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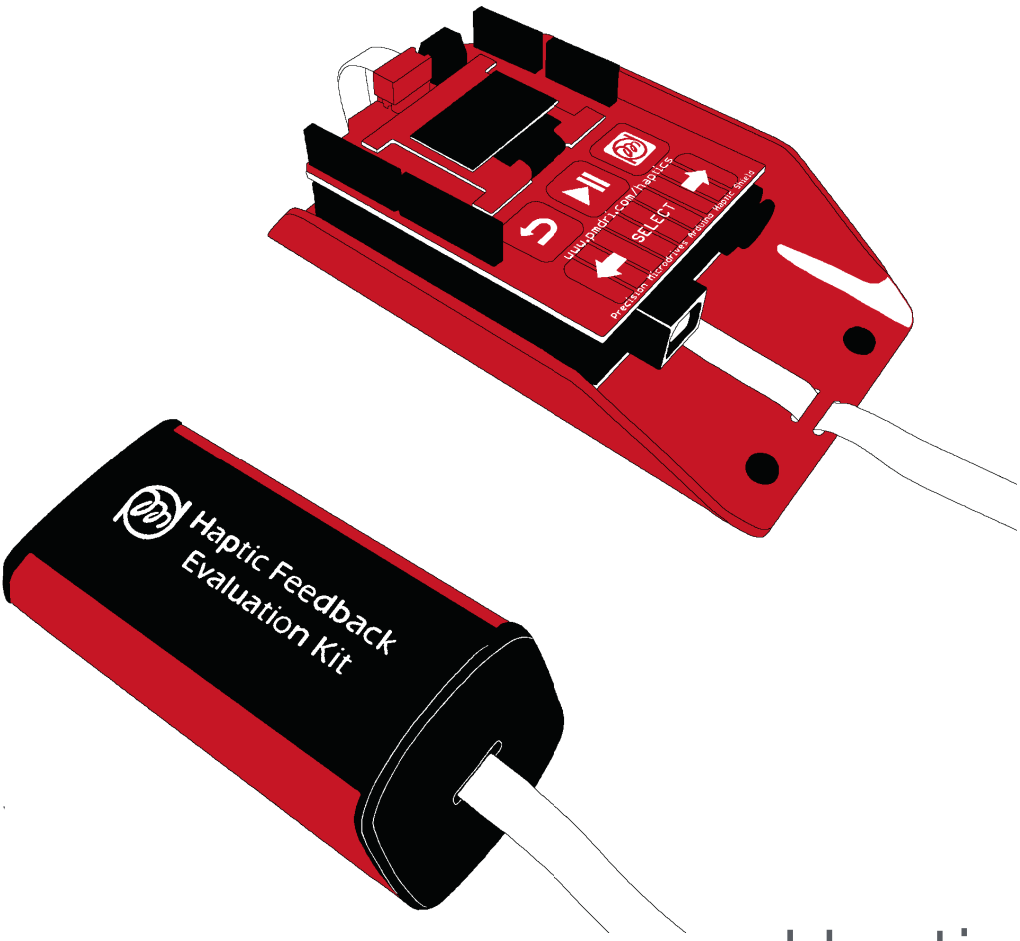

Haptic Feedback Evaluation Kit

Quick Start Guide

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1 Introduction

Welcome to the Haptic Feedback Evaluation Kit!

This Quick Start Guide will show you how to get up and running, whilst demonstrating the different modes of operation. There are also some useful references towards the end.

Learn more

Please read the full User Manual for complete information on technical details and advice for accessing the advanced features of the Haptic Feedback Evaluation Kit.

Additional Resources

Online at precisionmicrodrives.com/haptic-kit you can find a range of additional resources available, including:

- Downloadable PDF of this document
- Downloadable PDF of the full User Manual
- A4 printable posters for reference (Effect Table, True Haptics Menu Map, etc.)
- Tutorials on the advanced features
- Arduino code for different Modes of Operation and example applications
- Further resources as they are developed!

Further Development

Once you have experienced haptics with this kit, you may want to apply it to your own projects. We have an extensive range of vibration actuators that can be found on our website at precisionmicrodrives.com/vibration-motors and are available to purchase in our online shop. However, if you are unable to find what you are looking for or you need some support, our engineers are always happy to answer any questions. Please contact us using any of the methods shown below.

