Audio signal analysis for your PET from Eventide Clockworks.

Real-Time Spectrum Analyzer

By Robert Baker

Eventide Clockworks (265 West 54th Street, New York, NY 10019) offers several accessories for the PET/CBM. Of special interest is their THS224 Real Time 1/3 Octave Audio Analyzer.

Eventide provides all necessary hardware with the board. Power comes from the PET transformer, but not from its regulators. Installation of the analyzer allows rapid and versatile analysis of virtually any audio signal. Additional capabilities include voice recognition, statistical processing and room acoustics. The analyzer does not affect normal operation of the computer.

The analyzer board is mounted inside the PET, with spacers holding the board several inches above the PET main logic board. Two cables then connect the analyzer to the memory expansion connector(s) and the power connector of the PET. Another cable from the analyzer board attaches to a standard stereo jack, with a small metal bracket to mount it on the back of the PET. This connector supplies the audio input signal to the analyzer.

A ROM on the analyzer board provides various routines to control the associated hardware. The ROM occupies locations $B000 to B3FF hex on the PET address space. To save you the bother of memorizing many addresses, the USR function provides the linkage to the PET operating system. By calling various USR functions, the machine-language routines are accessed conveniently by BASIC programs.

On the newer 16K/32K PETs, you must alter a configuration jumper on the PET's main logic board to let the computer access the analyzer. Two jumpers control the selection of the empty ROM sockets during the 9, A and B selection times. By changing these jumpers, the analyzer board is then accessed by these address ranges.

Once these jumpers are changed, however, you cannot use any product that requires a ROM in the normally open ROM sockets (such as Word Pro or the Toolkit). This also prohibits upgrading to BASIC 4.0 ROMs, since there are five ROMs in the new set. Another reason for not being able to upgrade to BASIC 4.0 is that the analyzer uses areas of RAM in the second cassette buffer, which is also used by BASIC 4.0 when processing disk commands.

What Is Real Time?

The Eventide THS224 is classified as a "real-time, constant percentage bandwidth" spectrum analyzer. A real-time analyzer continuously analyzes all components of interest in the input signal and provides information in some usable form. This is in contrast to, for instance, the swept filter type of analyzer, which can analyze only one frequency at any given time.

There are three general methods of performing real-time analysis. The first, as used in this unit, provides a large number of bandpass filters so that all components are analyzed simultaneously. The other methods involve digital capture of signal segments and their processing, either by analog or digital techniques. While the latter two methods are in many cases more powerful, their disadvantages, such as high cost and slow speed, render them unsuitable for applications in which audio spectra must be observed many times per second.

The constant percentage bandwidth consideration also enters the picture. The phrase means that each filter has a bandwidth which, when divided into its center frequency, yields a constant. For instance, if a filter has 3 dB points 2 Hz apart at a 20 Hz center frequency, another filter should have a 3 dB bandwidth of 20 Hz at a 200 Hz center frequency, and so on. This characteristic, fortunately, is almost unavoidably achieved when building filters using identical hardware configurations and different resistive or capacitive values to select the center frequency.

Theoretically, the filter center frequencies are derived by starting with the first frequency desired and multiplying each successive filter center frequency by one-third octave, or the cube root of 2. Since it is desirable to have the filters correspond to decade ratios as well, several standards organizations (ISO/ANSI/IEEE and others) have agreed on a set of center frequencies which nicely rationalize the disparate ratios. The filters used in the Eventide analyzer are two-pole filters with a Q of

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10, which determines the bandwidth. They're all identical except for the resistor and capacitor values that determine the center frequencies, and the filter center frequencies conform to the standard values.

