SECTION I
GENERAL INFORMATION

1-1. DESCRIPTION.

1-2. The Hewlett-Packard Models 333A and 334A Distortion Analyzers are solid state instruments for measuring distortion on ac voltages. The Models 333A and 334A include two control loops that automatically tune both legs of a bridge circuit which rejects the fundamental when the rejection circuit is initially set within the range of the loops. The 334A has a high impedance detector which operates from 550 kHz to greater than 65 MHz and provides the capability of monitoring the distortion of the amplitude modulation on an rf carrier.

1-3. Distortion levels of 0.1% to 100% full scale are measured in seven ranges for any fundamental frequency of 5 Hz to 600 kHz. Harmonics are indicated up to 3 MHz. The high sensitivity of these instruments requires only 0.3V rms for the 100% set level reference. The distortion characteristics can be monitored at the OUTPUT connectors with an oscilloscope, a true rms voltmeter, or a wave analyzer. The instruments are capable of an isolation voltage of 400 volts above chassis ground.

1-4. The voltmeter can be used separately for general purpose voltage and gain measurements. It has a frequency range of 5 Hz to 3 MHz (20 Hz to 500 kHz for 300 μV range) and a voltage range of 300 μV to 300 V rms full scale.

1-5. The AM detector included in the Model 334A is a broadband dc restoring peak detector consisting of a semiconductor diode and filter circuit. AM distortion levels as low as 0.3% can be measured on a 3 V to 8 V rms carrier modulated 30% in the standard broadcast band. Distortion less than 1% can be measured at the same level of the carrier up to 65 Mc.

1-6. ACCESSORY FEATURES.

1-7. The accessory available with the 333A and 334A Distortion Analyzers is a voltage divider probe, -hp- Model No. 10001A. The features of the probe are:
   a. 10 megohms shunted by 10 pF, giving 10:1 attenuation.
   b. DC to 30 MHz bandwidth.
   c. 2% division accuracy.
   d. 600 V peak input.
   e. 5 ns rise-time.

1-8. OPTION.

1-9. Option 01 is a standard -hp- Model 333A or 334A with a special meter and meter amplifier, compensated to permit response to VU (volume units) characteristics.

1-10 INSTRUMENT IDENTIFICATION.

1-11. Hewlett-Packard uses a two-section serial number. The first section (prefix) identifies a series of instruments. The last section (suffix) identifies a particular instrument within the series. If a letter is included with the serial number, it identifies the country in which the instrument was manufactured. If the serial prefix of your instrument differs from the one on the title page of this manual, a change sheet will be supplied to make this manual compatible with newer instruments or the backdating information in Appendix C will adapt this manual to earlier instruments. All correspondence with Hewlett-Packard should include the complete serial number.

Table 1-1. Specifications

<table>
<thead>
<tr>
<th>MODEL 333A</th>
<th>Fundamental Input Greater Than 30 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTORTION MEASUREMENT RANGE</td>
<td>RANGE</td>
</tr>
<tr>
<td>Any fundamental frequency, 5 Hz to 600 kHz. Distortion levels of 0.1%-100% are measured full scale in 7 ranges.</td>
<td>100%–0.3%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>DISTORTION MEASUREMENT ACCURACY</td>
<td>RANGE</td>
</tr>
<tr>
<td>Harmonic measurement accuracy (full scale)</td>
<td>100%–0.3%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1%</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Elimination Characteristics:
- Fundamental Rejection > 80 dB
- Second Harmonic Accuracy for a fundamental of:
  - 5 Hz to 20 Hz: better than +1 dB
  - 20 Hz to 20 kHz: better than ±0.6 dB
  - 20 kHz to 100 kHz: better than -1 dB
  - 100 kHz to 300 kHz: better than -2 dB
  - 300 kHz to 600 kHz: better than -3 dB
Table 1-1. Specifications (Cont'd)

Distortion Introduced by Instrument:
- > -70 dB from 5 Hz to 200 kHz
- > -64 dB from 200 kHz to 600 kHz

Meter indication is proportional to the average value of a waveform.

