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IE-30A Manual

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Introduction

Congratulations! With your purchase of the Ivie IE-30A, you have one of the most powerful, portable, and accurate analyzers available. The IE-30A combines a full octave and 1/3 octave real time spectrum analyzer with a Type I precision sound level meter. Included with this package is an instrumentation quality, air condenser microphone and preamplifier**.** For years, air condenser microphones have been recognized as the world standard for accuracy.

Additionally, the IE-30A is calibrated both in dB SPL and in dBµV, which makes it suitable for a wide variety of simple and complex measurements, including sound pressure level, amplifier gain, frequency response, output power, peak accumulation, and impulse measurement, just to name a few.

Every IE-30A is built to last. The case is aluminum, coated with a durable, baked enamel, and the internal construction is 100% modular. Every IE-30A is thoroughly and painstakingly tested to assure complete performance. Each unit is then heat tested in an oven for 72 hours at 125^{o}F to assure reliability. Any unit that doesn't measure up doesn't leave the factory.

The following pages of this manual explain the many features and uses of the IE-30A. We suggest that it be read thoroughly.

Getting to Know the IE-30A

With your IE-30A, you should have received the following standard accessories:

* IE-30A equipped with "fast charge" nickel cadmium batteries.
* AC Adaptor/Charger (IE-190B or equivalent)
* Standard phone plug patch cord
* IE-1036A or IE-1036B real time analyzer probe.
* IE-2P precision microphone preamplifier
* 1133 free field, or 1134 random response, air condenser microphone
* IE-30A carrying case and IE-30A owner's manual

Please charge your IE-30A for two hours after it is unpackaged. This will assure two full hours of operating time before recharging is again necessary. Now, let's take a look at the IE-30A accessories, controls and features.

The IE-30A Microphone and Preamp

The IE-30A comes standard with a 1/2 inch air condenser microphone (your choice of a free field or a random response microphone), and the IE-2P Precision Preamplifier. 1/4 inch, 1/8 inch, and 1 inch air condenser microphones are available on a special order basis.

Providing such a quality front-end with your IE-30A is not an inexpensive proposition. You will discover that if you lose your microphone and preamp, it will cost more than a thousand dollars to replace them. However, we feel strongly that an analyzer and sound level meter can not be more accurate or reliable than the microphone that comes with it. If you look at other analyzers on the market today, you will find that many come without microphones, and many others come with relatively inexpensive commercial microphones. Providing laboratory quality microphones and preamplifiers with analyzers is almost exclusive to Ivie.

The IE-30A is a Type I sound level meter, and has the accuracy of Class III filters in the analyzer section (in SLM Types, low numbers are best; in filter Classes, high numbers are best). As long as you use the microphone and preamp that came with your analyzer, its accuracy and performance to specifications is assured. You may easily use other microphones with your IE-30A as long as you remember that all readings are then relative, and are not absolute. You must further remember that the spectral information shown on the analyzer will be colored by the response of the microphone you are using.

Other air condenser microphones which conform to international dimension and thread specifications can be used with your IE-30A by simply removing the microphone cartridge from the end of the IE-2P and replacing it with the air condenser cartridge you wish to use. Many air condenser microphones, including those made by B & K, ACO Pacific, and Rion are compatible with the IE-2P. If a one inch, quarter inch, or eighth inch microphone is to be used, adaptors will be needed to adapt to the half inch barrel of the IE-2P. Some one inch microphones require a polarization voltage of 28 volts instead of the 200 volts which is most common. In this case, the polarization voltage of the IE-2P will need to be switched. Some may require the use of the 20dB pad available in the IE-2P, and, of course, changing the microphone will always require recalibration of the system. (For information on changing polarization voltage, the 20dB pad, and recalibration, refer to the IE-2P manual and the section in this manual entitled "System Calibration for OSHA Measurements," under the heading of "Sound Level Testing.")

When using another microphone, it is important to know the frequency response of the microphone in order to interpret the display information of the IE-30A. The typical frequency response of the standard microphones for the IE-30A (the 1133 Free Field and the 1134 Random Response or Pressure Response) are shown below:

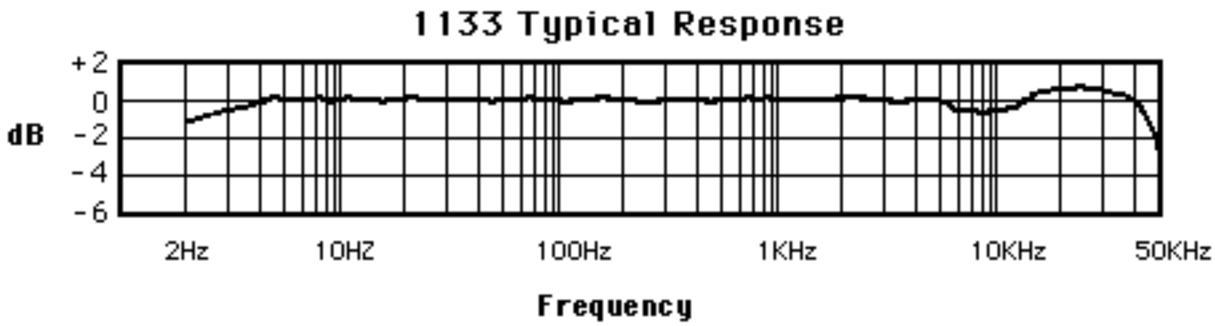


Figure I

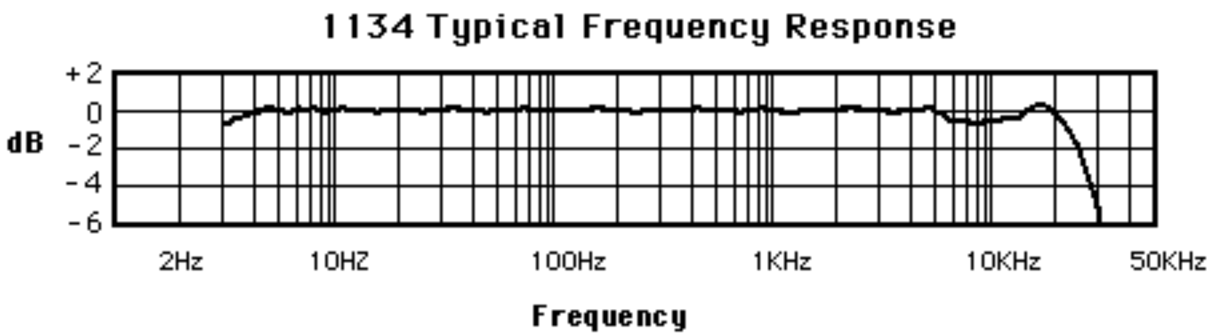


Figure II

As can be seen, these microphones have been chosen for their excellent response characteristics, and their ability to provide maximum accuracy to the measurement capability of the IE-30A. Should you have questions about microphones, or their application in analyzer measurements, please don't hesitate to contact us at the factory.

Inputs and Outputs -The IE-30A Microphone Input Plug and the 7 Pin Input/Output Connector

The Microphone Input Plug

The microphone input plug on the IE-30A is a six pin XLR-type connector. Following is an illustration of the pinout of this connector:

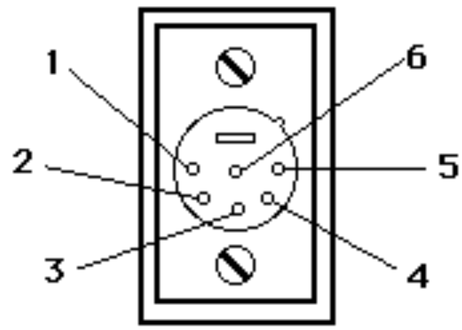


Figure III

Pin 1: Input pin. The input impedance is 100 kΩ. The maximum direct DC input before damage is 100 VDC. The maximum direct AC input is 300 VAC from 20Hz to 4kHz. For frequencies above 4kHz, derate maximum AC input by 6dB/octave (e.g. 150 VAC @ 8kHz, 75 VAC @ 16kHz, 6 VAC @ 20kHz)

Pin 2: Gain Trim pin. Varying the pin voltage between 8.0 VDC and 0.0 VDC varies the gain of the IE-30A over a 15dB range. This pin is not to be used for AGC purposes, but only as a long term gain adjustment for calibration requirements.

Pin 3: No connection.

Pin 4: Power (V_{cc}) for microphone preamplifier. It provides 10mA (maximum current) at 12 VDC.

Pin 5: Calibration pin. Pin 5 is normally tied to pin 4, which sets the IE-30A calibration for dBμV.* IF pin 5 is not tied to pin 4, calibration is set for dB.1μV.†

Pin 6: Ground. (*0dBμV = 1.0μV † 0dB.1μV = 0.1μV)

Microphone Extension Cords

It is helpful to know the microphone input pinout, especially if you plan to make your own microphone extension cord. Extension cables are available from Ivie in lengths from 25 ft. to 200 ft., in 25 ft. increments, but should you choose to make you own cord, that can be easily done using a minimum of three conductor shielded cable, and one male and one female 6 pin XLR-type connector. Pin 1 (signal) must be brought through, as well as pins 2 (gain trim) and 4 (power for the IE-2P Preamplifier). Pin 6 (ground) must also be brought through, and the shield of the cable can be used for this. A highly supple (and therefore, usually expensive) cable is recommended.

The IE-30A 7 Pin Input/Output Connector

The 7 Pin Input/Output Connector is illustrated below:

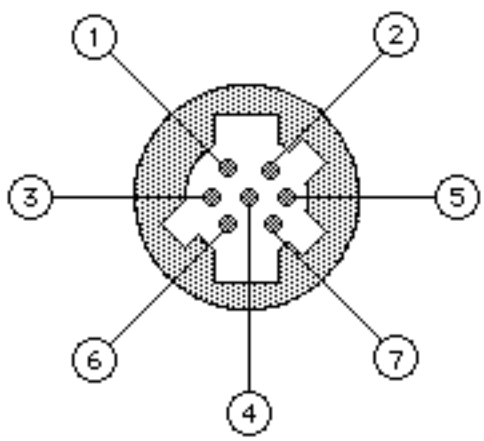


Figure IV

The pinouts are as follows:

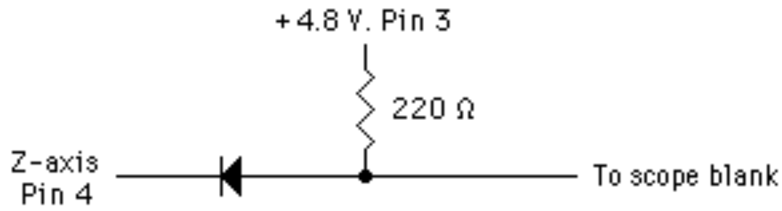
Pin 1. System (analog) ground.

Pin 2. SPL detection. Outputs DC voltage equal to .01 x SPL reading on display. (Output at 100 dB SPL is 1.0 VDC)

Pin 3. 4.8 volts DC. Can power up to 200 mA for use with accessories.

Pin 4. Z- axis: 4.8 volt logic level that is low when a display LED is on. May be used for Z-axis on oscilloscope.

Note: If Pin 4 is pulled low, it will light the display. Use this circuit to prevent 1/3 octave display interference from LO-Z inputs.



Pin 5. X-axis: Sawtooth waveform synchronized with display. May be used for scope display. f_o = ca. 80-100Hz, 0 to 2 volt ramp, 1 kΩ output.

Pin 6. Gate in: When pulled low (TTL or CMOS 5 volt compatible) it interrupts signal through analyzer.

Pin 7. Y-axis: Analog information of 1/3 octave display. With RTA display on dB Reference Line, voltage at Pin 7 is 7.0 VDC. In 3dB/step display mode, output is scaled a .1 V/dB. (1dB/step = .3 V/dB) Output Z = 1 kΩ. (The IE-30A Reference Line is shown in **Figure V** on the following page.)

