User's Guide

SLOU400 – September 2014

DRV2605L Multi-Driver ERM, LRA Haptic Driver Evaluation Kit User's Guide

1 Introduction

The DRV2605L device is a haptic driver designed for linear resonant actuators (LRA) and eccentric rotating mass (ERM) motors. The device has many features that help eliminate the design complexities of haptic motor control including:

- Reduced solution size
- High-efficiency output drive
- Closed-loop motor control
- Quick device startup
- Embedded waveform library
- Auto-resonance frequency tracking

The DRV2605LEVM-MD evaluation module (EVM) is an evaluation platform for the DRV2605LDGS. The kit includes an MSP430F5510 microcontroller (MCU), terminal output support for up tight LRAs or ERMs, sample waveforms provided by Immersion, and capacitive touch buttons which demonstrate the capabilities of the DRV2605L.

This user's guide contains instructions for setting up and operating the DRV2605LEVM-MD.

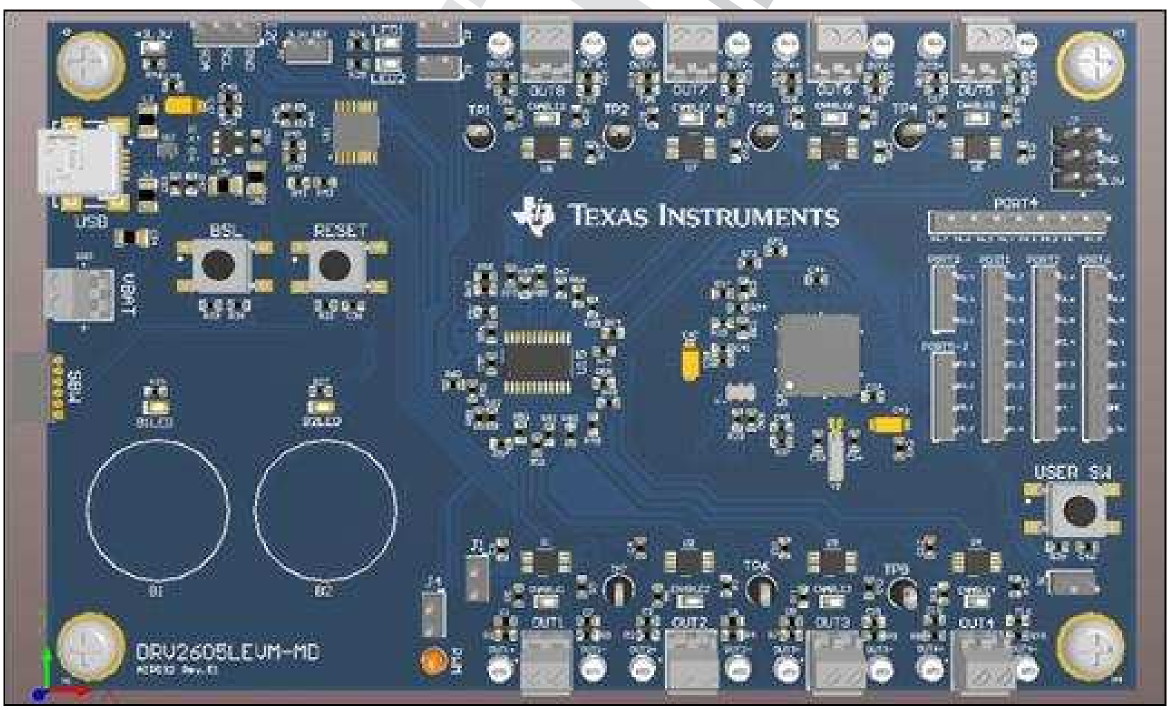

Figure 1. DRV2605LEVM

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2 Getting Started

The DRV2605LEVM-MD demonstrates how the DRV2605L device can be used in applications that require multiple haptic drivers (same slave addresses) to be setup independently but be played simultaneously. The board integrates the TCA9548A I^2C switch to control which I^2C lines of the possible eight DRV2605L drivers are connected to the master input I^2C bus. The switch has the ability to select any combination of channels to be connected to the master input I^2C bus.

The board also integrates the MSP430F5510 device with USB interface capabilities and bootstrap loading (BSL) functionality. The USB interfacing provides the user flexibility in controlling the DRV2605L device without having to modify the firmware. The BSL functionality simplifies the firmware updating process without the additional hardware and the use of Code Composer Studio™ software.

