

Functional Specifications for the Pace Maker Beat Recognition System

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Dr. Andrew Rawicz
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Re: Functional Specifications for the Pace Maker Beat Recognition System

Dear Dr. Rawicz:

The attached document, *Functional Specifications for the Pace Maker Beat Recognition System*, outlines the requirements of our project for ENSC 340. The goal of this project is to design a portable device that will aid musicians in maintaining desired rhythm and tempo.

This document describes the desired functionality of our system, and the specifications of the various components within the system. The functional components include input signal capture, an embedded DSP system, and a visual tempo display device.

This document will act as a guide to help us coordinate our efforts to complete this project. Should you have any questions or concerns regarding our proposal, please feel free to contact me at (604) 727-9454 or via email.

Sincerely,

Grzegorz M. Misa
VP Engineering
Simplesmart Inc.

Enclosure: Functional Specifications for The *Pace Maker Beat Recognition System*

Executive Summary

One of the two vitally important fundamental elements of music is rhythm. Studies have shown that people respond to and recall the rhythms of their favorite songs as much as they do the melodies and lyrics. Although rhythm is a skill that requires much effort and practice, little effort has gone into building tools to help students and professionals develop their rhythmic abilities.

SimpleSmart stands poised to unleash one of the world's first tools designed to provide real-time feedback to musicians on their rhythm. The Pace Maker is a beat recognition device, which will provide a musician with information on the tempo at which he/she is playing. Although other devices exist to help musicians keep a steady rhythm (such as the metronome), Pace Maker will be the first device to unobtrusively aid a musician's rhythm without imposing a rigid form which they must follow.

This document outlines the performance and operational specifications of the Pace Maker Beat Detection System. Specifically, the proof-of-concept design (planned for production by December 2001) is examined. A system overview and explanation of basic operation and setup is provided. As well, a set of requirements for various components and sub-systems is explored.

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Introduction

The Pace Maker is a real-time musical beat recognition system designed for use by drummers and percussionists. By processing a musical performance in real-time with our embedded beat-tracking software, Pace Maker determines the current tempo of the music and provides this information to the musician in a useful and unobtrusive manner.

The Pace Maker will benefit drummers and percussionists by aiding them in the training of their rhythmic skills and intuition, and by presenting them with greater control over the music they produce.

Applications

- Live Performance
- Studio Sessions
- Music Production
- Drum/Percussion Educators
- Home Study

Preliminary Feature Overview

- Real-time tempo tracking to within 3 B.P.M. (Beats Per Minute)
- Large, bright 3-character tempo display
- Intuitive user interface, offering absolute and relative tempo display modes
- “Built like a tank” to withstand heavy use and abuse

In December, 2001, Simplesmart Inc. plans to produce and demonstrate a proof-of-concept prototype of the Pace Maker system. The production unit will share all of the functionality of this prototype with a few possible enhancements (which will be endorsed or rejected on a per item basis). Possible improvements include:

- Finer tempo resolution (up to 1 BPM)
- Fully integrated MIDI output
- MIDI input
- Microphone preamp and throughput connector

The remainder of this document will outline the basic proof-of-concept design, its functional specifications and operating conditions.

System Overview

The Pace Maker beat detection system will include the following components:

- Main unit containing the processing hardware, tempo display and input/output connectors
- A cymbal stand clamp for supporting the main processing unit
- A trigger input with integrated hi-hat/cymbal stand clamp
- Power adapter and trigger cable

In addition to the included components, a user will require a microphone/microphones, a simple mixer and, of course, a drum set or other percussion instruments. It would also be possible to use the Pace Maker system with an electronic drum kit. In this situation, the microphone and mixer would not be required - the user could simply plug the line-out of the electronic drum sampler into Pace Maker's line-input.