FREQUENCY CALIBRATION ACCURACY
Better than ±5% from 5 Hz to 300 kHz
Better than ±10% from 300 kHz to 600 kHz

INPUT IMPEDANCE
Distortion Mode: 1 MΩ ±5% shunted by <70 pF.
Voltmeter Mode:
- 1 MΩ ±5% shunted by <30 pF (333A only),
- 1 MΩ ±5% shunted by <35 pF (334A only),
1 to 300 V ranges; 1 MΩ ±5% shunted by <70 pF, 300 µV to 0.3 V ranges.

INPUT LEVEL FOR DISTORTION MEASUREMENTS
0.3 V rms for 100% set level (up to 300 V may be attenuated to set level reference). The minimum measurable distortion for floating operation on the X1 frequency range is 50 dB below the fundamental.

DC ISOLATION
Signal ground may be ±400 Vdc from external chassis.

VOLTMETER RANGE
300 µV to 300 V rms full scale (13 ranges), 10 dB per range.

VOLTMETER FREQUENCY RANGE
5 Hz to 3 MHz (300 µV range: 20 Hz-500 kHz).

VOLTMETER ACCURACY:

<table>
<thead>
<tr>
<th>RANGE</th>
<th>±2%</th>
<th>±5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>300 µV</td>
<td>30 Hz-300 kHz</td>
<td>20 Hz-500 kHz</td>
</tr>
<tr>
<td>1 mV-30 V</td>
<td>10 Hz-1 MHz</td>
<td>5 Hz-3 MHz</td>
</tr>
<tr>
<td>100 V-300 V</td>
<td>10 Hz-300 kHz</td>
<td>5 Hz-500 kHz</td>
</tr>
</tbody>
</table>

NOISE MEASUREMENTS
Voltmeter residual noise on the 300 µV range:
< 25 µV rms terminated in shielded 600Ω; < 30 µV rms terminated in shielded 100 kΩ.

OUTPUT
For input frequencies from 20 Hz to 600 kHz, 0.1 V rms ± 0.01 V open circuit for full scale meter deflection; 0.05 V rms ± 0.005 V into 2 kΩ for full scale meter deflection.

AUTOMATIC NULLING MODE
Set Level: At least 0.2 V rms.
Frequency Ranges:
X1, manual null tuned to less than 3% of set level; total frequency hold-in ±0.5% about true manual null.
X10 through X10 K, manual null tuned to less than 10% of set level; total frequency hold-in ±1% about true manual null.

AUTOMATIC NULL ACCURACY
5 Hz to 100 Hz: Meter reading within 0 to +3 dB of manual null.
100 Hz to 600 kHz: Meter reading within 0 to +1.5 dB of manual null.

HIGH-PASS FILTER
3 dB point at 400 Hz with 18 dB per octave roll off. 60 Hz rejection > 40 dB. Normally used only with fundamental frequencies greater than 1 kHz.

POWER SUPPLY
100 V/120 V/220 V/240 V + 5% - 10%, 48 - 66 Hz, approximately 4 watts.

MODEL 334A
Same as Model 333A except as indicated below:

AM DETECTOR
High impedance dc restoring peak detector with semi-conductor diode operates from 550 kHz to greater than 65 MHz. Broadband input. Maximum input: 40 V p-p ac or 40 V peak transient.

CARRIER FREQUENCY
550 kHz to 1.8 MHz: Distortion introduced by detector is < 0.3% for 3 to 8 volt carriers modulated 30%.

1.6 MHz to 65 MHz: Distortion introduced by detector is < 1% for 3 to 8 volts rms carriers modulated 30%.

--- NOTE ---
Distortion measurement at carrier levels as low as 1 volt may be made with reduced accuracy.

