TND6198/D

Comprehensive Guide to the Implementation of Haptics into Modern Electronics Systems

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TECHNICAL NOTE

Derived from the Greek word 'haptikós', haptics is the scientific discipline that is concerned with touch. It has become an increasingly important and exciting area for progression in electronics engineering. Though initial research into haptics began as far back as the 1960s, it has really only been in the last decade or so (with the advent of touch screen based control) that we have started to see the widespread proliferation of this technology. Today there is some form of haptic functionality incorporated into a vast array of different items of electronic hardware. With this in mind, the intention of the following white paper is to detail the various haptic mechanisms that currently exist, what are the key attributes for each and which applications they are likely to prove most suitable for. It will go on to discuss ways in which certain approaches to driving haptics are now being used that allow substantial deployment and operational benefits to be realized.

Human machine interfaces (HMIs) is an umbrella term that covers a whole host of different methods through which we interact with technology. As electronics equipment has, over time, become more sophisticated, the significance of the HMI element has grown in magnitude. In many cases (such as smartphone handsets for example) the HMI incorporated can be the key differentiator by which original equipment manufacturers (OEMs) can get the edge over their competition. Touch based HMIs have gone from being a relative niche feature only a few years ago, to now being the stalwart of portable electronics design. In addition, they are getting ever greater traction in white goods, point-of-sales units, factory automation infrastructure and countless other areas. HMIs that are touch enabled have supplanted mechanical switches and pushbuttons, permitting more intuitive operation and enhancing the user experience. Haptic technology adds a further dimension to touch control − transforming it into a two way rather than just a one way thing. Using haptics it is possible to supply sensory stimuli to the individual operating the HMI. Through it feedback on operations being performed can be received − via mechanical vibration or, in other cases, a resistant force of some kind. This makes it is possible for the user to determine whether or not the intended operation has been completed successfully or not. Opportunities for haptics are opening up all the time, with the global market for haptics technology expected to witness a compound annual growth rate (CAGR) of 25.39% between now and 2020, allowing it to reach a $29.84 billion annual total by the end of that period (according to research published by Markets and Markets).

Fundamentals of Haptic Functionality

Generally speaking haptics work on the following principals. When the user places their finger upon a button that has been rendered on a touch screen display, the touch controller registers the touch point and the data relating to this is subsequently transferred to the system processor. Upon receiving that data, the processor activates the haptic, which in turn initiates the motor. It is this that generates the vibrational movement. The motor of course has to be driven by a suitable driver IC.

Examples of Haptic Implementations

There are numerous everyday situations where haptics are being employed. These include:

- Smartphones − where vibration of the handset can be used to alert the user when a text message, email or an incoming call is being received (with specific vibration profiles being set for each).
- Games Consoles − in which vibrations can serve a variety of different purposes in order to make gameplay feel more realistic. In war oriented games for instance it is possible to mimic the recoil from a gun as it is shot, or the shockwave emanating from an explosion. While in racing games it can emulate the response that a driver might feel when undertaking a steering maneuver, or when the vehicle is going over rough ground.
- Childcare Products − such as teething rings for infants.
- Training Equipment/Simulators − for use in medical, avionic and military applications.
- Indicator Systems − for informing restaurant customers when there table is ready, or for use in interactive exhibitions.

- Robotics and Mechatronics
- Tablet Computers
- Barcode Readers
- Toys
- Wearable Electronics
- GPS Units

Key Design Considerations

Haptics are now being utilized for all manner of diverse applications. Furthermore, the scope for their employment is continuing to increase all the time. As with every other area of electronic system design, there are a set of stringent criteria that need to be met. For haptic implementations, these will normally include:

- Maximizing System Responsiveness
- Ensuring that the Size of the Overall Solution is Kept to a Minimum
- Keeping the Bill of Materials Costs in Check
- Minimizing the Power Budget
- Ensuring High Reliability Levels

Haptic Motor Types

There are a multitude of different types of haptic motor actuator systems that are currently being employed within HMI designs. The main ones are as follows (they are summarized in Figure 1).

