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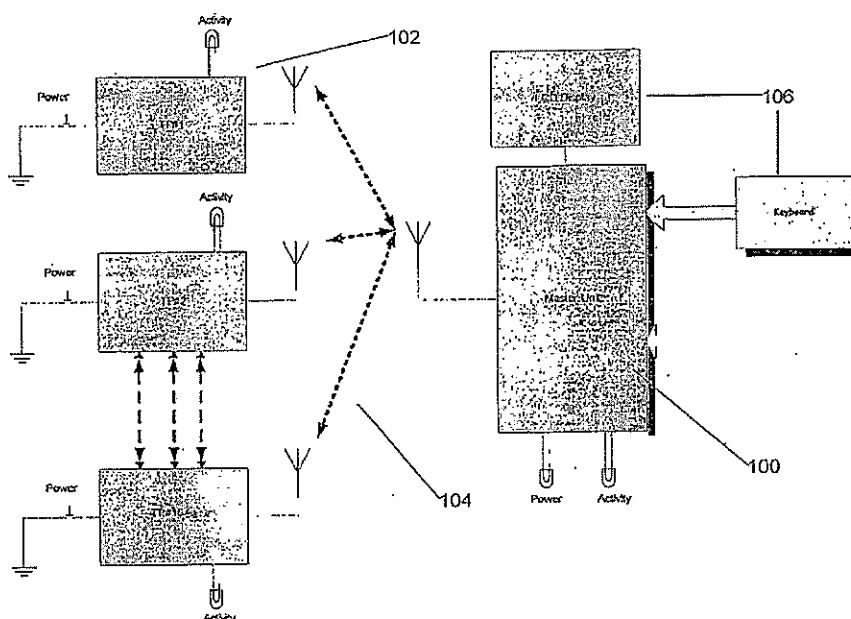
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(54) Title: SYSTEMS AND METHODS OF ELECTRONIC MUSCLE STIMULATION



(57) Abstract: An electronic muscle stimulation system comprising a plurality of stimulator units (102) configured for muscle stimulation of a user, a controller (100), wirelessly connected to each of said stimulator units (102), including an interface (106) configured for receiving user input including a selected muscle stimulation mode, said controller (100) configured for providing a wireless control signal to each stimulator unit (102) to thereby stimulate the users muscles, wherein the amplitude and frequency of said control signal are dependent on user input. The control signal may also be dependent on a music signal.

SYSTEMS AND METHODS OF ELECTRONIC MUSCLE STIMULATION

FIELD OF INVENTION

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The invention relates to a system and method of electronic muscle stimulation, a system and method of synchronising an Electronic Muscle Stimulator (EMS) with music and a system and method of synchronising sensation or stimulation provided to a user with a content signal.

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BACKGROUND

Massage has been well known for its relaxing and therapeutic properties for centuries. Massage is often combined with other treatments to further enhance its relaxing and therapeutic benefit. For example music or other audio may be provided simultaneously to further relax person receiving the massage.

More recently advances in electric and electronic technologies have allowed the use of an electrical pulse to be applied topically to induce muscle contractions. Such muscle contractions may be controlled to simulate the feeling of traditional or manual massage. Thus by controlling the frequency, amplitude and other characteristics of the applied electrical pulses, it becomes possible to simulate different types of massage.

Commercially available electrical pulse massagers or an Electronic Muscle Stimulators (EMS) typically include one or more stimulator units attached to the user via adhesive gel pads. Each stimulator unit has electrodes within the pad that contact the users skin to deliver the electric pulse. Some units have a separate controller that is typically connected to each stimulator unit using hard wired connections. Typically the controller is only single channel, and the hard wired connection may inconvenience, or impede the relaxation of, the user.

Some commercially available massagers include an audio function, such as FM radio or MP3 playback. Often such massagers also include different modes of massage. However the massager function and audio function are typically independent, and there is no coordination of the functions, for example each mode of massage and the particular music being played.

More generally in the field of provision of tactile sensation or stimulation to a user, the prior art has failed to come up with effective synchronisation of the sensation or stimulation provided to a user, to content simultaneously delivered to the user.

5

A need therefore exists to address at least one of the above problems.

SUMMARY

10 In accordance with a first aspect of the invention there is provided an electronic muscle stimulation system comprising:

a plurality of stimulator units configured for muscle stimulation of a user, and

a controller, in use, wirelessly connected to each of said stimulator units, including an interface configured for receiving user input including a selected muscle stimulation
15 mode, and said controller configured for providing a wireless control signal to each of said stimulator units to thereby stimulate the users muscles, wherein the amplitude and frequency of said control signal being dependent on said user input.

Said wireless connection may comprise a Radio Frequency (RF) connection.

20

Said system may be an electrical pulse massager or electronic muscle stimulator.