Contact Precision Microdrives

For questions about the Haptic Feedback Evaluation Kit, ordering and quotes, or technical queries please do not hesitate to get in touch:

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www.precisionmicrodrives.com

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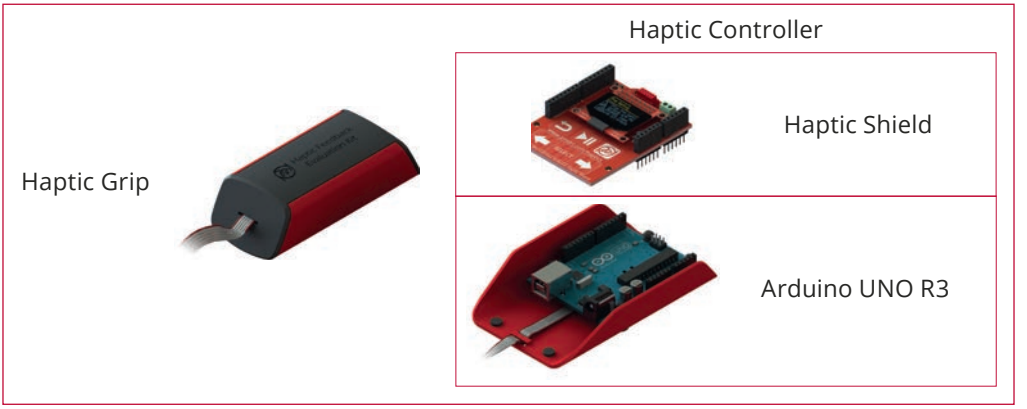
2 System Overview

The Haptic Feedback Evaluation Kit is comprised of two main hand-held units, the Haptic Controller and the Haptic Grip:

Haptic Feedback Evaluation Kit



Haptic Controller

Together, the Haptic Shield and the Arduino UNO R3 make up the Haptic Controller and act as the 'brains' of the system.

Arduino is an open source development platform for electronics, as a term it is colloquially use to describe the parent company, the product range, or a specific board. The UNO R3 is based on the Atmel ATmega328 microcontroller, its stackable headers enable the functionality to be extended by connecting customised boards, called 'shields', which mate with the Arduino.

The Precision Microdrives Haptic Shield is specially designed for haptic feedback, with capacitive touch buttons for input and a Texas Instruments DRV2605L haptic driver and MOSFET for vibration output.

Haptic Grip

The Haptic Grip houses 4 different vibration actuators to enable users to experience a range of haptic feedback and vibration alerting, including 3 ERMs (304-103, 306-109, 308-102) and the C10-100 LRA.

This makes it easy to compare haptic effects against each other and feel the effects independently of the Haptic Controller. It is designed to have a form factor that can represent a variety of end applications, such as hand held instruments or joystick interfaces.

A PDF reference is available at precisionmicrodrives.com/haptic-kit which lists key parameters of each motor included, with space for notes about other actuators you may use.

3 Setup & Installation

The Haptic Feedback Evaluation Kit arrives completely assembled with all hardware provided in the box. To start, simply connect the kit to one of the power sources outlined below.

Power

The Arduino allows you to supply power via the USB port or DC connector. You can use either option. However, please note that old versions of the Haptic Shield must be powered via USB only. If this Quick Start Guide was supplied with your kit, you have the new version and may proceed with your preferred choice. If you are reading this online, you should double check your version of the Haptic Shield by visiting precisionmicrodrives.com/haptic-kit.

If using a USB port on a computer or laptop to power the unit you may be subject to current limiting on the USB port. You will need to install the Arduino drivers to correct this. When the actuators are vibrating the current draw can peak over 100mA. By installing the drivers the Arduino is able to negotiate up to 500 mA. Not installing the drivers risks limiting the current to the motors, thereby reducing the performance and in some cases not allowing the kit to start-up.

(In some computers, particularly laptops, several USB ports can use the same internal power supply. If possible, remove other USB devices that may be connected to the same line as the kit.)

Drivers and Software

Installing the drivers and software for the Arduino Uno R3 is simple, but they are updated periodically. Therefore it is best to get the latest version and instructions from the Arduino website (note URLs are case-sensitive):

- Navigate to arduino.cc/en/Main/Software or search 'Arduino software'
- Install the Arduino software, includes drivers and IDE (1.8.7 at time of release)
- Refer to the Getting Started page for more help arduino.cc/en/Guide/HomePage

Existing Arduino Users and Kit Owners

If you already have the Arduino IDE installed, we recommend ensuring you upgrade to the latest version. If you wish to continue using an older version, please visit precisionmicrodrives.com/haptic-kit for legacy support.

