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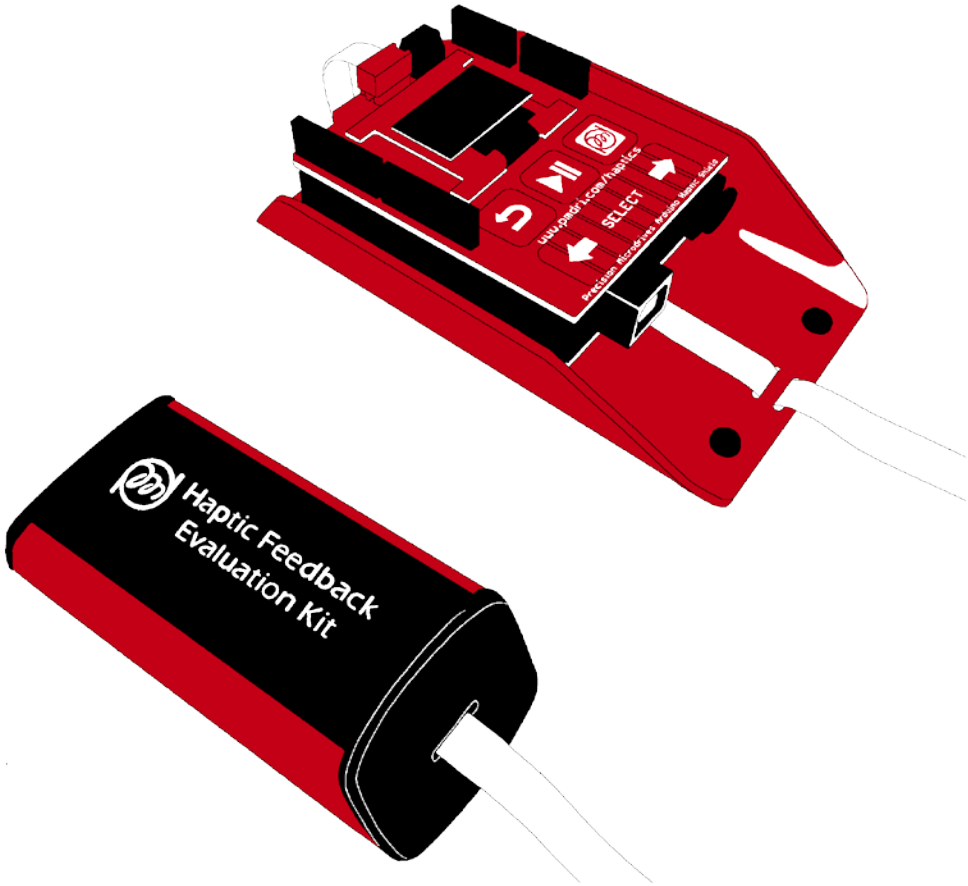


You can request technical assistance from our engineers by clicking here

Haptic Feedback Evaluation Kit

User Manual

Table of Contents

1 Introduction

Welcome to The Haptic Feedback Evaluation Kit! This is an open-source platform for experiencing haptic feedback and vibration alerting.

It serves a wide range of users. Those unfamiliar with the technology will benefit from the Intro Mode and its guided tutorials. In addition, the kit has multiple modes of operation which can support engineers and product designers throughout the development process by providing an easy to use platform for hardware and software prototyping.

This document provides technical details on each section of the kit, guides for installation and usage, and advice for accessing advanced features. There is also a Quick Start Guide provided with the kit to get users up and running immediately. Even more resources, such as tutorials and example code, can be downloaded from precisionmicrodrives.com/haptic-kit/features.

It is also recommended you request a copy of the full datasheet for the DRV2605L from Texas Instruments, this is the haptics driver in the kit. The datasheet is available for download online here: www.ti.com/product/drv2605L.

You can receive additional advice about vibration motors and haptic feedback in general, or keep up to date with Precision Microdrives, online in our Tech Blog and App Notes sections of www.precisionmicrodrives.com.

If you experience any issues or are looking for further advice, please contact Precision Microdrives at enquiries@ precisionmicrodrives.com. **Enjoy!**

2 System Overview

The Haptic Feedback Evaluation Kit is comprised of two main units, the Haptic Controller and the Haptic Grip.

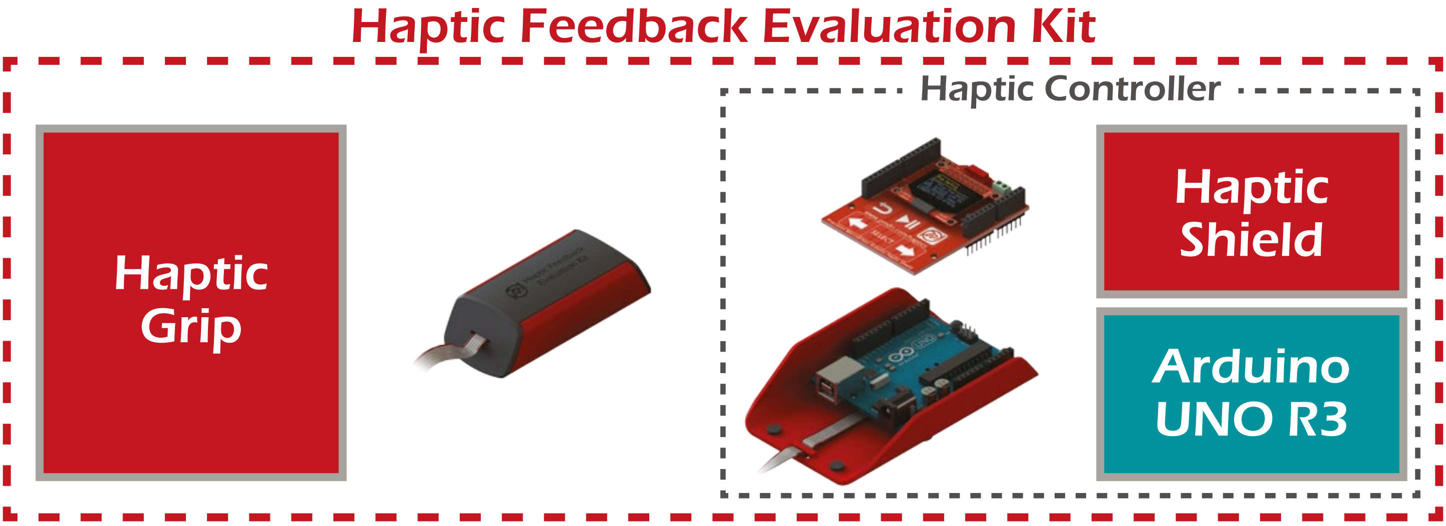


Figure 1. System view of The Haptic Feedback Evaluation Kit

The Haptic Controller includes an Arduino UNO R3 with a custom designed 'shield' from Precision Microdrives. It acts as the user interface, allowing the user to navigate through the menu systems on the OLED screen using the capacitive touch buttons. It also houses the hardware used to drive the motors, including a DRV2605L from Texas Instruments for haptic feedback (Section 5.2) and a MOSFET for simple vibration alerting (Section 5.4).

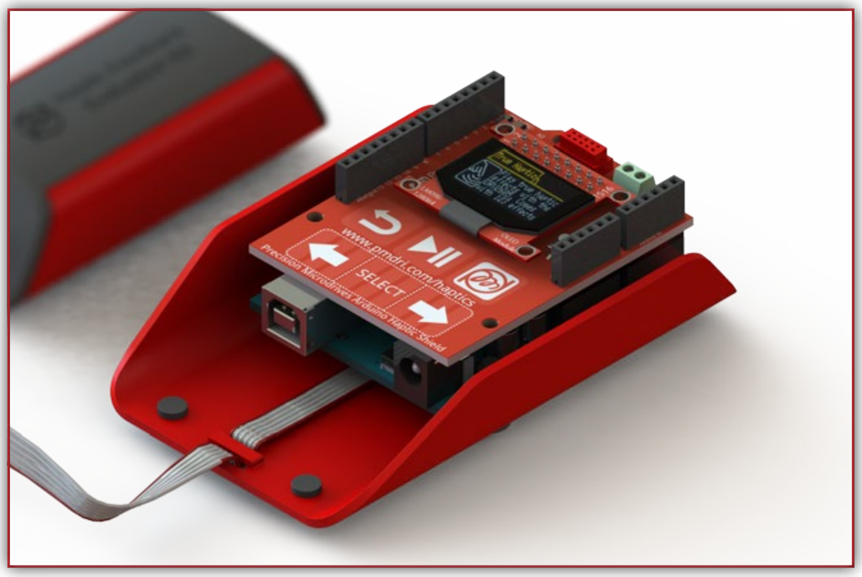


Figure 2. The Haptic Controller

The Haptic Grip contains the actuators that play the various vibration patterns sent by the Haptic Controller. The two are connected by a ribbon cable that carries the power, drive, and motor selection signals. With 3 different eccentric rotating mass vibration motors and 1 linear resonant actuator, the grip houses actuators from our high performance Precision Haptic™ range.

Figure 3. The Haptic Grip

2.1 The Haptic Controller

Arduino is an open source development platform for electronics which has many different boards available, the UNO R3 board is based on an Atmel ATmega328 microcontroller. Although the term 'Arduino' refers to the project as a whole, it is also colloquially used to refer to the specific board you are using – a convention we will use in this documentation.

The Arduino allows you to easily program the microcontroller through your computer using software that you can download online, see Section 3.3 for installation instructions. Due to its simplicity and versatility it is extremely popular with hobbyists and professionals who use it for prototyping and other projects. As a result there is a very active online community where you can find advice and details about the boards.

The stackable headers of the Arduino provide access to various pins on the board, PCBs can be designed to fit directly onto these headers and are known as 'shields'.

Arduino shields are often created for a specific purpose such as WIFI connectivity or SD card readers, our Haptic Shield works with the provided firmware (code for the microcontroller) to provide a user interface and drive the vibration actuators. This is achieved by including several components, the main ones are listed below.

Capacitive Touch Buttons

There are 12 capacitive touch buttons that are used to provide the input to the Haptic Controller. There are slight differences in their function depending on the mode of operation (Sections 4 & 5). The bottom 3 buttons are made of 9 segments, to enable a 'slider' functionality see our tutorials page for details. The MPR121 touch driver uses the I2C bus for communications.

Figure 4. The capacitive touch buttons

Screen

An OLED screen provides visual cues to the user about the current status of the controller. The menu system is displayed on screen and navigated using the capacitive touch buttons. Depending on the mode of operation the screen may display information about the effect being played, output actuator, or walk through tutorials. There are 8 lines of orange LEDs at the top and 24 lines of blue LEDs below. It is controlled via SPI.