Said selected mode may be selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof, and said
25 tapping mode corresponds to the frequency of said control signal, in use, between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal, in use, between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal, in use, above 35Hz

30 Said wireless connection may comprise a plurality of RF channels, wherein in use one RF channel is allocated by said controller, said controller and each stimulator unit are assigned a unique ID, and said controller independently controls each stimulator unit using said assigned IDs and said allocated channel.

Said control signal may comprise one or more commands selected from the group consisting of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time, short burst and combinations thereof.

5 Said wireless connection may be based on the IEEE® 802.15.4 standard.

In accordance with a second aspect of the invention there is provided a Music Synchronised Electronic Muscle Stimulator (EMS) comprising:

10 one or more stimulator units configured for muscle stimulation of a user,
a music system for providing an music signal to the user, and
a controller, in use, connected to each of said stimulator units, including an interface configured for receiving user input including a selected muscle stimulation mode, and said controller configured for generating a predominant frequency signal from said music signal and for providing a control signal to each stimulator unit to thereby stimulate
15 the users muscles, wherein the amplitude and frequency of said control signal being dependent on said user input and said predominant frequency signal.

20 The frequency of said control signal may depend on said selected muscle stimulation mode.

20 The frequency of said control signal may depend on the frequency of said predominant frequency signal.

25 The amplitude of said control signal may depend on the amplitude of said predominant frequency signal.

30 The system may further comprise a plurality of bandpass filters, each receiving said audio signal and corresponding to an audio frequency band, wherein said controller may select the bandpass filter with the highest level output and may set the nominal frequency of the selected bandpass filter as said predominant frequency signal.

35 The predominant frequency signal may be translated depending on said selected muscle stimulation mode, and the predominant frequency signal may be set as the frequency of said control signal.

Said selected mode may be selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof synchronised with said audio signal.

5 Said tapping mode may correspond to the frequency of said control signal, in use, between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal, in use, between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal, in use, above 35Hz.

10 Said control signal may comprise one or more commands selected from the group consisting of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time, short burst and combinations thereof.

15 In accordance with a third aspect of the invention there is provided a method of electronic muscle stimulation comprising the steps of:
 receiving user input including a selected muscle stimulation mode,
 providing a wireless control signal to at least one stimulator units wherein the amplitude and frequency said control signal depending on said user input, and
 stimulating a users muscles based on said wireless control signal.

20 Said wireless control signal may comprise a Radio Frequency (RF) control signal.

 The stimulator units may be electrical pulse massagers or electronic muscle stimulators.

25 Said selected mode may be selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof, and said tapping mode corresponds to the frequency of said control signal, in use, between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal, in use,
30 between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal, in use, above 35Hz

 The method may further comprise the steps of:
 allocating an RF channel,
35 assigning a unique ID to said controller and each stimulator unit,

independently controlling each stimulator unit using said assigned IDs and said allocated channel.

Said control signal may comprise one or more commands selected from the group
5 of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time and short burst.

Said wireless control signal may be based on the IEEE® 802.15.4 standard.

10 In accordance with a forth aspect of the invention there is provided a method of synchronising an Electronic Muscle Stimulator (EMS) to music comprising the steps of:
providing a music signal to a user,
generating a predominant frequency signal from said music signal,
receiving user input including a selected muscle stimulation mode, and
15 providing a control signal to a plurality of stimulator units, wherein the amplitude and frequency of said control signal depending on said user input and said predominant frequency signal, and
stimulating the users muscles depending on said control signal.

20 The frequency of said control signal may depend on said user selected mode.

The frequency of said control signal may depend on the frequency of said predominant frequency signal.

25 The amplitude of said control signal may depend on the amplitude of said predominant frequency signal.

The method may further comprise the steps of selecting the highest level output from a plurality of bandpass filters, each receiving said audio signal and corresponding to
30 a audio frequency band, and setting the nominal frequency of the selected bandpass filter as said predominant frequency signal.

The method may further comprise the steps of translating the predominant frequency signal depending on said selected muscle stimulation mode, and setting the
35 translated predominant frequency signal as the frequency of said control signal.

Said selected mode may be selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof.

5 Said tapping mode may correspond to the frequency of said control signal, in use, between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal, in use, between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal, in use, above 35Hz.

10 Said control signal may comprise one or more commands selected from the group consisting of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time, short burst and combinations thereof.

In accordance with a fifth aspect of the invention there is provided a system for
15 synchronising sensation and/or stimulation of a user with a content signal comprising:
 one or more sensation and/or stimulation units configured for providing sensation and/or stimulation of a user,
 an input for receiving a content signal,
 a controller, in use, connected to each of said sensation and/or stimulation units,
20 including an interface configured for receiving user input including a selected sensation and/or stimulation mode, and said controller configured for determining a sensation and/or stimulation cue from the content in said content signal and for providing a control signal to at least one sensation and/or stimulation unit to thereby provide sensation and/or stimulation to the user, wherein the control signal depending on said user input and said
25 sensation and/or stimulation cue.