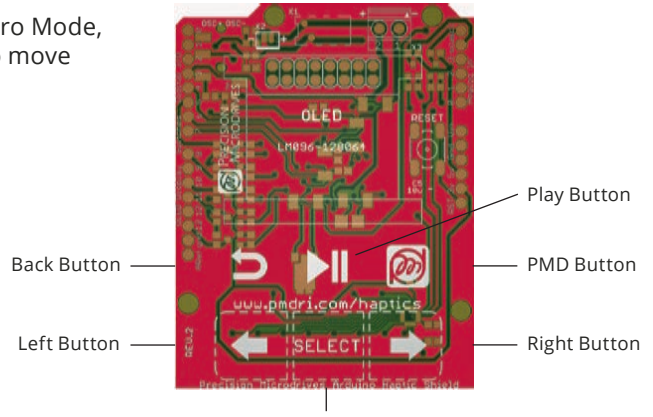
For owners of the Rev1 kit, please ensure you replace the libraries with the Rev2 versions. For full upgrade instructions, please visit precisionmicrodrives.com/haptic-kit.

4 Intro Mode

The Intro Mode firmware is loaded onto the Haptic Controller prior to shipping. After successfully completing the installation process and providing power, the kit will automatically start and the Precision Microdrives logo will appear on the OLED main screen.

Intro Mode serves as an introduction to haptic feedback and vibration alerting. This makes it perfect for those who are unfamiliar with haptics, or for demonstrating to colleagues the value of the features. Even if you are experienced with haptic feedback, you may wish to explore the tutorials to discover some of the additional features of the DRV2605L.

There are four tutorials in the Intro Mode, use the Left and Right buttons to move between them.



Press the Select button to start:

- Quick-Start Demo
- Haptic Feedback Tutorial
- Vibration Alerting Tutorial
- DRV2605 Overview

Develop Understanding

Each tutorial has several slides for you to read about the concepts demonstrated. They are easy to follow and you can go back by pressing the Left button, or exit with the Back button.

Feel Effects

At specific points in each tutorial you will be prompted to press the Play button. Different effects are played on the Haptic Grip or the Haptic Controller, you can repeat them by pressing the Play button a second time.

Apply

Not only will the tutorials walk you through the concepts of vibration alerting and haptic feedback, some also include example applications. Start thinking about how you would use haptics to improve your product, then try out the Engineering Mode.

5 Engineering Mode

The Engineering Mode uses different firmware that needs to be loaded into the Arduino, to perform this you will need to have installed the Arduino Environment (see Section 3) and have downloaded the code from precisionmicrodrives.com/haptic-kit. It gives access to a greater range of effects and functionality.

It is also recommended you read the Section 5 of the User Manual to get the most out of the Engineering Mode. The User Manual is available online at precisionmicrodrives.com/haptic-kit.

Upload the Code

To enter the engineering mode, you need to compile and upload the code through the Arduino Environment. Downloaded and extract the code to your chosen folder, open the EngineeringMode.ino file (.ino files are called 'sketches'). Supporting files called 'libraries' are included in the zip, ensure the Sketchbook Location (File -> preferences) points to the folder above the libraries folder. If everything is correct you can click the 'upload' button. More detailed instructions available in the User Manual or at precisionmicrodrives.com/haptic-kit.

Using True Haptics

Here you can experience haptic feedback through the DRV2605 which includes 123 different haptic effects and 6 libraries. Navigate clicks, bumps, pulses, and many more options.

Press the Play button to play the chosen effect and press the PMD button to cycle actuators. The True Haptics Menu Map and Effect ID Table (Sections 9 and 10) will help you find effects quickly.

Using Vibration Alerting

Vibration alerts can be played through the on-board MOSFET and PWM. Build your own vibration alerting waveform by setting each variable in the Vibration Alerting section, including vibration power, vibration waveform, on time, and off time. Please note that LRAs require an AC signal, so cannot be played by the on-board MOSFET.

Keep Developing

Try using the DRV2605 library and example code to start prototyping your own system. The Arduino can be used to accept inputs, the library lets you easily interface with the DRV2605, and you can connect to an external actuator using the terminals on the Haptic Shield.

6 Development Mode

Having approached haptics with the Intro Mode and gained a more in depth idea of what our motors can do through using the Engineering mode, you may be thinking about how you can develop this into your own project.

The Development Mode has been created to allows designers to implement haptics using our Haptic feedback kit. You can download the firmware from precisionmicrodrives.com/haptic-kit.

Modifying and uploading the code

All the software needed to run in our Haptic Kit is available on our website and users can deal in the Software without restriction, including without limitation, the rights to use, copy or modify it.

The Development Mode program is used to start writing your own code. It handles the initialisation of the pins, I^2C bus, and the serial port. Advanced users will find the DRV2605 Arduino Library Reference useful, but those unfamiliar with Arduino programming may find the tutorials and examples more beneficial.

To upload the code in the kit, follow the same instructions as in the Engineering Mode. This will give you complete access to the open source code. The motors are driven using the driver DRV2605 from Texas Instrument. The Development Mode will allow you to program the driver and choose the setting that best suits your application and the PMD motor you are using. You can refer to Texas Instruments (TI) to understand the features of the driver and map of addresses.