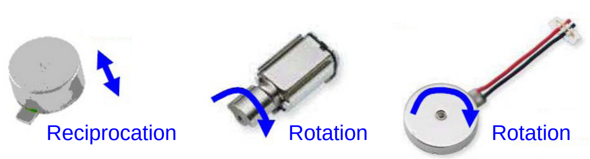

Figure 1. Different Haptic Motor Types

Eccentric Rotating Mass (ERM) − with this type of haptic motor an off-balance mass is caused to rotate. The movement of the mass results in an asymmetric centripetal force being generated, leading to the motor's displacement.

Cylindrical − this type is similar to ERM motors, but has substantially larger dimensions. Due to their size, cylindrical motors are not as quick to respond to vibrational activations which impinges upon their performance. Also, just as with the ERM type, such motors do not exhibit particularly high levels of durability.

Linear Resonance Actuator (LRA) − these rely on a magnet attached to the case by a spring. The magnetic field from the coil causes the initiation of vibration activity. This is similar to the way vibrations are produced in audio speakers to create sound). The vibration that is generated within an LRA is at a single frequency. LRA haptics have a number of major advantages over other haptic motor types (such as cylindrical or ERM). These units have better responsiveness (improving system performance), they can be housed in more compact enclosures (enabling them to be implemented in space constrained designs), they have a more rugged construction and they require only a minimal complement of external component parts to support them. These attributes mean that LRA technology is particularly very well suited to specification within modern portable applications.

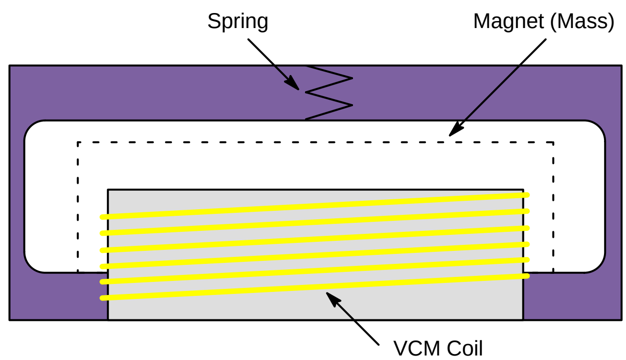

Figure 2. Schematic Showing Basic LRA Structure

Haptic Driver Solutions

The motor which generates the vibration needs to be accompanied by driver electronics. Originally the driving of haptics motors could be carried out through use of discrete devices. Normally these would be a clock generator IC with two buffer amplifiers, or a sine wave generator along with an audio amplifier IC. If the haptic design uses a clock generator based haptic driver, the buffer amplifiers work together with the clock generator to heighten the amplitude of the output. In addition they help to smooth off the sharp edges of the square wave voltage profile applied by the clock generator. If this smoothing was not done, then it is possible that the moving mass would crash into the casing. This would lead to unwanted audible noise being produced, energy being unnecessarily expended and potential damage to the haptic mechanism (thereby reducing its operational lifespan). Clock generator driving topologies also require a high power budget.

In contrast, with sine wave generator haptic drivers, the sharp edges that are witnessed on clock generator drivers do not materialize – thus delivering a response that is considerably smoother. The moving mass vibrates without the risk of it hitting the casing. Once again, however, the quantity of external components involved means that plenty of board space is needed.

It is clear that conventional haptic driver solutions have certain downsides that engineering teams need to be aware of. The semiconductor industry is now starting to introduce IC solutions that are better optimized for haptic implementation. These are dedicated, highly integrated haptic motor drivers which are able to outperform the discrete solutions already discussed.

