III. DESIGNING NEW TIMBRES

—Preliminary Version—

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In the introductory section, you learned to recall and play various preprogrammed timbres. You also learned some of the basics about timbre construction and how to do a few simple timbre modifications.

In this section you will learn

- more about sound wave analysis and synthesis;
- how to do more complex timbre modifications;
- how to construct your own timbres.

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TIMBRES AND SOUND WAVES

Timbre (pronounced "TAM-ber") is the tone color of a sound. It is what distinguishes a trumpet from a clarinet, for instance. In a formal definition, timbre is all the characteristics of a sound other than pitch and loudness. This includes things such as harmonic structure, decay time, vibrato and so on.

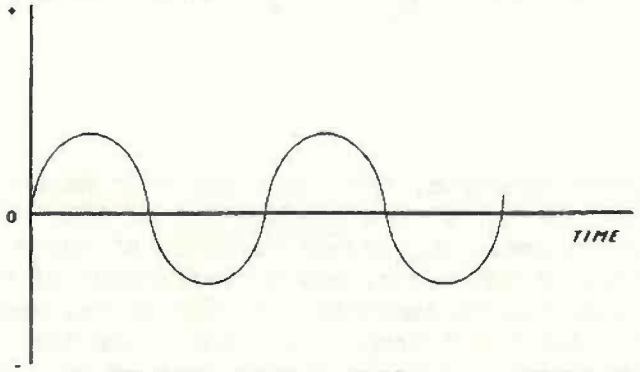
In the Synclavier (R), a sound is programmed on the keyboard and the resulting sound wave is called a timbre. When we speak of a trumpet timbre or a clarinet timbre, we are referring to the sound waves that produce those sounds.

A unique aspect of the Synclavier (R) timbres is that they are made up of from one to four individual partial timbres which are then added together to produce the complete sound. Each partial timbre is itself a complex sound with its own waveform or series of waveforms.

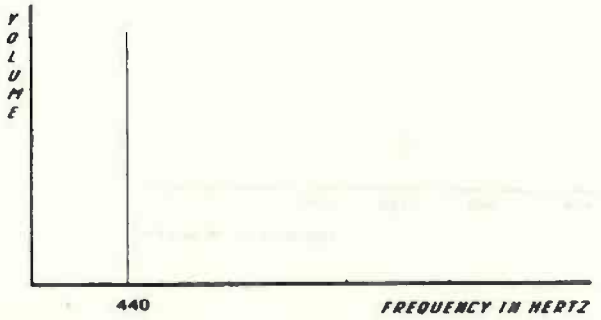
Before learning how to synthesize a timbre by building up a waveform from its components, it may be useful to review sound wave analysis, or how to break a complex wave into its separate components.

Sound Wave Analysis

A sound wave is a periodic waveform, or shape of sound, that repeats itself over time. The simplest waveform, the sine wave, is represented graphically as:

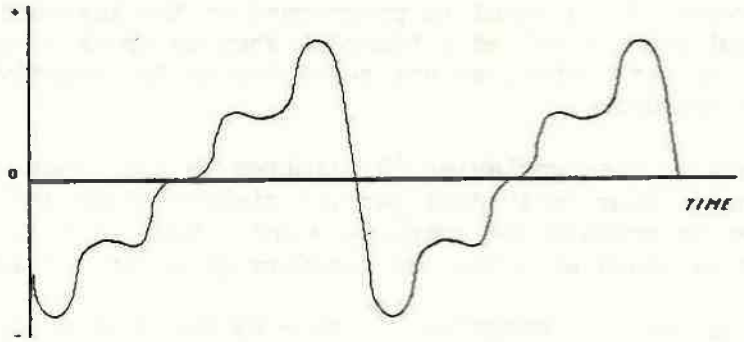


A sine wave can also be represented on a graph called a frequency spectrum. The single component of the sine wave, called the fundamental frequency, is placed at the frequency of the note played. It is also called the first harmonic. In the case of a sine wave, no other harmonics are present.

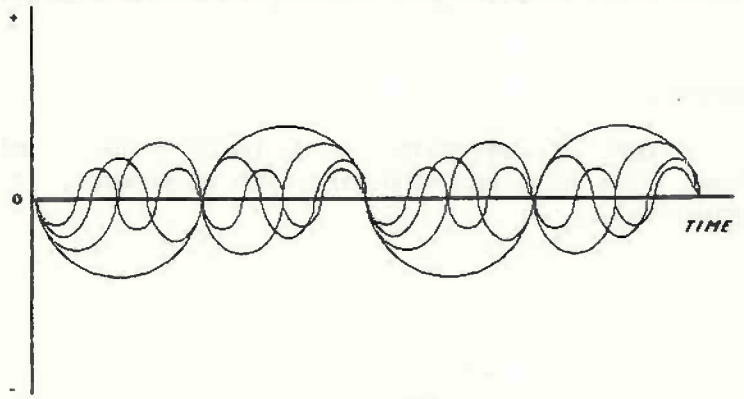


Complex waves are created when sine waves are superimposed one upon another. Joseph Fourier, the nineteenth century French mathematician, observed that all periodic waves, no matter how complex, are in fact sine waves of different amplitudes and phases with frequencies at the harmonics of the fundamental, all superimposed one upon another.

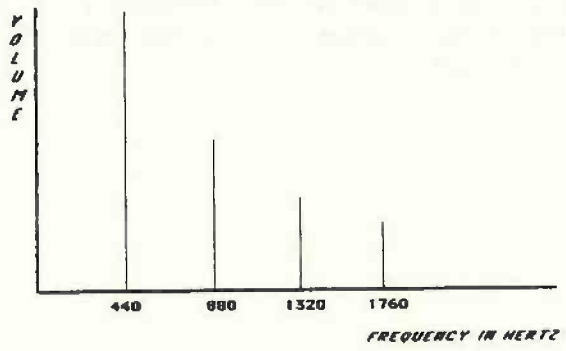
A complex wave, like this sawtooth wave sounding at 440 hertz,



can be broken down into four sine waves, each with its own volume and period:



Placed on the frequency spectrum, this wave has four harmonics. The first harmonic, at 440 hertz, with a coefficient of 100, sounds at 100 percent relative volume. The second harmonic at twice the fundamental frequency, or 880 hertz, has a coefficient of 50. The third is at three times the fundamental, or 1320 hertz, and has a coefficient of 33.3. And the fourth is at four times the fundamental, or 1760 hertz, and has a coefficient of 25.



The sounds produced by musical instruments are usually much more complex than the above single complex waveform.* Analysis of sounds produced by acoustic instruments shows that not only does each instrument have its own harmonic structure but also that that structure can vary according to a note's duration, volume and pitch.

For example, when a note is sounded on the piano, the full range of harmonics is present at the attack. After that moment, however, each harmonic has its own rate of decay, so that as the note fades, its harmonic structure is constantly changing.

A clarinet played mezzo forte will have the first four odd harmonics present. Yet a note played double forte on a clarinet may have the first seven odd harmonics plus additional, even-numbered harmonics while one played pianissimo may have only the first three odd harmonics.

Sounds produced by an oboe emphasize harmonic frequencies near 1000 hertz and 3000 hertz while frequencies near 2000 hertz are attenuated. Thus, a middle C played on an oboe will have louder second and fourth harmonics while a high C will have a louder fundamental and third harmonic.

The Synclavier (R) provides different methods for achieving realistic musical timbres. You can

- program the harmonic structure of a sound through additive synthesis;
- program the way the sound changes over time by constructing a temporal envelope;
- program frequency modulation to add brightness and/or special effects to a timbre;
- use the Sample-to-Disk (TM) Analysis Program to resynthesize or convert a recorded sound into a timbre with a time-varying harmonic structure;
- use real-time effects to produce a harmonic structure that changes according to how loudly the sound is played or to emphasize particular frequencies.

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* A classic textbook on musical acoustics is John Backus, The Acoustical Foundations of Music (W. W. Norton and Company, New York, 1969).

Additive Synthesis

The quality of sound of any periodic wave is determined by the number of its harmonics, their frequencies and their relative volumes and phases. Since these can be analyzed through Fourier analysis, the same principles applied in reverse can be used to construct a sound wave. Adding together sine waves of different frequencies, volumes and phases is called additive synthesis.

On the Synclavier (R), additive synthesis is accomplished with the HARMONIC CONTROL buttons. Each HARMONIC CONTROL button controls the relative volume and phase of a corresponding harmonic. Each of the four partial timbres that make up a complete Synclavier (R) timbre can be programmed for its own waveform, with as few as one or as many as 36 harmonics, with each harmonic having a unique relative volume and phase.

Frequency Modulation

Any periodic waveform may be frequency modulated. This process gives the wave additional frequency components, called sidebands. Very complex periodic and nonperiodic waveforms, or waveforms with inharmonic relationships between the frequency components, can be established with frequency modulation.

Additive Synthesis with Changing Waveforms

Synthesizing a sound wave by programming harmonics produces a single complex waveform for each partial timbre. The waveform of a partial timbre constructed this way cannot change during the note. Although harmonic components created through frequency modulation do vary over time, these are hard to control precisely.

The Synclavier (R) allows the construction of partial timbres from a chain of waveforms, or "timbre frames." As the note sounds, the waveforms are spliced together in easily controlled cross-fades. With timbre frames, a partial timbre can start, for example, with only a few harmonics and gradually change to a waveform with many harmonics.

In addition to the waveform, the volume and pitch of the partial timbre can change over time. You can use timbre frames to set up infinitely complex envelopes, like the resynthesis timbres created through the Sample-to-Disk (TM) Analysis program.

Waveform Envelopes

A periodic or nonperiodic wave that sounds at one volume, never increasing or diminishing, is called a steady state sound. Musical tones, however, have attacks and decays, peak volumes and volumes sustained over a period of time.

On the Synclavier (R), each partial timbre can be given a temporal shape. Separate envelope generators control the shape of the programmed harmonic components and the shape of the harmonic components created through frequency modulation. The envelope generators control the times of an attack, an initial decay, a final decay, a peak volume level and a volume level for the sustained portion of the note.

The steady state sound, modulated by the envelopes, forms the foundation of the partial timbre.

Partial Timbre Embellishments

Each partial timbre, once it is programmed for its waveform and envelope, can be given many musical embellishments. For example, each partial timbre can be individually tuned, can have its own stereo effects, vibrato, portamento and tremolo added, and so on.

Final Timbre Construction

Once a partial timbre has been programmed, with or without a time-varying waveshape and embellishments, it can be combined with up to three other partial timbres to form a complete timbre.

The timbre as a whole can be modified by adding a chorus effect or programming arpeggios and repeated notes. Once a complete timbre has been constructed, it can be given a name for easy reference and stored in a special timbre storage area, ready for instant recall.

PARTIAL TIMBRE PROGRAMMING

To program a partial timbre, you start by recalling an already defined timbre. This may be a sine wave, if you are constructing a waveform from scratch, or a more complex timbre you want to redesign.

Once the timbre has been recalled, you

1. select a partial timbre to program;

2. press the appropriate button for the parameter you want to change; and

3. dial in a new setting with the control knob.

In this section you will learn how to select partial timbres for programming, create a steady state waveform by dialing in harmonics, and program the volume envelope (VE).

Here is a summary of the buttons used to program partial timbres:

BUTTON	USE	FUNCTION
PARTIAL TIMBRE SELECT buttons	Press one or more buttons	Selects partial timbres for programming
HARMONIC SELECT	Press once, turn knob; or press repeatedly	Selects harmonic group
HARMONIC CONTROL buttons plus HARMONIC SELECT	Hold one or more buttons, press HARMONIC SELECT	Toggles HARMONIC CONTROL buttons between lit and blinking modes
HARMONIC CONTROL buttons (lit)	Press one or more buttons, turn knob	Programs volume level of selected harmonic(s)
HARMONIC CONTROL buttons (blinking)	Press one or more buttons, turn knob	Programs phase value of selected harmonic(s)

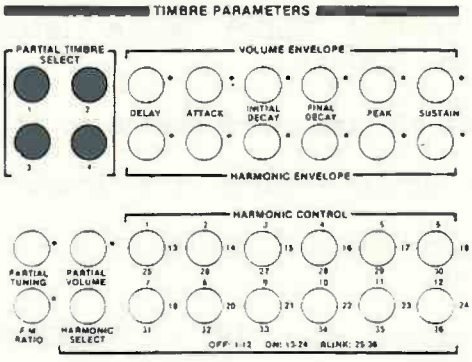
(Partial timbre programming button summary is continued next page.)

BUTTON	USE	FUNCTION
VE DELAY	Press once, turn knob	Programs delay time for attack
VE ATTACK	Press once, turn knob	Programs attack time
VE INITIAL DECAY	Press once, turn knob	Programs initial decay time
VE FINAL DECAY	Press once, turn knob	Programs final decay time
VE PEAK	Press once, turn knob	Programs peak volume
VE SUSTAIN	Press once, turn knob	Programs sustain volume
DECAY ADJUST	Press once, turn knob	Changes final decay on lower notes

Selecting Partial Timbres for Programming

In the Introduction, you learned how to select a specific partial timbre to listen to. You use the same procedure to select a partial timbre for programming.

As you know, each of the four buttons under PARTIAL TIMBRE SELECT designates a partial timbre. If one or more of these buttons is lit or blinking, the related partial timbre or timbres can be programmed.



Remember, when you press a PARTIAL TIMBRE SELECT button, it will either

- start blinking, if it has been lit;
- become lit, if it has been blinking;
- assume the same state as the previous button, if it has been unlit (the previous button will go out).

If you want to program two or more partial timbres at the same time, press the desired buttons simultaneously.

Programming Partial Timbres

Once you have selected the partial timbre or timbres you want to program, you will make the changes you want by pressing the appropriate button and turning the control knob. As you make the changes, the display window will reflect each new setting. When you play the keyboard, the modifications will be heard on every note you play.

There are several different ways you can program partial timbres. You can

- program a single partial timbre while listening to the other partial timbres in the timbre;
- program a single partial timbre and listen to it alone;
- program two or more partial timbres simultaneously.

To program a partial timbre while listening to all the partial timbres in the timbre, you

1. press the numbered button under PARTIAL TIMBRE SELECT (the button will light up);
2. press the button for the parameter you want to change and dial in the new setting.

To program a partial timbre and listen to its sound alone, you

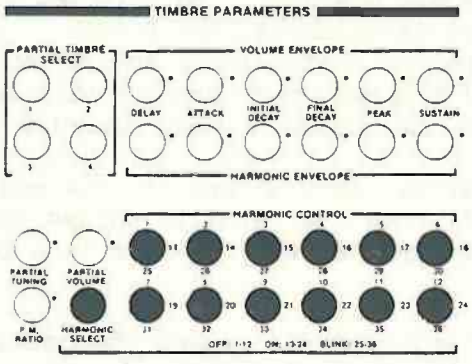
1. press the numbered button under PARTIAL TIMBRE SELECT twice so that the button is blinking;
2. press the button for the parameter you want to change and dial in the new setting.

To program two partial timbres simultaneously, you

1. select or solo two numbered buttons under PARTIAL TIMBRE SELECT by pressing them once or twice so that both buttons are lit or blinking;
2. press the button for the parameter you want to change and dial in the new setting. The new setting will be applied to both partial timbres.

Programming the Harmonics

You create a steady state waveform by dialing in the relative volume, on a scale of 0.0 to 100.0, of up to 24 harmonics.* A coefficient of 0.0 for a selected harmonic means that the harmonic will not be present in the waveform. A coefficient of 100.0 means that the harmonic will be present at full volume. The harmonics are accessed by the 12 buttons under HARMONIC CONTROL and the HARMONIC SELECT button.



The first harmonic, accessed by Button 1 under HARMONIC CONTROL, is the fundamental frequency of the waveform. In the sine wave of Instruction Timbre 1-1-1, it is set at 100. If you press A above middle C, a sine wave with a frequency of 440 hertz will be generated at 100 percent volume.

The second harmonic, accessed by Button 2 under HARMONIC CONTROL, is twice the fundamental frequency. If you set it at 50, for example, with the fundamental set as above, pressing A above middle C will cause a complex waveform to be generated. The waveform will consist of two superimposed sine waves, one with a 440 hertz frequency sounding at 100 percent volume and one with an 880 hertz frequency sounding at 50 percent volume.

