1-4. The 4391 contains a short section of rigid 50-ohm coaxial air dielectric transmission line. To make measurements relating to the traveling waves in a coaxial line, that line must be disconnected at some convenient point to permit the 4391 air line to be inserted.

Although the 4391 is normally supplied with two female N-type connectors, a variety of easily interchangeable connectors are available to facilitate connecting to the user's system.

Once the 4391 is installed in the coaxial line, a Plug-in Element or a pair of Plug-in Elements must be selected which correspond to the frequency and power levels to be measured.

In order to take full advantage of the 4391's capabilities, two elements in a 10:1 ratio of power range should be used. If only one element is used, the other socket should be filled with a dust plug or a higher power element. Also, for greatest accuracy, the element(s) should be chosen having the lowest possible power range that will not result in over-ranging. Table 1-1 lists elements required for each mode of operation.

Table 1-1. Plug-In Elements Required

MODE	FORWARD	REFLECTED
FWD CW	X	
RFL CW		X
SWR	X	X*
FWD PEP	X	
RFL PEP		X
% MOD	X	
FWD dBm	X	
RFL dBm		X
RTN Loss	X	X*

*The reflected element must have a nominal power range one tenth that of the forward element.

The higher power element is placed in the socket marked **FORWARD** and its arrow pointed in the direction of forward power flow (toward antenna or load). The lower power element is placed in the socket marked **REFLECTED** and is normally pointed in the direction opposite to forward power flow. The elements are clamped in place by the hold-down catches on the face of the line section. These catches must be used to avoid error due to the element not contacting the bottom or seating plane of the socket. With the element(s) in place, set the range switches to correspond with the nominal power range of the elements. For example, if the forward element is a 5 watt element, the switches are set at **5** and **x1**. For a 250 watt element they are set at **2.5** and **x100**. Sometimes it is necessary to use milliwatts or kilowatts as the unit of measure. In other words, 1 watt becomes **10 x 100** milliwatts and 2500 watts becomes **2.5 x 1** kilowatts.

SECTION 2
THEORY OF OPERATION

2-1. DESCRIPTION OF OPERATION

2-2. Figure 2-1 is a block diagram of the major functional parts of the 4391 RF Power Analyst. The Microcomputer integrated circuit shown, controls all the other portions of the instrument, which fall into two major groups as follows:

a. Keyboard, Range Switches, and Display Group. The keyboard and range switches serve only to pass information to the computer. The display, of course, returns information from the computer to the operator. The display, which is comprised of four seven-segment LED digits, is strobed digit by digit left to right at a rate of approximately 1 digit per millisecond. This serves to conserve battery power and drive circuitry while providing scanning for the columns of the keyboard. Each time a digit is strobed, the corresponding column of the keyboard is read and if a key is pressed, the computer puts the code for that key into a memory cell. The nine mode keys select which parameter is to be measured. The three modifier keys simply modify the way in which the result is displayed. The range selector switches identify to the computer the nominal full scale values of the elements used. They have no effect on input sensitivity, which is determined by the elements.

b. Plug-in Elements, Analog, Circuitry, and Analog-to-Digital Converter. These components are controlled solely by the computer. The Plug-in Elements in the line section provide low level positive voltages related to the instantaneous value of power. (See Figure 2-2.) The first group of solid state switches selects the forward element, the reflected element, or ground as the input to the preamplifier which boosts these signals to 0.1 to 2.0 volt range. The remaining switches shown as two groups direct the output of the preamp to the analog-to-digital converter either directly or through a peak or negative peak detector. The analog to digital converter converts the voltage to a 15 digit binary number.

2.3. Each reading output by the display is derived from as many as three different voltage readings using the circuitry described in paragraph 2-2. Once these voltages are measured, all the remaining operations are performed within the computer chip as follows:

The voltages are corrected for error due to DC drift in the analog circuitry. Each voltage is converted to square root of power using tables of stored data. Then these values are combined mathematically to arrive at the final result in binary. This is used to update the registers containing the last value, the maximum value, or the minimum value as required. Finally, the result is converted to a decimal number and placed into a register from which the display driving routine operates.

