Introduction
This chip is a 64-channel high voltage functional electrical stimulator for rehabilitation of stroke patients. By getting configuration and stimulation data packets through SPI interface of the chip, bi-phasic square waveforms with different amplitude, duration, frequency and polarity can be generated simultaneously for each channel. The function of the chip and the feasibility of FES will be verified in a system based on the proposed distributed network structure. The chip is to be fabricated in a 0.35μm X-FAB process.

Architecture of the chip
- Digital Controller: Distributes configuration words or stimulation data to each local controller through parallel bus according to address information.
- Analog Output: Generates square wave pulses according to the amplitude and frequency information received from local controller.
- SPI Interface: Receives data packets sent by outside unit.

Chip specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td></td>
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<td></td>
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<tr>
<td>Current Amplitude</td>
<td></td>
<td></td>
<td>1</td>
<td>mA</td>
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<tr>
<td>Amplitude Resolution</td>
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<td></td>
<td></td>
<td>μA</td>
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<tr>
<td>Wave Width</td>
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<td>10</td>
<td></td>
<td>ms</td>
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<tr>
<td>Interphase Interval</td>
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<td>200</td>
<td>μs</td>
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<tr>
<td>Pulse Frequency</td>
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<td></td>
<td>100</td>
<td>Hz</td>
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<tr>
<td>Output Mode</td>
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<td></td>
<td>bipolar</td>
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</table>

Structure of digital and analog module
- Power supply: 3.3V, 18V, 90V for different application.
- Timing Generator: Controls the pulse width or frequency.
- Current Mirror: Configurable, implemented with thick oxide transistors and works under high voltage to generate milliampere level current.
- Charge Cancellation: Discharge channel for redundancy charge to reduce the risk of long term tissue damage.

Architecture of the network FES system
- MU (Master Unit): Supervises the whole system, sends control signal and stimulation parameters through a serial bus to DSSUs.
- DSSU (Distributed Stimulation and Sensor Unit): Serves as a single channel stimulator adopting this high voltage chip.

Chip layout of the digital module

Future work
The network FES system on PCB has been verified, and animal experiment will be carried out later. The high voltage stimulator chip is currently under development and being planned to be used in the network FES system as a multi-channel stimulator in human clinical experiments.

Test results of the FES system
The output voltage of DC-DC converter without current load
The waveform of the output stage voltage across a load resistor

The core of MU and DSSU
- Each DSSU is designed as a node in the network, the number of stimulation channels could be easily changed according to specific needs.
- A sensor component can be incorporated in the DSSU to allow monitoring the physiological variables.

FES system test model

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