The IE-30A Preamp Output

The IE-30A contains a very quiet preamplifier that is used in conjunction with the analyzer and SPL meter, or can be used by itself as a stand alone preamp. It provides up to 80dB of gain, or up to 30dB of attenuation, a full 110dB of range, selectable in 10dB increments.

The preamp input is the microphone or probe input, and the output is the phono plug on the side of the IE-30A as shown in **Figure V** on the following page. The preamp follows the weighting of the SPL meter, either A, C, or Flat (unweighted). Gain is adjusted by the Reference Level "Up" and "Down" buttons. Input impedance is 100 kΩ. Now let's look at the IE-30A controls.

The IE-30A Front Panel Controls

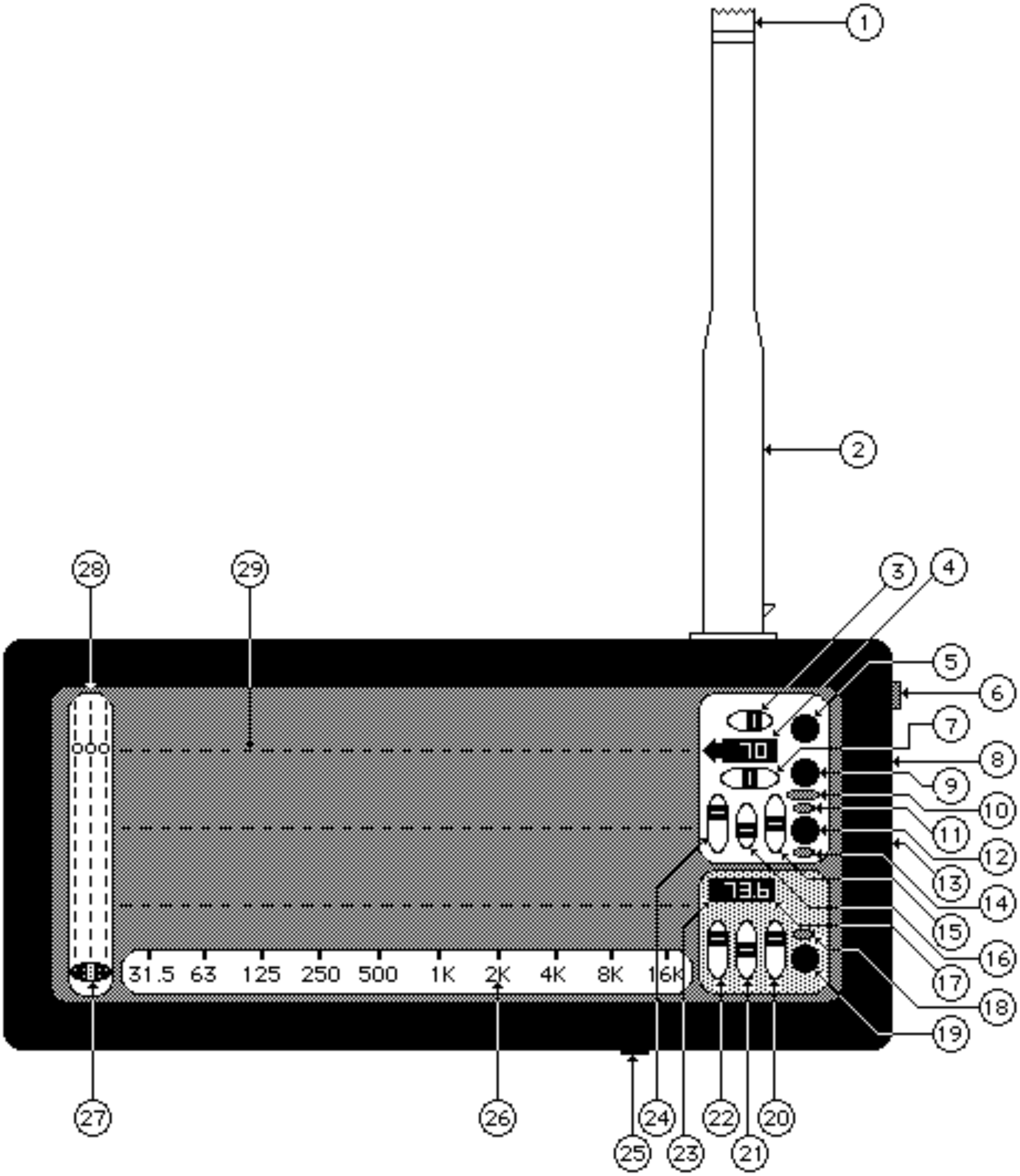


Figure V

You should become familiar with all the IE-30A controls and readouts. They are as follows:

1. 1133 or 1134 Microphone
2. IE-2P Precision Microphone Preamp
3. On/Off Switch
4. Display Reference Window (dB)
5. Reference "Up" Button
6. IE-30A Preamp Output Jack
7. Display Format Selector Switch
8. IE-30A Charger Input Jack
9. Reference "Down" Button
10. Battery & Charge Indicators
11. Real Time Mode Indicator
12. Memory/Real Time Alternate Button
13. 7 Pin Input/Output Indicator
14. Recall Memory Indicator
15. Memory Mode Switch
16. Memory Selector Switch
17. SLM Readout Display (Using Mic)
18. SLM "Freeze" Indicator
19. SLM "Freeze"/Clear Button
20. SLM Mode Switch
21. SLM Response Selector Switch
22. SLM Weighting Selector Switch
23. dBµV Readout Display (Using Probe)
24. Decay Time Selector Switch
25. Tripod Mount Nut
26. ISO Frequency Centers
27. Display Resolution Selector
28. Display Resolution Key
29. Reference Line

Using the IE-30A

Using the IE-30A as an Analyzer

As mentioned earlier, the IE-30A is really two instruments in one - a spectrum analyzer and an SPL meter. We will first discuss using the IE-30A as an analyzer. You will notice that the IE-30A front panel has been color coded so as to help differentiate between the analyzer controls and the SPL meter controls. The analyzer controls and functions are in white fields and the SPL meter controls are in an olive green field.

The first analyzer control that must be used is obviously the ON/Off switch (3). When the IE-30A powers up, it reverts to a preset 60dB setting at the Reference Line (28). This is indicated by the number "60" which will appear in the Display Reference Window (4). The amplitude at the Reference Line can be adjusted up and down in 10dB increments by using the Reference "Up" and Reference "Down" Buttons (5 and 9). The full range available is from 30dB to 140dB. The level at the Reference Line should be adjusted such that the signal being viewed is well up on the IE-30A screen. <u>The screen itself will automatically "edge light" in dim lighting conditions so that it remains readable - even in the dark. Conversely, as the viewing environment becomes more and more bright, the display LED's will become more and more bright such that the IE-30A will remain easily readable in all but the brightest of direct sunlight conditions.</u> The obvious price of bright light situations is battery life. Since the LED's are fed more and more current to remain readable as the environment brightens, battery life between charges is lessened.

It is possible to set the level at the Reference Line such that the signal is either off the bottom of the screen, or is driven above the screen, completely lighting it. Such under or over range signals cannot be accurately processed by the IE-30A. When signals are under or over range, the display and/or the SLM Readout Display (22) will blink indicating that what is displayed is not accurate. This situation is easily cured by adjusting the Reference Level. <u>It should be noted that the IE-30A does have the headroom to accurately measure signals which are somewhat above the display. The headroom is about 40dB for sine wave inputs, or about 20dB for complex wave forms.</u> This means that transient signals which momentarily jump the display off the top of the screen do not necessarily cause inaccuracies in the SPL readout. When this headroom is exceeded, however, display blinking begins and adjustment of the Reference Level is necessary.

The resolution of the the IE-30A display (1, 2, or 3dB per step) is controlled by the Display Resolution Selector (26). An LED will illuminate at the Display Resolution Key (27) to indicate the resolution selected. The columns of numbers in the Display Resolution Key are divided into increments of 1, 2, or 3dB per step. The purpose of these numbers is to determine the amplitude, in dB, that a signal rises of falls below the Reference Line. The column of numbers used is determined by the display resolution selected. If 1dB per step is selected, the dynamic display range of the IE-30A is only 15dB. 3dB per step, on the other hand, will provide a dynamic display range of 45dB. 30dB of dynamic range is provided when 2dB per step on the display is selected.

You will find that most signals will be best viewed in the 3dB per step display resolution. However, for equalization and other applications where finer resolution is desired, it is easily available - but at the cost of reduced dynamic display range.

The next consideration when viewing a signal is the display format. The Display Format Selector Switch (7) allows selection of an octave display, a 1/3 octave display, or a weighted 1/3 octave display. If a weighted display is selected, weighting is controlled by the SLM (Sound Level Meter) Weighting Selector Switch (21). The weightings available are "A," "C," and "Flat" (unweighted). When the display has been weighted, a yellow LED will illuminate in the "arrow" portion of the Display Reference Window to indicate weighting has been applied. It should be noted that the IE-30A preamp output has been weighted as well. (For more information on weighting, weighting curves, etc., consult the section of this manual entitled "Sound Level Testing".)

Another consideration when viewing a signal with the IE-30A is decay time. This is controlled by the Decay Time Selector Switch (23). This affects the averaging time of the detectors and therefore the speed at which the display moves. Three decay times are provided. The fastest, D1, is intended for monitoring work, and is fast enough to catch and display events of fairly short duration. D3, the slowest decay time provided, by contrast will not display short duration events. It is intended for use with pink noise which must be averaged over time to make it appear stable. Trying to view pink noise with the D1 decay time would allow so much display fluctuation, especially at the lower frequencies, that it would be marginally useful at best.

This concludes the discussion of the basic analyzer controls of the IE-30A. Next, let's look at the memory functions and controls.

IE-30A Memory Functions

The IE-30A provides two memories for the storage of spectral information. These memories are involatile and therefore remain in tact when the IE-30A is switched off. Once a spectrum is stored in memory, it can be removed only by overwriting it. The resolution of the data stored in a memory is limited to the resolution setting of the IE-30A at the time the memory was loaded. Spectra stored at a resolution of 3dB, for example, cannot be recalled and displayed at resolutions other than 3dB.

Storing a spectrum in memory is a simple process. The memory to be used, either Memory 1 or Memory 2, is selected by using the Memory Selector Switch (15). Next to the Memory Selection Switch is the Memory Mode Switch (14). It has three positions. Normally it is kept in the center, or "Alternate" position. To store a spectrum into memory, move the Memory Mode Switch to the upper, or "Store" position. To execute storage, press the Memory/Real Time Alternate Button (12). This will write the spectrum on the IE-30A screen into memory. The IE-30A screen will "freeze," demonstrating that a memory is being viewed, and not real time data. Additionally, the Recall Memory Indicator (13) will illuminate, showing that the IE-30A is in the memory display, or "Recall" mode.

To protect the memory information so that it cannot be accidentally overwritten, return the Memory Mode Switch to the center, or "Alternate" position. The memory will now be protected. Pressing the Memory/Real Time Alternate Button will now allow toggling between the "Real Time" and "Recall" modes. Real Time operation will be indicated by a moving display, and the illumination of the Real Time Mode Indicator (11), while the Recall Mode will be indicated by a frozen display and the illumination of the Recall Memory Indicator.

While in the "Recall" mode, the Memory Selector Switch can be used to toggle back and forth from one memory to the other. By use of the Memory Selector Switch and the Memory/Recall Alternate Button, memories may be compared with each other, or with real time data as desired. <u>It should be noted that only spectral information is written into memory. The screen resolution, Reference Line amplitude, and SPL are not stored. When in the "Recall" mode, the Display Resolution Key, Display Reference Window, and SLM Readout Display will blink indicating that their data may not be accurate.</u>

The Accumulate Mode

The bottom position on the Memory Mode Switch is the "Accumulate" position. In this mode, the IE-30A displays and holds the highest amplitude reading in each channel. The display remains frozen in this "accumulate" position until a higher amplitude comes along to overwrite the screen and push the spectral display higher on the screen. This is a very useful mode. Peak accumulations of data over time can be gathered and stored, and the spectral content of short duration phenomena can be captured, to name just a couple of applications.