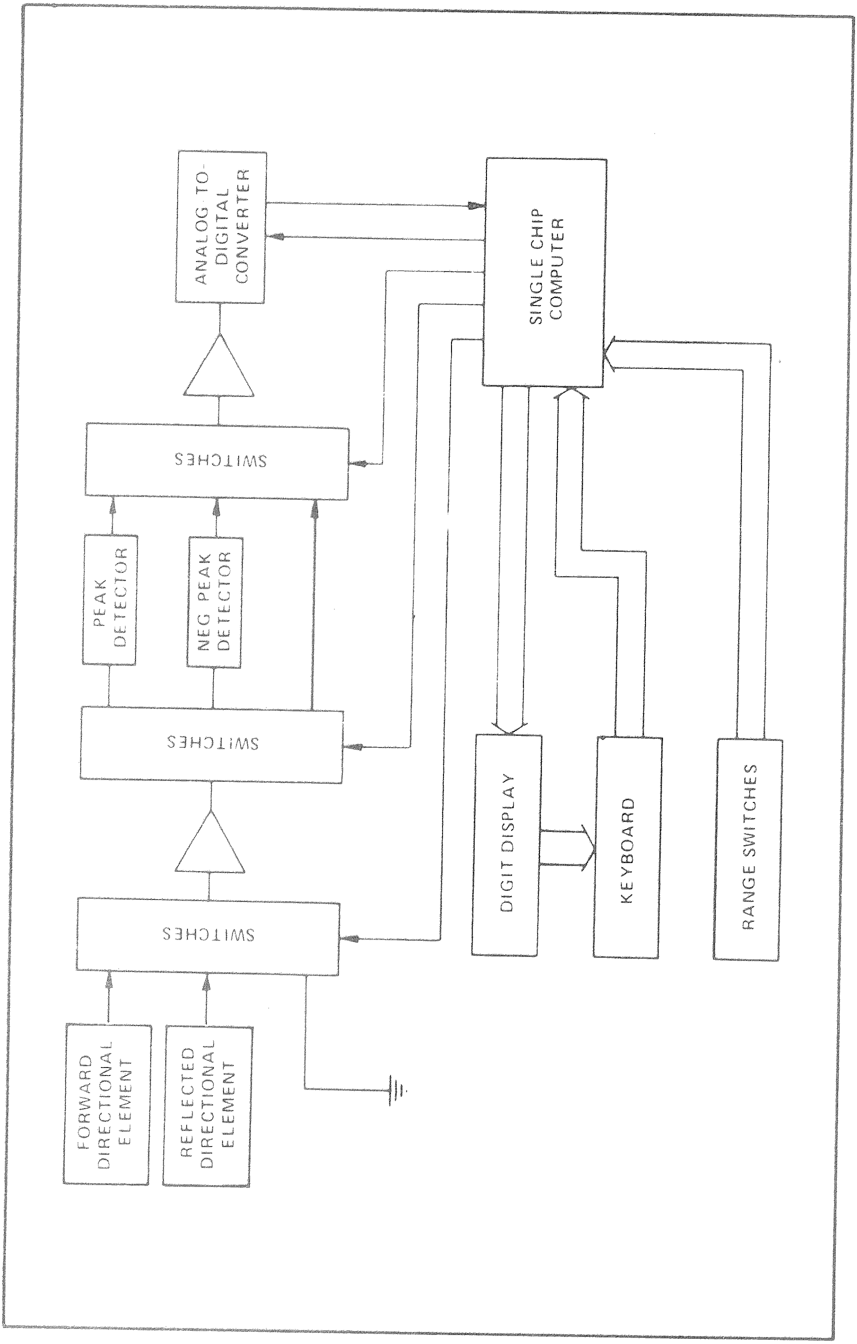
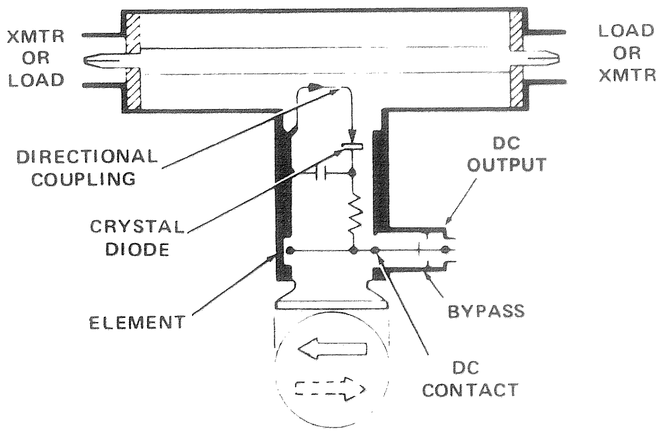


Figure 2-1. Circuit Block Diagram.