The frequency of said control signal may depend on said selected sensation and/or stimulation mode.

30 Said content signal may comprise an audio stream from which a predominant frequency signal may be extracted as said sensation or stimulation cue and the frequency of said control signal may depend on the frequency of said predominant frequency signal.

The amplitude of said control signal may depend on the amplitude of said
35 predominant frequency signal.

The System may further comprise a plurality of bandpass filters, each receiving said audio stream and corresponding to an audio-frequency band, wherein said controller may select the bandpass filter with the highest level output and may set the nominal
5 frequency of the selected bandpass filter as said predominant frequency signal.

The predominant frequency signal may be translated depending on said sensation and/or stimulation mode, and said translated predominant frequency signal may be set as the frequency of said control signal.
10

In accordance with a sixth aspect of the invention there is provided a method of synchronising sensation and/or stimulation of a user with a content signal comprising the steps of:

receiving a content signal,
15 determine a sensation and/or stimulation cue from the content in said content signal, receiving user input including a selected sensation and/or stimulation mode, providing a control signal to at least one sensation and/or stimulation units, wherein the control signal depending on said user input and said sensation and/or stimulation cue, and
20 providing sensation and/or stimulation to the user depending on said control signal

The frequency of said control signal may depend on said selected sensation and/or stimulation mode.

25 Said content signal may comprise an audio stream from which a predominant frequency signal is extracted as said sensation and/or stimulation cue and the frequency of said control signal may depend on the frequency of said predominant frequency signal.

The amplitude of said control signal may depend on the amplitude of said
30 predominant frequency signal.

The method may further comprise the steps of selecting the highest level output from a plurality of bandpass filters, each receiving said audio stream and corresponding to a audio frequency band, and setting the nominal frequency of the selected bandpass filter
35 as said predominant frequency signal.

The method may further comprise the steps of translating the predominant frequency signal depending on said selected sensation and/or stimulation mode, and setting said translated predominant frequency signal as the frequency of said control signal.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments of the invention will now be described with reference to the drawings, in which:

Figure 1 is a block diagram of the hardware components.

Figure 2 is a flow diagram of the system operation.

Figure 3 is a perspective view of an MU.

Figure 4 is the block diagram of the MU components.

Figure 5 is a perspective view of a TP.

Figure 6 is a block diagram of the TP components.

Figure 7 is a circuit diagram of a high voltage charge pump.

Figure 8 is a circuit diagram of a high voltage bi-direction switcher.

Figure 9 is a flow diagram of a wireless communications protocol.

Figure 10 is a graph of the example pulses generated by a TP.

Figure 11 is a block diagram of the MP3 player unit.

Figure 12 is a block diagram of the equalizer subunit.

Figure 13 is a graph the waveform showing the band levels during a 4s interval.

Figure 14 is a table showing the command structure between the MP and each TP.

Figure 15 is a flow diagram showing the synchronisation of the music with the massage pulse frequency and amplitude.

DETAILED DESCRIPTION

Figure 1 illustrates an exemplary embodiment comprising a Master Unit (MU) 100, including a user interface, and one or more slave units (TP) 102, each including a massager or stimulator device. The MU includes a user interface 106 that allows the user to select the desired massage parameters for each TP. The MU 100 communicates 104 with each TP 102, to control and monitor the delivered massage or stimulation.

Figure 2 illustrates operation of the system. In step 200 the user selects the desired mode on the MU 100. In step 202 the MU 100 sends a control signal to specific
TPs 102 to generate the required mode of stimulation. In step 204 each TP 102 interprets
the control signal and generates the required pulses. In step 206 the MU monitors the
5 delivered pulses and if necessary refines the next control signal. In step 208 the pulses
are delivered for a predetermined period and then the pulses are stopped.

The electrical pulses from each TP will stimulate the nerves of the human body
causing the surrounding muscles to contract. The pulses can be controlled to simulate
10 tapping, chopping & squeezing forms of massage. The selection of the massage mode;
intensity & duration is controlled & monitored at the MU.

One embodiment incorporates non-directional or RF communication between the
components. For example the MU may control up to 16 TP via one of the 16 RF channels
15 using a customised communications protocol.

Another embodiment incorporates synchronisation of the applied pulses to an
audio signal. The synchronisation may relate to frequency and/or amplitude. For
example the pulses may be synchronised in frequency and amplitude with the "beat" of
20 the music.

A still further embodiment incorporates synchronisation of sensation and/or
stimulation provided to a user with a content signal. The content signal may include an
audio stream, from which cues may be extracted to determine when and how to apply
25 sensation and/or stimulation to a user. For example the cues may relate to the frequency,
amplitude or the "beat" of the audio stream. As seen in Figure 16 in step 1600 a content
signal is received. In step 1602 a sensation and/or stimulation cue is determined from the
content in the content signal. In step 1604 user input is received including a selected
sensation and/or stimulation mode. In step 1606 a control signal is provided to a plurality
30 of sensation and/or stimulation units, wherein the control signal depending on said user
input and said sensation and/or stimulation cue. In step 1608 the sensation or stimulation
is provided to the user depending on the control signal.