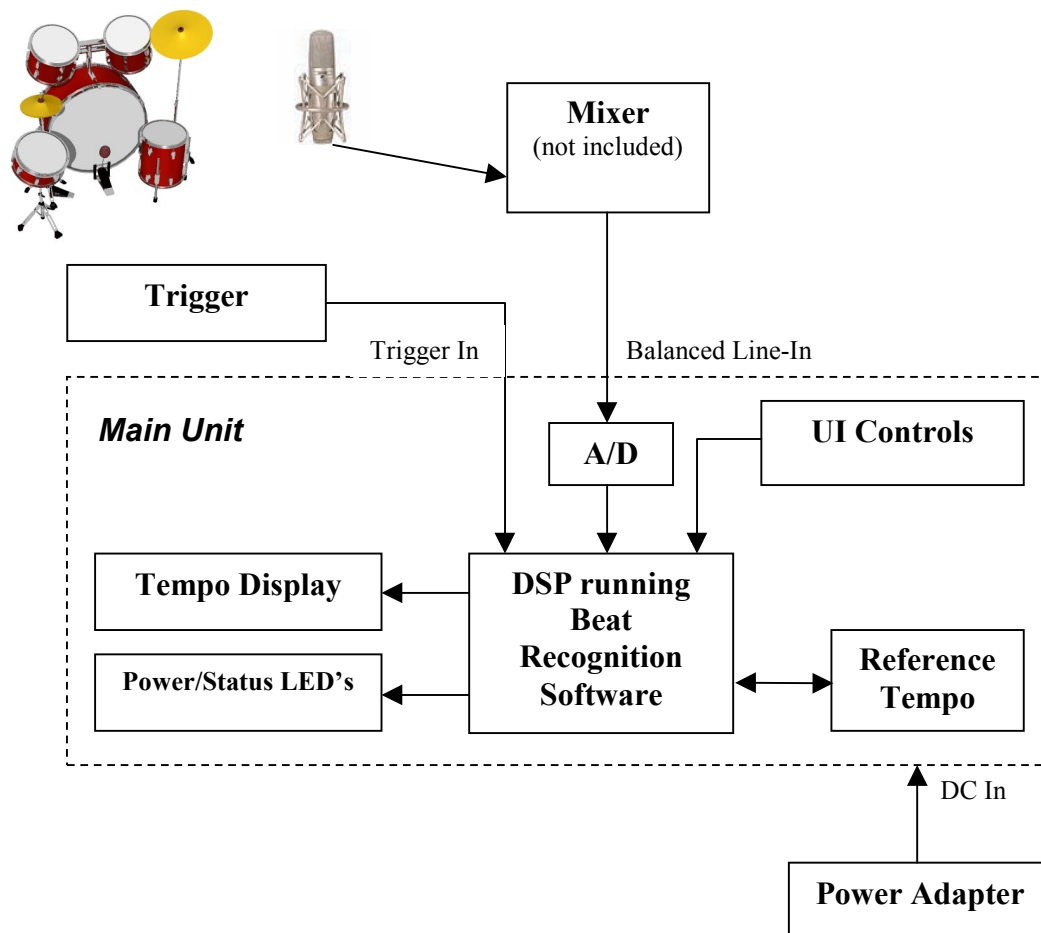


Figure 1: System Overview

System Operation

The Pace Maker system performs one basic function: detecting the tempo of the input sound source (ie a microphone on a drum set) or trigger in real-time. When the trigger is played twice or more in succession, the unit will detect the tempo with which the trigger is played. When the trigger is not being played, the unit will detect the tempo from the input audio source. It's that simple.

Absolute/Relative Mode

The tempo display operates in two modes: absolute and relative. In absolute mode, the unit simply displays the tempo that is detected from the sound source or the trigger, in B.P.M. (similar to how a speedometer in a car displays your absolute velocity). You can play the trigger before starting a song in order to see what tempo you're counting in at. Then when you start the song, you can monitor your absolute tempo.

In relative mode, however, the trigger has a different purpose. When the trigger is played in succession twice or more (within the unit's tempo range), the unit will set the reference tempo to the pulse of the trigger. Then, when an audio source is present, the unit will inform the user if he/she is playing faster, slower or at the same tempo as the reference. This way, the user can set the tempo at the beginning of the song and check back to make sure he/she is not speeding up or slowing down.

If the user wants to re-set the reference tempo in the middle of playing, all that is required is to hit the trigger once. The unit will reset the reference tempo to the currently detected tempo from the input audio source.

User Interface

The user interface shall conform to the following requirements:

- There shall be a dedicated switch for system power up.
- There shall be a button for switching between absolute/relative tempo display
- The display and controls shall be visible with no external light source.
- The tempo display shall be of considerable size in order to provide the musician with clear and visible feedback.
- The tempo display shall have 3-characters in order to represent the full range of possible tempos.
- The tempo display shall be refreshed every time a different tempo is detected.

System Setup

Setting up the Pace Maker system shall be extremely intuitive. The basic setup procedure will include supplying power to the unit, plugging an audio source into the line in jack and plugging the trigger into the trigger input. Once the unit is powered up (via the dedicated power switch), it will begin detecting the tempo of the input audio source. The unit will indicate if no rhythmic audio is present at the input.

When the unit is powered up, the user can select either the absolute or relative display mode and start playing! (Note: the unit defaults to absolute mode on power-up).

Hardware Overview

As shown in Figure 1, the primary unit houses all input/output connectors, the DSP processor, the tempo display (which indicates the beat count) and the UI controls. Input to the system is a line-level signal from a mixer (note: the production unit may also include a microphone input with mic preamp).

Electrical and Mechanical Properties

The system will meet the required electrical and mechanical properties listed in the tables below. The supplied power transformer will operate on 110-130VAC, 50-60Hz and will include a standard North American 3-prong plug. However, units marketed to countries outside of North America will include power supplies appropriate to the supplied AC power of the area.

Table 1: Required Electrical Properties

Operating Voltage:	DC 12V
Operating Current:	Not to exceed 1000mA
Line-Input:	+4/-10 dBu balanced/unbalanced on ¼" TRS connector

Table 2: Required Mechanical Properties

Mean Time Between Failure (MTBF):	Exceeding 100,000 hours
Duty Cycle (all jacks and buttons):	1,000,000 cycles

Physical Properties

The Pace Maker main unit will be constructed from aluminum and steel and shall be extremely strong, to withstand abuse from drumsticks, falling cymbal stands etc. (please see the section on test procedures). The unit will be available in a standard half-rack unit

size so that it may be integrated into a typical audio gear setup. It will also include a cymbal stand adapter so that it may be clamped onto a drummer's cymbal stand for ease of use.