OPTION: 01
Indicating meter has VU characteristics conforming to FCC Requirements for AM, FM, and TV broadcasting.
1. LINE switch turns instrument ac power on. Pilot lamp glows when instrument is turned ON.
2. Meter indicates distortion or voltage level of input.
3. MODE switch selects MANUAL or AUTOMATIC bridge tuning operation.
4. FREQUENCY RANGE switch selects frequency range which corresponds to fundamental of input signal.
5. COARSE BALANCE control provides coarse adjustment for balancing the Wien bridge circuit.
6. FINE BALANCE control provides a vernier adjustment for balancing the Wien bridge circuit.
7. Frequency dial tunes the Wien bridge circuit to fundamental of input signal.
8. HIGH PASS FILTER switch inserts or bypasses HIGH PASS FILTER in SET LEVEL and DISTORTION function. When inserted, filter provides > 40 dB attenuation to 50 - 60 Hz hum components but no attenuation to frequencies over 1 kHz.
9. OUTPUT connectors provide means of monitoring output of meter circuit.
10. Frequency vernier provides fine adjustment of frequency dial.
11. METER RANGE switch selects full scale range of meter in percent, dB and rms volts.
12. SENSITIVITY selector provides 0 - 50 dB attenuation of input signal in 10 dB steps in SET LEVEL and DISTORTION functions.
13. SENSITIVITY VERNIER control provides fine adjustment of sensitivity setting.
14. Mechanical zero adjust provides mechanical zero adjustment of meter.
15. FUNCTION switch selects type of operation of instrument.
16. Shorting bar connects circuit ground to chassis ground.
17. INPUT terminals provide connections for input signal.
18. NORM RF DET (Model 334A only) selects front panel INPUT or rear panel RF INPUT connector.
19. RF INPUT connector (Model 334A only) provides input connection for AM RF carrier input signal.
20. FUSE provides current overload protection for instrument circuits.
21. Line voltage switch sets instrument to operate from 100 V/120 V/220 V/240 V.
22. Ac power connector provides input connection for ac power.

Figure 3-1. Front and Rear Panel Description

3-0
SECTION III
OPERATING INSTRUCTIONS

3-1. INTRODUCTION.

3-2. The Models 333A and 334A Distortion Analyzers measure total harmonic distortion of fundamental frequencies from 5 Hz to 600 kHz; harmonics up to 3 MHz are included. The sharp elimination characteristics (>80 dB), the low level of instrument induced distortion, and the meter accuracy of these instruments result in highly accurate measurement of low level harmonic distortion.

3-3. An rms calibrated voltmeter is inherent in the 333A and 334A. The voltmeter provides a full scale sensitivity of 300 µV volts rms (residual noise <25µV volts). The voltmeter frequency range is from 5 Hz to 3 MHz except on the 0.003 volt range, which is from 20 Hz to 500 kHz.

3-4. CONTROLS AND INDICATORS.

3-5. Figure 3-1 illustrates and describes the function of all front and rear panel controls, connectors, and indicators. The description of each component is keyed to the drawing included within the figure.

3-6. GENERAL OPERATING INFORMATION.

3-7. INPUT CONNECTIONS.

3-8. The input signal can be connected to the 333A and 334A through twisted pair leads or a shielded cable with banana plug connectors. Keep all test leads as short as possible to avoid extraneous pickup from stray ac fields. When measuring Low-level signals, ground loops may occur causing erroneous readings. Ground loops may be avoided by connecting the 333A/334A Distortion Analyzer to an appropriate isolation transformer to break the chassis ground from power supply ground. Connect all other instruments to one power strip with the three-prong connectors as close as possible.

3-9. VOLTMETER CHARACTERISTICS.

3-10. The RMS VOLTS markings on the meter face are based on the ratio between the average and effective (rms) values of a pure sine wave. The ratio of average to effective values in a true sine wave is approximately 0.9 to 1. When the meter is used to measure complex waves, the voltage indicated may not be the rms value of the signal applied. This deviation of meter indication exists because the ratios of average to effective values are usually not the same in a complex wave as in a sine wave. The amount of deviation depends on the magnitude and phase relation between the harmonics and fundamental frequency of the signal applied. Table 3-1 lists the deviation of the meter indication of a sine wave partly distorted by harmonics. As indicated in the table, harmonic content of less than 10% results in very small errors.