ELEMENT CIRCUIT



The coupling circuit which samples the traveling waves is in the Plug-in Element. The circuitry of the Element and its relationship to the other components of the THRULINE are illustrated in the schematic diagram. Energy will be produced in the coupling circuit of the Element by both mutual inductance and capacitance from the traveling RF waves of the line section. The inductive currents will, of course, flow according to the direction of the traveling waves producing them. The capacitive portion of these currents is naturally independent of the direction of the traveling waves. Therefore, assuming that the Plug-in Element remains stationary, it is apparent that the coupling currents produced from the waves of one direction will add in phase, and those produced from waves of the opposite direction will accordingly subtract in phase. The additive or "ARROW" direction is, of course, assigned to the forward wave.

The electrical values of the Element circuits are carefully balanced and so designed that the current produced from the reverse wave will cancel the other almost completely. The resultant is a directivity always higher than 30dB, which means that the Element is highly insensitive (nulled) to the "REVERSE" direction wave. Being highly directional, the THRULINE Element is sensitive (at one setting) only to one of the traveling waves which produces standing waves by interference. THRULINE measurements are therefore independent of position along standing waves.

Figure 2-2. Plug-in Element Schematic Diagram.

Transmission Type and Scope Pattern	Frequency Spectrum (C: Carrier)	PEVrms (arbitrary)	PEP = PEV^2_{rm}/Zo	Average (Heating) Power	4391 Series CW Mode	4391 Series PEP Mode	4391 Series % MOD Mode	Model 43
CW (100V)	C	$\frac{100}{\sqrt{2}}$ V	100W	100W	100W	100W	0%	100W
AM 100% Mod. (200V)	C	$\frac{200}{\sqrt{2}}$ V	400W	150W	100W	400W	100%	100W
AM 73% Mod. (173V)	C	$\frac{173}{\sqrt{2}}$ V	300W	127W	100W	300W	73%	100W
SSB 1 tone (100V)	(C)	$\frac{100}{\sqrt{2}}$ V	100W	100W	100W	100W	0%	100W
SSB 2 tone (100V)	(C)	$\frac{100}{\sqrt{2}}$ V	100W	50W	25W	100W	100%	40.5W
TV Black Level (100V)	C	$\frac{100}{\sqrt{2}}$ V	100W	60.1W	—	100W	—	596W
Pulse (100V; 10% / 90%)	C	$\frac{100}{\sqrt{2}}$ V	100W	10W	—	100W	100%	—

Z_o 50 ohms

PEV Peak Envelope Voltage. Carrier (or suppressed carrier) PEV was arbitrarily chosen at 100 volts in all examples. PEV_{rms} $PEV/\sqrt{2}$.

Figure 2-3. Readings with Various Envelopes.

SECTION 3
OPERATING INSTRUCTIONS

3-1. OPERATING MODES

3-2. The 4391 has nine modes of operation which are selected by pressing the mode keys momentarily. In addition, each mode has three output options selected by pressing the modifier keys. Detailed descriptions of the modes and output options follow:

a. Reading Foward Power. (Figure 3-1.) For this measurement only a forward element is required. Install the meter and element according to the preceding paragraphs and move the power switch to **LINE** or **BAT** depending on the power source desired. When powered up, the 4391 always goes into the forward CW power mode. If the unit is already operating, the forward CW power mode is selected by pressing the **FWD CW** key momentarily. If the applied power exceeds 120% of the range, two right facing arrow heads (i.e., "greater-than" symbols) will be displayed. The operation of this error message does not depend on the correct setting of the range switches by the operator, nor will the meter or its elements be damaged if the switches are incorrectly set.

CAUTION

Never apply RF power to the 4391 unless both line section sockets are filled with either an element or a dust plug. If an element is used it is advisable to place the element with the arrow at a 90° angle to the coaxial line.

CAUTION

Always disconnect AC power before opening the 4391 enclosure. Removal of at least one battery cell is also recommended when servicing the instrument.

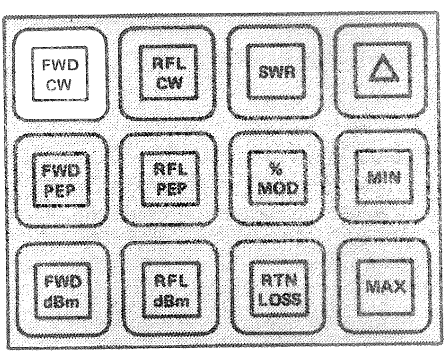


Figure 3-1. Forward Power (CW).