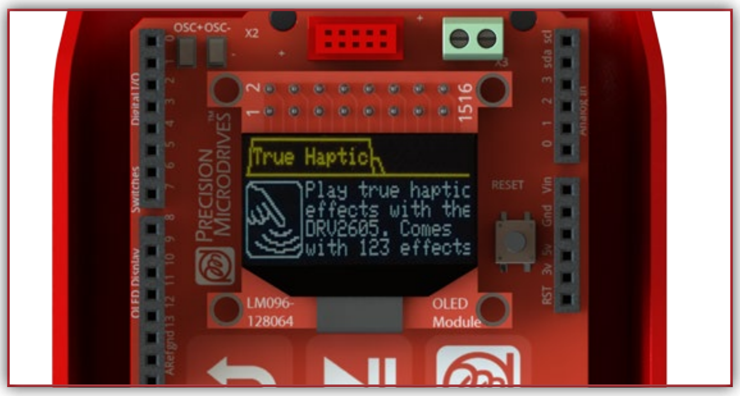


Figure 5. The OLED screen

DRV2605L

This is the haptic driver from Texas Instruments. It contains over 123 different haptic effects, with royalty free licensing from Immersion, and can drive both ERMs and LRAs. It has a range of advanced features including overdrive and active braking for haptic effects, and auto-resonance tracking for LRAs. It is controlled by the Arduino via the I2C bus, but also supports PWM.

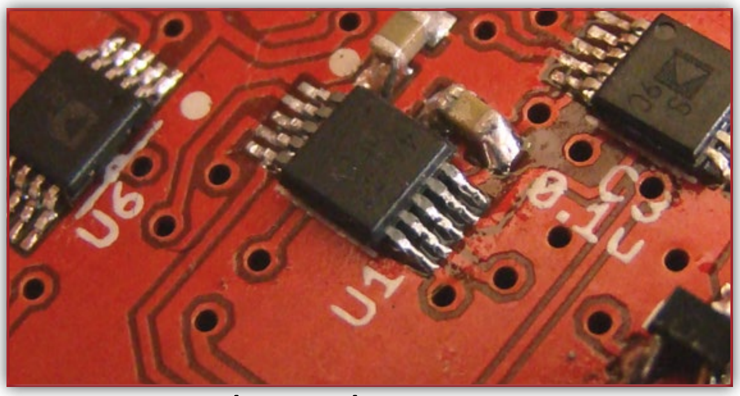


Figure 6. The DRV2506L

MOSFET

A simple transistor is used to drive vibration alerting patterns on ERMs. It uses a PWM signal from the Arduino, where varying the duty cycle controls the speed and vibration strength of the ERM. The duty cycle is handled by the Arduino code and you can build your own patterns in the Engineering Mode (Section 5). Please note LRAs require AC signals and can't be driven by the MOSFET.

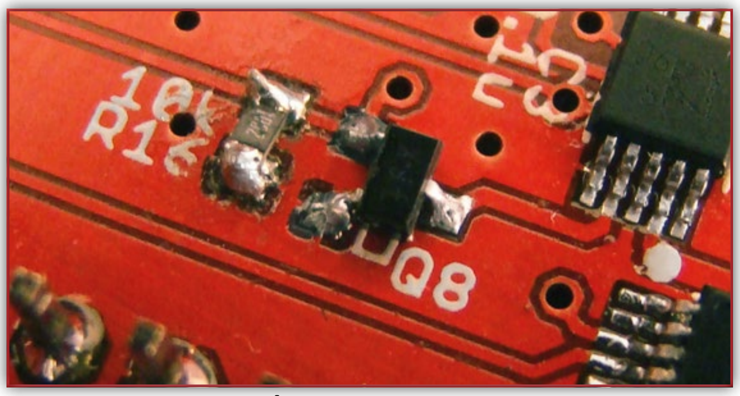


Figure 7. MOSFET

On-Shield Haptics

Touchscreens are a common application for haptic feedback, where the tactile feel of pressing buttons is lost. We have included an LRA (C10-100) and ERM (304-103) on the Haptic Shield to provide the user with haptic confirmation of their presses on the capacitive touch surface. They are both driven by the DRV2605L and can be used to compare the different actuator types.

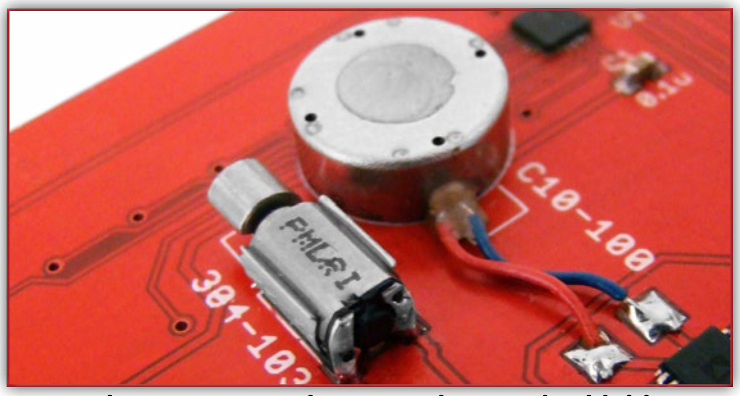


Figure 8. LRA and ERM on the Haptic Shield

Metal Base

The Haptic Controller is finished with a metal base that supports the Arduino and Haptic Shield. Mounting holes are positioned to fit the Arduino, which use rubber mounts to improve mechanical isolation between metal base and the Arduino with shield, reducing noise from the shield's haptics. A clip section helps secure the ribbon cable prevent the connector from being damaged.

Figure 9. Metal Base of the Haptic Controller

2.2 The Haptic Grip

The Haptic Grip is a small ergonomic unit that houses the vibrating actuators. Using a separate unit has several benefits:

- It allows you to easily experience multiple different actuators, including an LRA and a variety of ERMs.
- The form factor is representative of many end applications, such as the examples in Application Bulletin 014 which is available online at precisionmicrodrives.com.
- The haptics of the capacitive buttons on the Haptic Controller is separate from the Haptic Grip effects.
- You can easily share haptic experience with colleagues by handing the Haptic Grip to someone else.

You can access the Haptic Grip's internal components by peeling back the black rubber cover. It contains a small PCB that is mounted on the metal base, with a single quad channel multiplexer IC that handles the actuator selection signals from the Haptic Controller, reducing the need for excessive cabling. To aid debugging, there is an LED for each actuator which is lit when that actuator is selected by the Haptic Controller in addition to topside connection pads for each motor. Under the PCB are two leaded ERMs which are mounted directly into the base.

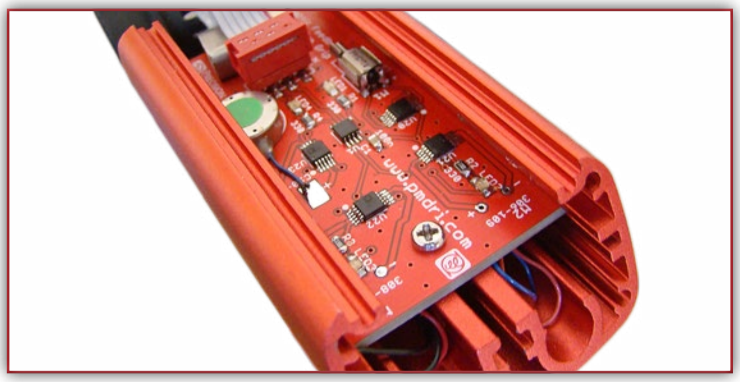


Figure 10. Inside the Haptic Grip

There are 3 eccentric rotating mass vibration motors and 1 linear resonant actuator housed in the Haptic Grip. The table below lists each actuator along with some basic information about their vibration output. Their datasheets are available online, along with a PDF of the Actuator Table (Appendix C) which has space to note other actuators.

Model Number	Type	Typical Normalised Amplitude	Rated / Resonant Vibration Frequency	Rated Voltage	Image	Full Datasheet
304-103	ERM	0.5 G	233 Hz (rated)	2.7 V		Download the 304-103 datasheet
306-109	ERM	3.5 G	200 Hz (rated)	3 V		Download the 306-109 datasheet
308-102	ERM	5.5 G	300 Hz (rated)	4.5 V		Download the 308-102 datasheet
C10-100	LRA	1.4 G	175 Hz (resonant)	2 V (RMS)		Download the C10-100 datasheet

Figure 11. The actuators included in the Haptic Grip

2.3 Firmware (Arduino Code)

An important part of the Haptic Feedback Evaluation Kit is the firmware code that is loaded into the Arduino. There are 3 modes of operation provided with the kit (Sections 4, 5, 6), it is possible to change between these modes as many times as you like. This is achieved by following the steps in Section 7.4. The firmware handles several important tasks that tie the separate sections of the system together:

- Building the menu system for user guidance
- Displaying text and images on the OLED screen
- Receiving input from the user through capacitive touch buttons
- Making logical decisions based on the menu system and user input
- Handling motor selection through analogue switches and multiplexers
- Interfacing with the DRV2605L or MOSFET to play haptic effects or vibration alerting patterns

As the firmware is open source and accessible through the Arduino software environment, it is possible to use the Haptic Feedback Evaluation Kit as a development platform for prototyping units. Arduino uses its own programming language based on Wiring, which is essentially a set of C/C++ functions called from the code. Therefore anyone familiar with C/C++ languages, or the Processing or Wiring projects, should find Arduino development an easy transition. Libraries and tutorials are provided at precisionmicrodrives.com/haptic-kit.

