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IE-17A
Microprocessor Audio Analyzer
Owner's Manual

Printed in U.S.A.

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SECTION I

MEETING THE IE-17A

MICROPROCESSOR AUDIO ANALYZER

INTRODUCTION

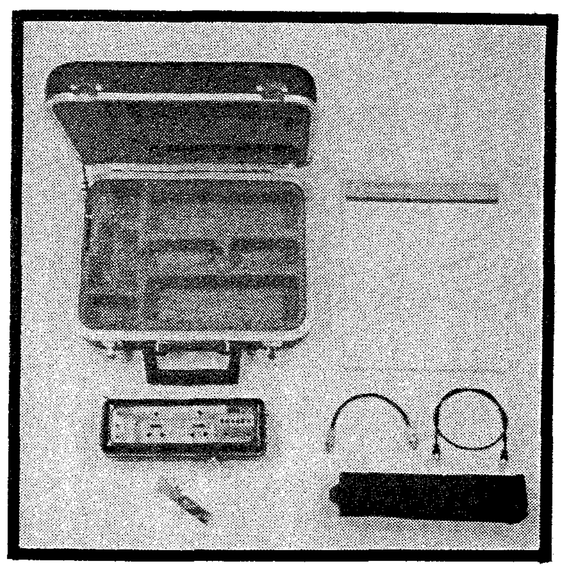
Congratulations! With the addition of the IE-17A Microprocessor Audio Analyzer to your IE-30A Audio Analysis System, you now command the most versatile and powerful acoustics measuring system available.

Now, under computer control, you can quickly and accurately measure such parameters as reverberation time (RT60), delay, and other time related phenomena. And, a permanent record of your test results can be produced by interfacing an X-Y recorder with your IE-17A.

As with other IVIE products, your IE-17A is built to give you years of trouble-free service. Its case is aluminum, fusion bonded with nylon, and its internal construction is 100% modular. It has been exhaustively tested to insure its performance to specifications, and its reliability has been assured by heat testing for over 100 hours at 125^{o} F. For many years to come, your IE-17A can be saving you time, and making your job easier.

The following sections in this manual detail the many features and applications for your new IE-17A. We suggest it be studied carefully in order that you may utilize the full potential of your IVIE acoustic analysis system.

With your IE-17A, you should have received the following items pictured below:



* IE-17A Microprocessor Audio Analyzer
* IE-30A/IE-17A Interconnect Cables
* IE-17A Owner's Manual
* New Foam Inserts for your IE-30A Carrying Case (Recent IE-30A's have been shipped with the proper foam insert, so a new foam insert may not have been included with your IE-17A)
* Test Cable Pouch for your IE-30A Carrying Case
* Hardware Packet for attaching IE-17A to IE-30A

Early IE-17A's were shipped with a small hardware packet including a bracket for attaching the IE-30A to the IE-17A. This is no longer necessary. The IE-17A, as now shipped, is easily attached to the IE-30A without use of additional hardware.

To mechanically connect the IE-30A to the IE-17A, simply position the IE-17A under the IE-30A and fasten the threaded screw connection. As you tighten the screw connection, the IE-17A will be pulled into the IE-30A, compressing the rubber "feet" on the units and assuring a firm connection.

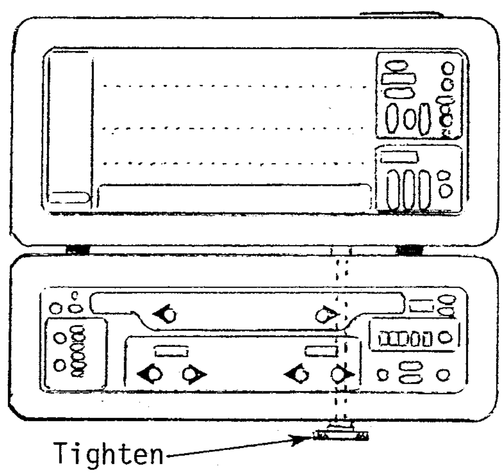


Figure 1

IE-30A/17A CONNECTOR DESCRIPTION

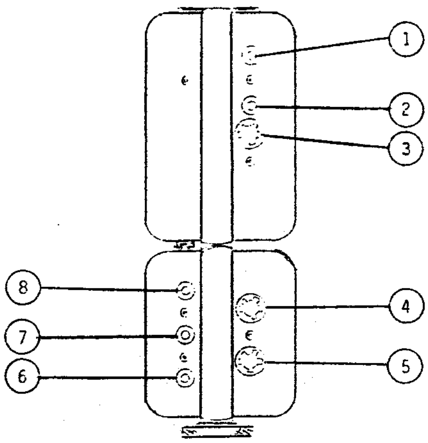


Figure 3

Below is a brief description of the IE-30A and IE-17A connectors. IE-30A/ IE-17A interconnections are detailed in the next section of this manual.

① IE-30A Preamplifier Output.

② IE-30A Adaptor/Charger Input Jack.

③ IE-30A Input/Output Digital Interface.

④ IE-17A Digital Interface. The digital interface between the IE-30A and IE-17A is described in detail in the section of this manual entitled, "IE-30A/IE-17A 7 Pin Digital Interface," on page 69.

⑤ IE-17A Peripheral Interface. This connector provides interface between the IE-17A and peripheral equipment such as oscilloscopes and X-Y plotters. Detailed information is provided in the section of this manual entitled, "IE-17A Peripheral Interface," on page 70.

⑥ IE-17A Source Control Output. (See ⑦ below)

⑦ IE-17A Source Conrol Input. The Source Control Input and Source Control Output are described in detail in the section of this manual entitled, "IE-17A Source Control Input and Output," on page 73.

⑧ IE-17A Delay Detector. As shown in the next section of this manual, the IE-17A Delay Detector is connected to the output of the IE-30A preamplifier, ①. When the IE-30A/IE-17A combination is being operated. Providing for the measurement of delay is the only function of this interface connector.

IE-30A/IE-17A ELECTRICAL CONNECTIONS

Electrical Connections between the IE-30A and the IE-17A are illustrated in Figures 4 and 5 below:

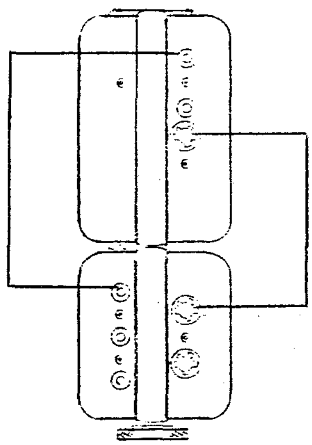


Figure 4

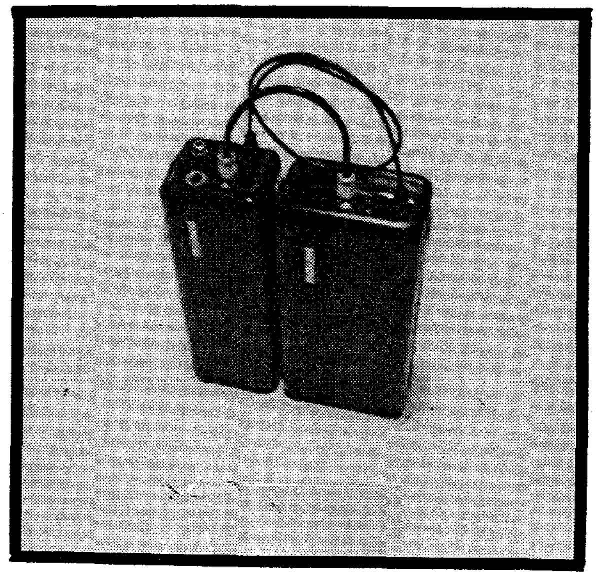


Figure 5

Using the phono patch cord, feed the IE-30A Preamp output into the IE-17A Delay Detector. Using the supplied umbilical, connect the digital interface of the IE-30A to the digital interface of the IE-17A.

The IE-30A/IE-17A system should now be ready for operation. Connection of the IE-17A to peripheral equipment such a oscilloscopes and X-Y plotters will be discussed in later sections of this manual.

IE-17A FRONT PANEL CONTROLS

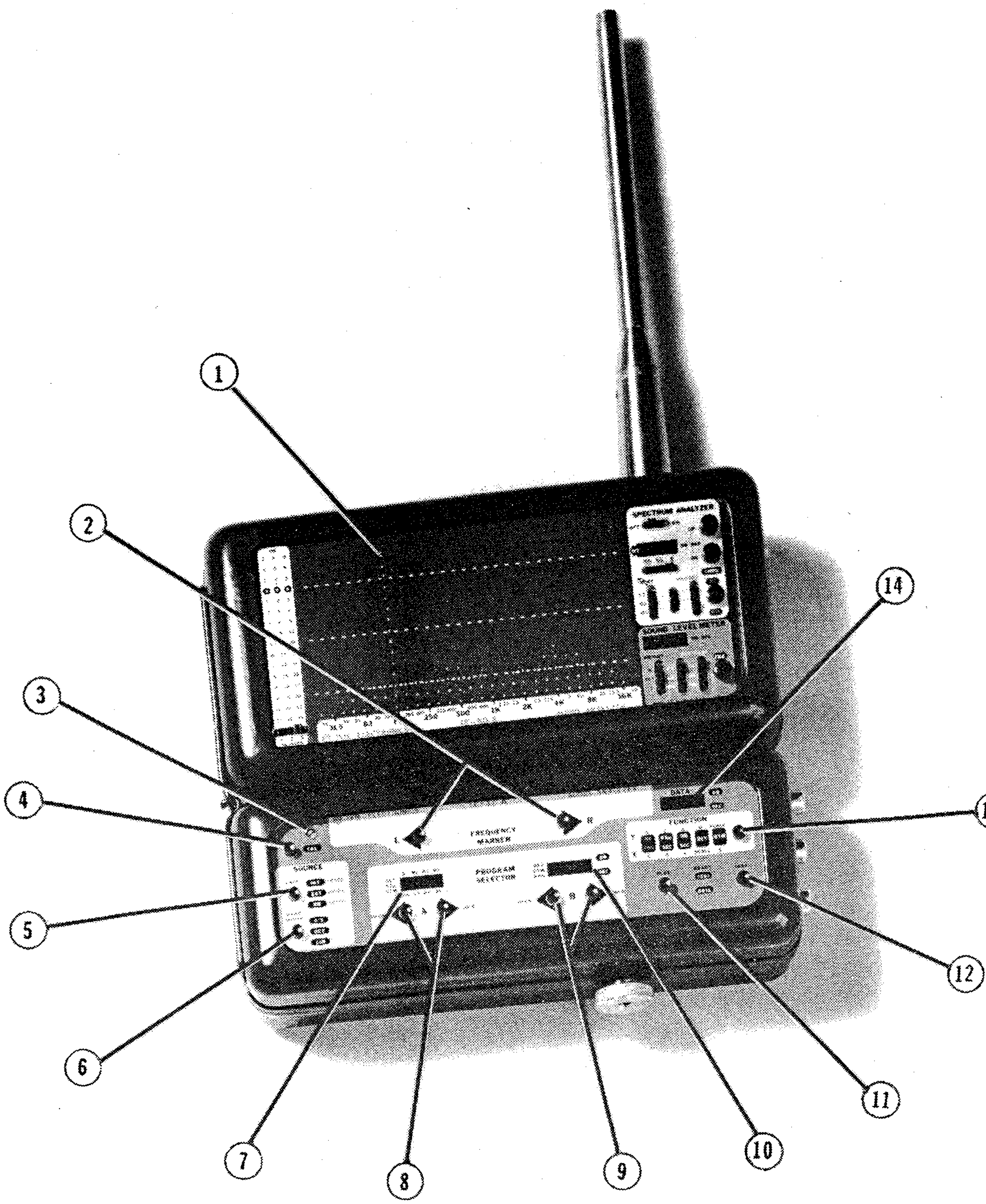


Figure 6

IE-17A FRONT PANEL DESCRIPTION

(1) Frequency Marker Wand. This wand indicates the 1/3 octave band or the octave band selected for measurements of various kinds.

(2) Frequency Marker Buttons. These are used to step the Frequency Marker Wand to the left or right across the IE-30A display screen.

(3) Writing Speed Control. This potentiometer adjusts the writing speed of X-Y plotters being driven by the IE-17A. Clockwise rotation increases writing speed.

(4) Calibration Button. This button is used to perform calibration of peripheral equipment (oscilloscopes and X-Y plotters) to the IE-17A.

(5) Gate Control Button. This button is used to control the gating capability of the IE-17A, and for the selection of internally or externally generated test signals.

(6) Bandwidth Button. This button selects the bandwidth of the IE-17A's integral bandpass and notch filters.

(7) Program Selector, Window A. This window indicates the IE-17A test program selected by the operator.

(8) Program A Control Buttons. These buttons allow the operator to select a particular test program. The selected program is then displayed in Program Selector Window A.

(9) Program B Control Buttons. These buttons allow the operator to select a particular measurement range.

(10) Program Selector, Window B. This window displays the measurement range selected by the operator.

(11) Plot Button. If an X-Y plotter is interfaced with the IE-17A, this button commands the plotter to write.

(12) Test Button. This button commands the IE-17A to perform the test or function selected by the operator.

(13) Function Selection Button. This button allows the operator to select the particular function he would like the IE-17A to perform.

(14) Data Window. Through this window, data stored in the IE-17A memories (such as test results) can be accessed.

NOTE: Several times in the next sections of this manual you will see numbers with a circle around them. Circled numbers refer to this front panel description.

The last page of this manual is a fold-out of the IE-17A front panel. It is there for convenience of reference while consulting the manual.

SECTION II

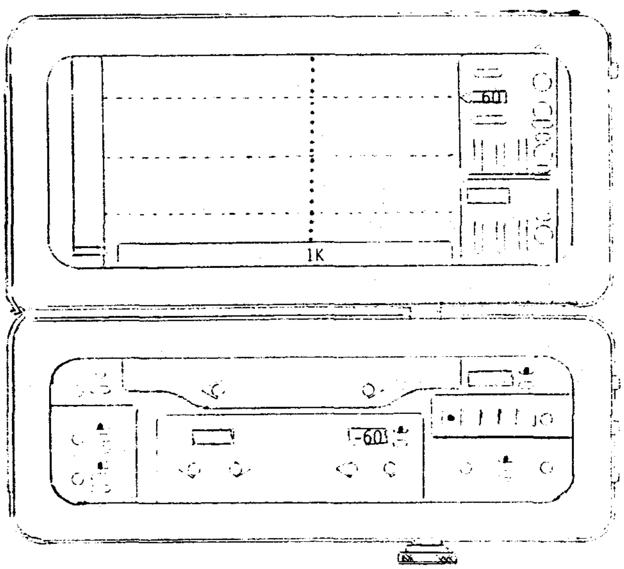
GETTING TO KNOW THE IE-17A

A BRIEF INTRODUCTION TO THE FUNCTIONS AND CONTROLS OF THE IE-17A MICROPROCESSOR AUDIO ANALYZER

POWER UP SEQUENCE

When the IE-30A/17A combination is turned on, the IE-17A undergoes a diagnostic power up sequence. This sequence triggers the IE-17A's internal, crystal controlled clock and verifies memory integrity.

If the power up and memory load diagnostics prove positive, the front panel of the IE-17A will indicate a "go" status by displaying the readings demonstrated in Figure 7 below:



DISPLAY READINGS

IE-30A	Reading
REFERENCE LEVEL----------	60dB
FREQUENCY MARKER WAND----	1KHz

IE-17A	Reading
SOURCE CONTROL-----------	"INT" and "1/3" LED's illuminated
PROGRAM SELECTOR B-------	-60dB (dB LED illuminated)
DATA WINDOW---------------	dB LED illuminated
FUNCTION SELECTOR---------	dB/FRQ
TEST----------------------	Ready LED illuminated

Figure 7

If the front panel of the IE-17A does not display the data shown in the above figure, turn the IE-30A off and back on. This will clear the diagnostic program and reinitiate the power up sequence once again.

The diagnostic program is further designed to locate defective memories. The location of the defective memory will be indicated by the display in the PROGRAM SELECTOR A WINDOW, (14) . If, after repeatedly switching the IE-30A off and on again, the display does not match that of the preceding figure, a memory may be defective. In that event, a number should appear in the PROGRAM SELECTOR A WINDOW indicating the location of the defective memory. The IE-17A will require factory authorized service if the diagnostic program locates a defective memory.

NOTE: Always check IE-30A battery status when powering up the IE-30A/17A. If the IE-30A batteries are low (red and green battery status LED's illuminated) the IE-17A will not function properly.

FUNCTION SECTION

The FUNCTION SECTION on the front panel of the IE-17A houses a push button, ⑬ , for selecting one of the five major functions of the IE-17A. There are also five windows in this section that indicate which of the five functions have been selected. The five major functions of the IE-17A are: dB (or amplitude) vs. Frequency, RT60, dB vs. Time, Delay and Gated Time Mode. Selection of the desired function is accomplished by pressing the FUNCTION BUTTON until the LED behind the appropriate FUNCTION WINDOW is illuminated.

PROGRAM SELECTOR

The PROGRAM SELECT BUTTONS, ⑧and ⑨, on the front panel of the IE-17A provide the user access to the microprocessor for the purpose of programming certain parameters in each IE-17A function. The PROGRAM SELECTOR SECTION allows selection of ranges when using the different functions of the IE-17A. The PROGRAM SELECTOR WINDOWS, ⑦ and ⑩ , define the data appearing in the DATA WINDOW, ⑭ . The parameters they control vary from function to function, and detailed descriptions of their operation can be found under the general function headings in Section III of this manual.

SOURCE CONTROL

The SOURCE CONTROL on the front panel of the IE-17A houses two push buttons, ⑤, and ⑥. The BANDWIDTH CONTROL BUTTON ⑥, is used to select filtering, if filtering is desired. Filters available for selection include octave, and 1/3 octave bandpass, and octave and 1/3 octave notch. Selecting LIN (linear) allows external signals to pass through the SOURCE CONTROL unfiltered.

The GATE MODE BUTTON, ⑤, allows the user to select between external and internal noise sources, and further allows him to place external signals under the gating control of the IE-17A microprocessor.

Much more detailed information concerning the SOURCE CONTROL signal handling capabilities, maximum input levels, etc. is presented in Section IV of this manual, pages 73 and 74.

Note: The IE-17A's internally generated SNARE pulse is a signal with unique characteristics. A complete description of the SNARE pulse can be found in Section IV of this manual on page 71.

FREQUENCY MARKER WAND

The flashing CURSOR WAND on the screen of the IE-30A, (1), is generated by the IE-17A for the purpose of marking the 1/3 octave or octave center frequency being measured or filtered by the IE-17A. The CURSOR WAND may be stepped left or right by using the L (left) and R (right) FREQUENCY MARKER BUTTONS, (2), in the FREQUENCY MARKER section of the IE-17A. Since the IE-17A filters track the CURSOR WAND as it moves across the IE-30A screen, the frequency center of the IE-17A filter is always the same as the frequency center of the channel the CURSOR WAND rests upon. Moving the wand to a given 1/3 octave or octave allows filtering at that frequency and bandwidth, if filtering is desired. The CURSOR WAND can also indicate the specific 1/3 octave or octave being tested in some IE-17A functions (RT60, dB/sec., etc.).

The CURSOR WAND may be "walked" off the IE-30A screen entirely. This is done by simply stepping the wand off either side of the screen. When this occurs, the IE-17A measures broadband information within the SPL meter.

TEST BUTTON

The TEST BUTTON, (12), initiates IE-17A measurements. Specific operation of the TEST BUTTON in each of the IE-17A's selectable functions is discussed in the Applications and Theory sections for each function.

Besides initiating measurements, the TEST BUTTON commands the IE-17A to load its own digital memory with the results of a test. Test results can then be accessed either at the IE-17A DATA WINDOW, or through the use of peripheral equipment such as oscilloscopes, or X-Y plotters.

PLOT BUTTON AND CONTROLLING THE PLOT

After data loading has been commanded by pressing the TEST BUTTON, the DATA LED will begin to flash. When it stops flashing, data has been loaded. To command a peripheral X-Y recorder to plot, simply push the PLOT BUTTON, (11). If at any time during the plot you should desire to stop the plotter, press the PLOT BUTTON again; the pen will lift and move to the lower right hand corner of the page.

DATA WINDOW

The DATA WINDOW, (14), in the upper right hand corner of the IE-17A front panel, is the window in which most of the measured and processed data appears. Amplitude in individual 1/3 octave bands, octave bands, or broadband, RT60 data, and delay data all appear in the IE-17A's DATA WINDOW. The small, illuminated "dB and "sec" windows beside the DATA WINDOW define the units of measure. More details as to specific information available at the DATA WINDOW is contained in the individual function Applications and Theory section of this manual.

SECTION III

USING THE IE-17A

APPLICATIONS AND THEORY

CALIBRATION OF PERIPHERAL DEVICES

The IE-17A is designed to drive peripheral devices, such as oscilloscopes and X-Y plotters. Care must be taken to properly connect these devices and calibrate them to the IE-17A.

The IE-17A PERIPHERAL INTERFACE PORT provides outputs to drive X-Y plotters and oscilloscopes. A brief mention of connections will be made here. For more details, refer to "IE-17A Peripheral Interface" in Section IV of this manual, page 70.

OSCILLOSCOPE HOOKUP

Any standard single channel ocilloscope (with ordinary phosphor), capable of being externally triggered, may be used.

1. Connect Pin #5 of the PERIPHERAL INTERFACE PORT to the Y axis input of the oscilloscope, D.C. coupled, and set initially to the .2V/div position.