The third harmonic, accessed by Button 3, is three times the fundamental frequency. And so on. As each harmonic is dialed in, the Synclavier (R) computes, by means of Fourier synthesis, the complex waveform and places it in a wavetable memory in the digital synthesizer.

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*In future releases, you will be able to program up to 36 harmonics.

To program a steady state waveform, use the following procedure.

1. Select the group of harmonics that contains the harmonic you want to program by pressing HARMONIC SELECT.

   Harmonic group 1-12 is selected by default when a timbre is recalled. Press HARMONIC SELECT to select 13-24. Press it again to return the harmonic group to 1-12.

2. Select the specific harmonic by pressing one of the numbered buttons under HARMONIC CONTROL. The selected button will light up. (If the button is blinking, the button is controlling the phase, not the harmonic coefficient; see below.) The current relative volume of the selected harmonic will be in the display window, along with the number of the harmonic.

3. Turn the control knob. As you turn it, the numbers in the display window will show the relative volume of the selected harmonic. Turn the knob slowly, as this is a particularly fine adjustment.

Changing the value of any harmonic causes the computer to recompute the waveform, which takes a short amount of time. However, if you hold down the HARMONIC CONTROL button while you dial the volume, the computer of the waveform will be delayed until you release the button.

You can program two or more harmonics simultaneously by pressing the respective buttons at the same time.

If the previously programmed settings are the same for the harmonics, all the changes will be the same. If the settings are different, the numerical values will be locked together and all will be changed by the same amount. If any of the changing numbers reaches maximum or minimum value for the parameter, it will remain the same while the others will continue to change.

When several harmonics are being programmed simultaneously, the number in the display window will indicate the setting for the lowest numbered harmonic.

Steady State Sound Wave

1. Recall Instruction Timbre 1-1-1, which has a single partial consisting of a sine wave.

2. Make sure Button 1 under PARTIAL TIMBRE SELECT is lit.

3. By default, the twelve buttons under HARMONIC CONTROL control the first twelve harmonics of the sound wave. Check this out by pressing Button 1 under HARMONIC CONTROL.

   100.0 COEF #1

   will appear in the display window. This means that the fundamental frequency of this sine wave will sound at maximum volume.

4. Press Buttons 2 through 12, one at a time. In each case,

   0.0 COEF

   will appear in the display window since only the first harmonic is present in a sine wave.

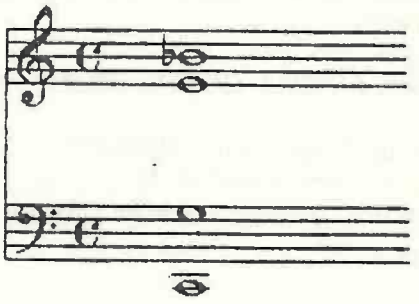
Now you are going to change this sine wave into a square wave, which contains only odd-numbered harmonics. The particular square wave you will create will sound something like a clarinet.

5. Press Button 3 again and turn the control knob gently to the right until the number 100 appears in the window. This increases the relative strength of the third harmonic to 100 percent. Press low C on the keyboard and listen carefully to hear the G above middle C present in the tone as well. This is the third harmonic.

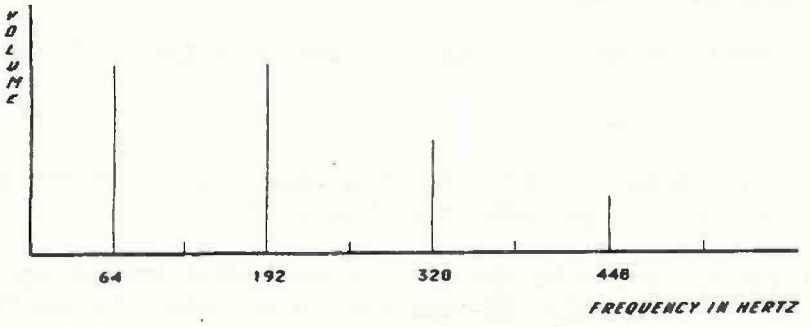
6. Press Button 5 and adjust the strength of the fifth harmonic to 33.3 percent. Press low C again and listen to hear a high E (a tenth above middle C) present in the tone. This harmonic will be much fainter, since you have programmed it at 33 percent relative volume.

7. Program the seventh harmonic at 20.0 percent.

You have just synthesized a clarinet-like sound. Press the lowest C on the keyboard. All the following tones are present as components of the sound:



The frequency spectrum of the wave looks like this:



Experiment with different strengths in the harmonics. The following table gives the relative volumes of the harmonics present in sawtooth, triangle, and square waveforms.

HARMONIC	SAWTOOTH	TRIANGLE	SQUARE	PULSE*
1	100.0	100.0	100.0	100.0
2	50.0	-	-	100.0
3	33.3	11.1	33.3	100.0
4	25.0	-	-	100.0
5	20.0	4.0	20.0	100.0
6	16.7	-	-	100.0
7	14.3	2.0	14.3	100.0
8	12.5	-	-	100.0
9	11.1	1.2	11.1	100.0
10	10.0	-	-	100.0
11	9.1	0.8	9.1	100.0
12	8.3	-	-	100.0
13	7.7	0.6	7.7	100.0
14	7.1	-	-	100.0
15	6.7	0.4	6.7	100.0
16	6.3	-	-	100.0
17	5.9	0.3	5.9	100.0
18	5.6	-	-	100.0
19	5.3	0.3	5.3	100.0
20	5.0	-	-	100.0
21	4.8	0.2	4.8	100.0
22	4.6	-	-	100.0
23	4.4	0.2	4.4	100.0
24	4.2	-	-	100.0

*A more effective and easier way to create PULSE wave is to set the first harmonic at 0.1.

Harmonic Phase Control

The phases of all harmonics except the first harmonic can be programmed for phase by activating the blinking mode for the HARMONIC CONTROL buttons. To do this,

1. press one or more HARMONIC CONTROL buttons and hold it (them) down while you. . .

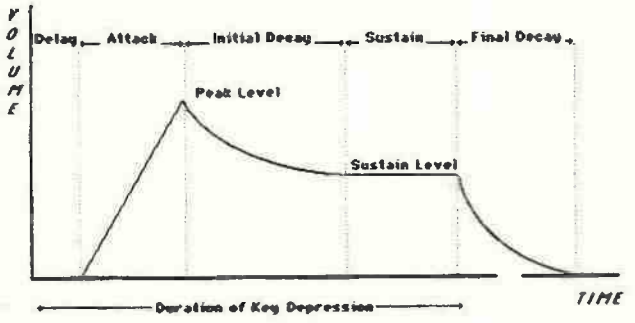
2. . . . press HARMONIC SELECT.

The button or buttons will blink. When you turn the control knob, the numbers 0 to 63 will appear in the display window. These numbers correspond to mathematical values between 0 and 2 pi (0 and 360 degrees).

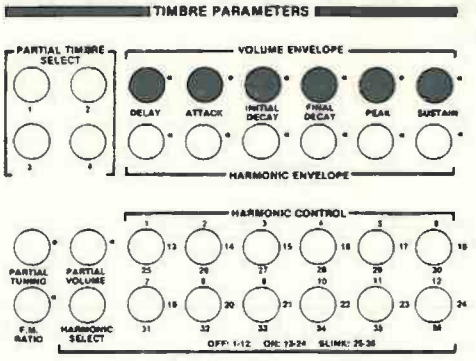
Programming the Volume Envelope

The Synclavier (R) volume envelope generator transforms the steady state tone of a partial timbre into a life-like, dynamic sound that has a beginning and an end. With the buttons that control the generator, you can divide the soundwave of a partial timbre into a series of time segments and set the volume levels for two of the segments.

The figure below illustrates the time segments and volume levels of a typical volume envelope.



Volume envelope programming is done with the six buttons located under VOLUME ENVELOPE and the control knob.



The first four buttons, DELAY, ATTACK, INITIAL DECAY, and FINAL DECAY, are used to set time intervals. They control the points at which the volume level changes.

BUTTON	TIME 1	TIME 2
DELAY	key depression	beginning of sound
ATTACK	beginning of sound	peak volume level
INITIAL DECAY	peak volume level	sustain volume level
FINAL DECAY	lifting of key	zero volume level

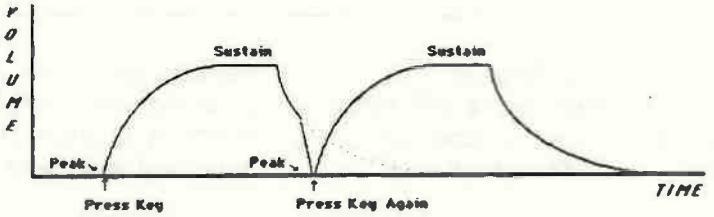
The range of time for each segment except the attack segment is 0 to 30.00 seconds. The range for the attack segment is 0 to 15.00 seconds.

The last two buttons, PEAK and SUSTAIN, are used to set two relative volume levels. The peak volume occurs the instant that the envelope changes from attack to initial decay. The sustain volume begins at the end of the initial decay and continues until the key is released.

Both peak and sustain levels can be set anywhere from 0.0 for no sound to 100.0 for maximum loudness. Although a typical waveform rises to a peak volume and falls off to the sustain level, the peak can be set equal to or below the sustain level. You can even set the peak level at zero.

Normally the attack of a note will start with zero volume. But if, when you strike a key, the preceding note of the same pitch and timbre is in final decay, the attack of the new note will begin at the current volume level.

With the ability to set the peak volume level at zero, you can assure an initial decrease in volume when the same key is pressed a second time during the final decay of the first note. Timbre 1-1-3 has this sort of volume envelope.



Using the VE Buttons

1. Recall Instruction Timbre 1-1-1, the sine wave. Make sure Button 1 under PARTIAL TIMBRE SELECT is lit.

2. Press DELAY. The display window will show a setting of zero milliseconds.

3. Turn the control knob until the display window shows a setting of around 100 milliseconds.

4. Play a note on the keyboard and listen for the brief delay before the note begins.

5. Press ATTACK. The attack segment is also set to zero milliseconds meaning that the rise to maximum volume is instantaneous.

6. Set the attack segment to 500 milliseconds. Play a note on the keyboard and listen to the volume level rise from zero to maximum over the half-second attack time.

7. Press INITIAL DECAY. It is currently set to zero milliseconds.

8. Set the initial decay segment to 5000 milliseconds. If you play a note on the keyboard, you will hear no change from the previous sound. This is because both the peak volume and the sustain volume are set at maximum and thus there is no change in volume level during the initial decay period.

9. Press PEAK. Its setting is 100. Leave it there.

10. Press SUSTAIN. Its setting is also 100. Change this to 50.

11. Now when you play a note, you will hear first the brief delay, then the half-second rise from zero to maximum volume, then the five-second fall to 50 percent volume. When you lift the key, the sound stops fairly quickly.

12. Press FINAL DECAY. It is set to 370 milliseconds. Change this to 5000.

13. Now press a key, hold it for at least five seconds and release it. Listen for the changes from zero volume to maximum volume to 50 percent volume and finally back to zero over the five-second final decay period.

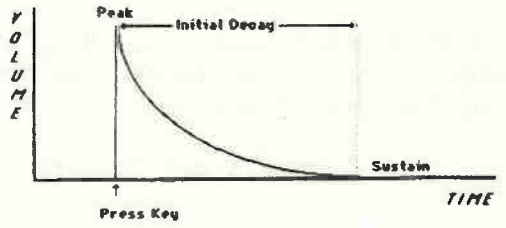
Programming a Non-Sustaining Timbre

Any sound with a 0.0 sustain volume level is a non-sustaining timbre. Interesting percussion sounds can be created by setting the peak level of a partial timbre to a high level and the sustain level to zero with no attack time and different length initial decay segments.

For example, with volume envelope settings of

DELAY	0
ATTACK	0
INITIAL DECAY	500
PEAK	100
SUSTAIN	0

a waveform like this would be produced:



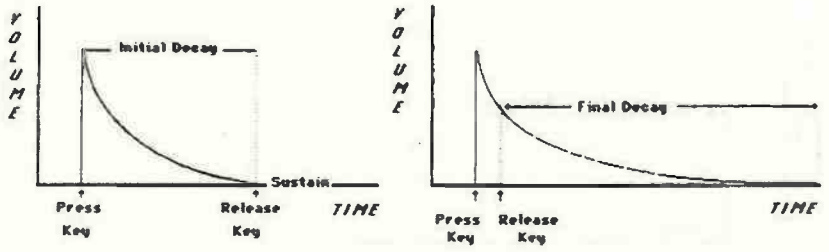
With no attack segment, the volume rises instantly as you press the key to maximum volume. It fades rapidly, no matter how long you hold the key down, since the sustain level is set to zero.

Percussion Sound

1. Recall Instruction Timbre 1-1-7, the woodwind timbre.
2. Press ATTACK and set it to zero.
3. Press SUSTAIN and set it to zero.
4. Play a percussive line in the bass range on the keyboard.
5. Press INITIAL DECAY. Its current setting is 583 milliseconds. Dial in a series of shorter and shorter settings, such as 250, 100, 50, and try the percussion line with each.
6. Dial a setting of zero. With no initial decay, the sound goes directly from attack to sustain. All you hear is a click for the peak volume.

If you add a final decay to this kind of percussion timbre, you can change the sound as you play by holding the keys down more or less time. That is, when you hold the key down, the sound will be the same as the previous sound, with the sound fading to zero at the end of the initial decay segment.

However, if you release the key before the end of the initial decay segment, the long final decay will begin while the note is still sounding and will decay as programmed for that level. The sustain level of zero is bypassed.



Ringing Percussion Sound

1. Continue with the previous ATTACK and SUSTAIN settings for Timbre 1-1-7.
2. Set INITIAL DECAY to 500.
3. Set FINAL DECAY to 2000.
4. Play holding each note at least half a second. The sound should be very similar to the sound in the previous exercise.
5. Now play and release each note as you strike it. The sound will ring as the timbre makes its final decay.

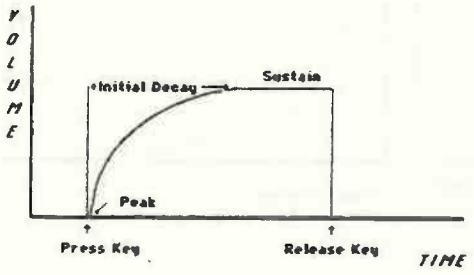
Programming a Sustaining Timbre

A low peak level and a high sustain level with a long initial decay creates a timbre that rises gradually from zero to a maximum volume without peaking. This makes an effective timbre for notes that seem to swell as you hold them down.

For example, with these settings,

INITIAL DECAY	4000
PEAK	0
SUSTAIN	100

the volume envelope might look like this:



with the sound taking four seconds to rise from zero volume to maximum.

Sustaining Timbre

1. Recall Instruction Timbre 1-1-4. This violin timbre has a peak volume level of zero and a sustain level of 100.0.

2. Set all the time intervals to zero and strike a note. The sound will have a crisp attack.

3. Press INITIAL DECAY and dial 4000. Hold the key down at least four seconds. The sound appears to have a long gradual attack because the initial decay setting takes the sound slowly from zero peak volume to maximum sustain volume.

4. Try different attack settings. The attack settings have no effect on the sound because the peak level is set at zero.

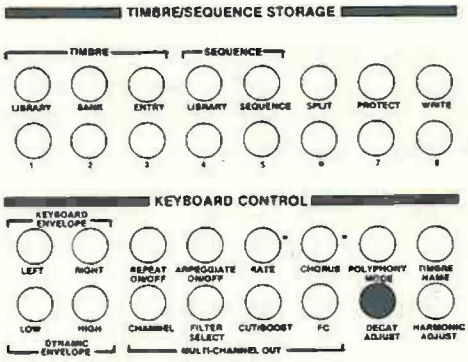
5. Now set the peak level at 50.0 and the attack at 500. When you play a note, you'll hear the volume rise quickly to 50 percent during the attack and then slowly to 100 percent during the initial decay.

   By combining the attack and initial decay times you can get swells of up to 45 seconds long.

Adjusting the Final Decay

The decay adjust function allows you to program longer final decays for notes with lower pitches. This feature can be used to enhance the realistic quality of certain sounds.

To activate the decay adjust function, You activate the decay adjust function by using the DECAY ADJUST button in the fourth panel.



To program a timbre with decay adjust,

1. press DECAY ADJUST;

2. turn the control knob to change the decay adjustment factor from 0.000 to 1.000.