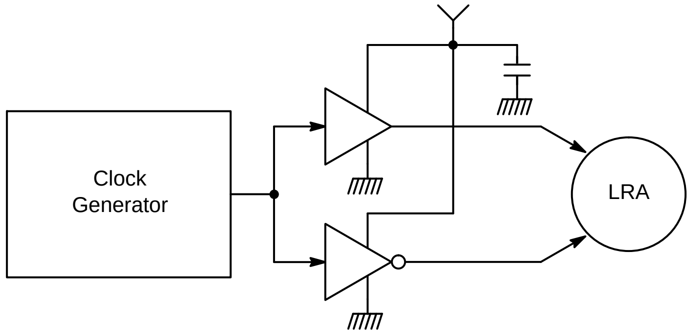

Figure 3. Schematic Describing Clock Generator Haptic Driver

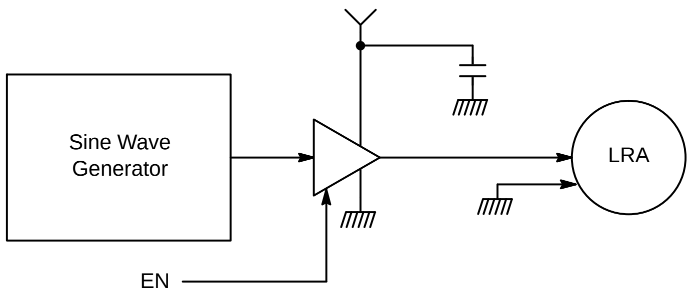

Figure 4. Schematic Describing Sine Wave Generator Haptic Driver

The haptic aspect of the HMI will operate with maximum responsiveness if the LRA is driven at a frequency which matches the resonant frequency that is inherent to the motor (F_R) being utilized. The value of FR can actually vary by as much as 5 Hz because of different factors and dynamics. Among these are LRA orientation, the ambient temperature, or the material the LRA is in contact with. The F_R, for example, will be different if the product containing the LRA is being held in the user's hand, is resting on a hard surface, is located in the user's pocket or is hanging from a strap. If the conditions are such that LRA produces insufficient vibration, then the vibration force can either be increased by ramping up the driving force or, alternatively, by adjusting the drive frequency (F_D) to match the new F_R value. It is therefore much more efficient if F_R can be tracked and the F_D adjusted so that it matches this. If the motor driver is not, however, able to align itself with the motor's F_R, the resulting vibration strength will be diminished and extra power will need to be expended to cover the deficit.