The board receives power in two ways. For applications that require two or less active DRV2605L devices device at the same time, the board can be powered through a USB port. For applications that require more than two drivers, the use of the external power supply terminals with a current rating of 1.6 A is recommended. Manual selection of USB power or external power can be set using the jumper headers MSP and DRV. When powered up, button 1 and button 2 (B1, B2) can be used to demonstrate the functionality of the DRV2605L device. See Section 3 for a detailed description of the demonstration application program.

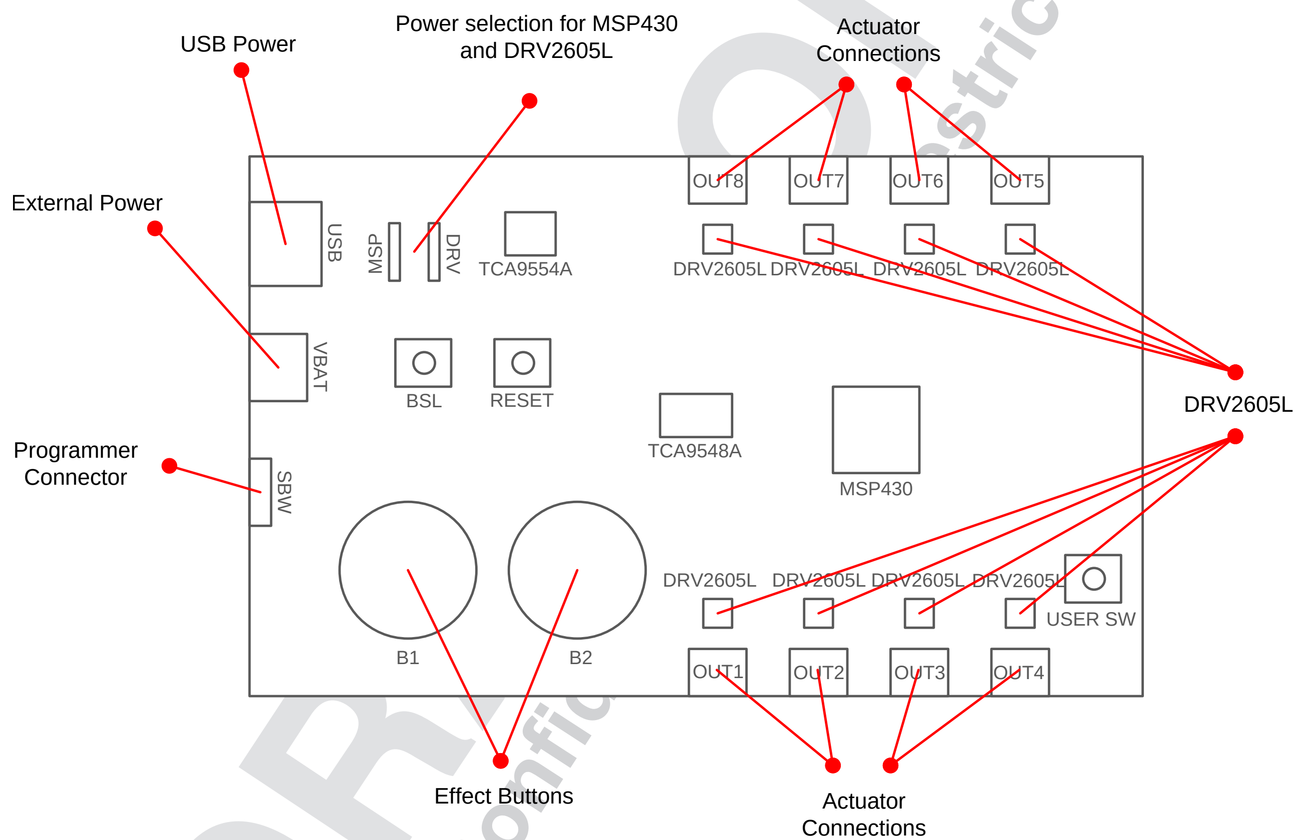

Figure 2. Board Diagram

2.1 Quick Start Board Setup

The DRV2605LEVM-MD firmware contains haptic waveform sequences that showcase the features and benefits of the DRV2605L device in a multi-driver application. Use the following setup instructions to begin the demand evaluation process:

1. Connect 4 ERM actuators to the terminal block outputs 1 through 4, and connect 4 LRA actuators to the terminal block outputs 5 through 8 on the board.
2. Connect the 5-V power supply to the VBAT terminal block.
3. Verify that the jumper connections on the board are correct as listed in Table 1.
4. Turn on the power supply. If the DRV2605LEVM-MD is powered correctly, the button LEDs turn on and flash indicating that the board has been successfully initialized.

