The Fairlight CMI is a portable music development and performance system which is manufactured in Sydney, Australia. It is available in several configurations, each with its own set of features and capabilities.

The standard hardware configuration consists of a high-resolution graphics display with light-pens, an alphanumeric keyboard, a six-octave music keyboard and a processor module. The system includes a computer and two eight-inch floppy disk drives. The audio output is created by eight "Viole-Cards" which each control 256 bytes of dedicated waveform memory and a digital-to-analog converter.

The system will function in a number of different modes which are selected and controlled through graphic displays. Its main capabilities include:

* SAMPLING OF SOUND
* ADDITIVE SYNTHESIS
* GRAPHIC MANIPULATION OF WAVEFORMS
* REAL-TIME KEYBOARD PERFORMANCE
* FLUSH-DISK STORAGE OF ALL DATA
* COMPOSITION LANGUAGE

This paper will describe in some detail the sound creation and manipulation features of the Fairlight CMI.
Any page may be selected by typing "for" (5.0, 15.)
The page concept allows rapid access
to many levels of control.

**ORGANIZATION : WAVEFORM MONKEY**

The CMI has eight audio outputs, or
channels, eight printed circuit
boards called Voice Cards, provide
separate 1/4 converters and
controlling circuitry for each
channel. Each card has a 16 Kbyte
memory, called waveform memory.
Sound is stored in this memory in
the form of digital samples.

When a note is pressed on the
Fairlight, the processor tells the
appropriate voice-card to start
outputting its waveform memory to
the dac. The sample rate is
scaled in proportion to the desired
frequency of the sound. The
amplitude is controlled by a ramp
function feeding the multiplying
input to the dac. The Fairlight
does not, technically speaking,
synthesize sounds in real-time; it
plays from memory. This technique
does emulate the digital look-up
oscillator, but is closer to
digital-sampling. Sounds are not
reconstructed from elemental
material in real-time. The beauty
of this method is that arbitrarily
complex sounds may be produced
in performance, without the limits of
computer time or matter of
oscillators.

**LOOPING**

One obvious limitation of a variable
sample rate technique is that the
memory is used up quite quickly on
high pitched sounds, where the
sampling rate is very high (e.g. in
one second at a 16 K sampling rate).

A possible solution would be more
memory, but we would still be hosed
with quick taps when we wanted
maintained tones. The CMI attacks
this problem through the use of
looping.

The 16 K waveform memory is divided
into 128 segments (each segment
contains 128 samples). Any
segment or group of segments may be
specified as the loop, indicating
that that portion will be output
repeatedly, as long as the key is
held down. When the loop is a
single segment, the result is a
steady-state tone. The spectrum of
the tone is that of the looped
waveform. When the loop is a
group of segments, complex non-harmonic
tones or textures can be extended in time.

In addition, a special output note
allows separate duration values for
each segment (multiple loops). This
feature allows the internal
progression in a sound to remain
counter in time, while being
transposed in frequency.

A large class of sounds exist which
fit nicely in the waveform memory, e.g.
persuasive sounds, with no need
for looping. There are also certain
sounds which suffer greatly in the
context of life, and the loop
isn't worry about competition from
this instrument. In general, the
Fairlight offers an enormous palette
of sounds to the musician, but it
can't do everything. Like a camera,
the CMI becomes transparent to the
viewer, with no characterizing sound
of its own. It is inherently
richer is sound material than any
form of synthesis.

566
There are three distinct ways of generating data in waveform memory.

1. SAMPLING OF EXTERNAL SOUND

2. ADITIVE SYNTHESIS

3. DRANIKS WAVENUMBER WITH THE LIGHT-PIST

Once a waveform segment or group of segments has been created, they may be manipulated further with the commands on page 6: mixing, merging, filling, reverse and rotation.

1. SAMPLING OF EXTERNAL SOUND

The Fairlight has the ability to sample audio signals from a microphone or line input. These signals are processed by an adjustable anti-aliasing filter and analog to digital converter.

Care must be taken in the sampling of pitched sounds, since looping takes place on segment boundaries. It is desirable for periodic waveforms to fit neatly into segments (100 sample groups). Thus a sampling rate must be determined, based on the fundamental frequency of the sound, and its length. A chart in the manual indicates the sample rates for normal equal-tempered pitches in various octaves (F128). A bit of filling with the sampling rate is usually required, so that waveforms line up with segment boundaries. Otherwise, a loop will "click" when it jumps back to a previous sample with a radically different amplitude.