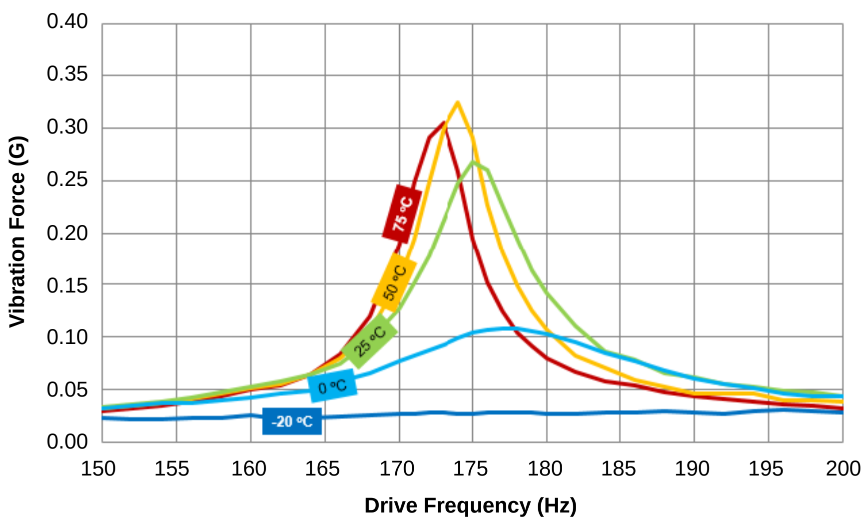

Figure 5. Relationship between F_R & Temperature

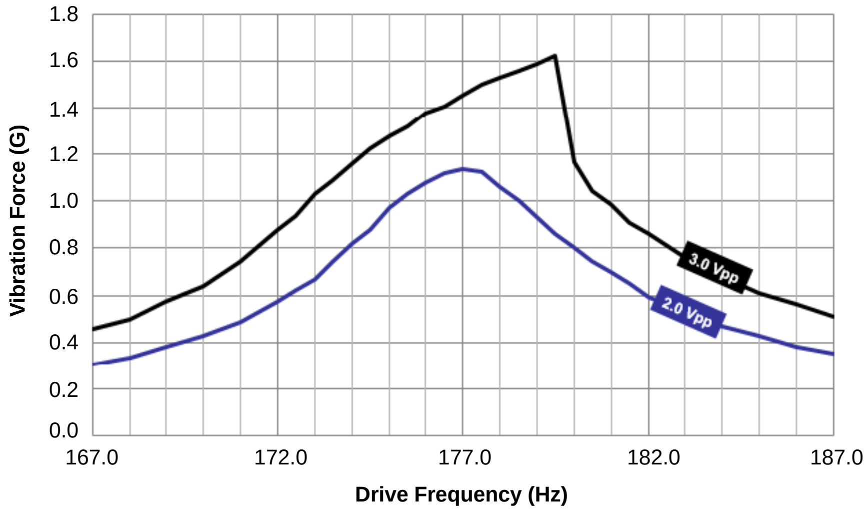

Figure 6. Relationship between F_R & Drive Amplitude

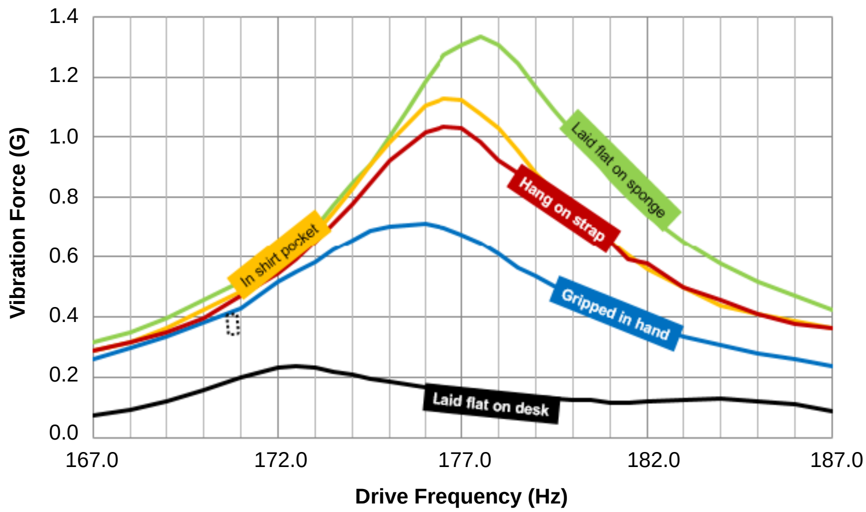

Figure 7. Relationship between F_R & Orientation

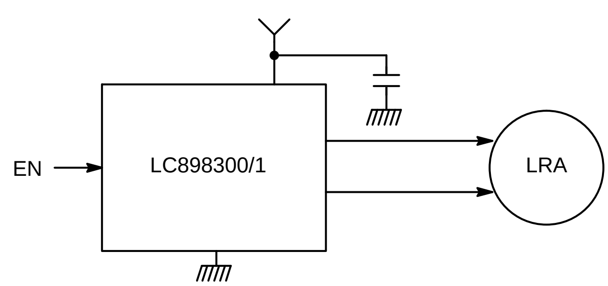

Figure 8. Schematic Detailing High Efficiency Haptic Driven by an ON Semiconductor LC89830x

ON Semiconductor is fully aware that the capacity to tune F_D is destined to be of huge importance to the future of haptic design. The company has developed highly efficient LRA driver series, the members of which can be controlled by a single enable pin. The LC898300, LC898301 and LC898302, thanks to their innovative auto-tune feature have the ability to automatically adjust their F_D to mirror the changes in the motor's F_R. This can increase the force of the perceived vibration by over 20%, making it far more efficient than conventional haptic driving solutions. They require minimal power but are capable of maintaining a high level of vibration. While the other solutions require four, if not five, additional components, these ICs only need a single bypass capacitor.

