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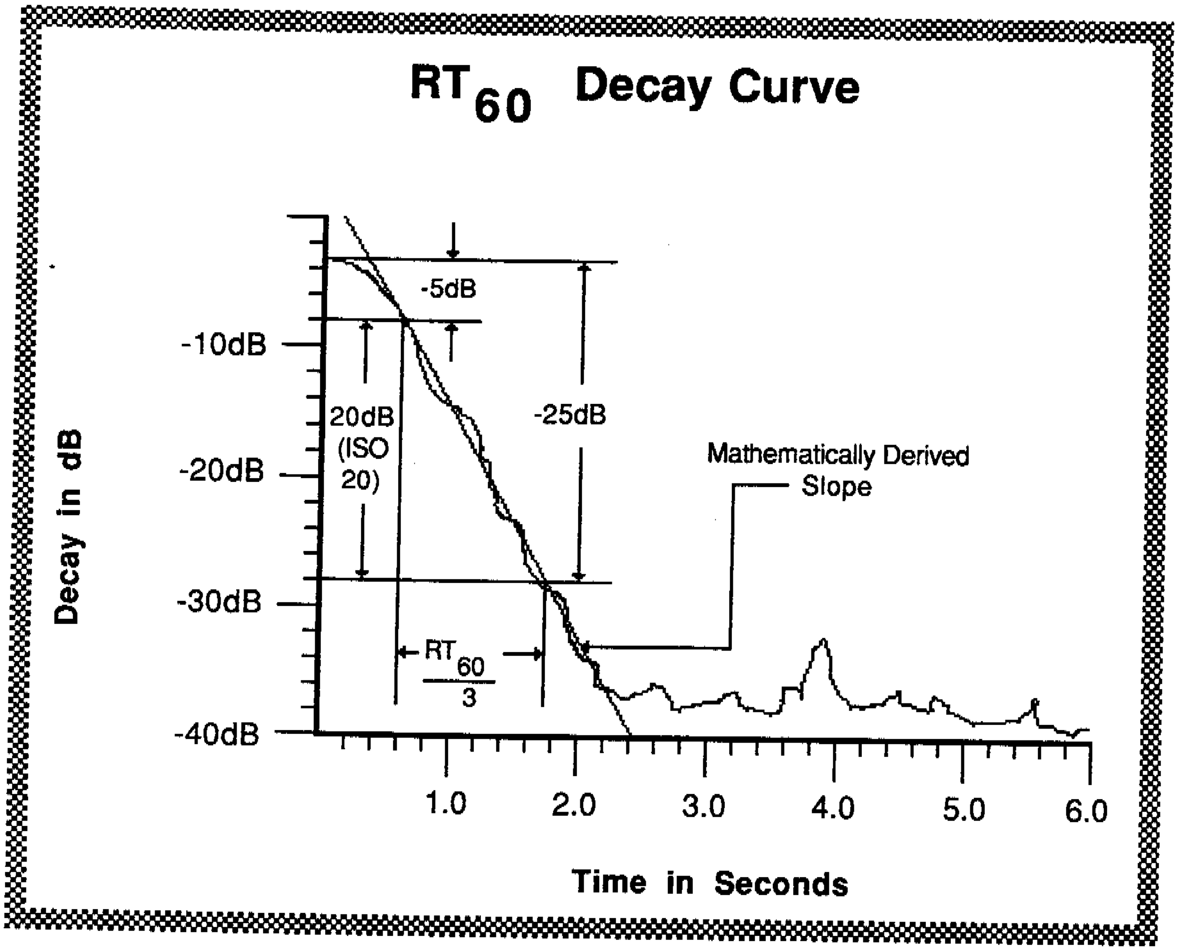
RT_{60} Software Manual for the Ivie PC-40 Audio Spectrum Analyzer



RT_{60} Manual for the Ivie PC-40 Audio Spectrum Analyzer

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RT_{60} Measurements Using the PC-40

Introduction and Theory of RT_{60} Measurements

In theory, reverberation measurements seem easy and straight-forward to make. In actual practice, they are not as easy as they might appear. RT_{60} is defined as the time, in seconds, it takes sound in a reverberant environment to decay 60dB in level. Measurements are usually made in narrow bands (octave or 1/3 octave), rather than broadband (20Hz to 20kHz). ISO standard octave bandwidths are the most common basis of measurement, with ISO standard 1/3 octave bandwidths being often used as well.

To make RT_{60} measurements, the following items are needed: a sound source to excite the environment being measured, a sound level meter to measure the sound decay, and a clock to measure the time over which the decay occurs. If our sound source were sufficiently powerful, and we had good hearing protection, we could excite an environment to a level 65 or 70dB (60dB of decay plus 5 to 10dB of headroom) above the ambient sound level. We could note the overall SPL, then shut off the sound while simultaneously starting a stop watch. We could watch the SPL meter until the sound level decayed 60dB, and then punch our stop watch. The time showing on the stop watch could be defined as RT_{60}.

The accuracy of the measurement would, of course, be affected by our ability to punch the stop watch at just the right times, and by our ability to read the SPL meter, determining exactly when the sound had decayed 60dB. In actual practice, a number of other factors affect both the accuracy and the interpretation of the data gathered. In the first place, it is usually not possible to generate sound levels which are 65 to 70dB above ambient - in many environments, such a level would approach the threshold of pain. This means that decay has to be measured over smaller windows than 60dB, with extrapolated RT_{60} then being calculated, rather than actually measured. Also, the rate of decay can vary over the measurement window, so, if an average of all rates of decay is desired, more calculations are involved. Additionally, methods of exciting the environment, along with other factors, can cause dramatic differences in the rate of decay for the first 5dB, when compared to the rest of the decay window. Consequently, we may want to be selective as to the section of the decay window we use to calculate decay time.

If we create a graphic plot of sound level versus time, we can observe the behavior of the sound as it decays. Of course, the number of amplitude samples we take over our time window will affect the resolution of decay curve we construct. Once we have this decay curve, we can make some decisions about which section of the curve to use to calculate RT_{60}. After a suitable section of curve has been selected, we face the problem of determining what the average rate of decay over that section of curve is. Once we have that, we can finish the RT_{60} calculation.