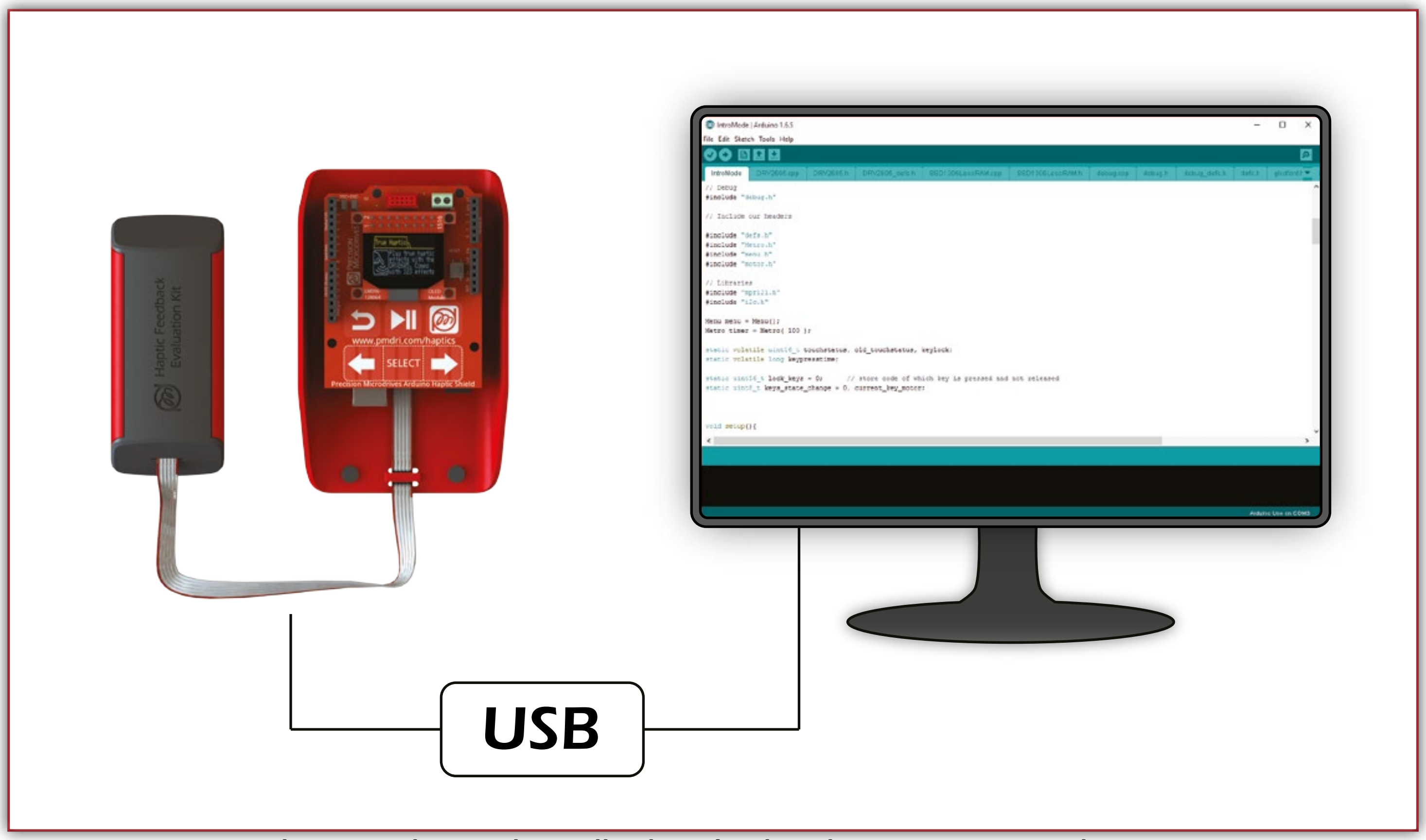


Figure 12. The Haptic Feedback Evaluation Kit connects to a PC via USB

3 Setup and Installation

The Haptic Feedback Evaluation Kit is designed to operate 'out-the-box' allowing users to immediately experience haptic feedback. Arduinos are powered using either the USB socket or DC power socket, both located at the bottom of the Haptic Controller.

3.1 Powering the Kit

The Arduino offers a choice of power supply, either the USB type B socket or the DC power connector can be used. This can be used to provide power to the kit as well as accessing the firmware on the Arduino (see Section 3.3 for installation) and debug information. The USB port can be plugged into a port on a computer or to a USB wall charger.

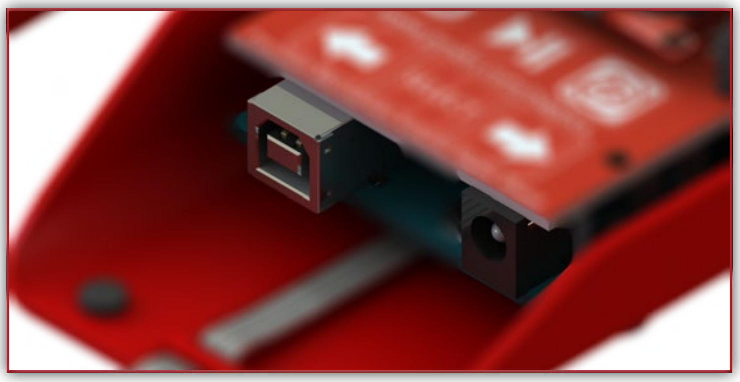


Figure 13. USB and DC connector power options

To provide enough current when using a USB port on a computer the Arduino drivers must be installed. The default current allocation to a USB device is 100 mA, with the drivers installed the Arduino is able to negotiate up to 500 mA. Please note that some PCs use the same USB bus to power several USB ports, therefore you should unplug any other USB devices unless you are sure enough current is being supplied to the kit.

To provide enough current when connecting to a USB wall charger double check the rating of the USB wall charger is no less than 500 mA.

The DC power connector requires a supply of 7 to 12 volts and should supply no less than 500 mA.

3.3 Installing Arduino Drivers and Software

The installation process for the Arduino is simple, however it is updated periodically through the Arduino website. We recommend following the most recent steps by visiting the Arduino 'Getting Started' page at arduino.cc/en/Guide/HomePage. This link above will allow you to:

- Install the Arduino UNO R3 drivers
- Install the Arduino coding IDE (recommended but only required if you intend to switch firmware modes, Section 7.4)

4 Intro Mode Operation

There are three firmware modes available, all of which are available for download from precisionmicrodrives.com/haptic-kit/codes.

The "**Intro Mode**" is the default mode of operation and is loaded onto the kit prior to shipping. It is aimed at non-technical users who are unfamiliar with haptic feedback and vibration alerting. It consists of 4 different tutorials (more information in Section 4.2):

- **Quick-Start Demo** is a fast explanation of haptic feedback and vibration alerting
- **Haptic Feedback Tutorial** explores haptics in greater detail, including some example applications
- **Vibration Alerting Tutorial** demonstrates how vibration alerting can be used with a MOSFET and PWM
- **DRV2605 Overview** takes a look at the Texas Instruments DRV2605L's features

We recommended you have a copy of the "Haptic Feedback vs Vibration Alerting" sheet (Appendix D) to accompany the tutorials. It is especially useful for sharing exactly what is required for implementing each technology.

You can switch to the "**Engineering Mode**" firmware to test all the available features of the kit by loading it onto the Arduino, instructions are available in Section 7.4.

4.1 Navigation

There is a single top-level menu that includes the four demonstrations / tutorials. To navigate between these menu options, use the Left and Right buttons. To enter a menu option, press Select.

Although they have different content, the menu options all work in the same way. Press Right to navigate forward through the slides. At specific points you will be prompted to press the Play button to experience different effects. To repeat the effects, press Play again.

You can exit the current demo / tutorial at any point and return to the top menu by pressing the Back button. In the Intro Mode the PMD button is not used.

4.2 Menu Options

4.2.1 Quick Start Demo

The Quick-Start Demo is a short overview that allows the user to experience vibration alerting first, followed by haptic feedback. The demonstration is very basic and is suitable for introducing the idea of adding vibration technology to a device, useful for sharing the concept with non-technical colleagues.

4.2.2 Haptic Feedback Tutorial

The Haptic Feedback Tutorial is designed to give the user an overview of haptic effects with example vibration patterns. It also includes an example application of a car parking sensor, showing how different haptic vibration patterns can be used to convey the same information.

The tutorial serves as a good introduction to haptic feedback and can be used by non-technical persons looking to develop their knowledge in the area. It is also useful for engineers and product developers to experience different haptic effects and get a quick overview of the capabilities of the DRV2605L and Precision Haptic™ actuators.

4.2.3 Vibration Alerting Tutorial

The Vibration Alerting Tutorial gives several examples of vibration alerting waveforms. It highlights how a vibration alerting waveform can be used to alert the user to events, and often represent warnings.

When used in conjunction with the Haptic Feedback Tutorial the user should be able to understand the difference in the two technologies and recognise if their design would benefit from advanced haptic feedback or the simpler vibration alerting. It is therefore useful for both non-technical and technical users.

4.2.4 DRV2605 Overview

All haptic effects are played by a special haptic feedback driver chip from Texas Instruments, the DRV2605L. This demonstration covers some of the advanced features of the chip, and lets users directly experience how they improve the vibration output.

It is shorter than the other tutorials and serves as a precursor to downloading the ‘Engineering Firmware’. For this reason it is of most use to engineers who intend to continue development with the kit and experiment with the DRV2605L itself.

Please note, the DRV2605L is functionally the same as the DRV2605 (which was used in the original Haptic Feedback Evaluation Kit). The main difference is the package of the chip, with the DRV2605L in an easier to solder (but larger) form factor. Certain sections of the code and tutorials may make reference to the DRV2605, especially where space on the screen is constrained - such as this tutorial’s menu title.

5 Engineering Mode Operation

To test all the available functions of the kit, the Engineering Mode can be loaded onto the kit once downloaded, see Section 7.4 for instructions.

It is aimed at technical users and engineers who are ready to start experimenting with haptic feedback and vibration alerting. It is also required to use some of the advanced features, such as external actuator connection, and further development.

It is recommended you print / load a copy of the True Haptics Menu Map and the Effect Table sheet (see Appendices G and H) to accompany this mode. It is especially useful for navigating to specific effects.

5.1 Navigation

The menu system is based on a hierarchy where you move left and right through the menu options (presented as tabs) and press Select to enter the selected menu option. The Back button moves you up a menu level and holding it down returns you to the top level.

In the top menu you can select between experiencing the True Haptic waveforms or building your own Vibration Altering pattern.

In Engineering Mode the PMD button cycles through the output actuators.

5.2 True Haptics

Here you can access all of the haptic waveforms and libraries stored on the DRV2605L. The effects are grouped into different categories and can be played on each of the actuators.

The screen shows the current status including the Menu Options, current Effect Library, the selected Effect, and the output motor:

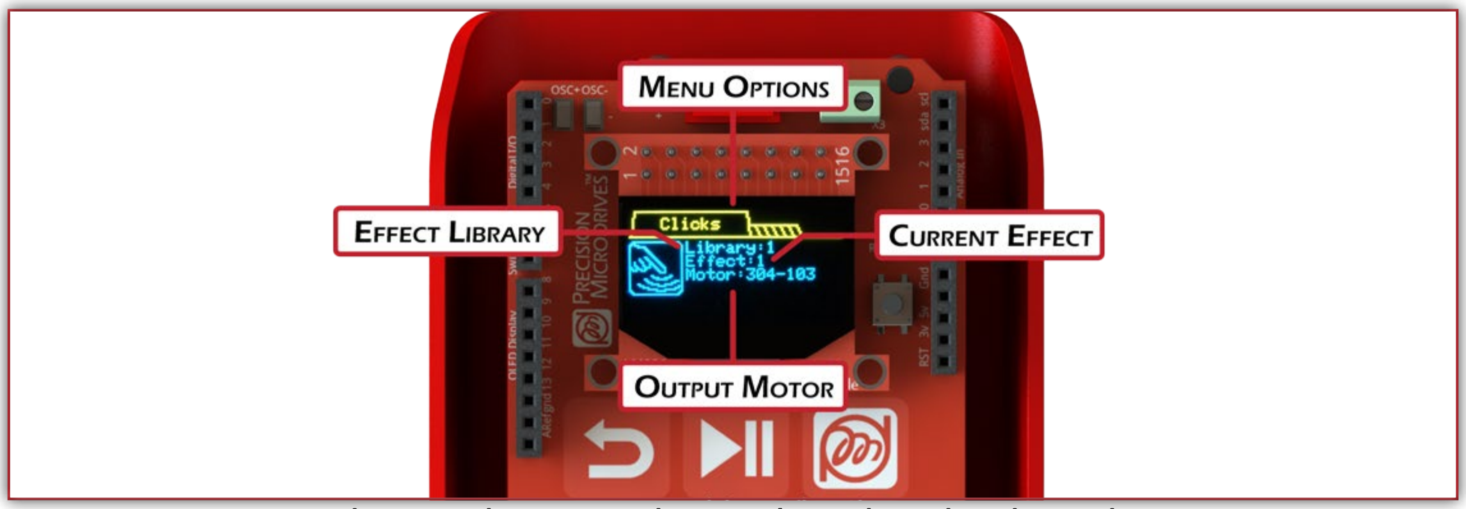


Figure 14. The True Haptics menu layout in Engineering Mode

The tabs at the top will show menu options until you navigate deep enough to the effects. Effects are displayed differently, and are identified by the effect number. For example, in the menu level "True Haptics -> Clicks -> Double" there are 3 further menu options; Strong, Medium, and Sharp. Selecting the menu option "Medium" displays 6 different effects, Medium 1 to Medium 6.