Master Unit (MU)

The MU 100 is shown generally in Figure 3. The MU 100 controls and monitors each TP 102 via one or more communication channels. The user interface 106 includes 6 controls or buttons 300 and an LCD 302. LEDs are provided to indicate power 304 and
5 operational status 306.

Referring to Figure 4 the components of the MU are shown in more detail. The operation of the MU is primarily controlled by a microcontroller 400. The MU microcontroller 400 is connected to the controls or buttons 300, the LCD 302 and the
10 LEDs 304,306. A rechargeable battery 402 is used to provide power to the MU. The power button 404 is used to turn on the MU from sleep. The mode button 406 allows user to select a massage mode. The intensity up/down buttons 408 are used to control the massage intensity. The start stop button 410 is used to start/stop a massage event. The device button 412 is to select the particular TP to operate.

The MU microcontroller 400 is a freescale microcontroller MC9S08GT16. The MU microcontroller 400 includes:

1. One parallel bus 428 for the LCD 302
2. At least 18 I/O pins for control inputs 300 (Start; Mode; Intensity Up; Intensity
20 Down & Duration); LED and LCD control signals.

The firmware determines how the MU microcontroller 400 interacts with each component, as will be described later. The firmware on both MU & TP is the same. An I/O port pin is assigned to allow the firmware to determine whether the device is the MU or
25 a TP. A high signal at this pin indicates to the firmware that the device is an MU.

Slave Unit (TP)

A TP 102 is shown generally in Figure 5. Each TP generates a series of high voltage short duration electrical pulses to the human body via an electrode pad 500. Each
30 TP is connected directly to the electrode pad 500 via two snap buttons 502. The snap buttons 502 also double as connections between the high voltage electronics and the electrodes within the electrode pad 500. Each TP is operated via a power button 504 & an LED indicator 506.

Referring to Figure 6 the components of each TP 102 are shown in more detail. A microcontroller 600 is connected to a high voltage generator 602, a high voltage switcher 604, the power button 504 & the LED indicator 506. The power button 504 is pressed and held to exchange ID with MU when initialising the system. The power button 504 is also used as an emergency stop button during massaging. A rechargeable battery 606 is used to provide power to the TP. The high voltage generator 602 provides the high voltage for the high voltage switcher 604 to deliver the pulses to electrodes 608, embedded into the electrode pad 500.

10 The TP microcontroller 600 is a freescale microcontroller MC9S08GT16. Both the MU & TP use the same model microcontroller. The TP microcontroller 600 includes; the:

1. At least 3 PWM (pulse width modulation) channels. One to drive a high voltage charge pump to generate the necessary +/- 70V high voltage. The other 2 PWM to control the direction; pulse width & frequency of massage pulse.
- 15 2. One ADC (Analog to Digital Converter) to control & monitor the intensity of the massager pulse.
3. At least 18 I/O pins for key inputs (Power) and LED control signals.

20 An I/O port pin is assigned to allow the firmware determine whether the device is the MU or a TP. A low signal at this pin indicates to the firmware that the device is a TP.

The firmware determines how the TP microcontroller 600 interacts with each component, as will be described later.

25 The high voltage generator 602 accepts a PWM signal 614 from the TP microcontroller 600. The duty cycle of the PWM signal 614 controls the voltage level at high voltage output 616 from 1V to 70V DC. The users selection of intensity using the MU intensity keys 408 determines the duty cycle of the PWM signal 614.

30 An example of a high voltage generator 602, is the charge pump circuit shown in Figure 7. The PWM signal 614 controls a switch 700 that controls the charging of output capacitor 702. The high voltage output 616 is provided from the output capacitor 702.

The PWM signal 614 from the microcontroller has a switching frequency of 10kHz. To achieve 70V output at the high voltage output 616, a duty cycle of about 60% is required. The duty cycle is discretely controlled over 120 normalized steps.

5 The high voltage output 616 is provided to the high voltage bi-directional switcher 604. 2 message pulse output PWM signals 618 from the TP microcontroller 600 are provided to the high voltage switcher 604 control the direction, frequency and pulse width of the final message pulses. The high voltage switcher 604 provides a monitoring signal 620 to an ADC input to the TP microcontroller 600, to monitor the delivered pulse.

10

An example of a high voltage switcher circuit is shown in Figure 8. The 2 message pulse output PWM signals 618 from the TP microcontroller 600 are known as PPON 800 (Positive Pulse ON) & NPON 802 (Negative Pulse ON). These 2 signals control the direction, frequency and pulse width of the current flowing into the human body. Normally
15 the pulses are set at alternate cycles of the message pulse in a single frequency cycle.