The 4391 arrives at values of CW power by a method quite different from analog meters such as the Model 43 also manufactured by Bird Electronic. While the two instruments will agree when the measured wave is of constant amplitude, AM or SSB waves will result in different indications (in the CW mode). This is because the analog instrument uses the inertia of the microammeter to "time-average" the varying signal coming from the element, whereas the 4391 uses peak and negative peak detector circuits to measure peak and minimum square root of power and combines them using the equation:

$$\text{CW Power} = \left(\frac{\sqrt{\text{Peak Power}} + \sqrt{\text{Minimum Power}}}{2}\right)^2$$

Using this technique, operation of the CW mode is predictable regardless of envelope shape (See Figure 2-3).

b. Reading Reflected CW Power. (Figure 3-2.) Operation of the reflected CW power mode is identical to that for forward CW power described above with two exceptions: the readings are taken from the element in the socket marked "reflected" and the range of the element is assumed to be 1/10 the range indicated by the range switches.

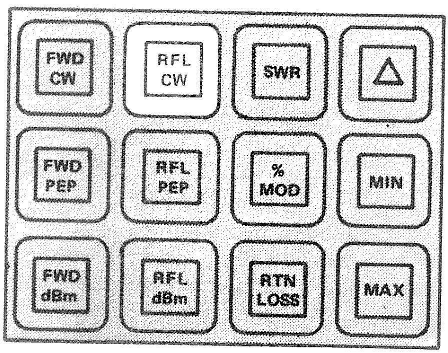


Figure 3-2. Reflected Power (CW).

c. Reading SWR. (Figure 3-3.) Two elements are required for this mode and they must have a 10 to 1 power range ratio. Press the SWR key momentarily. If the average forward power is between 10% and 120% of the full scale and the average reflected power is less than 120% of the reflected element range, SWR will be displayed. If any of the above conditions are not met, an error message will be displayed. Two arrows pointing to the right — or "greater-than" symbols — indicate over-range, while two left pointing arrows — or "less-than" symbols — indicate under-range or too little power. Refer to Table 3-1.

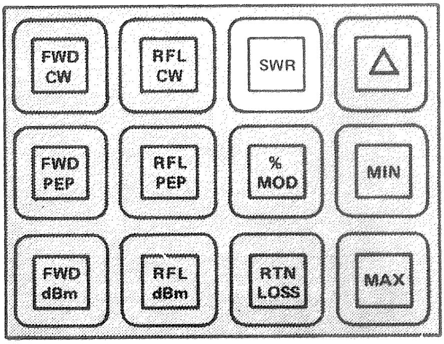


Figure 3-3. Standing Wave Ratio (SWR).

Table 3-1. Voltage Standing Wave Ratio (VSWR).

VSWR	Return Loss dB	Reflected Power %
1.01	46.1	0
1.02	40.1	.01
1.03	36.6	.02
1.04	34.2	.04
1.05	32.3	.06
1.06	30.7	.08
1.07	29.4	.11
1.08	28.3	.15
1.09	27.3	.19
1.1	26.4	.23
1.15	23.1	.49
1.2	20.8	.83
1.25	19.1	1.23
1.3	17.7	1.7
1.35	16.5	2.22
1.4	15.6	2.78
1.45	14.7	3.37
1.5	14	4
1.75	11.3	7.44
2	9.5	11.11
2.25	8.3	14.79
2.5	7.4	18.37
2.75	6.6	21.78
3	6	25
3.25	5.5	28.03
3.5	5.1	30.86
3.75	4.7	33.52

Table 3-1. Voltage Standing Wave Ratio (VSWR). (Cont.)

VSWR	Return Loss dB	Reflected Power %
4	4.4	36
4.25	4.2	38.32
4.5	3.9	40.5
4.75	3.7	42.53
5	3.5	44.44

d. Measuring Peak Envelope Power. (Figure 3-4). PEP power measurements are made in the same manner as the CW power readings described above, except that the **FWD PEP** and **RFL PEP** buttons are pressed and the readings are displayed directly as peak power.

NOTE

The accuracy of measurements made with modulation present which has a frequency, duty cycle, pulse width, or repetition rate **outside the range** of the instrument cannot be assured in any mode of operation.

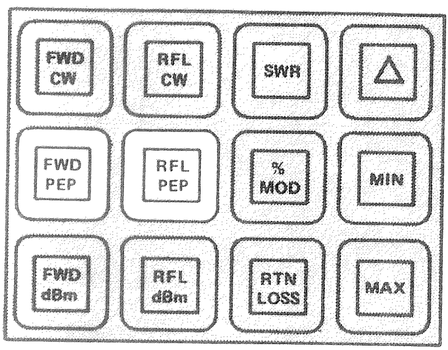


Figure 3-4. Peak Envelope Power (PEP).

e. Measuring Amplitude Modulation. (Figure 3-5.) Only a forward element is required for this mode. The element should be pointed in the direction of forward power and the % **MOD** key pressed. Modulation is displayed directly in percent, provided the average signal is above 10% and the PIP of the signal is below 400% of the element's nominal full scale. For specified measurement accuracy, the average CW power levels must be greater than one third of full scale. Modulation is calculated as follows:

$$\text{MODULATION} = \frac{\sqrt{\text{Peak Power}} - \sqrt{\text{Minimum Power}}}{\sqrt{\text{Peak Power}} + \sqrt{\text{Minimum Power}}} \times 100$$

and is therefore limited to the range of 0 to 99.9%. Over-modulation will be indicated as 99.9%. Refer to Table 3-2.