Figure 15. The differences between the Menu Option and Effect Option menu levels

There is an effect loaded and ready to play at all times, by default this is Effect 1, Library 1, on Motor 304-103. Pressing play will send the effect to the selected motor in the Haptic Grip.

To play an effect press the Play button at any point. Note that pressing the Play button at any menu level will play the loaded effect, unless your menu is at a new effect. In this case the kit will play the new effect shown on screen instead of the previous one loaded.

To change the effect use the Left, Right, and Select buttons to navigate to the desired new effect and press the Play or Select button.

To change the library navigate to the Library Menu Option, the last tab in True Haptics, and press select. Use Left and Right to select the new library and press Back once chosen. It is possible to press when scrolling through the libraries, making it easy to compare the difference between each library.

To change the output actuator cycle through the ERMs and LRA by pressing the Play button.

5.3 Audio-to-Vibe

This is a special feature of the DRV2605L which is accessible under the Audio tab in the True Haptic menu. In this mode, an audio signal is translated to vibration effects on the Haptic Grip. Plug an audio source into the provided headphone jack (under side, next to D0) and press Select. It is recommended you read the full tutorial online.

5.4 Vibration Alerting

This section enables you to build different vibration alerting waveforms and play them through any of the ERMs located in the Haptic Grip. The waveforms are created by varying the PWM duty cycle on the Arduino through the MOSFET. As a result, the DRV2605L is not used and the C10-100 LRA is not supported for vibration alerting.

Vibration alerting output is made from four simple variables which can all be edited. The output is then repeated until the user stops it. The screen shows the current status including the menu options, output motor and the four variables.

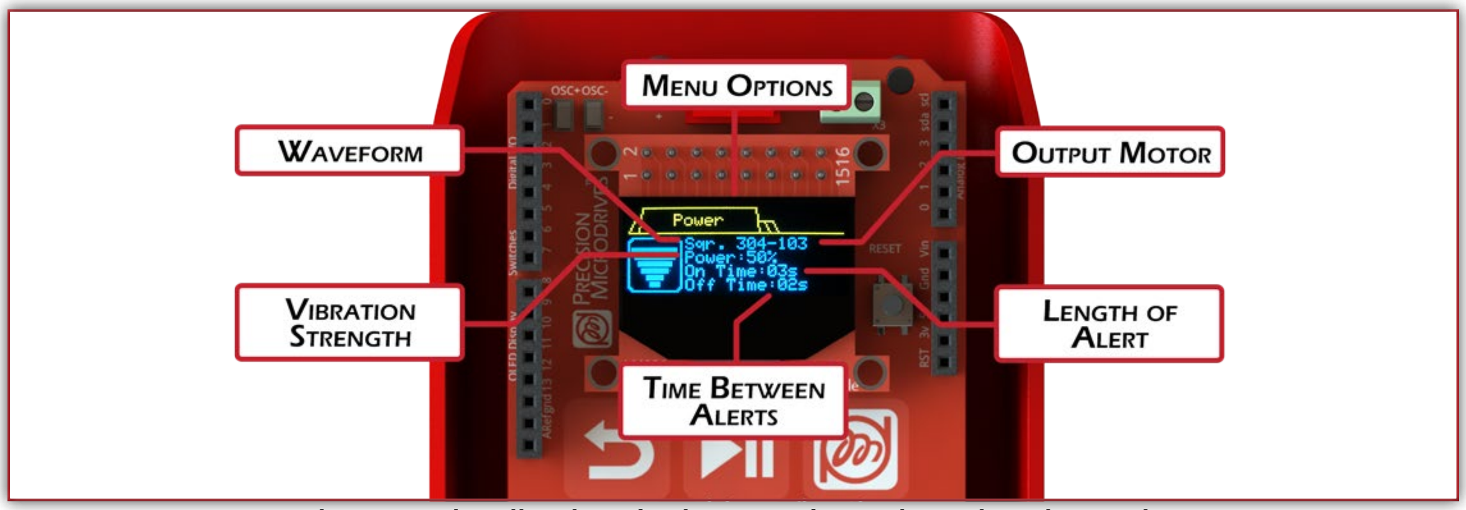


Figure 16. The Vibration Alerting menu layout in Engineering Mode

- **Waveform**

This is the shape of the voltage input to the ERM. There are 4 different waveforms available – square (Sqr), sine (Sin), triangle (Tri), and sawtooth (Saw). As the drive voltage is DC and the polarity is not switched, the sine waveform is actually a half sine wave:

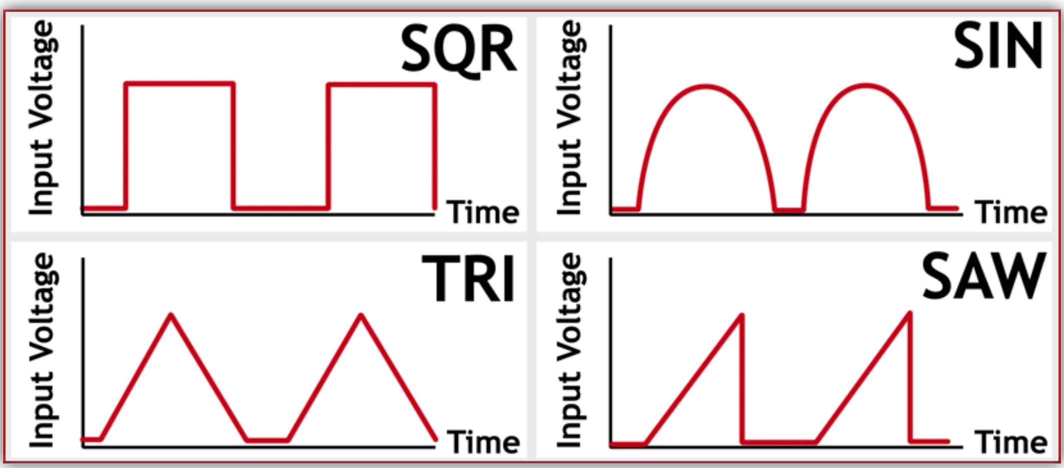


Figure 17. The different types of vibration alerting waveforms

- **Power**

The power represents the peak strength and is a percentage of the motor's rated voltage. Please take note of the selected motor's rated voltage when using an external actuator to avoid damaging your motor at high duty cycles.

- **On Time**

The on time determines the length of time the waveform is played across.

- **Off Time**

The off time controls the rest period between each wave cycle. Increasing the off time reduces the frequency of alerts, whereas setting it to zero immediately restarts the vibration waveform.

The following image shows how the four variables affect the vibration output:

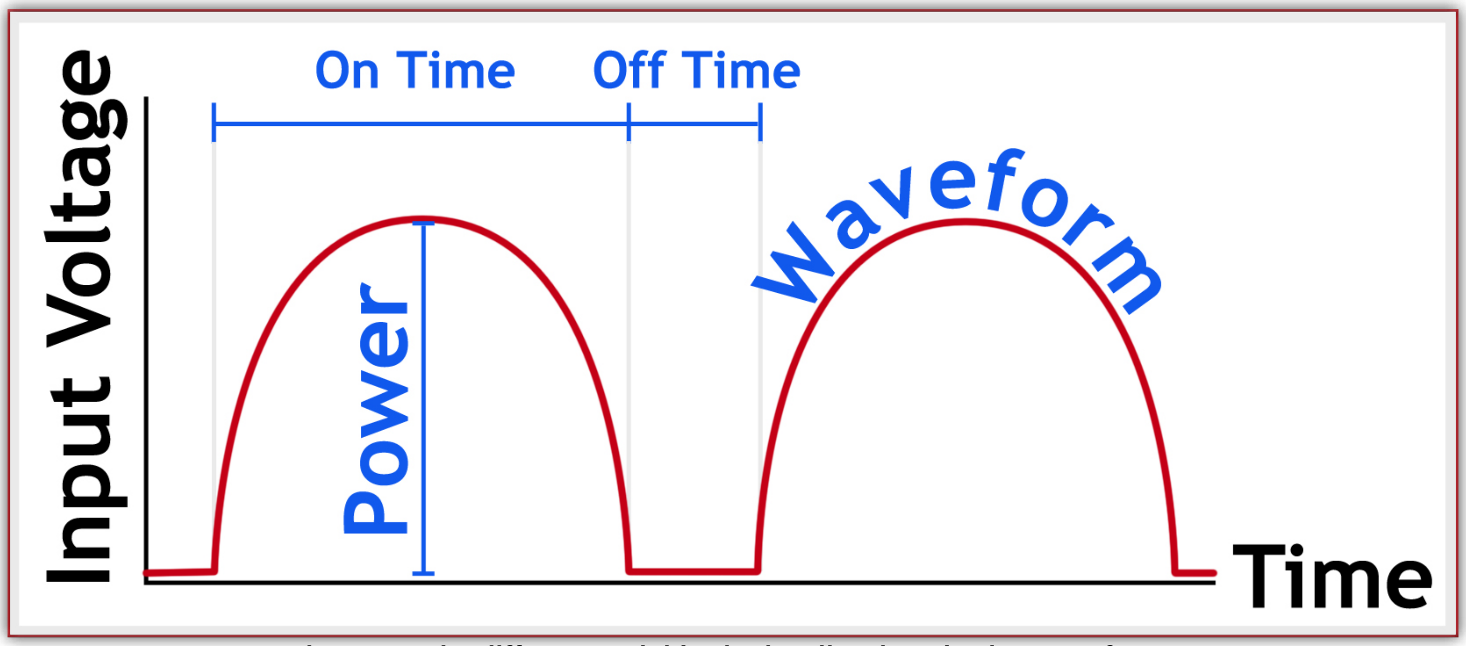


Figure 18. The different variables in the vibration alerting waveforms

To change the vibration alert change the desired variable by navigating to its menu option and press Select. Then use the Left and Right buttons to change the value, press Back or Select to confirm the change.

To play the waveform once the four variables have been set, press the Play button. Press Play again to stop and adjust the settings.

To change the output actuator press the PMD button, cycling to the desired ERM.

5.6 Debugging Feature

The Engineering Firmware includes an additional debug feature to help you understand the status of the kit. Selected information can be passed up the USB connection to a computer running the Arduino software. Therefore, this mode can only be used when the kit is powered through the computer's USB port rather than a standalone USB power socket or DC connector.

To enter the debug mode, you should have the Serial Monitor open in the Arduino software. This is found in the Tools menu, or you can use the keyboard short-cut Ctrl + Shift + M.