The PPON & NPON signals are both PWM signals with 512 μ s pulse width when the pulse frequency is below 10Hz. When the pulse frequency is above 10Hz, the pulse width varies from 64 μ s to 512 μ s, which is determined by the parameters on the message
20 pattern (described later). When PPON 800 is logical high & NPON 802 is logical low; Q3 804 & Q9 806 will turn on causing the high voltage to flow in one direction to the electrode connections 814. When NPON 802 is logical high & PPON 800 is logical low, Q4 808 & Q8 810 will turn on causing the current to flow in another direction to the electrode connections 814.

25

The frequency of the output pulse is controlled between 1 ~ 200 Hz. Generally pulse frequencies from 1~10 Hz result in a taping sensation; pulse frequency from 10~35Hz result in a chopping sensation & pulse frequency from 35~200Hz result in a squeezing sensation.

30

The output current flow is monitored by an op-amp 816 using the voltage across a small series resistor 818. The op-amp output is provided as the monitoring signal 620 to the TP microcontroller 600. This current signal represents the peak current going into the human body. The current signal is used as feedback to control the intensity as well
35 detecting whether the electrode pad is attached. The TP includes an automatic cut off

function when the electrode pad is not attached (detects when current is zero) as a safety measure.

Non directional/RF Communications

5 Referring to Figures 1, 4 and 6 the communication links are shown between the various modules in the system. The MU 100 incorporates a single chip RF transceiver 414 based on the IEEE® 802.15.4 standard. An example RF transceiver is the freescale RF transceiver MC13191. The MU microcontroller 400 is connected to the RF transceiver 414 via a SPI (Serial Port Interface) port 422 and uses an RF channel to communicate
10 with each of the TPs.

Similarly each TP incorporates a single chip RF transceiver 610 based on the IEEE® 802.15.4 standard. The TP microcontroller 600 is connected to the RF transceiver 610 via a SPI (Serial Port Interface) port 612. Other components may also connect by non
15 directional wireless communication, for example the headphones.

In order for MU to communicate with TPs; they both be assigned and exchange a unique ID. For example Figure 9a shows a pairing sequence between the TP & MU for this purpose. In step 900, when the power buttons at TP and MU are pressed and
20 released, the TP & MU will wake up from sleep. In step 901 when power button at TP is pressed and held for more than 4s, it will start the pairing process. Press the Mode Key at MU for more than 4s; the MU will continue sending out broadcast command (Get_ID) every 20ms for 2 seconds. In Step 904 a unique ID for TP & MU are assigned once. In step 905, each TP will scan thru the 16 channels every 40ms until it detects the Get_ID
25 broadcast signal. The TP will then exchange ID with MU using the RF channel set by MU.

Once the IDs & RF channels have been established; both the TP and MU may communicate. In step 902 the MU is then ready to control and monitor each TP, and each TP awaits commands from the MU. Both TP & MU power LEDs will blink at a lower speed
30 when linked.

Figure 9b shows the communication process between the various modules in the system, according to an example firmware programmed in both the MU and TP microcontrollers. In step 900B if the device key is pressed the device selection is set in the MU in step 900C. In step 900D if the mode key is pressed the pairing process (shown
35

in Figure 9a) is performed in step 900E. In step 900F if the intensity up/down keys are pressed the Set_Amplitude command is transmitted to the selected TP in step 900G. In step 900H if the mode key is pressed the Set_Message_Mode or Set_Message_Pattern command (depending on which mode is chosen) is transmitted to the selected TP once the start button is pressed in step 900I. In step 900J when the stop button is pressed the Stop_Message command is transmitted to the selected TP in step 900K. Alternatively a broadcast command may be used to stop all TPs. In step 900L if no key is pressed for more 30s the MU is put into sleep mode in step 900O. The RF transceiver 610 is turned off during sleep mode. The power button is used to wake up the device. When massage is on, the power button at TP is used as a safety stop.

Figure 14 shows the commands used for each step in more detail. Each command takes the form of a packet with the following format:

15 ***MU packet format***

TP_ID(2 bytes),cmd(1 byte),MU_ID (2 bytes), parameters(variable)

When TP_ID is 0xFFFF; all TPs will respond to this command. Only Get_ID and Stop_All command use this TP_ID. All commands will be initiated by MU only. When the MU first powers up, the MU_ID is 0x0000. A new ID will be assigned during GET_ID process.

TP packet format

MU_ID (2 bytes), respond (1 byte), TP_ID (2 bytes), data (variable)

When each unit is powered up, the TP_ID is 0xFFFF. A new ID will be assigned only when MU GET_ID command is received. Upon receiving the GET_ID command from MU, each TP will respond with the above packet. The respond byte is the received cmd byte. Figure 14 indicates the data returned.

Referring to step 900I up to 256 massage modes are allowed. As seen in the LCD 302 in Figure 3 there are a number of modes that may be selected by pressing the mode button 406. For example the modes include tapping mode 308, chopping mode 310, squeezing mode 312, Thai Massage mode 322 and Javanese Massage mode 324.

