# Multipurpose Two Channel Stimulator For Gait Correction

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## Introduction

From our clinical work for the correction of dropped foot following stroke we had identified a clinical need in several areas. Although the correction of dropped foot alone can significantly improve the mobility of many subjects, often individuals are left with problems controlling the knee, hip and ankle joints due to lack of or inappropriate muscle activity. Additionally there are many subjects who have bilateral dropped foot due to cerebral palsy, multiple sclerosis or familial paraplegia. With additional stimulation channels it is possible to activate other muscle groups. The Odstock Two Channel Stimulator (O2CHS) is a development of the device presented at the Strathclyde BES FES meeting (1).

## Design criteria

- The device is intended to be used as an orthosis and therefore will be used daily with minimum supervision. For simplicity it was decided to limit the device to 2 channels as it was felt that this is the maximum number that it reasonable be expect patients to cope with.
- The device was to be operated by FSR (Force Sensitive Resistors) foot switches using the tracking comparitor input stages developed for the dropped foot stimulator. FSR can be made into a thin and robust foot switch which can be attached to an inner sole or stuck with tape to the sole of the foot. The resistance - force response of FSR drift over time which means a straight comparitor input is unreliable. The tracing comparitor input stage follows the resistance of the FSR but with a delay due to a low pass filter. With the addition of hystorisis, this means any rapid change reversing the state of the FSR will cause the comparitor to change states. This input stage has made FSRs a practical proposition.
- The device must be as small as is practical within resources with a low power consumption giving several days of uses from a PP3. A PP3 battery was chosen to allow easy exchange of batteries so the user would not be left stranded while waiting for the battery to be charged.
- The design was based on the discreet logic technology used by the Odstock Dropped Foot Stimulator but constructed using surface mount technology to reduce the size. Control configuration are set by a series of switches and trimmer controls and is therefor a stand alone device requiring no external programmer. The controls are essentially those found in the ODFS for each channel with a few extra to determine the interaction of the two channels. Therefore a physiotherapist familiar with the ODFS would able to quickly understand the operation of the O2CHS.
- Test switches which duplicate the action of the foot switches allow the therapist to check the sequencing of the channels before the foot switches are used. Additionally they can be used by the user when finding the electrode positions and setting the output level.
- The output is up to 100mA with a pulse width of 300 micro seconds. The frequency can be adjusted from 20 to 60 Hz. The output is a standard transformer asymmetrical biphasic waveform in the standard version with a second version with alternate polarity at every other pulse for a symmetrical biphasic output.

## Control

The device can be considered as two dropped foot stimulators in one box. Each channel can be triggered by either foot rise or strike of it's foot switch. The output will then be active either for a fixed time or adaptive to the foot switch up to a maximum time out time. At the end of the simulation time a fixed extension time can be set delaying the end of the output. This is typically used to extend the output after heel strike to prevent foot flap when correcting dropped foot. Ramps can be set independently at the beginning and end of each output. Additionally channel two has a pre output delay so it's output can be used to stimulate muscles at time that do not coincide with foot switch state changes. Channel 2 can also

have its time out function in adaptive timing disabled. This is used for quadriceps stimulation to provide knee extension for as long as pressure is maintained on the heel switch.

There are two options for interaction between the two channels. Firstly foot switch can be used to control both channels. For example when the device is used for bilateral dropped foot channel 1 stimulates the first side at heel rise and then channel 2 stimulates the opposite side at heel strike, after a delay. For dropped foot correction with triceps for arm swing both channels are active together. The Second option for interaction was added specifically for the correction of dropped foot with calf stimulation. Channel 1 is used for the dropped foot correction and is triggered by toe lift on footswitch 2. Its output is ended by heel strike or to strike. Channel 2, which is used for calf stimulation is active while pressure is on the toe switch.

**Algorithms**

- *Bilateral dropped foot:* A single heel switch, channel 1 triggered by rise and ended by heel strike, channel 2 triggered by heel shrike after a short delay and ended by heel rise.
- *Dropped foot with calf:* A heel switch and a switch under the first metatarsal head. Channel 1 for common peroneal stimulation is triggered by toe off and ended by either heel strike or toe strike. Channel 2 is active while the toe switch is on the ground up to a max. time out.
- *Dropped foot with ham strings:* A heel switch or two switches as above. Common peroneal stimulation triggered by heel rise and ended by heel strike, ham strings triggered after a set delay after heel or toe strike
- *Dropped foot with quadriceps:* A single heel switch. Common peroneal stimulation as above, Quadriceps stimulation for as long as pressure is on the heel switch.
- *Dropped foot with triceps:* A single heel switch. Common peroneal stimulation as above, triceps stimulation synchronously.
- *Bilateral Quadriceps:* Two heel switches with no interaction between channels. Both channels give an output at heel strike.
- *Bilateral calves:* Two toe switches as above.

**Refrences**

1. Taylor PN, Burridge JH, Ewins DJ, Swain ID. A two channel stimulator for gait assistance. Electrical Stimulation - Clinical Systems. University of Strathclyde 1995.