The SoundLab:
a wearable computer music instrument

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Abstract
This paper discusses the design and implementation of a "wearable" digital musical instrument, compact enough to be carried and operated by a musician while standing. The system is controlled by pitch, amplitude and voltage detectors connected to pressure transducers and pickups. The musician has ready access to controls and displays mounted on the system enclosure or attached to an instrument or controller. Advantages of the system include ease of setup and transportation to a performance.

1 Introduction
The SoundLab is a portable computer music system consisting of an 8-bit microcontroller and an embedded DSP. It was initially developed by the author during a research residency at STEIM in Amsterdam, Holland.

The SoundLab design concepts are inherited from several previous systems. These include two systems whose development the author was directly involved in, the GMP/56K public-domain DSP and the BodySynth biofeedback MIDI controller as well as at the STEIM SensorLab, and the SelectTech HippPC.

The GMP/56K was developed in 1990 by Daniel Kelly and the author. It was sold in kit form as a "DSP Hacker Board". One user of the board, Phil Burk, developed an object-oriented interface for the DSP and the JMSL composition environment, with an accompanying library of DSP code units which ran at the GMP and on Digidesign cards [Burk 1991].

The BodySynth biofeedback MIDI controller was designed by Chris Van Ravels. The MIDI translation from the EMG signals to MIDI was performed by a 68HC11 running the Max-Forth interactive compiler in ROM. The author wrote object-oriented peak detection, envelope tracking, and MIDI output routines. The system was portable and self-contained, and could be easily carried to a rehearsal or concert [Brill 1991].

The SensorLab was developed as a common hardware and software base for many of the electronic music instruments created at STEIM. Its software is configured using a language called Spidey. This language is a "dataflow" language which permits a cause and effect relationship between analog and switch inputs and MIDI output. Its compiled output is downloaded to the SensorLab and acts as its current program [Anderton 1994]. Like the BodySynth, the system is portable and self-contained.

The SoundLab's design was also inspired by a number of "wearable" computers, which are small enough to be carried by the user on a backpack or shoulder-strap and operated while standing or walking. The SelectTech HippPC is a wearable IBM-PC compatible computer which the user operates with a reflective LED display called the Private Eye and a chordic keyboard for one-hand operation. NEC and Carnegie-Mellon University have also developed prototype wearable designs [Nahas 1993].

The SoundLab combines the direct access to sound offered by the GMP/56K with the portability and A/D sensing inputs of the BodySynth and SensorLab. Its name comes from being conceived as a SensorLab with built-in sound generating and processing capabilities.

The author is presently using a Sharp VO-690 electronic organizer as a control terminal, and is able to download Motorola LOD files to the SoundLab, and to control the SoundLab with OnCE-Forth, using the Sharp's terminal emulator capabilities.

2 System Architecture
The system consists of one or more Motorola 56004 DSPs connected to a Siemens 80C55 microcontroller. Unlike most portable music systems, the system is user-extensible. DSP object code can be downloaded to the 56004 in the field and modified using OnCE-Forth, a set of extensions to the resident Max-Forth in ROM.

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The SoundLab owes much of its capability and small physical size to the microcontroller and DSP which runs its software. The Siemens B6C353 consists of an 8051-style core with a variety of useful on-chip peripherals [Siemens 1991]. These include:

- Two more parallel ports than that of the 8051.
- 8 channels of A/D conversion with programmable reference voltages.
- An internal baud rate generator which allows the embedded UART to run at the standard 9600 baud rate using a 12 MHz system clock instead of the standard 11.059 MHz clock.

The Motorola 56004 is a relatively new version of the popular 56001 DSP. Like the 56002, it can run at a clock speed of 40MHz and supports the OnCE debugging port. Its embedded peripherals add features which were lacking in the 56001 [Motorola 1993]. These include:

- The Serial Audio Interface consisting of two high-speed stereo serial audio inputs and three stereo serial audio outputs, all of which directly support the I2S serial audio format in either clock master or clock slave modes.
- The Serial Host Port, a high-speed interface which can communicate with a host computer over I2C or SPI format.
- The External Memory Interface which allows I/O interfacing of the 56004 with up to 2 Mbyte DRAMS. Standard Apple-Style 256k, 1M and 2M SIMMS can be used in the SoundLab.

3 System Software

The newer Motorola Digital Signal Processors, such as the 56002, 56004 and 96000, all use a debugging port called OnCE, which stands for On-Chip Circuit Emulation. This built-in circuitry allows for a less expensive development system. The SoundLab uses this port to download DSP code, to upload and download waveform and coefficient data, and to interactively debug the current stored DSP program.

OnCE-Forth was implemented using the ROM-based Max-Forth which runs on the B6C353 and which acts as the system monitor. Max-Forth is an 8051-based port of the 68HC11 Max-Forth, both developed at Texas Instruments in Dallas, Texas. The B6C353 running OnCE-Forth transmits OnCE commands directly into the OnCE serial format using parallel port pins on the microcontroller. OnCE-Forth's utilities can be broken up into three areas:

- The low-level command code, which is written in assembly and shifts bits from serial to parallel format to and from the OnCE port.
- The data and instruction read/write routines which implement the basic OnCE commands. These include utilises for memory and register dump displays and for setting up memory access breakpoints.
- The LCD parser which reads incoming serial text from a standard Motorola LCD file and writes the data stored in the LCD file into the appropriate memory spaces of the 56004.

The system also includes Forth words for writing to the Serial Host Port interface and reading the A/D channels on the B6C353. The user is able to control algorithms running on the 56004 in real time using voltage inputs to the B6C353 A/D channels.

4 Future Development

The SoundLab is a versatile, self-contained computer music instrument. Additional software for the system is under development. The Forth code on the B6C353 is being extended to include objects similar to those in HML for real-time control of the 56004 algorithms. These include a dynamically patchable multi mode oscillator and delay, waveshaping and pitch shift algorithms. The system has been used at Enoteq by the author for DSP prototyping.

STEIM is at present making a product out of the SoundLab, and has enhanced the hardware by adding a PIC chip for the serial to parallel conversion. A version of the STEIM Spider real-time control language is being extended to control a library of DSP programs on the 56004.

References