# Feel the Real World

The final haptic feedback design solution

Need For Power Motor
www.nfpmotor.com

# Touch is….

…how we interact with...

…how we feel...

…how we experience…

…the **WORLD.**

# Touch Introduction

- Touch screens are replacing traditional user interfaces

| | |
|---|---|
| Cell Phones & Handhelds | Tablets |
| Laptops & Desktops | Portable Gaming Devices |

- Touch screens have obvious advantages
  - Direct **interaction** with on-screen content
  - Flexibility provided by a **dynamic** display
  - Rich **input and gesture** vocabulary
  - Improved mechanical **durability**
- Touch screens have one major disadvantage
  - **No physical or mechanical feedback** when the screen is pressed or an event occurs
  - Loss of ***tactile*** or ***haptic*** feedback

# What is Haptics?

**1** Haptics is the science and technology of touch

**2** It simulates surfaces and movements by using vibrations

**3** It's easy to implement and an inexpensive way to differentiate a product

**4** A way to experience something new

# Haptics in Tablets & Handhelds

**Applications come to life….**

- The turning of a page
- A keyboard you can feel
- The vibrations of a game or movie

# Experience something new…

- A game console-like experience in a mobile device
- Feel the beat of a drum or the strum of a guitar
- Play a pin-ball game as if you were in an old-fashion arcade

# Add Haptics Even to Existing Applications

*Almost any application or game with sound effects.*

# What can Haptics do for you?

Mobile

Medical

Education

Industrial

Commerce

Sports


White Goods

Consumer

Arts

Science

Gaming

Consumer

# Touch Screens & Surfaces

- **Remotes** with static or dynamic controls
  - Audio/Video
- **Appliances**
  - Ovens
  - Washer/Dryer
- **Home Systems**
  - Alarm
  - HVAC
- **Computer Pads**
  - Mouse pad
  - Drawing Tablet

# How can Need For Power Motor help?

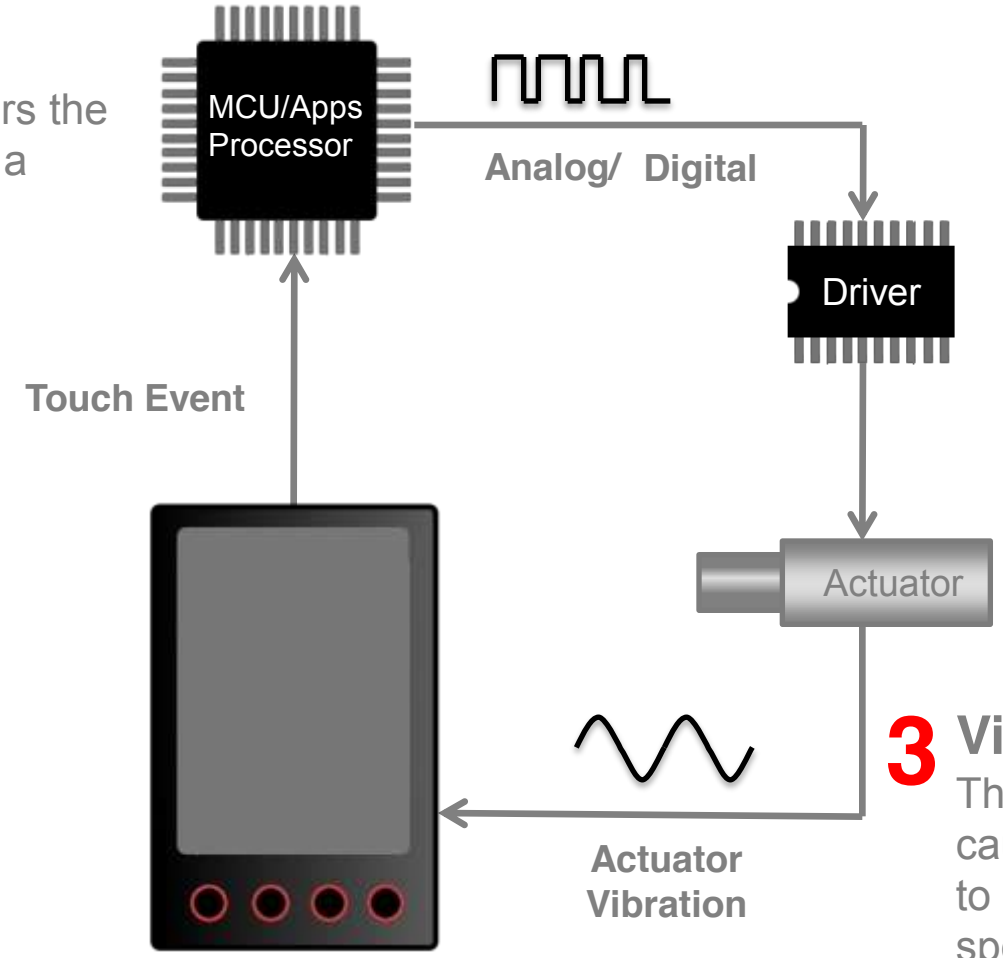
- NFP-Motor connects the digital world to your world using haptics technology

- We develop actuator drivers optimized for haptics applications
- Provide reference designs, schematics and hardware
- Work with customers and 3rd parties to provide complete hardware and software solutions
- A top choice for customers looking to enhance their products with haptics

# Haptic )IHBGBDBN Diagram

## 2 Generate

The touch event triggers the processor to generate a waveform.