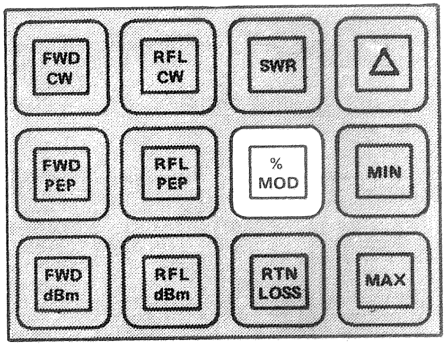


Figure 3-5. Amplitude Modulation (%).

Because of the threshold of the RF diode, a modulated signal which has a minimum power level below 0.3% of full scale will result in high modulation reading with uncertain accuracy.

Table 3-2. Amplitude Modulation.

Peak/CW Power	% Modulation
1	0
1.1	5
1.21	10
1.32	15
1.44	20
1.56	25
1.69	30
1.82	35
1.96	40
2.1	45
2.25	50
2.4	55
2.56	60
2.72	65
2.89	70
3.06	75
3.24	80
3.42	85
3.61	90
3.8	95
4	100

f. Measuring Power in dBm. (Figure 3-6.) Operation of the forward and reflected dBm modes is identical to the foward and reflected CW power modes, except that the resulting reading is converted to dB above 1 milliwatt before it is displayed. It should be noted that in doing this conversion, the range set on the slide switches is assumed to be watts rather than kilowatts or milliwatts. If it is not, 30.0 must be added to all dBm readings when the range is in kilowatts, or subtracted from all readings when it is in milliwatts. An error message is displayed if CW power is more than 24dB below, or peak power is more than 6dB above the nominal element range. Refer to Table 3-3.

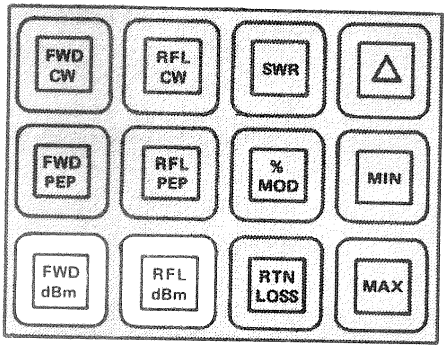


Figure 3-6. CW Power in dBm.

Table 3-3. Watts/dBm Equivalents.

Power	dBm
1 milliwatt	= 0dBm
10 milliwatts	= 10dBm
100 milliwatts	= 20dBm
1 watt	= 30dBm
2 watts	= 33dBm
4 watts	= 36dBm
10 watts	= 40dBm
20 watts	= 43dBm
40 watts	= 46dBm
100 watts	= 50dBm

g. Measuring Return Loss, Insertion Loss, or Attenuation. (Figure 3-7.) The measurement of return loss is the same as that of SWR except that the result is displayed in dB. In other words a reading of 21.65 indicates that reflected power is 21.6dB down from forward power.

Attenuation or insertion loss can be measured directly using an external single port line section (4230-006-1), a DC feed-in adapter (4381-050), and a DC cable (3170-058-6). The 4391 is inserted at the source end of the device being measured. The second line section is inserted at the load end and its DC

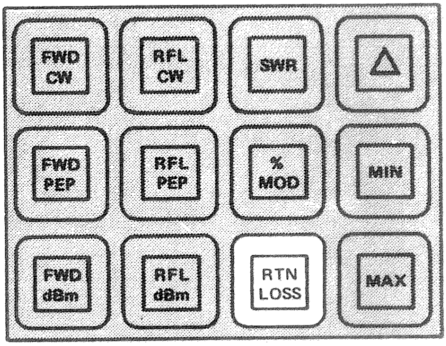


Figure 3-7. Return Loss, Insertion Loss, or Attenuation.

output is routed by the DC cable to the adapter inserted in the "reflected" socket of the 4391. Both elements are in this case pointed in the direction of forward power flow. If the two elements do not have a ten to one ratio a correction factor must be added to or subtracted from the "return loss" reading (See Table 3-4), depending on the ratio of the elements.