As well, the unit must be able to operate under a wide range of environmental conditions, including excessive heat and extreme cold.

Table 3: Required Physical Properties

Height:	44.3 mm
Width:	213 mm
Depth:	80 mm

Table 4: Required Environmental Properties

Operating Temperature Range:	-20C to 85C
Humidity and Pressure:	Typical humidity and pressure ranges

The trigger shall be a standard peizo-style drum trigger, supplied from an electronic drum trigger manufacturer. It shall conform to the same environmental properties as the main unit.

Given below is a list of hardware requirements that will help determine necessary prototype device.

- DSP chip processes 16 bit floating-point data;
- The embedded DSP system also must have directional link ports, an external port, DMA (Direct Memory Access) channels, registers, at least a 100Kb RAM, glueless multiprocessing integrated on the chip.
- Flexible programming in Assembly and C Languages is a feature of the selected DSP chip.
- High throughput memory bandwidth, executions time at 150MHz, and predicted executions for all the instructions are other features of the DSP necessary to carry out the goal of this project.
- 512k RAM for the DSP is required since a number of memory intensive filters will be implemented in the design (including IIR high, low and band-pass filters and a number of comb filter banks). This memory can be integrated in the DSP chip or it can be externally embedded on the DSP board.
- 12 or 14 bit A/D that converts audio at a rate of 22kHz.

Software Overview

The embedded software shall be firmware upgradeable to allow future versions of the software to be run on the existing hardware platform. The beat-detection algorithm shall conform to the following requirements:

- The unit shall operate in real-time.
- The unit shall respond to tempos within the limits of 60 – 200 B.P.M.
- Tempo detection shall be provided at a resolution of 3 B.P.M.

The detailed implementation of software will be discussed further in the corresponding design document.

Safety

The unit must adhere to safety standards that will help avoid hazardous situations. This includes having vents for thermal dissipation, proper electrical grounding and avoiding sharp features in the metal components.

Reliability & Serviceability

Due to the nature of use, the device must be able to sustain mild, but frequent vibrations for long periods of time. The unit must be able to function continuously for periods that will typically exceed a few hours. In the event of a failure, the unit must recover gracefully in a manner that will not affect or disrupt the performance of a musician. This includes recovery of operational modes and other settings during an unexpected startup.

The unit shall not be serviceable by the end user in any event. Appropriate precautions must be taken to inform and discourage the user from attempting to open the unit. The firmware of the unit shall be upgradeable by the end user. Instructions on servicing and upgrades will be made available to the user via the World Wide Web.

Testing

The unit shall undergo physical, electrical and software related testing. This section describes possible test strategies to ensure the highest level of quality and reliability. Note that the proof-of-concept prototype will not be tested for physical and severe electrical considerations, due to the expense of replacing the DSP board and processor.

The physical tests involve the device being exposed to mild and rough vibrations for long periods of time. The device will also be expected to survive a drop from a height of 5

feet. The display will be exposed to pressures and forces typically exerted by drumsticks. This will help determine the level of impact due to carelessness.

The electrical tests will involve reliability tests under varying temperature and humidity. Also, test for power surges will also be performed. Short circuit protection will also be considered in the design.

The software testing will focus mainly on boundary conditions. Input extremity conditions and corresponding outputs will be tested for error free operation. All independent paths within the software will be tested. The above mentioned both cover white-box and black-box testing techniques. As well, all algorithms will be thoroughly reviewed by each member of the design team for logical errors.

The unit will also undergo integration tests in which the performance and reliability of the entire system will be observed. This will include (but will not be limited to) test by independent end-users in real-life situations.

Potential System Limitations

The Pace Maker shall be limited by the following factors:

- Display cannot be too distracting to the musicians, but must clearly display the tempo information.
- The device can handle only relatively well acoustically isolated signals.
- The system cannot function in the case of power loss.
- The system may not be able to provide required resolution of BPM count due to restrictions imposed by the LED display (possible).
- The system may take a few seconds to reach its steady state value.

Terms

- MIDI:
MIDI (Musical Instrument Digital Interface) is a protocol designed for recording and playing back music on digital synthesizers that is supported by many makes of personal computer sound cards. Originally intended to control one keyboard from another, it was quickly adopted for the personal computer. Rather than representing musical sound directly, it transmits information about how music is produced. The command set includes note-ons, note-offs, key velocity, pitch bend and other methods of controlling a synthesizer.
- BPM:

BPM (Beats per Minute) refers to the number of steady pulse notes that would occur within the frame of one minute (for example, if a pulse note occurred at intervals of one second, the BPM would equal 60).

Conclusion

This document outlines an extensive set of performance specifications and operational requirements for the Pace Maker Beat Recognition System. Though the proof-of-concept design is thoroughly examined, improvements and additions to be made for the production units are also considered. Simplesmart's first rhythm-oriented musical tool has proven an exciting piece of work for the designers and we hope that musicians around the globe will benefit from the technology being developed at this company.