## 1 Touch

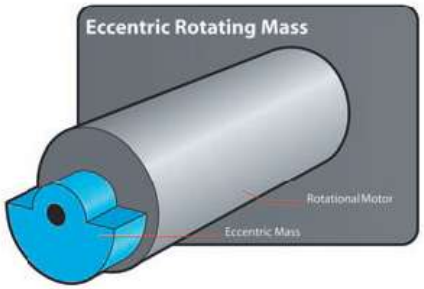
The touch screen controller sends a trigger signal to the processor when a press is detected.

## 3 Vibrate

The waveform causes the actuator to move in a specific direction or pattern to create a vibration.

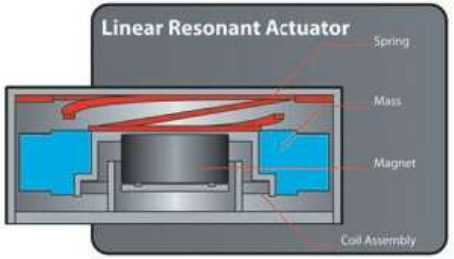
# Actuators

## Eccentric Rotating Mass (ERM)



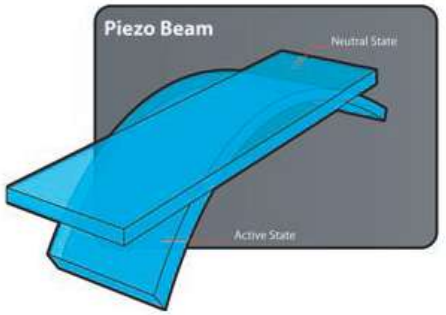

| | |
|---|---|
| **Voltage** | 1 – 10 $V_{DC}$ |
| **Power** | 10% of battery |
| **Frequency** | 1 – 300 Hz |
| **Response** | 40 – 80 ms |
| **Waveform** | DC Voltage |
| **Vendors** | Sanyo, Jinlong Johnson Elec. |

## Linear Resonant Actuator (LRA)




| | |
|---|---|
| **Voltage** | 2.5 – 10 $V_{DC}$ |
| **Power** | 5% of battery |
| **Frequency** | 175 Hz |
| **Response** | 20 – 30 ms |
| **Waveform** | Sine wave |
| **Vendors** | SEMCO (Samsung) |

## Piezo




| | |
|---|---|
| **Voltage** | 50 – 200 $V_{pp}$ |
| **Power** | 7% of battery |
| **Frequency** | 1-300Hz |
| **Response** | < 1 ms |
| **Waveform** | Sine wave |
| **Vendors** | AAC, Murata Hokuriku, TDK |

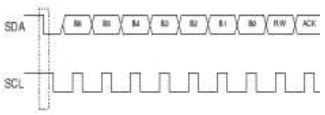
# Actuator Comparison

| Attribute | ERM | LRA | SL Piezo | ML Piezo |
|---|---|---|---|---|
| Actuator Type | Inertial | Inertial | Piezo | Piezo |
| Cost | $ | $$ | $$ | $$$ |
| High Definition Haptics | No | No | Yes | Yes |
| Localized Haptics | No | No | Yes | Yes |
| Whole-Device Haptics | Yes | Yes | Yes | Yes |
| Size | Bulky | Bulky | Thin | Thin |
| Drive voltage (Vp-p) | 10 V | 10 V | 150 V - 200 V | 30 V – 50 V |
| Control | DC | Amp. Mod. | Large BW | Large BW |
| Response time | 40-80 ms | 20-30 ms | <<1 ms | <<1 ms |
| Power Consumption | Poor | Best | Good | Good |
| TI Products | DRV8601<br>DRV**** | DRV8601<br>DRV**** | DRV****<br>DRV****<br>DRV**** | DRV****<br>DRV****<br>DRV**** |

SL – single layer, ML – multi-layer

* Under development, ** Concept

# DRV2604/5 Features




## Digital & Analog Interfaces

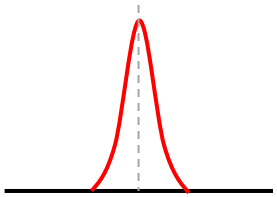
Content the device to an available $I^2C$, PWM, Audio, Analog, or GPIO

## Closed Loop Feedback

Automatically improve the response time of ERM and LRA actuators.

## Automatic Calibration

Automatically detect and configure the closed-loop feedback loop for every actuator



## Auto-resonance Detection

Automatically sense the resonance frequency of LRAs. Maximize vibration strength and improve consistency across devices.