You can connect an external actuator to the kit using the green screw terminal and program your own patterns, effects and recurrences. It is also worth noting that the OLED display is disabled in the Development Mode as it is designed to be very simple. This means that nothing will appear on it and the pins that were required to drive it are now available. The Pin Mapping in section 8 will help you identify which pins are free.

Tutorials and Examples

You will find on our website different tutorials and examples to follow with the Development Mode. Here is a few options for the users to continue investigating and developing new haptics applications.

1: How to connect an external motor to the Haptic Feedback Evaluation Kit
precisionmicrodrives.com/content/connecting-external-actuator-vibration-motor-to-the-m20-200-haptics-kit/

2: Driving multiple LRA's
precisionmicrodrives.com/content/new-haptic-feedback-evaluation-kit-tutorial-driving-multiple-lras/

3: Using the Audio-to-Vibe function
precisionmicrodrives.com/content/tutorial-using-haptic-feedback-with-music-or-audio-signals/

7 DRV2605 Library

The DRV2605 and DRV2605L from Texas Instruments are functionally similar, the DRV2605L is available in a 10VSSOP package and is used in the Haptic Feedback Evaluation Kit. However, you should be able to use the library with either chip. If you have any issues in Development Mode, please contact us.

Parent	Notes	Function Syntax	Description	Parameters	Returns
Motor.cpp	Recommended object: **Motor motor = Motor();** The Motor object encapsulates DRV2605 functionality and gives a simpler interface to playing vibration alerts and haptic effects. Only one should be instantiated at a time, as demonstrated in the IntroMode and EngineeringMode sketchs	selectMotor(**motorID**);	Selects the output motor on the grip. Required even if using external actuator	**motorID**: uint8_t	Void
		isCalibrated();	Checks to see if selected actuator has undergone calibration	None	Boolean Value True = calibrated False = not calibrated
		autoCalibrate();	Runs auto calibration on selected motor	None	Void
		playVibAlert(**waveform** , **pwr** , **onTime** , **offTime**);	Plays vibration alert on selected actuator. LRA is not supported so motorID = 3	**waveform**: uint8_t **pwr**: uint8_t **onTime**: uint8_t **offTime**: uint8_t	Void
		playFullHaptic(**library** , **effect**);	Plays haptic effect from DRV2605 on selected actuator. If LRA is selected (motor ID = 3) then library 6 must be used	**library**: uint8_t **effect**: uint8_t	Void
		getMotorID();	Gets current motorID	None	Int
		isPlaying();	Checks to see if an actuator is playing a haptic effect	None	Boolean Value True = playing False = not playing
		isPlayingVib();	Checks to see if an actuator is playing a vibration alert. Note 'off times' return a true value	None	Boolean Value True = playing False = not playing
		stopVibAlert();	Immediatly stops the effect / vibration alert being played	None	Void
		getMotorName();	Returns actuator product code	None	Char string
		isPlayingAudio();	Checks to see if DRV2605 is in Audio-to-Haptic mode	None	Int value equal to 1 if in Audio-to-Haptic
		Audio2Haptic(**withKeyPress**);	Haptic-to-Audio mode with calibration for motors	**withKeyPress**: bool	Void
DRV2605.cpp	Recommended object: **extern DRV2605 drv2605;** The DRV2605 class abstracts away the I2C communications to the DRV2605 chip, providing a streamlined interface for playing effects. Only one DRV2605 object should be instantiated. If using the DRV2605 object from the Motor class use 'extern', as above	autoCal(**ratedVoltage** , **overdriveClamp** , **LRA** , **compensation** , **backEMF** , **feedback**);	Manually adjusts features in the DRV2605	**ratedVoltage**: uint8_t **overdriveClamp**: uint8_t **LRA**: boolean **compensation**: uint8_t* **backEMF**: uint8_t* **feedback**: uint8_t*	Boolean Value True = successful False = not successful
		playFullHaptic(**library** , **effect** , **ratedVoltage** , **overdriveClamp** , **compensation** , **backEMF** , **feedback**);	Plays haptic effect from DRV2605 on selected actuator. Manually adjusts the features in the DRV2605	**library**: uint8_t **effect**: uint8_t **ratedVoltage**: uint8_t **overdriveClamp**: uint8_t **compensation**: uint8_t **backEMF**: uint_8 **feedback**: uint8_t	Void
		Audio(**LRA_AUDIO** , **ratedVoltage** , **overdriveClamp** , **compensation** , **backEMF**);	Enters the Audio-to-Haptic on DRV2605. Audio signal is on PWM input pin, requires motor calibration	**LRA_AUDIO**: uint8_t **ratedVoltage**: uint8_t **overdriveClamp**: uint8_t **compensation**: uint8_t **backEMF**: uint8_t	Void
debug.cpp	N/A	freeRAM();	Returns amount of unused RAM space in DRV2605	None	Int