Perhaps the best way to handle all of these variables and calculations is through the use of a computer. The PC-40 does just that. The diagram below helps to explain how the PC-40 works and why it works the way it does.

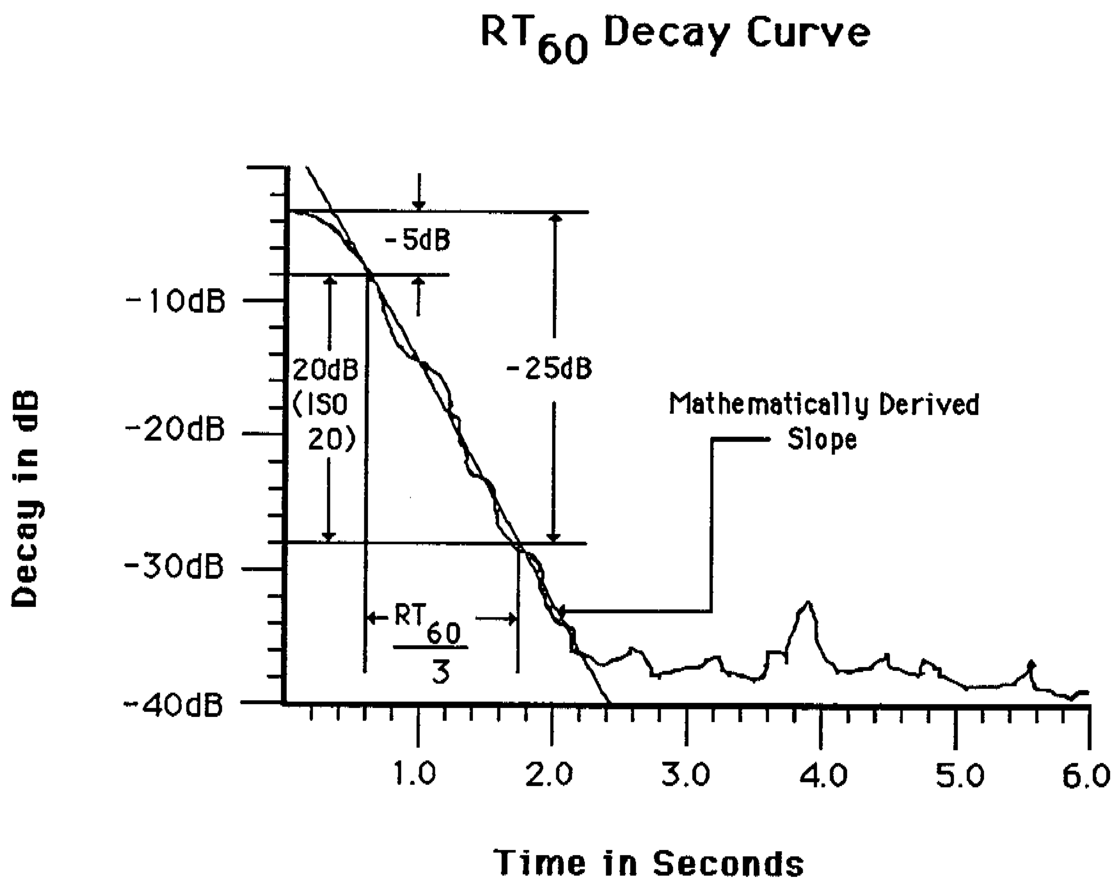


Figure 1

The above plot shows a decay curve and identifies sections of that decay curve. To insure statistical accuracy in measuring and plotting decay, the PC-40 takes samples (of amplitude in dB) at the rate of 100 samples per second, regardless of the length of the measurement window selected.

Notice that a 20dB section of decay curve has been identified. It begins at -5dB and ends at -25dB. Since 20dB is one third of 60dB, the decay time over this 20dB window would be 1/3 of the total RT_{60}, as the diagram shows. Not using the first 5dB of the decay curve in calculations of RT_{60} is an international practice that has evolved due to the variations often occurring in the first 5dB of decay, as compared to rest of the decay curve. The PC-40 uses the 20dB section of decay curve from -5dB to -25dB for RT_{60} calculations and delineates these calculations as ISO (20). The PC-40 also defines a 30dB decay window from -5dB to -35dB which can be used for calculations if there is sufficient decay available. The PC-40 delineates this as ISO (30). Additionally, the first 10dB of decay is often of major interest. Calculation of RT_{60} based on this section of the decay curve is delineated by the PC-40 as Early Decay. The PC-40 calculates ISO (20), ISO (30), and Early Decay times for each frequency band. A PC-40 tabular printout of RT_{60} includes numbers for all three of these. If there were insufficient decay to calculate ISO (30) or ISO (20), dashes would be printed to indicate insufficient data.

In our example above, a straight line has been fitted over the decay curve which represents the average slope of the decay. It is this line from which the final RT_{60} calculation is made, and therefore, the accuracy with which the line is fitted to the decay curve affects the accuracy of the final calculation. To insure the most accurate "fit" possible, the PC-40 uses linear regression (the "least squares" method) to fit the line to the decay curve.

The last item that needs to be mentioned is the improved statistical accuracy provided when several decay samples are taken and averaged together before RT_{60} calculations are made. Five or more samples are sufficient to provide excellent statistical accuracy. The PC-40 will average up to 99 decay samples, far more than are necessary.

Measuring RT_{60} Using Pink Noise and the PC-40 Audio Relay

Measuring RT_{60} with the PC-40 is really very simple and fast. Let's go through the procedure step by step. In an actual RT_{60} measurement, we would be feeding pink noise into a sound system through the PC-40 Relay. The Relay function is to shut off the sound as the test is begun. For the purposes of this discussion, we are going to "cheat" a little, and feed the pink noise electrically into the PC-40, instead of sending it through a speaker to the microphone. What we will be measuring is the decay of the PC-40 filters, rather than the decay of a room. The intent here is to conveniently familiarize you with the measurement procedure in the peace and comfort of your own office, before you have to go out and make a measurement.

A measurement setup is shown below which outlines our "office setup," and also the setup for an actual RT_{60} measurement. Only the output from the Audio Relay differs. Our "office setup" is demonstrated by the solid lines which show pink noise coming out of the Audio Relay, then feeding directly into the PC-40. A "real" measurement setup is demonstrated by the broken lines which show pink noise coming out of the Audio Relay, then feeding through a sound system, to be listened to by the PC-40 through its microphone.