## Audio-to-Haptics

Provide haptics to applications that do not have haptics and enhance bass from music and movies

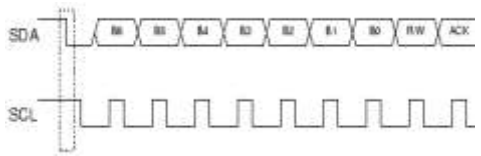
## Waveform Library

123 affects embedded, royalty free

## Automatic Diagnostics

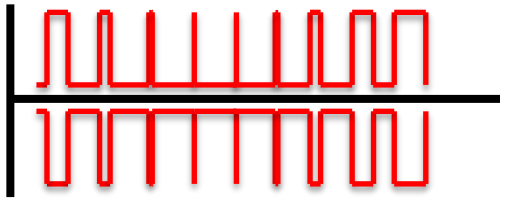
Automatically detect the status of the motor

# Interface Options



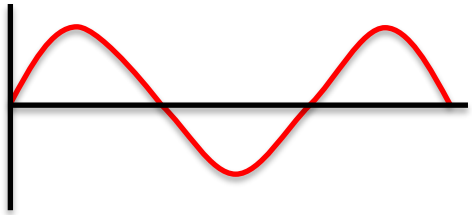

## I²C Interface

Can be used for control, waveform triggering, and real-time waveform playback.