2. Connect Pin #6 to the external trigger input of the oscilloscope.

3. Grounds must be carried to each connection via shielded cable.

OSCILLOSCOPE CALIBRATION

1. Turn the IE-30A/17A on. Check for proper operation.

2. Push the CALIBRATION BUTTON, (4), until the CAL LED beside it lights. This indicates that the IE-17A is now in a calibration mode.

3. Adjust the oscilloscope for D.C. coupled, external trigger.

4. Adjust the oscilloscope sweep rate (Time/Div) to about .2 msec/div until 10 "tick" marks appear, horizontally lined up across the X-axis of the screen. The vernier sweep adjustment, and the sweep position control are used to fine tune the horizontal spacing of these "tick marks" until they fall exactly on each of the first 10 vertical screen markings (usually 1cm apart), beginning with the first line on the left. See Figure 8.

5. Adjust the coarse and fine input attenuation adjustments on the oscilloscope (volts/div. or volts/cm) to first find and then adjust the heavy horizontal "tick mark." Move it to the right of the far right line on the screen until it rests at the upper right hand corner of the screen grid. A calibrated oscilloscope screen is demonstrated in Figure 8.

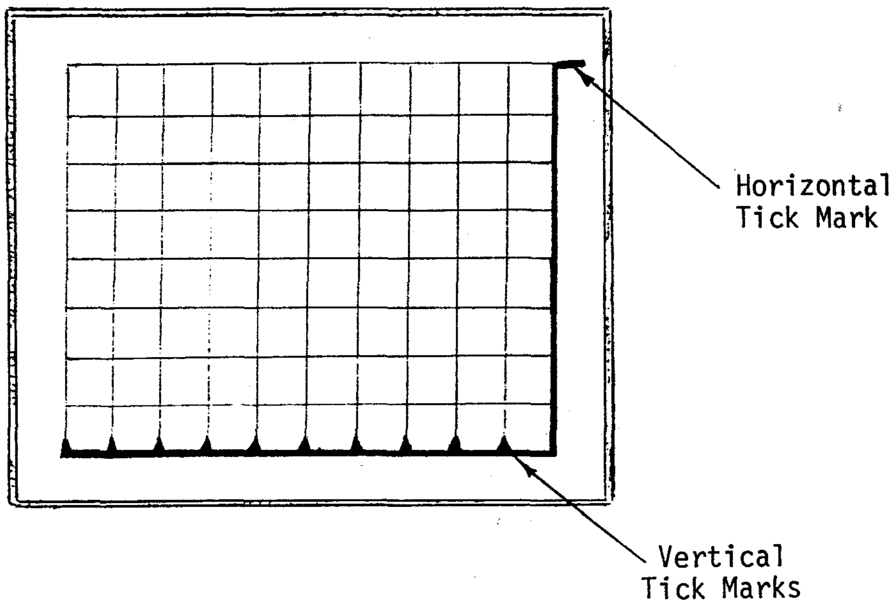


Figure 8

The above adjustments have calibrated the oscilloscope for X and Y axes. The horizontal "tick marks" represent octave or time divisions, depending on the IE-17A function selected, and the horizontal "tick mark" in the upper right hand corner represents full-scale amplitude. The Y-axis, full-scale, represents a range of 50dB, or a time period twice that of the X-axis, depending upon the IE-17A function selected.

Note: Some oscilloscopes with round CRT displays will not easily show the heavy horizontal "tick mark." With such scopes, it is necessary to adjust the octave/time (X-axis) "tick marks" to the left with the sweep vernier until the amplitude cal mark can be seen. Adjust the amplitude cal mark for full-scale reading, and then adjust the octave/time cal marks to their proper position.

PLOTTER HOOKUP

Any analog X-Y plotter capable of being driven full-scale by 2.5 VDC can be used with the IE-17A. A usable slew rate of 20 in/sec is ideal, but slower plotters can be compensated for by adjusting the IE-17A writing speed cal pot, (3). External pen lift is desirable.

1. Connect Pin #2 of the IE-17A PERIPHERAL INTERFACE PORT to the X-axis drive of the plotter.

2. Connect Pin #3 to the Y-axis drive of the plotter.

3. Connect Pin #4 to the external pen lift circuitry of the plotter. The IE-17A external pen lift command circuit is TTL compatible, but is not designed to switch higher voltage levels than TTL.

4. All leads to the plotter inputs should be shielded, and all grounds completed and tied to Pin #1 of the PERIPHERAL INTERFACE PORT.

X-Y PLOTTER CALIBRATION

1. Turn the IE-30A/17A on.

2. Push the CALIBRATION BUTTON, (4), until the CAL LED beside it lights. This indicates that the IE-17A is now in a calibration mode.

Note: When the IE-17A is in the cal mode, the FUNCTION SECTION is redefined. It now relates to the X and Y axes of peripheral equipment.

The redefined parameters are indicated by the graphics outside the windows housing the function indicator LED's. If, for example, the LED in the dB/FRQ window is illuminated, then for calibration purposes, X=0 and Y=0. If the next window is illuminated (RT60/SEC), then X=0 and Y=1.

3. Using the FUNCTION SELECTOR BUTTON, (13), select X=0, Y=0. The pen of the plotter, if all connections have been properly made, should be in the lower left hand corner of the paper or field of interest as in Figure 9 below.

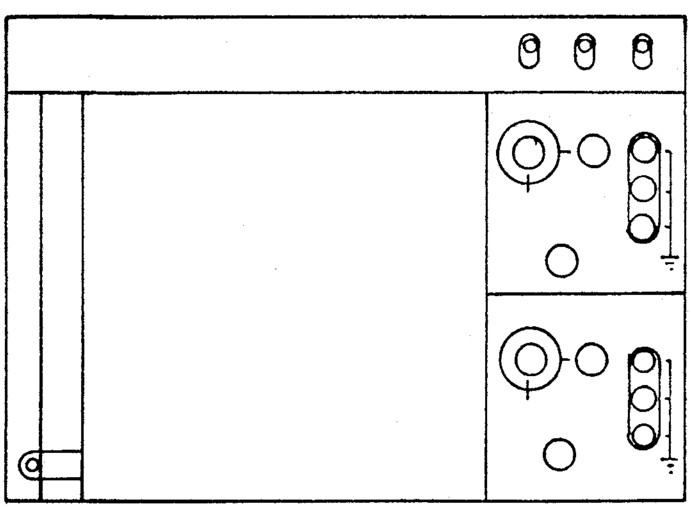


Figure 9

4. Adjust the X and Y controls on the plotter to properly position the pen a "0-0" (the intersection of the X and Y axes).

5. Push the FUNCTION SELECTOR BUTTON, (13), once to select the next calibration function, Y=1; X=0. This should move the plotter pen to the upper left hand corner of the paper or field of interest as demonstrated by Figure 10 below.

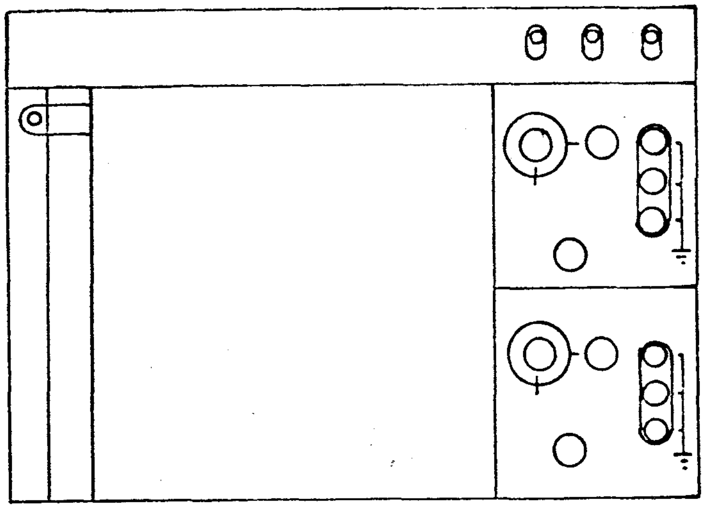


Figure 10

6. Adjust the Y-axis gain of the plotter to place the pen at the desired amplitude.

7. Push the FUNCTION SELECTOR BUTTON once again to select the next calibration function, Y=0; X=1. The plotter pen should move to the lower right hand corner of the paper or field of interest as demonstrated by Figure 11 below.

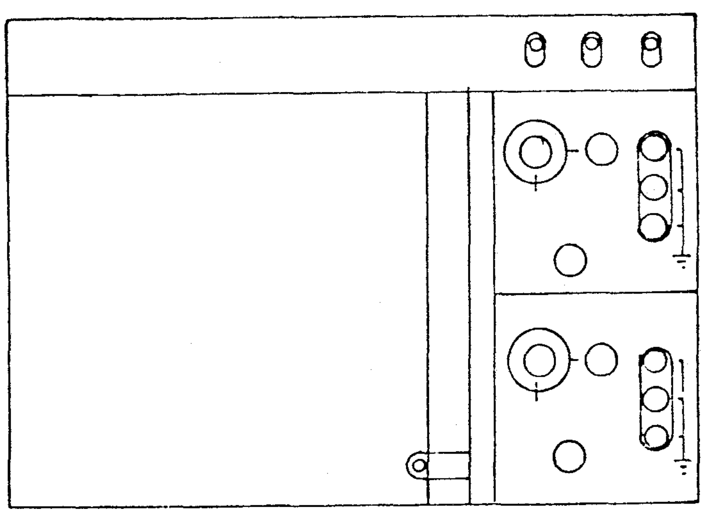


Figure 11

8. Adjust the X-axis gain of the plotter to place the pen at the desired magnitude along the X-axis. The X-Y plotter should now be calibrated for use with the IE-17A.

X-Y PLOTTER SCALING FEATURE

There may be times when plain white paper, rather than printed graph paper is the desired copy plate for plots. In these instances, the IE-17A is capable of drawing its own scaling lines. This can be done in the following manner.

1. After calibrating the X-Y plotter (the IE-17A should still be in the cal mode with the FUNCTION SELECTOR still at Y=0; X=1), push the FUNCTION SELECTOR BUTTON once more to select the next cal function, "X Scale." The IE-17A will automatically draw an X-axis line with 10 calibration "tick marks."

2. Push the FUNCTION SELECTOR BUTTON once more to select the next cal function, "Y Scale." The IE-17A will then automatically draw a Y-axis line with 10 calibration "tick marks." An X-Y scale drawn by an IE-17A is shown in Figure 12 below.

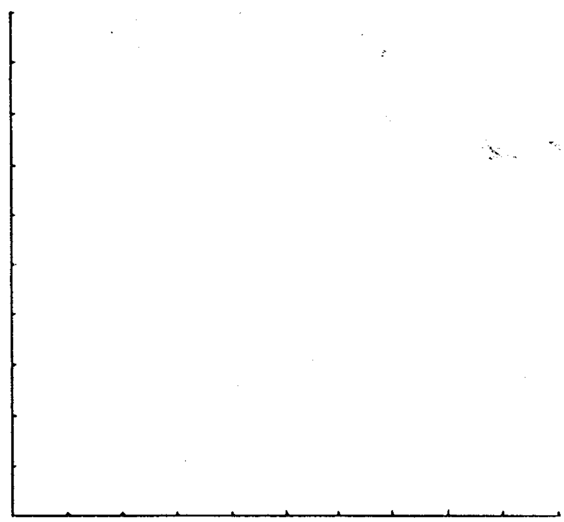


Figure 12

As with an oscilloscope, the horizontal "tick marks" represent octave bands or time divisions, depending on the IE-17A function selected, and the vertical "tick marks" represent 5dB increments of the 50dB range of the Y-axis. In those functions of the IE-17A where the Y-axis represents a time period twice that of the X-axis, the Y-axis "tick marks" divide the time window into 10 equal parts.

After calibration has been completed, press the CALIBRATION BUTTON, (4), once. This will take the IE-17A out of the calibration mode and return it to the measurement mode.

MEASUREMENTS OF THE DB/FREQUENCY MODE

Alone, the IE-30A is capable of measuring signal amplitudes in octave or 1/3 octave channels with a maximum resolution of 1dB. One of the powers of the IE-30A/IE-17A system is its ability to measure signal amplitudes in octave or 1/3 octave channels with a resolution of .1dB.

To measure amplitude in a specific octave or 1/3 octave channel, set the IE-30/17A controls as follows:

IE-30A Control	Setting
REFERENCE LEVEL	Set so signal can be seen "on screen"
DISPLAY FILTER SELECTOR	Either octave or 1/3 octave as desired
DETECTORS	D3
MEMORY SELECTOR	Set for real-time display
DISPLAY RESOLUTION	3dB/step

IE-17A Control	Setting
CALIBRATION BUTTON	Out of Cal Mode (Cal LED should not be lit)
FUNCTION SELECTOR	dB/Frequency
PROGRAM B	Set to match IE-30A REFERENCE LEVEL

With the IE-30A/17A controls set as above, step the CURSOR WAND to the channel of interest. The IE-17A DATA WINDOW will display the amplitude of the signal in that channel with .1dB resolution.

A simple example should serve to clarify the measurement procedure. Byron Sorenson has an expensive preamp that has a "loudness" switch. He wants to know what throwing the loudness switch will do to his preamp frequency response at the 250Hz octave channel. He feeds pink noise into his preamp, and feeds the preamp output into the IE-30A/17A. His test setup is shown in Figure 13 on the next page.

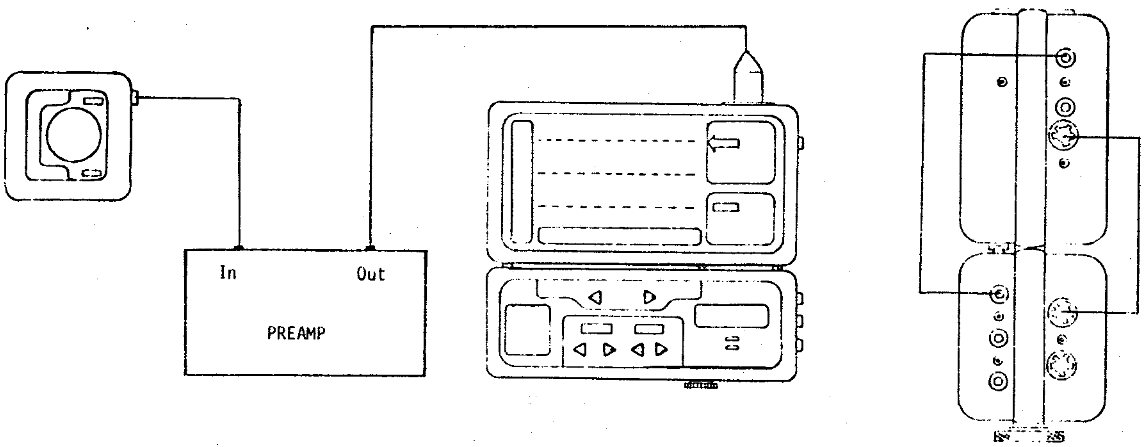


Figure 13

Byron sets his IE-30A/17A controls as follows:

IE-30A Control	Setting
REFERENCE LEVEL	100dB
DISPLAY FILTER SELECTOR	Octave
DETECTORS	D3
MEMORY SELECTOR	Set for real-time display
DISPLAY RESOLUTION	3dB/step

IE-17A Control	Setting
CURSOR WAND	250Hz
CALIBRATION BUTTON	Out of Cal Mode
FUNCTION SELECTOR	dB/Frequency
PROGRAM B	100dB

With the loudness switch off, Byron reads an amplitude of 110.4 in the DATA WINDOW. Since he is looking at an electrical signal, the IE-30A and IE-17A are calibrated in dB microvolts. Byron is measuring an amplitude of 110.4dB µv in the octave channel centered at 250Hz.

Next, Byron turns the loudness switch on. He notices a change in his preamp frequency response displayed on the screen of his IE-30A, and reads a new level of 113.8dB µv in the DATA WINDOW of the IE-17A. Turning his preamp loudness switch on has given him 3.5dB of gain at the 250Hz octave channel.

If he wanted to do so, Byron could easily walk the CURSOR WAND anywhere else on the IE-30A screen to measure the amplitude in any given channel with a .1dB resolution. If he were using the IE-30A microphone and measuring an acoustic signal rather than an electrical signal, the IE-30A/17A would be calibrated in dB SPL, rather than dB µv.

Important Notes

1. To make amplitude measurements as has been described, the IE-30A DISPLAY RESOLUTION must be set at 3dB/step. Calibration of the IE-30A/17A is set for the 3dB/step resolution, and readings taken at 2dB or 1dB/step would be uncalibrated.

   The 3dB/step resolution setting is actually an advantage in that it gives maximum dynamic range on the IE-30A display, and still allows high resolution measurements in individual channels.

2. The IE-17A cannot measure amplitudes that are above or below the IE-30A display screen. Amplitudes extending above the IE-30A display will be "chopped off" when the IE-17A sees them. Amplitudes below the IE-30A screen cannot be accurately measured either. The IE-30A REFERENCE LEVEL needs to be adjusted so that signals being measured can be seen "on screen."

3. It is important to match the reference in the IE-17A PROGRAM SELECTOR B WINDOW to the REFERENCE LEVEL setting of the IE-30A. This insures calibration of the two instruments to one another, and provides for accurate amplitude measurements.

   A sometimes useful measurement variation is possible. If the PROGRAM B reference level is set to 0, the readings in the DATA WINDOW indicate dB above or below the REFERENCE LEVEL of the IE-30A. If, for example, the IE-30A REFERENCE LEVEL is set to 80dB, the PROGRAM B reference of the IE-17A is set to 0, and the reading in the IE-17A DATA WINDOW is -7.3dB, then the amplitude of the signal being measured is 7.3dB below 80dB (72.7dB).

X-Y PLOTS

A powerful function of the IE-30A/IE-17A in the dB/Frequency Mode is its capability to produce X-Y plots on either an oscilloscope or an X-Y plotter. Interfacing the IE-17A with an oscilloscope or an X-Y recorder is a simple procedure.

OSCILLOSCOPE PLOTS

Connection of an oscilloscope to the IE-17A has already been discussed in this section of the manual on pages 16 and 17. Additional information is contained in Section IV, page

An oscilloscope may be used in conjunction with an X-Y plotter, or by itself. If used with a plotter, it will allow you to preview the X-Y plots before committing them to paper. A storage scope is not required because of the memory capability of the IE-17A. The oscilloscope display is continually refreshed by the IE-17A memory.

The real-time display of the IE-30A, or the contents of either IE-30A memory can be transferred to the screen of an oscilloscope. To accomplish this, calibrate the oscilloscope to the IE-17A as previously described. For plotting real-time data, set the IE-30A controls such that a real-time display appears "on screen." IE-17A controls should be set as follows:

IE-17A Control	Setting
CALIBRATION BUTTON----------------------	Out of the Cal Mode (Cal LED should not be lit)
FUNCTION SELECTOR----------------------	dB/Frequency

When you are ready to transfer the IE-30A frequency response to an oscilloscope display, press the IE-17A TEST BUTTON once (the TEST LED must be illuminated — if the DATA LED is illuminated instead, push the TEST BUTTON once to illuminate the TEST LED, and once more to actuate the plot). The IE-17A computer will scan the analog output of each IE-30A filter and transfer the data to memory. It will do this within 8 milliseconds. The IE-17A will then automatically display the data on the oscilloscope. If a different plot is desired, touch the TEST BUTTON once to rearm the system, then press it again to actuate a new plot. Whatever is displayed on the IE-30A screen will be automatically committed to an oscilloscope plot.

To plot the contents of an IE-30A memory, simply recall the memory to the IE-30A screen, then push the IE-17A TEST BUTTON. The memory contents will then be plotted on the oscilloscope.

PLOTS USING AN X-Y RECORDER

For those times when a hard copy of the IE-30A display is necessary, the IE-17A provides easy interface with an X-Y plotter. Connection of an X-Y plotter to the IE-17A was discussed earlier on pages 17 through 20, and additional information is available in Section IV, page 70.

To use an X-Y plotter, first calibrate it to the IE-17A as described previously. Next, set the IE-30A and IE-17A controls just as you would if you were going to plot with an oscilloscope. When you pushed the TEST BUTTON to initiate a scope plot, the test data was stored in the IE-17A computer memory. To recall memory and actuate a plot on the X-Y recorder, simply push the PLOT BUTTON. The IE-17A will "remember" what was displayed on the IE-30A screen when you pressed the TEST BUTTON, and will plot it with the X-Y plotter.

If, for some reason, you want to abort the plot after it has started, push the PLOT BUTTON again. The pen will lift and move to the lower right hand corner of the plotter.

If the IE-30A display plotted is a 1/3 octave display, the X-Y plotter will plot a line graph. If the IE-30A display is an octave display, the X-Y recorder will plot a bar graph. Examples of octave and 1/3 octave display plots are shown in Figure 14 below.