A setting of 0.000 will cause all keys on the keyboard to trigger notes with the final decay programmed in the volume and harmonic envelopes.

The sound triggered by the rightmost key on the keyboard will always retain the original final decay. As you increase the setting, the final decays will gradually increase for all the other keys. A setting of 0.500 will double the length of the final decays every two octaves to the left of this key. A setting of 1.000, the maximum, will double the length of the final decays every octave.

Decay Adjust

1. Recall Instruction Timbre 1-1-7. This woodwind timbre has a VE initial decay of 583 milliseconds and a final decay of 90 milliseconds.

2. Press DECAY ADJUST. You will see the number 0.026 in the display window.

3. Play C2 (an octave below middle C) and C5 (two octaves above). Hold each more than half a second and then release them simultaneously. You'll hear the final decays of both notes end almost at the same time.

4. Now recall Instruction Timbre 1-2-6. This timbre has three partial timbres, each very different from the other.

5. Make sure Partial Timbre 1 is selected.

6. Press DECAY ADJUST and dial in an adjustment factor of 0.500. As you play high and low notes, you'll hear all three partial timbres decay at the same rate in the treble range. In the bass range, however, the final decay of Partial Timbre 1 will be much slower.

FREQUENCY MODULATION

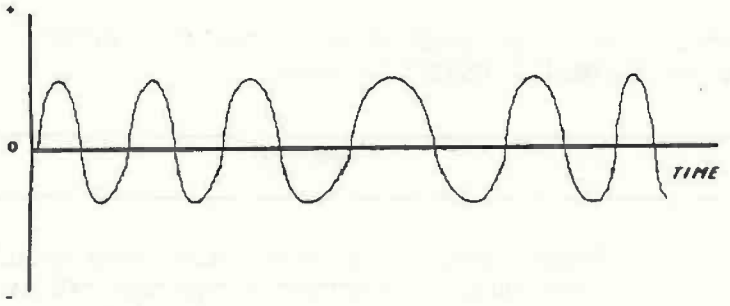
With frequency modulation (FM), the periodic waveform is modulated by another wave to create additional frequency components that may vary over time. FM can be used to create bright, percussive sounds, such as Timbres 1-1-2 (church bell) or resonant sounds, such as 1-1-5 (violin).

Frequency modulation is programmed using the F.M. RATIO, the HARMONIC ENVELOPE and the HARMONIC ADJUST buttons.

BUTTON	USE	FUNCTION
F.M. RATIO	Press once, turn knob	Positive value sets modulator to carrier frequency ratio; negative value sets fixed modulator frequency
HE DELAY	Press once, turn knob	Programs FM delay time
HE ATTACK	Press once, turn knob	Programs FM attack time
HE INITIAL DECAY	Press once, turn knob	Programs FM initial decay
HE FINAL DECAY	Press once, turn knob	Programs FM final decay time
HE PEAK	Press once, turn knob	Programs FM peak volume level
HE SUSTAIN	Press once, turn knob	Programs FM sustain volume level
HARMONIC ADJUST	Press once, turn knob	Changes harmonic brilliance on upper versus lower notes

Frequency modulation, at its simplest level, is a process in which the frequency of one tone is varied constantly through interaction with a second frequency. The frequency being modulated is called the carrier frequency; the one doing the modulating is called the modulator frequency.

If the modulator frequency is 5 hertz, for example, the result will be a vibrato. The frequency of the carrier wave will be constantly varying; the pattern of the frequency variations will repeat five times per second.



Vibrato is a simple case of frequency modulation, in that the modulator frequency is quite slow. More commonly in sound wave synthesis, the modulator frequency is a factor of the carrier frequency.*

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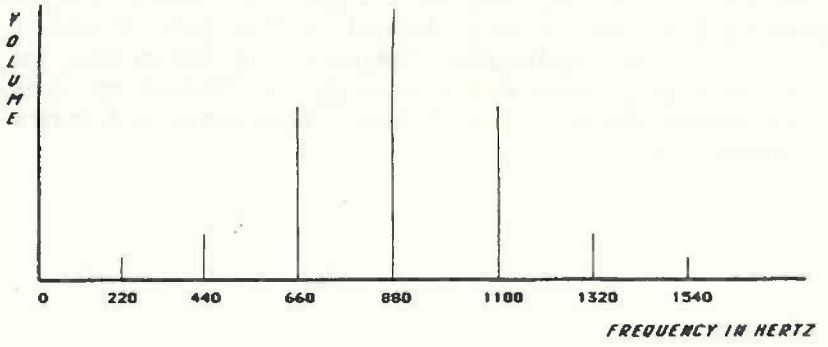
*For a detailed discussion on the use of FM in sound wave synthesis, see John Chowning, "The Synthesis of Complex Audio Spectra by Means of Frequency Modulation" in Journal of the Audio Engineering Society, Vol. 21, No. 7 (1973), pp 526-534. Reprinted in Computer Music Journal, Vol. 1, No. 2 (1977), pp. 46-54.

When a tone is frequency modulated, additional frequency components, called sidebands, are added into the harmonic structure. These sidebands lie above and below the center frequency, each separated by an interval equal to the frequency of the modulator frequency. That is, an 880 hertz carrier wave modulated by a 220 hertz modulator wave will have sidebands above and below the 880 hertz center frequency at intervals of 220 hertz each.

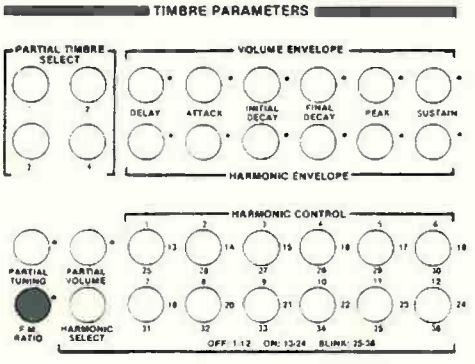


Setting the Modulating Wave Frequency

On Synclavier (R), the frequency of the modulator sine wave can be set as either

- a ratio between the modulator frequency and the carrier frequency; or
- a fixed number in hertz.

An FM ratio is set by pressing the F.M. RATIO button in the first panel and turning the control knob. Or, for integer ratios of 1.000 through 16.00, by repeatedly pressing F.M. RATIO.



Dialing an integer ratio between the modulator and carrier frequencies will produce sidebands that coincide with, and thus strengthen, the natural harmonics of the carrier wave.

Dialing a non-integer ratio will produce sidebands that are inharmonically related to the carrier wave. Thus, small changes in the FM ratio may produce dramatic changes in tone color.

A fixed modulator frequency independent of the carrier frequency is set by pressing F.M. RATIO and dialing in negative values. With a fixed modulator frequency, whether a partial timbre contains harmonic or inharmonic frequencies will depend on the note played. For example, With a fixed modulator frequency of 440 hertz, an A played on the keyboard will have its harmonics reinforced by harmonically related sidebands while a G will have inharmonic sidebands clashing with the harmonics.

Changing the FM Ratio

1. Recall Instruction Timbre 1-2-7. This bass timbre has a harmonic structure that includes the first five harmonics (a sawtooth wave). Turn off the portamento that has been programmed into the timbre by pressing the PORTAMENTO ON/OFF button in the fifth panel.

2. Press HE SUSTAIN and dial in 100. You will learn the function of this button in the next section.

3. Press F.M. RATIO. The number in the window, 1.000, is the ratio of the modulator frequency to the carrier frequency. If you press C below middle C, you will hear a 130.8 hertz sawtooth wave modulated by a 130.8 hertz sine wave. You should hear a strong fundamental frequency as well as a second harmonic (middle C) and third harmonic (G above middle C), all of them being reinforced by the modulator frequency and its sidebands.

4. Turn the control knob to the right. Stop at different intervals, such as 1.020, 1.100, 1.500 and press a key at each step. You should hear an increasing number of inharmonic frequencies.

5. Continue to turn the knob, stopping to listen to the sound when you reach 1.75 and 1.950. The number and volume of the inharmonic frequencies decreases as you approach 2.000.

6. Now dial in 2.000 and listen. If you press low C now, the original 130.8 hertz sawtooth wave is being modulated by an 261.6 hertz sine wave. In addition to the fundamental and second and third harmonics, the fourth and fifth harmonics are accented (high C and E above high C). The inharmonic frequencies are gone.

7. Now dial a series of ratios less than 1.000, such as 0.900, 0.750, 0.500 and 0.001. Again you will hear inharmonic components of varying strengths. At 0.500, the modulator frequency is half the carrier frequency and you will hear the octave below the fundamental accented. At 0.001, you will hear a tremolo, since the modulator is creating sidebands with frequencies very close to the fundamental.

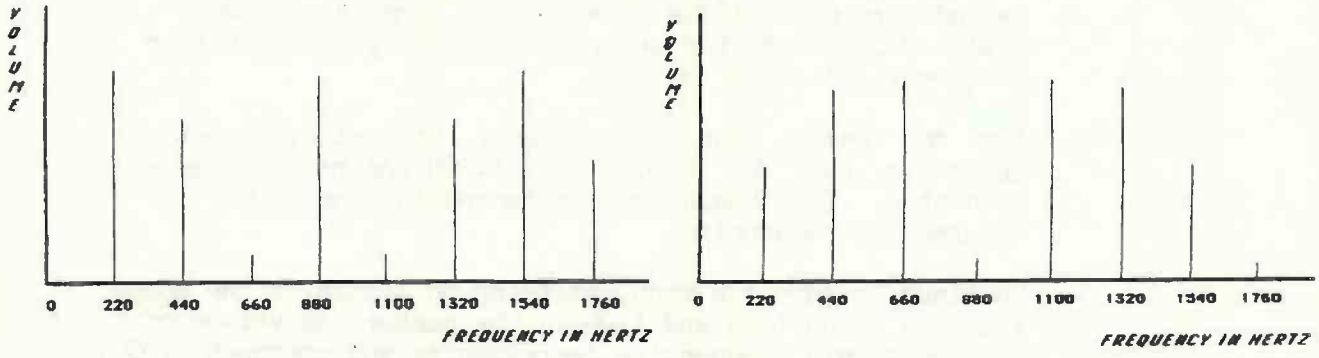
8. Dial in -440.0 hertz for a fixed modulator frequency. Compare the sound of A above middle C, a 440 hertz wave modulated by a 440 hertz wave, with G above middle C, a 392 hertz wave modulated by the 440 hertz wave.

Programming the Harmonic Envelope

The number of significant sidebands, that is, sidebands that affect the quality of the tone, depends on the depth of modulation, or volume of the modulator wave. The relative strength of each sideband is described by a set of mathematical functions known as Bessel functions. The basic theory states that

> as the depth of modulation increases, the strength of the carrier frequency decreases and the strength of the sidebands increases.

Compare, for example, these two frequency spectra of an 880 hertz sine wave modulated by a 220 hertz sine wave. The volume of the carrier wave is the same for both waves, while the depth of modulation is different for each wave.



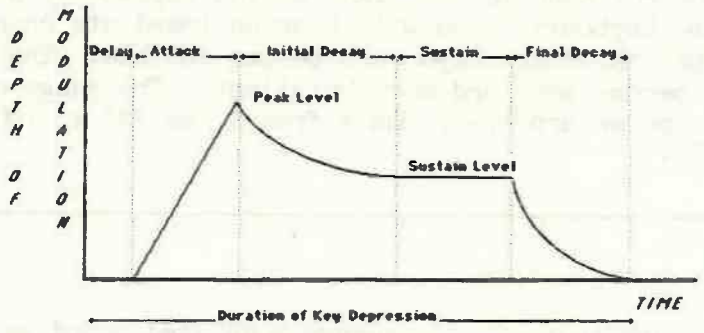
Notice that the modulated wave on the left has a strong fundamental frequency (880 hertz) plus strong frequency components at 220, 440, 1320 and 1540 hertz. This means that the sound will include the two As below the high A fundamental, plus the E and G above high A.

The modulated wave on the right, however, has an attenuated fundamental frequency with strong frequency components at 440, 660, 1100 and 1320 hertz. This means that the sound will include middle A, the E above high C, the C# above that and the G above that.

Each sound will be distinctly different from the other.

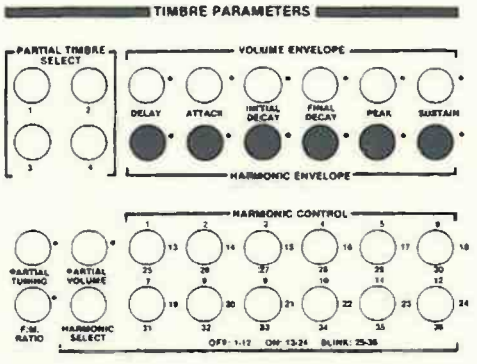
On Synclavier (R), the depth of modulation is controlled by the harmonic envelope (HE) generator. Like the volume envelope generator, the HE generator transforms a steady state modulator sine wave into a wave that varies in volume over time. It is, in fact, a volume envelope generator for the modulator wave instead of the carrier wave.

A typical harmonic envelope looks like a typical volume envelope, with the volume moving from zero at the attack to a programmed peak level, through an initial decay to a sustain level and, finally, through a final decay to zero.



At zero depth of modulation, there will be no sidebands introduced into the harmonic structure of the carrier wave. At the greatest depth of modulation the sidebands will be at their strongest and the carrier frequency will be attenuated. Thus, a frequency modulated tone will vary from its programmed harmonic structure to having additional FM generated harmonic components depending the programming of the harmonic envelope.

You program the harmonic envelope by using the six buttons above HARMONIC ENVELOPE in the first panel.



The following exercise will give you a sense of how the depth of modulation controls the number and strength of the sidebands produced by FM.

Increasing the Depth of Modulation

1. Recall Instruction Timbre 1-1-1, the sine wave.
2. Press HE SUSTAIN. The number 0 will appear in the display window since there is no FM in this timbre.
3. Turn the control knob to the right as you repeatedly strike a key on the keyboard. You will hear an immediate change as additional harmonic components become audible. The sound will become more and more brilliant. The range of settings is on an arbitrary scale from 0 (no FM) to 1000 (maximum FM).

Since the harmonic spectrum of a frequency modulated sound wave depends on the depth of modulation, the harmonic envelope generator can produce dynamic changes in a tone's harmonic structure as it proceeds from attack to final decay. The harmonic envelope can transform a sine wave into a complex waveform or into an inharmonic nonperiodic sound during a single note, depending on the programming.

You will find the initial decay parameter particularly useful in controlling the depth of FM. If a partial timbre has an HE peak level higher than the HE sustain level, you can use the initial decay setting to lengthen a bright attack. If a partial timbre has a low HE peak level and high HE sustain, the initial decay setting can be set so that maximum brightness is reached gradually.

Adding Brightness to the Attack and Final Decay

1. Continue with Timbre 1-1-1. Press HE INITIAL DECAY and dial in a setting of 500.

2. Press HE PEAK. Dial in different settings such as 50, 300, 500 and 1000, playing a note at each setting. You should hear each attack as brighter than the previous one, with the final one at 1000 being a clanging sound.

3. Set HE PEAK at 500 and dial in different HE initial decay settings, such as 1000, 3000, 6000 and 10000. As the initial decay gets longer, you can hear the changing harmonic components of the tone until finally the unmodulated sine wave is reached.

4. Leave HE PEAK at 500 and set HE INITIAL DECAY to 5000. Set VE FINAL DECAY at 5000 and HE FINAL DECAY at 5000. Press a key and release it to hear the brightness extend into the final decay. Press a key and hold it longer than 5 seconds to hear a final decay without FM.

5. Set HE DELAY to 50. Press a key to hear the sound begin as a sine wave and then "snap" into a frequency modulated sound.

Brightening a Timbre Gradually

1. Recall Instruction Timbre 1-1-1.

2. Leave HE PEAK at 0 and set HE SUSTAIN to 60.

3. Dial in different settings for HE INITIAL DECAY, such as 1000, 5000 or 10000 milliseconds. Play a note at each setting and hold it. At each higher setting, the note brightens more gradually.

4. Set the HE INITIAL DECAY to 5000. Set the VE FINAL DECAY to 10000 and the HE FINAL DECAY to 5000. Play a note and hold it for at least five seconds. Listen to the tone brighten over the five seconds, then decay to no FM five seconds after you release the key while the final decay without FM takes another five seconds.