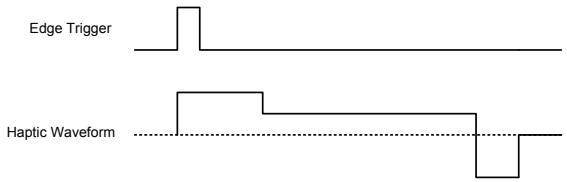
## PWM

Control both ERM and LRA using a PWM signal



## Analog Input

Drive hatpics through an available DAC

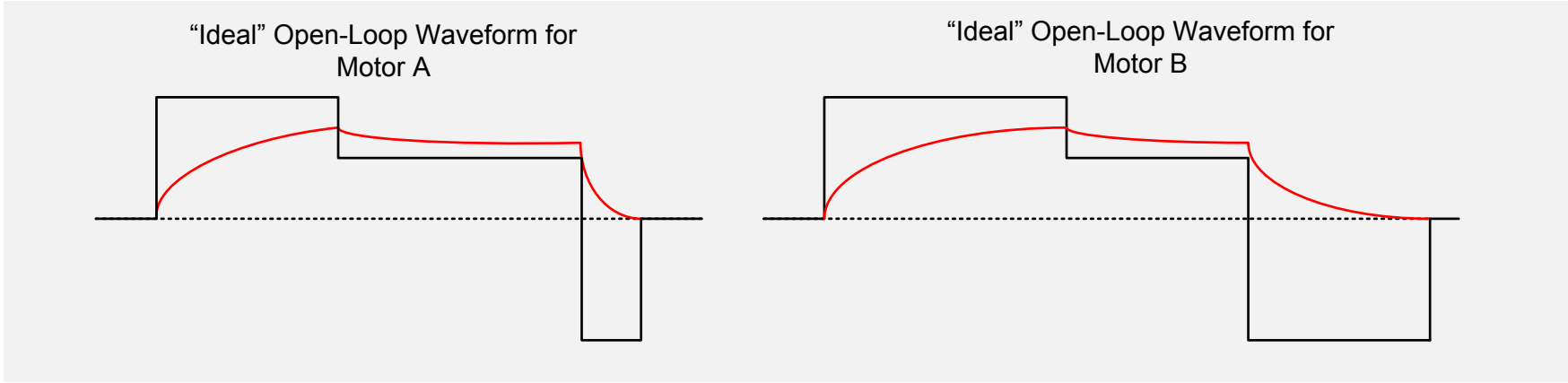



## Trigger Mode

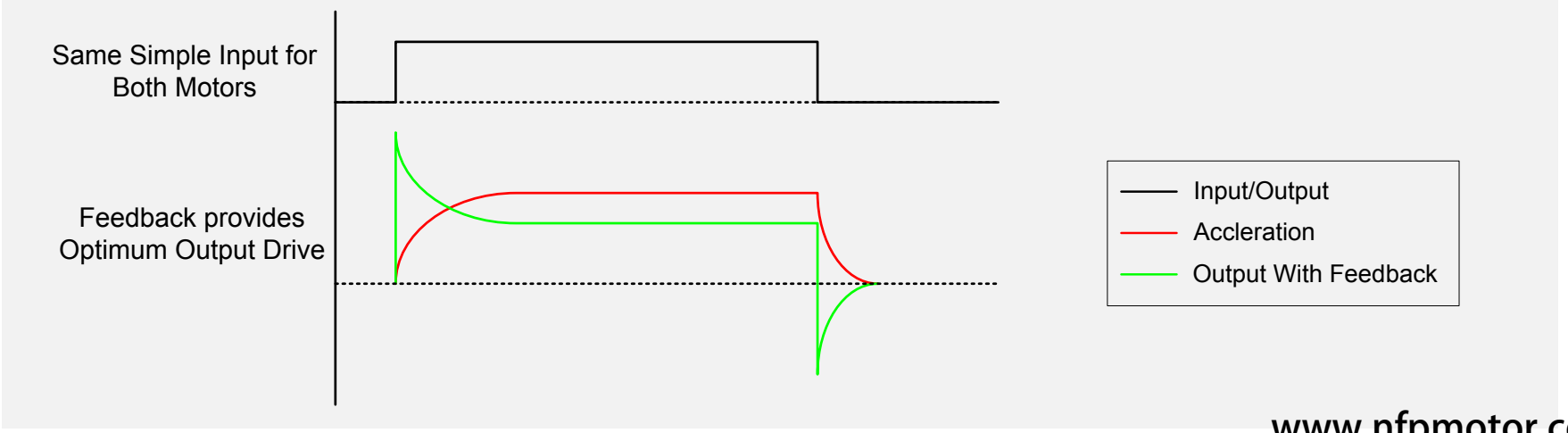
Trigger waveform output using a GPIO

# Driving with Closed-Loop Feedback

**Open-Loop:** Waveform startup and braking must be calculated and tested for each motor




**Closed-Loop:** Waveform startup and braking is automatic without testing and characterization



# Closed-Loop Feedback

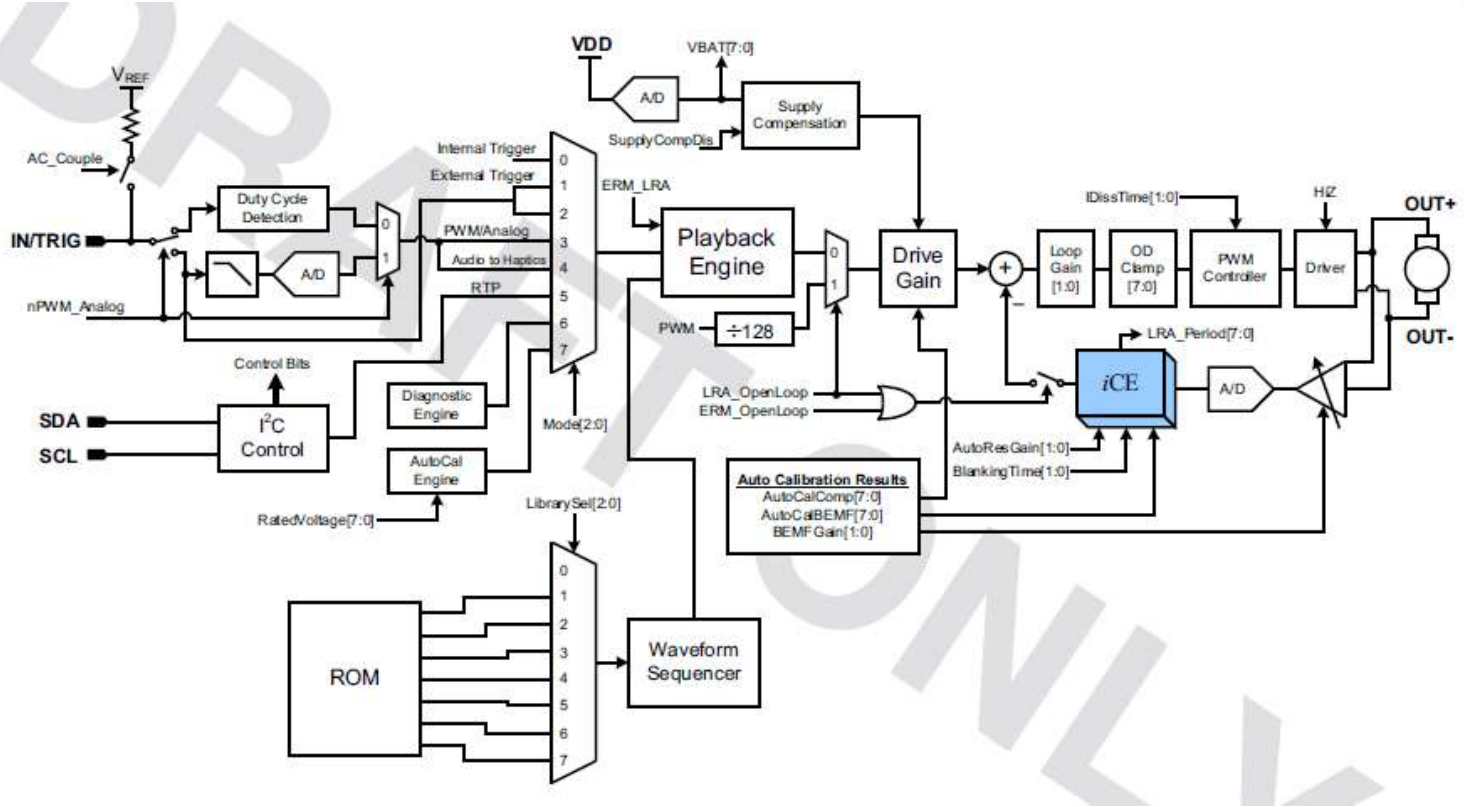
## No Feedback


## DRV2605 Feedback


Faster Startup with **Automatic Overdrive**

Quicker and more controlled braking with **Automatic Braking**

# Auto Calibration




Our driver uses a patented algorithm based on our characterization and testing of numerous ERM and LRA. Auto-calibration ensure that no matter the actuator the DRV2605 is setup to accurately control it.

# Auto-Resonance Detection

## Auto-Resonance Detection

### Better Actuator Braking performance

Braking is important for creating “sharp” and “crisp” haptics effects as well as “event separation” for multiple-event waveforms like double-clicks.