When in the "Accumulate" mode, pressing the Memory/Real Time Alternate Button once will stop the accumulating process and write the accumulated data into memory. "Accumulate" is a memory function. Pressing the Memory/Real Time Alternate Button a second time will clear the accumulators and allow the accumulation process to begin again. This is often desirable, especially at the beginning of a measurement. When entering the "Accumulate" mode, usually data will be frozen on the screen and will need to be cleared by pressing the Memory/Real Time Alternate Button twice prior to beginning a measurement.

As in other memory storage, an accumulated memory may be protected by returning the Memory Mode Switch to the center "Alternate" position.

Using the IE-30A as a Sound Level Meter

As mentioned earlier, all the IE-30A sound level meter controls are located in the olive green field at the bottom, right of the front panel. The IE-30A is a Type I sound level meter, and as such, is capable of making all the Type I specified measurements. These include the ability for "Fast," "Slow," "Peak," and "Impulse" measurements. The IE-30A also has weighting available for "A," "C," or "flat" (unweighted) measurements.

"A" weighted, "C" weighted, or unweighted measurements can be selected using the SLM Weighting Selector Switch (21). When weighting is selected for the sound level meter, the output of the IE-30A preamplifier is weighted as well.

Sound level measurements may be continuous, or a measurement "hold" function is provided. When the "hold" function is employed, the highest SPL measured is "frozen" in the SLM Readout Display (22) until a higher reading comes along to displace it. To select either a continuous measurement display, or the "hold" function, the SLM Mode Switch (19) is used. The top position (CT) selects a continuous measurement display, and the bottom position (HD) selects the "hold" function. The center position, (IM) for "Impulse" measurements will be discussed below.

As earlier mentioned, the IE-30A provides "Fast," "Slow," "Peak," and "Impulse" measurements of sound pressure level. To make this selection, the SLM Response Selector Switch (20) is used. The top position (FT) is "Fast," the center position (SW) is "Slow," and the bottom position (PK) is "Peak." All of these measurements are defined by international specifications for type accepted sound level meters. The detectors employed for both "Fast" and "Slow" measurements are true RMS detectors, while the detector for "Peak" measurement is a true peak detector. These three measurements can be made in either the continuous mode, or the "hold" mode.

The selection for "Impulse" measurements is a little unorthodox. To select "Impulse" measurements, the SLM Mode Switch must be in the center (IM) "Impulse" position. Additionally, the SLM Response Selector Switch must be in the top (FT) "Fast" position. This correctly sets up the detectors for "Impulse" measurements. With the SLM Mode Switch set to "Impulse," and the SLM Response Selector Switch set to either "Slow" or "Peak," the IE-30A will still make measurements, but they will be undefined, and therefore less than useful . For proper "Impulse" measurements, the SLM Response Selector Switch must be set to "Fast."

Now that we have examined the controls of the IE-30A, we are ready to look at some measurements in greater depth. Let's begin with sound level measurements.

Sound Level Testing

Introduction

The decibel (dB) scale has been adopted internationally for use with sound level meter testing. The scale begins at a reference of 0 dB in sound pressure level (0 dB SPL) which corresponds to the smallest sound that can be heard by a healthy human ear, and is equal to 2µN/m^2, or perhaps more commonly, 20µPa. Following is a chart which shows some various sound pressure levels (SPL's) relative to typical environmental sounds:

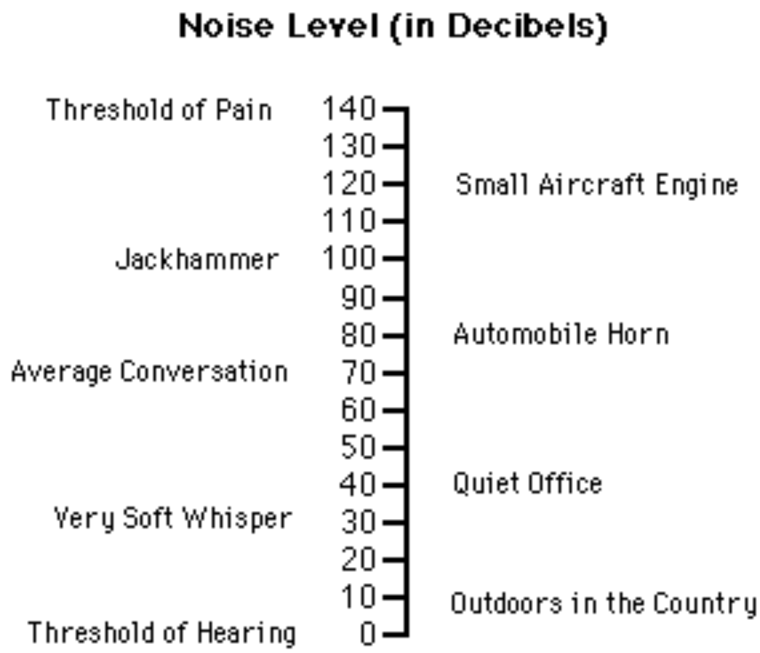


Figure VI

When studying sound level measurements, it is of major importance to understand the response characteristics of the human ear. Our ears do not respond equally to all the frequencies of the audio spectrum - in other words, they are not "flat" in their response. To further complicate matters, the response characteristics of human ears change with different SPL's. At relatively quiet SPL's, our ears attenuate high frequency sounds to some degree, and drastically attenuate low frequency sounds. As SPL's increase, our ears get more efficient at low frequencies and their response to sound becomes more "flat," although they never achieve a totally "flat" response. Following is a set of curves which approximate the hearing response of human ears. The "A" curve shows how ears hear, or perceive sound at low SPL's, while the "C" curve shows how we hear at relatively high SPL's.

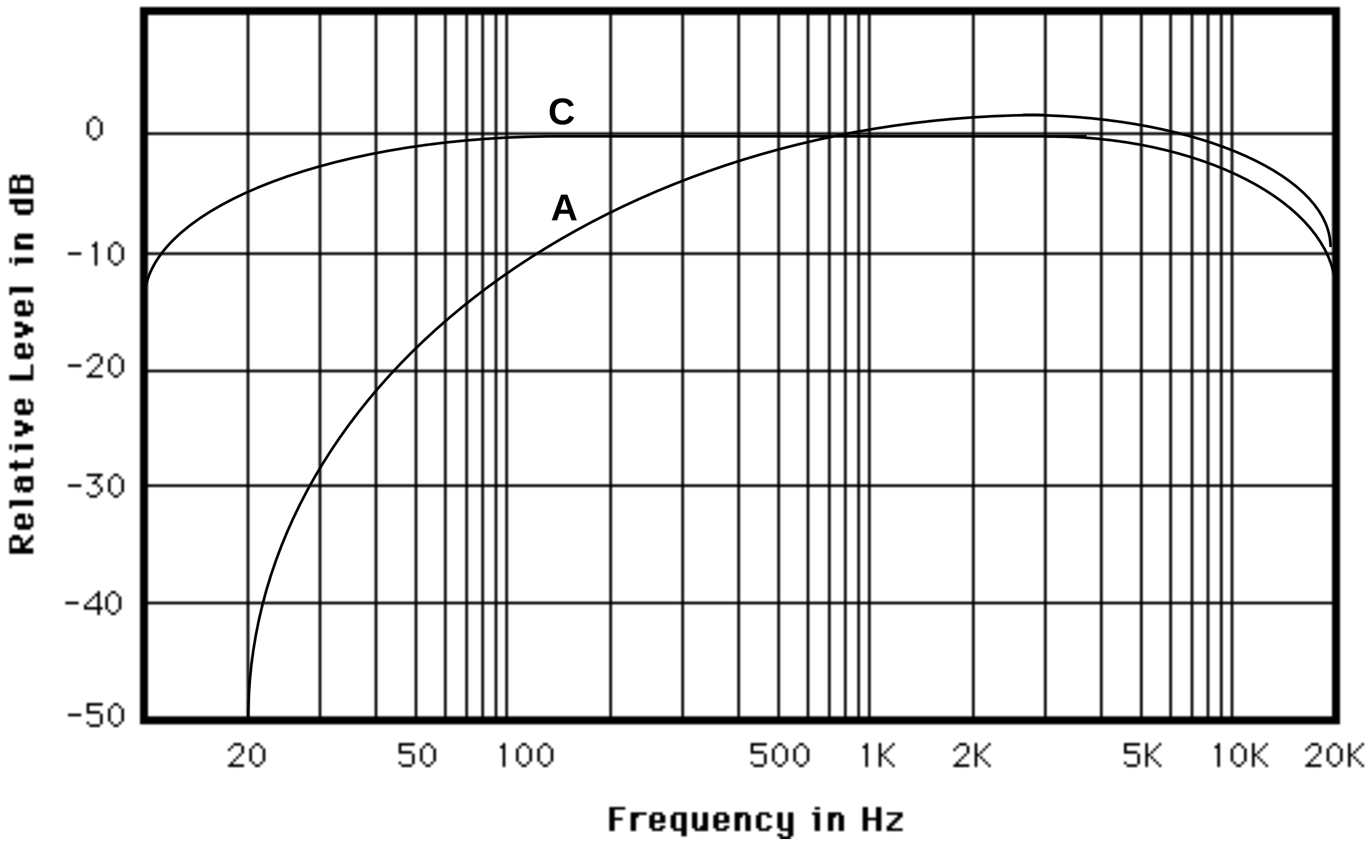


Figure VII

These curves have been integrated into sound level meters for testing sound levels. "A" weighted (dBA) measurements use the "A" curve above, "C" weighted (dBC) use the "C" curve above, and "Flat" (dB SPL) measurements use no weighting at all.

Noise which causes hearing damage has been found to correlate most closely with the "A" curve. Consequently, OSHA requirements, and many other government regulations are generally specified in dBA. The Walsh-Healey Public Contracts Act, for example, specifies the following permissible human exposure levels for industrial noise. Notice that all duration levels are specified in dBA.

Permissible Noise Exposures

Hours Duration Per Day	dBA SPL Slow Response
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
.5	110
.25	115

Figure VIII

In addition to being concerned about the weighting we use when we make SPL measurements, we need also to be aware of the measurement environment. Sound environments can range from near-field to free-field to diffuse-field. A free-field environment is one that is free of reflections, and is typical of anechoic chambers (sound absorbing rooms) that have acoustically padded walls, floors, and ceilings.

Diffuse (reverberant) fields are often encountered and are purposely created by reverberation chambers that have been designed to cause as much reflection between ceilings, walls, and floors as possible. A diffuse-field is one in which the sound is uniformly distributed throughout the room. Machine noise tests are more often made in reverberant chambers, as they are less costly to build than anechoic chambers.

Typical sound measurements environments, however, are usually some combination of free-fields and diffuse fields, and great care must be taken with the measurements to help assure that accurate results are obtained. Errors can occur when determining the noise from a single source if tests are made too close (near-field) to the source being measured (See **Figure IX**, page 19). The near-field SPL can change dramatically with small position changes of the sound level meter. <u>To avoid near-field errors, the sound level meter should be located away from the source by at least a distance equal to one wavelength of the lowest frequency</u>

radiated from the source, or more than twice the distance of the largest dimension of the source, whichever distance is greater.