The actual pulse pattern for the basic modes eg: tapping mode 308, chopping mode 310 and squeezing mode 312 are stored in the TP microcontroller 600 onboard memory. Thus only the simple Select_Message_Mode command of 1 byte is required if these modes are selected by the user.

5

Other modes such as Thai Massage mode 324 and Javanese Massage mode 326 may be customised or added at the MU by connection to another device, such as a PDA or computer to upload the pulse pattern. Figure 10 shows examples of each of the different patterns including, ramp 1000, burst 1002, short pulse 1004 and combination of ramp and burst 1006 that can be used to in these customisable pulse modes. If the user selects one of those modes, much more data must be transferred for which the Set_Message_Pattern command is used, which consists of 11 bytes of parameters as described below.

15 **Control Byte**

Bit 0 --- A 1 indicate last pattern. Go to first pattern until time out.

Bit 1 --- Ramp Up On Off.

Bit 2 --- Ramp Down On Off.

Bit 3 --- Burst On Off.

20 Bit 4 --- Turn On Left Massage.

Bit 5 --- Turn On Right Massage.

Bit 6 --- Turn On Sweep.

Bit 7 --- Turn On Therapy.

Duration Byte

25 1 to 240s.

Start Frequency Byte

1 to 200 Hz. Use in normal and sweep mode.

Stop Frequency Byte

1 to 200 Hz. Use in sweep mode only.

30 **Short Pulse Width Byte**

The upper byte relates to short pulse the lower byte relates to pulse width up to 480 μ s. A step of 32 μ s in pulse width is used. Short pulses of up to 16 μ s may be used for massage frequencies of less than 10 Hz.

Ramp Up Time Byte

35 1 to 255 in 5ms steps.

Ramp Down Time Byte

1 to 255 in 5ms steps.

Burst On Time Byte

1 to 255 in 5ms steps.

5. ***Burst Off Time Byte***

1 to 255 in 5ms steps.

Sweep Time Byte

1 to 255 pulse per sweep. Except where pulse frequency is below 10 Hz, in which case 3 pulses per sweep is substituted.

10 ***Therapy Byte***

1 to 31s on upper byte for On. 1 to 31 s on lower byte for Off.

Audio Synchronisation

15 The user may be able to select a number of desired modes (step 200 in Figure 2) on the user interface. An example mode may incorporate synchronising the electrical pulse output with the amplitude and/or frequency of an audio signal. The system may simultaneously deliver therapeutic music and synchronised high voltage electrical pulses to the user.

20 As seen in the LCD 302 in Figure 3 there are music synchronised modes that may be selected by pressing the mode button 406. For example the modes include music sync tap mode 314, music sync squeeze mode 316, Music sync chop mode 318 and Music sync mixed mode 320.

25 The music may be supplied by MP3 format audio stored on removable media. Referring to Figure 4 the MU microcontroller 400 is connected to an MP3 player 418 and an equalizer sub unit 416. The MP3 player 418 connects to the MU microcontroller 400 using a serial communication port 426 for example RS-232C. The multiplexed output of the equaliser sub unit 416 is supplied to an ADC input 426, and is in turn controlled via a control output 430, of the MU microcontroller 400. The MP3 player 418 provides a
30 headphone output 420 with adjustable level and a fixed output 432 to the equaliser subunit 416.

Figure 11 shows an example of an MP3 subsystem using a single MP3 chip 1100.
35 The music is stored on built in or removable flash memory 1102, which can be pre-

selected during production, or may be varied by the user. The MP3 chip 1100 decodes the stored music and provides the decoded digital audio stream to a DAC 1104. The analogue audio output from the DAC 1104 is a fixed level output, which is fed to the equaliser subunit 416. This arrangement allows a threshold level to be fixed for use by the

5 MU microcontroller 400. A power amplifier 1106 has a volume control input that allows MP3 chip to control the volume level instead of the adjusting the digital volume before the DAC.

Figure 12 shows an example of an equaliser subunit 416 that accepts a fixed level

10 music output 432 from the MP3 player 418. It is necessary to have fixed level input so that the level of the high voltage electrical pulse is independent of the headphone level. The fixed level input 432 is first passed through an anti alias filter 1200.

The anti aliased signal is passed through a 5 band bandpass filter. The bandpass

15 filter provides the level of the following frequency components: 100Hz band 1204, 330Hz band 1206, 1kHz band 1208, 3.3kHz band 1210, & 10 kHz band 1212. Each of the bandpass signals is passed through a peak detector to provide a DC signal indicative of the level of that band.