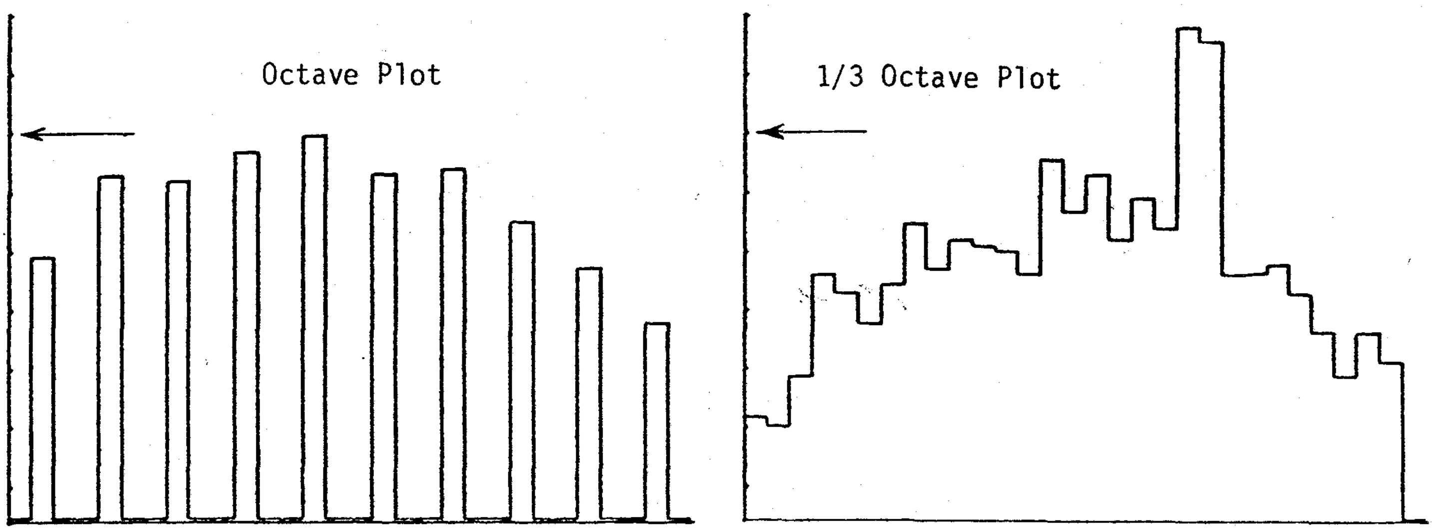


Figure 14

Important Notes

1. For purposes of calibration, the Y axis on X-Y plots represents 50dB, full-scale. The second "tick mark" from the top (see the arrows in plots above) is always equal to the value of the REFERENCE LEVEL setting of the IE-30A at the time the plot was actuated. If, for example, the REFERENCE LEVEL setting of the IE-30A were 90dB when the two plots in Figure 14 we actuated, then the arrows would indicate a 90dB absolute level at the "tick marks" they point to.

2. It should be noted that the Y-axis on X-Y plots represents 50dB, full-scale, only when the IE-30A is in the 3dB/step resolution setting. If the IE-30A is in the 2dB/step resolution position, the Y-axis full-scale value will be 30dB. If the IE-30A resolution is 1dB/step, the full-scale value of the Y-axis will equal 15dB.

   Regardless of the IE-30A resolution setting, the second "tick mark" from the top on the Y-axis will always be equal in value to the REFERENCE LEVEL of the IE-30A.

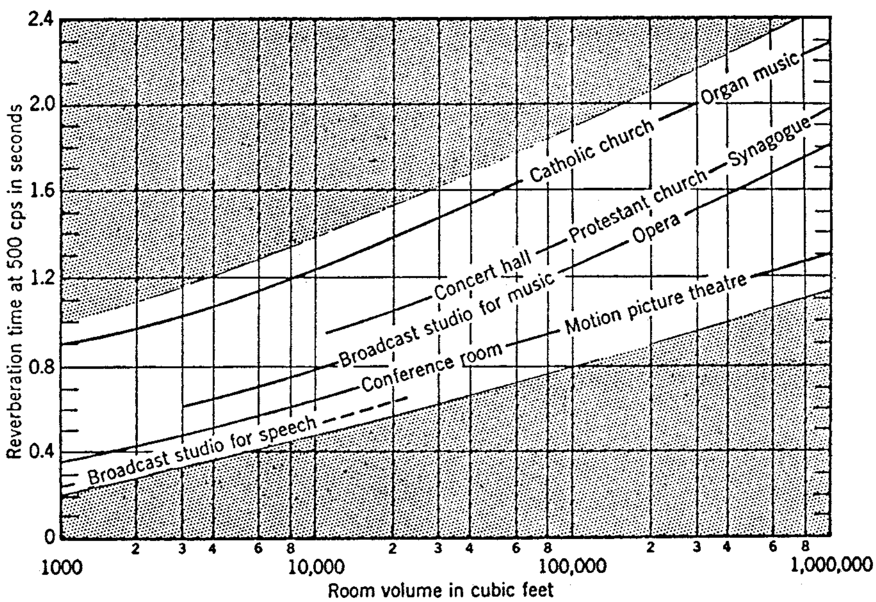
3. Maximum resolution of the IE-30A screen is 1dB. However, an oscilloscope or X-Y plot of the real-time display of the IE-30A is not limited to a 1dB resolution. The IE-17A does not "read" the IE-30A screen, it samples the analog output from the individual filters and plots that data. Plot resolution, therefore, is better than .2dB. Plots of the contents of the IE-30A memories, however, have the same resolution as was selected on the IE-30A when the data was committed to memory (1, 2, or 3dB/step).

4. The FREQUENCY MARKER WAND must be showing on the screen of the IE-30A before a frequency response plot can be transferred to an oscilloscope or X-Y plotter. If the FREQUENCY MARKER WAND is stepped off screen into the SPL meter, then the transferred plot will be of a single broadband SPL value, instead of the frequency vs. amplitude information being displayed on the screen of the IE-30A. A single, broadband SPL value will plot as a straight line, parallel to the X-axis.

5. If you are using an oscilloscope and an X-Y plotter together, you will notice that the oscilloscope screen will go blank while the X-Y recorder is plotting. This occurs because data output from the IE-17A memory is slowed to be compatible with the X-Y recorder drive circuitry. After the plot has been completed, the oscilloscope display will be restored and continually refreshed.

REVERBERATION TIME MEASUREMENTS

Reverberation is a measurement of the decay rate of sound. More specifically, reverberation time (RT60) is defined as the "time" it takes for reverberant energy in a room to decay 60dB, after the energy has been shut off. Normally, the RT60's of narrow bands of energy (1/3 octave or octave bands) are measured at several frequencies of interest, and then the data is compared to determine the absolute, and the relative room decay rates at the different frequencies. While the ideal room would have equal RT60's at all frequencies, most rooms exhibit RT60's that vary significantly with frequency. The objective is to engineer rooms that neither have dead bands (energy absorbed too quickly) nor distortion and feedback (energy not being absorbed fast enough - too reverberant). Acoustical engineers generally agree on the acceptable levels of RT60 relative to the room volume, and the intended acoustical application of the room in question. A suggested guideline for a frequency of 500 Hz is shown in the chart below:



Optimum reverberation times for rooms of various volumes and uses. *(Compiled from the literature and from the experience of Bolt Beranek and Newman, Consultants in Acoustics.)*

Figure 15

RT60 USING AN AMPLIFIER SYSTEM

The following block diagram represents a typical IE-30A/17A equipment setup for measuring RT60.

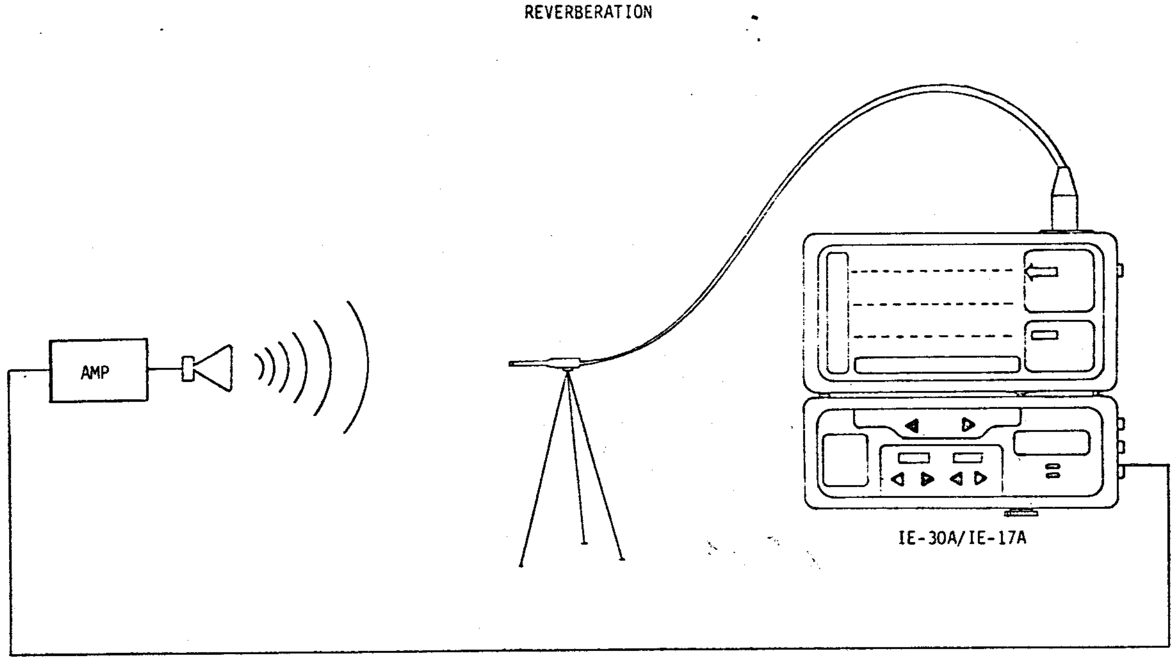


Figure 16

1. Connect the IE-17A to the IE-30A, and to the amplifier system as shown in the wiring diagrams below.

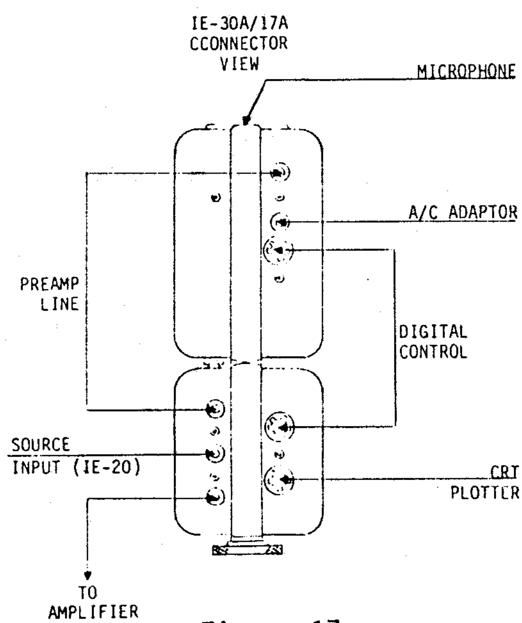


Figure 17

2. Front Panel Settings:

IE-30A Controls	Control Settings
OFF/On	On
dB/STEP	3 dB
1/3 or 1 octave filters as desired by operator	
dB REF	Set to desired room SPL level
DECAY	D1
MEMORY	Set for real-time display
SOUND LEVEL METER	A, SW, CT

IE-17A Controls	Control Settings
FUNCTION	RT60
SOURCE-GATE	INT
SOURCE-BANDWIDTH	1/3 or 1 octave as desired.
PROGRAM SELECTOR A	Used only to interpret test data.
PROGRAM SELECTOR B	Set to desired time range.
FREQUENCY MARKER	Set to desired test frequency.

3. Connect and calibrate the oscilloscope and X-Y plotter, if these accessories are used for RT60 measurements. (See pages 16 through 20 for details).

4. MEASUREMENT PROCEDURE

Attenuate the signal output of the noise generator before turning it on, to prevent blasting the amplifier/speaker system with too much energy. With the pink noise generator turned ON, increase the signal output level until the desired room SPL level is reached. Try to insure an adequate signal to noise ratio ($>$ 30dB) of the pink noise relative to the room ambient noise. In those environments where the signal to noise ratio is less than 30dB, the operator will have to settle for a decreased measurement for range RT60. Other signal sources, sinewaves, warble tones, and noise generators can be used with the IE-17A.

With the desired SPL level of band limited noise in the room, an RT60 measurement is executed by simply pushing the TEST BUTTON on the IE-17A front panel. The measurement data is ready for user analysis when the DATA READY light stops flashing, and data appears in the DATA WINDOW.

PROGRAM SELECTOR "A" controls are used to select the calculated RT60 data from the processor's memory files. The available values of calculated RT60 are shown in the table below:

Decrement (DECR) — Memory Pointer — (INCR) Increment

PROGRAM SELECTOR A	Calculated RT60 for:
1 - 5	First 5dB of decay
2 - 5	Second 5 dB of decay
3 - 5	Third 5 dB of decay
4 - 5	Fourth 5 dB of decay
5 - 5	Fifth 5 dB of decay
6 - 5	Sixth 5 dB of decay
1 - 10	First 10 dB of decay
2 - 10	Second 10 dB of decay
3 - 10	Third 10 dB of decay
1 - 15	First 15 dB of decay
2 - 15	Second 15 dB of decay
1 - 20	First 20 dB of decay
1 - 30	First 30 dB of decay

Figure 18

The increment (INCR), and decrement (DECR) buttons of PROGRAM SELECTOR A move the memory pointer through the files of calculated RT60 values for all positions along the decay curve. Calculated values of RT60 are displayed in the DATA window of the IE-17A and are expressed in seconds.

EXAMPLE MEASUREMENT

PROGRAM SELECTOR A indicates the numbers 1-10, and the answer in the DATA window is 2.46 seconds (sec). This implies that the measured RT60 during the first 10dB of decay (1-10) is equal to 2.46 seconds.

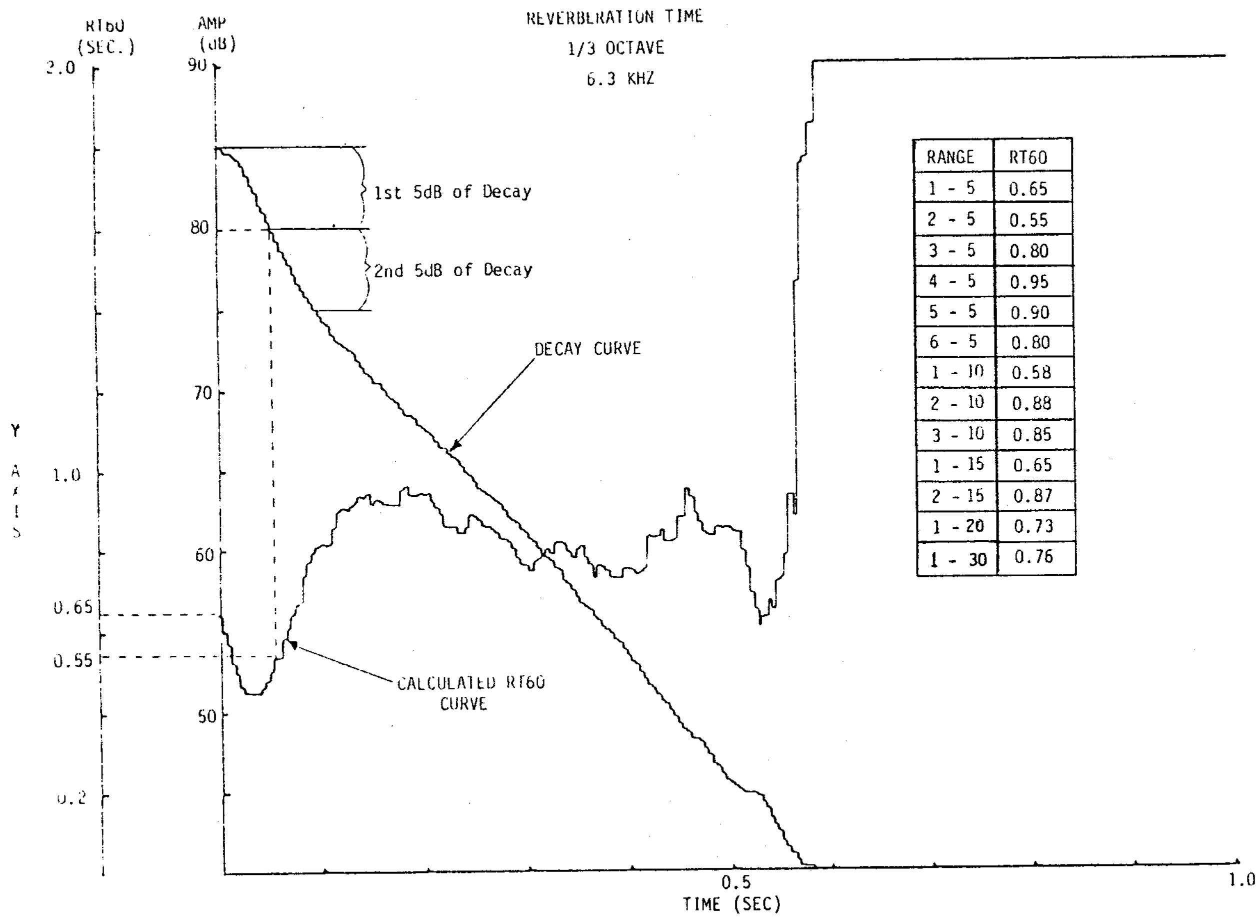
It would be incorrect to say that the room decayed only 10 dB in 2.46 seconds. Interpreted correctly, the measured time of 2.46 seconds represents the time taken for the room energy to decay over the defined range of 60dB (RT60), assuming that it decayed at the same rate as measured during the first 10dB of decay. Basically, then, RT60 is a mathematical extrapolation of data taken over a small dB range as if that same decay rate occurred over the entire 60dB range. The obvious question is why don't we simply measure RT60 over a 60dB range, and forget all the mathematics? Hopefully, the answer is just as simple; few rooms have a dynamic range of 60dB. In fact, most rooms exhibit a range of only 25-35 dB between the ambient noise and normal listening levels. RT60 measurement systems must use mathematical extrapolation to satisfy the definition of RT60. Mathematical extrapolation then, represents little more than facing the facts of life.

There would be little incentive to measure RT60 over 60dB even if a room had the dynamic range. One reason is that a normal room will exhibit different decay rates (a non-linear decay) during a measurement sequence for the same frequency band. The room will likely show a different decay rate for the first 10dB of decay than for the second or third 10dB increment of decay. We are naturally more concerned about the room effects of the first few dB of decay, than we are about energy that is thirty or forty dB below the room listening levels. The IE-30A/17A system allows the segmentation and analysis of any portion of the decay curve so that room effects can be analyzed properly. The effective value of RT60 for a room is determined more by room characteristics of the first 10-20dB of decay than by the actual decay value for all 60dB of decay.

PLOTTING AND DISPLAYING RT60 DATA

Plotting the RT60 decay curve, and the calculated RT60 curve with the IE-17A is an automatic task that is activated by pressing the PLOT BUTTON. Depressing the PLOT BUTTON causes the X-Y recorder to plot the conventional decay versus time curve first, and the next push of the button generates a plot of the calculated RT60 at every point along the decay curve.

Labeling the plot, and interpreting the data deserves some discussion. In Figure 19 below is represented a typical RT60 plot with the axes labeled:



RANGE	RT60
1 - 5	0.65
2 - 5	0.55
3 - 5	0.80
4 - 5	0.95
5 - 5	0.90
6 - 5	0.80
1 - 10	0.58
2 - 10	0.88
3 - 10	0.85
1 - 15	0.65
2 - 15	0.87
1 - 20	0.73
1 - 30	0.76

Figure 19

1. The X-axis expresses time and its full scale value is equal to the range selected by PROGRAM SELECTOR B before the measurement sequence was started. In the previous example, a 1.0 second range was in PROGRAM SELECTOR B -- hence the X-axis, full scale, equals 1.0 seconds.

2. The Y-axis has dual scales. For interpreting the decay curve, the Y-axis equals 50dB. Absolute readings are possible since the second "tick mark" from the top of the Y-axis is always equal in value to the setting of the REFERENCE LEVEL of the IE-30A. In our example, the REFERENCE LEVEL of the IE-30A was 80dB, so the second "tick mark" on the Y-axis equals 80dB.

The second Y-axis scale is used to interpret the calculated RT60 curve. When reading the calculated RT60 curve, the Y-axis expresses time and its full scale value is always equal to twice the value of the X-axis. In our example, the X-axis full scale is equal to 1.0 seconds, so the full scale value of the Y-axis is equal to 2.0 seconds.

3. The IE-17A DATA WINDOW can give us data concerning the calculated RT60 for several segments of the decay curve. The table in Figure 19 presents the information available from the DATA WINDOW. The plotted decay and RT60 curves allow us to greatly expand the available data. If we choose any point along the decay curve, we can determine the calculated RT60 for the 5dB increment of the decay curve <u>beginning</u> at the point we have selected.

For example, if we choose the point on the decay curve where the decay curve intersects the Y-axis, we can determine the calculated RT60 for the 5dB increment of decay beginning at the Y-axis (the first 5dB of decay). We do that by looking straight below the point on the decay curve we have selected (in this case, down the Y-axis since the point we selected is on the Y-axis) until we intersect the calculated RT60 curve. The RT60 value at that point is 0.65 seconds, as shown in Figure 19. This agrees with the displayed information in the IE-17A DATA WINDOW - the first 5dB of decay does have a calculated RT60 value of 0.65 seconds.

If we wish, we can further verify the curves by choosing another point along the decay curve and determining the calculated RT60 value. If we choose the point along the decay curve where the second 5dB of decay begins, we can determine the value of the second 5dB of decay by moving straight below our selected point until we intersect the calculated RT60 curve. As Figure 19 demonstrates, the value of the RT60 curve at that point is 0.55 seconds. Our curves tell us that the calculated RT60 value for the second 5dB of decay is 0.55 seconds, which again agrees with the information in the DATA WINDOW.