5. Set both HE and VE FINAL DECAY back to 100. Play a series of notes. Notes you sustain will have FM while notes played quickly will have none.

6. Press F.M. RATIO to get a ratio of 2.000. Notice how changing the FM ratio has an even more dramatic effect on a partial timbre with varying FM depth than it did on a steady state sound.

Adjusting the Harmonic Content

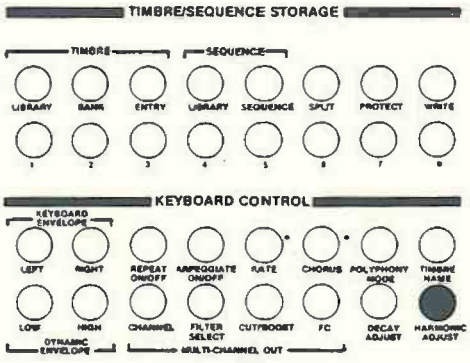
The harmonic adjust feature allows you to adjust the depth of modulation of a partial timbre across the octaves of the keyboard. You can create a partial timbre with strong FM sidebands on the bottom notes and very slight ones on the top notes. Or vice versa.

With this feature, you can increase the brilliance of "mushy" lower notes without producing harshness in the upper notes. Timbres created from partial timbres programmed this way will sound more consistent across the keyboard. The need for external equalization will be reduced.

To activate the harmonic adjust function,

1. press the HARMONIC ADJUST button in the fourth panel;

2. turn the control knob to select an adjust factor between -30 and +30.



Dialing a negative number will increase the sidebands below middle C while decreasing those above. Dialing a positive number will give the partial timbre more FM on the higher notes and less on the lower ones.

Harmonic Adjust

1. Recall Instruction Timbre 1-1-7. This timbre is programmed for FM.

2. Press HARMONIC ADJUST and dial -30. Play some notes and listen to the clarity of the bass notes and softness of the treble ones.

3. Dial +30. Now the bass notes have lost their brightness while the treble ones are more piercing.

TIMBRE FRAME CONSTRUCTION

A partial timbre constructed by programming harmonics and a volume envelope produces a complex waveform that varies in volume over time. The harmonic structure, however, remains the same throughout the duration of a note.

Frequency modulation provides a changing harmonic structure, but the frequency components introduced through FM are not easily controlled and can sometimes produce undesirable noise.

Timbre frame construction allows precise control of a partial timbre's harmonic structure over time. Most of the preset timbres on the timbre diskettes have timbre frames. They were constructed from the Sample-to-Disk (TM) Analysis program, which is used to sample a live sound and convert it into a Synclavier (R) timbre.

Creating a partial timbre with timbre frames from scratch is complicated and may prove somewhat time-consuming. However, once you understand the process of timbre frame construction, you can use timbre frame programming to modify preset timbres to suit your own taste.

Here is a summary of the buttons used for timbre frame construction:

BUTTON	USE	FUNCTION
PARTIAL TIMBRE SELECT buttons	Hold down one or more buttons, press START	Inserts a timbre frame on selected partial timbre
PARTIAL TIMBRE SELECT buttons	Hold down one or more buttons, turn knob	Selects timbre frame for programming on selected partial timbre
PARTIAL TIMBRE SELECT button	Hold down one or more buttons, press STOP	Deletes selected timbre frame on selected partial timbre
PARTIAL TIMBRE SELECT button	Hold down one or more buttons, press BOUNCE	Prepares selected timbre frame for bouncing to newly created frame

(Timbre frame button summary continued next page)

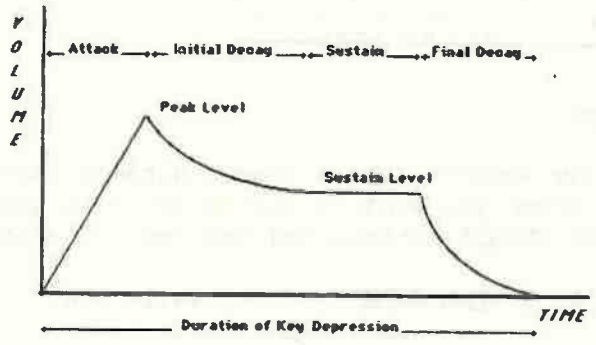
BUTTON	USE	FUNCTION
HARMONIC SELECT	Press once, turn knob; or press repeatedly	Selects harmonic group
HARMONIC CONTROL buttons plus HARMONIC SELECT	Hold one or buttons, press HARMONIC SELECT	Toggles HARMONIC CONTROL buttons between lit and blinking modes
HARMONIC CONTROL buttons (lit)	Press one or more buttons, turn knob	Programs volume level of selected harmonic(s)
HARMONIC CONTROL buttons (blinking)	Press one or more buttons, turn knob	Programs phase value of selected harmonic(s)
VE DELAY	Press once, turn knob	Adds delay to front of frame
VE ATTACK	Press once, turn knob	Sets splice time between waveforms
VE INITIAL DECAY	Press once, turn knob	Sets splice type
VE FINAL DECAY	Press once, turn knob	Sets range for pitch randomness
VE FINAL DECAY	Press once, turn knob	Turns on non-sustaining timbre function for continued timbre frame splicing
VE PEAK	Press once, turn knob	Sets frame peak level
VE SUSTAIN	Press once, turn knob	Changes volume for all frames
HE ATTACK	Press once, turn knob	Sets factor for speed of frames
HE PEAK	Press once, turn knob	Sets pitch offset for frame
HE SUSTAIN	Press once	Turns on looping function for timbre frame looping

When you program a partial timbre with timbre frames, you are constructing a series of waveforms, each with its own harmonic structure and volume envelope, and splicing them to the original partial timbre.

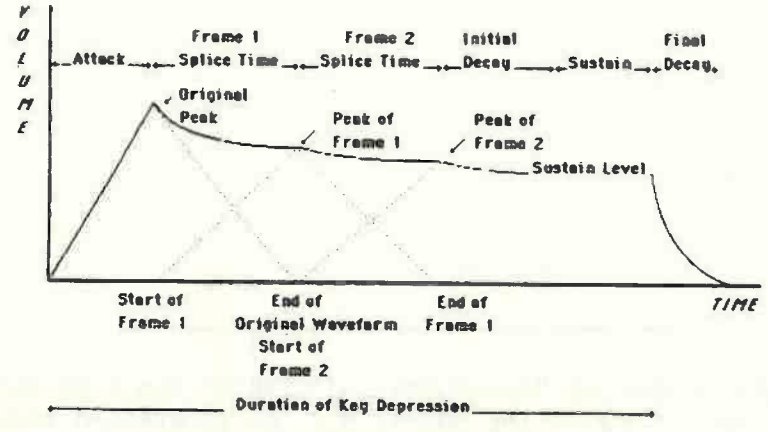
Each spliced-in waveform, or timbre frame, consists of a set of harmonics, a delay time, a splice time and shape and a peak volume level. In addition, a timbre frame can have a pitch envelope, so that fluctuations in pitch can be programmed into the partial timbre.

As the partial timbre is played, the original partial timbre and the timbre frames is spliced together smoothly and evenly. The sound starts with the attack of the waveform programmed for the original partial timbre. When peak volume is reached, splicing of the first timbre frame begins. When peak volume of the first timbre frame is reached, splicing of the second timbre frame begins. The cross-fading of frames can occur in either a linear or a logarithmic S-curve pattern.

After all specified timbre frames have been performed, the initial decay of the original partial timbre will begin, followed by the programmed sustain level and finally the final decay.



ORIGINAL PARTIAL TIMBRE

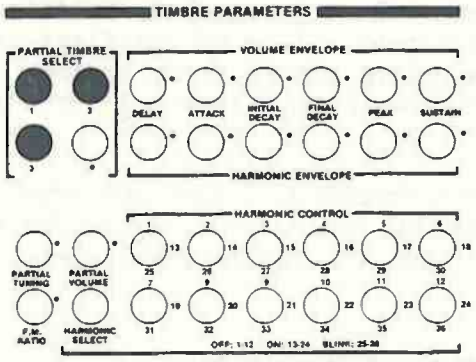


PARTIAL TIMBRE WITH TWO TIMBRE FRAMES

This sequence of events will occur only if the key is held longer than the programmed length of the timbre frames. Whenever you release the key, the note will immediately go into final decay using the waveform of the current timbre frame.*

Any number of timbre frames can be added to a partial timbre. Each partial timbre in a timbre can have its own set of timbre frames. Because of the cross-fading between waveforms, each partial timbre with timbre frames will use two synthesizer voices.

You access timbre frames by using the PARTIAL TIMBRE SELECT buttons and the control knob.



Selecting a Timbre Frame

When a partial timbre has several timbre frames already inserted, you will select the timbre frame you want to listen to or to program using the PARTIAL TIMBRE SELECT buttons and the control knob:

1. Hold down the PARTIAL TIMBRE SELECT button while you. . .

2. . . . turn the knob until the desired frame number appears in the window.

When number of the desired frame appears in the display window, the frame has been accessed and can be listened to or programmed.

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*There is also a special "non-sustained timbre" function which will simply play the attack of the sound, all the programmed timbre frames, and the initial decay, regardless of how long or short a time you hold the note. This special function is described later.

Soloing Timbre Frames

You can listen to the waveform and pitch of a single timbre frame by soloing it and holding down a key. To do so,

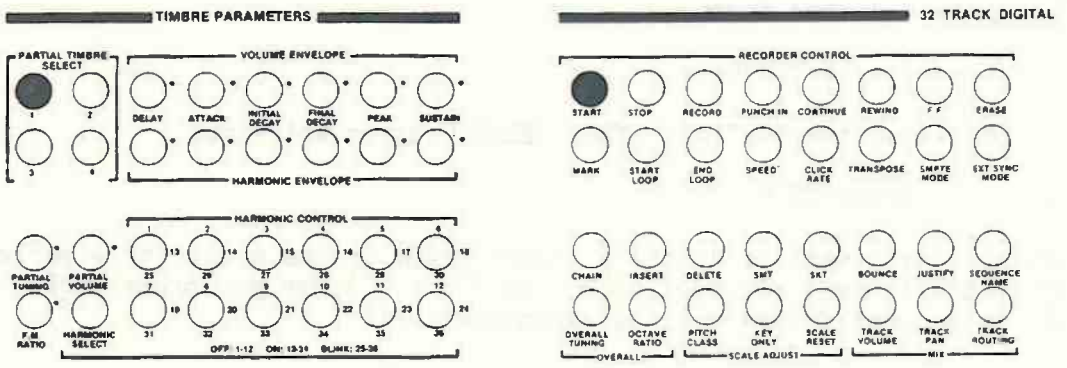
1. select the timbre frame you wish to solo;

2. hold down the PARTIAL TIMBRE SELECT button while you play a note.

The attack in the original waveform will be played and then the splice to the selected timbre frame will begin. When this waveform reaches its peak volume, it will stay there until you release the key.

Inserting a Timbre Frame

You can insert a timbre frame into a partial timbre by using the PARTIAL TIMBRE SELECT buttons and the START button under RECORDER CONTROL in the second panel.



To add a timbre frame to a partial timbre,

1. press and hold down the PARTIAL TIMBRE SELECT button while you. . .

2. . . . press START.

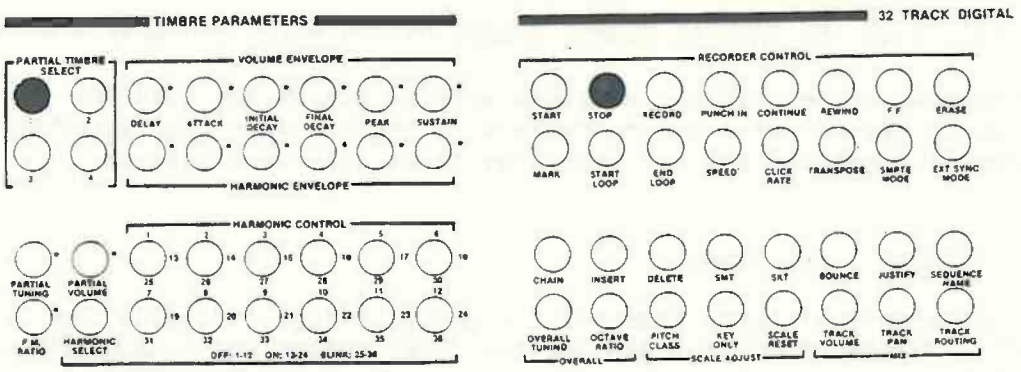
A timbre frame with a sine wave waveform, a peak volume level of 100 and a splice time of 1000 milliseconds will be added to the selected partial timbre.

The original partial timbre is called Frame 0. Each added timbre frame is numbered starting with 1.

If you want to insert a timbre frame into the middle of a series of timbre frames, you must first select the timbre frame after which you want the new timbre frame inserted. When you press START, the new frame will be inserted after the selected frame and all subsequent frames will be automatically renumbered.

Deleting a Timbre Frame

You can delete any timbre frame by using the PARTIAL TIMBRE SELECT buttons and the STOP button under RECORDER CONTROL in the second panel.



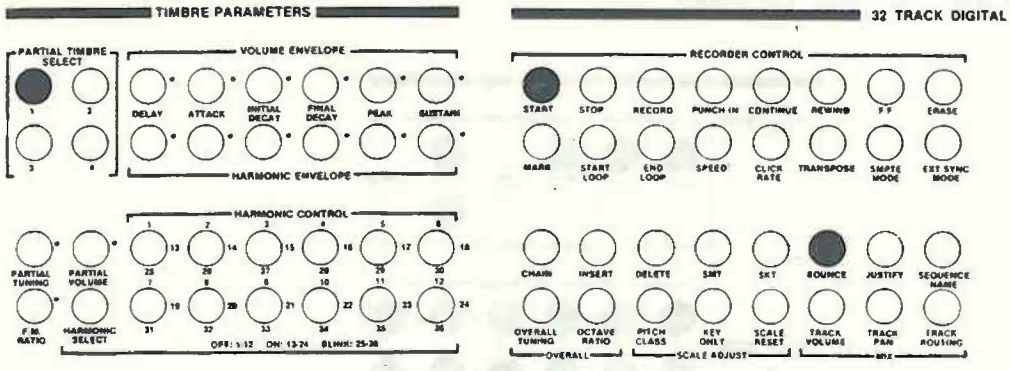
To delete a timbre frame,

1. select it, as above;
2. hold down the PARTIAL TIMBRE SELECT button while you . . .
3. . . . press STOP.

Again, if you want to delete a timbre frame in the middle of a series of timbre frames, you must select it first. After you press STOP, all subsequent frames will be renumbered.

Bouncing a Timbre Frame

You can also create a timbre frame by "bouncing" an already programmed timbre frame to a newly created one. You do this by using the PARTIAL TIMBRE SELECT buttons in the first panel and the BOUNCE and START buttons under RECORDER CONTROL in the second panel.



Bouncing timbre frames makes programming a gradually changing partial timbre easier, since some parameters may not change greatly from one timbre frame to the next.

To bounce a timbre frame,

1. select the timbre frame you want to bounce by pressing and holding down the appropriate button under PARTIAL TIMBRE SELECT and dialing the selected timbre frame;

2. continue to hold down the partial timbre button while you. . .

3. . . . press BOUNCE and then release both buttons (the TRACK SELECT buttons will blink);

4. press START.

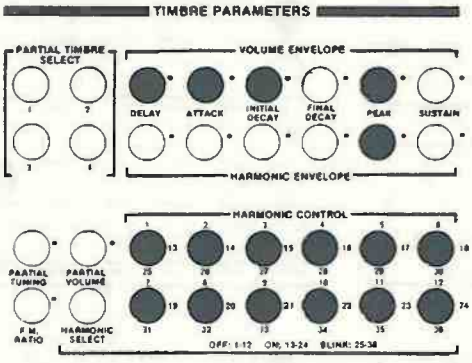
A timbre frame immediately following the timbre frame selected for bouncing will be created with the values of the bounced timbre. The original timbre frame is not affected by the bounce, since it has been duplicated, not moved.

You can also use this procedure to bounce a timbre frame from one partial timbre to another, provided both partial timbres are active within the keyboard timbre. To do this, simply press the appropriate button under PARTIAL TIMBRE SELECT before pressing START.

NOTE: Although you can bounce information from Frame 0 to any other frame, it is impossible to bounce information from another timbre frame to Frame 0. It is possible to skip over Frame 0 by setting the VE PEAK of Frame 0 to 0.1 and the VE ATTACK to 0 millisecond. Since this procedure requires a significantly greater amount of computer time to begin new notes, this procedure should be used sparingly.