Table 3-4. Correction Factors.

Ratio of Elements	Added dB	Ratio of Elements	Added dB
1:1	−10	100:1	10
2:1	−7	200:1	13
2.5:1	−6	250:1	14
4:1	−4	400:1	16
5:1	−3	500:1	17
10:1	0	1000:1	20
20:1	3	2000:1	23
25:1	4	2500:1	24
40:1	6	4000:1	26
50:1	7	5000:1	27

h. Monitoring Maximum and Minimum Readings. (Figure 3-8.) While operating in any of the modes described, the 4391 will continuously keep track of the highest and lowest reading obtained. This action begins after ten reading cycles to allow time for the peak detectors to settle from the previous mode. To recall the maximum or minimum reading, hold the **MAX** or **MIN** key depressed. When these keys are released, the meter goes back to displaying the current value of the parameter being measured. Recalling maximum or minimum does not stop the meter from continuing to monitor the current value and updating the minimum and maximum registers. To clear the minimum and maximum register, the mode key must be pressed again or a new

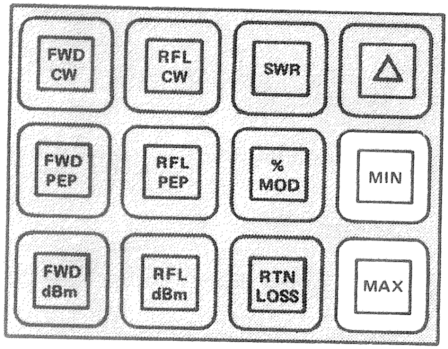


Figure 3-8. Maximum or Minimum Readings.

mode selected. For example, if CW power deviations are to be monitored, the 4391 is installed as described at the beginning of this section and turned on, then the power source is turned on and allowed to stabilize. Once the system has stabilized, and **FWD CW** key is pressed to clear the **MAX** and **MIN** registers. At any time during test the **MAX** and **MIN** keys can be used to recall the maximum and minimum values without affecting the test. However, pressing **FWD CW** or changing modes will clear the registers.

i. Using the Peaking Aid. (Figure 3-9.) The peaking aid is useful for making adjustments to optimize any of the parameters which the 4391 measures. After the mode is selected, the delta (Δ) key is pressed momentarily. This blanks the least significant digit of the display, and replaces it with a right facing arrow head if the measured quantity is increasing and a left facing arrow head if it is decreasing. If there is no change, the digit is left blank. To find a peak, begin making the adjustment in whichever direction produces a right facing arrow head and continue slowly in that direction until the arrow head turns around. At this point the peak has been reached. To check to make sure the peak has not been passed, press the **MAX** key to read the highest value read and release it to read the current value. The two should be the same. Desired minimum levels (e.g. of reflected power or of SWR) are found in a similar manner.

j. Battery Care. With average use, the nickel-cadmium batteries in the 4391 will power the unit for eight hours before recharging is required. The 4391 will maintain rated accuracy until all the decimal points light, indicating recharing is required. Recharging is accomplished by connecting AC power to the unit. This takes approximately 14 hours when the unit is turned off, or 24 hours when it is operating in the "line" position. To prolong the life of the batteries, it is recommended that they be allowed to discharge until the decimal points light periodically before recharging. If the batteries lose the ability to hold a charge they can be replaced with standard C-size nickel-cadmium batteries. See Section 4 for important precautions regarding static electricity when opening the housing.

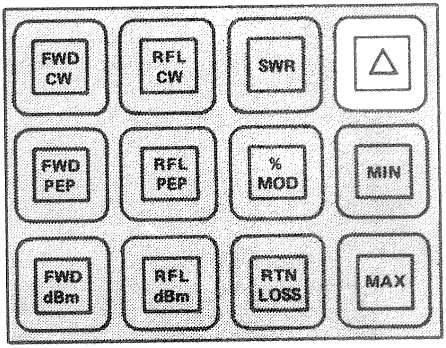


Figure 3-9. Peaking Aid (△).

k. Operating on AC Power. For AC power operation, the 4391 is simply connected to an AC receptacle using the line cord provided. The correct AC voltage is selected via a rear panel switch. The meter may be operated in this manner with the batteries removed if desired.

SECTION 4
MAINTENANCE INSTRUCTIONS

4-1. GENERAL

4-2. Due to its complexity, repair of the 4391 in the field is recommended only for certain malfunctions.