<table>
<thead>
<tr>
<th>Input Voltage Characteristics</th>
<th>True RMS Value</th>
<th>Meter Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental = 100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Fundamental + 10% 2nd harmonic</td>
<td>100.5</td>
<td>100</td>
</tr>
<tr>
<td>Fundamental + 20% 2nd harmonic</td>
<td>102</td>
<td>100 - 102</td>
</tr>
<tr>
<td>Fundamental + 50% 2nd harmonic</td>
<td>112</td>
<td>100 - 110</td>
</tr>
<tr>
<td>Fundamental + 10% 3rd harmonic</td>
<td>100.5</td>
<td>96 - 104</td>
</tr>
<tr>
<td>Fundamental + 20% 3rd harmonic</td>
<td>102</td>
<td>94 - 108</td>
</tr>
<tr>
<td>Fundamental + 50% 3rd harmonic</td>
<td>112</td>
<td>90 - 116</td>
</tr>
</tbody>
</table>

NOTE

This chart is universal in application since these errors are inherent in all average-responding voltage-measuring instruments.

3-11. When making distortion measurements where the fundamental frequency is suppressed and the remainder of the signal is measured, the reading obtained on an average responding meter may deviate from the true total rms value. When the residual wave contains many inharmonically related sinusoids, the maximum error in the distortion reading is about 11% (11% of the measured distortion) low for distortion levels below 10%.

EXAMPLE:

<table>
<thead>
<tr>
<th>Measured Distortion</th>
<th>Maximum Error In Meter Indication</th>
<th>Total Distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5%</td>
<td>+0.11x0.025 = 0.025</td>
<td>0.025 + 0.0027 = 0.0277 or 2.5%</td>
</tr>
</tbody>
</table>

This example represents the maximum possible error, and in most cases the error is less. In distortion measurements, the reading of an average-responding meter is sufficiently close to the rms value to be satisfactory for most applications.

3-12. OUTPUT TERMINALS.

3-13. The OUTPUT terminals provide a 0.1 V rms open circuit output for full scale meter deflection. These terminals can be used to monitor the output signal with an oscilloscope, a true rms voltmeter, or a wave analyzer. The combination of the distortion meter and oscilloscope provides more significant in-
formation about the device under test than the expression of distortion magnitude alone. Information obtained from the oscilloscope pattern is specific and reveals the nature of distortion which sometimes occurs at such low levels that it is difficult to detect in the presence of hum and noise. The impedance at the OUTPUT terminals is 2000 ohms, therefore, capacitive loads greater than 50 pF should be avoided to maintain the accuracy of meter readings.

3-14. OPERATING PROCEDURES.

3-15. INSTRUMENT TURN-ON.

a. Set the 115-230 VAC switch to coincide with the line voltage in use. Turn switch to ON position. Pilot lamp will glow, indicating application of primary power.

3-16. ADJUSTMENT OF METER MECHANICAL ZERO.

3-17. The meter is properly zero-set when the pointer rests over the zero calibration mark and the instrument is in its normal operating environment and is turned off. Zero-set the meter as follows to obtain maximum accuracy and mechanical stability:

a. Turn instrument on and allow it to operate for at least 20 minutes, to let meter movement reach normal operating temperature.

b. Turn instrument off and allow 30 seconds for all capacitors to discharge.

c. Rotate zero adjustment screw clockwise until pointer is left of zero and moving upscale.

d. Continue rotating screw clockwise; stop when pointer is exactly at zero.

e. When pointer is exactly over zero, rotate adjustment screw slightly counterclockwise to relieve tension on pointer suspension. If pointer moves off zero, repeat steps c through e, but make counterclockwise rotation less.

3-18. DISTORTION MEASUREMENT.

[CAUTION]

DO NOT EXCEED THE INPUT VOLTAGES LISTED BELOW TO PREVENT DAMAGING COMPONENTS ON A2 BOARD.

VOLTMETER FUNCTION –1V RANGE AND BELOW, AND DISTORTION ANALYZER FUNCTION – MAXIMUM SENSITIVITY.
1. 300 V ABOVE 100 Hz
2. 50 V ABOVE 1 kHz

3-19. MANUAL MODE.

a. Turn instrument on and mechanically zero meter according to procedure in Paragraphs 3-15 and 3-16.

3-2

b. Set NORM-R. F. DET. switch to NORM.

c. Set FUNCTION switch to SET LEVEL.

d. Set MODE switch to MANUAL.

e. If fundamental frequency is 1kHz or greater, set HIGH PASS FILTER switch to IN.

f. Set SENSITIVITY selector to MIN. position, and rotate VERNIER control maximum counterclockwise.