The level from each of the 5 bands is multiplexed 1216 into a single output, which

20 is then fed into the ADC 424 input of the MU microcontroller 400. The control signal 430 consists of a reset & strobe signal. The strobe signal 1218 will advance the multiplexer 1216 to the next band to output. The reset signal 1220 will reset the multiplexer 1216 to output the first band, which is the 100Hz band 1204. As seen in Figure 13 the MU controls

25 the multiplexer to cycle through the DC levels of the 100Hz band 1204, 330Hz band 1206, 1kHz band 1208, 3.3kHz band 1210, & 10 kHz band 1212 every 0.5ms.

Referring to Figure 9b in step 900M if Music sync mode is selected then the Set_Frequency_&_Amplitude command is transmitted to the selected TP in step 900N.

30 Figure 15 shows the process of determining the Set_Frequency_&_Amplitude command, according to an example firmware programmed in both the MU and TP microcontrollers. An outer loop runs every 4s. The outer loop includes step 1500 of determining the highest level of the 5 frequency bands over the preceding 4s period. In step 1502 the message pulse frequency is set based on the nominal frequency of the bandpass filter with the

35 highest level output ("the predominant frequency"). The frequency command is

determined based on the user selected massage mode (eg: music sync tap mode, music sync chop mode & music sync squeeze mode), the translation strategy relating to that user selected massage mode and the predominant frequency during the last 4s.

5 An inner loop runs at an interval of 25 ms. In step 1504 the amplitude of the selected frequency band is measured every 0.5ms. In step 1506 the amplitude of the command is based on the output DC level or amplitude of the selected bandpass filter over the 25ms period.

10 Referring to step 1502 the predominant frequency is translated into the massaging frequency. The massage pulse frequency ranges from 1 to 200 Hz. For each music sync mode a different translation strategy will apply. For example in music sync tap mode the translation results in pulse frequencies between 1 to 10Hz. In music sync chop mode the translation results in pulse frequencies between 10 to 35Hz. In music sync squeeze mode
15 the translation results in pulse frequencies above 35Hz. For example where the music sync chop mode is selected an example translation strategy is shown below:

	100Hz	→	25Hz
	330Hz	→	28Hz
20	1000Hz	→	30Hz
	3300Hz	→	32Hz
	10000Hz	→	35Hz

25 This translation of the predominant frequency to a resulting applied pulse of between 25Hz to 35Hz will result in a chopping sensation on human body. In the example audio signal depicted in Figure 13 where the predominant frequency is 10kHz, the applied pulse will have a frequency of 35Hz and will vary in amplitude depending on the DC output level of the 10kHz band pass filter. It is possible to translate the 100Hz band to a tapping frequency such that when a heavy bass music is being played; a tapping
30 sensation is experienced. However; a delay in synchronisation may be felt when pulse frequency below 15Hz is used.

It may be desired to limit the extent to which the music can affect the massage pulse. For example if the music level is below a lower threshold the massage pulse

defaults to the lowest intensity setting. If the music level is above an upper threshold for more than 3s, the massage pulse is paused for 0.1s to 0.2s.

5 It may also be desired to vary the synchronism relationship between the music and the massage pulse over time. For example the translation of pulse frequency to the music frequency band may be in an increasing manner over time.

10 It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the example embodiments without departing from the spirit or scope of the invention as broadly described. The example embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS:

1. A Music Synchronised Electronic Muscle Stimulator (EMS) comprising:
 - one or more stimulator units configured for muscle stimulation of a user, a music system configured for providing a music signal to the user, and
 - a controller, in use, connected to each of said stimulator units, including an interface configured for receiving user input including a selected muscle stimulation mode, and said controller configured for generating a predominant frequency signal from said music signal and for providing a control signal to each stimulator unit to thereby stimulate the users muscles, wherein the amplitude and frequency of said control signal being dependent on said user input and said predominant frequency signal,
 - further comprising a plurality of bandpass filters, each receiving said audio signal and corresponding to an audio frequency band, wherein said controller selects the bandpass filter with the highest level output and sets the nominal frequency of the selected bandpass filter as said frequency signal.
2. The Music Synchronised Electronic Muscle Stimulator claimed in claim 1 wherein the frequency of said control signal being dependent on said selected muscle stimulation mode.
3. The Music Synchronised Electronic Muscle Stimulator claimed in claims 1 or 2 wherein the frequency of said control signal being dependent on the frequency of said predominant frequency signal.
4. The Music Synchronised Electronic Muscle Stimulator claimed in any one of claims 1 to 3 wherein the amplitude of said control signal being dependent on the amplitude of said predominant frequency signal.
5. The Music Synchronised Electronic Muscle Stimulator claimed in any one of claims 1 to 4 wherein said predominant frequency signal is translated depending on said selected muscle stimulation mode, and said predominant frequency signal is set as the frequency of said control signal.