Using this method, we can determine calculated RT60 for any point along the decay curve. Since the decay curve is plotted against absolue dB values, we can also see absolute noise levels, and measure room signal to noise ratios.

In RT60 measurements where room signal to noise ratios are low, the IE-17A may not be able to calculate the RT60 for the first 30, or even the first 20dB of decay.

In Figure 20 below, the decay curve "runs into" the noise before it has decayed 30dB.

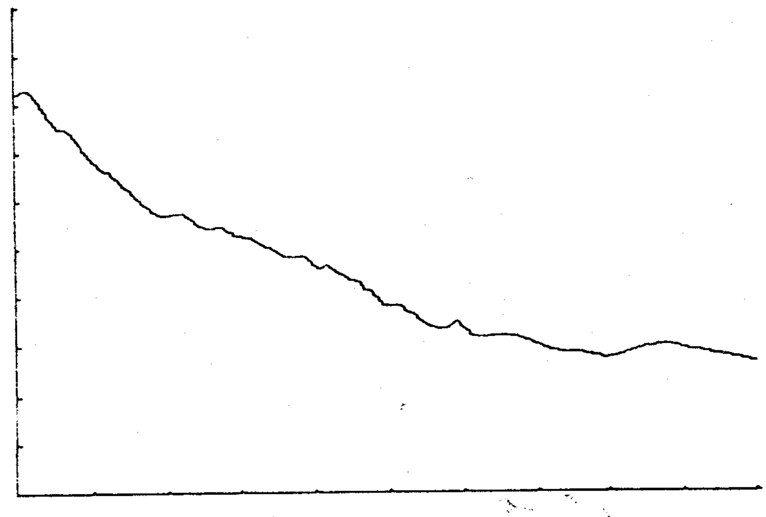


Figure 20

Obviously, the IE-17A cannot calculate the RT60 value for the first 30dB of decay, because 30dB of decay has not occured. If you select 1-30 in PROGRAM SELECTOR A to command the IE-17A to read out the calculated RT60 for the first 30dB of decay, the DATA WINDOW will display dashes "----" to tell you the value cannot be calculated.

As with all measurement routines in the IE-17A, plotting functions, once initiated, can be aborted by depressing the PLOT BUTTON on the IE-17A front panel. An abort command automatically finds the next data file, and awaits the PLOT command to plot the information. Using this feature, you can selectively plot any data curves in memory, without being forced to record more data than you need, or want.

TAKING MULTIPLE SAMPLES OF RT60

Bands of pink noise, either 1 octave, or 1/3 octave, are used most frequently to measure RT60, as opposed to sine waves, or warble tones, etc. To properly characterize a room with sine waves would require that RT60 be measured at numerous frequency points....a rather tedious process.

When pink noise is used, we are essentially averaging the RT60 effects of many sine waves simultaneously (in spectral bands), thus reducing the time requirements to characterize room RT60. However, pink noise is random noise, and when used for RT60 measurements will cause some equivalent randomness in RT60 answers for repeated tests of the same frequency. The lack of exact repeatability in answers is not an indication of instrument inaccuracy, but is the result of the randomness of pink noise, and the integration time of the filters used for the measurement.

The IE-30A/17A system has the capability to perform statistical analysis on several data samples taken at the same frequency, to provide highly accurate and repeatable answers for random noise RT60 measurements. Taking several test samples at each frequency is more than just a preference when using random noise, it is a matter of accuracy and repeatability. The IVIE system eliminates the need to perform manual computations, even when multiple data samples are taken. The following procedure describes the technique for multiple sample measurements.

TEST PROCEDURE FOR MULTIPLE SAMPLES

Performing multiple sample analysis is a simple extension of the previously described RT60 measurement method. The multiple sample procedure is described below:

1. Set up the test system for RT60 as described previously, and adjust the source output for the desired room SPL level.

2. Push the test button. The room sound will shut off and the IE-17A will begin taking data. The data ready light will continue to flash until all calculations are completed for the test sample.

3. To take an additional RT60 sample, depress the test button on the IE-17A. The room pink noise should turn on. Wait a few seconds for the room SPL level to stabilize, and repeat step #2. The results of the tests will be automatically averaged together by the IE-17A.

4. Repeat steps #2 and #3 for as many RT60 samples as desired. Generally, five to ten samples are adequate to give accurate results. It is desirable to increase the sample number for accurate RT60 measurements performed at low frequencies, because of the increased randomness of pink noise in narrow band filters.

5. Record the data and plot, if desired.

6. Select a new frequency and/or range as desired, and restart the multiple test sequence.

The IE-17A was designed to reduce and prevent measurement errors. The IE-17A will not allow the mixing of RT60 data from different ranges and frequencies, because multiple samples are only valid when taken at the same frequency, and for the same test range. If the SOURCE, FREQUENCY, FUNCTION, or RANGE control is altered, all data memories will be automatically reset to zero when the test button is depressed. The IE-17A front panel controls that can be used without resetting data memories to zero are CAL, PROGRAM SELECTOR "A", PLOT and TEST. If the IE-17A is in the calibrate (CAL) mode, the FUNCTION button can be used to set up CRTs and plotters without memory erasure. If you wish to take a new set of samples for the same frequency and range just measured, change any front panel control that causes the memory to be erased. For example, if RT60 is being remeasured at 1 KHz, with a range of 5 seconds, step the frequency marker out of the 1 KHz channel momentarily, and then back to 1 KHz. When the test button is pushed, all memories will be reset for a new RT60 sample series.

TRIGGERING RT60 FROM AN EXTERNAL SOURCE

It is sometimes necessary in the measurement of RT60, to use a sound source other than an electronic amplifier, usually because an amplifier system is not yet installed in the room, and a portable sound system is not available. Several acousticians use blank pistols, air horns etc., to eliminate the more cumbersome portable amplifier system. The IE-30A/17A measurement system can be triggered by an external audio impulse.

When a pistol is fired in a room (or any other impulse sound source for that matter) the sound level in the room rises to a maximum and then decays at the rate of RT60 as determined by the room decay characteristics. A typical room response to an impulse sound is shown in Figure 21 below:

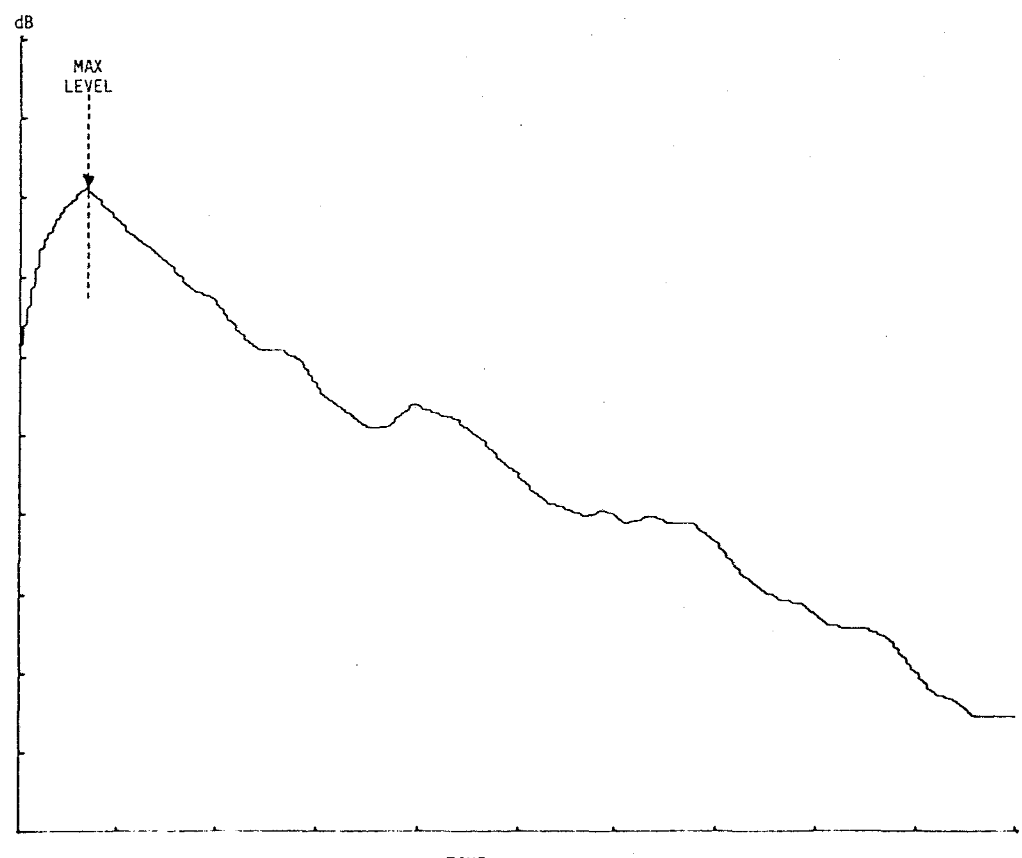


Figure 21

RT60, however, is a measurement of the decay rate of sound in a room, not the rise time. The IE-17A, being a smart instrument, stores both the rise time and the decay time data following a trigger impulse of sound in the room. The computer then searches through the data files to locate the maximum SPL level in the room, reconstructs only the decay portion of the curve, and calculates the RT60 values. When you plot RT60 data that has been generated using impulse sources, only the decay portion of the curve (and the calculated RT60 curve) is plotted by the computer. See Figure 22 below. The rising energy portion of the curve is eliminated because its RT60 would be infinite and meaningless.

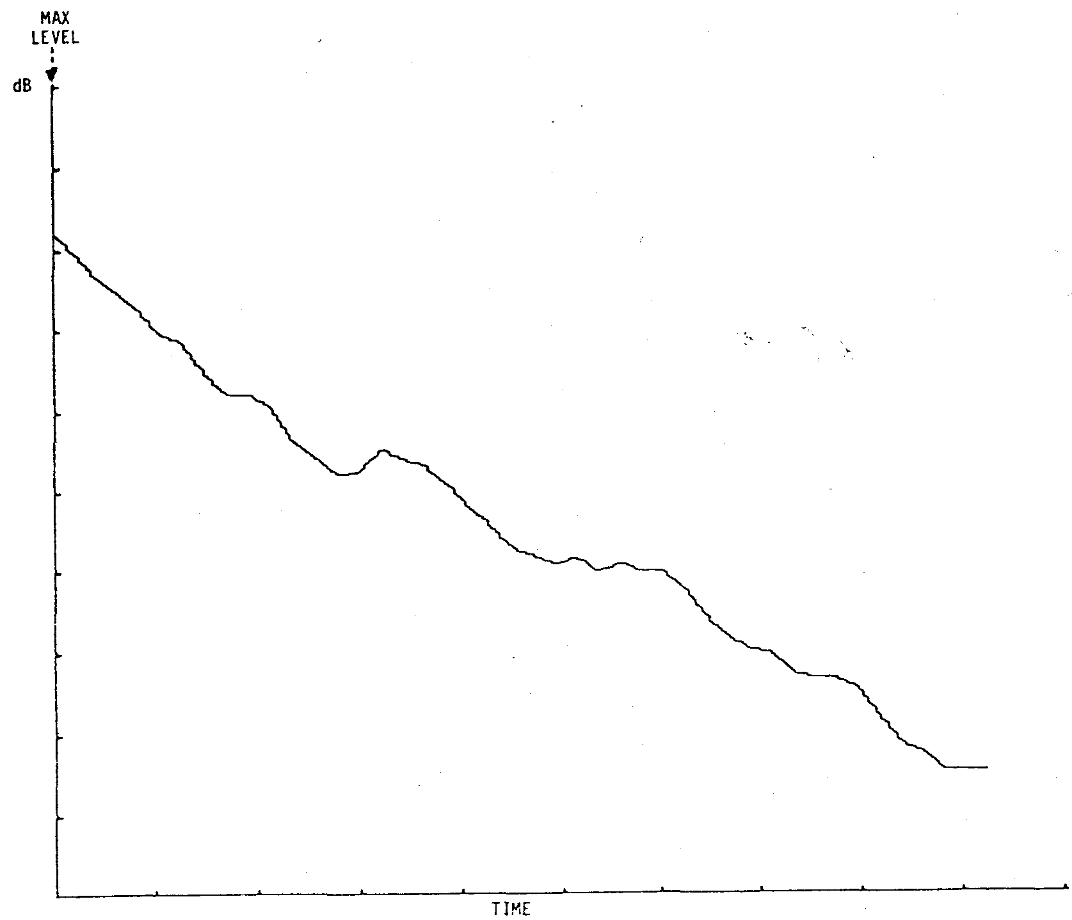


Figure 22

Use the following step by step procedure to externally trigger the IE-17A.

Procedure

1. Set up the IE-30A/17A system exactly as before, with the exception of the pink noise source and the amplifier. These components are eliminated for an externally triggered test of RT60.

2. Set the IE-17A SOURCE-GATE control to "EXT" (external trigger).

3. Depress the TEST button once to arm the external trigger mechanism. A flashing TEST-READY LED indicates that the system has been properly armed.

4. Any room signal that rises above a level that is 10dB below the selected REFERENCE level on the IE-30A will trigger the IE-17A to take samples of room energy for a time period equal to the range selected on the IE-17A (PROGRAM SELECTOR B).

5. Impulse the room with a sound level having a peak (in the band of interest) slightly above the REFERENCE level on the IE-30A, but not off the top of the display screen. You may have to experiment with the adjustment of the IE-30A REFERENCE setting in order to maximize the screen display level wihtout overdriving the IE-30A.

6. When the IE-17A system is properly triggered, the flashing TEST READY light will turn off and the DATA READY light will flash during data collection and calculation. The data ready light will then become steady state when the measurement sequence is complete. Measured RT60 data using an impulse source is interpreted the same way as RT60 data measured using continuous energy.

Note: Care should be taken when measuring amplitude versus time in RT60 or other functions, so that the time (X-axis) is set for optimal display. Using PROGRAM SELECTOR B, make experimental tests to set the measurement range such that the display slope will utalize the full value of the X-axis.

On the following page, a plot is shown which displays the effects of choosing three different ranges in PROGRAM SELECTOR B.

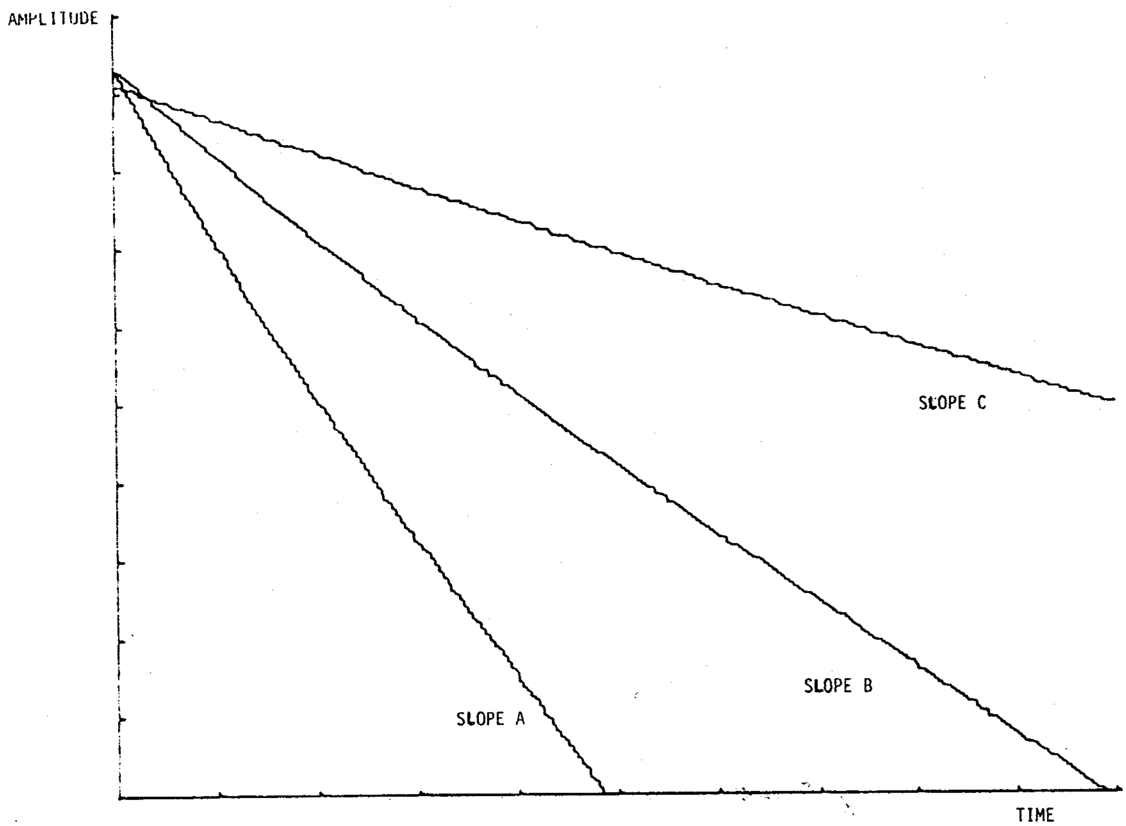


Figure 23

In Figure 23, three decay slopes are shown. In slope A, the time programmed in PROGRAM WINDOW B was too long, resulting in decreased resolution. Slope C results from too short a programmed time. Slope B represents an ideal time selection in that the entire length of the X-axis is used. The resultant decay slope provides maximum information.

MEASUREMENT OF THE DB/SECONDS MODE

In any application where it is advantageous to view fluctuations in amplitude over a definable period of time, the IE-17A in the dB/seconds mode can provide measurements of high accuracy. Observing amplitude decay in a room to isolate flutter echoes and non-linear decay slopes, use of amplitude/time plots in vibration analysis, and measurement of acoustic build-up (room resonances and other geometric phenomena) are just a few of the applications where this function is very useful.

The dB/seconds function allows the plotting of amplitude changes over a programmable time base of from 0.1 to 100 seconds full scale in 10 ranges. An oscilloscope with external triggering capabilities, or an X-Y plotter must be used to view the amplitude versus time plot generated by the IE-17A. However, the IE-17A need not be connected to an oscilloscpe or X-Y plotter during the test period when data is collected. The memories in the IE-17A will retain the data as long as the IE-30A connected to it remains ON and the batteries charged, so the tests can be performed, and the plot constructed by a peripheral device later.

The IE-17A in the dB/seconds mode can monitor and record amplitude changes in 1/3 octave bandwidths, octave bandwidths, or broadband (SPL meter). Figure 24 is an example of a plot produced using an X-Y recorder and an IE-30A in the dB/seconds mode.

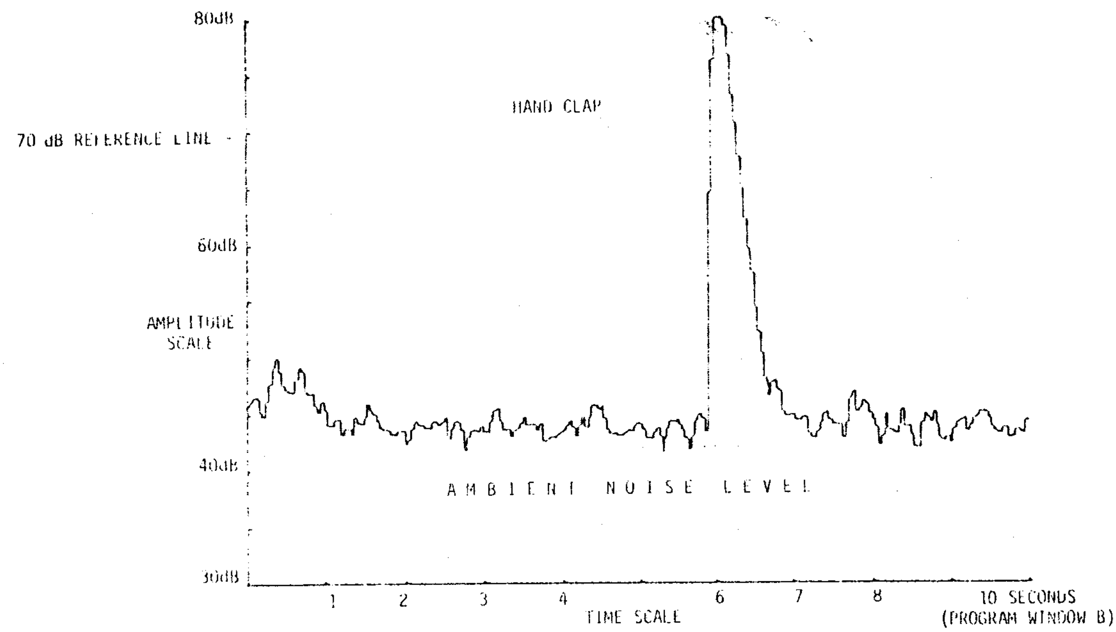


Figure 24

In the above plot, the IE-17A was monitering room noise, in the 1kHz octave band, over a 10 second time period. The dramatic increase in amplitude, about 6 seconds out on the X-axis, was caused by a hand clap. The rise time of the energy is shown, and we can also see that it took about three quarters of a second for the noise to decay 30dB. Having just completed studying the section on RT60 measurements, that information should be quite meaningful to you.

Measurement resolution deserves some discussion. As you learned in the manual section covering measurements in the dB/Frequency mode, IE-17A resolution is not limited to the display resolution of the IE-30A. (1dB/step maximum). Since the IE-17A samples the analog output of the IE-30A filters, resolution is .2dB. In the 3dB/Step IE-30A resolution setting, this allows maximum dynamic display range and still provides the high resolution of .1dB. It is very important to note, however, that the IE-17A is calibrated to measure the analog output of the IE-30A filters when the IE-30A is in the 3dB/step resolution setting. If the IE-30A is in the 2dB or 1dB/step resolution setting, measurements made by the IE-17A will not be calibrated in the dB/sec mode.