**2x** **More Force**
when driving the linear resonant actuator at resonance

**50%** **Less Power**
when driving haptics events like clicks/alerts when compared to drivers with no automatic resonance detection

### Simplified Input Signaling

No specific input frequency required.
Accepts PWM signals from 10kHz – 250kHz

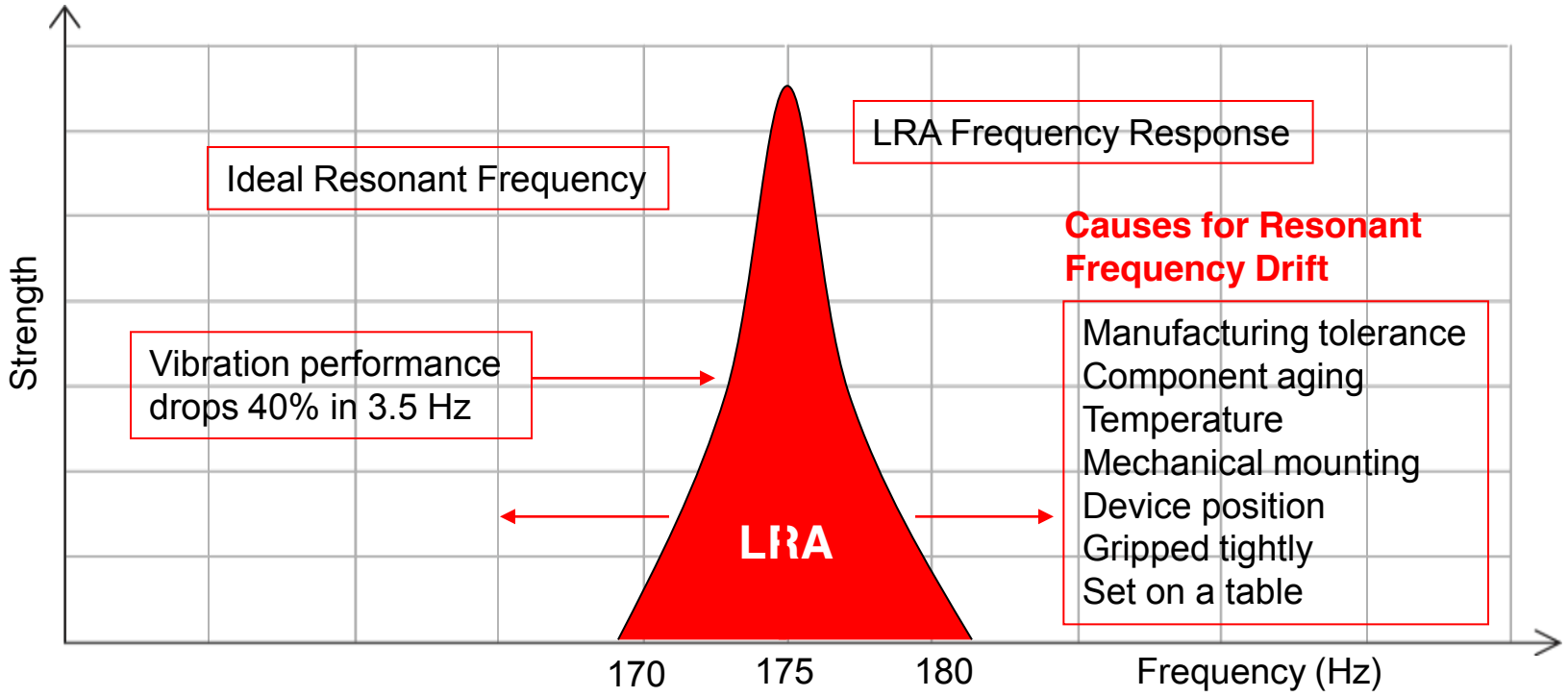
### Sensing Integrated

Resonance frequency detected through outputs

# Auto-Resonance – Why?

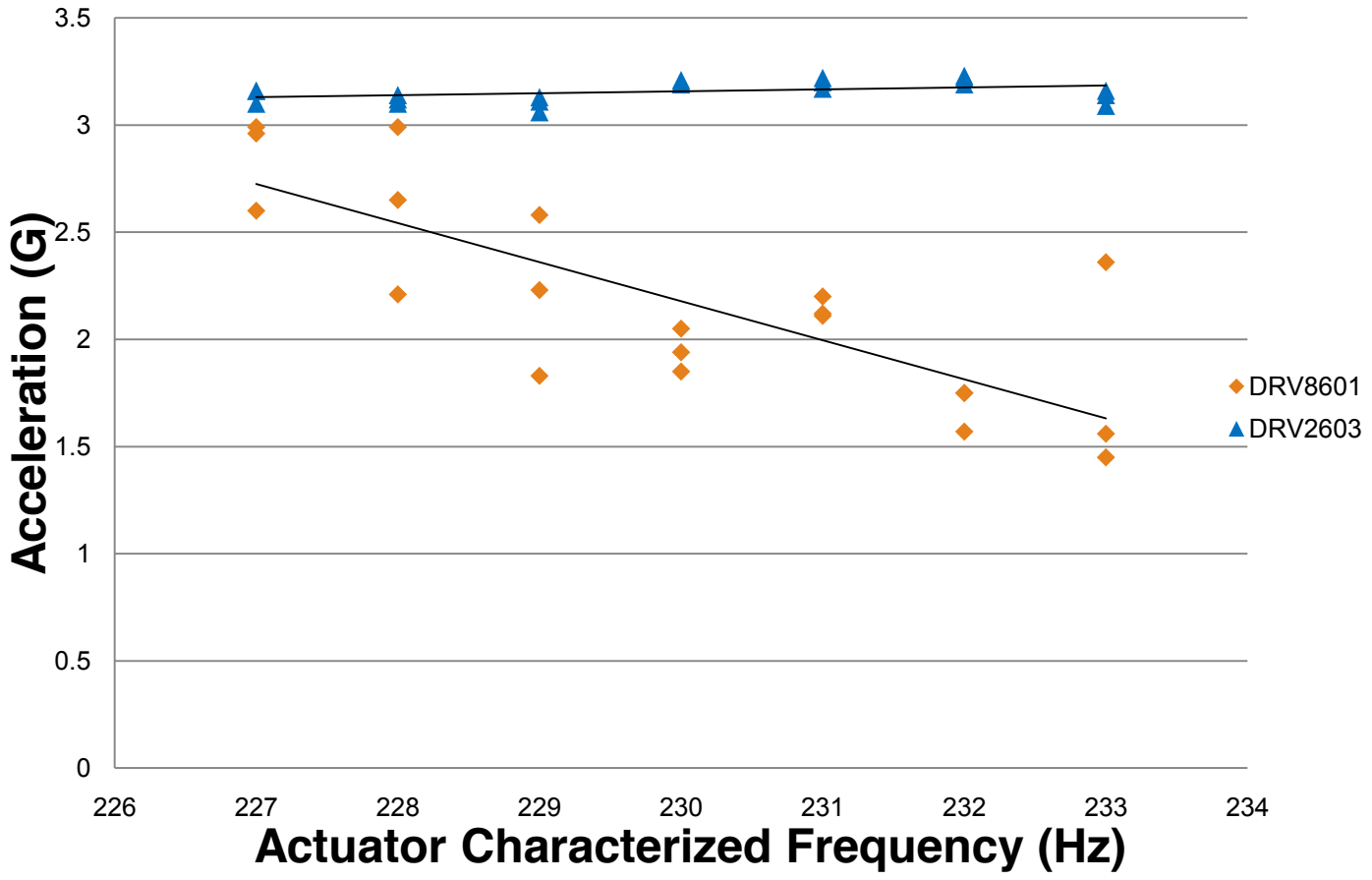
The LRA resonance frequency will change because of electrical, mechanical, and environmental factors. An LRA has a very narrow resonance so driving slightly off resonance can cause weak vibration strength.

## LRA Resonant Frequency Drift



# Auto-Resonance Provides Consistent Feel

**The orange dots indicate the vibration strength when using a driver without auto-resonance, the blue dots show the vibration is more consistent when using auto-resonance.**



# Audio-to-Haptics

**Create haptics using audio for applications that do not natively support haptics**

**Use audio-to-haptics to enhance music and movies by adding bass vibrations**

**Audio Only**


**Audio + Haptic Vibrations**


**More realistic experience with haptic vibrations**

# Embedded Waveform Library

The DRV2605 has 123 embedded waveforms (called TS2200C) that can be used without licensing fees. Simply send a trigger command to play waveform or use the included software API.