NOTE

The bandwidth of the SENSITIVITY selector is reduced in the two extreme CCW positions (positions used with an input signal greater than 30 V).

g. Set METER RANGE switch to SET LEVEL, and set BALANCE COARSE and FINE controls to center position.

h. Connect signal to be measured to 333A/334A INPUT terminals.

WARNING

REMOVE SHORTING STRAP BETWEEN FRAME GROUND (⊥) AND CHASSIS GROUND (△) TERMINALS ON FRONT PANEL INPUT TERMINALS WHEN MEASURING DISTORTION BETWEEN TWO POINTS WHICH ARE DC OFFSET FROM GROUND POTENTIAL.

i. Set SENSITIVITY selector to obtain meter indication greater than 1/3 full scale.

j. Adjust SENSITIVITY VERNIER for full scale meter indication if making distortion measurement in percent; if making distortion measurement in dB adjust SENSITIVITY VERNIER for 0 dB meter indication.

NOTE

If unable to adjust for full scale or 0dB indication, (which indicates input signal is below 0.3 volts), set METER RANGE selector down-scale. Use this new setting as the 100% or 0dB SET LEVEL position, thus making the next range 30% or -10 dB, etc.

k. Set FREQUENCY RANGE switch and frequency dial to fundamental frequency of input signal.

l. Set FUNCTION switch to DISTORTION.

m. Adjust frequency dial vernier and BALANCE COARSE and FINE controls for minimum
meter indication. Set METERRANGE switch down-scale as necessary to keep meter indication on scale.

n. Repeat step m until no further reduction in meter indication can be obtained.

o. Observe distortion either in percentage or dB, as indicated by meter deflection and METERRANGE switch setting. For example, if meter indicates 0.4 and METERRANGE setting is 1%, distortion measured is 0.4% of fundamental. Similarly, if meter indicates -6 dB and METERRANGE setting is -40 dB, distortion measured is -46 dB from fundamental.

--- NOTE ---
In MANUAL mode the accuracy of distortion measurements is affected by frequency stability of the input signal. An inaccuracy in distortion indications occurs when the frequency drift of the input signal exceeds the bandwidth of the rejection curve.

p. If desired, rms voltage of input signal can be measured by setting FUNCTION switch to VOLTMETER, and setting METERRANGE switch to obtain an on-scale indication.

3-20. AUTOMATIC MODE.

a. Perform steps a through l of Paragraph 3-19.

b. Adjust frequency dial vernier and BALANCE COARSE and FINE controls for minimum meter indication.

c. When meter indication is less than 10% of SET LEVEL indication, set MODE switch to AUTOMATIC. (If fundamental cannot be manually nulled below 10% of SET LEVEL indication, automatic mode cannot be used).

d. Set METERRANGE switch down-scale to obtain on-scale meter indication.

e. Observe distortion either in percentage or dB, as indicated by meter deflection and METERRANGE switch setting. For example, if meter indicates 0.4 and METERRANGE setting is 1%, distortion measured is 0.4% of fundamental. Similarly, if meter indicates -6 dB and METERRANGE setting is -40 dB, distortion measured is -46 dB from fundamental.

f. If desired, rms voltage of input signal can be measured by setting FUNCTION switch to VOLTMETER, and setting METERRANGE switch to obtain an on-scale indication.

3-21. DISTORTION MEASUREMENT OF AM RF CARRIERS (334A only).

--- CAUTION ---
DO NOT EXCEED MAXIMUM INPUT VOLTAGES LISTED ON REAR PANEL.

a. Turn instrument on and mechanically zero meter according to procedure in Paragraphs 3-15 and 3-16.

b. Set NORM.-R. F. DET. switch to R. F. DET.

c. Connect input signal to R. F. INPUT terminal on rear panel.

d. Refer to Paragraph 3-19 for manual distortion measurement; refer to Paragraph 3-20 for automatic distortion measurement.

--- NOTE ---
If no meter deflection can be obtained with an RF input, diode A4CRI should be checked. A spare diode is located on the outside of the A4 shield.