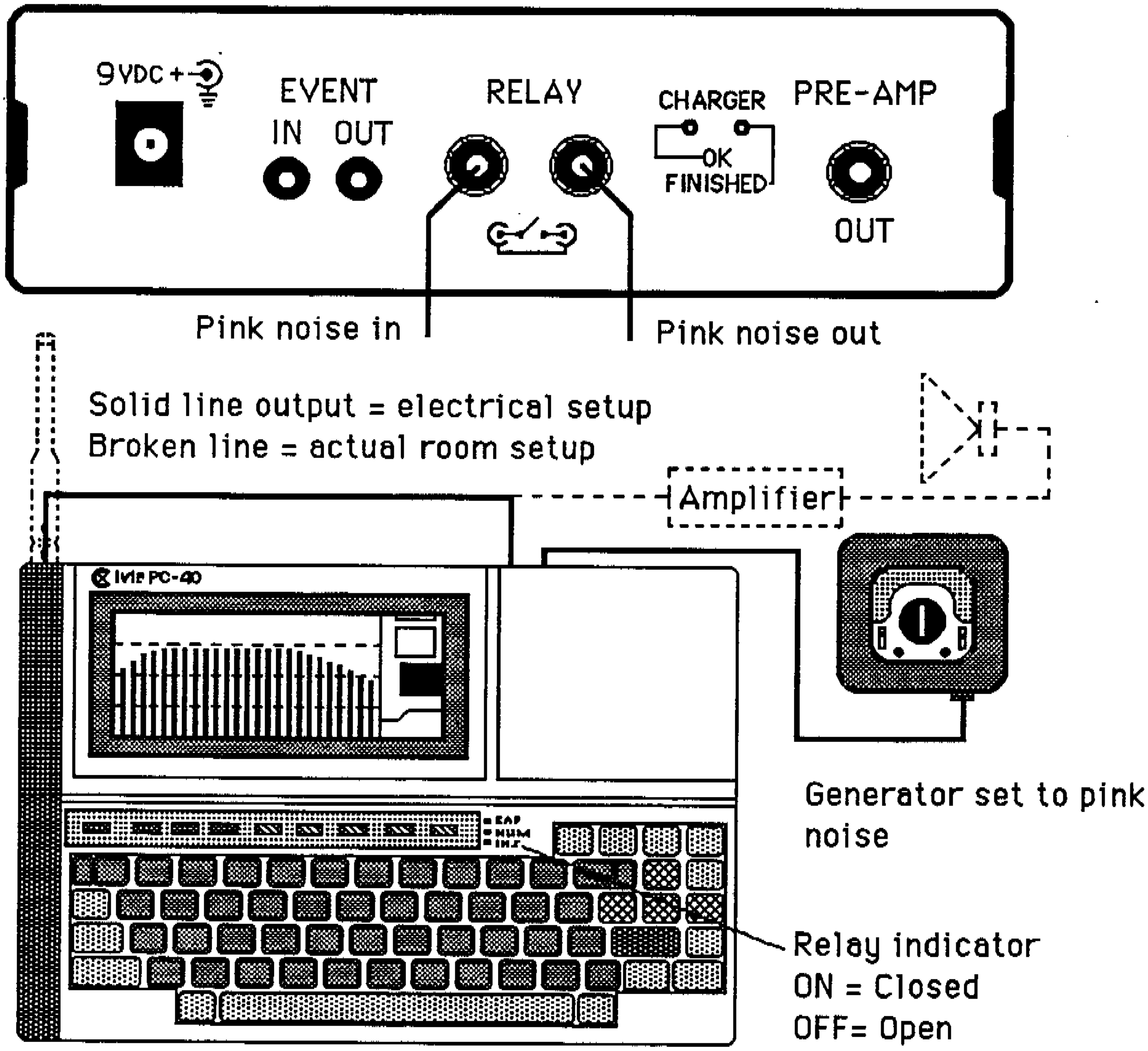


Figure 2

As already mentioned, the setup in Figure 2 shows both the normal setup for measuring room RT_{60} through the PC-40 microphone, and our electrical "office" setup for feeding pink noise directly back into the PC-40. This electrical setup can be accomplished using an Ivie 83AD adaptor (6 pin XLR to phono) plugged directly into the microphone input. If this adaptor is not available, the 1036B RTA Probe supplied with the PC-40 can be used by connecting it to the BNC input of the PC-40, and then clipping the probe to the output of the noise generator. In this instance, you would have to go into the UTILITIES menu of the PC-40, select Mic/Probe, and change the input to dBm, or dBV. If you failed to make this change, (switching the PC-40 from mic input to probe input) the PC-40 would still be looking for signal coming in through the mic input, and all it would see is crosstalk from the probe input.

Once the setup is completed as shown in Figure 2, and pink noise can be seen on the PC-40 screen, RT_{60} measurements can be begun. To make a measurement, the following keystrokes are necessary:

Press **UTILITIES** to select the UTILITIES menu. You will see RT_{60} listed.

Hold down the **Shift** key and press **PF1** to select RT_{60}.

The PC-40 will prompt, asking you to select a sample time base. You may choose from 1.81 seconds to 10.86 seconds. (If instead you get a prompt at this point that says data is already in memory and will be lost if you continue, see page 16 of this manual under "Allocation of Buffer Memory.") Regardless of the sample time you choose, the PC-40 will take samples at the rate of 100 per second, so accuracy of measurement will not be affected by choosing a long sample time for a short RT_{60} measurement. Resolution of the decay plot will be affected, though, because the entire width of the display screen will be equal to the time base you select. If you, for example, select a time base of 10.86 seconds to measure a filter decay that is less than a half a second, the decay plot will be compressed against the left side of the display. If you chose a 1.81 second window instead, the decay plot would be expanded and much easier to follow visually. It is best, therefore, to choose the shortest time base that will allow for your measurement. Of course, if you choose a time base that is shorter than the decay time you are trying to measure, you won't get complete measurement results.