Setting the Timbre Frame Parameters

When you learned how to program the harmonic structure and volume envelope of a partial timbre, you were actually learning how to program Frame 0 of a partial timbre. This section describes how to program the other timbre frames. You will be using the HARMONIC CONTROL buttons, and the VE DELAY, VE ATTACK, VE INITIAL DECAY, VE PEAK and HE PEAK buttons.



Waveform

The waveform of the timbre frame is specified by setting the relative volume levels of the 36 harmonics using the HARMONIC CONTROL buttons as described in the section on partial timbre programming. The default timbre frame is set at 100.0 for the first harmonic and 0 for the others.

Phase control

All the harmonics of non-frame 0 timbre frames, including the fundamental, may be adjusted for phase. You program for phase by activating the blinking mode for the HARMONIC CONTROL buttons and dialing in a number between 0 and 63, as described in the section on partial timbre programming.

Delay time

A delay may be added to the front end of the timbre frame. This will postpone the splice by maintaining the previous waveform for the specified length of time as well as delaying the start of the new waveform.

Set the delay time by pressing VE DELAY and dialing a number from 0 to 20.00 seconds. The default is 0.

Splice time

During the splice time, the previous waveform will fade as the new one rises to its peak volume.

Set the attack time by pressing VE ATTACK and dialing a number from 0 to 20.00 seconds. The default is 1000 milliseconds.

Short splice times can be used to create very "real" attack transients. Long splice times of one, two, or three seconds can create slow moving harmonic shifts that make for pleasing and very interesting sounds.

Logarithmic or linear splice type

You may select a linear or exponential (S-Curve) cross-fading pattern. Since what you hear is on a decibel scale, a linear splice will be heard as a nonlinear change and an exponential splice will be heard as a gradual, linear change. S-Curve splices sound especially superb with long splice times.

Select the splice type by pressing the VE INITIAL DECAY button and dialing a number between 0 for fully exponential and 1000 for fully linear. The default is 500.

Peak volume level

Each timbre frame has its own peak volume level which is reached at the end of the splice.

Set the peak level by pressing VE PEAK and dialing a number between 0.0 (no volume) and 100.0 (full volume). The default is 100.0.

Pitch offset

The entire partial timbre can be given a pitch envelope by setting each timbre frame to a pitch that differs from the pitch of the previous frame by the amount of a pitch offset.

Set the pitch offset by pressing the HE PEAK button and dialing a number between -48.00 to +48.00 in semitones. You can also change the pitch offset in semitone intervals by pressing HE PEAK repeatedly. The default is 0 (no offset).

The starting pitch of the partial timbre will be determined by the frequency of the note being played, the partial tuning setting (explained in the following section) and the overall tuning setting (explained in the tabbed section, "Keyboard Control/Real-Time Effects").

When the splice to Timbre Frame 1 begins, the starting pitch will start to glide up or down by the amount of the pitch offset. The glide will be completed at the moment new waveform reaches its peak level.

If an additional pitch offset is specified for Timbre Frame 2, the pitch will start to glide from the pitch reached at the previous peak level, again up or down by the amount of the pitch offset.

The cumulative effect of pitch offset set for each timbre frame allows for a wide variety of special effects. Positive and negative pitch offsets that cancel each other create sounds that fluctuate around the starting pitch. All positive or all negative pitch offsets create sounds that move continuously in one direction.

Timbre Frame Construction

1. Recall Instruction Timbre 1-1-1, the sine wave.

2. Press VE PEAK and dial in a peak volume setting of 40.

3. Create Timbre Frame 1:

   a. Press and hold Button 1 under PARTIAL TIMBRE SELECT. (FRAME 0, for Timbre Frame 0; will appear in the display window.)
   b. Press START. (FRAME 1, for Timbre Frame 1, will appear in the display window.)

   Timbre Frame 1 has default settings of a 1000 millisecond splice time and 100 peak volume.

4. Press VE PEAK and dial in a setting of 60.

5. Add the third harmonic to the Frame 1 sine wave:

   a. Press Button 3 under HARMONIC CONTROL.
   b. Dial in a setting of 33.3.

6. Bounce Timbre Frame 1 to Timbre Frame 2:

   a. Press and hold Button 1 under PARTIAL TIMBRE SELECT.
   b. Press BOUNCE.
   c. Press START.

   Timbre Frame 2 has, instead of the default settings, the same values as Timbre Frame 1.

7. Press VE PEAK and dial in a volume of 80.

8. Add in the fifth harmonic with a coefficient of 20.

9. Bounce Timbre Frame 2 to Timbre Frame 3.

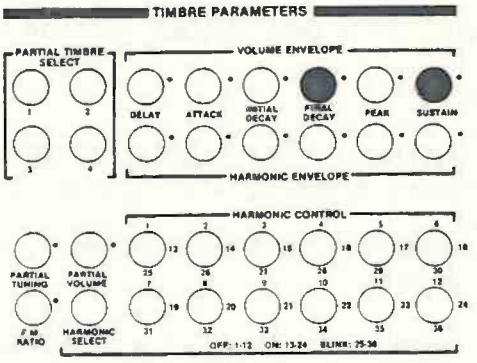
10. Press VE PEAK and dial in a volume of 100.

11. Add in the seventh harmonic with a coefficient of 14.3.

12. Press HE PEAK twice to set the pitch offset for this timbre frame at one semitone.

13. Press a single key and hold it. You should hear the sine wave gradually change to a square wave while steadily increasing in volume. After two and a half seconds, the pitch will rise a semitone.

Two additional parameters can be set on one frame only and will be applied to the whole partial timbre. They may be set on any frame other than Frame 0. These parameters will be programmed using the VE SUSTAIN and VE FINAL DECAY buttons.



Partial timbre volume control

The partial timbre volume control parameter allows you to quickly adjust the peak levels of all the timbre frames in a partial timbre by changing just one value in one timbre frame (usually Frame 1). In this way, you adjust the total loudness of the partial timbre. This makes it easy to adjust the relative volumes of partial timbres, each with a long chain of timbre frames, within the same timbre.

Set the partial timbre volume level by pressing VE SUSTAIN and dialing a number between 0.0 (no volume) and 100.0 (full volume). The default value is 100.0. By decreasing this number, all the volume levels in the frames will be lowered by the specified percentage.

Pitch randomness

Certain classes of sounds, particularly percussive timbres, are more effective if a slight, random pitch variation is applied. A random pitch variation also prevents undesirable phase cancellations which can occur when multiple notes in the same sound are played at once.

Set the pitch randomness by pressing VE FINAL DECAY and dialing a randomness between 0 and 48.00 semitones. This establishes a "randomness range" above and below any note that is played. The pitch randomness is usually set on Frame 1.

When you play a note, a random pitch will be chosen from within this range and will be maintained for as long as the note lasts. If the same note is played again, however, a different random pitch will be chosen from within the range. By repeatedly pressing the same key, you can play a sequence of sixteen different random notes. If recorded, these notes will not necessarily be played back in the original pattern of pitches.

A small "randomness range" helps create a natural sound when you are playing multiple simultaneous notes with a timbre using timbre frames. For special effects, you might try setting a large range.

Pitch randomness can only be applied to partial timbres with at least one timbre frame. If you want to set pitch randomness on a timbre without timbre frames, create a "dummy" timbre frame by "bouncing" Timbre Frame 0 to Timbre Frame 1.

Creating a Random Pitch Timbre

1. Recall Instruction Timbre 1-2-8, the "Syd" timbre.
2. Press VE FINAL DECAY and dial in 5 semitones.
3. Play a single key several times in succession and listen to the pitch of each note.

Continued Timbre Frame Splicing

In timbres with timbre frames, the timbre frame splicing stops when the key is released and the initial decay begins from the waveform of the frame in progress. Normally this is true for sustaining and non-sustaining timbres alike.

However, you can program a special continued splicing function for non-sustaining timbres. This function is very effective for creating plucked sounds, such as guitar or harp, where you want to use a series of timbre frames to produce an authentic decay. With continued splicing timbres, the entire series of frames will be triggered for each note even if you play very rapidly. This kind of sound cannot be damped once a note has been triggered.

To create a continued splicing timbre, you must set up two specific conditions on each active partial timbre in the sound:

- The VE SUSTAIN level of Frame 0 each partial timbre must be set at 0. (This is, of course, what defines a partial timbre as non-sustaining.)
- The VE FINAL DECAY time of Frame 0 must be greater than the sum of the splice times for all the timbre frames plus the INITIAL DECAY time set on Frame 0.

When these two conditions are met, all notes played will step through the complete set of timbre frames and then decay to zero at the rate set by the INITIAL DECAY setting. The FINAL DECAY setting will not determine the rate of decay; it will just be used to turn on the non-sustaining timbre function.

Continued Timbre Frame Splicing

1. Recall Timbre 1-6-1 from Timbre Diskette #5.

2. Make sure that Button 1 under PARTIAL TIMBRE SELECT is lit. By default, Frame 0 is selected.

3. Set the VE SUSTAIN setting at 0.0. This makes the timbre non-sustaining.

4. Dial in a VE FINAL DECAY of 100 milliseconds. This is shorter than the sum of the splice times of the timbre frames.

5. Hold down a note on the keyboard. The note will run through all the frames and then stop. You will hear the entire "plucked" sound.

6. Play a note on the keyboard and then release the key while the note is still sounding. You will hear the sound decay to zero in 100 milliseconds after the key is released. Timbre frame splicing stops as soon as you release the key.

7. Now dial in a VE FINAL DECAY of 4454 milliseconds. This is the sum of the crossfade times of the fifteen timbre frames in this partial timbre. (Normally, you would dial any large number for the final decay to achieve continued splicing. This precision is for illustration purposes.)

8. Play a note on the keyboard and then quickly release it. You will hear the note splice through all the timbre frames and then decay to zero.

9. Play a note and hold it down. You will hear the same sound.

10. Now, shorten the FINAL DECAY by one millisecond to 4453.

11. Hold a note down and you will hear all the timbre frames. Play a note on the keyboard and then quickly release it. You will hear the note splicing stop as you release the key; the long final decay will have the waveform of the frame active when you released the key.

You might want to have two guitar-like timbres in your sound library, one with a short final decay (as in Step 3) and one with a continued splicing decay (as in Step 6). The timbre with the short final decay can be used (perhaps in conjunction with the sustain pedal) to create musical lines that mimic a guitarist's left hand articulation. The timbre with the long continued splicing decay is more playable on a keyboard, but of course cannot be damped once the key is released.

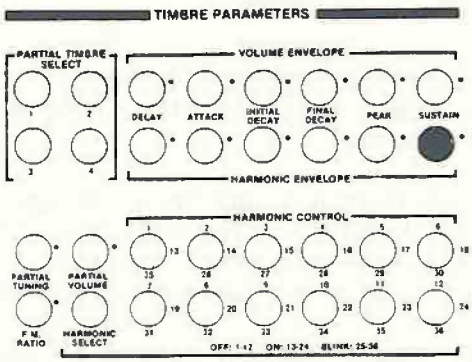
Timbre Frame Looping

You can apply a loop to a series of timbre frames so that the series of frames will be played over and over so long the note is held. To do this,

1. select the endloop point in the series of timbre frames by holding the PARTIAL TIMBRE SELECT button and turning the knob until the number of the desired last frame appears;

2. turn on the looping function by pressing the HE SUSTAIN button;

3. turn the control knob to select the startloop point.



When you play a note, the system will play the frames up to the specified ending frame and then return to the starting frame. This loop will continue as long as you hold down the key.

Timbre frame looping can be used to create life-like vibrato with a sound that repeatedly fluctuates between different waveforms. It can also be combined with amplitude modulation or unusual vibrato settings for many special effects. Or, try adding a loop to a partial timbre with a pitch envelope programmed for the frames.

You can also add a timbre frame loop to a non-sustaining timbre that has been programmed for continued splicing for a number of special effects. For example, you could program a timbre frame loop which loops from a frame other than the last frame of the partial timbre. So long as a key is held down, the note will loop between the specified starting and ending frames in the loop. When the key is released, the note will continue splicing through all the frames in the timbre, including those which occur beyond the endloop frame.

Looping Timbre Frames

1. Continue with Timbre 1-6-1 from Timbre Diskette #5, with its continued splicing.

2. Press Button 1 under PARTIAL TIMBRE SELECT and hold it down while dialing in Frame 10.

3. Press HE SUSTAIN and dial in Frame 2.

4. Play a series of rapid notes followed by a sustained note. The sound appears to repeat as the loop between Frame 10 and Frame 2 takes place. When you release the sustained note, the remainder of the timbre frames will follow.

ADDING SPECIAL EFFECTS TO PARTIAL TIMBRES

The foundation of each partial timbre is its steady state waveform modifed by a volume envelope and perhaps FM and/or timbre frame construction. To this foundation, many special effects can be added. Each changes the partial timbre in its own special way. All changes you make can be stored with the timbre.

Here is a summary of the buttons used to modify partial timbres:

BUTTON	USE	FUNCTION
VIBRATO WAVE	Press once, turn knob; or press repeatedly	Changes vibrato wave shape
VIBRATO RATE	Press once, turn knob	Changes vibrato rate
VIBRATO DEPTH	Press once, turn knob	Changes vibrato depth
MOD DEPTH*	Press once, turn knob	Changes vibrato depth of FM modulator only
ATTACK/DECAY*	Press once, turn knob	Changes attack or decay time of vibrato
INVERT	Press once	Toggles invert modifier on or off
QUANTIZE	Press once	Toggles quantize modifier on or off
BIAS	Press once	Toggles bias modifier on or off

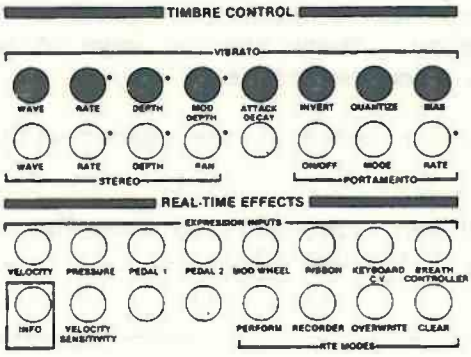
(Special effects button summary continued on the following page.)

*This function will be available in future releases.

STEREO WAVE	Press once, turn knob; or press repeatedly	Selects stereo panning mode or waveform; modes 21 through 24 select amplitude modulation waveforms
STEREO RATE	Press once, turn knob	Changes stereo or AM panning rate
STEREO DEPTH	Press once, turn knob	Changes stereo or AM panning depth
STEREO PAN	Press once, turn knob Press twice	Changes stereo panning center Resets panning center to zero
PORTAMENTO ON/OFF	Press once	Toggles portamento on or off
PORTAMENTO MODE	Press once	Toggles logarithmic or linear mode
PORTAMENTO RATE	Press once, turn knob	Changes portamento rate
PARTIAL CHORUS	Press once, turn knob	Establishes and tunes chorus effect for selected partial timbre(s)
PARTIAL TUNING	Press once, turn knob; or press repeatedly	Changes tuning base for selected partial timbre(s)
PARTIAL VOLUME	Press once, turn knob	Changes overall volume for selected partial timbre(s)
KEYBOARD ENVELOPE (RIGHT AND LEFT)	Hold down button, press one key (or two)	Sets upper and lower end of keyboard range (and fade range) for selected partial timbre(s)

Adding Vibrato

Each partial timbre can be given vibrato, or periodic variation in pitch. There are several wave shapes available as well as a wide range of depths and rates. You program vibrato by using the eight VIBRATO buttons under TIMBRE CONTROL in the fifth panel.



To add vibrato to a partial timbre,

1. select a vibrato wave shape either by pressing WAVE and dialing in a number from 1 to 12 or by pressing WAVE repeatedly (see table below);

2. set the vibrato rate by pressing RATE and dialing in a number from 0 to 50.00 hertz;

3. set the vibrato depth by pressing DEPTH and dialing a range of 0.0 to 24.00 semitones.*

A delayed attack can be set for the vibrato. To do this, press the VIBRATO ATTACK/DECAY** button and dial in a positive number of up to ten seconds.

A vibrato with a delayed attack will build up gradually, rather than all at once. With a vibrato decay, the vibrato will fall off gradually. With these controls, the vibrato will sound more like the vibrato of an acoustic instrument.