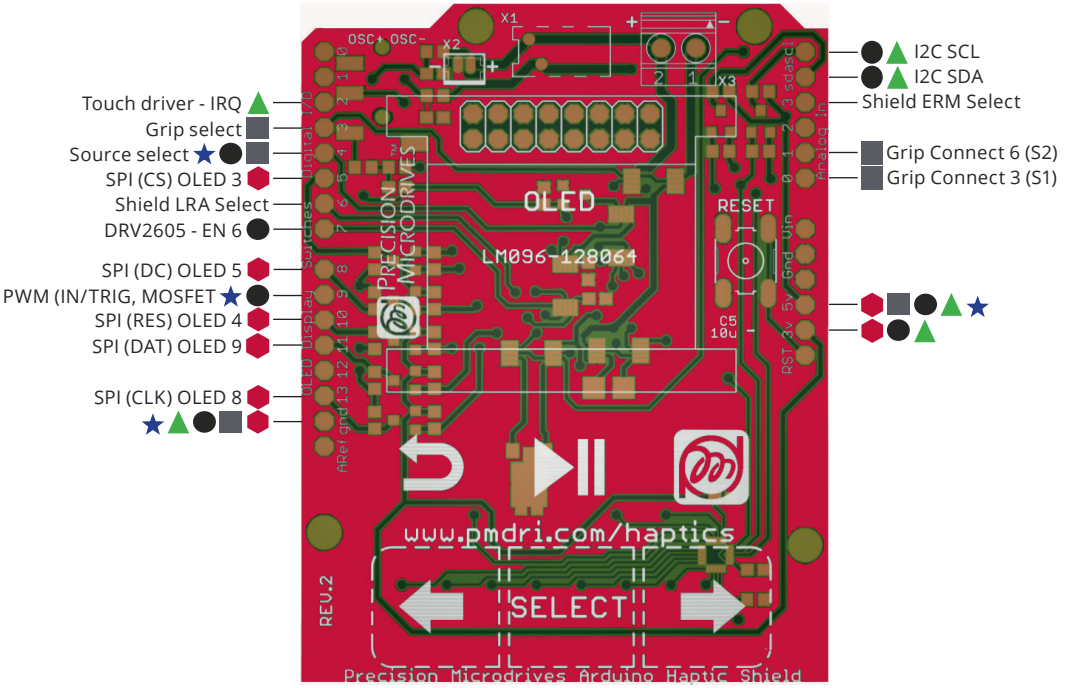
Parameter	Type & Limits	Values	Description
motorID	0 ≤ int ≤ 3	0 = 304-103 1 = 306-109 2 = 308-102 3 = C10-100	Selects the output actuator
waveform	0 ≤ int ≤ 3	0 = Square 1 = Sine 2 = Triangle 3 = Sawtooth	Changes the output waveform for vibration alerts
pwr	0 ≤ int ≤ 100	0% - 100%	Peak output strength of the selected waveform
onTime	0 ≤ int ≤ 255	Tenths of Seconds	Length of time the vibration alert vibrates for
offTim	0 ≤ int ≤ 255	Tenths of Seconds	Length of time between vibration alerts
library	1 ≤ int ≤ 6	1 - 5 for ERMs, 6 for LRAs	The haptic library on the DRV2605L to be used
effect	1 ≤ int ≤ 123	See Effect ID table	The haptic effect on the DRV2605L to be used
ratedVoltage	0 ≤ int ≤ 255	Voltage applied to ERM = **ratedVoltage** x 0.02118	See full DRV2605L datasheet for LRA voltage
overdriveClamp	0 ≤ int ≤ 255	Voltage applied to ERM = **overdriveClamp** x 0.02159	See full DRV2605L datasheet for LRA voltage
LRA	bool	True = LRA Mode, False = ERM Mode	Sets bit 7 of register 0x1A, setting DRV2605L in to LRA or ERM mode
Compensation	0 ≤ int ≤ 255	Auto Calibration Compensation Coefficient = 1 + **compensation** / 255	Manually adjusts compensation for resistive losses in the driver
backEMF	0 ≤ int ≤ 255	Auto Calibration Back EMF (V) = (**backEMF** / 255) x (2.88 V / **BEMFGain**)	Manually adjusts results for back EMD of the actuator. **BEMFGain** is set by **feedback**
feedback	int, specific values only	N/A	Manually adjusts feedback control register, see full DRV2605L datasheet for details