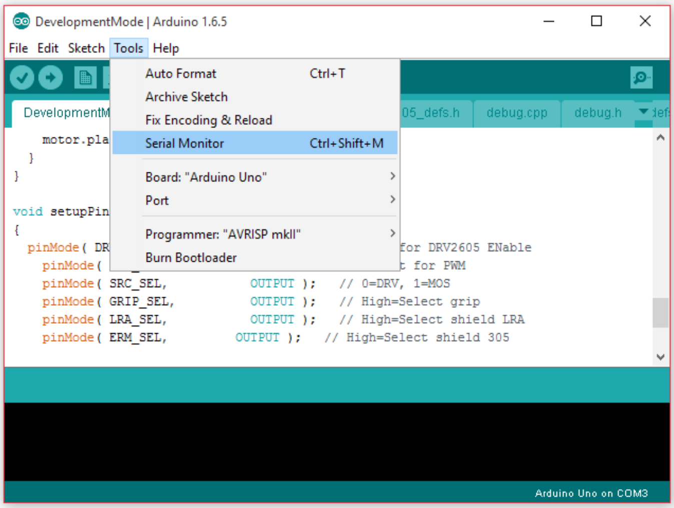


Figure 19. The serial monitor in the Arduino IDE

Navigate to the top level of the Engineering Mode menu, then hold down the PMD button to enter the Debug Mode. The screen on the Haptic Controller will present you with three options, each of which will print different information on the serial monitor window.

- **Dump Settings**

Prints the values stored in the DRV2605L EEPROM. These values are the motor calibrations and a bitmask for which motors are calibrated. It appears as a “Mem Dump” followed by a single hexadecimal byte in the serial monitor.

- **Reset Auto Calibration**

Wipes the motor calibration values stored in the EEPROM. This means none of the motors are seen as calibrated and the kit will re-run the auto calibration when each motor is selected. This is confirmed by printing the status byte, “AutoCal success” and the new auto calibrated values on the serial monitor.

- **Firmware Information**

Prints the current version of the firmware on the serial monitor. This can be edited in the debug_defs.h file if creating your own revisions of the program.

6 Development Mode Operation

The Development Mode is a bare-bones sketch that allows you to build your own working prototype using the Haptic Feedback Evaluation Kit.

It handles setting up the DRV2605L and Arduino, such as configuring the pins and initialising the I2C bus, but the main section of code can be edited to behave as you require. There are also multiple functions built in to the DRV2605L library to handle common functions, such as playing a haptic effect.

By default, the OLED screen and the capacitive buttons are not supported in Development Mode, their functionality must be programmed manually.

In addition to the software, the kit can be used to connect external components through the stackable headers on the Haptic Shield. This can be installed into the Arduino, or can be connected to separately if desired. There are several example applications that demonstrate using the Development Mode online at precisionmicrodrives.com/haptic-kit/tutorials.

The DRV2605L Library and Pin Mapping documents (Appendices E and F) are also good resources, as they describes the functions available for use in the Development Mode and the pins required by different components on the Haptic Shield. These can both be downloaded from precisionmicrodrives.com/haptic-kit/documents.

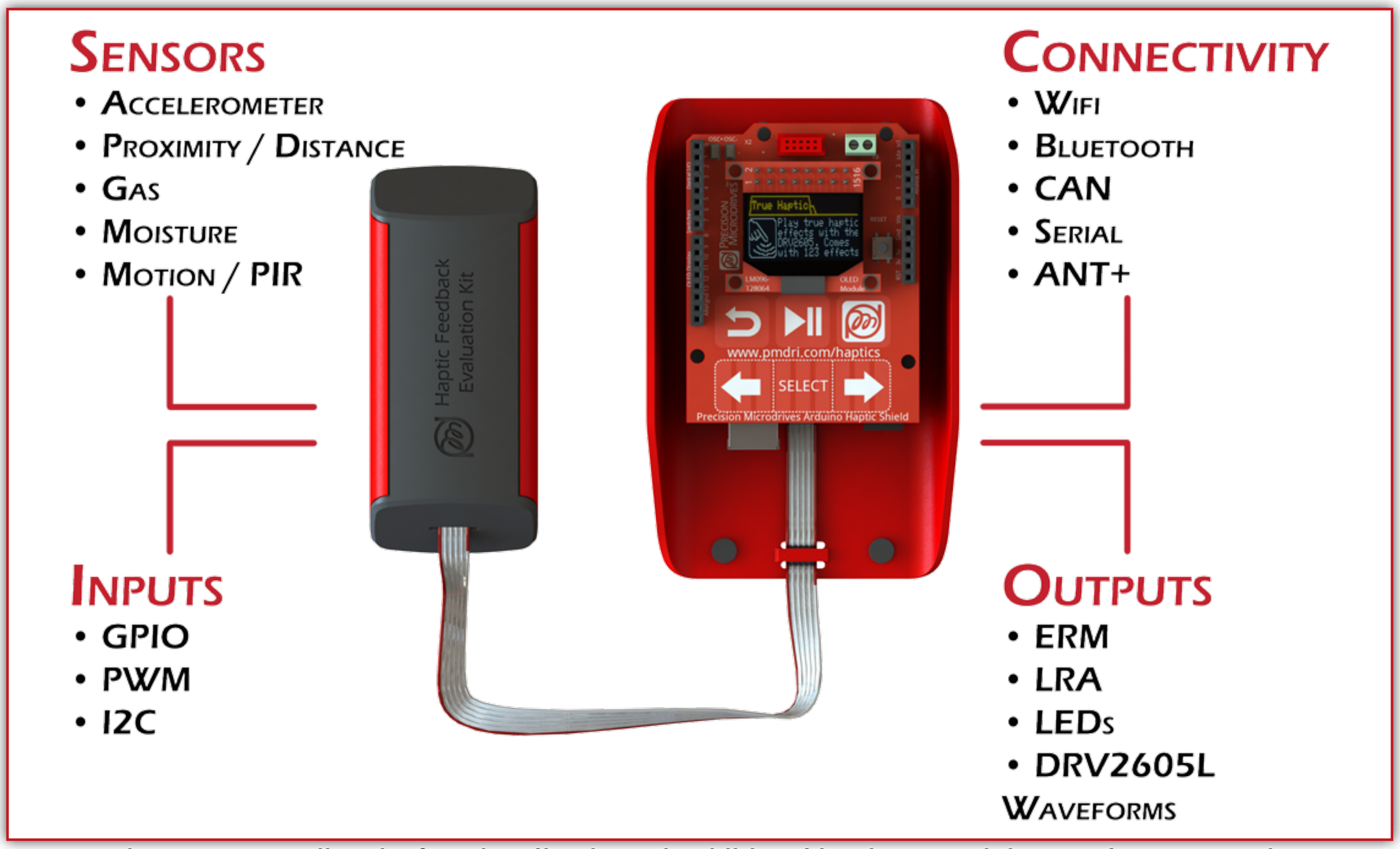


Figure 20. Extending the functionality through additional hardware and the Development Mode

7 Advanced Options

The kit has a number of additional features to aid understanding of key concepts and assist further development and prototyping.

7.1 Test Points

As there are many different signals and components in the kit, there are several opportunities to collect measurements. For additional information on the points you are measuring, refer to the schematics in Appendix B.

- **Stackable Headers**

The Arduino pins can be accessed through the stackable headers on the Haptic Shield. Refer to Pin Mapping (Appendix F) and the Schematics (Appendix B) to see which signals are present on each pin. Typical applications might include adding further components to the I2C bus, monitoring the PWM signals, or the DRV2605L's EN pin.

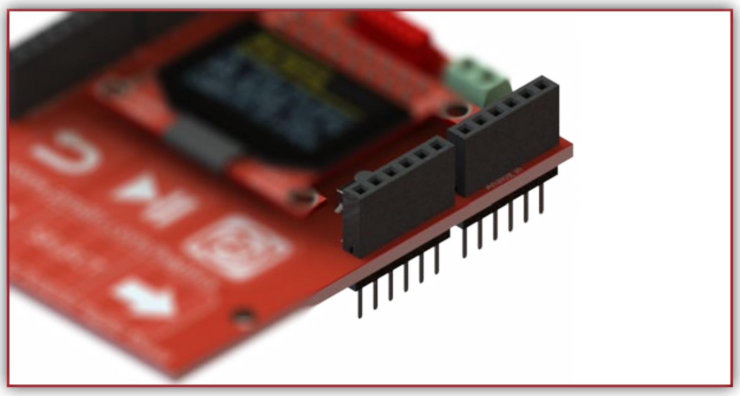


Figure 21. Stackable headers on the Haptic Shield

- **OSC+ and OSC-**

These connections are provided to analyse the output signal from the DRV2605L. Section 7.1 of the DRV2605L's datasheet describes the test setup for graphs and additional information. The resistors and capacitors described in the test setup are present on the Haptic Shield, simply connect the oscilloscope directly to the OSC+ and OSC- pins.

- **External Actuator Connectors**

There are two external actuator connectors provided on the Haptic Shield. Either X2 (the Molex connector) or X3 (the screw terminal) can be used to analyse the signal being sent to a motor. These connectors operate in parallel with the Haptic Grip so take care not to connect a motor to them when the Haptic Grip is also plugged in.

- **Motor Connections in Haptic Grip**

To offer a choice of actuator outputs, the drive signal passes through analogue switches to the desired motor. These are designed to have a minimal impact on performance, but it is possible to measure the signal directly at the motor terminals. In the Haptic Grip, two oversized vias provide access to the underside ERMs.

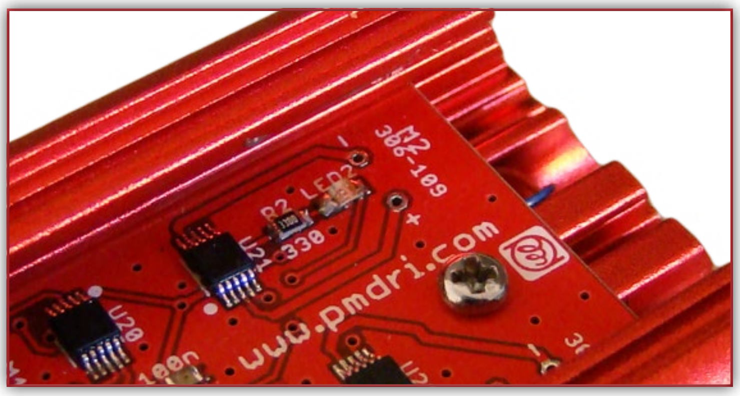


Figure 22. The available test points in the Haptic Grip

7.2 External Actuators

There are two external actuator connectors available on the Haptic Shield. Both connectors are taken in parallel with the drive signals that are sent to the Haptic Grip and can therefore output signals from either the MOSFET or the DRV2605L.

You should only play an effect on one actuator at a time, only connect one external actuator at once and be sure to disconnect the Haptic Grip from the Haptic Shield.

To connect an external actuator, first unplug the grey ribbon cable from the Haptic Grip. Then attach your actuator to either the screw terminal (X3) or Molex connector (X2). When using the screw terminal, clamp the screws onto the power leads, ensuring the screws make connection with the wires and not just the isolation.