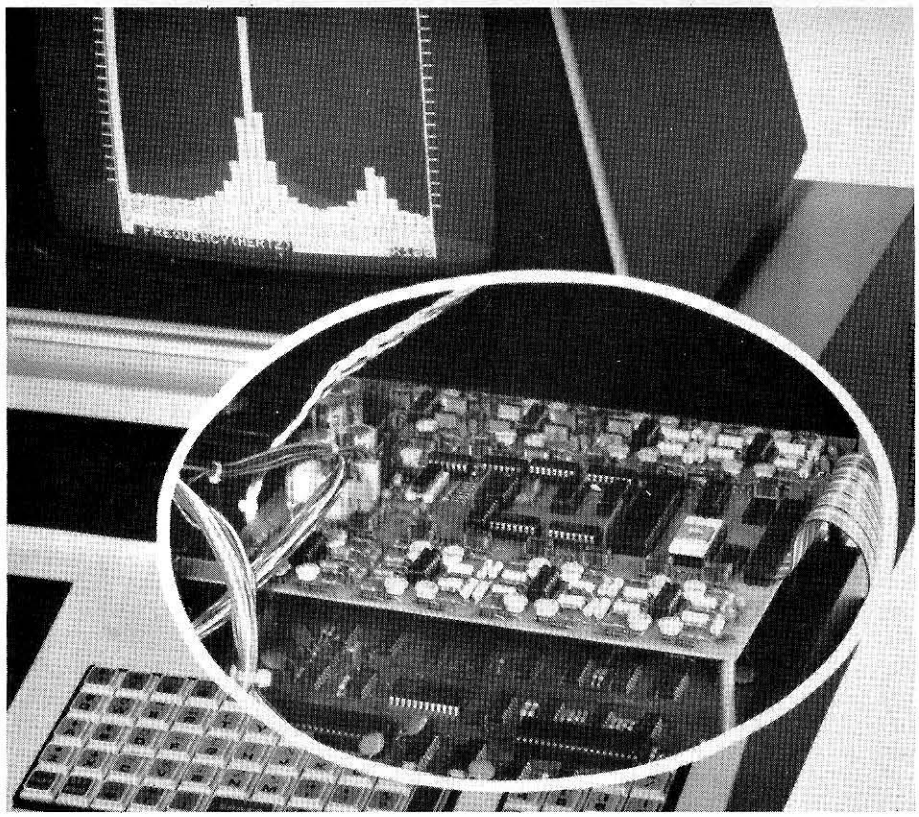
Although the input signal could be applied immediately to the filter inputs, it is customary and convenient to provide a variable gain preamplifier. The most important reason for this is to preserve an adequate dynamic range. The filter peak-to-peak output voltage swing is limited by the power supplies to almost 20 volts. The voltage measurement capability of the unit divides the positive half of this swing into 255 even steps. If the input signal were, say, only 2 volts, then only 25 steps could be measured and the accuracy and resolution of the analyzer would be drastically limited.

Operation

Variable gain is implemented in a somewhat unusual fashion in the Eventide analyzer. A standard operational amplifier in an inverting configuration is used as the "preamp." In the feedback loop of the opamp is a CMOS digital-to-analog converter (DAC) with its input code controlled by the PET. The DAC is of the "four quadrant multiplying" type, meaning that the reference input (connected to the preamp output) is multiplied by the digital word applied to the converter. If the maximum word (255) is applied, the reference is multiplied by one, giving an opamp gain of one; when the input code is 128 the gain is now 2, or 6 dB, and so on.

The gain available from the preamp is sufficient for almost all ordinary signal sources, such as audio consoles, hi-fi "aux" outputs, guitar pickups, etc. It is not sufficient for very low-level signals, such as dynamic microphones, phono cartridges and telephone pickup loops. An external preamp is recommended for this type of application.

Once the input signal is applied to the filters, it is separated into its various frequency components. With the filter outputs being ac signals, they may assume any value between their peak amplitudes. To make a measurement of their absolute values, the "envelopes" amplitude must be measured. This is done with a diode detector much like that used in an AM radio receiver. Whenever the filter output instantaneous amplitude is more positive than the voltage



Eventide's real-time audio spectrum analyzer plugs right into the PET.

on the capacitor at the output of the filter, the diode conducts and the charge is transferred to the capacitor. The analyzer also has one diode detector that is directly connected to the input signal to measure the level of the composite input signal. In this case, all input signals, regardless of frequency, affect the charge on the capacitor.

To graphically display a spectrum, the various charges on the detector capacitors must be measured and converted to bar heights on the PET display. This is done in three steps:

- Scan the various filter outputs,
- Cause the A/D converter to measure the voltage on the detector capacitor, and
- Store the values in the second cassette buffer areas.

In practice, each of these steps is performed sequentially for each filter before going on to the next. The data collected is then processed by the various ROM routines provided on the analyzer board, however desired by the user software.

As mentioned earlier, the various machine-language routines contained in the analyzer ROM are accessed via USR functions. When first turned on, the PET has no knowledge that the analyzer is there. A specific SYS command must first be issued to initialize the analyzer board and preset the entry address for subsequent USR functions. Then the various USR functions are issued as desired.