Table 1. Default Jumper Settings for Demonstration Program

JUMPER	POSITION	DESCRIPTION
J1	Shorted	Connects decoupling cap to the V_{DD} pin, used for power consumption measurements
J2	Shorted	3.3-V reference voltage for I^2C transactions on the TCA9548A device
J3	Shorted	User LED
J4	Don't care	User LED
J5	Shorted	Trigger and PWM input to the DRV2605L device
J6	Shorted	User switch
MSP	Short pins 2 to 3	VBAT power to the MSP430 device (Shown in Figure 3)
DRV	Short pins 2 to 3	VBAT power to the DRV2605L device (Shown in Figure 3)

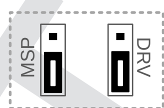

Figure 3. Jumper Position for MSP and DRV Headers

NOTE: This board has the ability to control both ERM and LRA actuators at the same time. The default firmware is set so that only the actuators that are connected to the board are active. The connected driver and the actuator type must be hardcoded in the firmware in order for the system to know the user's hardware configuration. If the default configuration of 4 ERM actuators on outputs 1 through 4 and 4 LRA actuators on outputs 5 through 8 is not desired, see Section 3.4 for more details on how to customize the board.

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3 DRV2605L Demonstration Program

Ceveral functionality sections can be initiated to demonstrate how the DRV2605LEVM-MD can be used for multi-driver applications. The user can interact with the capacitive touch buttons to output a variety of waveform sequences to the actuators externally connected to the board and to enable all the drivers and I^2C channels for full access to the DRV2605L devices through the I^2C headers.

The user can also access USB functionality through the user switch. The capacitive touch buttons (B1 and B2) and user switch (USER SW) have the following functionality:

- B1: The DRV2605L devices are setup individually and RTP mode is configured. Sequential button presses activate the next DRV2605L device in sequential order starting at driver 1, ending at driver 8, and then looping back to driver 1.
- B2:
  - Mode 1 – Enables all of the drivers and channels of the TCA9548A device for the user to gain access to all of the DRV2605L devices.
  - Mode 2 – Drivers 1 through 4 are enabled, RTP mode is setup, and all drivers are played simultaneously

- Mode 3 – Drivers 5 through 8 are enabled, RTP mode is setup, and all drivers are played simultaneously
- Mode 4 – Driver 1 through 4 are setup in RTP mode, played sequentially in order, and then briefly played simultaneously.
- Mode 5 – Driver 5 through 8 are setup in RTP mode, played sequentially in order, and then briefly played simultaneously.

• USER SW: Turns on USB communication and disables capacitive touch buttons

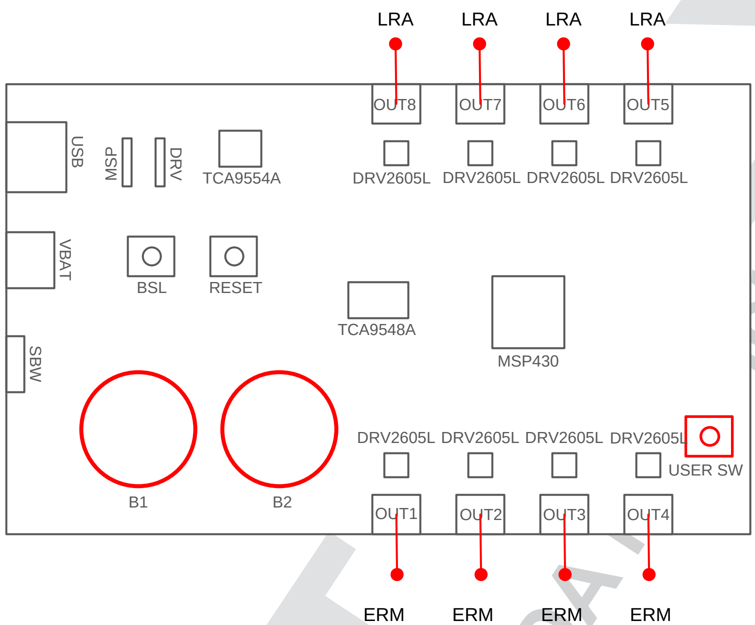


Figure 4. Board With Actuator Setup

Figure 4 shows the actuator setup of where the LRAs and ERMs are connected to the board. B1 and B2 are the capacitive touch buttons that, when pressed, play the waveform sequence as described in Section 3.1 and Section 3.2.