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*In future releases, you will be able to set a vibrato depth for the modulator wave with partial timbres programmed for FM. To do this, you will press the MOD DEPTH button in the fifth panel and dial a range of 0.0 to 24.00 semitones. Dialing a negative number will cause the modulator depth to follow the changes set by the DEPTH button.

**In future releases, you will also be able to set a final decay for the vibrato. To do this, you will press the VIBRATO ATTACK/DECAY button in the fifth panel and dial in a negative number of up to 10 seconds.

Changing Vibrato Wave Shape

There are twelve possible vibrato wave shapes. The first five are applied only to the carrier frequency. The second five are applied to both the carrier and modulator frequency, provided the partial timbre has above zero HE PEAK or SUSTAIN settings. The last two are random wave shapes.

Each vibrato wave shape has a different symbolic number, as shown in the table below. There are two ways to select a different wave shape. You can either

1. press the WAVE button and dial the number with the control knob; or

2. press the WAVE button repeatedly to step through the cycle of numbers, 1 through 12.

VIBRATO WAVE #	CARRIER WAVE	MODULATOR WAVE
1	Sine	None
2	Triangle	None
3	Sawtooth	None
4	Inverted Sawtooth	None
5	Square	None
6	Sine	Sine
7	Triangle	Triangle
8	Sawtooth	Sawtooth
9	Inverted Sawtooth	Inverted Sawtooth
10	Square	Square
11	Random	None
12	Random	Random

Random wave shapes are calculated using pitches within the range set up by the current VIBRATO DEPTH settings. The random value is passed through a digital sample-and-hold with a clock rate determined by the VIBRATO RATE setting.

When using either of the random wave settings, you will probably never get exactly the same wave shape twice.

There are three additional functions which can be used to modify the vibrato wave shapes. All three are simple on/off functions activated by pressing the appropriate button.

The Invert Function

When the invert function is turned on, the selected vibrato wave shape will be inverted. For example, a triangle wave shape will become an inverted triangle wave shape.

The Quantize Function

Normally, the fluctuations in pitch produced by the vibrato function are smooth and gradual. When the quantize function is turned on, however, the fluctuations in pitch will be quantized, or stepped, in semitone intervals.

The Bias Function

Normally, when vibrato is added to a partial timbre, the pitch of each note will fluctuate above and below the pitch of the key being pressed. The total range in semitones is determined by the DEPTH setting. When the bias function is turned on, the vibrato is raised so that the pitch fluctuation is all above the pitch of the key being pressed. The "bottom" of the vibrato is set at the pitch of the key being pressed and the "top" the number of semitones is set by the DEPTH setting above the pitch of the key being pressed. (When the invert bit is on, the fluctuation will be reversed.)

There are several special effects you can set up when using the quantize function:

- You can adjust the steps of the quantization by setting different frequencies with the SCALE ADJUST button (see the tabbed section, "Keyboard Control/Real-Time Effects").

- You can combine quantized vibrato with the REPEAT function (see the the following section, "Creating and Modifying the Whole Timbre"). Set up a REPEAT RATE integrally related to, but not, necessarily, identical with the VIBRATO RATE. As you hold down a note, the volume and harmonic envelopes will be applied periodically to different steps in the cycle.

- You can add the ARPEGGIATE FUNCTION to the above (see the following section).

- You can combine any or all of these functions in very complicated "sample-and-hold" or "sequencer" effects.

Adding Vibrato

1. Recall Instruction Timbre 1-1-7. This woodwind timbre is programmed for FM and vibrato.

2. Press WAVE. You will see

   6-SINE2

   in the display window, meaning that the sine wave vibrato applies to both carrier and modulator.

3. Press VIBRATO DEPTH and dial a depth of 1.00 semitone. Play a note and listen to the vibrato.

4. Press VIBRATO WAVE and dial in 1-SINE, so that the vibrato applies only to the carrier wave. Compare this sound with the sound of the vibrato applied to both waves.

5. Press WAVE repeatedly to step through the cycle to RANDOM2. Listen to the sound move at random up or down a semitone.

6. Press DEPTH and dial in 6.00 semitones. Now the vibrato moves at random throughout an entire octave.

7. Now change the wave shape to 6-SINE2 again and dial a depth of 2.00 semitones.

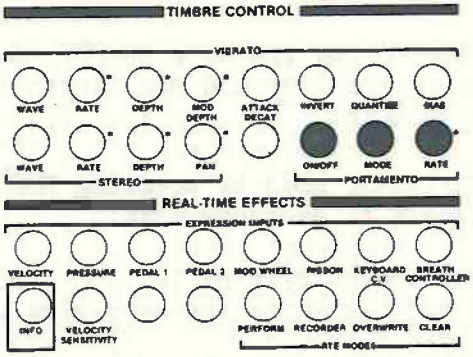
8. Press QUANTIZE and listen to the tone step through the vibrato.

9. Press BIAS and listen to the vibrato move up from the pitch of the keyboard.

10. Press INVERT and listen to the vibrato move down from the pitch on the keyboard.

Adding Portamento

When the portamento function is active on the partial timbre, glissandos will be produced between notes. You program portamento by using the three PORTAMENTO buttons under TIMBRE CONTROL in the fifth panel.



To add portamento to a partial timbre,

1. turn on the portamento effect by pressing the ON/OFF button under PORTAMENTO.

2. select the logarithmic mode, if desired, by pressing the PORTAMENTO MODE button (if button is not lit, the portamento will be linear);

3. set the portamento rate by pressing the PORTAMENTO RATE button and dialing in a number from 0.000 to 1.000.

The PORTAMENTO RATE button controls the rate of the change in pitch, and thus the duration of the glissandos. At a rate of 0.000, it will take almost a minute for a pitch to travel from one end of the keyboard to the other. Smaller changes in pitch will occur at the same rate. At a rate of 1.000, the change between one pitch and the next will be instantaneous.

The portamento rate can be linear or logarithmic. A linear portamento rate will change the pitch at the same rate throughout the entire glissando. A logarithmic portamento rate will accelerate the change in pitch.

When the MODE button is lit, the portamento rate will be logarithmic. When the MODE button is not lit, the rate will be linear.

Portamento

1. Recall Instruction Timbre 1-1-4. This violin timbre has a portamento rate of 0.400 programmed into all four of its partial timbres.

2. Turn on the portamento by pressing ON/OFF under PORTAMENTO. Play a few notes on the keyboard and listen to the sound glide from note to note.

3. Turn on the logarithmic mode by pressing MODE and listen to the glide accelerate to each new note.

4. Press RATE. The current setting is .400. Dial a rate setting of .200 and listen to the very slow glide.

5. Dial a rate setting of 1.000. In effect, this turns off the portamento since the pitch change is instantaneous. Compare the sound with the sound when the portamento function is turned off.

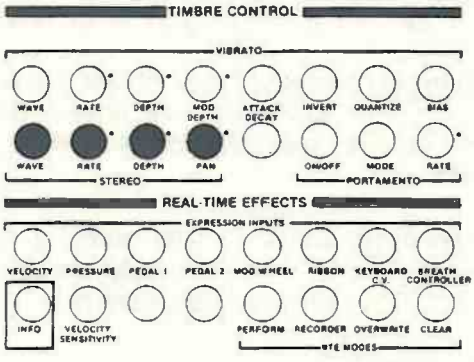
Adding Stereo

With the stereo option, you can balance the dual outputs of each individual timbre precisely, placing each partial timbre on any of 100 locations between left and right speakers. Thus a timbre with four partial timbres can appear to come from four different locations. When a memory recorder sequence is played, sounds can appear to come from as many locations as you have voices in your Synclavier (R).

You can also program each partial timbre so that it will move around during live performances or playback of recorded sequences. A partial timbre can move according to key location or it can automatically pan from speaker to speaker during held notes. One partial timbre can move from left to right while others move in reverse direction. Or, by proper positioning of the speakers, some sounds can move toward the listener while others recede.

Stereo settings for each partial timbre will be saved when you store a timbre on diskette. This information is also recorded when you create a sequence. You can also add stereo to old recorded sequences simply by adding stereo to the timbres in them.

You program stereo using the four STEREO buttons under TIMBRE CONTROL in the fifth panel.



Static Stereo

By default, a static stereo image is present on a partial timbre with each note played appearing to come from the center of the stereo image. To change the stereo position, press the STEREO PAN button in the fourth panel and dial the center position setting in the range of -50 (full left) to +50 (full right).

To reset the panning center to zero, press the PAN button twice.

Moving Stereo

The stereo position can also serve as a centerpoint for a moving sound. The pattern, range and centerpoint of the movement are programmed by the buttons WAVE, DEPTH and PAN. The actual movement will be determined by either the specific keys played (modes 3 and 4) or the RATE button (automatic modes 5 and 6, 9 through 12, and 15 through 18).

To establish moving stereo,

1. press WAVE and dial in a numeric symbol for a stereo panning mode or waveform selected from the table below; or press the WAVE button repeatedly to step through the mode numbers;

2. press STEREO DEPTH and dial in a stereo panning depth from 0 to 50 panning units.

3. press PAN and dial in a center position for the moving stereo within the range of -50 (full left) to +50 (full right).

Automatic Panning

In the automatic panning modes, the output is moved around in the stereo image at a set rate while you hold down a key.

Modes 9-12 are synchronous modes. All notes in a chord will be panned together. As you add each new note, the panning picks up at the point in the panning cycle where panning for the previous note left off.

Modes 15-18 are independent modes. The panning of each note will begin at the beginning of the panning cycle, at the designated centerpoint for the partial timbre.

To activate automatic panning,

1. select one of the automatic panning modes by pressing STEREO WAVE and dialing in the appropriate number for the selected mode;

2. set the panning rate by pressing STEREO RATE and dialing in a rate from 0.0 to 6.00 hertz;

3. set the panning depth by pressing STEREO DEPTH and dialing in a depth from 0 to 50 panning units;

4. change the center position, if desired, by pressing the STEREO PAN button and dialing in a center position from -50 (full left) to +50 (full right).

NOTE: With a depth or rate of 0, there will be no automatic panning.

STEREO MODES

#	MODE DEFINITION
0	Output of the partial timbre remains at defined stereo center position. (Default mode)
1/2	Reserved for future use.
3	Stereo positions mapped to keys on the keyboard. With default center position of 0 and depth setting of 50, centerpoint is at F# above middle C, with lower notes to the right and higher ones to the left. Both centerpoint and depth settings can be adjusted.
4	Mirror image of mode 3.
5	Automatic "ping pong" panning between right and left ends of panning range with each new note triggering a move to the opposite end.
6	Mirror image of mode 5.
7/8	Reserved for future development.
9	Synchronous automatic panning using a sine wave. Panning moves from centerpoint to the right and then to the left.
10	Mirror of mode 9.
11	Synchronous automatic panning using a square wave. Panning moves from centerpoint to the right and then to the left.
12	Mirror of mode 11.
13/ 14	Reserved for future development.
15	Independent automatic panning using a sine wave. Panning moves from centerpoint to the right and then to the left.
16	Mirror of mode 15.
17	Independent automatic panning using a square wave. Panning moves from centerpoint to the right and then to the left.
18	Mirror of mode 17.
19	Random panning with each note placed at a random position within the panning range.
20	Mirror of Mode 19.

Adding Stereo

1. Recall Instruction Timbre 1-1-8. Play a note and hold it. The sound should be coming from the center of the speakers or headphones.

2. Press STEREO PAN and dial a center position of 50. Play a note and hold it. The sound is now coming from the right speaker.

3. Dial a center position of -50. Now the sound is coming from the left speaker.

4. Reset the center position to 0 by pressing PAN again.

5. Press STEREO WAVE repeatedly until

   3-KEYBOARD

   appears in the display window.

6. Press STEREO DEPTH and dial in a depth of 50.

7. Play a series of notes above and below middle C. You'll hear the higher notes coming from the right and the lower ones from the left.

8. Now press WAVE and dial in 11, the synchronous automatic panning mode that uses a square wave.

9. Press RATE and dial in a panning rate of 0.50 hertz.

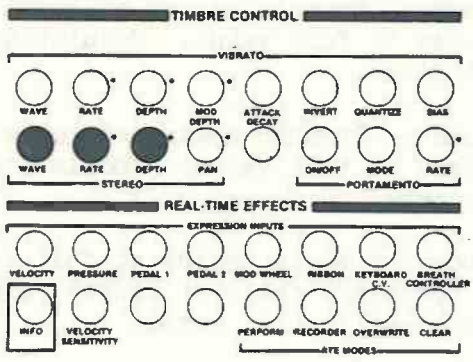
10. Play a note and hold it. Listen to the sound "ping-pong" back and forth from right to left speakers.

11. Now add notes to create a slow arpeggio. Listen to the way each note synchs in on the stereo pan.

12. Now select Wave 15, the independent sine wave panning mode. Play the same arpeggio and listen to each note panning independently.

Adding Amplitude Modulation

You can add amplitude modulation, or tremolo to a partial timbre. by using the STEREO WAVE, RATE and DEPTH buttons under TIMBRE CONTROL in the fifth panel.



There are four tremolo modes, two attack modes and two decay modes. The attack modes begin at the lowest point in the modulation cycle and rise to full volume. The decay modes begin at the full volume point in the modulation cycle and drop down to the low. Both attack and decay modes can be either

- o synchronous, in which amplitude modulation is synchronized for all notes on the keyboard; or

- o independent, in which the modulation of each note begins at the beginning of the modulation cycle, either at the top or the bottom, depending on whether it is an attack or decay mode.

To establish amplitude modulation on a partial timbre,

1. press the STEREO MODE button and select one of the four amplitude modulation modes by dialing a number frnm 21 to 24 (see table below);

2. press STEREO RATE and dial a rate between 0.0 and 6.0 hertz;

3. press STEREO DEPTH and dial a depth of amplitude modulation from 0 to 50.

Note that with a depth of modulation of 0, the amplitude will not fluctuate, but will remain at the specified VE PEAK and SUSTAIN levels. With a setting of 50, the amplitude will fluctuate between the full programmed volume level and zero.

AMPLITUDE MODULATION MODES

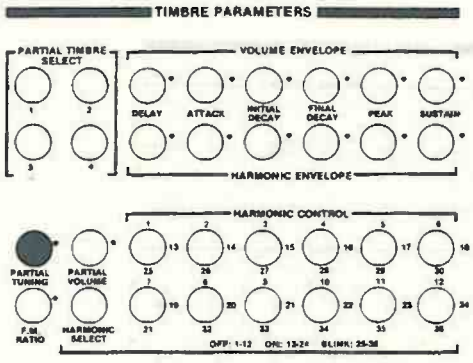
#	MODE DEFINITION
21	Synchronous attack mode. Tremolo begins at lowest point in modulation and rises to full value. Modulation is synchronized for all notes.
22	Independent attack mode. Tremolo begins at lowest point in modulation and rises to full value. Modulation is independent for each note.
23	Synchronous decay mode. Tremolo begins at full volume point in modulation cycle and falls to lowest point. Modulation is synchronized for all notes.
24	Independent decay mode. Tremolo begins at full volume point in modulation cycle and falls to lowest point. Modulation is independent for all notes.

Adding Tremolo

1. Recall Instruction Timbre 1-1-8 again.
2. Select the synchronous attack mode by pressing STEREO WAVE and dialing in 21.
3. Press STEREO RATE and dial 6.0.
4. Press STEREO DEPTH and dial 25 for a fluctuation between half and full loudness.
5. Play a chord and hold it down. The tremolo on all the notes of the chord will move simultaneously from half to full loudness.
6. Press STEREO WAVE and dial in 22 for the independent attack mode.
7. Play an arpeggiated chord and hold it down. You will hear the tremolo on each note individually.

Tuning a Partial Timbre

Each partial timbre can be individually tuned by using the PARTIAL TUNING button in the first panel.



To activate the partial tuning function, press PARTIAL TUNING and use the control knob to dial any tuning relative to A 440.0 from 0.0 to 1760.0 in .1 hertz increments.