Following through with our measurement setup, select a time base of 1.81 seconds by pressing the number **1**. The PC-40 will prompt again, asking if you wish octave analysis. If you select **Y** (Yes), the PC-40 will measure RT_{60} in octave bandwidths. If you select **N** (No), the PC-40 will measure decay in 1/3 octave bandwidths.

For our example, hit **N** to select 1/3 octave band measurements. The PC-40 screen should now look like Figure 3 below.

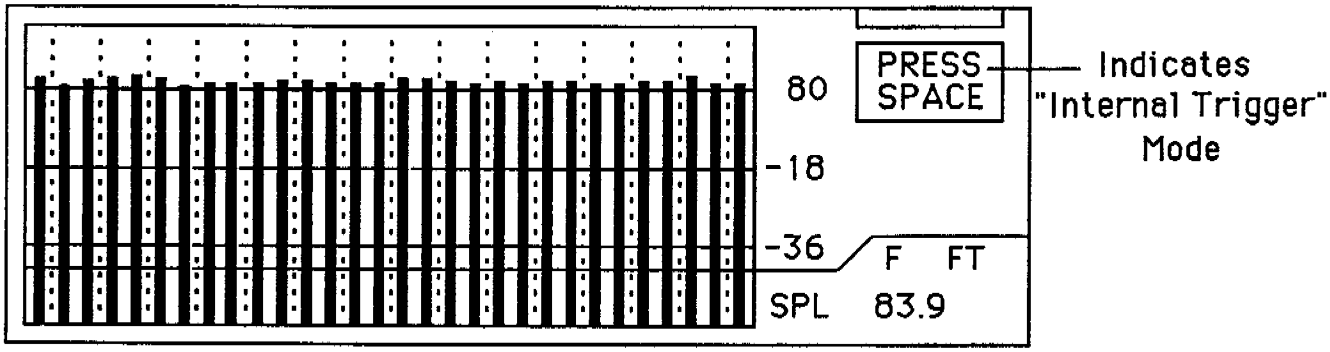


Figure 3

The PC-40 is now ready to make a measurement. If you are not happy with the level of noise showing on the screen, you can adjust the Reference Level, or even adjust the level of noise coming from the noise generator. Once you are happy with the display, press the **Space Bar** to begin a measurement.

The PC-40 Relay will open, turning off the noise (visual indication of the Relay status is provided by the Relay LED indicator - see Figure 2), and the measurement will begin. After a moment, you should get a PC-40 screen that looks something like Figure 4 on page 7. (Your decay curve will likely look different from the one here because the one here has been tailored to make it easier to demonstrate the measurement manipulations possible.)

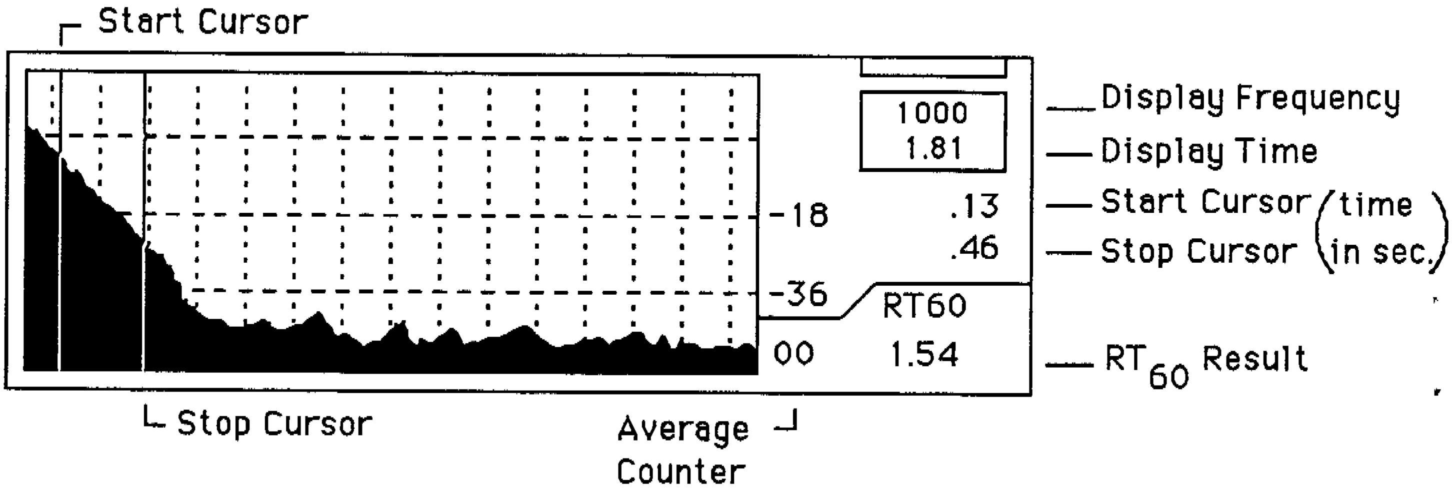
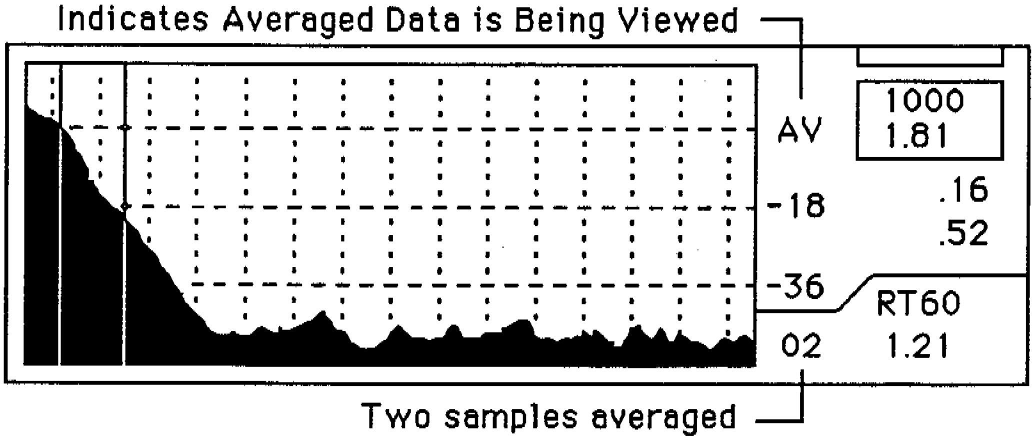