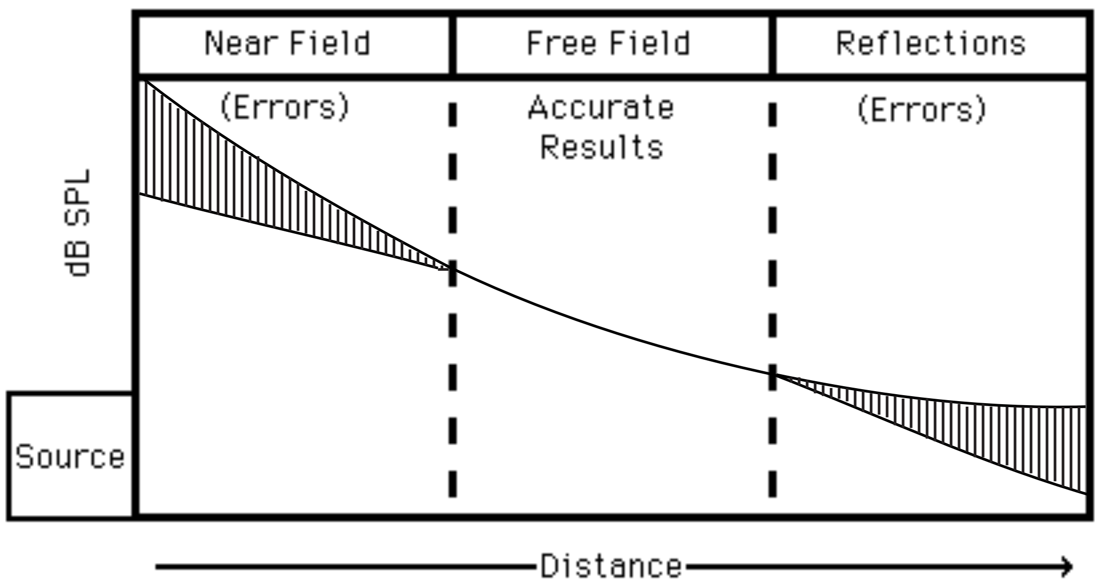
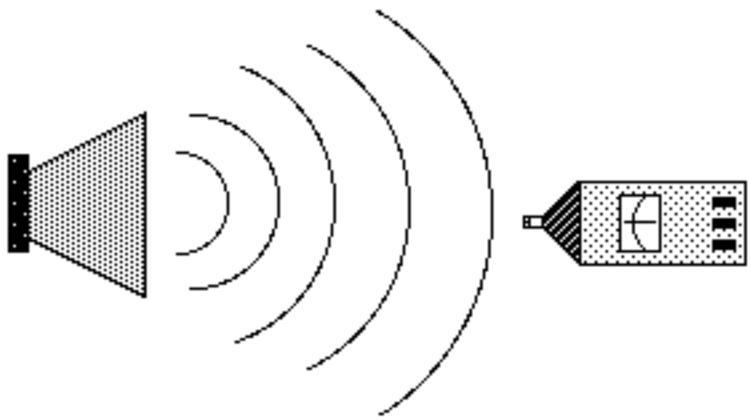


Figure IX

As can be seen from the above illustration, errors can occur not only when we are too close to the source, but also, when we get too far from the source being measured, room reflections and other room noises may interfere with our readings. The most desirable condition for noise testing would be to perform all tests in a reverberant chamber (diffuse-field) or an anechoic chamber (free-field). Since this is usually not possible, the next best alternative is to find a free-field as close to the object being tested as possible. It is easy to identify a free-field because the inverse square law holds true there. The inverse square law describes the relationship between sound pressure level and distance in a free-field. When the distance from the sound source doubles, the SPL will drop by 6 dB. If the distance is doubled again, the SPL will drop by another 6 dB. If this relationship occurs, the sound waves are traveling unobstructed from the source to you, and by definition, you are standing in a free-field.

Free Field vs. Random Response or Pressure Response Microphones

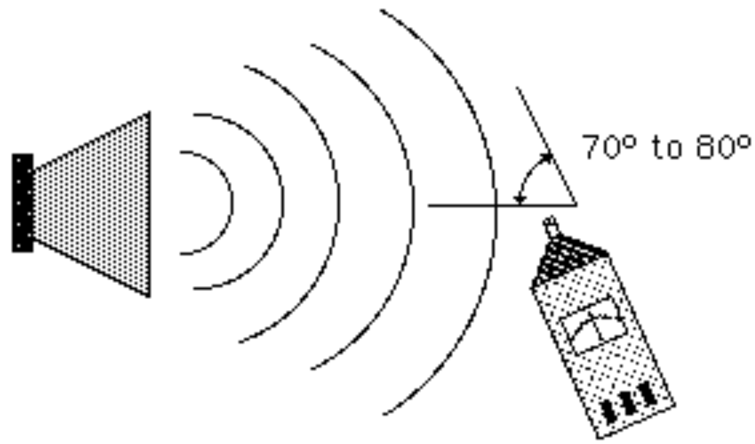
Both free field microphones and random response microphones are used to measure SPL. In Europe and other areas where IEC standards are required, a free field microphone is required. A free field microphone is intended to be used in a free field environment, and should be pointed directly at the sound source as shown below:



Using a Free Field Microphone in a Free Field Environment

Figure X

In the United States and other areas where ANSI specifications are followed, a random response microphone is normally used on a sound level meter. A random response microphone is intended to be used in a diffuse or reverberant field. However, in free field use, a random response microphone can be used to approximate the response of a free field microphone by positioning the microphone at an angle of 70 to 80 degrees to the sound source, as shown on the following page:



Using a Random Response Microphone in a Free Field Environment

Figure XI

Body Effects on Sound Measurements

Something that must be considered when making sound measurements with a hand-held analyzer, is the effect of the operator's body on readings. The operator's body may detract substantially from the accuracy of the measurements. At frequencies near 400 hz, sound reflecting from the body could cause up to 6 dB or error, if measurements are made within three feet of the operator. To minimize this effect, the PC-40 should be positioned as far away from the body as possible. It would also be appropriate to use a microphone extension cable in those instances when it is deemed necessary.

Correcting for Background Noise

Often the need arises to make SPL measurements in the presence of background noise. This can be easily done as long as the SPL of the primary source is <u>at least</u> 3 dB greater than the background noise. Following are the steps for making such a measurement.

1. Measure the total noise. (Background and primary source)

2. Turn off the primary noise source and measure the background noise only. Both tests should be made with the microphone in the same location.

3 Calculate the difference between the two readings measured. If the difference is less than 3 dB, accurate measurements cannot be made. If the difference is between 3 dB and 10 dB, the following chart can be used to make the needed correction.

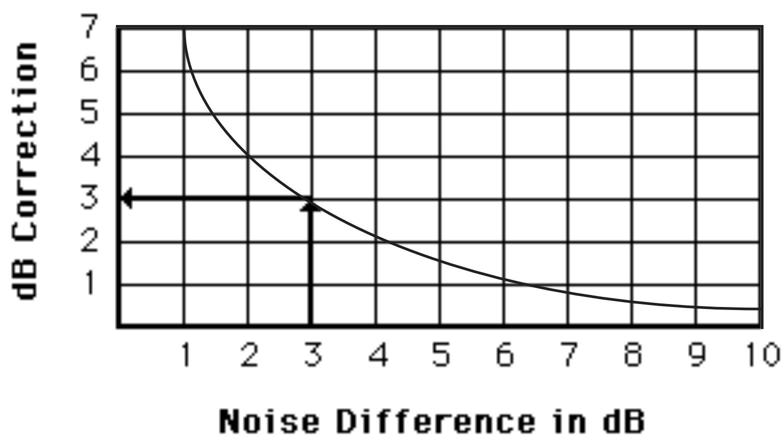


Figure XII

To use the chart, locate the difference of the two measurements on the horizontal axis. From that point, go up to intersect the curve, and then left to the vertical axis. Then subtract the value on the vertical axis from the total noise level first measured.

Example: Total noise = 75 dB. Background noise = 72 dB. Difference = 3 dB. Chart correction = 3 dB. Primary source noise = 75 dB - 3 dB = 72 dB.

There is something very interesting about this example. Notice that the background noise SPL is the same as the source noise SPL, yet when we add those equal noise levels together, the increase is only 3 dB. (72 dB of background noise plus 72 dB of primary source noise equals 75 dB total) 3 dB is only a slight change in the level of "loudness" perceived by the human ear.

This same ratio applies to amplifier power when fed to a speaker. If we double the power (watts) going to a speaker, the change in sound level is only 3 dB, a barely audible change. This gets to be pretty important if we have a huge system using 10,000 watts of power and we decide we want it just a little louder - a mere 3 dB. All we have to do to accomplish this is add another 10,000 watts!

Adding Sound Levels

Since we have just discussed an illustration of adding sound levels together, let's explore the subject further. If two primary sources are measured independently, it is possible to determine what the sound level would be if both sources were operating together. The following chart can be used to determine this, when both tests are made with the IE-30A in the same location.

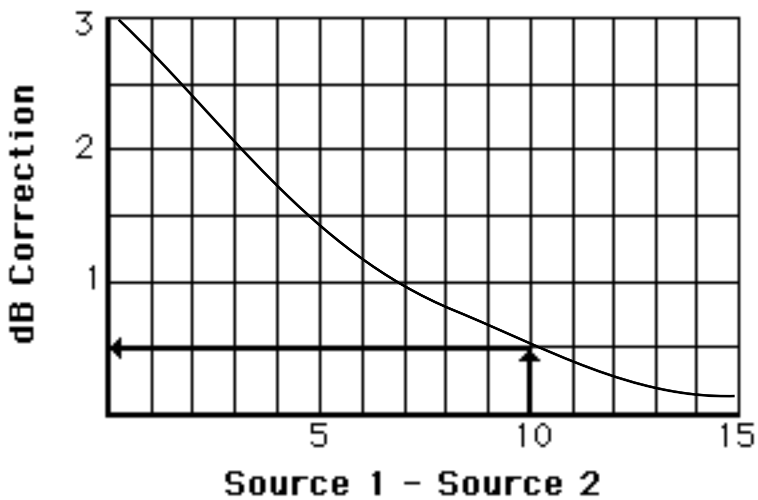


Figure XIII

To use the chart, first measure the levels of the two sources independently and then find the difference between the two levels. Locate the difference on the bottom of the chart. Go up until the curve is intersected, and then go left to the vertical axis. Then add the correction in dB indicated by the vertical axis to the value of the highest reading made. This number indicates the combined SPL of the two sources.

In the example shown above, Source 1 equals 79 dB, and Source 2 equals 69 dB. The difference is 10 dB. Chart correction is .5 dB, so the total noise is 79.5 dB.

System Calibration for OSHA Measurements

OSHA measurements generally require equipment that meets minimum specification standards - at least an ANSI Type II sound level meter, for example. (The IE-30A is a Type I Sound Level Meter, and therefore exceeds OSHA minimum requirements). In addition to the equipment meeting minimum specification standards, it must also be properly calibrated in order for an acceptable OSHA measurement to be made.

What this normally requires is calibration prior to the measurement, and then a recheck of calibration after the measurement is made. In the case of SPL measurements, a calibration device (either a pistonphone or an acoustic calibrator) must be used. The standard IE-30A microphone is a 1/2 inch, air condenser microphone. It's size and thread specifications are the same as other internationally recognized 1/2 inch microphones. Any quality calibration device will work, if it is used properly. Most calibrators are made to accommodate a 1 inch microphone, and they have an insert to adapt them to 1/2 inch microphones. Use the 1/2 inch adapter and make sure the microphone fits snugly inside the insert.

To calibrate for OSHA measurements, fit the calibrator on to the IE-30A microphone and turn on both the calibrator and the IE-30A. Following the directions that come with the calibrator, calibrate the IE-30A to the proper SPL. The IE-30A calibration potentiometer is found in the IE-2P microphone preamplifier. It is recessed inside the IE-2P tube, as shown below, and has to be accessed with a small screw driver.

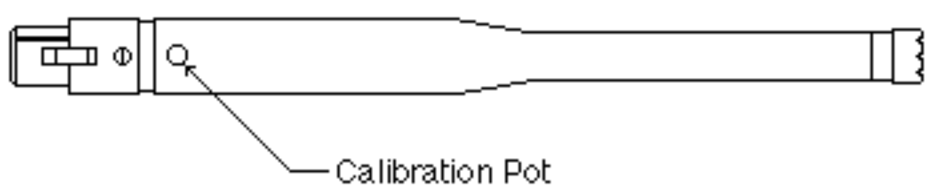


Figure XIV

Electrical Testing with the IE-30A

We have discussed some acoustic measurements with the IE-30A, but one of the most useful functions of the analyzer is the measurement of electrical signals. Since the IE-30A is calibrated in dBµV., it is capable of making a wide range of useful measurements related to audio. Let's examine a few of them. These are by no means all of the measurements that can be made, but they will provide a base which can be expanded to meet many requirements.