3.1 Button 1

For button 1, each of the DRV2605L devices is independently setup for RTP mode at full magnitude 0x7F and played sequentially. Each press of the capacitive touch button plays the next driver. The TCA9548A device (I^2C switch) is configured so that only the corresponding DRV2605L device is connected to the master input I^2C bus. When the configuration is complete, default register settings, RTP mode, and the RTP magnitude are sent to the DRV2605L device. After some time, the RTP mode shuts off.

3.2 Button 2

Button2 has 5 modes that can be accessed through sequential button presses. The user must sequentially cycle through all of the other modes to get back into the same mode.

3.2.1 Mode 1

Mode 1 allows the user full access to all of the DRV2605L devices on the board by enabling them and connecting all of the I^2C lines. An external host processor can be connected to the I^2C headers to allow communication to the DRV2605L devices without having to use the on-board MSP430F5510.

3.2.2 Mode 2 and Mode 3

Mode 2 and mode 3 enable and connect the I²C lines for drivers 1 through 4 and drivers 5 through 8, respectively. The four DRV2605L devices are sent the same default initialization settings for the ERM actuators (Mode 2) and LRA actuators (Mode 3). The drivers are then setup in RTP mode with magnitude 0x7F. The waveform plays for 2 s and then the drivers are changed to internal trigger mode (to stop RTP mode).

3.2.3 Mode 4 and Mode 5

Mode 4 and mode 5 enable and connects the I²C lines for drivers 1 through 4 and drivers 5 through 8, respectively. The four DRV2605L devices are sent the same default initialization settings for ERM actuators (Mode 4) and LRA actuators (Mode 5). When the settings are received by the DRV2605L devices, each DRV2605L device is individually enabled sequentially and setup for RTP mode with magnitude 0x7F at a 500-ms interval. Driver 1 or 5 outputs the RTP waveform for 500 ms, then the next sequential drivers (driver 2 or 6, 3 or 7, 4 or 8) repeat the same conditions as driver 1. As soon as driver 4 or 8 completes the waveform output, all drivers go out of RTP mode for 100 ms and then enter RTP mode with magnitude 0x7F for 100 ms to create a brief pulse action.

3.3 User Switch

At board startup, the capacitive touch buttons are automatically enabled and USB communication is disabled even though USB communication was initialized. To enter USB communication for use with the multi-driver graphical user interface (GUI), the user switch must be pressed. LED1 turns to indicate that the firmware is active for USB transactions. When the user switch is pressed and the board is in USB communication mode, the capacitive touch buttons are disabled. A power cycle or software reset is required to go back to capacitive-touch mode.

3.4 Firmware Modifications

Before the board can accept any combination of LRA and ERM actuators connected to the DRV2605L devices, the firmware is required to be modified because it must know which actuators are connected to which haptic drivers. Additional hardware-like dip switches are required to detect real-time changes with actuators or enable the drivers. The header file, *haptics.h*, contains the definitions of driver 1 through driver 8, and actuator 1 through actuator 8 which are mapped to arrays that are used in haptic methods as follows:

- Haptics_DriversEnableConfig()
- Haptics_EnableAvailableDrivers()
- Haptics_ActuatorTypeConnected()
- Haptics_SwitchAvailableDrivers()

The driver definitions can be either *CONNECTED* or *NOT_CONNECTED*. The actuator definitions can be either *ACTUATOR_ERM* or *ACTUATOR_LRA*. When each definition is defined properly, the methods provided configure the TCA9554A and TCA9548A devices to enable the DRV2605L devices and connect the I²C lines of the drivers to the master I²C bus properly.

4 Measurement and Analysis—Waveform Sequences

The DRV2605L device uses PWM modulation to create the output signal for both ERM and LRA actuators. To measure and observe the DRV2605L output waveform, connect an oscilloscope or other measurement equipment to the filtered output test points, *OUT+* and *OUT–*. Figure 5 shows the setup of the terminal block and test points used to connect external actuators and measure waveforms.