Figure 4

Averaging Several Measurement Samples Together:

If we were going to take several sample measurements to average them together, we would hit the **AVERAGE** button at this point. This would enter all the data from the first measurement into the accumulators and the average counter (See Figure 4 above) would increase by 1. Then, to ready the PC-40 to take another sample, press **STORE**. This would reset the display screen back to its "trigger ready" mode as shown in Figure 3. The pink noise would again come on and we would be ready to take another measurement by pressing the **Space Bar**. Successive measurements could be entered into the averaging accumulators as we continued to follow this same procedure. It is important to note that when averaging samples, the display shown is the display of the last sample taken. In order to view the average of all samples taken, press **V** (for view). This will display the averaged data, and the Average Counter will list the number of samples that have been averaged. In addition, the letters "AV" (for "Average") will appear next to the Message Window to give visual indication that averaged data is being displayed, as shown in Figure 5 on page 8.



Averaging Several Measurement Samples

Figure 5

For our example here, we will not take the time to average several samples. You can easily do that by following the above procedure when making an actual measurement. Instead, let's examine the data shown on the PC-40 screen in Figure 4 on page 7.

Understanding the RT_{60} Display Screen

The PC-40 display shown in Figure 4 on page 7 provides a great deal of information. Firstly, the start and stop cursors are shown selecting a section of decay curve. The Message Window tells us what frequency band we are looking at (in this case, 1000 Hz), and the time window we have selected (in this case, 1.81 seconds).

Below the Message Window, the time location of the start and stop cursors is displayed. Notice that the start and stop cursors, in Figure 4, are at .13 seconds and .46 seconds respectively. Our time references are 0.0 seconds, the left side of our decay display, and 1.81 seconds, the far right side of our display. (You may recall that the time window we selected was 1.81 seconds long. Our display, therefore, shows that exact time window.)

At the bottom, right of the display, the average counter tells us the number of samples we have averaged together to generate our data (In Figure 4, we have not averaged any measurement samples together, so the average counter says 00). Lastly, our RT_{60} calculation is displayed: 1.54 seconds.

We could conclude, then, by looking at Figure 4: after a single sample measurement, the calculated RT_{60}, based on the 20dB of decay from approximately -5dB to -25dB on the decay curve, is 1.54 seconds. This, however, is only the beginning of the information available.

Figure 4 shows the PC-40 "default display." That is, the 1000 Hz bandwidth is shown, the start and stop cursors have selected the ISO (20) measurement (-5dB to -25dB on the decay curve), and the location of the cursors is shown in time. The PC-40 can display the decay curve and calculated RT_{60} for any of the other frequency bands (it measured all the bands simultaneously), it can display ISO (30) automatically (-5dB to -35dB on the decay curve), and it can indicate the location of the cursor wands in dB relative to the Reference Line, as well as in time. Furthermore, you may select any portion of the decay curve you desire, and the PC-40 will calculate RT_{60} over that portion of the curve. Lastly, you may print any decay curve, or get a tabular printout of calculated RT_{60} at every bandwidth. The commands to accomplish all of these are simple.

To change the display from ISO (20) to ISO (30): Hold down the **CTRL** button and hit the "**Up**" arrow key on the PC-40. Your display should then look something like this.

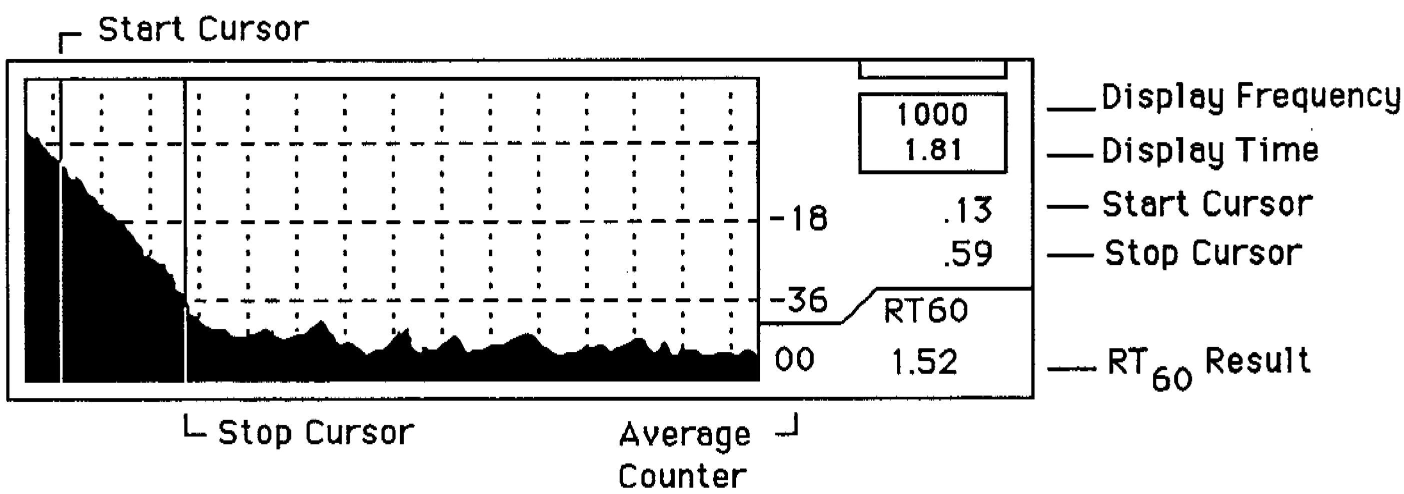


Figure 6

Notice that the start and stop cursors are now located at approximately -5dB and

-35dB, with the stop cursor time and the calculated RT_{60} number having been changed accordingly. To change back to ISO (20), hold down the **CTRL** key and press the "**Down**" arrow key. In this manner, you may toggle back and forth from ISO (20) to ISO (30).

To have the start and stop cursors indicate in dB relative to the Reference Line: Hit the letter **D** (for dB) on the keyboard. Your display should now look something like this.