> **CAUTION**
>
> The 4391 contains MOS integrated circuits which may be damaged by static electricity. Open the housing only when sure that there are no static producing materials such as carpeting or styrofoam where the work is to be done. Work on a conductive, grounded work surface touching it frequently to discharge static from your body. If a part is to be stored or shipped, wrap it in aluminum foil.

4-3. LINE SECTION PROBLEMS

4-4. **Worn or Damaged Connectors.** This problem can result in high standing waves. Inspect the connectors visually and replace if required.

4-5. **Worn Element Seats.** The element seat is not plated as manufactured so visual inspection is of little value in detecting this problem. A badly worn seat will cause an element to read 1 or 2% higher than it does in a new line section with power held constant. Remedy by replacing the line section. See Paragraph 4-25 for disassembly.

4-6. **Intermittent Contact.** Touching or slightly rotating the element causes large changes in the reading. Clean the contacts on the element and in the sockets of the line section with a mild cleaning solvent such as alcohol. If the contacts in the line section are recessed too far, bend them out slightly with a small screwdriver. Take care not to bend them out so far as to interfere with the insertion of the element.

4-7. **Loose Catches.** If a catch is loose, the element can be rotated easily and may rock slightly under light finger pressure, resulting in loss of accuracy. This problem can usually be repaired by bending the catch slightly. If not, the line section must be replaced.

4-8. No Output From One Socket. This can result either from a poor contact as described above, or a faulty connection, or short between the line section and the MCU and analog PC board. Check with a VOM and repair.

4-9. BATTERY PROBLEMS

4-10. Short Life. If the batteries lose their ability to hold a full charge, they should be replaced with new batteries available from Bird. Note that any C-size nickel-cadmium battery may be used. See Paragraph 4-25 for disassembly.

4-11. Unit Will Not Operate at All Under Battery Power. This condition probably results from a bad connection. Check all battery connections with a VOM and repair the bad connection.

4-12. POWER SUPPLY PROBLEMS

4-13. Does not function in line position. Check for blown fuse, broken line cord or 115/230 selector switch set incorrectly.

4-14. KEYBOARD PROBLEMS

4-15. Key Does Not Make Contact. If only one key is not working, the problem is in the keyboard. Replace the keyboard. See Paragraph 4-25 for disassembly.

4-16. Row or Column Not Working. This is likely to be caused by an open or short circuit inside the keyboard or between the keyboard and the computer chip. Remedy by locating short or open and correcting it.

4-17. DISPLAY PROBLEMS

4-18. One Segment on One Digit Out. This can only be caused by a defective LED display, its socket, or an open connection where the socket is soldered to the PC board. Switch displays to isolate the problem.

4-19. Entire Digit Malfunction. This is usually caused by a fault in the drive circuitry to the digit. If the keyboard is malfunctioning, check for a short or an open between the microcomputer chip and the drive transistors for the digit readout.

4-20. Same Segment on All Digits Malfunctioning. This problem can only be caused by a defective 7447 driver IC or a short or open between the driver and the displays.

4-21. No Decimal Point or All Decimal Points. The decimal point is driven by a PNP transistor near the 7447 IC. A short or open on either side of this transistor can cause the problem. Note: An all decimal point display may indicate low supply voltage or a defect in the supply voltage circuitry. The DC input at the power switch should measure at least 7.0 volts DC.

4-22. Strange Counting Sequence. If this happens, there is a problem in the binary coded decimal signal coming from the computer chip to the driver IC. Isolate the problem and repair. The 7447 IC may be at fault.

4-23. OTHER DISORDERS

4-24. For problems more complex than those listed above, it may be necessary to return the meter to Bird for analysis or to replace one or both circuit boards. A call or telegram to the Bird Customer Service Department will help determine the best solution to these problems.

> **CAUTION**
>
> The 4391 contains MOS integrated circuits which may be damaged by static electricity. Open the housing only when sure that there are no static producing materials such as carpeting or styrofoam where the work is to be done. Work on a conductive, grounded work surface touching it frequently to discharge static from your body. If a part is to be stored or shipped, wrap it in aluminum foil.

4-25. DISASSEMBLY

4-26. Front Panel Removal. To take off the front panel, first loosen but do not remove the five #4-40 oval head screws on each side of the housing. Then remove the size #4-40 oval head screws and four #6-32 pan head screws holding the front panel on. The front panel may now be carefully pulled up at its upper end (to clear the line sections blocks), then simply lift out the panel from case.

The main PC board can be tilted upwards by removing the front four of the six #4-40 oval head screws securing its mounting rails. These screws hold the mounting rails to the inside of the case and are located on each side of the housing just below the top edge. The back two screws, just above the RF connectors, although loosened, remain in place. This board must be removed completely in order to remove the line section.