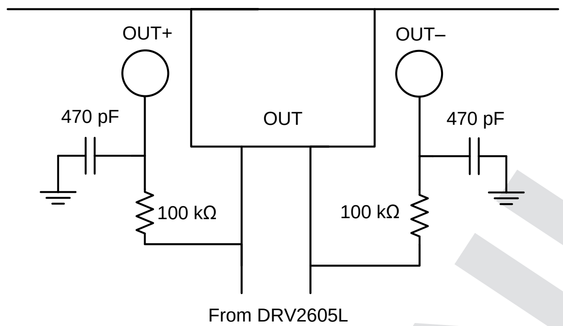


Figure 5. Terminal Block and Test Points

4.1 TripleClick and StrongClick Example Waveforms

Figure 6 displays the tripleClick waveform output for an LRA (trace C1 and C2) and the strongClick waveform for an ERM (trace C3 and C4) the same time. The differential output (trace Math) is trace C1-CT the ERM was operated in open-loop mode while the LRA was operated in auto-resonance (closed loop) mode.

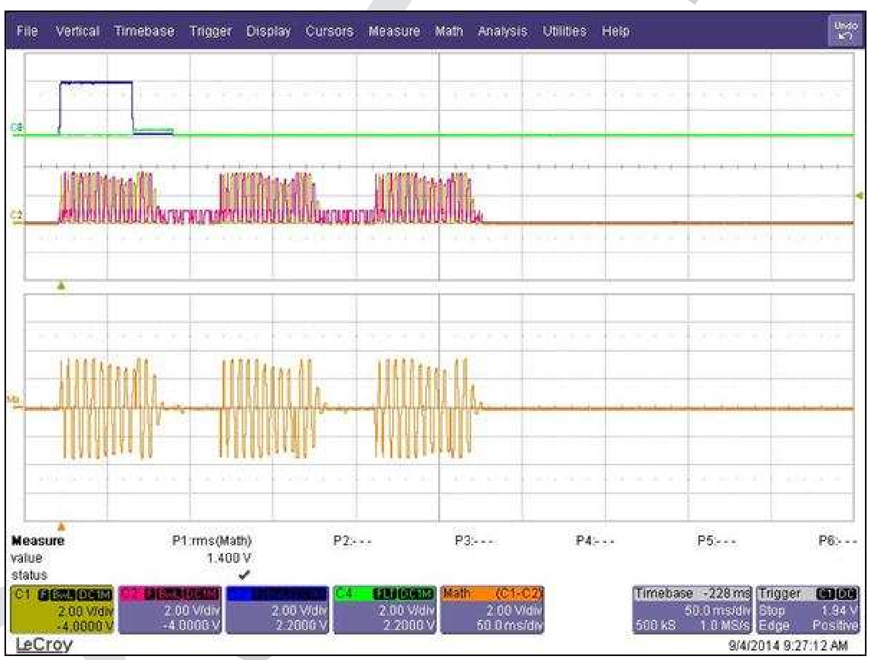


Figure 6. TripleClick and StrongClick Waveform Played at the Same Time

4.2 Pulsing Strong Example Waveforms

Figure 7 displays the pulsingStrong waveform output for an ERM (trace C1, C2). The differential output (trace Math) is trace C1-CT the ERM was operated in open-loop mode. The peak acceleration for the waveform is 156.1 mV_{PP} or 1.37 G.

Figure 7. Pulsing Strong waveform for ERM in Open-Loop Mode

4.3 Strong Buzz Example Waveforms

Figure 8 and Figure 9 show the output waveform (trace C1 and C2), the differential output (trace Math), and the acceleration profile (trace C4) for the buzz waveform. Figure 8 displays the waveform in auto-resonance mode while Figure 9 displays the same waveform in open-loop mode. Auto-resonance mode allows the acceleration profile to have a higher peak acceleration at a lower V_{RMS} voltage.

Figure 8. Strong Buzz Waveform for LRA in Auto-Resonance Mode

Figure 9. Strong Buzz Waveform for LRA in Open-Loop Mode

5 TCA9554 - I²C GPIO Expander

The TCA9554 GPIO expander is used to enable the DRV2605L device. Because the multi-driver board has the ability to control up to 8 haptic drivers, the TCA9554 device is able to control the enable lines of the DRV2605L device through I²C and free up GPIO pin space on the MSP430F5510 device for other peripherals. The pseudo code listed in Table 2 shows how the TCA9554 device is used as an output configuration.