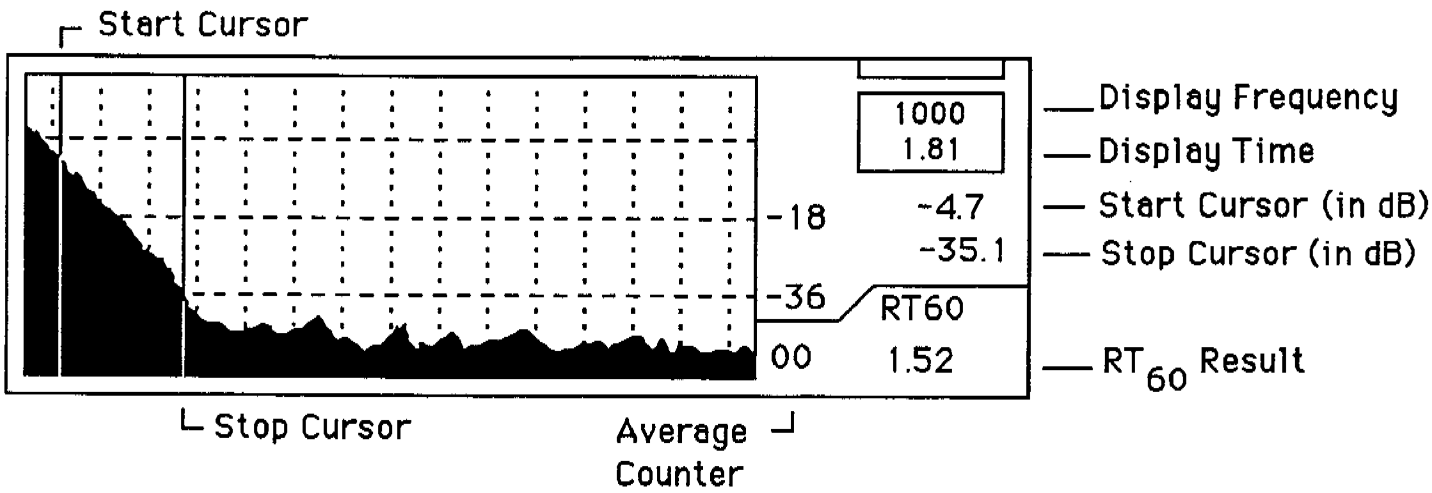


Figure 7

Notice that we are measuring ISO (30), and our start and stop cursors are approximately 30dB apart. ISO (30) measurements specify -5dB to -35dB on the decay curve and the PC-40 will choose values as close to these as possible to locate the start and stop cursors. Notice, however, that the dB locations of the start and stop cursor printed below the Message Window are dB relative to the Reference Line, not relative to the beginning of the decay curve. In our example above, the start cursor is 4.7dB below the Reference Line, which is about 5dB down on the decay curve. (In our example, the decay curve begins almost exactly at the Reference Line.)

To change the display indication of the start and stop cursors from dB back to time: Hit the letter **T** (for time). Hitting the letters **D** and **T**, then, will allow toggling between dB and time when displaying cursor locations.

To display the decay curve from a different frequency band: Hit the "**Up**" arrow key to go up in frequency, and the "**Down**" arrow key to go down in frequency. You will notice as you do this that the new frequency you have selected appears in the Message Window. The decay curve for that frequency is also displayed automatically, and the calculated RT_{60} is shown as well. The decay curves and RT_{60} information for each frequency band are in the PC-40 memory, and you may step through each band to view any frequency you wish. Let's continue with our example. Press the "**Down**" arrow key and select the 500 Hz bandwidth. After you have done this, you should get a display similar to Figure 8 below.

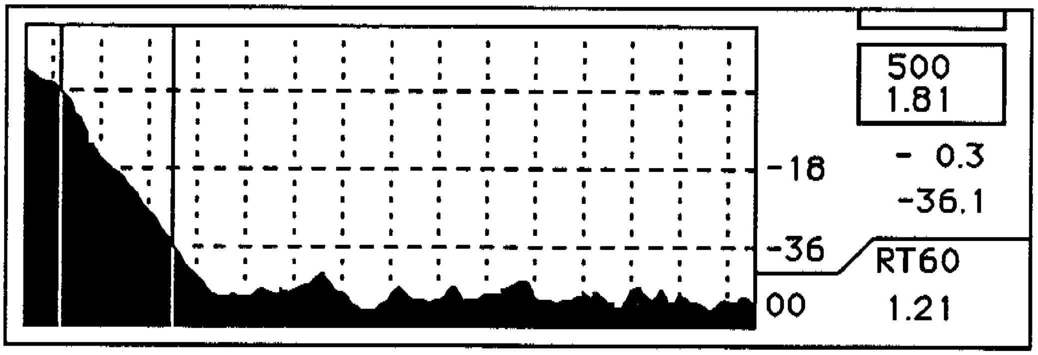


Figure 8

Notice that the start and stop cursors are still in ISO (30) on the new decay curve, and their locations are shown in dB. This is how we left them before we changed frequency bands.

To change the location of the start and stop cursors: The arrow keys are used. To move the start cursor left or right, press the "**Left**" or "**Right**" arrow key. To move the stop cursor left or right, hold down the **Shift** key while pressing the "**Left**" or "**Right**" arrow key. To move both cursors simultaneously, hold down the **CTRL** key while pressing the "**Left**" or "**Right**" arrow key. Once you have selected the section of decay curve you wish with the start and stop cursors, press the "Recalculate" button (**PF5**) to calculate RT_{60} based upon the section on curve you have selected. (You will notice that as soon as you begin to move either the start or stop cursor, the calculated RT_{60} number will disappear from the display. It will not reappear until you have placed the cursors where you want them and then pressed the "Recalculate" button.)

To print out any decay curve: Follow the same procedure as in printing other screens of information - hold down the **CTRL** button while pressing **PF5**. This will give you a "screen dump" printout, just as in other functions of the PC-40. Of course, you must display the decay curve you want to print out before you can print it.

To print a tabular RT report of all bands measured: Hold down the **CTRL** key and press **P** for "print." The PC-40 will visually step through all the decay curves and print out a tabular report that looks something like the one printed out below. This one is a printout for octave bandwidth measurements, but 1/3 octave measurements would print out in a similar fashion, with all thirty 1/3 octave channels printing out instead of just ten octave channels.