4-27. Removing the Line Section. Remove the eight pan head screws holding the QC connectors and remove the connectors. Remove the four oval head screws which hold the line section to the sides of the case. Using finger pressure, spread the case open just enough to pull the line section straight up and out.

4-28. Removing the Line Section PC Board. Remove the four screws holding the PC board to the line section. Pull the board straight away from the line. Note the positions of the spacers and white teflon beads for reassembly.

4-29. DECREASING THE SETTLING TIME.

4-30. When low duty cycle and low repetition rate pulse measurements are not required, resistors R09 and R10 on the line section PC board can be changed to 4.7MΩ and 2.2MΩ, ¼ watts, respectively, this halves the settling time while maintaining good rejection of 50 or 60 Hz noise.

4-31. CALIBRATION

4-32. Recalibration of the Model 4391 is accomplished by using a direct current source. Equipment required is an adjustable current source, or a battery with a multiple turn potentiometer, connected in series with its leads, capable of supplying 30 microamperes into a 1400 ohm load, and a 4½ digit microammeter. A DC feed in Adapter P/N 4381-050 is also useful and is recommended.

4-33. Connect the negative side of the current source to the body of the line section in the Model 4391. Connect the positive side of the current source to the positive terminal of the microammeter. The negative terminal lead of the microammeter is attached to the wiper contact in the forward Element socket of the line section. If the DC Adapter (P/N 4381-050) is used, the negative side of the current source is connected to the outer conductor of the BNC connector and the lead from the negative terminal of the microammeter goes to the BNC center contact.

4-34. Set the 4391 range switches to the 10 and x100 settings. Turn the unit on and select the forward CW mode. Adjust the current source until the microammeter indicates 30.00 ±.05 microamperes. The Model 4391 display should now read 1000 ±5. If the display shows an error greater than the ±5 tolerance, remove the front panel, as described in Section 4-25 Disassembly. Adjust the calibration potentiometer, located just below the forward Element socket, until a reading of exactly 1000 is obtained.

No other calibration is required. For maximum accuracy, calibration should be checked, and the unit recalibrated if necessary, at least once a year.

SECTION 5
PARTS LIST

5-1. GENERAL

5-2. The parts listed in this section are those recommended for replacement by the manufacturer. Do not disassemble beyond the instructions of Section 4, Maintenance since replacement parts other than those described are not available.

MODEL 4391 PARTS LIST

Qty. Req'd.	Description	Part Number
1	Line Section (less PC Board)	4381-005
6	Batteries (Recharable) "C" Size	5-1230
1	Battery Holder	4391-019
6	Clip, Battery Retainer	5-1325
2	Keyboard, Module	5-1277
1	Legend, Keyboard	4386-012
3	Switch, Toggle SPDT	5-1327
4 (DS1-DS4)	Display, LED	5-1337
1	Bezel, Display	4381-060
1	Filter, Red	4381-061
6	Pushnut	5-1076-2
1	Bail	4381-012
1	Filter, Power Line	5-1275
1	Fuse Holder	5-1326
1	Fuse 1/8 A, 250 VAC	5-721-8
1	Switch, Slide	5-1088
1	Transformer	5-1276
1	Transformer Assy., (includes rectifier circuit)	4391-020
1	PC Board Assembly (on line section)	4391-005
1 (UO1)	OP AMP Wideband	5-1330
2 (UO2, UO3)	Comparator, Voltage	5-1328
1 (UO4)	OP AMP, Micropower	5-1332
2 (UO5, UO6)	Multiplexer, Analogue	5-1333
1 (UO7)	Converter, Analogue to Digital	5-1217
2 (CRO1, CRO2)	Diode	5-1225
1	PC Board Assy., Processor	4391-007
9 (QO1-QO9)	Transistor (2N3906)	5-1090
1 (UO8)	NAND Gate (74LS00)	5-1219
1 (UO9)	I.D. Microcomputer	4381-035
1 (U10)	Decoder, Driver	5-1220
1 (U11)	Regulator Voltage (5 volt)	5-1100-1
1 (U12)	Converter, Voltage (5 volt)	5-1331
1 (U13)	Regulator, Positive (3 term)	5-1334-1
1 (U14)	Comparator, Voltage	5-1267
1 (X1)	Crystal, Microprocessor	5-1214
1	Connector, Socket, Assy.	4391-021
1	Power Cord, 115V	5-1286
1	Power Cord, 230V	5-1287
1	I/O Cable Ass'y.	4380-514

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