Register	Name	Datasheet	Register	Name	Datasheet
0x00	Status Register	pg 34	**0x15**	Audio-to-Vibe Maximum Output Drive Register	pg 41
0x01	Mode Register	pg 35	**0x16**	Rated Voltage Register	pg 41
0x02	Real-Time Playback Input Register	pg 36	**0x17**	Overdrive Clamp Voltage Register	pg 42
0x03	Library Selection	pg 36	**0x18**	Auto-Calibration Compensation-Result Register	pg 42
0x04:0x0B	Waveforem Sequencer Register	pg 37	**0x19**	Auto-Calibration Back-EMF Result Register	pg 42
0x0C	Go Register	pg 37	**0x1A**	Feedback Control Register	pg 43
0x0D	Overdrive Time Offset Register	pg 38	**0x1B**	Control1 Register	pg 44
0x0E	Sustain Time Offset, Positive Register	pg 38	**0x1C**	Control2 Register	pg 45
0x0F	Sustain Time Offset, Negative Register	pg 39	**0x1D**	Control3 Register	pg 48
0x10	Brake Time Offset Register	pg 39	**0x1E**	Control4 Register	pg 49
0x11	Audio-to-Vibe Control Register	pg 40	**0x1F**	Control5 Register	pg 50
0x12	Audio-to-Vibe Minimum Input Level Register	pg 40	**0x20**	LRA Open Loop Period Register	pg 50
0x13	Audio-to-Vibe Maximum Input Level Register	pg 40	**0x21**	Voltage Monitor Register	pg 51
0x14	Audio-to-Vibe Minimum Output Drive Register	pg 41	**0x22**	LRA Resonance-Period Register	pg 51

8 Pin Mapping

Key of pin requirements

- OLED 3V3, 5V, GND, 5, 8 , 10, 11, 13
- Haptic Grip 5V, GND, A0, A1, 3, 4
- DRV2605 3V3, 5V, GND, A4, A5, 5, 7, 9
- Capacitive Touch 3V3, 5V. GND, A4, A5, 2
- MOSFET 5V, GND, 4, 9



12C Addresses

USING 7 BITS ADDRESSING	
Capacitive Touch Driver MPR121	0x5D
Haptic Driver DRV2605L	0x5A

9 True Haptics Menu Map

Looking to find a specific effect in the True Haptics menu? You can use the reference below in conjunction with the Effect Table to find the menu location of each effect available on the DRV2605L.

Clicks

Single	Strong	1, 2, 3, 17, 18, 19, 20
	Medium	21, 22, 20
	Tick	4, 5, 6, 24, 25, 26
	Transition	58, 59, 60, 61, 62 ,63
Double	Strong	10, 11, 27, 28, 29, 30, 37, 38, 39, 40
	Medium	31, 32, 33, 41, 42, 43
	Tick	34, 35, 36, 44, 45, 46
Triple	Triple	12

Ramps

Up	Short	86, 110, 87, 111, 92, 116, 93, 117
	Medium	84, 108, 85, 109, 90, 114, 91, 115
	Long	82, 106, 83, 107, 88, 112, 89, 113
Down	Short	74, 98, 75, 99, 80, 104, 81, 105
	Medium	72, 96, 73, 97, 78, 102, 79, 103
	Long	70, 94, 71, 95, 76, 100, 77, 101

Other

Buzzes	Buzzes	13, 14, 47, 48, 49, 50, 51, 118
Bumps	Bumps	7, 8, 9
Pulses	Pulses	52, 53, 54, 55, 56, 57
Hums	Hums	64, 65, 66, 67, 68, 69, 119, 120, 121, 122, 123