Audio sampling gives the musician a real-time control over acoustical materials. "Sound objects" and elements of chance become plastic and predictable. Experimentation is interactive, not a laborious process of cutting tape or waiting for the "printout". This is probably the most powerful feature of the instrument.
HARMONIC PROFILES (P4)

HARMONIC FADEs (P5)

SYNTHESIZED WAVEFORM

Additive Synthesis: Two Ways of displaying harmonic content of a sound, pages 4 and 5. P5 can be scrolled to show any segment.

2. ADDITIVE SYNTHESIS (Page 4 & 5)

Waveform segments may be generated by specifying the strength of the harmonics. Page 5 shows the user a set of 32 'Harmonic Faders' on the screen, which represent the first 32 harmonics of the selected waveform. Every waveform segment has its own set of these 'faders', which can be manipulated with the light-pen, specified numerically, or copied from another segment of the same sound. A composite waveform is then generated and written into waveform memory when the command 'Compute' is hit with the light-pen. The resultant sound may then be played on the keyboard for evaluation.

Page 4 gives an alternative view of the harmonic faders. In vertical lines across the screen represent the first 32 waveform segments. The strength of a harmonic in consecutive waveforms is plotted by a line graph. Essentially an envelope, 'Up/Down' calls these displays 'Profiles'. The user selects those profiles we wishes to view superimposed (up to 3). It is quite simple to draw profiles by hand of arbitrary complexity.

Most of the time page 4 profiles are used to create mode one sounds. Mode 4 is the arbitrary crescendo output mode by which waveform memory is read out serially, in a continuous stream of samples. As the sound is made-up in pitch, it decreases in duration. Mode 1 is an alternative algorithm which involves a segment duration value for each waveform segment. Essentially, each segment is repeated for a specified time period; then the next waveform is cycled, then the next. Since mode 1 is an output method, required sounds may be converted to push 1 for modification. This mode also uses independent amplitude ramps for each segment. The amplitude value and the duration value may be displayed as profiles on page 4.
3. WAVEFORM DRAWING

Page 6 controls many of the Fairlight's most unique functions. It allows the user to draw waveforms on the screen, or modify existing waveforms with the light-pen. A set of commands allows manipulation of the segments. In brief these are:

Display the specified waveform segment or series of segments. The time versus amplitude graph of any of any of the 128 segments of waveform memory is shown on the screen. These may be flashed in sequence automatically, creating an animated view of the waveform.

Fill the specified waveform segment or segments with the segment currently displayed. This command allows a drawn waveform to be placed in memory, or the memory of waveform segments between different voice files.

ZERO Set all points of the displayed segment to zero.

REFLECT
MEME Interpolate between any two segments graphically. This command creates a smoothly changing set of waveforms between any two waveforms.

MEI adds the last specified waveform segment in increasing proportion to the previous segments. Unlike merge, the in between segments retain use amount of their original contents.

REVOLVE The order of all the samples in waveform memory.

REFLECT Fills all memory after a specified segment with a mirror image of the memory before that segment.

ROTATE Left or right: Move waveform memory forward or backward on itself. Segments that fall off the end reappear at the other end.

JOG-FLIP all segments may be viewed simultaneously in perspective with the first segment in front. This command does not affect the sound, but may be very valuable in assessing the results of sampling and manipulations.

Page 6 is quite useful in creating textures with both its electronic and an acoustic quality. One can, for example, merge from an acoustic to a synthesized waveform; then going into the first few segments with the lightwave, add percussive raise or snip to the attack. The page 6 commands form a powerful signal processing library for the CM1.

PERFORMANCE CONTROLS

(Page 3 & 4?)

The Fairlight may be operated from the music keyboard as a polyphonic instrument. A sophisticated sequencer is included which can simultaneously record and playback up to 8 "tracks". The music composition language offers the editing and playing of scored music. All of these performance modes use the basic instrument definition on page 3 to determine the pitch and voice of every note. A keyboard map shows 8 hypothetical keyboards which are each assigned registers. Registers are then defined by their degree of polyphony ("polyphony") and their tuning, in octaves, semitones and cents. Finally the voice registers are loaded with the voice files from the disk. For example if a split keyboard were desired, the user would define two registers, A and B, and assign them to the top 3 and bottom 3 octaves of keyboard 1. The polyphony of each register would be set to 4, thereby using all output channels. Then a voice file is loaded into each register, which fills the waveform memory of the voice card allocated to that register. Up to 8 separate registers may be set up, or one with 8 note polyphony. It is also possible to have more than one voice activated from one keypress. All performance on the CM1 use the keyboard map to determine the assignment of notes to channels. Physically only two keyboards may be attached; the other six are software images which the sequencer and composition language may play upon. Keyboard scale is also programmable, with the novel default values of the 12th root of 2. The entire definition of page 3 may be saved
and recalled as an 'Instrument file', enabling it will cause all the voice files to be loaded.