The Molex connector is a 1.25mm pitch, PicoBlade™, vertical, 2 circuit, wire-to-board header with friction lock (p/n 53047-0210). It mates with the 51021 crimp housing series and 50058 or 50079 crimp terminals. Precision Microdrives can provide motors with custom connectors and lead lengths, to receive advice on connector types, pricing, or MOQs please contact us at precisionmicrodrives.com/contact-us/quotation.

7.3 Direct Access to DRV2605L

There are two ways to directly access the DRV2605L.

The easiest method is to use the Arduino, simply edit the mode of operation sketches, create your own sketch with the Development Mode and DRV2605L library, or your own I2C or PWM based interface with the DRV2605L as you wish. To help, Section 6 discusses how to edit the Arduino code and access the Arduino library for the DRV2605L from Precision Microdrives.

Alternatively, the Haptic Shield can be removed from the Haptic Controller and plugged into a breadboard or connected to via the stackable headers, allowing you use a different processor to interface with the DRV2605L.

Used in conjunction with the external actuator connectors, it is possible to mount an ERM or LRA in a prototype mechanical system, e.g. touchscreen or hand-held mould, and continue to use the DRV2605L for haptics effects.

7.4 Changing Modes of Operation

You can change between the modes of operation as many times as you wish. This is done by writing a new sketch (.ino file) to the Arduino. The kit has the Intro Mode loaded by default, a new program can be transferred (written) to the Arduino through the USB connection by the Arduino IDE (software installed on the computer).

To change between modes of operation, you will need to download additional resources.

The first is the Arduino software environment. It is open-source, free, and available on Windows, Mac OS X, and Linux. See Section 3.3 for installation of the Arduino drivers and software.

The second is the program files for the different modes of operation. We provide all the source code for the Intro Mode, Engineering Mode, and Development Mode with further coding examples, including a library for the DRV2605L, at precisionmicrodrives.com/haptic-kit. Download the 'Modes of Operation' files and extract them to a folder on your hard drive.

You must then correctly install the included libraries for the code to compile and upload. In the zip is a folder called '**libraries**', this folder must be in the location of your Arduino IDE's '**sketchbook**'. If have a previous version of the codes installed, **please delete any old copies of the files in the libraries folder before replacing them**.

To upload a new code, open the desired .ino file in the folder you have just extracted it to. Once the Arduino IDE opens with the code, press the upload button.

7.5 Editing the Arduino Code and Using the DRV2605L Arduino Library

As an added benefit of the Haptic Feedback Evaluation Kit you now own an Arduino! You can use it as a standalone development tool for other projects, or preferably use it to create a prototype haptic feedback device. The Arduino UNO R3 is based on the ATmega328 processor, which you can use in your final design (it is available in smaller packages). To aid prototyping with the DRV2605L, a library written by Precision Microdrives is available for download at precisionmicrodrives.com/haptic-kit/codes. This includes a series of pre-built functions that take advantage of the DRV2605L features. See Appendix E for a list of available functions.

It is recommended you use the series of examples precisionmicrodrives.com/haptic-kit/tutorials which show different basic skeleton codes demonstrating how to use the functions.

For general errors and problems using the Arduino it is best to seek advice from the Arduino community at **arduino.cc**. If you require any help specifically using the DRV2605L Arduino Library please contact us at precisionmicrodrives.com/contact-us/technical-support.

7.6 DRV2605L Auto Calibrate Feature

The DRV2605L has many additional features to improve haptic effects, such as overdrive and active braking or auto resonance detection for LRAs. Auto calibration is another feature provided by the DRV2605L to improve the haptic performance.

Auto calibration monitors the back-EMF of the actuator and uses the results to adjust the output from the driver, tailoring the haptics for that exact actuator. More information on this can be found on the DRV2605L datasheet.

Each of the modes of operation implements the auto calibrate feature differently. Both the Intro Mode and Engineering Mode handle this for you, and you can check the values using the debugging feature in the latter. In Development Mode you must call the function, see the DRV2605L Library in the Appendix E for more details.