Alerts

Alerts	Alerts	5, 16

Library

Library	Library	1, 2, 3, 4, 5

Audio2Haptics

Audio-2Haptics	Audio-2Haptics	Off, On

Shield Haptics

Shield Haptics	Shield Haptics	ERM, LRA

10 Effect Table

ID	Waveform	Menu
1	Strong Click 100%	Clicks > Single > Strong
2	Strong Click 60%	Clicks > Single > Strong
3	Strong Click 30%	Clicks > Single > Strong
4	Sharp Click 100%	Clicks > Single > Tick
5	Sharp Click 60%	Clicks > Single > Tick
6	Sharp Click 30%	Clicks > Single > Tick
7	Soft Bump 100%	Other > Bumps
8	Soft Bump 60%	Other > Bumps
9	Soft Bump 30%	Other > Bumps
10	Double Click 100%	Clicks > Double > Strong
11	Double Click 60%	Clicks > Double > Strong
12	Triple Click 100%	Clicks > Triple
13	Soft Fuzz 60%	Other > Buzzes
14	Strong Buzz 100%	Other > Buzzes
15	750ms Alert	Other > Alerts
16	1000ms Alert	Other > Alerts
17	Strong Click 1 100%	Clicks > Single > Strong
18	Strong Click 2 80%	Clicks > Single > Strong
19	Strong Click 3 60%	Clicks > Single > Strong
20	Strong Click 4 30%	Clicks > Single > Strong
21	Medium Click 1 100%	Clicks > Single > Medium
22	Medium Click 2 80%	Clicks > Single > Medium
23	Medium Click 3 60%	Clicks > Single > Medium
24	Sharp Tick 1 100%	Clicks > Single > Tick
25	Sharp Tick 2 80%	Clicks > Single > Tick
26	Sharp Tick 3 60%	Clicks > Single > Tick
27	Short Double Click Strong 1 100%	Clicks > Double > Strong
28	Short Double Click Strong 2 80%	Clicks > Double > Strong
29	Short Double Click Strong 3 60%	Clicks > Double > Strong
30	Short Double Click Strong 4 30%	Clicks > Double > Strong
31	Short Double Click Medium 100%	Clicks > Double > Medium
32	Short Double Click Medium 2 80%	Clicks > Double > Medium
33	Short Double Click Medium 3 60%	Clicks > Double > Medium
34	Short Double Sharp Tick 1 100%	Clicks > Double > Tick
35	Short Double Sharp Tick 2 80%	Clicks > Double > Tick
36	Short Double Sharp Tick 3 60%	Clicks > Double > Tick
37	Long Double Sharp Click Strong 1 100%	Clicks > Double > Strong
38	Long Double Sharp Click Strong 2 80%	Clicks > Double > Strong
39	Long Double Sharp Click Strong 3 60%	Clicks > Double > Strong
40	Long Double Sharp Click Strong 4 30%	Clicks > Double > Strong
41	Long Double Sharp Click Medium 1	Clicks > Double > Medium
42	Long Double Sharp Click Medium 2 80%	Clicks > Double > Medium
43	Long Double Sharp Click Medium 3 60%	Clicks > Double > Medium
44	Long Double Sharp Tick 1 100%	Clicks > Double > Tick
45	Long Double Sharp Tick 2 80%	Clicks > Double > Tick
46	Long Double Sharp Tick 3 60%	Clicks > Double > Tick
47	Buzz 1 100%	Other > Buzzes
48	Buzz 2 80%	Other > Buzzes
49	Buzz 3 60%	Other > Buzzes
50	Buzz 4 40%	Other > Buzzes
51	Buzz 5 20%	Other > Buzzes
52	Pulsing Strong 1 100%	Other > Pulses
53	Pulsing Strong 2 80%	Other > Pulses
54	Pulsing Medium 1 100%	Other > Pulses
55	Pulsing Medium 2 60%	Other > Pulses
56	Pulsing Sharp 1 100%	Other > Pulses
57	Pulsing Sharp 2 60%	Other > Pulses
58	Transition Click 1 100%	Clicks > Single > Transition
59	Transition Click 2 80%	Clicks > Single > Transition
60	Transition Click 3 60%	Clicks > Single > Transition
61	Transition Click 4 40%	Clicks > Single > Transition
62	Transition Click 5 20%	Clicks > Single > Transition