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RT-60 REPORT AFTER 01 SAMPLES

FREQ.	EARLY	ISO (20)	ISO (30)
31.5	1.79	1.55	----
63	1.63	1.51	1.59
125	1.40	1.36	----
250	1.02	0.99	1.00
500	0.98	0.96	0.94
1000	0.85	0.84	0.81
2000	0.76	0.73	0.74
4000	0.69	0.68	0.68
8000	0.65	0.64	0.62
16000	0.61	0.62	0.60

Figure 9

Notice that three RT_{60} numbers are printed for each band: Early Decay, which is calculated from the first 10dB of decay, ISO (20), which is calculated from the -5dB to -25dB section of the decay curve, and ISO (30), which is calculated from the -5dB to -35dB section of the decay curve. If there is not sufficient decay to do an ISO (20) or ISO (30) calculation, dashes ---- will be displayed or printed out.

Once you have completed your measurements, you will want to exit the RT_{60} program and perhaps annotate the file that has been created. To exit the program, press **UTILITIES**. This will create a condition on the display screen that should be familiar to you - the screen will appear to do a carriage return and a cursor will appear at the bottom of the display to allow you to annotate the RT_{60} file, if you wish. When annotation has been completed, hit Return, and the UTILITIES menu will appear. Pressing **UTILITIES** again will return the system to a real-time function.

Note: Annotating any one decay curve (1000 Hz, for example) will automatically annotate the rest of the decay curves. You need not annotate each curve separately. Annotation will also appear on tabular printouts.

Measuring RT_{60} Using a Blank Pistol or Other External Sound Sources

It may not always be possible to use an existing sound system to make an RT_{60} measurement, so an alternative method is sometimes necessary. A blank pistol is often used, but in smaller rooms, a popped balloon or something similar may be adequate. If this method is used, it is important that the measurement device be turned on at the proper time to begin making the measurement. The PC-40 accomplishes this by "external triggering."

External triggering occurs when measurement is begun by some external means, as opposed to beginning by some means internal to the analyzer (such as pressing the **Space Bar**). The PC-40 uses sound, at a given frequency and amplitude, to trigger the beginning of the measurement process. Both the frequency band used, and the amplitude required to effect triggering are selectable.

No equipment setup is necessary for this method of measuring RT_{60} other than the PC-40 itself. Set it up exactly the same way as described previously in making room measurements using pink noise. Select RT_{60} from the Utilities Menu, select a time window for sample taking, and choose either octave or 1/3 octave bandwidths for measurement purposes. This should bring you to the display shown in Figure 10 on the next page, which is similar to the display you saw in Figure 3, page 6, except that now you will be looking at ambient room noise instead of pink noise.

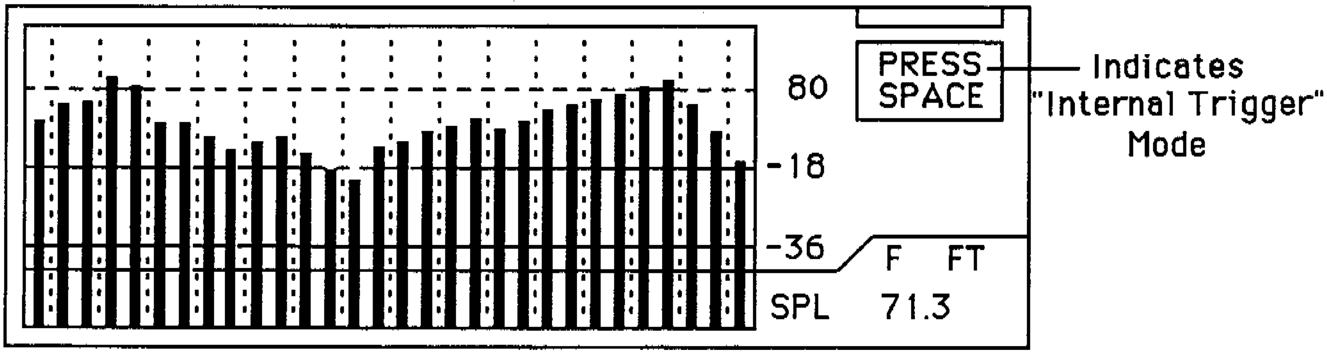

Figure 10

The Message Window says "Press Space" indicating that the PC-40 is in the "Internal Trigger" mode and is waiting for you to press the **Space Bar** to begin a measurement. We must change the PC-40 to "External Triggering." To do this, hit the letter **T** (for trigger) on the keyboard. (Hitting **T** again will toggle the PC-40 back to the "Internal Trigger" mode. Successive presses of the letter **T** will toggle the PC-40 back and forth between "Internal Triggering" and "External Triggering.") The Message Window will change and you will see the "default" frequency band (1000 Hz) and the "default" amplitude (0.0dB, which is equal to the Reference Level) displayed, as shown below.

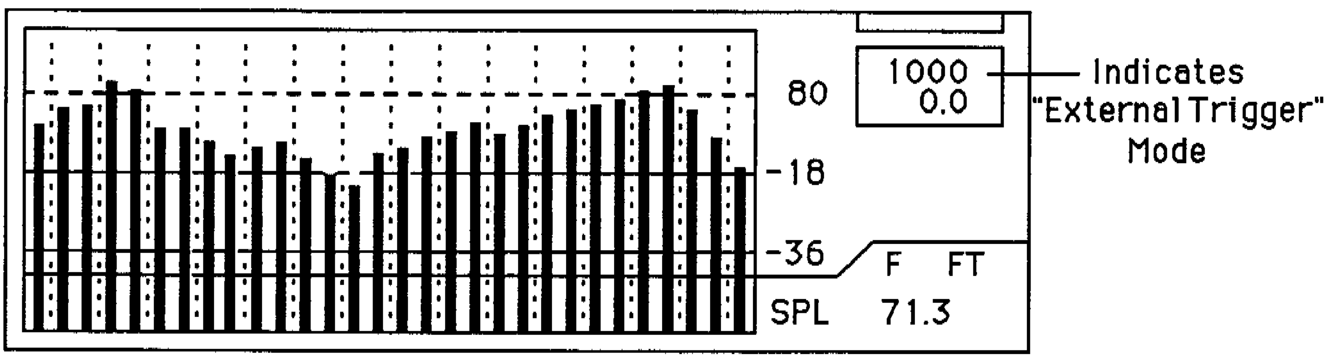

Figure 11

The trigger frequency band and the trigger amplitude may be changed by using the arrow keys. To change the frequency band, use the "**Up**" and "**Down**" arrow keys. To change the trigger amplitude, use the "**Left**" and "**Right**" arrow keys. Once you have selected the desired trigger frequency and amplitude, you are ready for the next step.