Measuring Output Power

Measuring the output power of an amplifier or audio system is nothing more than a simple mathematical extension of measuring voltage. Power is an impedance related measurement. If we know the impedance of the load and also the rms voltage across the load, we can then calculate the power by squaring the voltage and dividing it by the impedance (in ohms) as shown in the following equation:

$$\frac{E^2}{R} = \text{Power rms} = \frac{(\text{Voltage rms})^2}{\text{Load } \Omega} = \text{watts}$$

Amplifier power is normally measured by replacing the speakers with a resistive load capable of handling the rated amplifier power. The input voltage required for the full rated output power is usually specified by the amplifier manufacturer along with a test frequency, or range of frequencies.

The probe which comes with the IE-30A should be used for all power measurements. With its switchable 20 and 40dB attenuation, it is capable of measuring from .3 pico watts ($.3 \times 10^{-12}$) to 31 kilowatts into an 8Ω load, or from 5mv ($r \times 10^{-6}$) to 500 volts.

Let's look at an example. A manufacturer specifies his amplifier output power to be 100 watts rms into a 4 ohm load for a 1 volt rms input signal. The test frequency given is 1 kHz. The test setup is show on the following page:

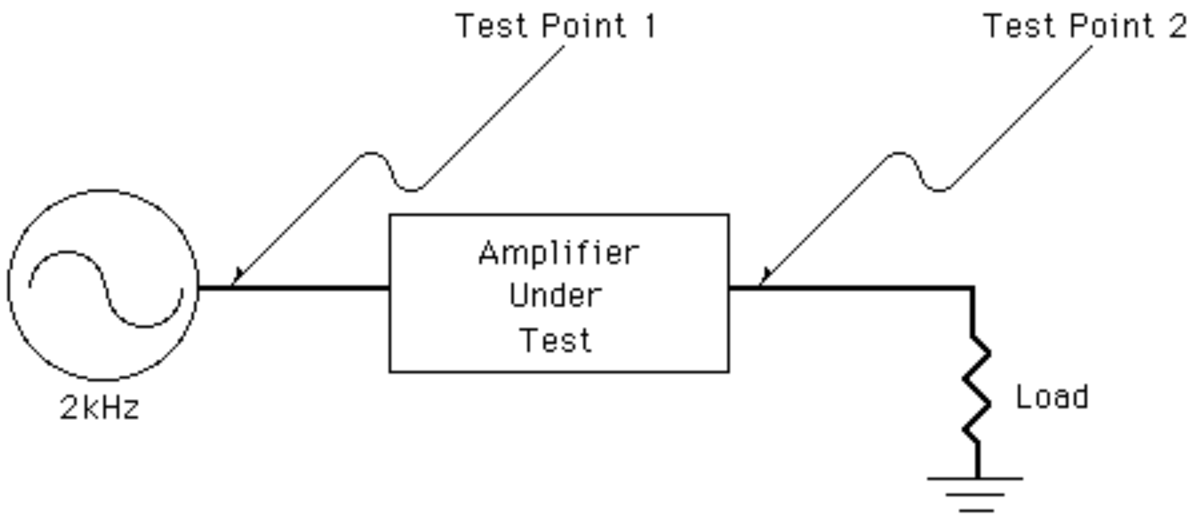


Figure XV

The procedure for making the measurement is as follows:

1. Connect a 100 watt rated 4Ω load to the output terminals of the amplifier.

2. Tune a sine wave function generator to a frequency of 1 kHz and initially set its output voltage to zero. Plug the generator output into the signal input jack of the test amplifier.

3. Connect the probe of the IE-30A to the output of the sine wave generator, (test point 1), and adjust the output signal to a level of 1.0 Vrms (+120dBµV). Remember, when using a 20dB attenuator with the IE-30A, a displayed signal level of 100dBµV is equal to a true signal level of +120dBµV (100dBµV + 20dB). The generator should remain connected to the test amplifier through this step.

4. Next, connect the IE-30A probe to test point 2 and measure the voltage across the 4Ω load at the amplifier's output. (The reading will be in dBµV, but conversion table #1 in the Appendix will convert directly to Vrms).

5. Mathematically square the measured voltage and divide the result by 4Ω. The result will be output power. An even easier approach would be to refer to table #4 in the Appendix and read directly from dBµV to P^4 (power into a 4Ω load).

For this particular example, if we assume that the measured voltage across the 4Ω load is 22.4 Vrms, we read on the table the power into 4 ohms to equal 125 watts.

$$\left(\frac{21.8^2}{4}\right)$$

Measuring Gain and Loss

Gain and loss measurements are usually considered to be relative measurements. That is, gain and loss are not described in absolute units like volts, dBµV, or dB SPL. Gain and loss measurements are comparisons of the output signal divided by the input signal and are usually expressed in dB, a unitless measure.

Using the IE-30A, gain and loss can be measured with either a sine wave generator, or with a pink noise generator. The advantage of using a pink noise generator, like the Ivie IE-20B, is that both gain (or loss) and frequency response are displayed simultaneously.

For now, let's examine some measurements using sine waves. For details on using pink noise for gain and loss testing, consult the section of this manual entitled "Pink Noise Testing."

Perhaps the easiest way to demonstrate gain and loss testing is with specific examples. Let's look at a couple. First Problem: Measure the gain of a preamplifier with a 10 mv input signal at a frequency of 2 kHz. The test setup and procedure is as follows:

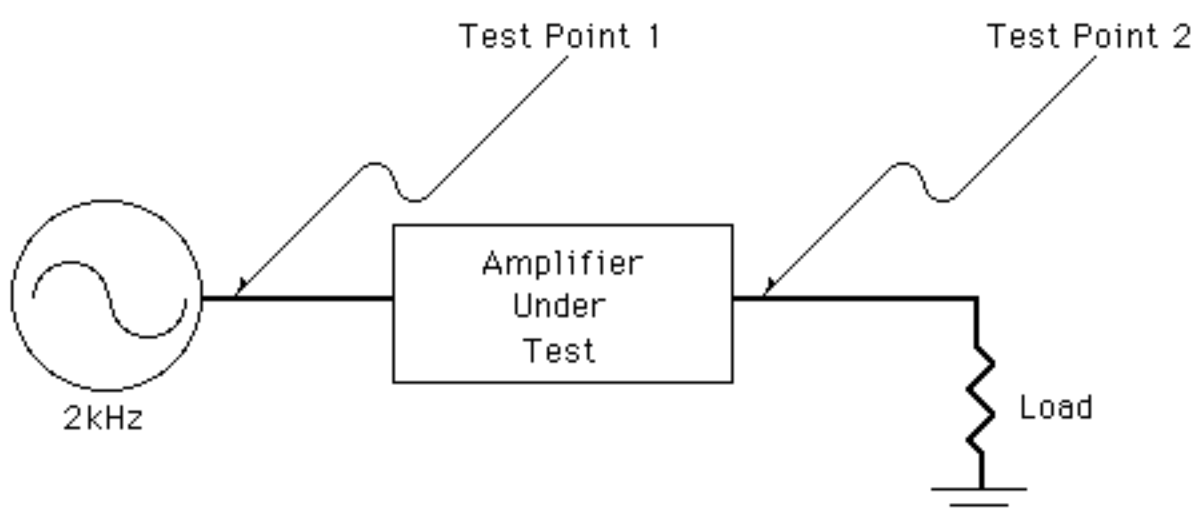


Figure XVI

1. Set up the equipment as shown with the output level of the sine wave generator set to zero.

2. Most preamplifiers have a very low output impedance and do not usually require a terminating load. Power amplifiers should always be terminated with an appropriate load when measuring power, gain, or frequency response.

3. A 10 mv input is equivalent to an IE-30A reading of +80 dBµV as can be seen using table 1 in the Appendix. Connect the IE-30A to test point 1 and adjust the signal source for a +80 dBµV output.

4. Measure the dBµV level at test point 2 at the output of the test amplifier. Let's assume we measure an output equal to 105.8 dBµV. Obviously, the amplifier has gain.

5. Subtract the reading at test point 1 from the reading at test point 2, observing the signs.

$$\text{Gain} = 105.8 \text{ dB} - 80 \text{ dB} = 25.8 \text{ dB}$$

The amplifier gain is 25.8 dB at 2 kHz for the 10 mv input signal.

For gain and loss testing, we are only interested in the difference between the dB readings taken on the IE-30A. It is not correct to say that the gain is equal to 25.8 dBµV. Gain is a relative measurement, not an absolute one, and is normally expressed in dB.

Note: Measuring the gain of amplifiers with output voltages in excess of 2 volts will require external attenuators on the IE-30A It is recommended that the IE-1036 RTA probe which came with the IE-30A be used for these applications.

Second problem: A manufacturer specifies his audio device to have less than 10 dB of insertion loss at a frequency of 1 kHz. Verify his specification.

The test setup is shown on the next page. The difference between this measurement and the last one is that this time we will be looking for loss instead of gain. Additionally, this time we will use the IE-30A analyzer display screen to make our measurement, along with the SLM Readout Display which gives us our dBµV readout.

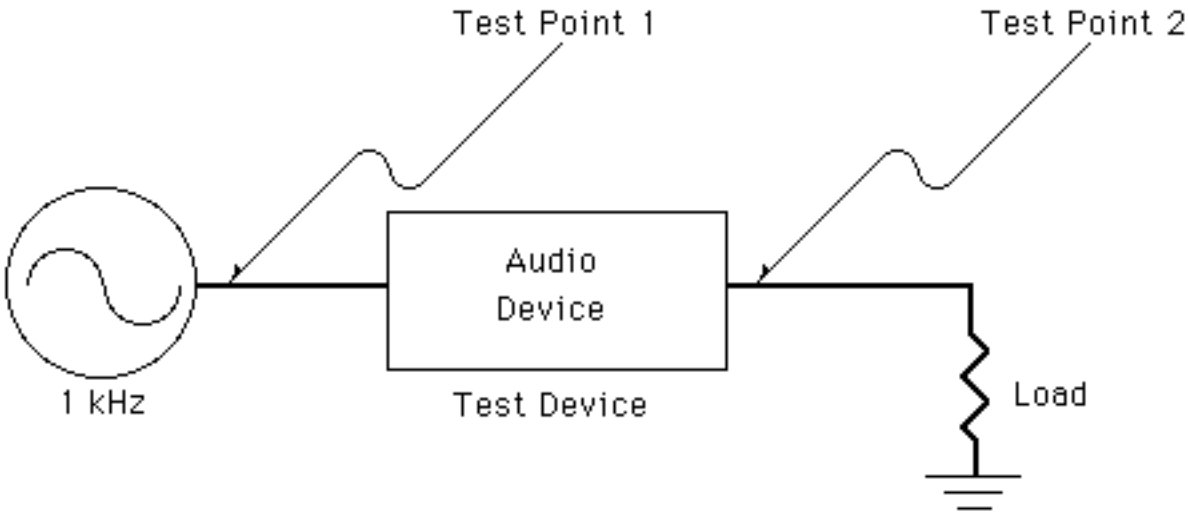


Figure XVII

1. Set up the equipment as shown above.

2. Set the IE-30A to 1dB per step for best resolution. Connect the IE-30A to test point one and adjust the 1 kHz output level of the generator such that the signal on the display of the IE-30A reaches the Reference Line, as shown below.
   Note: An input level of 1 volt rms will raise the display to the Reference Line when the Reference Line is set to 120 dB.