6. The Music Synchronised Electronic Muscle Stimulator claimed in any one of claims 1 to 5 wherein said selected muscle stimulation mode is selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof synchronised with said audio signal.
7. The Music Synchronised Electronic Muscle Stimulator claimed in claim 6 wherein said tapping mode corresponds to the frequency of said control signal in use between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal in use between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal in use above 35Hz.
8. The Music Synchronised Electronic Muscle Stimulator claimed in any one of claims 1 to 7 wherein said control signal comprises one or more commands selected from the group consisting of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time and short burst.
9. A method of synchronising an Electronic Muscle Stimulator (EMS) to music comprising the steps of:
 - providing a music signal to a user,
 - generating a predominant frequency signal from said music signal, receiving user input including a selected muscle stimulation mode, providing a control signal to at least one stimulator units, wherein the amplitude and frequency of said control signal being dependent on said user input and said predominant frequency signal, and
 - stimulating the users muscles depending on said control signal;
 - further comprising the steps of selecting the highest level output from a plurality of bandpass filters, each receiving said audio signal and corresponding to an audio frequency band, and setting the nominal frequency of the selected bandpass filter as said predominant frequency signal, further comprising the step of translating said predominant frequency signal depending on said selected muscle stimulation mode, and setting said translated predominant frequency signal as the frequency of said control signal.
10. The method claimed in claim 9 wherein the frequency of said control signal being dependent on said selected muscle stimulation mode.

11. The method claimed in claim 9 or 10 wherein the frequency of said control signal being dependent on the frequency of said predominant frequency signal.
12. The method claimed in any one of claims 9 to 11 wherein the amplitude of said control signal being dependent on the amplitude of said predominant frequency signal.
13. The method claimed in any one of claims 9 to 12 wherein said selected muscle stimulation mode is selected from the group consisting of muscle stimulation simulating: tapping, chopping, squeezing and combinations thereof, synchronised with said audio signal.
14. The method claimed in claim 13 wherein said tapping mode corresponds to the frequency of said control signal in use between 1 to 10Hz, said chopping mode corresponds to the frequency of said control signal in use between 10 to 35Hz, and said squeezing mode corresponds to the frequency of said control signal in use above 35Hz.
15. The method claimed in any one of claims 9 to 14 wherein said control signal comprises one or more commands selected from the group consisting of: amplitude, frequency, direction, pulse width, ramp up time, ramp down time, burst on time, burst off time and short burst.
16. A system for synchronising sensation and/or stimulation of a user with a content signal comprising:
 - one or more sensation and/or stimulation units configured for providing sensation and/or stimulation of a user,
 - an input configured for receiving a content signal, and
 - a controller, in use, connected to each of said sensation and/or stimulation units, including an interface configured for receiving user input including a selected sensation and/or stimulation mode, and said controller configured for determining a sensation and/or stimulation cue from the content in said content signal and for providing a control signal to at least one sensation and/or stimulation unit to thereby provide sensation and/or stimulation to the user, wherein the control signal being dependent on said user input and said sensation and/or stimulation cue,

wherein said content signal comprises an audio stream from which a predominant frequency signal is extracted as said sensation and/or stimulation cue and the frequency of said control signal being dependent on the frequency of said predominant frequency signal,

wherein the amplitude of said control signal depends on the amplitude of said predominant frequency signal,

further comprising a plurality of bandpass filters receiving said audio stream, each corresponding to an audio frequency band, wherein said controller selects the bandpass filter with the highest level output and sets the nominal frequency of the selected bandpass filter as said predominant frequency signal.

17. The System claimed in claim 16 wherein the frequency of said control signal being dependent on said selected sensation and/or stimulation mode.
18. The System claimed in any one of claims 16 to 17 wherein the predominant frequency signal is translated depending on said selected sensation and/or stimulation mode, and said translated predominant frequency signal is set as the frequency of said control signal.
19. A method of synchronising sensation and/or stimulation provided to a user with a content signal comprising the steps of:
 - receiving a content signal,
 - determining a sensation and/or stimulation cue from the content in said content signal,
 - receiving user input including a selected sensation and/or stimulation mode,
 - providing a control signal to at least one sensation and/or stimulation units, wherein the control signal being dependent on said user input and said sensation and/or stimulation cue,
 - providing sensation and/or stimulation to the user depending on said control signal,
 - wherein said content signal comprises an audio stream from which a predominant frequency signal is extracted as said sensation and/or stimulation cue and the frequency of said control signal depends on the frequency,
 - wherein the amplitude of said control signal being dependent on the amplitude of said predominant frequency signal,

further comprising the steps of selecting the highest level output from a plurality of bandpass filters, each receiving said audio stream and corresponding to an audio frequency band, and setting the nominal frequency of the selected bandpass filter as said predominant frequency signal.

20. The method claimed in claim 19 wherein the frequency of said control signal being dependent on said selected sensation and/or stimulation mode.
21. The method claimed in any one of claims 19 or 20 further comprising the steps of translating the predominant frequency signal depending on said selected sensation and/or stimulation mode, and setting said translated predominant frequency signal as the frequency of said control signal.