Or press PARTIAL TUNING repeatedly to step through a cycle of octave changes in tuning:

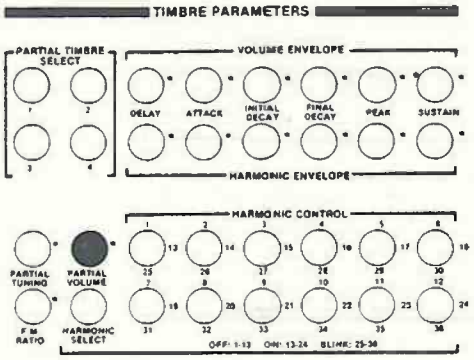
110.0 220.0 440.0 880.0 1760.0

Partial timbre tuning becomes very important when the partial timbres are combined. Harmonic as well as inharmonic relationships between the frequency components of the partial timbres can be created in this way. Also, small tuning offsets on the different partial timbres that make up a complete timbre can produce tremolo or amplitude modulation from the way the waveforms interact.

You can establish constant tuning for a partial timbre by dialing in a negative number. When you do this, the partial timbre will be synthesized at the pitch specified to the right of the minus sign, regardless of what note is played. This makes it possible to create a guitar timbre, for example, that has the sound of unpitched guitar pick on one partial timbre while the remaining ones contain the sound of the guitar strings.

Adjusting the Volume

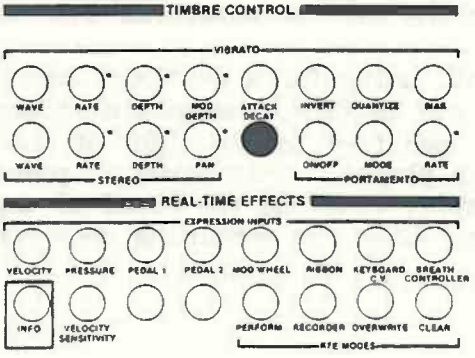
The overall volume of each partial timbre may be adjusted by using the PARTIAL VOLUME button in panel 1.



To adjust the volume of a partial timbre, press PARTIAL VOLUME and dial a number between 0 for no volume to 100 for full volume.

Adding Chorus

The partial chorus function adds another voice to the selected partial timbre without affecting the other partial timbres in the timbre. To add chorus, press the PARTIAL CHORUS button (the unlabeled button in panel 5) and dial in a number between 0.000 and 10.000.



The number dialed in establishes the interval above or below the pitch of the selected partial timbre, with 1.000 representing a unison. Dialing an integer will add a pitch that reinforces the harmonics of a tone. That is, dialing 2.000 tunes the added voice to the second harmonic, or an octave; dialing 3.000 tunes the added voice to the third harmonic, or the fifth above the octave; and so on. The following table gives the harmonic ratios for the first sixteenth harmonics of a fundamental frequency.

INTERVALIC RELATIONSHIP OF FIRST 16 HARMONICS TO FUNDAMENTAL FREQUENCY

HARMONIC	INTERVAL FROM FUNDAMENTAL FREQUENCY
1	Unison
2	Octave
3	Octave plus a perfect fifth
4	Two octaves
5	Two octaves plus a major third
6	Two octaves plus a perfect fifth
7	Two octaves plus a minor seventh
8	Three octaves
9	Three octaves plus a major second
10	Three octaves plus a major third
11	Three octaves plus a perfect fourth sharpened by a quartertone
12	Three octaves plus a perfect fifth
13	Three octaves plus a minor sixth sharpened by a quartertone
14	Three octaves plus a minor seventh
15	Three octaves plus a major seventh
16	Four octaves

Dialing a number less than 1.000 tunes the added pitch to a frequency below the fundamental frequency, with the octave, second octave and third octave below given by 0.500, 0.250 and 0.125 respectively.

Dialing a non-integer above 1.000 tunes the added pitch to inharmonic frequencies.

Other frequencies to tune the added pitch to might include:

1.250	Major third
1.500	Perfect Fifth

Remember, when you add the chorus effect to a partial timbre, you use an additional synthesizer voice.

Tuning, Volume and Chorus

1. Recall Instruction Timbre 1-1-4. You learned in the introduction that the first and fourth partial timbres of this timbre are tuned to 440.0, the second to 440.2 and the third to 439.8.

2. Select Partial Timbre 1, press PARTIAL TUNING and step through the cycle to 220 hertz. Play some notes and listen to the effect of a cello added to the violin sound.

3. Press PARTIAL VOLUME and dial in a volume level of 40. The cello is not so overpowering now.

4. Press PARTIAL CHORUS (the unlabeled button in the upper half of panel five). Dial in a ratio of 0.500 to add the octave below the fundamental of this partial timbre (which is itself an octave below the other partial timbres). Listen to the full string sound, with a contrabass added to the cello and violins.

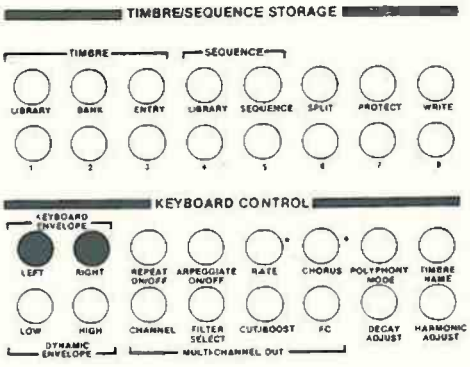
Keyboard Envelope

The keyboard envelope function allows you to place a partial timbre on a particular section of the keyboard. You can place different partial timbres of a whole timbre on overlapping or separate sections of the keyboard. For special effects, you can assign completely different sounding partial timbres to different sections of the keyboard. Or you can use this feature to develop whole timbres, such as piano or strings, that may be played up and down the keyboard with authenticity throughout.

The section on the keyboard to which a partial timbre is assigned is called the keyboard envelope. It consists of three parts:

- the full volume region;
- the upper tapered region or keys above the full volume region where the sound is softer the higher you play;
- the lower tapered region or keys below the full volume region where the sound is softer the lower you play.

The keyboard envelope is set using the KEYBOARD ENVELOPE buttons under KEYBOARD CONTROL in the fourth panel.



To set the upper limit of the keyboard envelope,

1. press the button labeled RIGHT under KEYBOARD ENVELOPE in the fourth panel and hold it down while you. . .

2. . . . press one key or two.

If one key is pressed, the upper limit is defined as a straight cut-off point. If two keys are pressed, then an endpoint plus an upper fade-out region is defined.

To set the lower limit of the keyboard envelope,

1. press the button labeled LEFT under KEYBOARD ENVELOPE and hold it down while you. . .

2. . . . press one key or two.

Again, if one key is pressed, the lower limit is defined as a straight cut-off point. If two keys are pressed, then an endpoint plus a lower fade-out region is defined.

You can also use the control knob to dial a number or two numbers designating the upper and lower limits and fade-out regions. The numbers can be outside the keyboard range.

Keyboard Envelope

1. Continue with Timbre 1-1-4. Partial Timbre 1 was tuned to 220 with a chorus effect an octave lower than that in the last exercise.

2. Solo Partial Timbre 1.

3. Press KEYBOARD ENVELOPE LEFT and hold it down while you. . .

4. . . . press the C two octaves below middle C and the A below that. The notes can be played separately or simultaneously.

5. Press KEYBOARD ENVELOPE RIGHT and hold it down while you. . .

6. . . . press G below middle C and G above middle C.

7. Play the partial timbre through its full range.

8. Solo Partial Timbres 2, 3, and 4.

9. Press KEYBOARD ENVELOPE LEFT and hold it down while you. . .

10. . . . press G above middle C and G below middle C.

11. Press KEYBOARD ENVELOPE RIGHT and hold it down while you. . .

12. . . . press the C two octaves above middle C and the C above that.

13. Unsolo the three partial timbres and play a series of notes, using the full range of the keyboard. In the bass range, you will hear only the cello and contrabass, both of which will fade on the lowest notes. In the treble range, you will hear only the violins. In the middle range, you will hear the full string sound.

CREATING AND MODIFYING THE WHOLE TIMBRE

Up to four partial timbres can be combined to create a whole timbre. You can mix sounds with different waveforms, different volume and harmonic envelopes, different tunings, different portamento rates, different vibratos, and so on.

You have already encountered some of the ways partial timbres can be combined, such as

- tuning some partial timbres above or below the fundamental while others are tuned precisely at 440.0, as in Timbre 1-1-4;
- layering several entirely different sounds, as the piano, harpsichord and octave trill of Timbre 1-2-6;
- placing each partial timbre on a different portion of the keyboard as you did with Timbre 1-1-4 in the last exercise of the previous section.

Other ideas for combining partial timbres will emerge as you work with timbres.

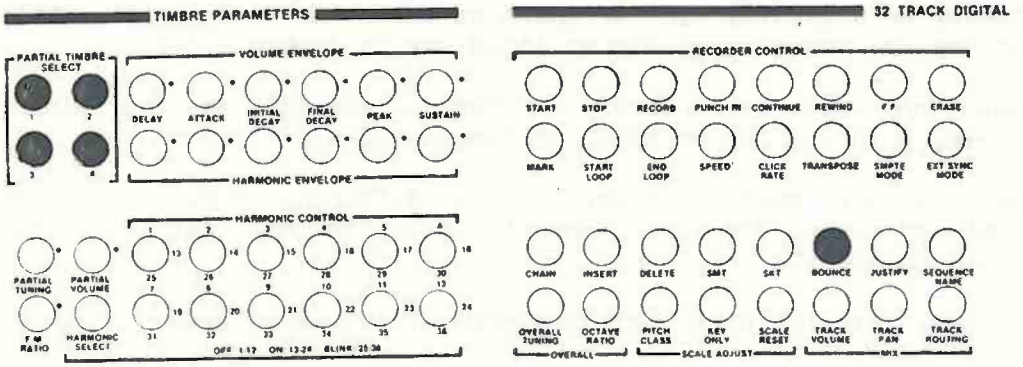
Once you have built your complete timbre by combining several partial timbres, you can modify the entire timbre by adding a chorus effect, creating an arpeggio or repeating function or controling the keyboard polyphony.

Here is a summary of the buttons used to create and modify the whole timbre:

BUTTON	USE	FUNCTION
BOUNCE	Press once, press PARTIAL TIMBRE SELECT buttons	Copies parameters of one partial timbre onto another
CHORUS	Press once, turn knob	Establishes and tunes overall chorus effect
REPEAT ON/OFF	Press once	Turns on or off repeat mode
ARPEGGIATE ON/OFF	Press once	Turns on or off arpeggiate mode
RATE	Press once, turn knob	Changes repeat and/or arpeggiate rate
POLYPHONY MODE	Press once, turn knob	Specifies number of notes a timbre may play simultaneously
TIMBRE NAME	Press once, turn knob	Selects character for timbre name

Building the Complete Timbre

Sometimes you will build a complete timbre by selecting each partial timbre and programming it separately. Other times you may want to use several basically similiar partial timbres with a few variations. In this case, you use the PARTIAL TIMBRE SELECT buttons in the first panel and the BOUNCE button in the second panel to replicate all the settings of one partial timbre onto another. Once the partial timbre has been duplicated, you can make minor changes in each.



To copy the settings of one partial timbre onto another,

1. press the BOUNCE button;

2. select the partial timbre you wish to copy from;

3. select the partial timbre you wish to copy to.

You can erase, or deactivate, a partial timbre quickly with the BOUNCE button as well. To do this,

1. select a partial timbre and set its VE peak and sustain levels to zero;

2. bounce this inactive partial timbre onto the partial timbre you wish to erase.

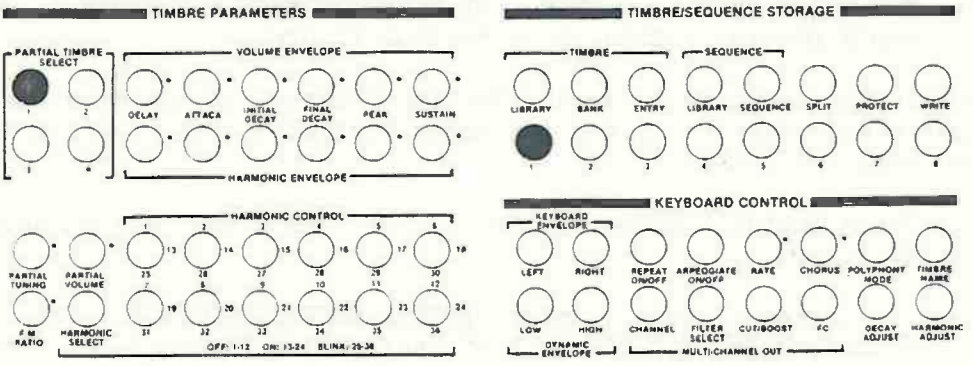
You can also recall a partial timbre from another timbre in the same bank as the keyboard timbre and add it to the keyboard timbre.

To do this, you must first make sure that the partial timbre of the keyboard timbre onto which you are placing the recalled partial timbre is "inactive," that is, has zero VE peak and sustain settings.

Then you

1. press the numbered button under PARTIAL TIMBRE SELECT corresponding to the number of the partial timbre you want to recall and hold it down while you . . .

2. . . . press the numbered button under TIMBRE/SEQUENCE STORAGE of the timbre from which you want to recall the selected partial timbre.



The partial timbre with the same PARTIAL TIMBRE SELECT number will be recalled from the timbre selected and placed into the empty partial timbre slot of the keyboard timbre.

In this way you can build up new combinations of partial timbres from the same bank.

Combining Partial Timbres

First, you are going to move Partial Timbre 1 into the space for Partial Timbre 2.

1. Recall Instruction Timbre 1-1-8. This timbre has a single partial timbre with 14 timbre frames.

2. Press BOUNCE.

3. Press Button 1 under PARTIAL TIMBRE SELECT.

4. Press Button 2 under PARTIAL TIMBRE SELECT. Both Partial Timbre 1 and Partial Timbre 2 will now have the trumpet timbre. Solo each one to check this out.

5. Now erase Partial Timbre 1 by bouncing Partial Timbre 3, an empty partial timbre, onto Partial Timbre 1.

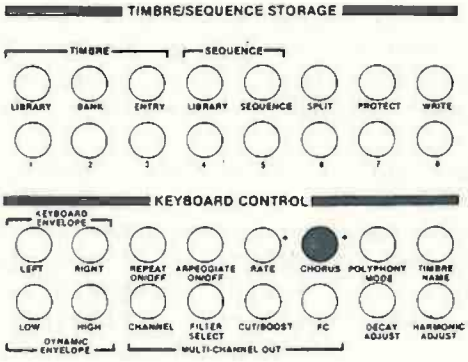
Next, you are going to recall Partial Timbre 1 of the sine wave timbre and place it in the now empty Partial Timbre 1 slot of the keyboard timbre.

6. Press Button 1 under PARTIAL TIMBRE SELECT and hold it down while you. . .

7. . . . press Button 1 under TIMBRE/SEQUENCE STORAGE. This transfers Partial Timbre 1 of Instruction Timbre 1-1-1 (the sine wave) into the now empty Partial Timbre 1 of Instruction Timbre 1-1-8. Solo each partial timbre to check this out.

Adding Chorus

Previously you added chorus to a single partial timbre. You can also activate a chorus function to reproduce all the active partial timbres on additional synthesizers by using the CHORUS button in the fourth panel.



You can create a doubling effect, with the sound of several similar instruments playing the same note with either in exact unison or with slightly different tunings to replicate a group of first violins, for example. Or you can add the extra voices to reinforce a particular harmonics or to create parallel harmony. You can also dial in a completely inharmonic relationship.

The chorus ratios are the same as for the partial chorus function described in the previous section. That is, a setting of 1.000 tunes the added chorus to the fundamental, a setting of 2.000 the second harmonic or an octave above the fundamental, a setting of 3.000 the third harmonic or a fifth above the octave and so on. (See "Adding Chorus" in the previous section for the table of harmonic ratios.)

When you use the chorus effect, you double the number of voices required to play the timbre. A timbre with one partial timbre with chorus will require two voices. A timbre with two partial timbres with chorus will require four voices, and so on.

To activate the chorus function,

1. press CHORUS;

2. turn the control knob to set the chorus ratio, or interval.

You can dial any ratio from 0.000 to 10.000. To return the setting to 1.000, or unison, press CHORUS again.

Chorus

1. Recall Instruction Timbre 1-1-8 again.

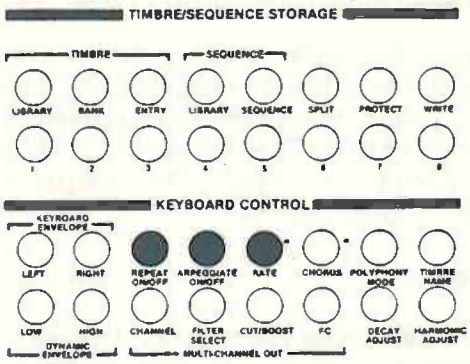
2. Press the CHORUS button and experiment with settings between 0.990 and 1.010. Play some rapid notes and then a sustained note. Listen to the effect the two close frequencies have on each other. This is called "beating" and is similar to what happens in frequency modulation.