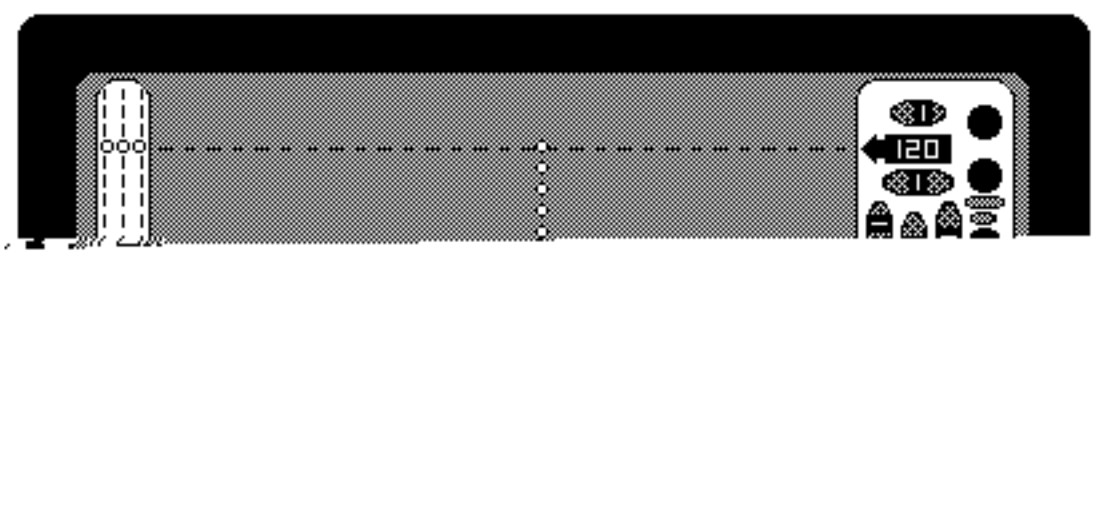


Figure XXIII

3. Move the IE-30A test probe to test point 2 and note the decrease in the signal level. The IE-30A display should then look something like **Figure XIX** on the following page:

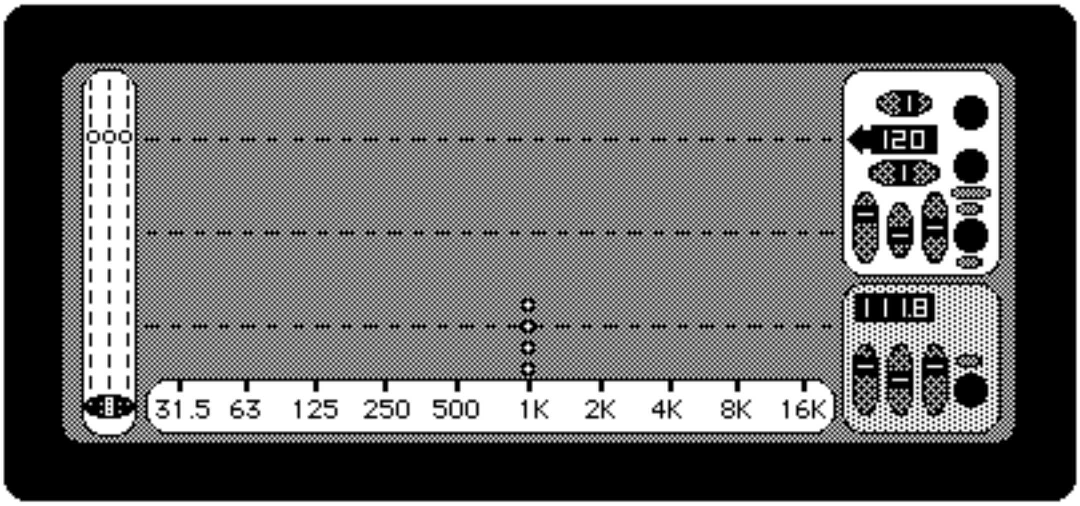


Figure XIX

4. Calculate the insertion loss. In the example above, the display has decreased by 8 dB, and the SLM Readout Display (which has greater resolution) has decreased by 8.2 dB. We would conclude the insertion loss to be 8.2 dB, well within the manufacturer's specification.

From the simple example above, we can begin to see the power of the IE-30A when used for electrical testing. For many applications it becomes even more powerful when used in conjunction with pink noise. Let's next examine in detail some pink noise measurements using the IE-30A and the IE-20B Noise Generator.

Pink Noise Testing with the IE-30A

Introduction - Pink Noise Theory

When is pink noise flat? Never!

There are a few fundamentals that should be understood before doing pink noise testing. Pink noise is random noise that appears flat only after being averaged over time by special detectors on a real-time analyzer, or a true rms voltmeter. On an oscilloscope, or a standard voltmeter, pink noise appears to be a mass of random voltage spikes - which is exactly what it is. However, when averaged over time, the noise appears very flat and the output rms voltage is highly stable. When measuring with pink noise and the IE-30A, the detectors in the IE-30A should always be in the pink noise averaging mode, which is the slowest available (D3).

We are often asked, "How flat is your noise generator?" That can be a misleading question, because noise is never flat. As we have said, noise is random in nature, and can be made to "appear" flat only when averaged over a sufficiently long period of time. Noise is a statistical phenomenon, and the averaging time necessary to create a "flat" appearance is mathematically predictable. Far better questions to ask are , "How flat are the filters in your noise generator?" and "What is the averaging time of the detectors in your real-time analyzer?"

To create pink noise, a noise generator first generates white noise. Our white noise generation is accomplished by a statistically accurate, shift register technique. Since white noise is equal energy per frequency, the energy content doubles each time you step up an octave. Such a signal is therefore too "hot" at high frequencies to be used as a sound system test signal. Pink noise, or equal energy per octave, is a much better test signal. To produce pink noise from white noise, we run the white noise through a 3dB per octave roll-off filter. The accuracy, or "flatness" of this filter determines the "flatness" of the pink noise produces. The filters in our noise generators are six pole filters and are very flat, which results in a very flat time-averaged output. The detectors in the IE-30A (the pink noise, or "slow" detectors) are designed to allow a maximum, ±1dB flutter when the analyzer is in the 1dB/step mode. Furthermore, this mild flutter occurs only at the lower frequencies. Since each 1/3 octave bandwidth contains exactly twice as many discrete frequencies as the adjacent 1/3 bandwidth below it, as we increase in frequency, we increase in statistical stability. This means that as we continue to climb in frequency, we need shorter and shorter averaging times to achieve statistical stability. The IE-30A does, in fact, have shorter averaging times for the detectors at the higher frequency bandwidths. Even with these shorter averaging times, the higher frequency bandwidths are slightly more statistically stable than the lower frequency bandwidths.

You can create statistical instability in your measurement by changing the IE-30A detector response from "slow" (D3), to "medium" (D2) or even "fast" (D1). You will notice increased random movement of the display, especially at the lower frequencies. In the "fast" mode, it is virtually impossible to obtain a reasonable pink noise reading at low frequencies. It can easily be seen that making pink noise "flat" is as much a function of a good spectrum analyzer and its chosen integration time, as it is a function of a good noise generator.

What is Crest Factor?

An important aspect of a noise generator is its crest factor. The output of Ivie noise generators is calibrated in volts rms, and crest factor is the ratio of the peak voltage to the rms voltage. If a noise generator had a crest factor of 2, we could expect instantaneous voltage peaks, or spikes (either positive or negative) to reach an amplitude twice our rms output voltage. In other words, an rms voltage output of 1 volt could see peaks as high as 2 volts.

The purpose of pink noise is to provide a reference signal that approximates program material as closely as possible. If the crest factor is too low, we provide a signal with little dynamic range, which will not give us a very clear picture of how our sound system may perform with program material having normal dynamics. If our crest factor is to high, on the other hand, we will provide a signal with such a broad dynamic range that we could be causing clipping. Experimentation has shown that a crest factor of from 3.5 to 4.0 seems to work best and most closely approximate normal program material dynamics. Ivie noise generators have a crest factor of 3.75.

In conclusion, pink noise approximates actual audio signal better than any other type of signal source. It is also one of the best signal sources available for doing rigorous testing of amplifier durability, and transient signal handling capabilities. Pink noise is used in conjunction with a real-time analyzer more widely than any other signal source. Some analyzers have pink noise generators built into them. Ivie has chosen to keep its noise generators separate from its analyzers, even though it is more expensive to do so, because experience has shown that the location where we want to inject pink noise into a system is rarely the same location where we want to have our analyzer. Additionally, having the noise generator in the same box with the analyzer generates the temptation to match one to the other, by "tweaking" the analyzer filters to match the pink noise output. Some manufacturers do in fact do this, which makes the analyzer incompatible with another pink noise source. At Ivie, we believe it is better to have both instruments independently flat, and so that is the approach we use. Any Ivie noise generator will work with any Ivie analyzer.

The last thing we wish to say about pink noise is that it **cannot** be used for gating or pulsing techniques. The random nature of pink noise (which is, in fact, its greatest asset) prevents it from being spectrally complete or repeatable in short bursts. Consistent results cannot be produced.

Room Response Testing

Pink noise is often used in conjunction with a real time analyzer for testing room response and for equalizing sound systems. Preferred equalization curve requirements differ according to the intended use of the sound system and its environment, and there are many opinions as to what those curves should look like. It is not the intent of Ivie to recommend one equalization curve or process over another, but to provide equipment with sufficient flexibility to allow the user to make his own choices.

There are, however, some useful techniques that are quite universal in application. These involve such things as system documentation, electrical testing and trouble-shooting, and measurement of acoustical performance. Some of these techniques are explored in the next section of this manual entitled "Electrical Testing and System Documentation Using Pink Noise." Acoustical testing is touched upon as well, but there is much that is left unexplored. There are many aspects of these techniques about which much has been written and argued - whether to use one microphone, or several; whether to do only time averaging, or do spatial averaging as well - this list goes on and on. The reader is encouraged to study and learn as much about all of these approaches as he can, and to make his own determination as to the techniques he prefers. The IE-30A will accommodate them.

Electrical Testing and System Documentation Using Pink Noise

One of the most useful aspects of the IE-30A Audio Spectrum Analyzer and the IE-20B Pink Noise Generator is their ability to be used in tandem to perform a great variety of of useful electrical measurements. These measurements can not only verify system specifications, but, when properly documented, can also save literally hours in trouble shooting.

The first step in making electrical measurements is calibrating the analyzer to the pink noise generator to establish a reference. The following illustration demonstrates this:

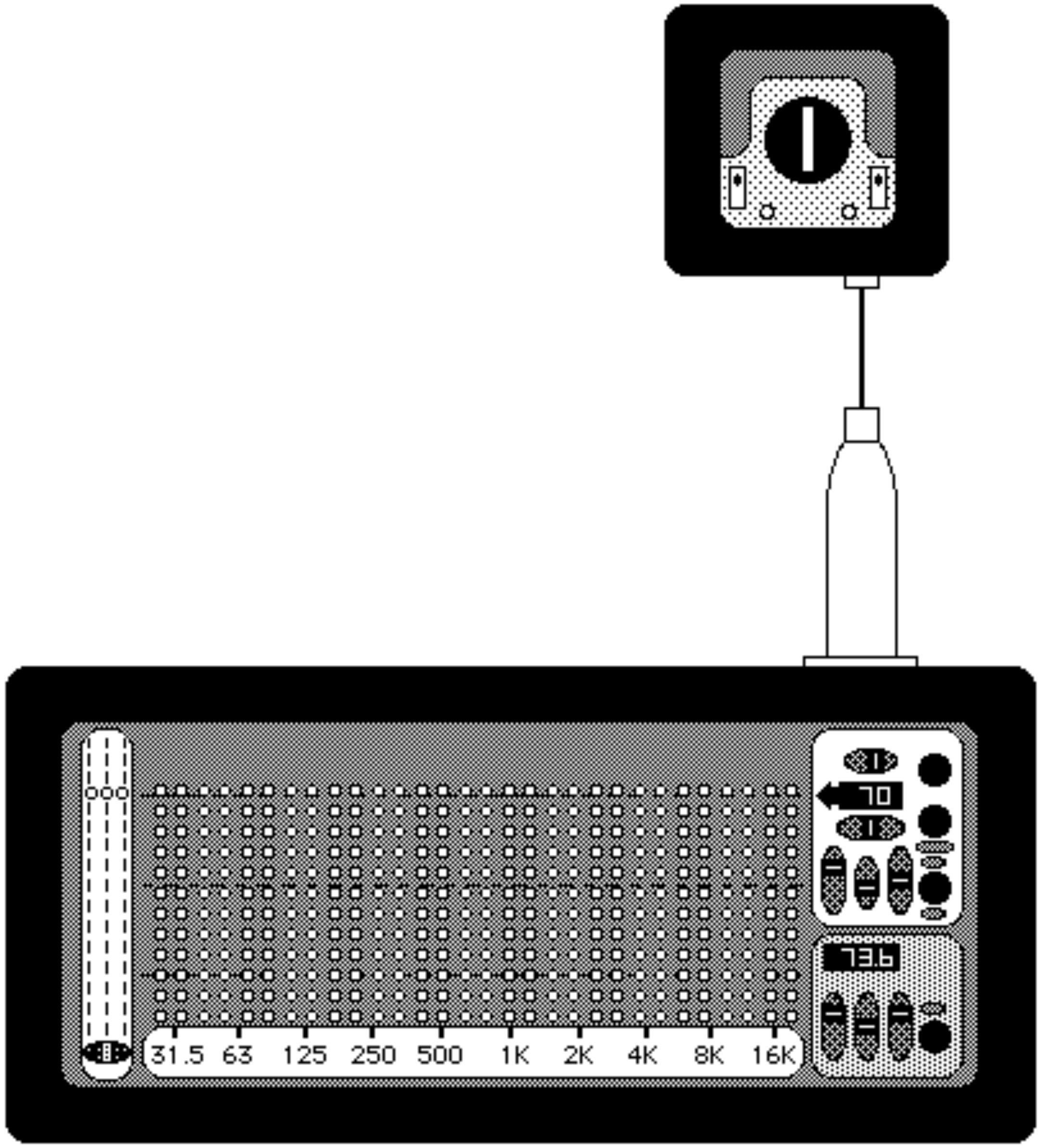


Figure XX

In this example, the pink noise level has been set such that the amplitude of the display reaches the Reference Line. With the analyzer being capable of measuring dB µvolts, an exact signal level can be read directly to a resolution of .1dB. We now have a reference spectral content, amplitude within each 1/3 octave band, and the absolute level of the input signal.

If we now insert an audio device into the circuit between the pink noise generator and the analyzer, we can measure all kinds of parameters. Let's take insertion loss as an example. We insert the device to be tested as shown below:

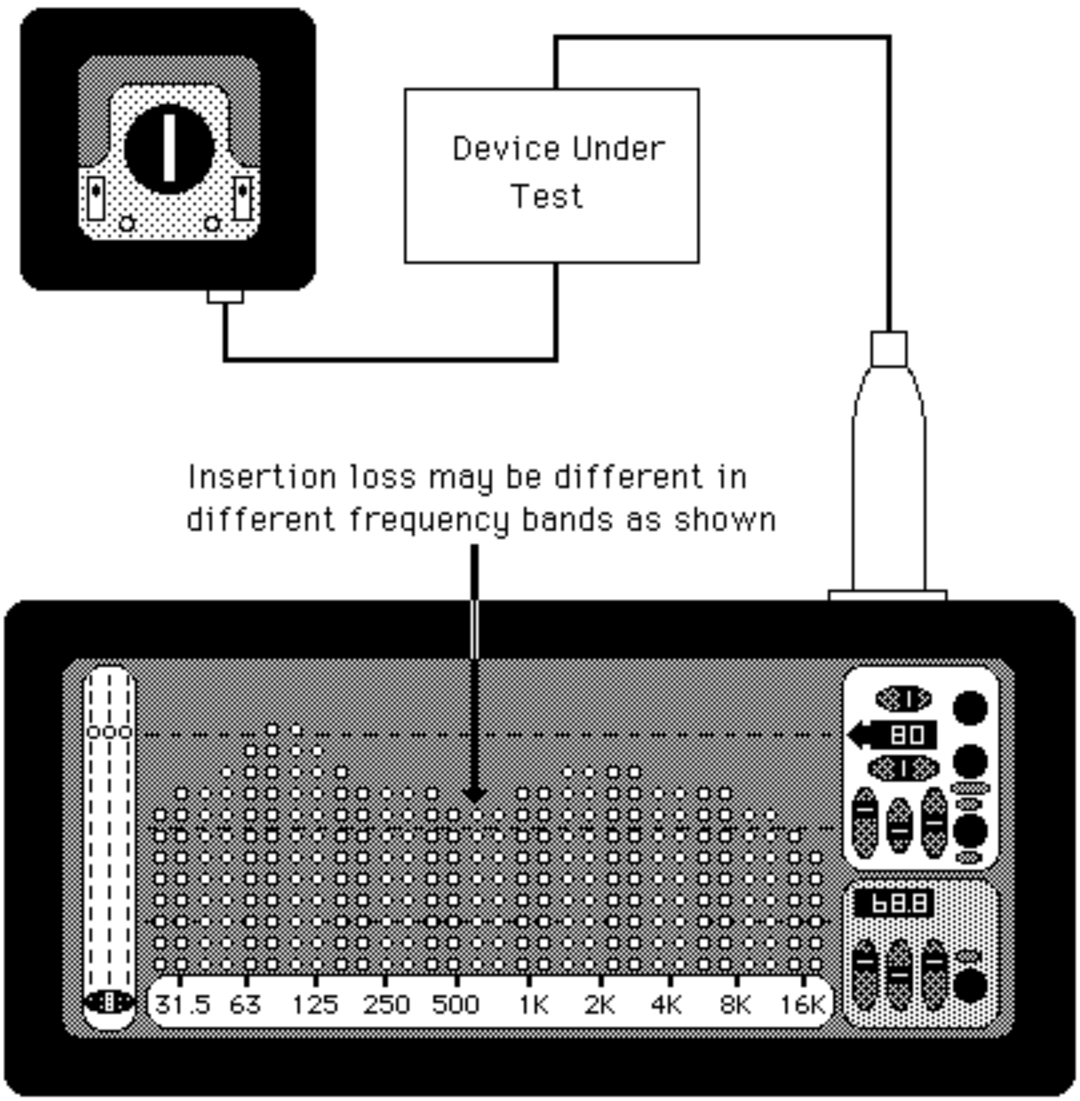


Figure XXI

In this measurement we can see the frequency selective nature of insertion loss. We can also measure, in dB, the exact drop in total signal level.

If our device under test were an amplifier, we could measure its 1/3 octave frequency response, and its voltage gain. If the device under test were a crossover, we could measure its gain or loss, see the frequency response of each leg, view the crossover point, and verify the roll-off associated with the band pass filters. We could measure the gain structure and frequency response of a single filter, or a whole bank of filters such as found in an equalizer.

Let's consider another interesting measurement. We can set it up feeding pink noise into the front end of our sound system. Using the IE-30A probe, we can tap into the output of our amplifier (the amplifier should be loaded) and look at the spectral display of information coming from the amplifier. Setup would be as shown below:

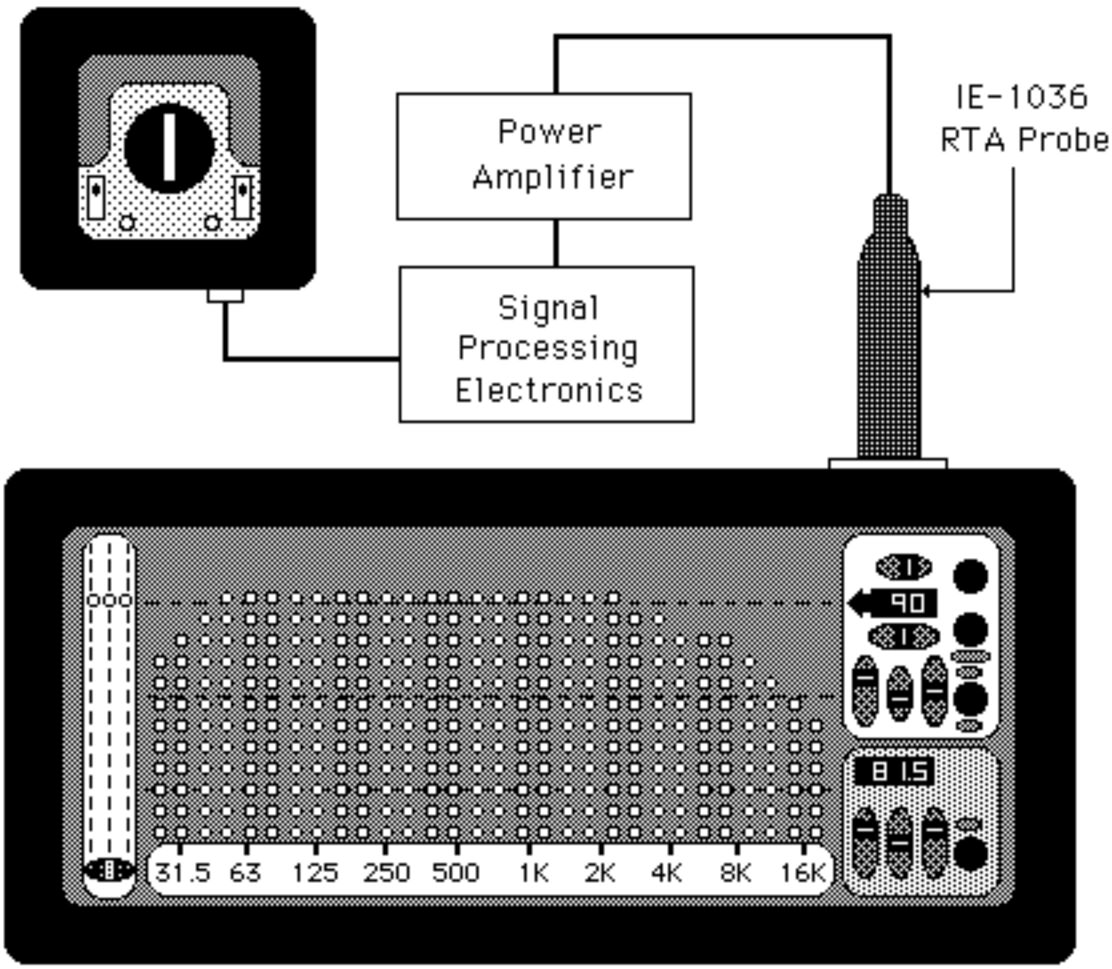


Figure XXII

Again, it would be important in our setup to make certain that the amplifier we are testing has been properly terminated, as shown below:

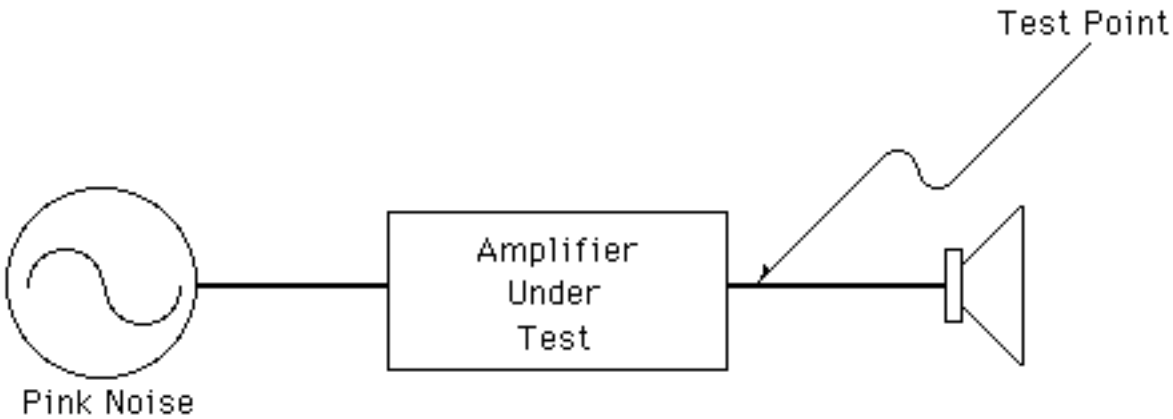


Figure XXIII

Notice that the output from the amplifier has been adjusted with both low and high end rolloff - not unlike we would expect to see. Other than that, the response looks very flat.