The other control page on the CMI is page 7. Originally envisaged as a switch patch-panel, it now displays a list of the real-time control parameters. Every voice has a copy of page 7 of its own. The user plays constants or names of variables into the functions listed. Three slide pots and two switches, mounted to the left of the music keyboard, can be assigned control of non functions.

The functions and their valid values are:

Modes (0 or 1) output mode or desired styles.
Sustain (on, off or switch) determines whether a voice plays out completely or stops when the key is released.

Amplitudes (+ or - 355 or key velocity or front panel pot) 1 Sample release time in milliseconds.

Attack (number or key velocity) Attack time in milliseconds.

Filter (-1 to 15) Fine tuning of low pass filter that shapes the output.

Vibrato Intensity (number or front panel control)
Vibrato Speed (number or front panel control)
Portamento (on, off or front panel switch)
Glissando (on, off or switch) Vibrato (on, off or switch) on slide time is made constant between any two notes.

Offset, Decay time in constant, so time will increase with the interval between notes.

Inputs on the back of the keyboard may be used for additional switches and controls.

SEQUENCER

The Sequencer on page 9 runs on a video pulse which we are generating internally or taken from an external source. The internal pulse may be adjusted, but not while the sequencer is recording or playing.

Each of the eight 'tracks' of the sequencer is directed to one of the eight keyboards on page 3. By changing either this mapping, or by changing the register assignments on page 3, we recorded tracks can be played on any voice. Operation is very simple since input and output files have been designated. The user chooses the track he wishes to record on. The real keyboard is thereby mapped through the track and plays on the hypothetical keyboard assigned to that track. The familiar sequencer RECORD and STOP control the sequencer. All recorded tracks are played back, while all new Impressions are recorded, including velocity information. The CMI can access the disc during recording for virtually infinite storage.

MUSIC COMPOSITION LANGUAGE

MCL is an alpha-numeric language which allows precise definition of a musical performance with minimum effort (except wrestling with the text editor). The default specification and true structure of the language reduce redundant information to a minimum.

Like the sequencer, MCL runs from an internal or external sync oscillator, and plays into the keyboard map on page 3. It allows numerical specification of key velocity, which affects whatever function is patched to it on page 7.
Time increments may be as small as desired (flashing is possible). Any parameter may be assigned a default value which each note will assume unless specified otherwise.

The time structure is in three levels. One "slice" can call on up to eight "parts", each part then calls on any series of "sequences" and tells them which keyboard to play on. The sequence contains the actual note information, but also can contain repeats.

The actual editor for creating these music files is a bit cumbersome compared to a modern sound editor. It is believed that Fairlight is aware of this, and are just balancing out what piece of software wants help first. A nice feature they have just added allows the user to play a singing of notes on the keyboard, and here the alphanumeric names for the keys appear in the music editor (no, not the time values). For a detailed description of MCI, see Gary Chang's paper elsewhere in the proceedings of the 1980 ISCM.

**SYSTEM TECHNICALITIES**

The Fairlight is a powerful micro-computer which is actually sold also as a business computer in Australia. The main processor is made up of two Motorola 6800's operating out-of-phase on the same 68100 block of memory. This architecture allows multitasking by letting the two micro-processors perform separate tasks without interruption. When the MCI is turned on, the operating system is booted from drive A, as different functions are called upon, overlays are loaded from disk. Drive B contains the user's files. It is possible to load voices from disk while playing on the keyboard, this facility is aided by a small command keypad on the right of the main keyboard.

**FAIRLIGHT SOUND DEVELOPMENT**

572
IMPLICATIONS

The Fairlight CMI represents a new approach to the development of music by computer techniques. Unlike large installations in the past, the system simplicity removes programming hurdles from the composer's path. Once a set of human interface controls are mastered, an intuitive dialogue develops between man and machine.

The importance of real-time interaction cannot be underestimated when a musician is dealing with new sound. The cybernetic feedback loop between action and perceived result directly limits speed of learning. In the Fairlight, for the first time, sounds of unlimited complexity may be explored quickly, and new directions taken from perceptions of them.

In addition to making conventional synthesis methods intuitive and interactive, the CMI offers several new techniques for synthesis and control of sound.

Finally, the CMI presents a university the only economical alternative to building a real-time computer music studio from scratch. Through the use of micro-computer technology and (relative) mass production, Fairlight has produced a music development lab at a very low cost. It's features compare to those at the few well-endowed university studios, and may be completely unique. The future will see more composers and designers drawing from the inspiration of the Fairlight CMI.