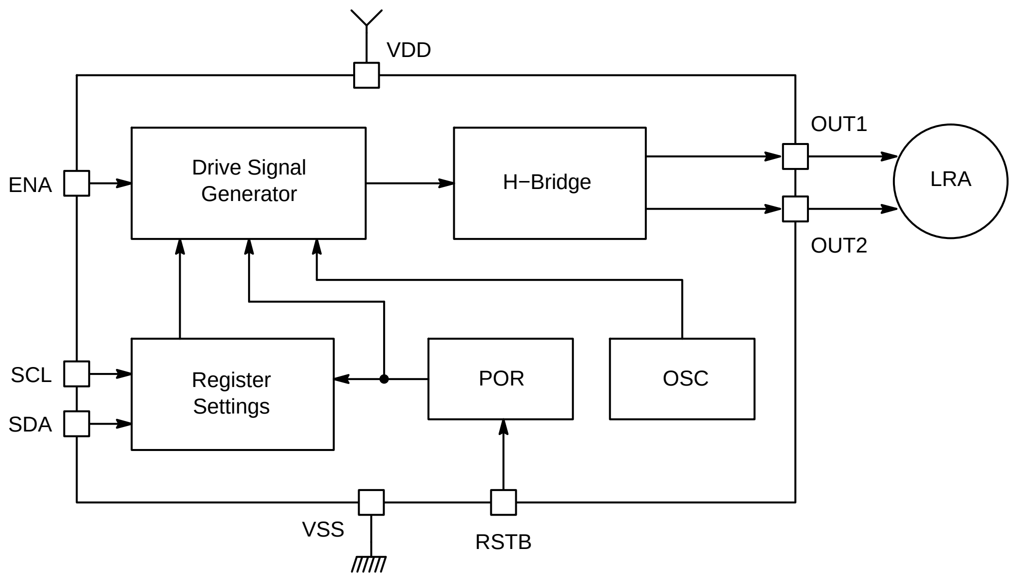

Figure 9. Functional Block Diagram of LC898300

These devices can get the same level of vibration force as the sine wave drive method, but using only 80% of the current. They do this by cutting in half the on/off periods in the drive current. By rounding off the corners on the output, there is no audible noise to contend with. In addition, through the brake function, the vibration can be turned off much more rapidly. This means it can be used to deliver a broader spectrum of haptic effects − revealing new possibilities for HMI designers. Figure 11 shows that by reducing the peak current from 90 mA to 85 mA and having a more efficient waveform, it is possible to get an average current for the sine wave of 45.8 mA rather than 57.3 mA. Furthermore, they only require a solitary external bypass, thereby reducing the utilization of board real estate, as well as lowering the overall bill of materials costs − both of which are highly important in space constrained, cost sensitive consumer electronics designs. These drivers are initially configured using an I^2C interface, once complete a single wire can be used to turn them on and off.