USR (0)—DISABLE FUNCTION disables the analyzer and returns the PET to normal operation.

USR (1)—SCALE FUNCTION erases the PET screen and displays the blank graph scales for displaying analyzer data.

USR (2)—BARGRAPH FUNCTION fills in the axes displayed by USR (1). The data from which the graph is derived resides in the second cassette buffer, between memory locations $33A and 35A hex. This function can be used to plot any data contained in these locations, so the routine may be used with other BASIC programs.

USR (3)—SCAN FUNCTION performs the spectrum analysis, reading the amplitude of the input signal as passed by the individual filters. The results of the analysis are placed in the buffer between $33A and 35A as described before. The various modes of operation (logarithmic, linear, single, average, fast and slow) are active during the SCAN operation and directly affect the data placed in the buffer. The effect of each of these modes is described under its particu-

lar USR function later. The return parameter of USR(3) is an integer between 0 and 30, representing the number of the frequency cell with the highest signal level.

USR (4)—SLOW DECAY FUNCTION sets a flag which is accessed during the scan routine. Normally the scan routine takes the absolute amplitude of the data in each frequency cell and transfers it to the buffer location as described earlier. If the decay flag is set, the current amplitude data in any given cell is compared with the previous amplitude of the same cell. If the new data is greater than the old data, the new data replaces the old data. If the old data is greater than the new data, the amplitude is permitted to decrease only by an amount set in location $3A3 hex. The decay rate constant is normally initialized to 6 but may be poked to any desired value.

USR (5)—FAST DECAY reverses the effect of USR(4). The decay flag is reset, and the value of the decay rate constant becomes irrelevant.

USR (6)—AVERAGE FUNCTION places the analyzer in the average mode and zeroes two areas in the second cassette buffer used to store the data developed in the average mode. The first area is the number of averages counter, a double byte counter at locations $3A0-3A1 hex. When the average flag is set, the double byte counter is incremented each time a scan function is activated.

Simultaneously, the data from the various frequency cells is added to corresponding double byte cells in the new buffer area starting at hex location $35D. The data in these locations corresponds to the sum of the amplitudes of the data in the first displayable cell on the screen from the time that USR(6) was originally invoked. The data may be normalized by dividing the current data in each cell by the current number of averages.

USR (7)—DISABLE AVERAGE resets the average flag and prevents additional scans from changing the stored data. The number of averages mentioned above is returned by the function.

USR (8)—LINEAR causes the height of the bargraph created by USR(2) to be precisely equal to the absolute amplitude of the data returned by the scan [USR(3)] process.

USR (9)—LOGARITHMIC SCALE sets the LOG flag which tells the scan function to compute the logarithm of the amplitude in each frequency cell and deposit this value in the buffer. This is done after any averaging is performed and before any variable rate decay function is performed.

If any other USR argument is attempted, an error message will be displayed to indicate an illegal USR call was issued.

Upon initialization, a value of 128 decimal is poked into the gain control port located at 46080 ($B400 hex). This corresponds to a pre-amplifier gain of 6 dB (or a voltage gain of 2). The analyzer gain can be controlled by poking appropriate values into this location. The rule is that the signal gain increases by 6 dB for each division by 2 of the data poked into address 46080. Warning: poking a value of zero will remove all feedback from the operational amplifier. This results in unstable operation that will not damage the analyzer, but the display will be unstable and incorrect.

The analyzer board comes with three programs on cassette, a Mylar overlay for the keyboard and all necessary installation hardware. The programs include diagnostic and calibration routines along with a program called Interactive. This is a general-purpose utility program for ordinary use of the analyzer. It provides control of the various analyzer functions directly from the keyboard. The keyboard overlay identifies specific keys that are used when running the Interactive program. It also provides a handy reference of all USR functions and buffer locations.

Summary

The analyzer is a well-designed accessory for the PET. It comes with a six-month warranty, extensive documentation and several interesting applications notes. The manual even includes a complete schematic, parts list and board layout diagram. It's a valuable and worthwhile accessory that should be of interest to many PET owners. Write to Eventide Clockworks for pricing and further information. Various versions are available to cover all model PETs. Just remember the restrictions on using additional ROMs and the second cassette buffer.■