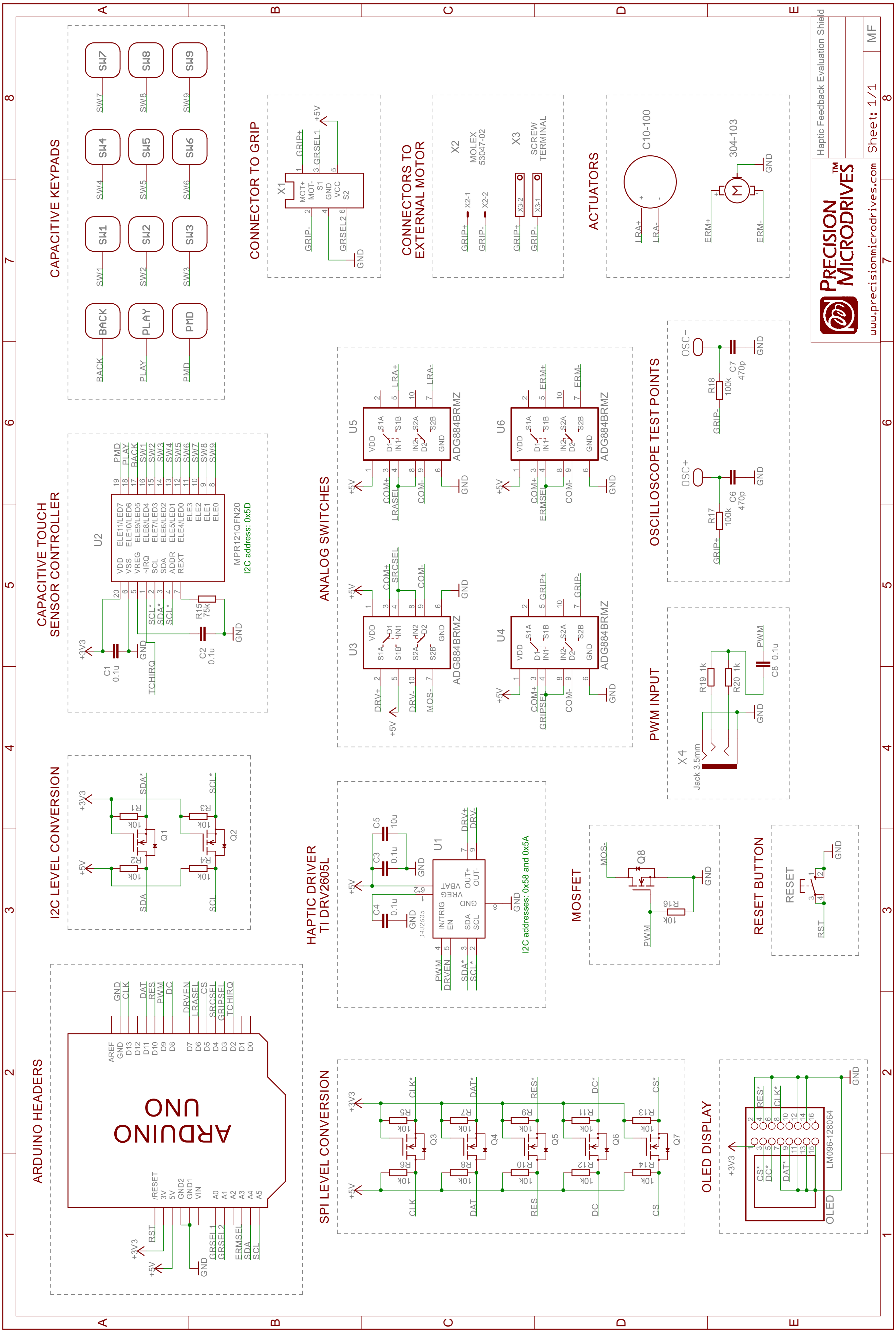
8 Appendices

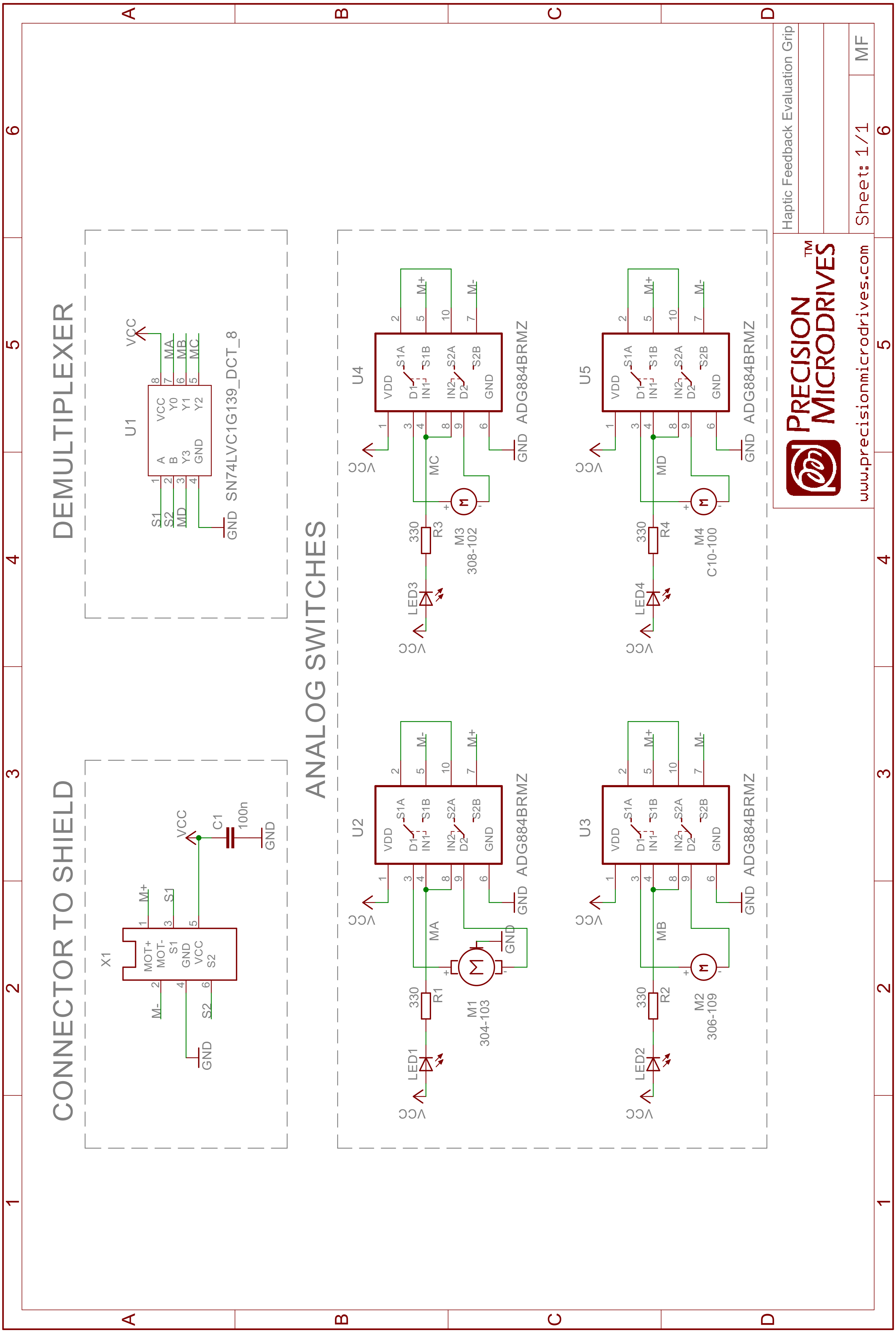
A Glossary

Active Braking	The haptic technique of reversing the polarity of the voltage applied to an ERM to stop the motor quicker. When using an LRA the phase of the drive signal is shifted 180°.
Actuator	Refers to the output component that creates the vibration force, either an ERM or LRA.
Arduino	An open source electronics prototyping platform. Often used to refer to the specific board in use, e.g. "connect to pin D3 on the Arduino". The Haptic Feedback Evaluation Kit uses an Arduino UNO R3 board.
Auto Calibration	A feature of the DRV2605L that calibrates the driver to compensate for the actuators characteristics, improving haptic performance.
DRV2605L	Haptic driver chip from Texas Instruments. Mounted on the Haptic Controller, it stores 123 different haptic effects and sends the drive signal to the actuator after receiving instruction from the Arduino via I2C. Functionally the same as the DRV2605.
ERM	"Eccentric Rotating Mass" – a type of vibration motor that rotates an unbalanced load to create displacement. See precisionmicrodrives.com/vibrating-vibrator-vibrationmotors/pager-motors-erm-motors.
Haptic Controller	The section of the Haptic Feedback Evaluation Kit that acts as the user interface. It contains the capacitive touch buttons for input, an OLED screen for navigation, the Arduino for processing, and the DRV2605L and MOSFET to drive the actuators.
Haptic Feedback	Using advanced vibration patterns to communicate information to the user. The patterns are achieved by using different drive techniques, such as Active Braking and Overdrive, which are normally created using a dedicated haptic driver.
Haptic Feedback Evaluation Kit	The Haptic Controller and Haptic Grip together, a complete system for users to learn about haptic feedback and evaluate the performance of different actuators with the DRV2605L. The Arduino enables it to be a development platform for haptic devices.
Haptic Grip	The section of the Haptic Feedback Evaluation Kit that houses 4 Precision Haptic actuators and acts as the output. It is a handheld grip that vibrates when the Haptic Controller sends a drive signal, used both for haptic feedback and vibration alerting.
I2C	"I-squared-C" or "I-two-C" – a serial digital communication bus used to communicate between the Arduino and the DRV2605L. Implemented by the Arduino using the 'Wire' library, details on this can be found at arduino.cc/en/reference/wire.

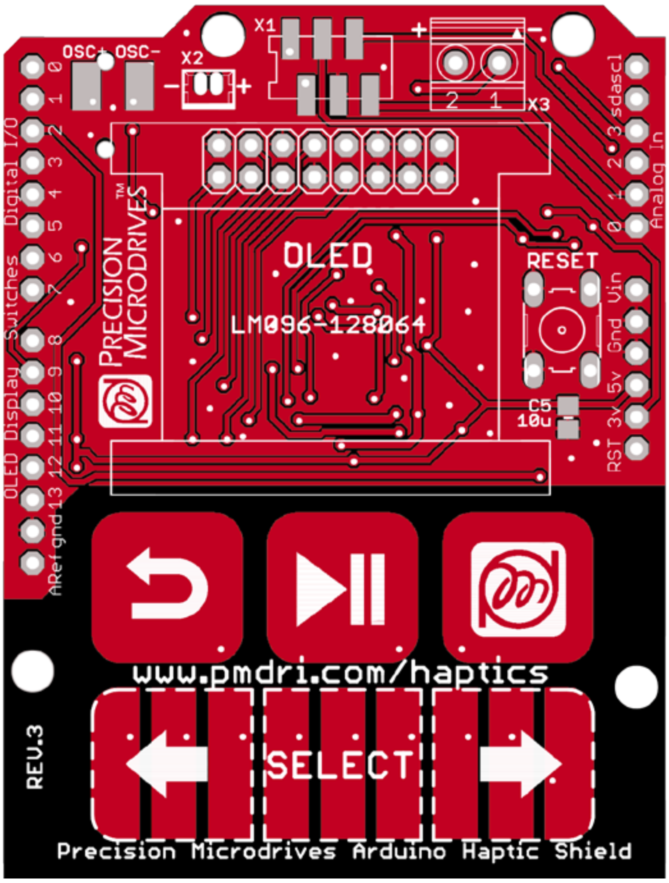
IDE	"Integrated Development Environment" – a software application that enables users to create a program. The Arduino IDE allows the programmer to control the Arduino with the source code editor. Sections 2.3, 3.5, and 6 of this manual cover using the Arduino IDE.
LRA	"Linear Resonant Actuator" – a type of vibration actuator that oscillates a magnetic mass on a spring to create displacement. precisionmicrodrives.com/vibratingvibrator-vibration-motors/linear-resonant-actuator-lra-haptic-vibration-motors.
Overdrive	The haptic technique of applying the actuators maximum voltage (above the rated voltage) to generate more electromagnetic force, causing the actuator to start quicker.
MOSFET	A transistor that can act as a switch to control a component that draws a lot of current (e.g. an ERM) with a low current source (e.g. an Arduino). Can support a PWM signal for vibration alerting.
PWM	"Pulse Width Modulation" – a digital signal of a fixed frequency .The "on time" vs "off time" of a single clock cycle is expressed as a percentage and known as the "duty cycle". Varying the duty cycle can control the speed (and vibration strength) of an ERM. Implemented by the Arduino using the "analogWrite()" function, details on this can be found at arduino.cc/en/reference/analogwrite.
Sketch	The code or 'program' that is written to the Arduino. On a PC this appears as a .ino file, such as the IntroMode.ino. A sketch is opened in the Arduino IDE and contains a series of instructions for the Arduino to carry out. The IDE compiles the sketch and writes it onto the board through the USB port. See arduino.cc/en/Tutorial/Sketch for more information.
Vibration Alerting	Using basic vibration patterns to communicate information to the user. Typically used to alert the user to an event in a simple "on / off" vibration pattern. Normally created with a PWM signal and a MOSFET, although dedicated drivers are also commonly used for additional benefits.

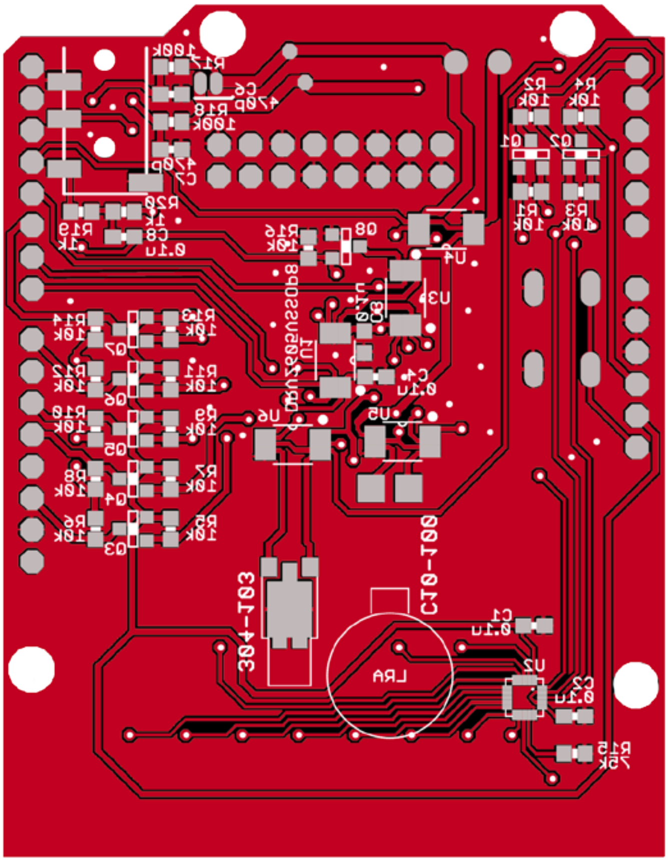
B Schematics



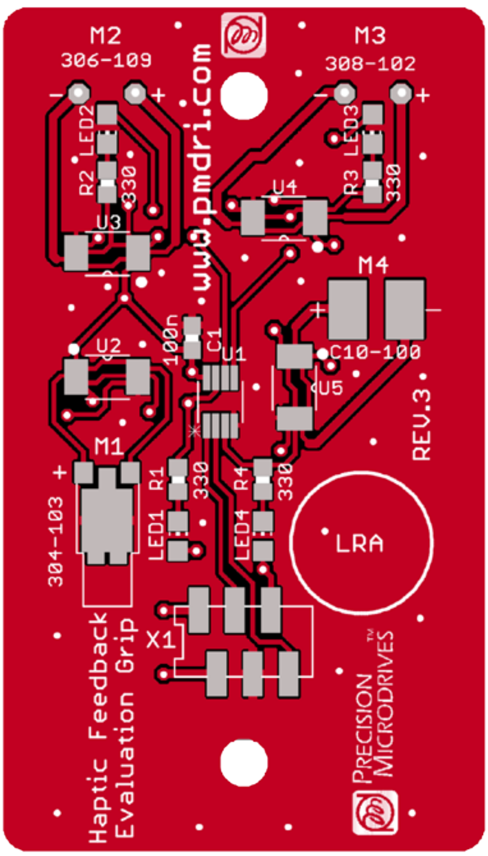

DEMULTIPLEXER
U1
SN74LVC1G139_DCT_8
VCC
A
B
Y3
GND
Y0
Y1
Y2
S1
S2
MD
MA
MB
MC
GND
CONNECTOR TO SHIELD
X1
MOT+
MOT-
S1
GND
VCC
S2
M+
M-
S1
S2
GND
VCC
C1
100n
GND
ANALOG SWITCHES
U2
U3
U4
U5
ADG884BRMZ
VDD
D1
IN1
IN2
D2
GND
S1A
S1B
S2A
S2B
MA
MB
MC
MD
M+
M-
GND
VCC
LED1
LED2
LED3
LED4
R1
R2
R3
R4
330
M1
304-103
M2
306-109
M3
308-102
M4
C10-100
Haptic Feedback Evaluation Grip
PRECISION MICRODRIVES™
www.precisionmicrodrives.com
Sheet: 1/1
MF