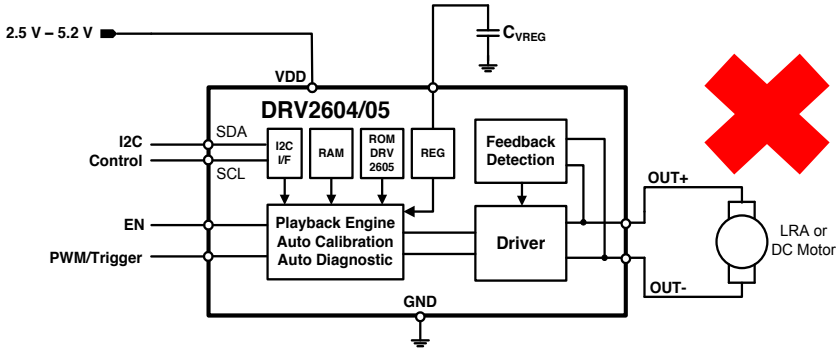
0 Strong Click
1 Med Strong Click 60%
2 Low Strong Click 30%
3 Sharp Click
4 Sharp Click 60%
5 Sharp Click 30%
6 Soft Bump
7 Med soft Bump 60%
8 Soft Bump 30%
9 Double-Click
10 Double-click 60%
11 Triple-Click
12 Soft Fuzz
13 Strong Buzz
14 [reserved]
15 [reserved]
16 Strong Click 1 - 100%
17 Strong Click 2 - 80%
18 Strong Click 3 - 60%
19 Strong Click 4 - 30%
20 Medium Click 1 - 100%
21 Medium Click 2 - 80%
22 Medium Click 3 - 60%
23 Sharp Tick 1 - 100%
24 Sharp Tick 2 - 80%
25 Sharp Tick 3 – 60%
26 Short Double Click Strong 1 – 100%
27 Short Double Click Strong 2 – 80%
28 Short Double Click Strong 3 – 60%
29 Short Double Click Strong 4 – 30%
30 Short Double Click Medium 1 – 100%
31 Short Double Click Medium 2 – 80%
32 Short Double Click Medium 3 – 60%
33 Short Double Sharp Tick 1 – 100%
34 Short Double Sharp Tick 2 – 80%
35 Short Double Sharp Tick 3 – 60%
36 Long Double Sharp Click Strong 1 – 100%
37 Long Double Sharp Click Strong 2 – 80%
38 Long Double Sharp Click Strong 3 – 60%
39 Long Double Sharp Click Strong 4 – 100%
40 Long Double Sharp Click Medium 1 – 100%
41 Long Double Sharp Click Medium 2 – 80%
42 Long Double Sharp Click Medium 3 – 60%
43 Long Double Sharp Tick 1 – 100%
44 Long Double Sharp Tick 2 – 80%
45 Long Double Sharp Tick 3 – 60%
46 Buzz 1 – 100%
47 Buzz 2 – 80%
48 Buzz 3 – 60%
49 Buzz 4 – 40%
50 Buzz 5 – 20%
51 Pulsing Strong 1 – 100%
52 Pulsing Strong 2 – 60%
53 Pulsing Medium 1 – 100%
54 Pulsing Medium 2 – 60%
55 Pulsing Sharp 1 – 100%
56 Pulsing Sharp 2 – 60%
57 Transition Click 1 – 100%
58 Transition Click 2 – 80%
59 Transition Click 3 – 60%
60 Transition Click 4 – 40%
61 Transition Click 5 – 20%
62 Transition Click 6 – 10%
63 Transition Hum 1 – 100%
64 Transition Hum 2 – 80%
65 Transition Hum 3 – 60%
66 Transition Hum 4 – 40%
67 Transition Hum 5 – 20%
68 Transition Hum 6 – 10%
69 Transition Ramp Down Long Smooth 1 – 100 to 0%
70 Transition Ramp Down Long Smooth 2 – 100 to 0%
71 Transition Ramp Down Medium Smooth 1 – 100 to 0%
72 Transition Ramp Down Medium Smooth 2 – 100 to 0%
73 Transition Ramp Down Short Smooth 1 – 100 to 0%
74 Transition Ramp Down Short Smooth 2 – 100 to 0%
75 Transition Ramp Down Long Sharp 1 – 100 to 0%
76 Transition Ramp Down Long Sharp 2 – 100 to 0%
77 Transition Ramp Down Medium Sharp 1 – 100 to 0%
78 Transition Ramp Down Medium Sharp 2 – 100 to 0%
79 Transition Ramp Down Short Sharp 1 – 100 to 0%
80 Transition Ramp Down Short Sharp 2 – 100 to 0%
81 Transition Ramp Up Long Smooth 1 – 0 to 100%
82 Transition Ramp Up Long Smooth 2 – 0 to 100%
83 Transition Ramp Up Medium Smooth 1 – 0 to 100%
84 Transition Ramp Up Medium Smooth 2 – 0 to 100%
85 Transition Ramp Up Short Smooth 1 – 0 to 100%
86 Transition Ramp Up Short Smooth 2 – 0 to 100%
87 Transition Ramp Up Long Sharp 1 – 0 to 100%
88 Transition Ramp Up Long Sharp 2 – 0 to 100%
89 Transition Ramp Up Medium Sharp 1 – 0 to 100%
90 Transition Ramp Up Medium Sharp 2 – 0 to 100%
91 Transition Ramp Up Short Sharp 1 – 0 to 100%
92 Transition Ramp Up Short Sharp 2 – 0 to 100%
93 Transition Ramp Down Long Smooth 1 – 50 to 0%
94 Transition Ramp Down Long Smooth 2 – 50 to 0%
95 Transition Ramp Down Medium Smooth 1 – 50 to 0%
96 Transition Ramp Down Medium Smooth 2 – 50 to 0%
97 Transition Ramp Down Short Smooth 1 – 50 to 0%
98 Transition Ramp Down Short Smooth 2 – 50 to 0%
99 Transition Ramp Down Long Sharp 1 – 50 to 0%
100 Transition Ramp Down Long Sharp 2 – 50 to 0%
101 Transition Ramp Down Medium Sharp 1 – 50 to 0%
102 Transition Ramp Down Medium Sharp 2 – 50 to 0%
103 Transition Ramp Down Short Sharp 1 – 50 to 0%
104 Transition Ramp Down Short Sharp 2 – 50 to 0%
105 Transition Ramp Up Long Smooth 1 – 0 to 50%
106 Transition Ramp Up Long Smooth 2 – 0 to 50%
107 Transition Ramp Up Medium Smooth 1 – 0 to 50%
108 Transition Ramp Up Medium Smooth 2 – 0 to 50%
109 Transition Ramp Up Short Smooth 1 – 0 to 50%
110 Transition Ramp Up Short Smooth 2 – 0 to 50%
111 Transition Ramp Up Long Sharp 1 – 0 to 50%
112 Transition Ramp Up Long Sharp 2 – 0 to 50%
113 Transition Ramp Up Medium Sharp 1 – 0 to 50%
114 Transition Ramp Up Medium Sharp 2 – 0 to 50%
115 Transition Ramp Up Short Sharp 1 – 0 to 50%
116 Transition Ramp Up Short Sharp 2 – 0 to 50%