3. Now dial a 0.125 setting to add a tuba (three octaves lower than the fundamental) to the trumpet sound. You will need to play in the middle range or above since the chorus is three octaves below the fundamental. If you play A below middle C, for example, the chorus fundamental will be at 27.5 hertz, at the lower threshhold of hearing.

Adding Repeated Notes and Arpeggios

The repeat and arpeggiate functions cause multiple notes to be triggered by each pressing of a key. With the repeat function alone, the same note or chord will be repeated at the established rate, over and over until you take your finger off the key or keys. With the arpeggiate function alone, pressing two or more keys will cause the notes to sound one after another at the established rate. Combining the two functions creates repeating arpeggios.

You program the repeat and arpeggiate using the REPEAT ON/OFF, ARPEGGIATE ON/OFF and RATE buttons under KEYBOARD CONTROL in the fourth panel.



To activate the repeat mode,

1. press REPEAT to turn on the repeat function;

2. press the RATE button and dial the desired rate, from 0.00 to 100.0 hertz.

To activate the arpeggiate mode,

1. press ARPEGGIATE to turn on the arpeggiate function;

2. press the RATE button and dial the desired rate, from 0.00 to 100.0.

The same rate button is used for both functions. If both REPEAT and ARPEGGIATE buttons are lit, the arpeggio will be repeated at the rate established so long as you hold down the keys.

As you learned in the previous section, repeats and arpeggios can be recorded in the memory recorder just as they sound in real time.

Repeat and Arpeggiate

1. Recall Instruction Timbre 1-2-4. This vibes timbre has been programmed with a repeat/arpeggiate rate of 10.79 hertz.

2. Press REPEAT to turn on the repeat function. You will notice that as soon as you lift your finger, the repeat will stop and the note will go into final decay.

3. Turn off the repeat function by pressing REPEAT.

4. Press ARPEGGIATE. Press several keys and hold them down. The notes will arpeggiate at the established rate.

5. Press RATE and change the rate setting to 5.00 hertz. Try hitting a large chord with both hands all at once. No matter how fast you press the keys, the notes will always arpeggiate at the set rate. The notes will be played in the order that you press the keys. The computer can always pick this out, even if you can't.

6. Now press REPEAT again.

   The notes will continue arpeggiating at the set rate as long as you hold down the keys. As you press more keys, those notes will be added to the arpeggio. If you lift your finger from a key, that note will be subtracted.

Keyboard Polyphony Control

With the keyboard polyphony control function, you can limit the number of notes that can be played at the same time on the keyboard or on a specific memory recorder track.

Most of the timbres on the system diskette are programmed to be fully polyphonic on the keyboard. With these timbres, you can simultaneously play notes until you use up all the voices in your system. Thus, the maximum keyboard polyphony depends on both the number of voices in your system and the voices used in the keyboard timbre.

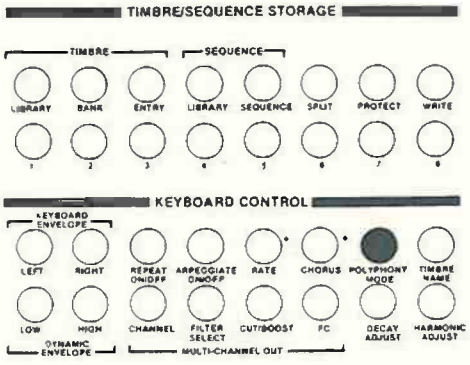
With maximum keyboard polyphony, the system will play any new note by assigning it to unused voices. If there are not enough unused voices to play the note, the system will try to free up voices by cutting off any notes in final decay. If there are still not enough voices, the new note will not play and bars will appear in the display window.

Timbres can be programmed for less than maximum keyboard polyphony. A polyphony number of 1 makes the timbre monophonic on the keyboard. As you learned in the introduction, each new note will cut off the previous note in monophonic timbres. You will be able to play clean trills or other fast sequences, even if the timbre has many timbre frames or a long final decay. But you will not be able to play a chord.

To activate the polyphony control, you

1. press POLYPHONY MODE in the fourth panel;

2. dial the number of desired simultaneous notes with the knob.



Keyboard Polyphony Control

1. Recall Instruction Timbre 1-2-4 again. The timbre has a final decay of over two seconds.

2. Press POLYPHONY MODE. The polyphony number appearing in the display window should equal the number of voices in your system.

3. Play some notes rapidly and listen to the overlapping final decays.

4. Now dial in a keyboard polyphony control setting of 1 to make the timbre monophonic on the keyboard.

5. Play some more rapid notes and listen. Only one key will sound at a time. Each succeeding note cuts off the preceding note. Only the last note played will have full final decay.

6. Hold down a key while striking another. The sound of the first will cut off as soon as the second is pressed.

7. Now dial 2 and experiment with scales and arpeggios. At any one time only two voices will be heard. When you play the third note in a sequence, it will cut off the first.

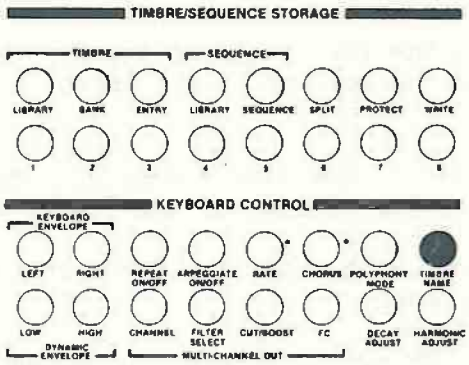
Timbre Name Entry

Once you have built a complete timbre, you may want to give it a name that will be stored with it when you save the timbre. Once a name has been entered, it automatically appears in the display window whenever the timbre is called up.

To activate the timbre name function, you

1. press the TIMBRE NAME button in the fourth panel and release it;

2. select up to 16 characters using either the control knob or the keys on the terminal.



When you press TIMBRE NAME, the current timbre name, if any, will appear in the upper half of the display window. The first character of the name will be flashing, ready to be changed. If no name has been entered for the current timbre, the window will be blank and there will be a blinking underline. The flashing character or blinking underline is the equivalent of a cursor on the terminal video display.

To select characters with the control knob, you

1. turn the knob until the character you want appears in the display window;

2. press TIMBRE NAME again and release it to move the blinking cursor one space to the right;

3. repeat steps 1 and 2 until the timbre name is complete.

To delete a character, turn the control knob all the way to the right.

To move the cursor forward to any character in the name, press TIMBRE NAME repeatedly. At the end of 16 spaces, the cursor will wrap around to the beginning character or space. You can also move the cursor forward or backward rapidly by holding down TIMBRE NAME while you turn the control knob. In this case, however, the cursor will not wrap around when you come to the end of the 16 spaces.

To select characters at the terminal, simply type in the characters on the terminal keyboard. Use the DELETE key to erase a character and the cursor control arrows to move back and forth within the name. Use the spacebar to enter spaces and press RETURN to return the cursor to the beginning of the name.

Timbre Name

1. Recall Instruction Timbre 1-2-6. The name

   3 PARTIALS!

   will appear in the lower half of the display window. Play a few notes on the keyboard and think up a new name for the timbre.

2. Press TIMBRE NAME. The timbre name will move to the top half of the display window and the 3 will be flashing.

3. Turn the control knob until the first character of your new timbre name appears.

4. Press TIMBRE NAME again. The space between the new character and "PARTIALS" will have a blinking bar. Dial in a new character.

5. If you have a terminal keyboard, press the left arrow key. The P of "PARTIALS!" will begin to flash.

6. Type in a new character, using upper or lower case.

7. Complete the new timbre name using either the terminal or the control knob.

COPYING AND STORING TIMBRES

No matter how many modifications you make on a timbre, you can always return to the original sound by recalling the timbre from the diskette again. But, once you have created your own timbres, you will want to store your own new sounds so that they, too, can be recalled.

This section explains how to store timbres on storage devices and how to copy them from one diskette to another.

Here is a summary of the buttons used for copying and storing.

BUTTON	USE	FUNCTION
*TIMBRE LIBRARY	After selecting BANK and ENTRY, press and hold, then press Button 1-8	Accesses F1 drive for timbre storage or recall
TIMBRE BANK	Press once, then Button 1-8	Places selected timbre bank into computer memory
TIMBRE ENTRY	Press once, then Button 1-8	Recalls selected timbre from bank onto keyboard
WRITE	After selecting BANK and ENTRY, press and hold, then press Button 1-8	Writes currently active bank or entry to the specified location on the storage device
**PROTECT	Press once	Turns on or off the protection state of the current timbre bank or entry

*In future releases, the TIMBRE LIBRARY button will be used to access up to eight different storage devices.

**The PROTECT button will be functional in future releases.

Storing Timbres

You can store a new timbre on any of the timbre diskettes or system diskettes. However, if you store a timbre in a space occupied by another timbre, the original timbre will be erased in the process.

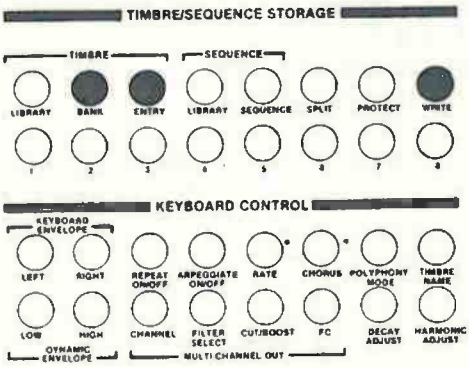
The diskette labeled

> Master Timbre Diskette
> COPY THIS DISKETTE

contains an empty timbre storage area for storing new timbres. The storage area is divided into eight banks, each of which can hold up to eight timbre entries. The actual number of timbres that can be stored in each bank depends on the amount of the storage space each timbre takes up. Timbres with a lot of programmed parameters will take up more space than ones with fewer parameters.

The Master Timbre Diskette is write protected; that is, you cannot store anything on it. Instead, you use it to make copies of the timbre storage area onto blank formatted diskettes. To do the format and copy procedure, you will use the diskette labeled "Format & Duplicat for Synclavier." Instructions for using this diskette are in the Appendix to "Synclavier (R) User's Guide."

Once you have a timbre diskette ready for storing new timbres, you can store any new timbre active on the keyboard. You will do this using the TIMBRE BANK and ENTRY buttons and the WRITE button under TIMBRE/SEQUENCE STORAGE in the fourth panel.



To store a timbre that is active on the keyboard,

1. remove the system diskette;

2. insert the timbre diskette where you want to store the sound into the MAIN drive;

3. press the TIMBRE BANK button and the numbered button of the bank where you wish to store the timbre;

4. press the TIMBRE ENTRY button;

5. press the WRITE button and hold it down while you. . .

6. . . . press the numbered button of the space where you want to store the timbre.

None of these procedures will affect the keyboard timbre.

The new timbre will be stored on diskette and can be recalled from that bank and entry at any time. Whatever was there before, however, has been erased, so be careful when you choose the location for storing a new sound.

Be sure to press the WRITE button before you press the TIMBRE ENTRY button. Otherwise, you will recall that timbre to the keyboard and lose the keyboard timbre you wanted to store.

When you store a timbre, you store all the information about the timbre, including

- the harmonic structure of the steady state wave;
- the volume envelope;
- each timbre frame's harmonic structure and volume envelope;
- all FM parameters;
- all partial timbre special effects (vibrato, portamento, stereo, tremolo, tuning, volume, chorus, final decay, keyboard envelope);
- all modifications of the complete timbre (chorus, arpeggiate or repeat function, polyphony);
- keyboard control settings such as special scale tunings or the octave ratio (see the tabbed section, "Keyboard Control/Real-Time Effects");
- the timbre name.

If you try to store a timbre or timbre bank onto a diskette that contains no special timbre storage space,

SYSTEM FILE IS MISSING

will appear in the display window.

Since each timbre takes up a different amount of space, you may not be able to store a timbre in a space that appears empty. In this case, when you attempt to store the timbre,

NOT ENOUGH ROOM FOR TIMBRE

will appear in the display window.

You may want to keep a special working diskette just for developing timbres. As you make modifications, you store each change on the working diskette so that you can always return to a previous stage in the development. Once the sound is finalized and ready for use in performance, you can transfer it to a permanent place in your libary of timbres.

For further insurance, it's a good idea to make duplicate copies of any diskettes containing valuable timbres. To do this, use the diskette labeled "Format and Duplicat for Synclavier." Instructions for using this diskette are in the Appendix to the "Synclavier (R) User's Guide."

Copying an Entire Bank of Timbres

You can also copy an entire bank of sounds from one diskette onto another. To do this,

1. press TIMBRE BANK and the appropriate number button to place the bank you wish to copy in computer memory;

2. remove the diskette from the disk drive and replace it with the diskette on which you want to store the bank;

3. press TIMBRE BANK;

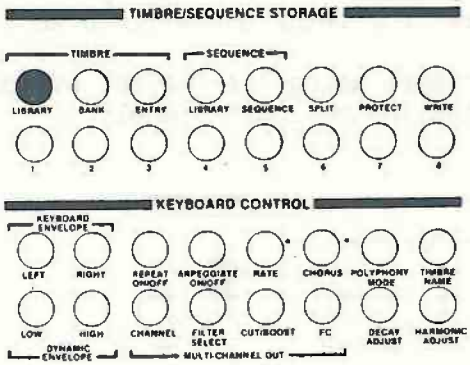
4. press the WRITE button and hold it down while you. . .

5. . . . press the number button under TIMBRE/SEQUENCE STORAGE corresponding to the bank location you want to copy to.

Once the disk motor has stopped, the entire bank of eight timbres will be stored in the new bank.

Storing Timbres on Other Storage Devices*

In a dual drive system, you can store timbres on the diskette in the AUXILIARY drive by using the TIMBRE LIBRARY button under TIMBRE/SEQUENCE STORAGE in the fourth panel.



To store a timbre on the diskette in the AUXLIARY DRIVE,

1. press TIMBRE BANK;

2. press TIMBRE LIBRARY and hold it down while you . . .

3. . . . press the numbered button corresponding to the bank where you want to store the new timbre;

4. press TIMBRE ENTRY;

5. press TIMBRE LIBRARY and hold it down while you . . .

6. . . . press WRITE and the numbered button of the space where you want to store the timbre.

You can also store an entire bank on a timbre diskette located in the AUXILIARY drive. To do this,

1. place the timbre bank you want to store in computer memory;

2. . . . press TIMBRE BANK;

3. press TIMBRE LIBRARY and hold it down while you . . .

4. . . . press WRITE and the numbered button of the bank location that you want to copy to.

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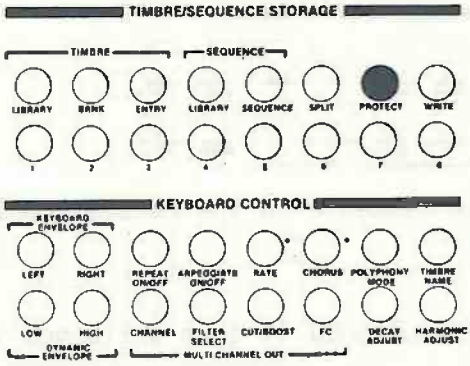
*In future releases, you will also be able to store timbres in different areas on the Winchester disk using the TIMBRE LIBRARY button.

Protecting Timbres From Overwriting*

When you store a timbre or a bank of timbres, you will completely overwrite any timbre or bank of timbres previously stored in that space on the diskette. In future releases you will be able protect either a single timbre from being overwritten accidentally.

You write protect a timbre using the PROTECT button under TIMBRE/SEQUENCE STORAGE in the fourth panel.



To write protect a timbre,

1. place into computer memory the bank containing the timbre you want to copy;
2. press the PROTECT button;
3. press WRITE, then TIMBRE ENTRY and the number button.

To protect an entire bank from being overwritten accidentally,

1. press PROTECT;
2. press TIMBRE BANK and the numbered button of the bank you want to copy;
3. press WRITE, TIMBRE BANK and the numbered button the bank onto which you to copy.

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*The write protect function will be available in future releases.