ID	Waveform	Menu
63	Transition Click 6 10%	Clicks > Single > Transition
64	Transition Hum 1 100%	Other > Hums
65	Transition Hum 2 80%	Other > Hums
66	Transition Hum 3 60%	Other > Hums
67	Transition Hum 4 40%	Other > Hums
68	Transition Hum 5 20%	Other > Hums
69	Transition Hum 6 10%	Other > Hums
70	Transition Ramp Down Long Smooth 1 100-0%	Ramps > Down > Long
71	Transition Ramp Down Long Smooth 2 100-0%	Ramps > Down > Long
72	Transition Ramp Down Medium Smooth 1 100-0%	Ramps > Down > Medium
73	Transition Ramp Down Medium Smooth 2 100-0%	Ramps > Down > Medium
74	Transition Ramp Down Short Smooth 1 100-0%	Ramps > Down > Strong
75	Transition Ramp Down Short Smooth 2 100-0%	Ramps > Down > Strong
76	Transition Ramp Down Long Sharp 1 100-0%	Ramps > Down > Long
77	Transition Ramp Down Long Sharp 2 100-0%	Ramps > Down > Long
78	Transition Ramp Down Medium Sharp 1 100-0%	Ramps > Down > Medium
79	Transition Ramp Down Medium Sharp 2 100-0%	Ramps > Down > Medium
80	Transition Ramp Down Short Sharp 1 100-0%	Ramps > Down > Strong
81	Transition Ramp Down Short Sharp 2 100-0%	Ramps > Down > Strong
82	Transition Ramp Up Long Smooth 1 0-100%	Ramps > Up > Long
83	Transition Ramp Up Long Smooth 2 0-100%	Ramps > Up > Long
84	Transition Ramp Up Medium Smooth 1 0-100%	Ramps > Up > Medium
85	Transition Ramp Up Medium Smooth 2 0-100%	Ramps > Up > Medium
86	Transition Ramp Up Short Smooth 1 0-100%	Ramps > Up > Short
87	Transition Ramp UP Short Smooth 2 0-100%	Ramps > Up > Short
88	Transition Ramp Up Long Sharp 1 0-100%	Ramps > Up > Long
89	Transition Ramp Up Long Sharp 2 0-100%	Ramps > Up > Long
90	Transition Ramp Up Medium Sharp 1 0-100%	Ramps > Up > Medium
91	Transition Ramp Up Medium Sharp 2 0-100%	Ramps > Up > Medium
92	Transition Ramp Up Short Sharp 1 0-100%	Ramps > Up > Short
93	Transition Ramp Up Short Sharp 2 0-100%	Ramps > Up > Short
94	Transition Ramp Down Long Smooth 1 50-0%	Ramps > Down > Long
95	Transition Ramp Down Long Smooth 2 50-0%	Ramps > Down > Long
96	Transition Ramp Down Medium Smooth 1 50-0%	Ramps > Down > Medium
97	Transition Ramp Down Medium Smooth 2 50-0%	Ramps > Down > Medium
98	Transition Ramp Down Short Smooth 1 50-0%	Ramps > Down > Strong
99	Transition Ramp Down Short Smooth 2 50-0%	Ramps > Down > Strong
100	Transition Ramp Down Long Sharp 1 50-0%	Ramps > Down > Long
101	Transition Ramp Down Long Sharp 2 50-0%	Ramps > Down > Long
102	Transition Ramp Down Medium Sharp 1 50-0%	Ramps > Down > Medium
103	Transition Ramp Down Medium Sharp 2 50-0%	Ramps > Down > Medium
104	Transition Ramp Down Short Sharp 1 50-0%	Ramps > Down > Strong
105	Transition Ramp Down Short Sharp 2 50-0%	Ramps > Down > Strong
106	Transition Ramp Up Long Smooth 1 0-50%	Ramps > Up > Long
107	Transition Ramp Up Long Smooth 2 0-50%	Ramps > Up > Long
108	Transition Ramp Up Medium Smooth 1 0-50%	Ramps > Up > Medium
109	Transition Ramp Up Medium Smooth 2 0-50%	Ramps > Up > Medium
110	Transition Ramp Up Short Smooth 1 0-50%	Ramps > Up > Short
111	Transition Ramp Up Short Smooth 2 0-50%	Ramps > Up > Short
112	Transition Ramp Up Long Sharp 1 0-50%	Ramps > Up > Long
113	Transition Ramp Up Long Sharp 2 0-50%	Ramps > Up > Long
114	Transition Ramp Up Medium Sharp 1 0-50%	Ramps > Up > Medium
115	Transition Ramp Up Medium Sharp 2 0-50%	Ramps > Up > Medium
116	Transition Ramp Up Short Sharp 1 0-50%	Ramps > Up > Short
117	Transition Ramp Up Short Sharp 2 0-50%	Ramps > Up > Short
118	Long Buzz for Programmatic Topping 100%	Other > Buzzes
119	Smooth Hum 50%	Other > Hums
120	Smooth Hum 40%	Other > Hums
121	Smooth Hum 30%	Other > Hums
122	Smooth Hum 20%	Other > Hums
123	Smooth Hum 10%	Other > Hums

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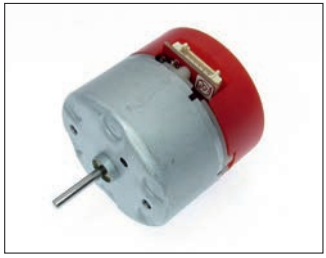
Design for application case studies

ENCAPSULATED VIBRATION MOTOR FOR A CPR TRAINING DUMMY

- Low volume, high value manufacturing
- Custom CNC machined enclosure
- Optimised haptic performance
- Custom PCB including EMI filters



PRECISION SPEED AND TORQUE CONTROLLED SERVO WITH INTEGRATED TUNABLE PID LOOP FOR SINGLE-USE SCIENTIFIC INSTRUMENT

- Medium volume, high value assembly
- Adapted control software including digital IO (to customer's specification)

CUSTOMISED PRECISION GEAR MOTOR WITH ROBUST OPTICAL ENCODER

- High volume production
- Application specific output shaft
- Rear motor shaft with noise resistant optical encoder
- Tailored motor performance curves