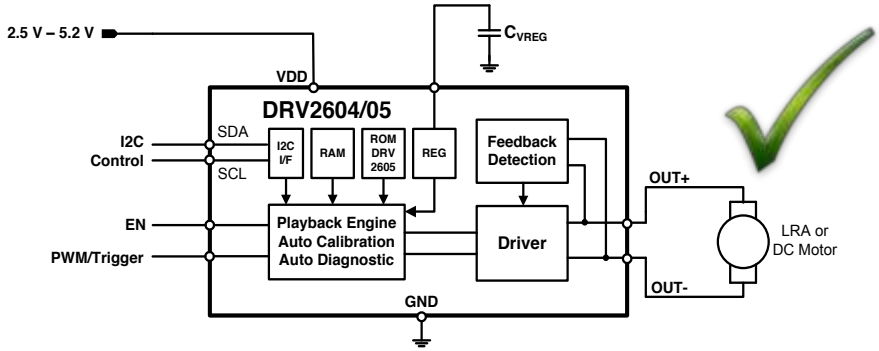
# Automatic Actuator Diagnostics

**Automatic Diagnostics** allow you to test the actuator through the DRV2605 in production.

**Detect if the actuator is:**

- Not Connected
- Shorted or Over-Current is detected
- Generating poor back-EMF (this identifies a bad actuator)



# DRV8601

## Haptics Motor / Linear Vibrator Driver with Ultra-Fast Turn-On

### Features

- High Current Output of **400 mA** from 3V Supply
- 2.5 V - 5.5 V Operation
- Support for Loads as Low as 7W
- Input Frequency Range: 20 Hz - 30 kHz
- Only 3 External Components Needed
- Fast Turn-On Time of **100 us**
- Low Quiescent Current of **1.7 mA**
- Low Shutdown Current of **10 nA**
- Output Short Circuit Protection
- Thermal Overload Protection
- 2 mm x 2 mm MicroStar BGA package
- 3 mm x 3 mm QFN (DRB)

### Benefits

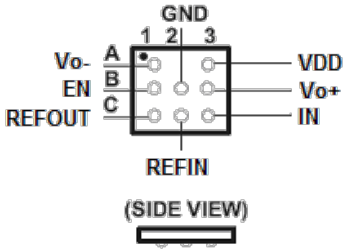
- Drives ERM and LRA Actuator types
- Direct Connection to Battery
- Drives both Motors (ERM) and Linear Vibrator (LRA)
- Wide Range of Input Frequencies
- Very Small Solution Size
- ~60x faster Haptic Feedback Response
- ~10x lower quiescent current for low power
- Low Shutdown Power Consumption
- Protection from Accidental Short Circuit
- Protection from Overheating
- Small Size, Saves Board Space

### Applications

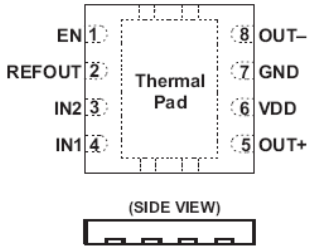
- Mobile Phones
- Tablets
- Portable Navigation Devices
- Portable Gaming Consoles

### Pin-out information

MicroStar Junior™ (ZQV) PACKAGE
(TOP VIEW)




DRB Package
(Top View)

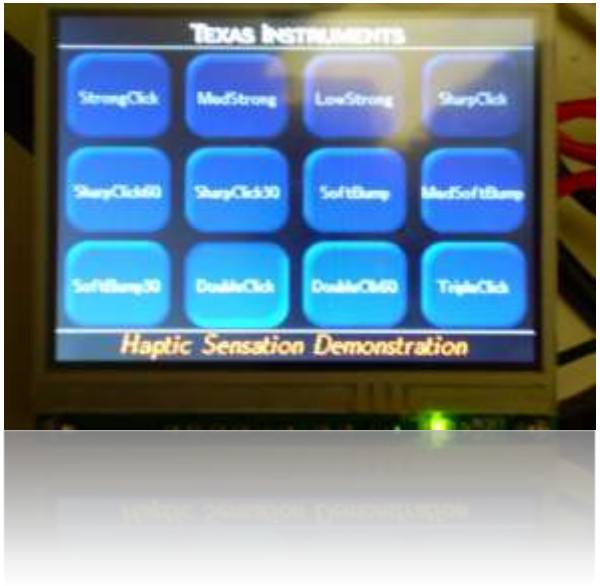



### Availability

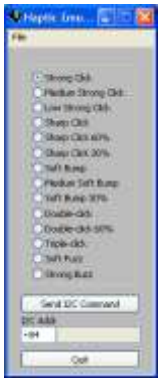
**Samples:** Now
**EVM:** Now
**Production:** Now

# DRV8601 Demo Boards

- ERM Haptics Demo using a Stellaris Touch Screen
- Uses MSP430 + DRV8601 to generate effects through $I^2C$




- ERM Haptics Demo using a GUI
- Uses MSP430 + DRV8601 to generate effects from GUI



# Thanks