efficiency (approximately 1.1-1.3 Watt) audio amplifier **512**. The amplifier **512** may be powered directly from the battery voltage **514** to minimize the implementation cost.

[**0073**] In one embodiment, the drive circuit uses four control signals: ENABLE **505**, (polarity) INVERT **504**, PWM_FREQ **502**, and PWM_MAG **503**.

[**0074**] The ENABLE **505** signal is active high: A low will disable the audio amplifier **512**. A high state will enable the audio amplifier **512**.

[**0075**] The INVERT **504** signal is used to stop the actuator by inverting the phase of PWM_FREQ **502**. It is normally set to a logic value of 0, but is switched to a logic value of 1 for the duration required to stop the motion. Leaving it set to a logic value of 1 longer may cause the motion to start in the opposite phase. The timing of the INVERT **504** signal may be calculated and applied by the system **100** for braking an actuator. In other embodiments, the timing of the INVERT **504** signal may be calculated and applied by a processor.

[**0076**] The PWM_FREQ **502** signal may be set to the actuator's fundamental resonant frequency. In operation the PWM_FREQ **502** duty cycle may be set at 50%. The frequency may be set in accordance with the actuator's specified resonant frequency. The actuator's resonant frequency may fall within a tolerance. Accordingly, the level of vibration could be significantly different from device to device if this tolerance is too high.

[**0077**] The PWM_MAG **503** signal is set at a higher switching frequency than PWM_FREQ **502**. A frequency of 20 Khz may provide quiet operation. In other embodiments, other operating frequencies may be used. The level of voltage that may be applied across the actuator's leads may vary proportionately with the duty cycle of PWM_MAG **503**.

[**0078**] Assuming a 1.8 Volts supply on the XOR gates **506**, **507** and an actuator that requires 2.3V RMS, the voltage gain is 1 and is matched to the duty cycle, for example a 75% duty cycle represents 75% of the maximum output of the motor. The voltage gain is adjusted by selecting a matched ratio of resistors **508**C to **508**A and resistors **508**D to **508**B. In other embodiments, the maximum duty cycle may be less than 100% to respect the actuator specifications if the gain is more than 1.

[**0079**] In one embodiment, the circuit does not filter down the harmonics of the fundamental frequency resulting in a quasi-square wave, increasing the energy supplied to the actuator. In such an embodiment, the "vibration" gain is increased from what would be a sinusoid waveform.

[**0080**] The logic levels of the XOR gates **506**, **507** are compatible with the signal generator **501** 1.8 Volts logic level since the XOR gates **506**, **507** are also powered with the same 1.8V supply. The INVERT **504**, PWM_FREQ **502** and PWM_MAG **503** signals drive the XOR gates **506**, **507** directly. The ENABLE **505** signal is also the same 1.8V logic level. In other embodiments, the logic level may need to be shifted to insure compatibility with the logic source.

[**0081**] XOR gate **506** generates the signal for the + input of the audio amplifier **512***b*. The signal is a square wave that can inverted by setting INVERT **504** to a logic state of 1, or can be transmitted without modification by setting INVERT **504** to a logic state of 0.

[**0082**] XOR gate **507** generates the signal for the – input of the audio amplifier **512***c*. This is approximately a 20 kHz variable duty cycle rectangular wave. The polarity of the pulses are inverted in relation to the output of the other XOR gate **506**.

[**0083**] The signal formed by the XOR gates **506**, **507** is filtered to reduce high frequency content for the amplifier **512**. Resistors **510***a*, **510***b* and capacitor **511***b*, **511***c* form a low pass filter. Capacitor **515** provides decoupling for the amplifier **512**. Capacitor **509** provides decoupling to the internal circuits of the amplifier.

[**0084**] Signal generator **501**, in the embodiment shown, generates rectangular waves PWM_FREQ **502** and PWM_MAG **503** using pulse-width modulation. Other embodiments may generate rectangular waves using other methods including, but not limited to, ripple counters, D/A converters, oscillators, ADCs, or a processor. PWM_FREQ **502** may be set to the actuator's fundamental resonant frequency. In operation the duty cycle of the pulse-width modulation may be set at 50%. PWM_MAG **503** may be set at a higher frequency than PWM_FREQ **502**. A frequency of 20 Khz may provide quiet operation. In other embodiments, other operating frequencies may be used. The amplitude of an actuator signal that may be applied to the actuator may vary proportionately with the duty cycle of PWM_MAG **503**. **FIG. 6** shows a graph **600** illustrating the inversion of a signal **602** driving a resonant actuator and a graph **601** illustrating a comparison between the motion of a first resonant actuator **604** driven by the signal **602** and the motion of a second resonant actuator **605** allowed to return to rest without braking, in one embodiment of the present invention. Graph **600** shows a signal **602** configured to drive a resonant actuator. The signal **602** is a rectangular wave with a frequency approximately resonant to the actuator. When time is approximately equal to 1 second, the signal **602** is inverted **603**. The inversion **603** of the signal **602** results in a change in the phase of the signal **602** by approximately 180 degrees, while the inverted signal retains a frequency approximately resonant to the actuator.

[**0085**] Graph **601** shows the motion of two resonant actuators, the motion **604** of the first actuator is generated by driving the first actuator with the signal **602**. The motion **605** of the second actuator is generated by a signal (not shown) similar to signal **602**, however, the signal driving the second actuator is not inverted, but rather it is simply shut off at time=1 second to allow the resonant actuator to return to rest. As can be seen in graph **601**, the motion **604** of the first actuator and the motion **605** of the second actuator are very similar for the portion of the graph **601** leading up to time=1 second when the signal **602** driving the first actuator is very similar to the signal driving the second actuator.

[**0086**] At time=1 second, the signal **602** driving the first actuator is inverted **603**, while the signal driving the second actuator is shut off. As can be seen in graph **601**, the motion **604** of the first actuator decreases to a resting state before time=1.05 seconds. While the motion **605** of the second actuator has not ceased by time=1.2 seconds. Thus, the inversion **603** of the signal **602** driving the first actuator results in a substantial decrease in the braking time of the resonant actuator as compared to the resonant actuator that has no braking force applied to it.

[**0087**] The signal **602** shown is merely a representative example of a signal configured to drive and brake an