

Powering performance

Maximising battery operating time in a 'gym for the lungs'.

By **Chris Harris**.

Training and exercise equipment is a highly fashion conscious industry sector and even POWERbreathe, a respiratory exercise system design recognised by the Design Council in 2001, needed to evolve to meet the needs and expectations of its users.

Manufacturer HaB International recognised that it had to offer users new levels of information, control and usability – and this meant adding electronics. At the same time, the company recognised that the equipment would end up in a corner gathering dust if the batteries didn't last for an acceptable time.

Electronic product design specialist ML Electronics was presented with the challenge of creating an electronic design that fully met users' expectations, but which could also run comfortably from rechargeable NiMH AAA batteries – including driving an integral 12V stepper motor.

Battery life, cost and compact size were the major constraints in bringing the award winning portable inspiratory training tool up to date.

Gym for the lungs

POWERbreathe is a handheld inspiratory muscle trainer, a multifunctional training tool for lung function, providing a wide variety of applications for a broad range of people – from athletes to patients with respiratory problems, such as chronic obstructive pulmonary disease and asthma.

Using resistance training, an approach similar to using weights and pulleys to hone muscles in the arms and legs, the POWERbreathe concept was initially developed in 2001. The original POWERbreathe Classic series, which was based on mechanical pressure threshold training using a load calibrated spring, was named a Millennium Product by the UK Design Council.

In developing POWERbreathe Kinetic, the third generation of the product, HaB International needed to respond to the needs of the iPod

generation by offering users more control over their exercise regime, along with the ability to provide more information on how their exercise is progressing. This entailed introducing an lcd and microcontroller.

Amongst the new features offered by the POWERbreathe Kinetic series is an electronically controlled, rapid response valve to create a resistance to inhalation. Training resistance matches the dynamic changes in breathing muscle strength throughout the breath and then adapts automatically to increases in inspiratory muscle strength at the start of each training session. Training measurement results are displayed on an lcd screen, allowing quick and easy monitoring of training progress and optimisation of training technique. An lcd menu system allows users to navigate between different settings and to view training results.

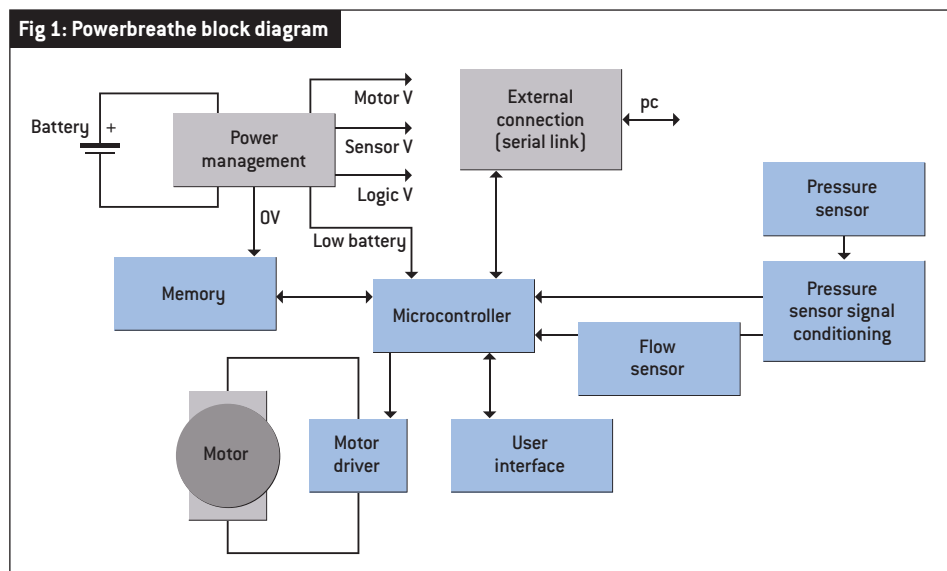
Small size, small power

Working closely with Smallfry, HaB's product and design innovation team, the key challenge

for ML Electronics was to achieve the very low power consumption in a small form factor envisaged by Smallfry's concept design, whilst ensuring the bill of materials and manufacturing costs were kept to a minimum so the product remained affordable.

Foremost in the brief was the specification that POWERbreathe should be able to run from a maximum of three NiMH cells and to be recharged via a 5V supply provided to the USB port. Batteries were required to last two weeks on a full charge, enabling the user to follow a training programme of 30 breathe in/breathe out cycles, twice a day. The design also required the batteries to drive a 12V stepper motor, which controls the valve that provides different levels of breathing resistance via a variable diameter orifice.

This limited power budget, space constraints and available bill of materials eliminated the possibility of fast charging, so advanced power management techniques and power efficient circuit design were used for optimising the power consumption.



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Power management scheme

At the heart of the POWERbreathe electronics is a PIC microcontroller. This takes values from a pressure sensor and uses them to control the stepper motor, ensuring that 'resistance' is constant throughout the breath. Motor performance and control speed were critical, in order to ensure sufficiently fast feedback. HaB's inspiratory muscle training technology selects the most effective training load automatically, based on respiratory muscle strength. Training results, progress and physiological respiratory measurements are monitored continuously and displayed on the high contrast lcd. Better still, the user's performance and progress can be analysed on a pc through the device's USB connection.

ML Electronics used many of the features available in the PIC processor, including microamp real time clocks, low power system voltage monitors and the ability to run the cpu core at a different speed from the peripherals.

Functional circuitry was completed with differential amplifiers to provide inputs from the breath pressure sensor and a stepper motor driver linked to a low cost off the shelf motor. In addition, the design provides a buzzer – to tell users when to start and stop – LED and lcds, a function button and a USB 2.0 interface. All circuits can be switched in and out to conserve power.

A great deal of care and experimentation was required before the boost converter, which takes the battery voltage to the 12V rail, could be specified.

The goal was to find a device that could realistically maintain 12V regulation when the battery was low, even under the

relatively heavy load current drawn by the motor. A number of candidate dc/dc converters offered promising datasheets but, upon closer inspection, failed to live up to their specifications. The chosen device uses a PWM control scheme to regulate the output voltage over all load conditions and this was tested by MLE under real world conditions. It also features a power saving shutdown mode, decreasing the supply current to typically 0.1 A.

More crucially, the hardware design needed to minimise voltage drops everywhere. This not only impacted on the tracking and layout, but also necessitated using FETs instead of diodes, which resulted in a compact pcb. Unlike standard diodes, FETs consume no current when they are off and voltage drops are zero when they are full on.

A key pcb design aspect was the power consumption caused by any voltage drop along the length of the copper tracks. Even a 0.1V drop can translate to a significant lowering of battery life.

POWERbreathe Kinetic is currently going into volume production and will be

available shortly, helping users to maintain their health and fitness resolutions.

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