The Reference Level must now be properly set. Ambient noise should be far down on the display, or even below the display screen. The blank pistol or balloon generated noise should bring the display up near the Reference Level, high enough to trip the "trigger," but not so high that it drives the display above the PC-40 screen. You may have to experiment by firing the pistol or popping the balloon a time or two to see where the noise registers on the PC-40 display in order to get the Reference Level properly set. Your experimentation may also cause you to want to change the trigger amplitude or the trigger frequency.

After you are happy with your settings - you know that the noise will bring the display up near the Reference Line, and will definitely trip the trigger at the frequency and amplitude you have chosen, you can "arm" the system so that it will make a measurement when the trigger is tripped. Up until this time, you have been able to adjust and experiment without making measurements because the system has not been armed.

To arm the system, press the **Space Bar**. Once this is done, the system will be armed and a visual indication will be provided by inverse video appearing in the Message Window. An armed system display with the proper Reference Level setting will look something like this.

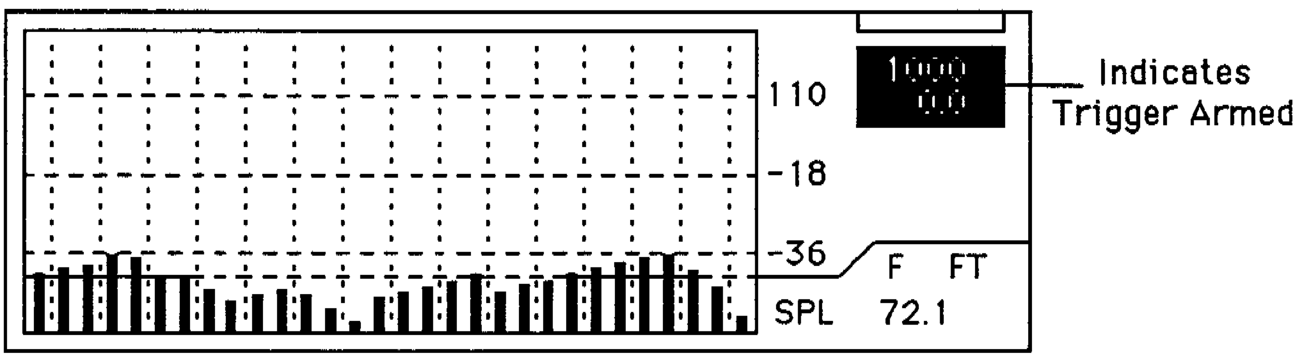

Figure 12

Firing the pistol or popping the balloon will now trip the trigger and a measurement will be made.

The procedures for averaging multiple measurements, manipulating displays, and printing out data is exactly the same as has been previously described for making measurements using pink noise.

Allocation of Buffer Memory and Clearing Files

The RT_{60} program uses the same buffer memory as the Record Function. If you have been using the Record Function and then go to RT_{60}, the PC-40 will prompt, telling you that if you proceed with RT_{60} measurements, data already in the record buffer memory will be lost. The converse is also true, if you have been making an RT_{60} measurement and then enter the Record Function, the same prompt will appear. Just be aware that both functions share some of the same memory, and if you wish not to lose data as you change functions, save that data to another location (RAM disk, external disk drive, etc.).

If you have been making RT_{60} measurements and have quit the program, the data remains in nonvolatile buffer memory. If you enter the RT_{60} program at some later time, the program will return to the same spot where it was terminated. The last display showing at the time of termination will be the display that is recalled. If you wish to continue that same measurement (take some more samples, for example) you may do so - it will be as though you had never quit the program.

However, if you wish to begin a completely new measurement, the data will need to be cleared. To clear all data from the RT_{60} program, hold down the **CTRL** button while pressing **R** (for "Reset"). This will clear the buffer memory and ready the PC-40 to begin a new battery of measurements. If you take a "bad" reading, or want to clear the data from the program for any other reason, this same procedure may be followed. (Please note, however, that all RT_{60} data will be lost, including data that has been averaged.)

Changing the Display Time Base for Data Already Taken

Earlier in this manual we discussed the wisdom of choosing a sample window that would provide maximum visual display of the decay curve. For example, we wouldn't want to choose a very long sample time for a short decay because the decay curve would be compressed against the left side of the display, giving poor visual information.

There is a simple way, however, to change the time base (and, therefore, the resolution) of the display window for data that has already been taken, should we need or want to do so. In other words, if we make the mistake (Heaven Forbid!) of choosing too long a sample time, and get a compressed display, we can expand it by shortening the display window. To do this, hold down the **Shift** key and press the "**Up**" or "**Down**" arrow keys. This will step the display through the time windows from 1.81 seconds minimum to 10.86 seconds maximum.

Obviously, this cannot create data that is not there. Time windows may only be shortened, they cannot be increased above the time window wherein the measurement was actually taken. (Remember, the sample rate is 100 samples per second, regardless of the time period chosen. 181 samples, for example, are taken over the 1.81 second window, and increasing the time base of the display will not cause the PC-40 to display more than 181 samples.)

Shortening the time base, on the other hand, can be quite useful for visually examining the behavior of the decay curve. Some care should be exercised in noting the position of the start and stop cursors on the display. It is possible, on a long decay time, to keep shortening the time base on the display, which expands the decay curve and moves the cursors to the right, until the cursors have been moved off the screen.

The "Help" Function

As with all other functions of the PC-40, the Help screens contain useful information in making measurements. If you don't have this manual with you, and have forgotten a "command" or "keystroke," don't forget to try the Help screen where a summary of all the keystorke commands is shown. It will probably save you a call to the factory.