Next, for fun, we can look at the acoustic output of the speaker being fed by the amplifier to compare its spectral output with its electrical input. This time, instead of using the IE-30A probe, we plug in the microphone and listen to the speaker without changing our input signal. Any differences in spectral information will reflect the performance of the speaker in its environment. Incidentally, research has shown that the anechoic response of a speaker can quite accurately predict its response in an ordinary room. If we have a plot of the anechoic response, we would expect the response in our room to correlate.

At any rate, our test setup would change as shown on the following page:

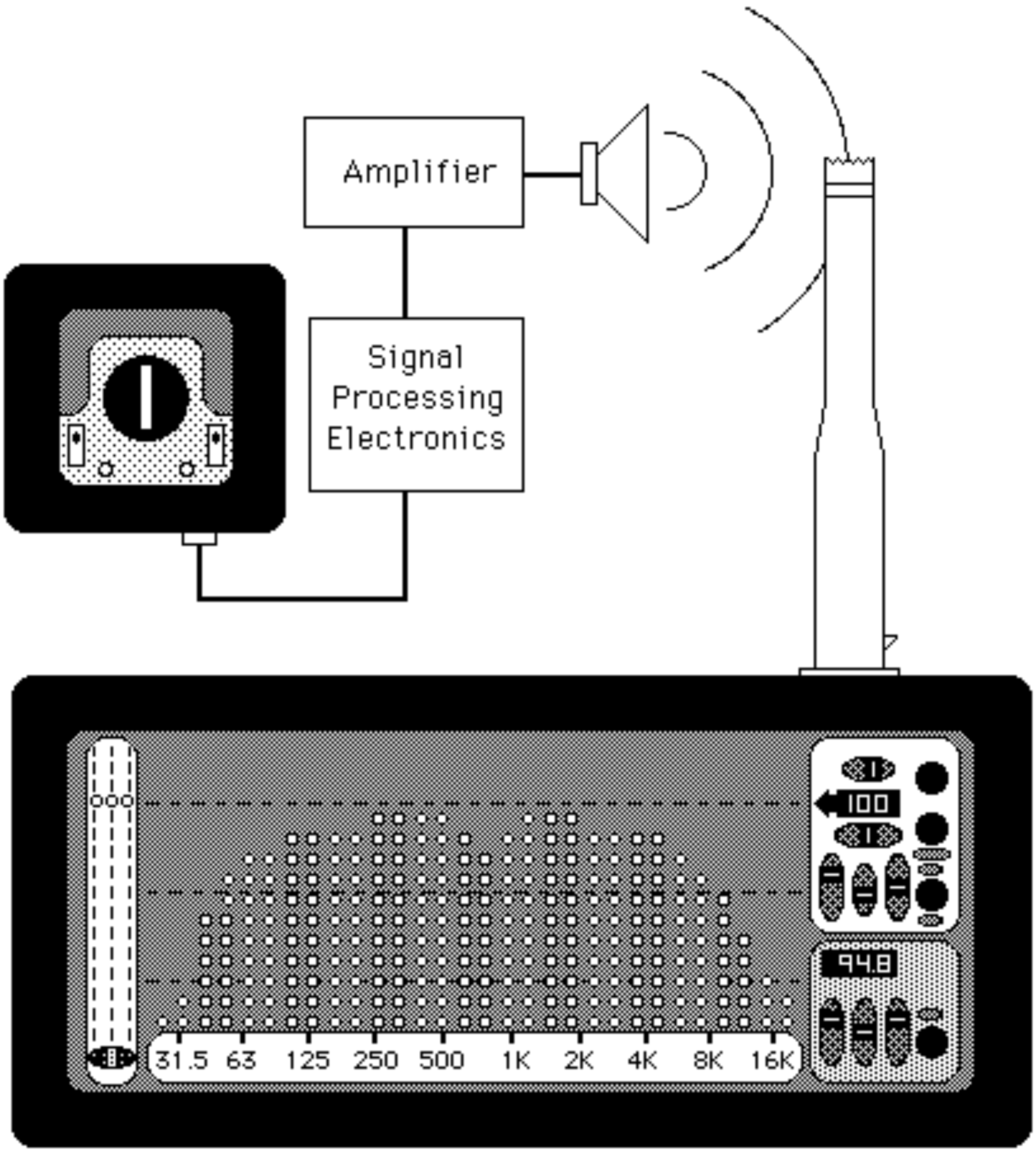


Figure XXIV

Obviously, we would expect to see some differences in response, as this illustration shows.

The power of this simple measurement process should become somewhat evident. By adding simple variations to the above setups, the parameters we can measure or verify are extensive. Let's consider the value of this approach in trouble shooting.

We are called back to a system which is not properly operating. It's a fairly simple system - a four input automatic mixer with an aux channel for music, a 1/3 octave equalizer, a two-way crossover, two one hundred watt amps for bass, and three fifty watt amps driving the high end.

We bring our set of documentation for this job, and we plug our pink noise generator into the music channel of the mixer. Our documentation shows the following:

1. The input level at which we should set our pink noise.

2. The settings on the mixer.

3. The output level and a plot of the spectral response of the mixer (which is also the input information for the equalizer).

4. The output level of the equalizer and a spectral plot of its output.

5. The output level of each of the legs of the crossover, and a spectral plot of each one showing crossover point and filter skirts.

6. The input level, gain, and output spectral plot for each amplifier.

7. A map of the listening area for the system with several points located. For each point, there is a spectral plot and dB SPL referenced.

It is now a quick and simple matter to step through each component of the system with the analyzer and a probe. Any defective component or change in setting can be quickly detected. Setting changes can be speedily corrected. If everything checks out electrically, measurements at the documented points in the listening area can identify speaker problems. Since we know what the output and spectral content of each amplifier is, we can verify that information at the input of a speaker to make certain we have no wiring problems.

Obviously, we have not covered every sound system parameter, but it can be easily seen that spending a little time in system documentation can save a lot of time in trouble shooting and correcting system problems.

Appendix: Table 1: dBµV to Vrms

dBµv	Vrms	dBµv	Vrms	dBµv	Vrms	dBµv	Vrms
-6	0.5 µv	39	89.1 µv	84	15.8 mv	129	2.82 v
-5	0.56 µv	40	0.1 mv	85	17.8 mv	130	3.16 v
-4	0.63 µv	41	0.112 mv	86	20.0 mv	131	3.55 v
-3	0.71 µv	42	0.126 mv	87	22.4 mv	132	3.98 v
-2	0.70 µv	43	0.141 mv	88	25.1 mv	133	4.47 v
-1	0.89 µv	44	0.158 mv	89	28.2 mv	134	5.01 v
0	1.00 µv	45	0.178 mv	90	31.6 mv	135	5.62 v
1	1.12 µv	46	0.200 mv	91	35.5 mv	136	6.31 v
2	1.26 µv	47	0.22 4mv	92	39.8 mv	137	7.08 v
3	1.41 µv	48	0.25 1mv	93	44.7 mv	138	7.94 v
4	1.58 µv	49	0.282 mv	94	50.1 mv	139	8.91 v
5	1.78 µv	50	0.316 mv	95	56.2 mv	140	10.00 v
6	2.0 µv	51	0.355 mv	96	63.1 mv	141	11.2 v
7	2.24 µv	52	0.398 mv	97	70.8 mv	142	12.6 v
8	2.51 µv	53	0.447 mv	98	79.4 mv	143	14.1 v
9	2.82 µv	54	0.501 mv	99	89.1 mv	144	15.8 v
10	3.16 µv	55	0.562 mv	100	0.1 v	145	17.8 v
11	3.55 µv	56	0.631 mv	101	.112 v	146	20.0 v
12	3.98 µv	57	0.708 mv	102	.126 v	147	22.4 v
13	4.47 µv	58	0.794 mv	103	.141 v	148	25.1 v
14	5.01 µv	59	0.891 mv	104	.158 v	149	28.2 v
15	5.62 µv	60	1.00 mv	105	.178 v	150	31.6 v
16	6.31 µv	61	1.12 mv	106	.200 v	151	35.5 v
17	7.08 µv	62	1.26 mv	107	.224 v	152	39.8 v
18	7.94 µv	63	1.41 mv	108	.251 v	153	44.7 v
19	8.91 µv	64	1.58 mv	109	.282 v	154	50.1 v
20	10.0 µv	65	1.78 mv	110	.316 v	155	56.2 v
21	11.2 µv	66	2.00 mv	111	.355 v	156	63.1 v
22	12.6 µv	67	2.24 mv	112	.398 v	157	70.8 v
23	14.1 µv	68	2.51 mv	113	.447 v	158	79.4 v
24	15.8 µv	69	2.82 mv	114	.501 v	159	89.1 v
25	17.8 µv	70	3.16 mv	115	.562 v	160	100.0 v
26	20.0 µv	71	3.55 mv	116	.631 v	161	112.2 v
27	22.4 µv	72	3.98 mv	117	.708 v	162	125.9 v
28	25.1 µv	73	4.47 nv	118	.794 v	163	141.3 v
29	28.2 µv	74	5.01 mv	119	.891 v	163	158.5 v
30	31.6 µv	75	5.62 mv	120	1.00 v	165	177.8 v
31	35.5 µv	76	6.31 mv	121	1.12 v	166	199.5 v
32	39.8 µv	77	7.08 mv	122	1.26 v	167	223.9 v
33	44.7 µv	78	7.94 mv	123	1.41 v	168	251.2 v
34	50.1 µv	79	8.91 mv	124	1.58 v	169	281.8 v
35	56.2 µv	80	10.0 mv	125	1.78 v	170	316.2 v
36	63.1 µv	81	12.6 mv	126	2.00 v	171	354.8 v
37	70.8 µv	82	12.6 mv	127	2.24 v	172	398.1 v
38	79.4 µv	83	14.1 mv	128	2.51 v	173	446.7 v
						174	501.2 v

Appendix: Table 2: dBµV to dBm

dBµv	dBm	dBµv	dBm
-6	-123.8	39	-78.8
-5	-122.8	40	-77.8
-4	-121.8	41	-76.8
-3	-120.8	42	-75.8
-2	-119.8	43	-74.8
-1	-118.8	44	-73.8
0	-117.8	45	-72.8
1	-116.8	46	-71.8
2	-115.8	47	-70.8
3	-114.8	48	-69.8
4	-113.8	49	-68.8
5	-112.8	50	-67.8
6	-111.8	51	-66.8
7	-110.8	52	-65.8
8	-109.8	53	-64.8
9	-108.8	54	-63.8
10	-107.8	55	-62.8
11	-106.8	56	-61.8
12	-105.8	57	-60.8
13	-104.8	58	-59.8
14	-103.8	59	-58.8
15	-102.8	60	-57.8
16	-101.8	61	-56.8
17	-100.8	62	-55.8
18	-99.9	63	-54.8
19	-98.8	64	-53.8
20	-97.8	65	-52.8
21	-96.8	66	-51.8
22	-95.8	67	-50.8
23	-94.8	68	-49.8
24	-93.8	69	-48.8
25	-92.8	70	-47.8
26	-91.8	71	-46.8
27	-90.8	72	-45.8
28	-89.8	73	-44.8
29	-88.8	74	-43.8
30	-87.8	75	-42.8
31	-86.8	76	-41.8
32	-85.8	77	-40.8
33	-83.8	78	-39.8
34	-82.8	79	-38.8
35	-81.8	80	-37.8
36	-80.8	81	-36.8
37	-78.8	82	-35.8
38	-79.8	83	-34.8

Appendix: IE-30A Block Diagram