Now that we have discussed some of the measurement potential of the IE-30A/17A in the dB/seconds mode, let's examine the procedure for making an actual measurement. The equipment setup is described by Figure 25 below:

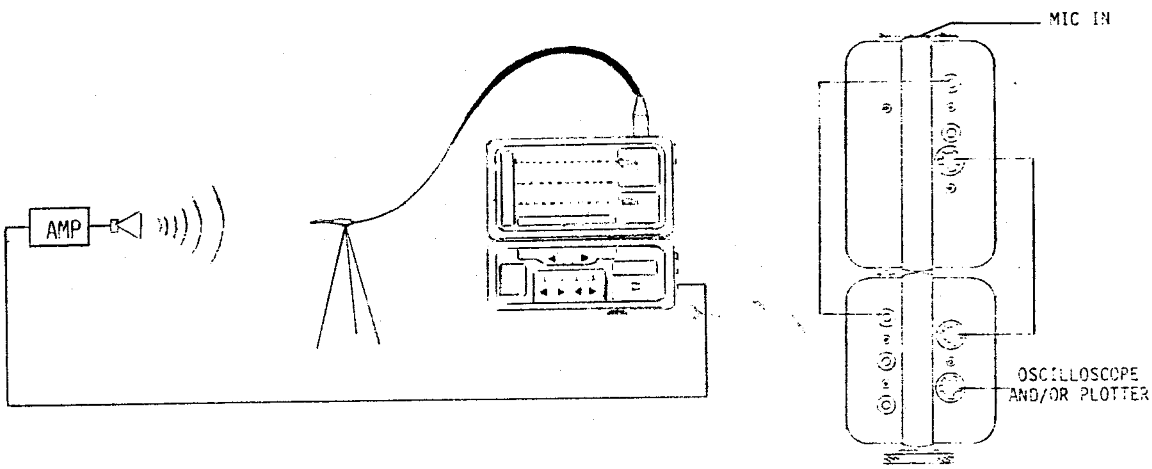


Figure 25

Set the IE-30A/17A Controls as follows:

IE-30A Controls	Control Setting
OFF/ON	ON
dB/STEP	3dB/STEP - ALWAYS
REFERENCE LEVEL	Set to desired level for measurement
DELAY	D1
MEMORY	Set for Real-Time display
SPL METER	Set controls as desired

IE-17A Controls	Control Setting
FUNCTION SELECTOR------------	dB/Seconds
SOURCE-GATE------------------	INT
PROGRAM SELECTOR A-----------	Not operative in this function
PROGRAM SELECTOR B-----------	Set to desired range (.1 to 100 seconds)
FREQUENCY MARKER-------------	Place frequency marker over desired channel

MEASUREMENT PROCEDURES

In Figure 25, the signal source input is a microphone. It could just as easily be an accelerometer, or an electrical input. In order to make the measurement, temporarily generate the signal to be tested. Adjust the IE-30A REFERENCE LEVEL so that the signal can be seen well up "on screen" of the IE-30A.

To initiate the measurement, press the TEST BUTTON once (the TEST READY LED must be illuminated before the test can be initiated. If the DATA LED is illuminated instead, push the TEST BUTTON once to illuminate the TEST LED, and then push it again to start the measurement). The IE-17A will monitor the amplitude in the channel you have selected over the time window you have chosen and will store the data in memory. If an oscilloscope is connected to the IE-17A, it will plot the changes in amplitude as they are being stored in memory.

While the measurement is in progress, the DATA LED will flash and the oscilloscope will plot the amplitude variations. When the measurement is complete, the DATA LED will stop flashing. AT this point, an X-Y recorder can be commanded to produce an amplitude versus time plot by pushing the PLOT BUTTON. For information concerning calibration at oscilloscopes or X-Y plotters to the IE-17A, consult pages 16 through 20 in this manual.

The IE-17A can also be triggered externally to initiate an amplitude versus time plot. This is accomplished by selecting EXT (external) in the IE-17A SOURCE CONTROL. After selecting EXT, the TEST BUTTON needs to be pushed to arm the system. The TEST READY LED will flash to indicate that the system is armed and is waiting to be externally triggered.

Triggering will occur when signal rises above the division line below the REFERENCE LINE on the IE-30A screen as demonstrated in Figure 26 on the next page.

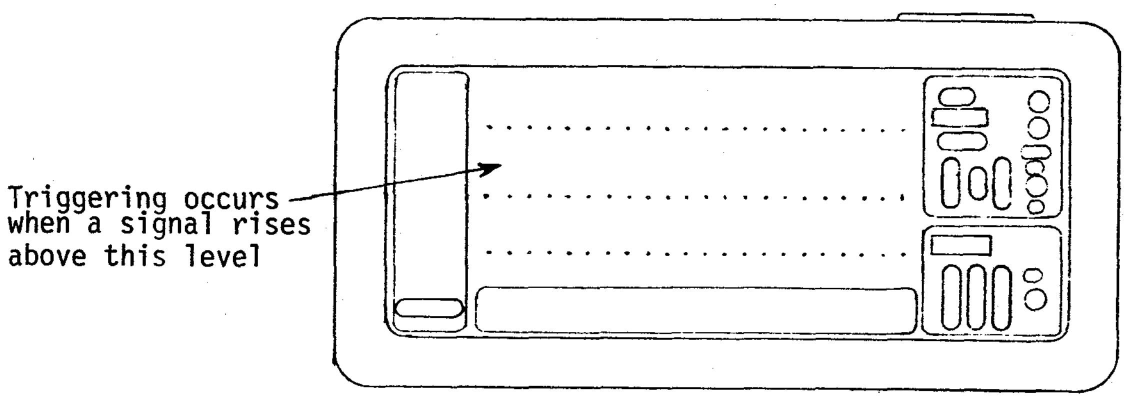


Figure 26

Once the system has been triggered, the DATA LED will flash indicating that a measurement is being performed.

The easiest way to become familiar with the dB/seconds mode of the IE-17A is to make an actual measurement. Let's attempt to duplicate the measurement which produced the plot in Figure 24. Connect the peripheral equipment as previously discussed. Set the IE-30A/17A controls as follows:

IE-30A Controls	Setting
OFF/ON	ON
dB/STEP	3dB/step
DISPLAY FORMAT SELECTOR	Octave Display
REFERENCE LEVEL	70dB
MEMORY	Real-Time display
SPL METER	As desired

IE-17A Controls	Setting
FUNCTION SELECTOR	dB/seconds
SOURCE-GATE	INT
PROGRAM SELECTOR B	10 seconds
FREQUENCY MARKER	1 kHz

After the controls are set, initiate the measurement using the TEST BUTTON. The DATA LED will begin to flash as the test is being performed. Approximately 6 seconds after the measurement begins, clap your hands once smartly. After the measurement is complete, observe the results on the oscilloscope, or command an X-Y recorder to plot the results by pushing the PLOT BUTTON. The resulting plot should look something like Figure 27 below. Of course, relative noise level may vary greatly depending upon the test environment.

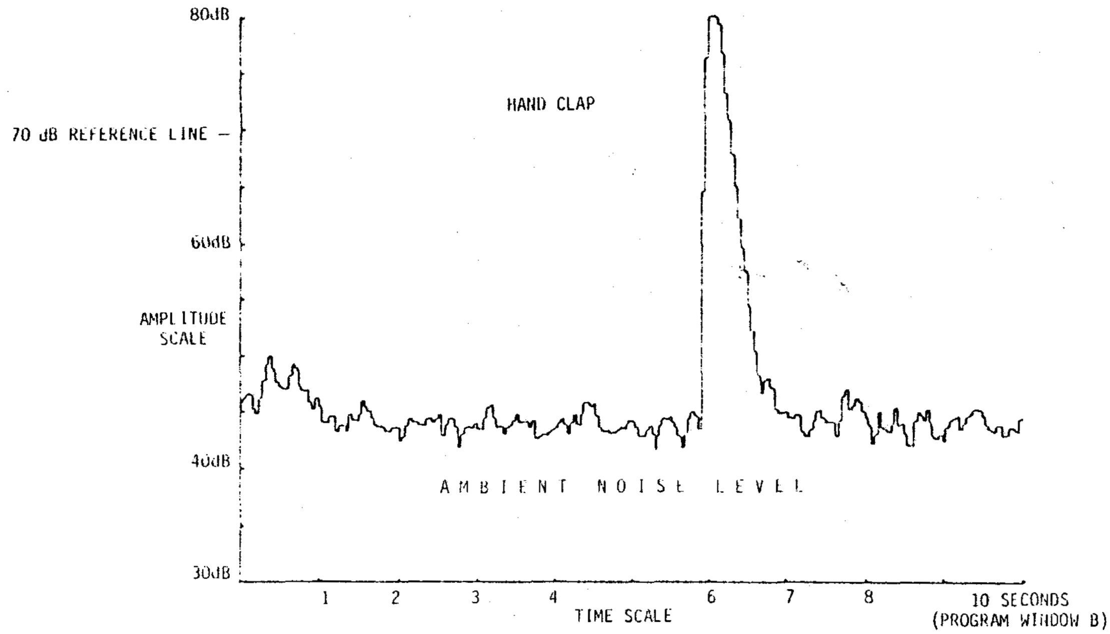


Figure 27

DELAY: THEORY AND MEASUREMENT

An often important parameter in acoustical environments is distance, or time as it relates to distance. For example, we may want to know the time it takes sound from a primary speaker cluster to reach the vicinity of a secondary speaker cluster so we can properly set the delay line going to the secondary cluster. In other analyses, we may be interested in the distance of a major reflective surface from a critical listening area. You could probably add many other examples to those we have listed.

The question is, how do we measure time as it relates to sound travel or distance? Obviously, we could use a tape measure to find distance and then convert to time mathematically, but often a tape measure is inconvenient, at best. We could also approach the problem from the other direction. That is, if we had the ability to measure the length of time it took sound to travel some distance of interest, we could convert that time measurement to a distance measurement mathematically.

One of the exciting features of the IE-17A is its ability to measure the time it takes sound to travel from point A to point B. That time increment is generally called the "delay time", or simply "delay". The IE-17A can measure delay times from .0002 seconds to 99.99 seconds with a resolution of 100 microseconds.

In terms of distance, this means we can measure distances from just inches to many miles, with a maximum resolution of about 1½ inches. We may never need to measure that long of a delay time, but there are applications where we may need the capability to measure exceedingly short delay times. Some of those applications will be discussed later in this section of the manual.

To get better acquainted with the IE-17A's delay measuring capability, let's examine how it makes a delay measurement. The IE-17A has both an impulse signal generating capability and a crystal controlled clock that are accessable to the IE-17A microprocessor. The third necessary ingredient is the sound pickup capability of the IE-30A in combination with the IE-17A. The figure below illustrates the measurement setup:

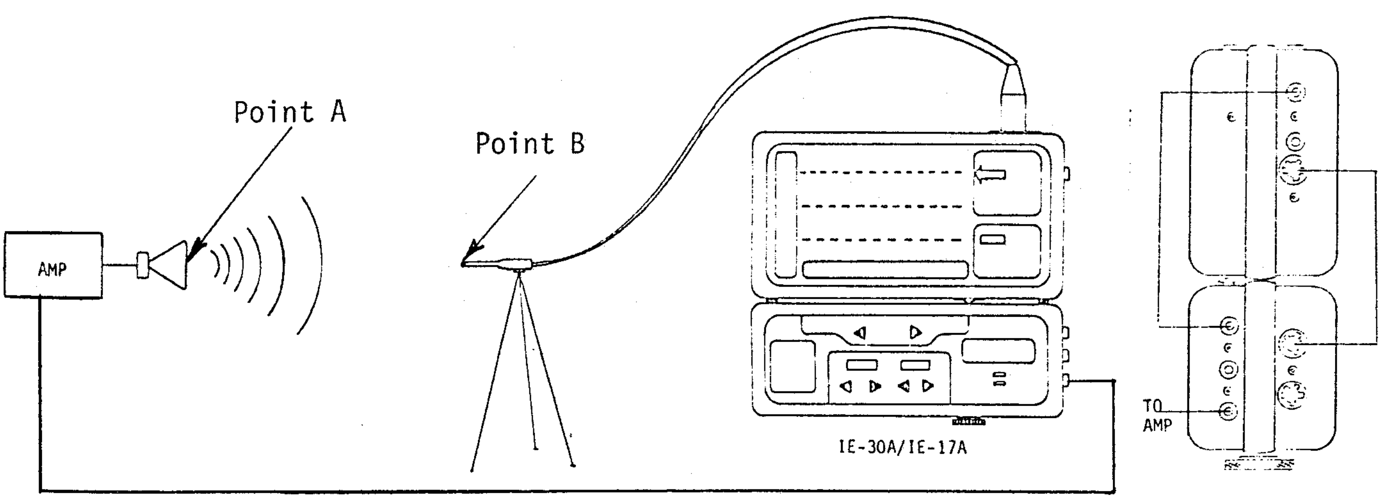


Figure 28

To make the measurement, we energize the sound system with the impulse generated by the IE-17A. When the impulse is triggered, the crystal controlled clock is triggered as well, and it begins counting. The IE-17A computer is now waiting for some sound to arrive at the IE-30A microphone. As soon as the leading edge of the sound reaches the IE-30A microphone, the clock in the IE-17A is stopped. The computer calculates the elapsed time and displays the answer in the DATA WINDOW of the IE-17A. We now know how long it took sound to travel from point A to point B.

Let's take a closer look at what occurs during the measurement process we have just described. Figure 29 below demonstrates the series of events, as they occur in time, once the delay measurement has been initiated.

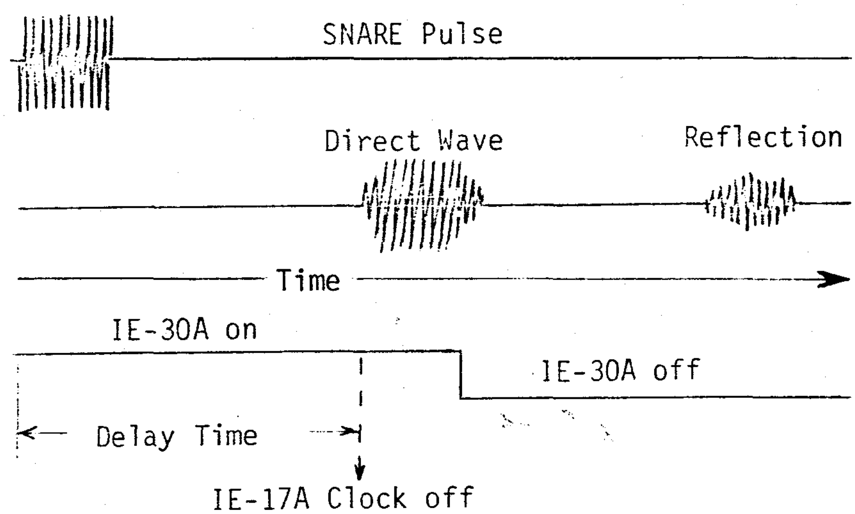


Figure 29

As the SNARE pulse is fired, the quartz clock begins to cycle. As soon as the leading edge of the sound wave reaches the IE-30A microphone, the clock stops and delay time is calculated.

It is important to note that the computer does not gate the IE-30A off until 10 msec after the quartz clock stops. This means that the entire 10 msec wide pulse enters the IE-30A for spectral analysis. If the IE-30A is set for the memory accumulate mode before the pulse is triggered, it will display the frequency response of the transmitted pulse. Likewise, if the SPL meter is set to the hold mode, the maximum SPL of the pulse will be registered.

Also note that the IE-30A is gated off at the same instant the "direct wave" has passed the microphone. This means that only the direct wave was measured: the analyzed data is, therefore, "anechoic." We have, then, not only measured delay, but we have also captured the maximum SPL, and made an "anechoic" analysis of the frequency response.

This, of course, assumes that the microphone is far enough from any reflecting surfaces to prevent reflections from entering the microphone during the 10 msec time window. To prevent this from happening, the microphone should be at least 6 feet from any reflecting surface.

If, after we have measured the delay time between point A and point B, we want to know the distance from point A to point B, we can calculate it mathematically using the simplified formula:

$D = VxT$

Where: D = Distance, V = velocity of sound, T = time

If we use 1130ft/sec as the velocity of sound, we can quickly convert time measurements to distance measurements. If we want to be more precise, we must consider the effects of temperature on the velocity of sound. Recognizing the temperature factor, a useful formula for calculating sound velocity in feet per second is:

$$V = 49\sqrt{459.4 + {}^{o}F}$$

or for velocity in meters per second:

$$V = 20.06\sqrt{273 + {}^{o}C}$$

A simple example will serve to clarify the use of the formulas for converting an IE-17A time measurement to distance. In our example, the IE-17A has measured a delay of 86.1 milliseconds, and the room temperature is 72 ^{o}F.

$D = VxT$
$D = (V)(.0861)$
$V = 49\sqrt{459.4 + 72}$
$V = 1129.55$
$D = (1129.55)(.0861)$
$D = \underline{97.25 \text{ feet}}$

DELAY MEASUREMENT USING SNARE PULSE

Now that we are familiar with how the IE-17A measures delay, we are ready to make an actual measurement. The test setup has been outlined previously in figure 28. Set the IE-30A and IE-17A controls as follows:

IE-30A Control	Setting
OFF/ON	ON
REFERENCE LEVEL	Initial setting: 60dB
DISPLAY FILTER SELECTOR	1/3 octave
DECAY	D1
MEMORY	AT - Realtime
dB/STEP	3dB
SPL METER	Any settings desired

IE-17A Control	Setting
FUNCTION--	DLY (Delay)
SOURCE--	INT (Internal SNARE Pulse)
PROGRAM SELECTOR B--------------------------	See Following Paragraph

The last setting, PROGRAM SELECTOR B, is a resolution setting. If we set PROGRAM SELECTOR B to 1 second, the IE-17A will measure delay over a 1 second time window. Measurement resolution will be 1 millisecond. Using the PROGRAM SELECTOR B increment and decrement buttons, we can select measurement windows of .1 second, 1 second, 10 seconds, or 100 seconds. Resolutions would be 100 microseconds, 1 millisecond, 10 milliseconds, and 100 milliseconds respectively. For the highest possible resolution, always choose the shortest range that will work for the delay measurement you are performing.

It is important that the pulse firing into the room be seen "on screen" of the IE-30A. With the IE-30A/17A controls set as described above, hold the IE-17A TEST BUTTON down. You should hear the impulse fire about every second. Adjust the IE-30A REFERENCE LEVEL until the firing pulse registers near the REFERENCE LEVEL on the IE-30A screen. Room noise should be at the bottom of the IE-30A screen, or off screen entirely, to insure an adequate signal to noise ration ($>$20dB). If room noise is to high, increase the gain of the amplifier driving the speaker to improve the signal to noise ratio, then readjust the IE-30A REFERENCE LEVEL to compensate.

In some rooms, it may not be possible to get good signal to noise ratios. In those instances, you will have to settle for the best ratio you can get.

As you were holding the TEST BUTTON down, you may have noticed the LED's labeled TEST and DATA alternaltely flashing. To perform a delay measurement the TEST LED must be illuminated. If the DATA LED is illuminated instead, push the TEST BUTTON once. The TEST READY LED should now be illuminated; the system is ready to make a delay measurement. To perform the measurement, simply touch the TEST BUTTON once. The pulse will fire, and the computer will automatically calculate the delay and display the answer in the DATA WINDOW. To verify the measurement, touch the TEST BUTTON once to reset the system, then press it again to perform the delay measurement. Because the system is digital, repeatability can vary plus or minus one count. This is not an indication of error, only the expression of the limitations of a digital readout system.

Note: The answer in the DATA WINDOW will always be in seconds. A decimal will always be visable except when a .1 second range is selected in PROGRAM SELECTOR B. In this instance, a decimal is not visable, but is assumed to be to the left of the left-most digit in the DATA WINDOW. For example, a reading in the DATA WINDOW of 0947 would be interpreted as .0947 seconds.

Note: If the DATA WINDOW displays dashes,- - - -, instead of an answer, the system is over range. Simply change the time window in PROGRAM SELECTOR B to the next longer range. If, for example, PROGRAM SELECTOR B is set for .1 second, and the IE-30A microphone does not see sound within .1 second, the DATA WINDOW will display dashes. Simply select the next longer range until a repeatable time delay answer is displayed in the DATA WINDOW.

MEASUREMENT OF REFLECTIONS

The previous discussion provided an operational description of the measurement of the delay time of the direct wave. The IE-17A is also capable of measuring the delay time, the spectrum, and the maximum SPL of discrete reflections. A discrete reflection is a reflection that is separate, in time, from any other signals as shown below.