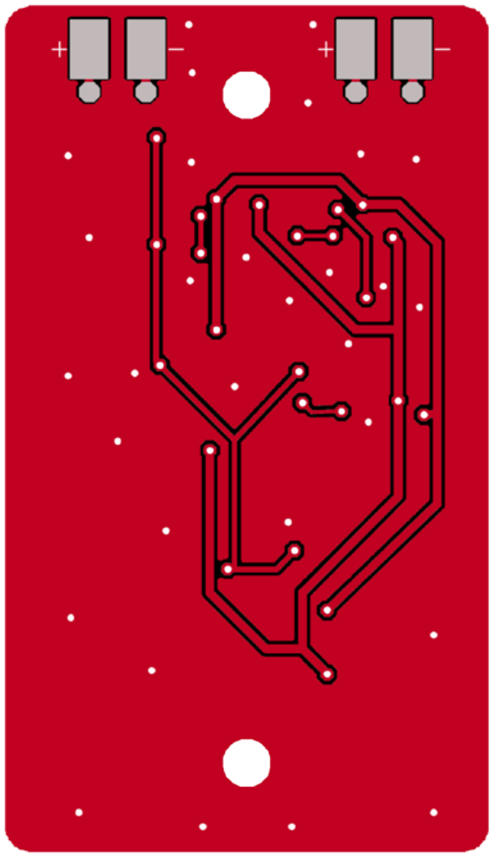
Haptic Shield





Haptic Grip

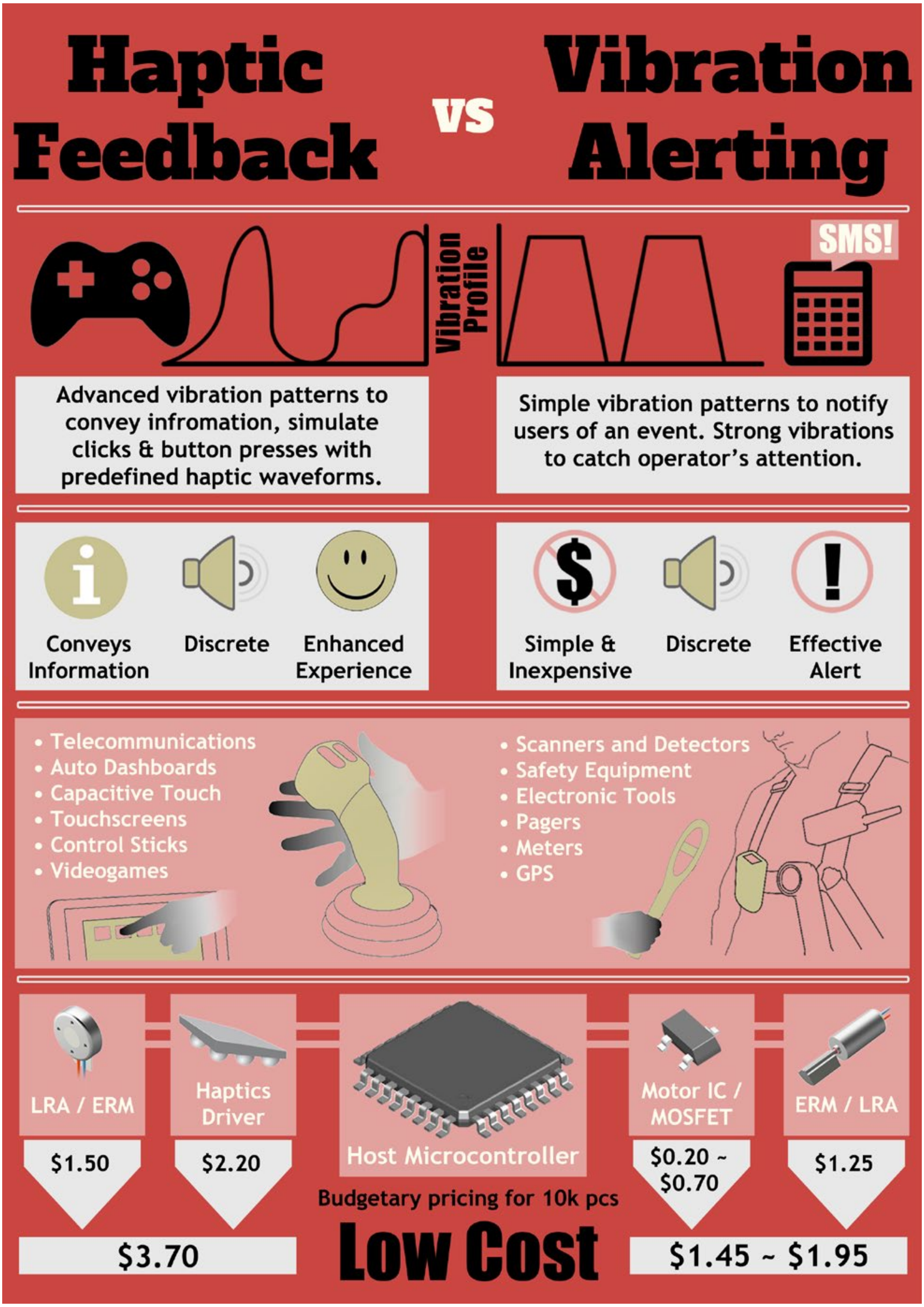




C Actuator Table

Model Number	Type	Typical Normalised Amplitude	Rated / Resonant Vibration Frequency	Rated Voltage	Image	Notes
304-103	ERM	0.5 G	233 Hz (rated)	2.7 V		
306-109	ERM	3.5 G	200 Hz (rated)	3 V		
308-102	ERM	5.5 G	300 Hz (rated)	4.5 V		
C10-100	LRA	1.4 G	175 Hz (resonant)	2 V (RMS)		

D Haptic Feedback vs Vibration Alerting



E 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

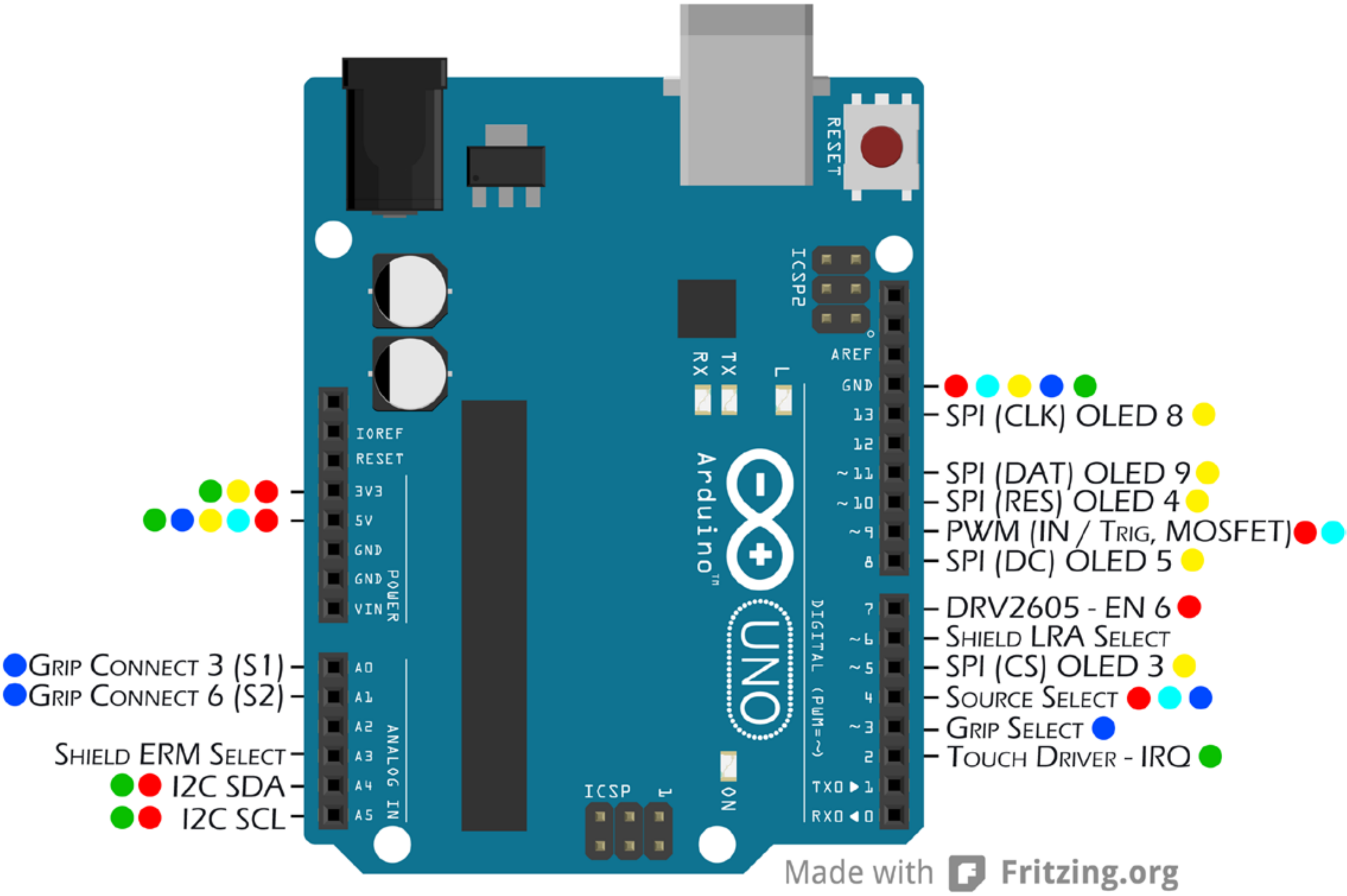
Parameter	Type & Limits	Values	Description
motorID	0 ≤ int ≤ 3	0 = 304-103 1 = 306-109 2 = 308-102 3 = C10-100	Selects the output actuator
waveform	0 ≤ int ≤ 3	0 = Square 1 = Sine 2 = Triangle 3 = Sawtooth	Changes the output waveform for vibration alerts
pwr	0 ≤ int ≤ 100	0% - 100%	Peak output strength 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

F Pin Mapping

Pin Requirements

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



I2C Addresses
Using 7-bit Addressing

Capacitive Touch Driver MPR121	0x5D
Haptic Driver DRV2605L	0x5A

G 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

H 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
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

10 Further Resources

You can request technical assistance from our engineers by clicking here

See also

Arduino UNO R3 Drivers and Software: arduino.cc/en/Main/ArduinoBoardUno

DRV2605L Datasheet: ti.com/product/drv2605l/description

Tutorials & Example Applications: precisionmicrodrives.com/haptic-kit/tutorials-and-examples

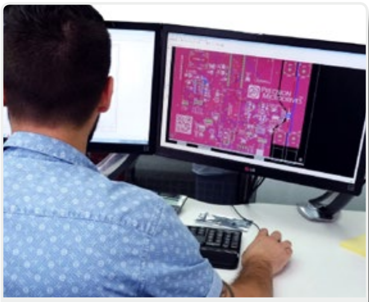
Customer Support

Technical Support Form: precisionmicrodrives.com/contact-us/technical-support

Downloadable Resources: precisionmicrodrives.com/haptic-kit/documents

Website: precisionmicrodrives.com/haptic-kit

enquiries@precisionmicrodrives.com www.precisionmicrodrives.com Tel: +44 (0) 1932 252 482



Engineering

With engineering teams in London, Hong Kong, and China, we are able to offer first class support throughout the entire design cycle. Accelerate your development by engaging with experienced staff, safe in the knowledge that we work closely with factories on your behalf to ensure specifications are met.

Quality

Our business is built upon advanced testing and quality control, delivering our partners' orders "on time and to spec". This means more than our BSI ISO9001 certification, we focus on continually improving our processes to ensure we deliver high performing products and services at competitive price points.

Supply

With a large inventory of parts available without MOQ, we are able to scale alongside projects and support the full product life cycle, from sample orders to 100k+ production runs. Our geographic diversity and unique set-up enables us to configure the supply to chain to offer the most cost-effective service available.

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