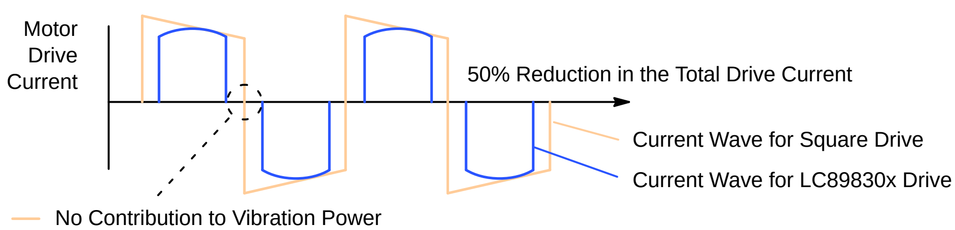

Figure 10. Drive Profile Comparison − Square Wave & LC89830x

ON Semiconductor has an extensive range of evaluation boards to assist engineers in determining which of its ICs is the best fit for their particular application. Many of the boards have the capacity to be modified. This enables engineers to get very close to the final solution before they have to commit their board layout and design to the prototype or pre-production solution.

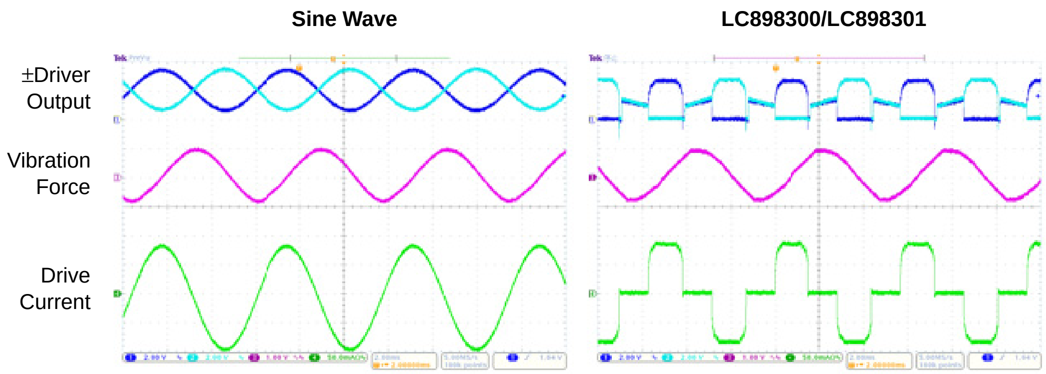

Figure 11. Oscilloscope Plots Showing How LC898300/LC898301 Devices Can Deliver Vibrational Force Equal to Sine Wave Drive Using Much Lower Current

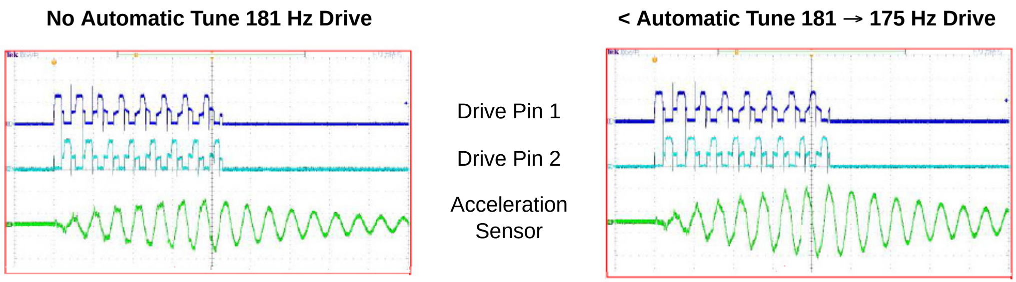

Figure 12. Improvements to LRA Performance via Automatic Tuning Function

In conclusion, haptics are being integrated into an increasing number of portable consumer, industrial control, gaming domestic appliance and home automation systems. They provide feedback to those operating electronic equipment to ensure that the system has received the desired input and safeguard against potential errors occurring. Alternatively they can be used to mimic certain actions in order to enable markedly better user experiences to be derived. Through their incorporation, supported by an optimized driving technology (especially where it is possible for the drive frequency to be tuned), more advanced touch based HMI solutions can be created, which deliver a higher level of engagement and thereby differentiate themselves from standard touch enabled HMIs. ON Semiconductor's proprietary haptic driving technology is considerably more power efficient and space conscious, as well as being functionally richer, than competing solutions on the market.

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