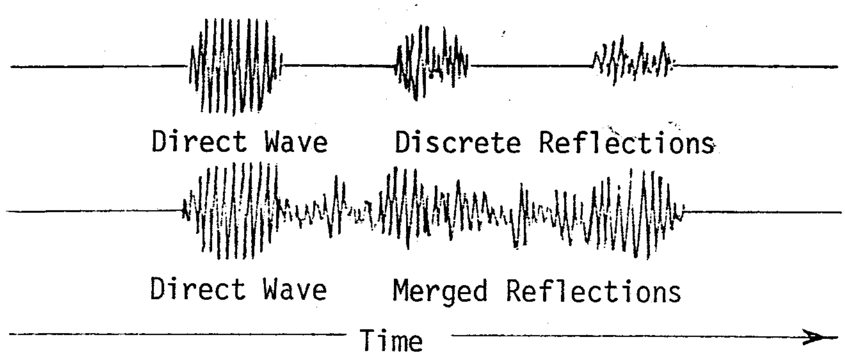


Figure 30

If reflected energy arrives at the position of the microphone before the direct wave has completely passed the microphone, the two signals become merged. Merged direct waves and reflections can occur in small rooms, or when the microphone is placed too close to a reflective surface. Reflections must be separate from each other and from the direct wave, as shown above, in order for the IE-17A to measure the delay time of a reflection accurately. If the wave front of a reflection is merged into to direct wave pulse, the delay detectors cannot sense the difference between direct and reflected energy. An understanding of how the IE-17A measures the delay time of reflections will help to explain the above problem.

After the direct wave delay time is measured, the data is stored in the processor memory. When R1 (reflection number 1) is selected using PROGRAM SELECTOR A, and the TEST BUTTON pressed; a 10 msec pulse is transmitted by the IE-17A, and the quartz timer begins to count. However, the IE-30A is gated off, and is not allowed to analyze until the direct wave has passed the position of the microphone. Having just measured the delay of the direct wave, the processor knows exactly when the direct wave will pass. For greater clarification, let's examine an actual measurement.

The IE-17A is used to measure the delay time of a direct wave with resulting data of 49.6 msec. Because the transmitted delay pulse is always 10 msecs duration, the processor must hold the IE-30A off for 59.6 msec (49.6 + 10) to allow time for the entire 10 msec direct wave to pass the microphone position. There is one more factor that must be compensated for in the timing sequence, and that factor is speaker response. Most speakers will not perfectly reproduce a pulse, but will require some start-up time, and will exhibit some decay ring, depending upon the physical mass and design of the transducer. The processor must, therefore, allow an additional IE-30A hold off time of 5 msec to compensate for the transducers used. The result is that the processor cannot begin to analyze data for a time period of 15 msec following the measured delay time. The timing diagram below describes this measurement sequence.

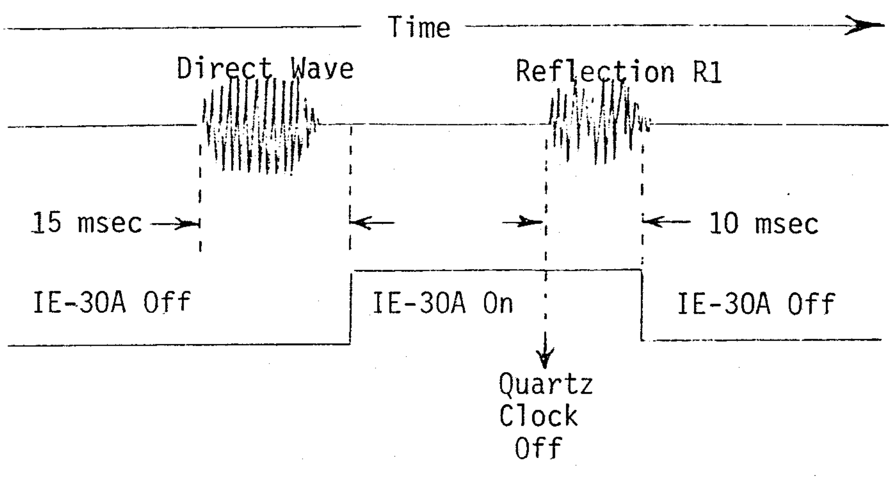


Figure 31

In summary, if the measured direct wave delay is 49.9 msec, the IE-30A will not begin to look for a reflection until after 64.6 msec (49.9 + 15) have elapsed.

A discrete reflection must have a delay time that is a least 15 msec longer than the direct wave, to be accurately measured by the IE-17A. For each successive reflection measurement, the IE-17A timing pattern is the same. For obvious reasons then, the processor will not allow the measurement of R1 until D has been measured, and the same is true for R2 and R3; they must be measured successively.

To help eliminate the potential of false readings, the following measurement procedures should be observed:

1. If the microphone, or speaker positions are changed during a sequential test of D, R1, R2 and R3, the resulting data will be incorrect.

2. The impulse spectra should be a least 20dB above room ambient noise. Otherwise, room noise may falsely trigger the delay detector with resulting errors in data.

3. You should get very suspicious of the existence of measurement errors, if successive measurements produce time delays that are 15 msec larger than the previous measurement. This could be an indication that the reflections are not discrete, or are not separated in time by at least 15 msec from the direct wave, or from each other. It could also mean that the room noise floor is so great that every time the IE-30A is gated on to scan for reflections, the room noise triggers the IE-17A clock off.

4. In the DELAY mode of the IE-17A, the processor will produce a 10 msec pulse internally (SNARE), with the SOURCE CONTROL set to INT. External signal generators producing sine waves or noise can be used with the IE-17A if the SOURCE CONTROL is set to EXT. However, a 10 msec pulse of random pink, or white noise will produce less repeatable results than the SNARE pulse, or sine waves.

The reader is referred to the GTM section of the manual for further discussion on reflection measurements. Combining GTM with an externally triggerable oscilloscope creates an extremely powerful tool for anechoic tests, and doing analysis of the reverberant field, leading to the measurement of frequency response, articulation loss, and acoustic absorption.

Now that we have discussed the way that the IE-17A measures reflection delay, let's examine the procedure for making actual measurements.

EQUIPMENT SETUP

The equipment setup for measuring reflections is exactly the same as for measuring the delay of the direct wave, but has been repeated here for your convenience. Notice that instructions for the addition of an oscilloscope have been added. An oscilloscope can provide valuable information, as will be described later. Figure 32 outlines the measurement setup.

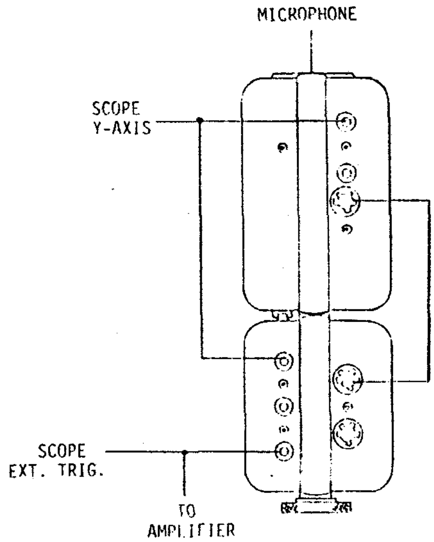


Figure 32

Set the IE-30A/17A controls as follows:

IE-30A Controls	Control Settings
OFF/ON	ON
dB/STEP	3dB
REFERENCE	Set for 20dB S/N ratio
FILTERS	1/3 Octave
DECAY	D1
MEMORY	Real Time (RT)
SLM	Wherever desired

IE-17A Controls	Control Settings
FUNCTION	DELAY
SOURCE-GATE	INT
SOURCE-BANDWIDTH	LIN
PROGRAM SELECTOR A	D then R1 then R2 then R3
PROGRAM SELECTOR B	Set to desired time range
FREQUENCY MARKER	Not used

The oscilloscope peripheral is not needed for this measurement, but can be very useful in viewing the isolated direct wave and the reflections captured by the IE-30A/17A system. There is no meaningful plot that can be made in DELAY mode and so an X-Y recorder is not needed.

PROGRAM SELECTOR A is used to select the direct wave (D) or a reflection (R1, R2, or R3), but they must be measured sequentially, beginning with D. The computer will not allow the selection of R1 until D has been measured, and the same is true for R2 and R3.

Next, hold the TEST BUTTON down on the IE-17A causing the 10 msec pulse to be triggered repetitively. This will allow you to adjust the REFERENCE LEVEL on the IE-30A, and the amplifier volume so that the pulse spectrum registers near the IE-30A REFERENCE LEVEL as shown below:

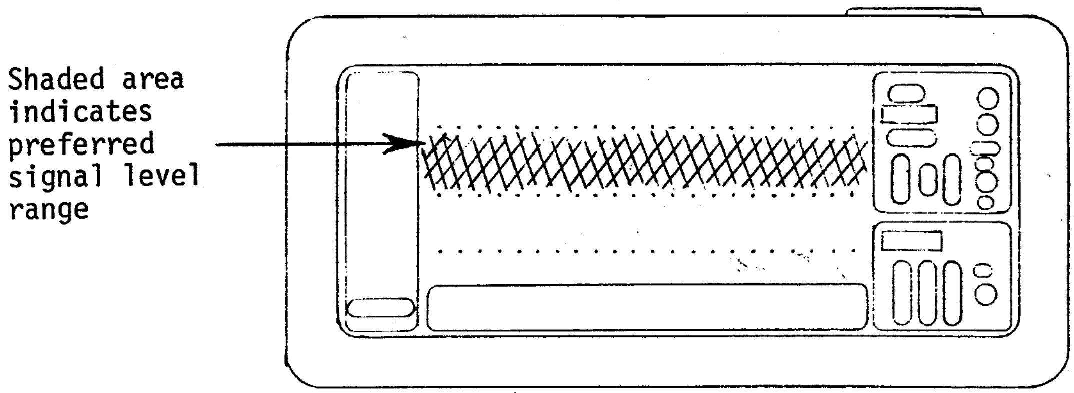


Figure 33

A 20dB signal to noise ratio should be maintained in the room to obtain accurate, repeatable results. Push the TEST BUTTON to initiate the delay measurement just as you did previously. Perform the test several times to check for repeatability. If the system has been set up properly, the measured delay time in the DATA WINDOW should repeat with each pulse to ± 1 count of the least significant digit.

After D has been measured, PROGRAM SELECTOR A can be used to select the first reflection (R1) measurement mode. Once again, press the TEST BUTTON so that the pulse triggers. The measured value will appear in the DATA WINDOW. Test again for repeatability. The measured delay time for R1 should be repeatable with each new pulse. Reflections R2 and R3 are measured in an identical manner. After all four parameters are measured in the DELAY mode, the INCR/DECR buttons can be used to review the measured data for D, R1, R2, and R3. Selecting D, R1, R2, or R3 in PROGRAM SELECTOR A will cause the corresponding measured delay time to be displayed in the IE-17A DATA WINDOW.

If you are using an oscilloscope, you will note that the oscilloscope displays only the direct wave, or the reflection being measured at that moment. All other pulses have been excluded by the gating action of the processor.

DELAY MEASUREMENTS USING EXTERNAL SIGNAL SOURCES

It is also possible to make delay measurements using an external signal source with the IE-17A. To accomplish this, simply feed the external signal source into the SOURCE CONTROL INPUT of the IE-17A, and select EXT (external) on the SOURCE CONTROL. This signal will be automatically gated for delay measurements.

External signals may also be filtered, if desired, when making delay measurements. To select filtering, use the BANDWIDTH BUTTON on the IE-17A SOURCE CONTROL. Octave, 1/3 octave, or LIN (linear, or nonfiltered) may be chosen. The CURSOR WAND on the screen of the IE-30A will indicate the frequency center of the filter being used. The CURSOR WAND can be stepped to either the left or right to choose the desired frequency center for filtering.

MEASURING ELECTRICAL DELAY

The IE-30A/17A combination can be used to measure the delay of electrical devices such as analog and digital delays. The device under test should be connected to the IE-30A/17A as shown in Figure 34. The test procedure for electrical delay measurements is essentially the same as for acoustical delays.

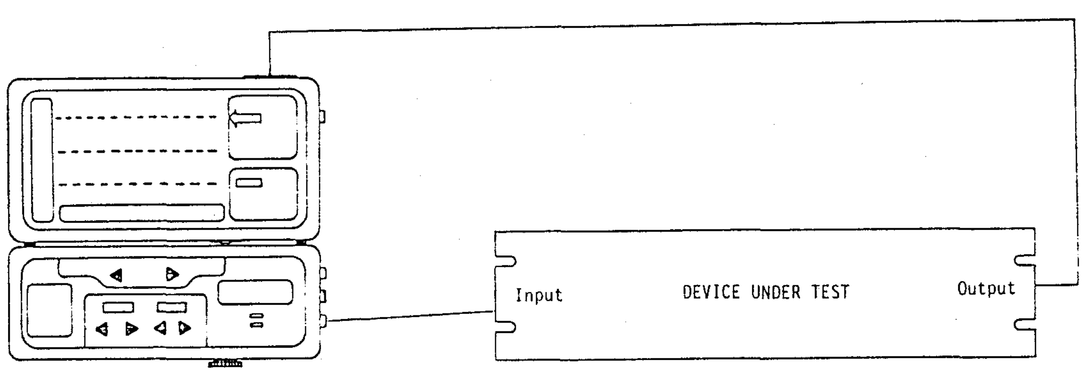


Figure 34

GATED TIME MODE MEASUREMENTS

Using the gated time mode (GTM) function in the IE-17A will enable the measurement of room and device parameters previously requiring many thousands of dollars worth of very exotic test equipment.

The IE-30A/17A system can be used for numerous applications of impulse testing such as anechoic responses in non-anechoic rooms, absorption coefficients, and isolation of the direct wave, or of any reflection of a transmitted signal. Several applications notes regarding specific new applications of GTM will be made available by Ivie Electronics in future months.

With the IE-17A you can program the pulse width (PW) of the source, delay time (DT), aperture time (AT), and cycle time (CT). The following descriptions will help to define the programmable features of GTM.

1. <u>Pulse Width (PW)</u> - defines the length of time (in seconds) that the signal source is gated on. Pulsewidth is settable from 1 millisecond (.001 second) to 9.999 seconds in 1 millisecond steps.

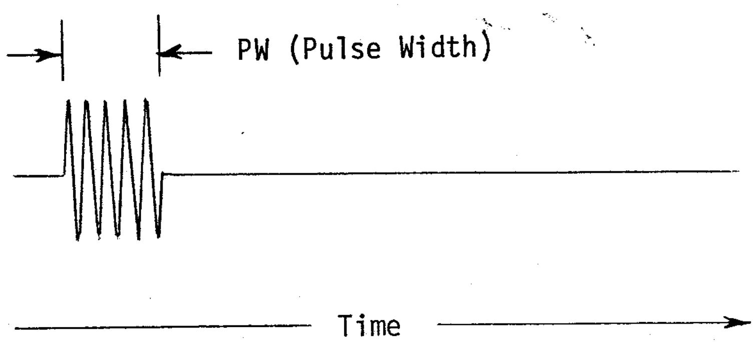


Figure 35

2. <u>Cycle Time (CT)</u> - defines the length of time (in seconds) between signal source pulses. Settable from 00.00 seconds (for a single shot pulse) and from .01 to 30.00 seconds in 10 millisecond steps.

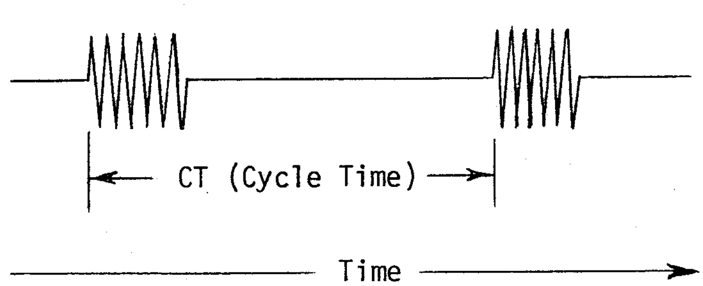


Figure 36

3. Delay Time (DT) - defines the length of time (in seconds) between the leading edge of the triggered pulse and the moment the IE-30A is gated on to begin analysis. With a resolution of 1.0 millisecond, the range is programmable from 1.0 millisecond to 9.999 seconds.

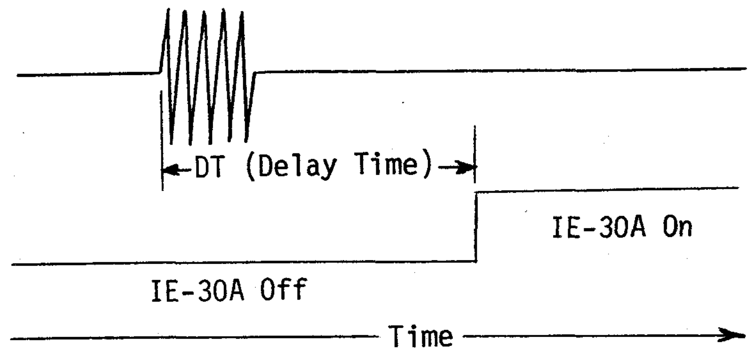


Figure 37

4. Aperture Time (AT) - defines the length of time (in seconds) that the IE-30A is activated for analysis. Range is from 1.0 millisecond to 9.999 seconds in 1.0 millisecond steps.

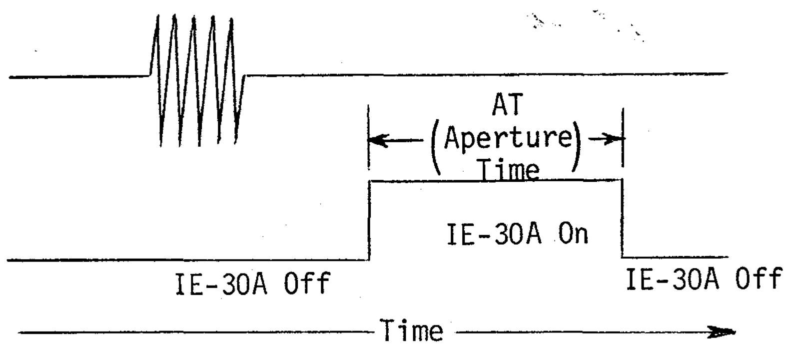


Figure 38

DATA ENTRY FOR GTM MEASUREMENTS

When the IE-30A/17A system is first turned on and the GTM function selected, the computer presets the gated time parameters to the following values:

PW = 0.100 sec.
CT = 01.00 sec.
DT = 0.010 sec.
AT = 0.090 sec.
SOURCE: EXT, LIN

NOTE: Unless the cycle time (CT) is set equal to 00.00 (for a single shot pulse test) the numeric value of the cycle time must always be greater than the sum of the delay time (DT) and the aperture time (AT). The computer will prevent any erroneous selections of the timing parameters. Generally, if the timing parameters resist being changed to those values desired by the operator, the timing sequence is incorrect and should be rechecked.

Making changes to the preset values of PW, CT, DT and AT requires the use of PROGRAM SELECTORS A and B. When GTM is selected PROGRAM SELECTOR A is used to select the timing parameter to be changed, and PROGRAM SELECTOR B is used to change the value of the timing parameter selected. As shown (in Figure 39) a lighted LED bar segment appears in the display window of PROGRAM SELECTOR A above the timing parameter selected. In the figure below, cycle time (CT) has been selected. PROGRAM SELECTOR B is used to change the actual value of the selected timing parameter; the current value is shown in the display window of PROGRAM SELECTOR B, with units of seconds.

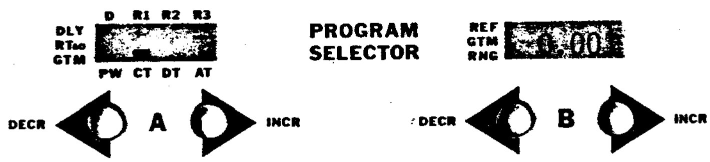


Figure 39

Depressing the INCR button, or the DECR button of PROGRAM SELECTOR B once will change the timing value by one millisecond. Holding the button down will cause the display to cycle automatically, first in 1.0 millisecond steps, then in 10 msec steps, then 100 msec steps and finally in 1 second steps until the maximum range is reached, or until you release the button. Any time you release the button and depress it again, the display resolution will revert to 1.0 msec step changes. This digital step accelerator feature enables the user to have high resolution, and still have the capability to span large ranges quickly.

USE OF OSCILLOSCOPES IN GTM MEASUREMENTS

An oscilloscope is an excellent IE-17A peripheral tool for maximizing the power of GTM. The oscilloscope can be used to view the exact timing sequences initiated by the IE-17A, as well as the room pulse patterns, as they occur at the microphone, showing the direct wave and all the resulting reflection patterns. The oscilloscope facilitates the selection of that portion of the total impulse spectrum you desire to analyze. For example, you may wish to analyze just the direct wave (the anechoic response), and exclude the interference caused by the reflections in the environment. An oscilloscope allows the operator to view exactly what the IE-30A is analyzing.

For use with the GTM function of the IE-17A, the oscilloscope is necessarily wired differently than for other uses of the IE-17A. As shown below, the trigger output of the IE-17A is connected to the external trigger of the oscilloscope. Likewise, the IE-30A preamp output line is branched to the IE-17A, and also to the oscilloscope input.