3-22. VOLTAGE MEASUREMENT.

a. Turn instrument on and mechanically zero meter according to procedure in Paragraphs 3-15 and 3-16.

b. Set NORM.-R. F. DET. switch to NORM.

c. Set FUNCTION switch to VOLTMETER.

d. Set METERRANGE switch to a range exceeding amplitude of signal to be measured.

e. Connect signal to be measured to INPUT terminals.

f. Set METERRANGE switch to give a reading as close to full scale as possible, and observe meter indication.

g. The dB scale of the 333A/334A is calibrated in dBm, such that 0 dBm = 1 milliwatt dissipated by 600 ohms. Therefore, a dBm measurement must be made across 600 ohms. However, dB measurements across other impedances can be converted to dBm by use of the Impedance Correction Graph of Figure 3-3. For example, to convert a -30 dB reading across 200 ohms to dBm, locate the 200 ohm impedance line at the bottom of the graph. Follow the impedance line to the heavy black line, and read the meter correction at that point. The correction for 200 ohms is +5 dBm; thus the corrected reading is -25 dBm.

3-3
3-23. METER INDICATION.

3-24. The 333A/334A meter is calibrated to indicate in both dB and volts. It is interesting to note that the METER RANGE markings differ from most ac voltmeter range markings. On most ac voltmeters (600 ohms) 0 dB corresponds to the 1 volt range. This is not true in the case of the 333A/334A. Since the instrument is primarily a distortion analyzer, measurements are in dB (relative measurement) rather than in dBm (absolute measurement). Zero dB on the 333A/334A corresponds to 0.3 volt range rather than the 1 volt range. This allows a 10 dB greater dynamic range of distortion measurements.

3-25. If measurements are to be made in dBm, 10 dB must be subtracted from the METER RANGE setting. Thus 0 dB becomes the -10 dBm range for absolute power measurements. Zero dBm is equal to 1 milliwatt dissipated by any impedance and in this particular case is 600 ohms. The +10 DECIBELs marking on the meter face indicates that when voltmeter measurements are being made, the indication (METER RANGE plus meter indication) is 10 dB greater than when power (dBm) measurements are being made.

3-26. In short, when distortion and voltage measurements are being made, utilize the instrument METER RANGE and meter scale as they exist. For absolute power measurements in dBm, simply subtract 10 dB from the METER RANGE setting.

3-27. USE OF OUTPUT TERMINALS.

3-28. In VOMETER and SET LEVEL functions, the 333A/334A can be used as a low distortion, wide-band amplifier. A portion of the meter input (0.1 V rms open circuit for full scale meter deflection is provided at the OUTPUT terminals.

3-29. In DISTORTION function, the distortion (0.1 V rms open circuit for full scale deflection) is provided at the OUTPUT terminals for monitoring purposes.

NOTE

The INPUT terminal and the OUTPUT terminal should not be connected directly together when making low level measurements. These terminals are isolated from each other by 1 ohm which reduces the effects of common mode voltages.

3-30. 333A/334A WITH OPTION 01.

3-31. Operating procedures for the 333A/334A with Option 01 are the same as for the standard instrument. The only difference between the standard and optional instrument is that the Option 01 has a special meter and meter amplifier which is compensated to respond to VU (volume unit) characteristics.

3-32. MANUAL NULLING.

3-33. Since the frequency and balance controls are rather sensitive in the MANUAL mode, the following information is supplied to simplify nulling the 333A/334A in the MANUAL mode. When nulling the 333A/334A in the MANUAL mode, connect the equipment as shown below and adjust the 333A/334A frequency and balance controls for the waveform shown in step a below. Additional waveforms are provided to simplify nulling.

a. No harmonic distortion. Frequency and balance adjustment correct.
b. Frequency and balance control improperly adjusted.
c. Frequency approximately correct; balance incorrect.
d. Balance approximately correct; frequency incorrect.
e. Second harmonic predominant; frequency and balance adjusted.
f. Second harmonic predominant; frequency and balance adjusted; phase changed.
g. Second harmonic predominant; frequency and balance adjusted; phase changed.
h. Third harmonic predominant.
i. Balance incorrect; meter reading off scale.
j. Frequency incorrect; meter reading off scale.
Figure 4-1. Block Diagram