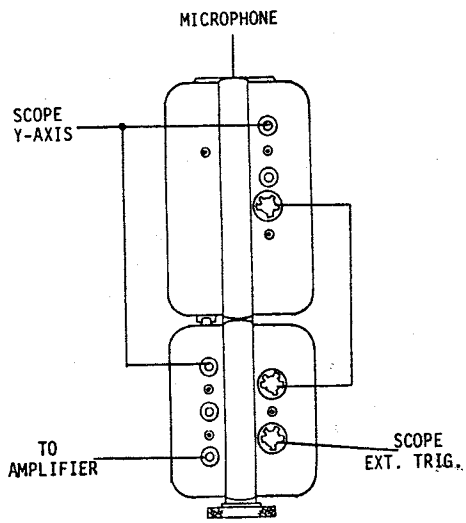


Figure 40

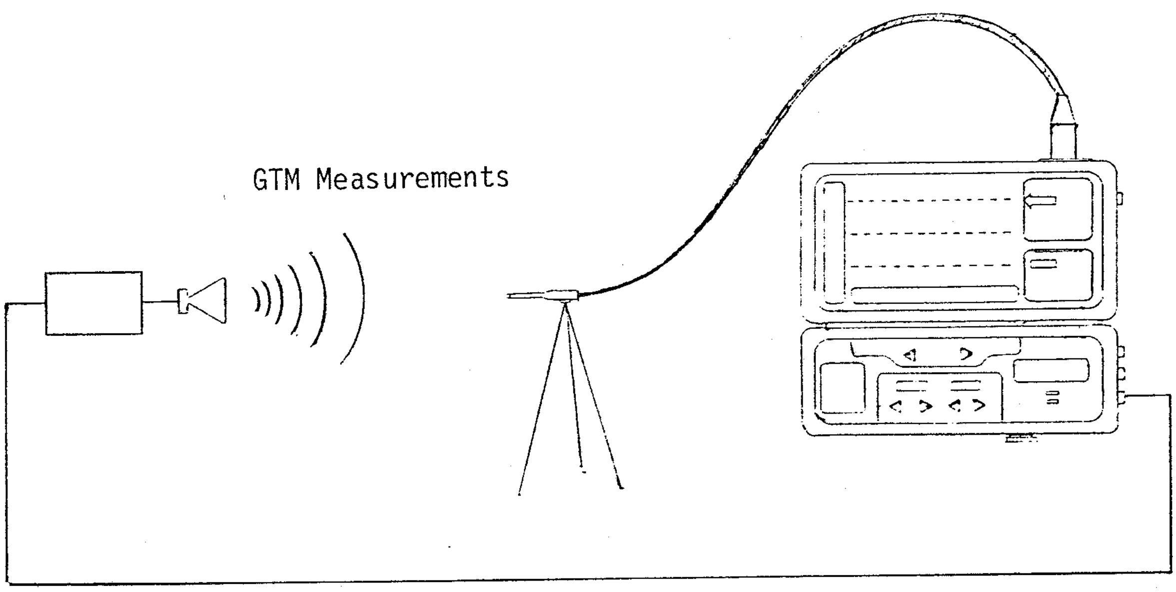


Figure 41

As an exercise to gain familiarity with GTM, using an oscilloscope, set up the system as shown in Figures 40 and 41.

Instrument Control Settings

IE-30A CONTROLS	CONTROL SETTING
OFF/ON	ON
DB/STEP	3dB
FILTERS	1/3 OCT
dB REF	Set to desired level
DECAY	D1
MEMORY	Set for real time display
SLM	LIN, PK, CNT

IE-17A CONTROLS	CONTROL SETTING
FUNCTION	GTM
SOURCE-GATE	EXT (for external source)
SOURCE BW	LIN
PROGRAM SELECTOR A	Select timing parameter
PROGRAM SELECTOR B	Set timing parameter
FREQUENCY MARKER	Not used with GTM

In the first example setup of GTM, no X-Y recorder will be used in order to focus upon learning just the IE-17A control functions. An X-Y recorder will be added to the wiring diagram later to provide swept plot capabilities.

The external signal source shown can be any sine wave generator. Initially set the frequency to approximately 1 kHz. Good test habits dictate that we attenuate signal source outputs fully before plugging them into operating systems to prevent damaging the speaker cones. The signal source output can then be increased slowly to a safe SPL level.

As you have probably noticed, the IE-17A begins emitting pulses automatically, when GTM is selected. When GTM is first selected, the computer will preset the four timing parameters to the following values:

PW = 0.100 sec
CT = 01.00 sec
DT = 0.010 sec
AT = 0.090 sec

Now, as an exercise, reset the timing parameters to the following values.

PW = 0.010 sec (10 msec)
CT = 00.50 sec (500 msec)
DT = 0.001 sec (1 msec)
AT = 0.100 sec (100 msec)

Set the oscilloscope time base to 10 msec/div, and to external trigger, and adjust the trigger threshold for a swept display. Because CT = 0.50 sec, the oscilloscope should sweep every one-half second, if the external trigger has been properly adjusted. The external trigger can be set for either a plus or minus polarity. As a final oscilloscope adjustment, select a Y-axis gain setting that provides an adequate visual display of the received pulses, coming from the IE-30A preamp. For the purposes of this example, we will assume that the following CRT display appears on your oscilloscope.

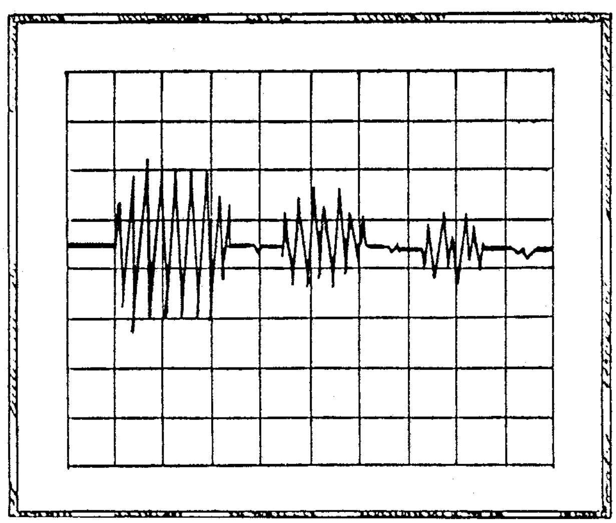


Figure 42

In this example, the source is a 1 kHz sine wave that has a 10 msec pulse width, and is triggered two times per second. Using a calibrated oscilloscope time base, we can see and measure the delay times of the direct wave, or of any reflection. Using the measured delay times of the reflections, we can calculate distance, and locate the reflective surfaces in the room. We can also view the relative magnitudes of any of the pulses. If the IE-30A microphone is placed next to a reflecting surface, the reflected pulse will merge with the tail end of the direct wave because the direct wave and the first reflection arrive at the microphone almost simultaneously. Reflections that are clearly separate in time from the direct wave, and from other reflections are called discrete reflections. Reflections that overlap either the direct wave, or other reflections are called merged reflections. Merged pulse spectra can occur if the selected pulse width is too wide, or if the microphone is near to reflective surfaces, or if room RT60 is so long that one pulse train does not decay adequately before the next pulse is transmitted by the IE-17A. Proper use of GTM will only be attained with experience in microphone placement, and in selecting the timing parameters for the IE-17A.

It is not generally understood that reflection characteristics are a function of the transmitted frequency as well as the angle of incidence of the reflection. Changing the frequency of the external signal source will provide a graphic display of room characteristics versus frequency. Acoustic materials do change absorptivity as a function of the reflection's grazing angle.

Suppose that one objective of the above example test is to measure the SPL of just the direct wave. To capture just the direct wave, we would need to select a delay time (DT), and an aperature time (AT) that would allow the IE-30A to analyze only when the direct wave is passing the microphone. By viewing the CRT, the delay time D of the direct wave can be quickly seen, or by going to the IE-17A DELAY function, the delay can be accurately measured with 0.1 msec resolution.

> NOTE: The IE-17A will remember the last selected range values for each measurement function, unless you turn off system power. This allows you to set up the GTM system as desired, change the measurement mode to DELAY, measure delay, and then, return to GTM without having to reset the timing parameters.

Enter the value of the measured delay time of the direct wave as the delay time (DT) parameter in GTM. Now set the aperture time (AT) equal to the transmitted pulse width, which for our example is 10 msec (0.010 sec). These settings of the timing parameters will cause the IE-30A analyzer to turn on when the direct wave arrives, and to turn off when the direct wave has passed. Figure 43 on the following page demonstrates the changed display which should occur on your oscilloscope CRT.

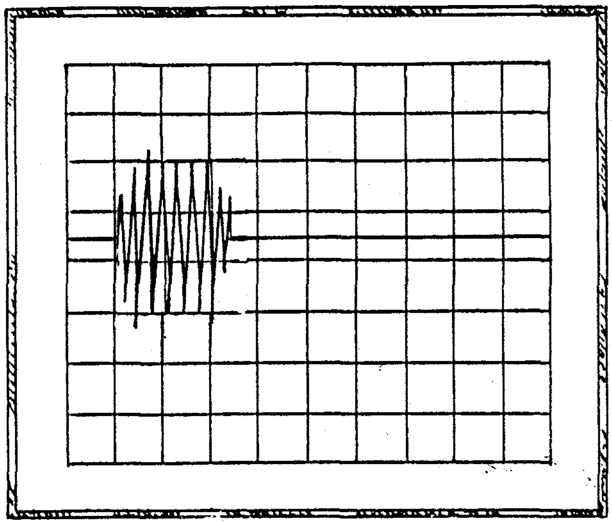


Figure 43

When you have correctly set the timing values for DT and AT, you will see on the oscilloscope CRT that the only pulse spectra displayed is that of the direct wave. All others have been excluded. The SPL value of the direct wave is displayed in the the DATA window of the IE-17A, and is updated with each new pulse. In the same manner, the SPL of any discrete reflection can be measured, independent of the rest. Enclosing all the reflections within the IE-30A aperture window will provide a measurement of the reverberant field. Knowing the SPL of the direct wave, versus the reverberant field, RT60, and room ambient noise, can lead to the calculation of articulation loss at any selected frequency.

GTM MEASUREMENT THEORY AND TECHNIQUES

This section of the GTM manual will provide information concerning the theory of impulse testing, and the test techniques required to assure measurement accuracy.

Pulse Spectrum

A fixed frequency sine wave, if viewed in the frequency domain, has an infinitely narrow bandwidth. A rectangular, sine wave pulse (tone burst) has an infinite bandwidth (in theory), and is a composite of many sine waves and their harmonics. The frequency spectrum of a sine wave versus a tone burst are shown in Figures 44 and 45 below.

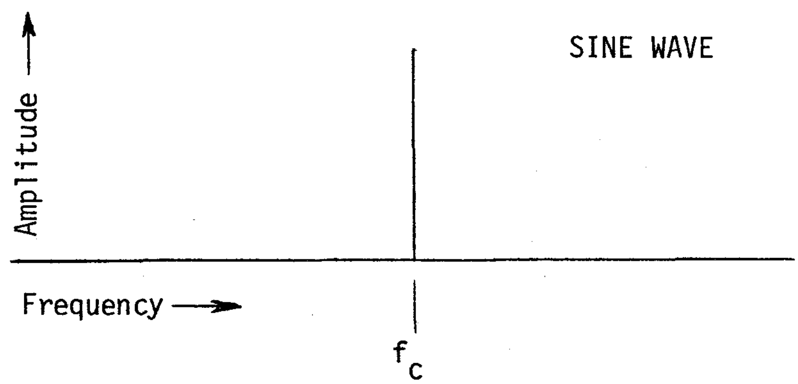


Figure 44

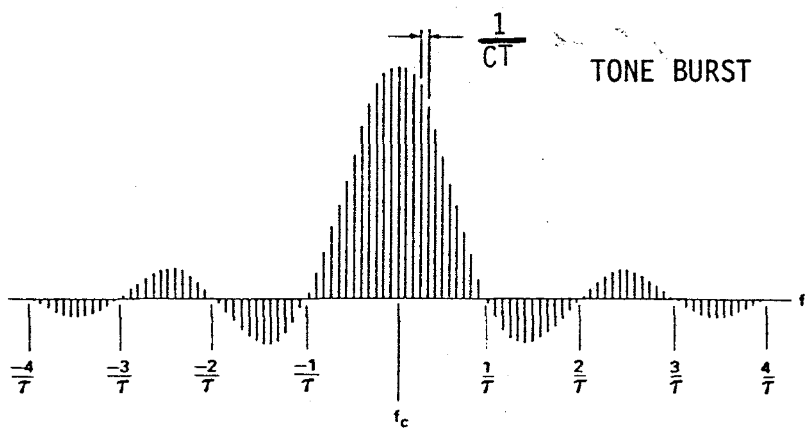


Figure 45

The envelope of the pulsed spectrum follows the mathematical form $Y = \frac{\sin X}{X}$ and is comprised of a main center lobe and several side lobes, separated by amplitude null points. Spacing between the spectral lines of the lobes is equal to the pulse repetition frequency, and is also equal to 1/CT (IE-17A Cycle Time). The frequency spacing between null points of the tone burst is equal to $1/\tau$, where τ is equal to the programmed Pulse Width (PW) of the IE-17A. It follows, therefore, that the narrower the selected pulse width, the wider the sidelobes, and the longer the cycle time, the more closely spaced are the spectral components, as demonstrated in Figures 46 through 49 on the following page.

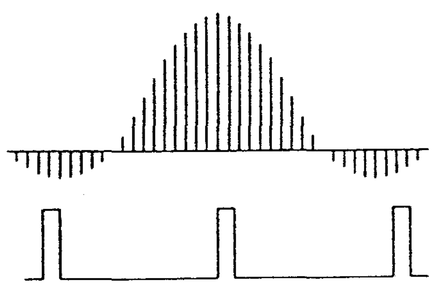


Figure 46. Narrow pulse width causes wide spectrum lobes; long cycle time results in low spectral line density.

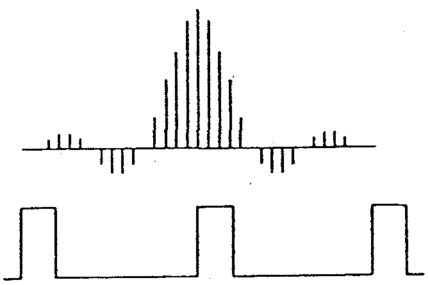


Figure 47. Wider pulse than Figure 46 causes narrower lobes, but line density remains constant since CT is unchanged.

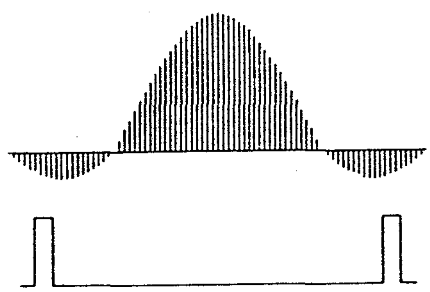


Figure 48. Longer cycle time than Fig. 46 results in higher spectral density. Lobe width is same as Fig. 46 since pulse widths are identical.

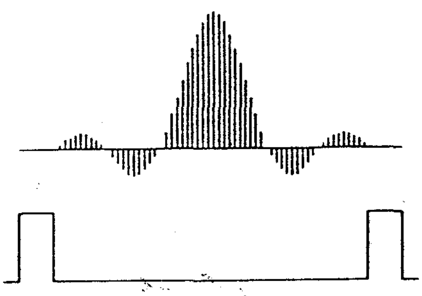
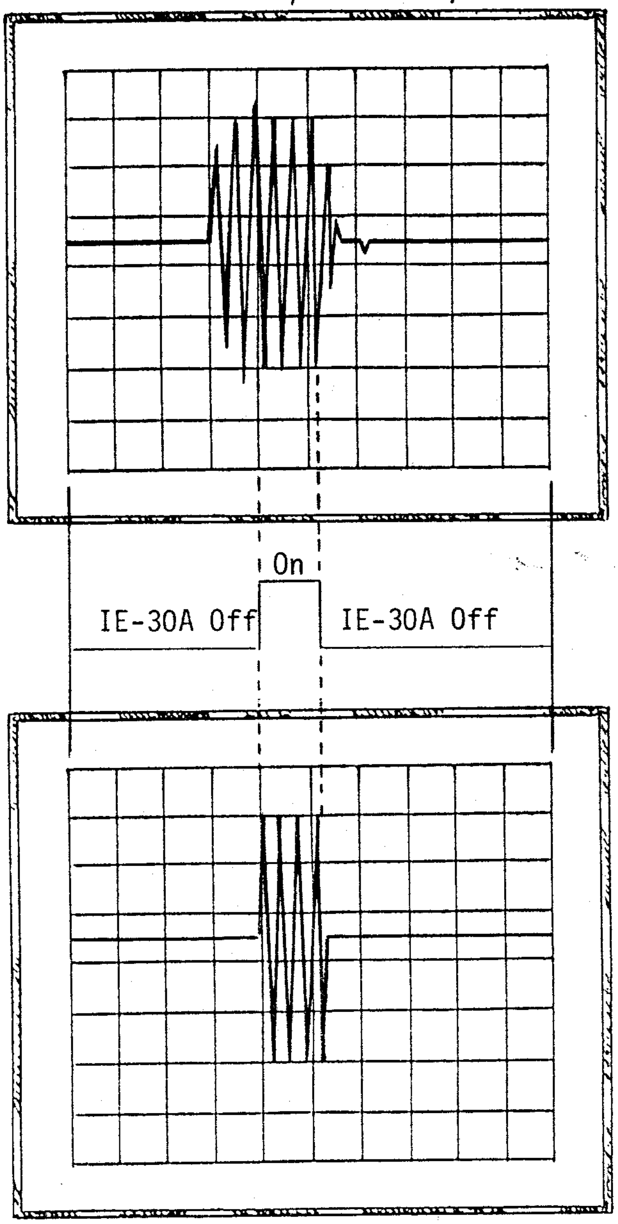


Figure 49. Spectral density and cycle time unchanged from Fig. 48, but lobe widths are reduced by wider pulse.

A person might observe from the above discussion, that testing with a tone burst is very different spectrally than testing with a sine wave, and thereby conclude that the test results must also be different, and not comparable. However, this seemingly obvious conclusion is not a correct one, for the following reason. When the leading edge of a rectangular tone burst reaches a speaker cone, there are initial transient response characteristics created in the speaker which are spectrally unlike a steady state sine wave response. A speaker cone, having mass, does not respond instantaneously to impulse signals, but has a finite rise time, of a few milliseconds, before a steady state sine wave response is reached following a tone burst.

If a PW is selected from the IE-17A that exceeds the time required by the speaker to reach steady state, and if we select DT and AT so that we only view the steady state portion of the pulse coming out of the speaker, then, we are viewing a sine wave response that is as pure as a sine wave tone. Through proper setup and adjustment of the IE-30A gating system, the actual sine wave response of a speaker can be measured, rather than the impulse response of sin x/x. In essence, the IE-30A/17A system can be programmed to avoid the non steady state portion of a speaker pulse, thus eliminating the sin x/x response spectrum. As an example, Figure 50 below shows a typical speaker response to a tone burst. Note the speaker transients at both pulse turn on and turn off.

Direct Wave Speaker Response



Steady Stated Gated Waveform

Figure 50

The receive window on the IE-30A should be programmed to turn on only during the steady state portion of the pulse, thus eliminating harmonics and sidelobes of the pulse.

Aside from the fact that the world has "standardized" on steady state sine wave testing of acoustic devices, there are very good reasons why sine wave testing may be unrealistic. First, a sound system is rarely used for reproducing steady state sine waves, with exception to a laboratory test environment. Both voice and music spectrum are impulse by nature, and good arguments can be given for including the device transients in the measured data; after all, thats what we hear. Secondly, steady state sine waves produce room standing waves, whereas impulses, having short term duration, may not exist for sufficient time in the room to create standing waves. Several very interesting research papers could be, and should be written on this subject.

As with any measurement technique used, the signal to noise (S/N) ratio is a critically important factor. We must be certain, even with pulse testing, that the pulse amplitude is larger than the ambient noise by several dB. The IE-30A real-time analyzer is an ideal tool to view S/N ratio on screen.

Another subject that is deserving of some discussion is that of room dimensions, and microphone placement versus cutoff frequency. The lowest frequency at which a quality anechoic chamber can measure sound is determined by the physical dimensions of the anechoic room. The same room dimension limitations exist for anechoic testing in ordinary rooms, using GTM. So in terms of the lowest measureable frequency, an anechoic room has no advantage over an ordinary room of the same size used with GTM. It should be recognized however, that an anechoic room, by virtue of its sound damping insulation, should have a lower ambient noise, and thus a larger dynamic range than an ordinary room environment.

To measure the anechoic response of a device in a non anechoic environment, the room must be large enough to avoid reflections reaching the microphone at the same time as the direct wave. Basically then, a pulse width must be selected which is wide enough to allow the speaker to reach a steady state condition for measurement, but not so wide as to cause merging of any reflections with the direct wave. These conditions, of course, can be confirmed by viewing the oscilloscope CRT.

There are two criterion which should be considered in the measurement of speaker systems, to assure that the measurements are being made in the far field. The minimum distance between the measurement microphone, and the speaker system being measured, must at least equal the largest physical dimension of the speaker system. Also, you must be certain that the microphone is at least one wavelength (of the lowest frequency to be measured) away from the speaker system. Wavelength in feet, or in meters can be calculated using the formulas below.

$$\text{wavelength} = \frac{1130}{f_L} \text{ feet}$$

$$\text{wavelength} = \frac{344}{f_L} \text{ meters}$$

f_L = lowest frequency (in Hz)

SWEPT GTM MEASUREMENTS

Use of swept sine waves with GTM will open several new areas of analysis involving: 1) anechoic testing in non anechoic environments, 2) detailed reflection analysis, 3) acoustic absorption coeffecients, 4) articulation losses, 5) speaker enclosure analysis, 6) flutter echo, 7) three dimensional RT60, 8) transmission loss, and a host of other applications.

An X-Y recorder, and a swept frequency oscillator are essential elements of the test setup. Note in the wiring diagram below that with the exception of the calibration mode of the IE-17A, the X-axis of the recorder is driven by the ramp from the swept frequency source. The Y-axis of the X-Y recorder is driven by the IE-17A as shown.

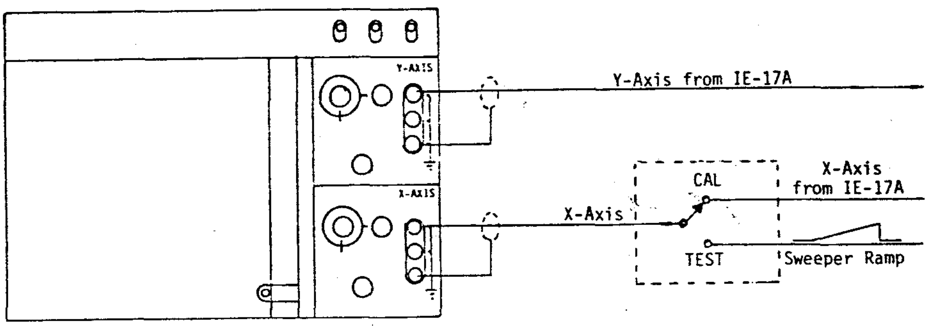


Figure 51

A small box with an installed switch is used in the X-axis line of the X-Y recorder to provide the capability to put calibration lines on blank paper (for the Y-axis), using the IE-17A, and also have the capability to sweep the X-axis using the source ramp. Only the Y-axis is calibrated using the IE-17A, because the X-axis is calibrated as a function of the sweeper ramp and the frequencies being swept. Standard log paper can be used for the frequency axis if the sweeper being used has a log sweep mode.

Plots that are generated using GTM and swept sine waves will have the same envelope (shape) as an equivalent swept analog system, but will appear slightly different in that the curve has been digitized by the computer to a resolution of 1.0dB. As a result, the swept plot will have a staircase appearance as shown in Figure 52 on the following page.

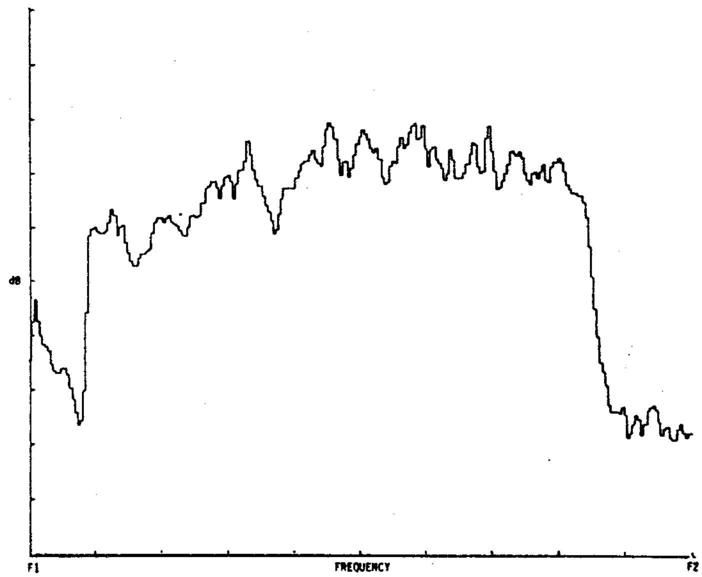


Figure 52

The theory of operation for a swept measurement is really quite simple. A sine wave source that is being swept very slowly (typically 1-3 minutes full range) is fed into the IE-17A gating system, where it is processed into a pulse, and then, injected into an audio system. The IE-17A can be programmed to receive the direct wave, or a reflection or any other portion of the transmitted spectrum. With each new pulse, the IE-17A performs a sample and hold on the SPL level of the signal and translates the measured amplitude to a DC voltage on the Y-axis plotter line that is exactly proportional to the signal amplitude in dB. Simultaneously, the ramp ouput from the sweeping signal source is driving the X-axis of the recorder, providing a new frequency position for each pulse sample taken. As the signal source sweeps over its frequency range, the IE-17A captures the signal amplitudes which correspond to the frequencies being swept. Resulting plots may be of the direct wave versus frequency, or in other words, the anechoic response of the device being tested. Or, you may wish to see a plot of the direct wave compared with a reflection, over the same frequency range. Or, you may wish to plot the direct field versus the reverberant field, for the same frequency range. The resulting data can lead to a thorough analysis of anechoic response, flutter echo, absorption coefficients, articulation losses etc.

Higher resolution plots can be achieved by slowing the sweep rate of the source, or by narrowing the frequency sweep range.

THE IE-17A PERIPHERAL INTERFACE

The IE-17A Peripheral Interface plug has the pin configuration shown in Figure 54 below:

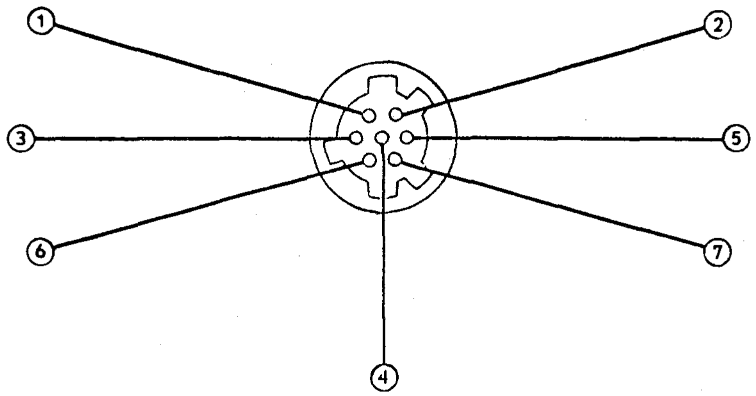


Figure 54

The pins provide the following functions:

(1) Ground.

(2) X axis drive for an X-Y plotter. The output voltage varies from 0.0 VDC to +2.5 VDC in 256 steps.

(3) Y axis drive for an X-Y plotter. The output voltage varies from 0.0 VDC to +2.5 VDC in 256 steps.

(4) TTL compatible pen lift control for those X-Y plotters which have a pen lift feature. (Not designed to switch higher levels than TTL.)

(5) Y axis drive for an oscilloscope. The output voltage varies from 0.0 VDC to +2.5 VDC in 256 steps. The refresh rate from the IE-17A memory is 150 Hz, so more than one plot can be produced on screen without requiring a dual trace oscilloscope. A standard scope is all that is needed.

(6) Oscilloscope Sync. The scope sync will work with either positive or negative triggering. Depending upon the oscilloscope used, positive triggering may be a little more stable than negative, or vise versa. You may wish to try both to determine whether one proves more stable than the other. In most cases, both will work equally well.

(7) Unused.

More information concerning applications and interface of peripheral equipment with the IE-17A is provided in other sections of this manual.

THE SNARE PULSE

The IE-17A computer is capable of internally systhesizing a spectrally flat, 10msec wide pulse called SNARE PULSE. The SNARE PULSE in not pink noise - pink noise varies greatly (especially at the lower frequencies) from pulse to pulse when only a 10msec wide window is observed. The SNARE PULSE, by contrast, is repeatable from pulse to pulse within $\pm$ 1dB across its entire frequency spectrum.

While the SNARE PULSE is repeatable from pulse to pulse, it does roll off slightly at the botton end. Figure 55 below is an IE-17A plot of a single shot SNARE PULSE fired into an IE-30A in the memory accumulate mode, with 3dB per step display resolution. The "tick marks" are 5dB apart.

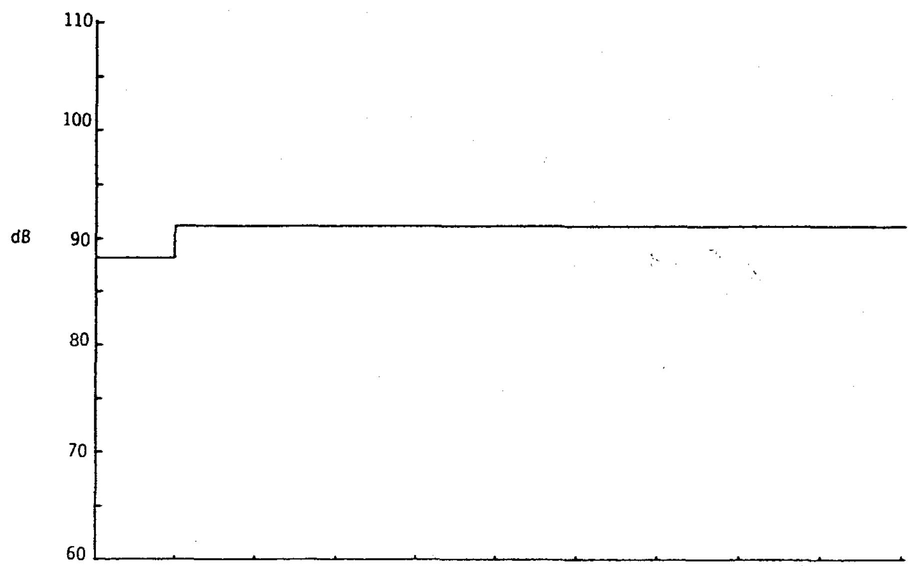


Figure 55

Additional single shot SNARE PULSES fired into an IE-30A would produce the same frequency spectrum plotted above, $\pm$ 1dB. Uses of the SNARE PULSE are described in other sections of this manual, and in forthcoming applications notes from Ivie Electronics.

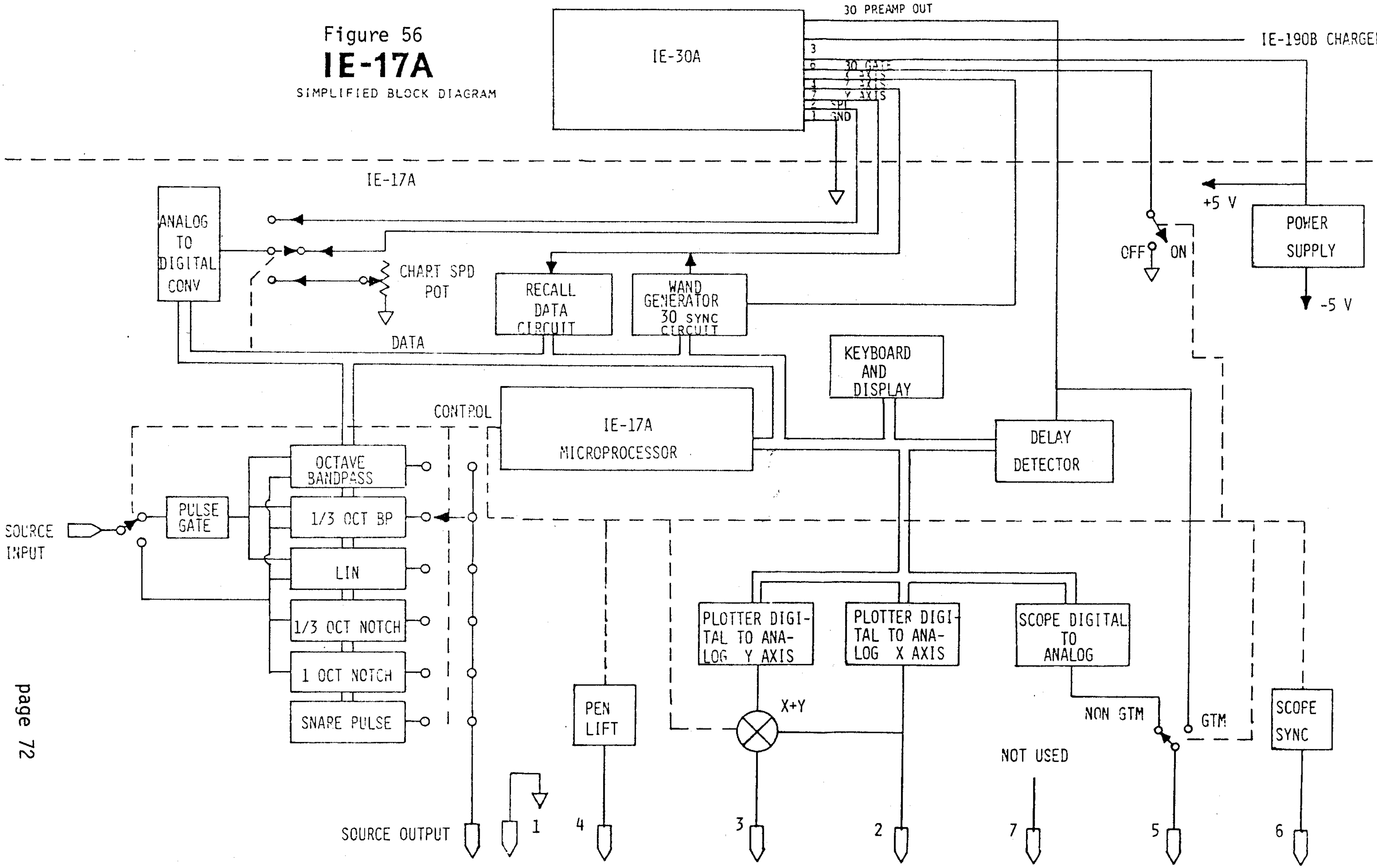
Note: The SNARE PULSE is designed for use with the IE-30A in the D_1 response mode only. It is not designed to work with other spectrum analyzers, or with the IE-30A in the D_2 or D_3 response modes.

Note: To electrically look at the SNARE PULSE with an IE-30A in the memory accumulate mode, the delay line connection between the preamp output of the IE-30A and the delay line input of the IE-17A must be disconnected. If connected, the delay line will abort the firing of the SNARE PULSE.

Figure 56

IE-17A

SIMPLIFIED BLOCK DIAGRAM



IE-17A SOURCE CONTROL INPUT AND OUTPUT

One of the features of the IE-17A is its ability to accept external audio signals, and process them various ways to facilitate different types of measurements.

Borrowing from the IE-17A block diagram, the Source Control Input and Output and associated circuitry can be described by Figure 57.

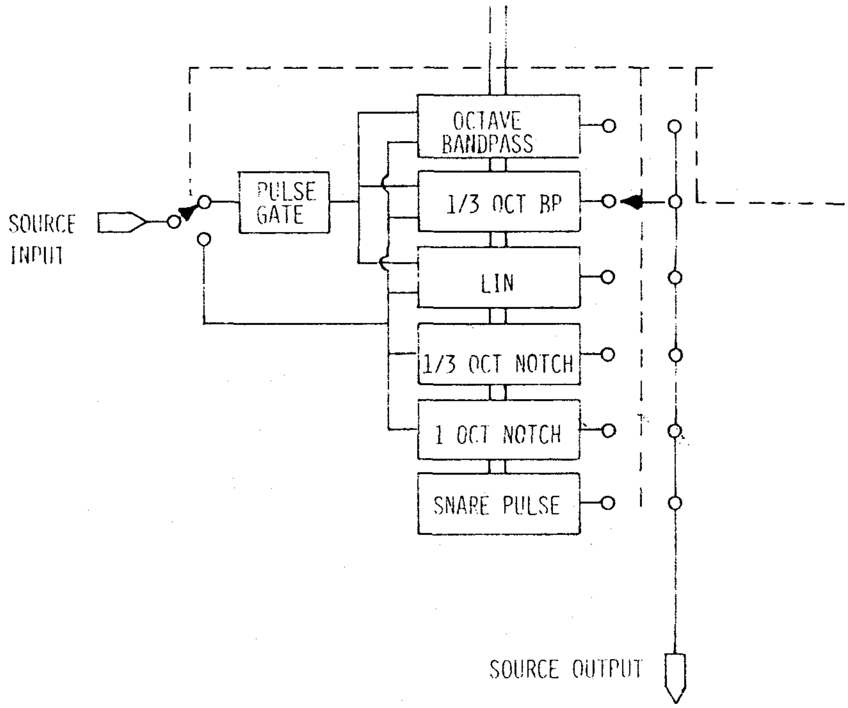


Figure 57

Signals entering through the Source Control Input can be bandpass filtered in octave or 1/3 octave bandwidths, or can pass through unfiltered. The gain on bandpass filtered signals is approximately 13 dB, while unfiltered signals have no increase in gain. This allows switching from a filtered to an unfiltered signal without dramatic changes in the level of the signal appearing at the Source Control Output.

The table on the following page outlines the maximum signal handling capability of the IE-17A Source Control electronics for sine wave inputs.

Filter	Maximum Input Voltage	Gain	Maximum Output Voltage
1/3 OCT	.29 VRMS (.4v.pk)	13dB Gain	1.3 VRMS (1.8v.pk)
1 OCT	.29 VRMS (.4v.pk)	13dB gain	1.3 VRMS (1.8v.pk)
LIN	1.6 VRMS (2.3v.pk)	0dB gain	1.6 VRMS (2.3v.pk)

The Source Control electronics are capable of handling the full range of signal outputs from the IVIE IE-20 series noise generators, from full output to maximum attenuation. As further demonstrated in the preceeding block diagram, the IE-17A Source Control input has available a 1/3 octave or octave notch filter for signal processing. The minimum depth of the notch is 30dB.

In addition to the bandpass and notch filtering functions, the IE-17A Source Control has gating capability. External sources can be gated, or pulsed, or the IE-17A can generate its own internal SNARE pulse. The SNARE pulse is discussed in detail on page

As demonstrated in the block diagram, external signals passing through the IE-17A gate cannot be processed through the notch filters in the Source Control, and the internally generated SNARE pulse cannot be processed through any of the filters of the IE-17A Source Control.

IE-17A SPECIFICATIONS

Measurement Ranges

dB SPL and dB µv: same range as IE-30A

RT60: 1/3 octave or octave: 30 1/3 octave bands; 10 1 octave bands
.5 to 100 seconds full-scale in 8 ranges
Resolution: 10 milliseconds

dB/Seconds: 1/3 octave, 1 octave or broadband
100 ms to 100 seconds full-scale in 10 ranges
Resolution: 10 milliseconds

Delay: .0002 to 99.99 seconds
Max Resolution: 100 µs

GTM: Fully programable pulse width, cycle time, delay time and aperature time

Peripheral Interface

X-Y plotter:
X-Y axis output level full scale: 0-2.5 volts
Adjustable plotter speed
Oscilloscope interface:
Y axis output drive full scale: 0-2.5 volts
X axis sync for either positive or negative triggering

Internal Signal Generation

Snare pulse: full spectrum (25 Hz - 20 KHz) response
Single 10 millisecond pulse repeatability: +/- 1 dB full spectrum
Output: 2 V pk-pk

Mechanical

All modular construction provides dependable operation with ease of maintenance. Dimensions (w x h x d) 203 x 70 x 54 mm (8" x 2-3/4" x 2-1/8").
Tripod mount socket
Aluminum IE-17A case fusion bonded with nylon
Weight: .85 Kg (1.8 lbs)
Shipping Weight: 2.0 Kg (4.5 lbs)

Environmental

All circuits temperature compensated.
Operating temperature -10°C to +50°C.
Non-operating temperature -30°C to +65°C
Operating humidity 0 to 90%

Power

Uses power from IE-30A (battery or AC operation)

WARRANTY

The IE-17A is warranted against defects in materials and workmanship for one (1) year from the date of purchase. During the warranty period, IVIE ELECTRONICS will repair or, at its option replace, components which prove to be defective provided the unit is returned, shipping prepaid, to an authorized IVIE ELECTRONICS service facility. Defects caused by modifications, misuse or accidents are not covered by this warranty. No other warranties are expressed or implied. IVIE ELECTRONICS is not liable for consequential damages. All requests for repairs and information should include the instrument serial number to assure rapid service.

SERVICE

It is the intention of IVIE ELECTRONICS to provide quality service for the IE-17A whether in or out of the warranty period. If the IE-17A should require service, please return it shipping prepaid to an IVIE ELECTRONICS facility. Shipping the instrument in its original packaging is recommended. Repair will be made and the unit will be returned as soon as possible.

Due to the subminiaturized packaging techniques used, IVIE ELECTRONICS cannot assume responsibility for repairs made at other than an authorized service center.

SECTION IV

ADDITIONAL INFORMATION

IE-30A/IE-17A 7 PIN DIGITAL INTERFACE

The I/O connectors of the IE-30A and the IE-17A have the pin configuration shown in Figure 53 below:

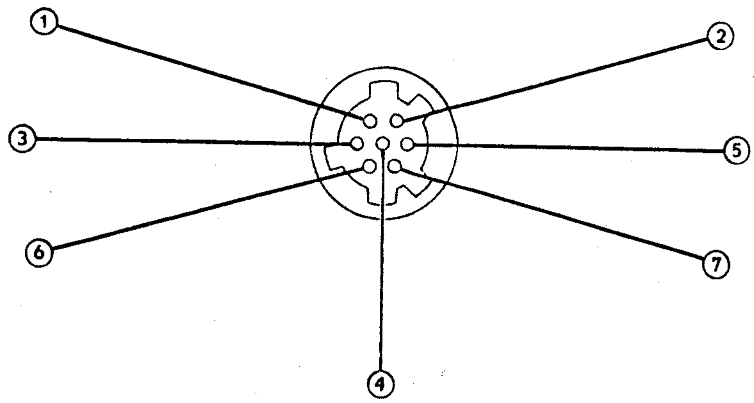


Figure 53

When the IE-30A is connected to the IE-17A using the supplied umbilical, Pin 1 of the IE-30A is connected to Pin 1 of the IE-17A, Pin 2 to Pin 2, and so on through Pin 7.

The electrical interface between the IE-30A and IE-17A is described in the table below.

Pin #	IE-30A	IE-17A
①	Ground	Ground
②	SPL Output - Variable DC	SPL ADC
③	4.8v. Output	Power Supply Input
④	Display Control	Frequency Marker
⑤	Clock Line	X-Axis Sync
⑥	Gate In	Gate Control
⑦	Y-Axis Output Variable D.C.	Y-Axis ADC

End of Document