Table 2. TCA9554 Output Configuration Pseudo Code

OPERATION	DESCRIPTION
I2C_SetSlaveAddr(TCA9554_SLAVE_ADDR)	//set slave address
I2C_WriteSingleByte(0x03, ~(bit_set_for_output))	//configure as output port
I2C_WriteSingleByte(0x01, output_bits)	//output values

The TCA9554 device is configured completely through I²C commands. The expander must be configured as an output port for the corresponding drivers (8 drivers). The output port command register is 0x03. Each bit of the 8-bit value represents the 8 output ports of the device. A value of zero in each bit corresponds to an output configuration. The variable, *bit_set_for_output*, has the respective bits set as outputs. When the output port is configured, register 0x03 does not need to be accessed unless those ports will be used as some other port function. After the ports are configured as outputs, a write command to register 0x01 is used to set the value of the output to either 0 or 1. The default values for outputs are initialized to 0. See the TCA9554 data sheet, SCPS233, for more information on the TCA9554 device.

5.1 I²C Register Value Examples

The following examples listed in Table 3 and Table 4 show exact I²C transactions with slave addresses, registers, and values to enable one DRV2605L device and to enable three or more DRV2605L devices.

Table 3. TCA9554 I²C Transaction for Enabling driver 1

	I²C Action	Slave Address (7-bit)	Register	Value	Description
1	Write	0x20	0x03	0xFE	Configures IO expander for output port at channel 1
2	Write	0x20	0x01	0x01	Sends a high signal to output channel 1

Table 4. TCA9554 I²C Transaction for Enabling drivers 1, 4, 5, and 8

	I²C Action	Slave Address (7-bit)	Register	Value	Description
1	Write	0x20	0x03	0x66	Configures IO expander for output port at channel 1, 4, 5, and (corresponds to drivers 1, 4, 5, 8).
2	Write	0x20	0x01	0x99	Sends a high signal to output channel 1, 4, 5, and (corresponds to drivers 1, 4, 5, 8).

6 TCA9548A - I²C Switch

The DRV2605LEVM-MD is designed for multi-driver applications. The TCA9548A I²C switch was used to independently setup haptic drivers and play the waveforms simultaneously. The pseudo code listed in Table 5 allows the user to verify proper operation of the I²C switch and communication with the DRV2605L device.

Table 5. TCA9548A Operation Pseudo Code

OPERATION	DESCRIPTION
I2C_SetSlaveAddr(TCA9548_SLAVE_ADDR)	//set slave address
I2C_WriteSingleByte(driver_position)	//channel selection

[Table 5](#) lists the sequence for how to command the TCA9548A I²C switch. Any combination of channels can be selected. When the slave address of the TCA9548A device is set, a single byte is required to initialize channel selection. No register address is needed to send the channel selection value, but if a register input must be available for the I²C write function, use the data value as the register value because the device will take the last byte sent to it.

6.1 I²C Register Value Examples

The examples listed in Table 6 and Table 7 show exact I²C transactions with slave addresses, registers, and values to enable one DRV2605L device and to enable three or more DRV2605L devices.

Table 6. TCA9548A I²C Transaction for Enabling Driver 1

	I²C Action	Slave Address (7-bit)	Register	Value	Description
1	Write	0x70	N/A	0x01	Configures I²C switch to connect channel 1 I²C lines

Table 7. TCA9548A I²C Transaction for Enabling Driver 1, 4, 5, and 8

	I²C Action	Slave Address (7-bit)	Register	Value	Description
1	Write	0x70	N/A	0x99	Configures I²C switch to contact channel 1, 4, 5, and (corresponds to drivers 1, 4, 5, 8).

6.2 Operation Analysis

The TCA9548A operation can be verified with a logic analyzer hooked up to the master I²C bus input into the device and to the channel outputs. Figure 10 shows the data and clock lines of the I²C commands to the switch and to the GPIO expander to show proper operation of the devices together.

Figure 10. TCA9548A Logic Analyzer Operation

The TCA9554 device is first configured for output ports for drivers 6 and 7 with a value of 1 at the output. The TCA9548A device is switched to driver 7 (channel 8) and sent a read command to the DRV2605L device to verify communication with the haptic driver. The switch is then configured to select driver 6 (channel 7) and is then sent the same read command. Figure 10 shows proper operation of the switch in the case of isolating specific channels.

7 Power Supply Selection

The DRV2605LEVM-MD can be powered by USB or an external power supply (VBAT). Jumpers *DRV* and *MSP* are used to select USB or VBAT for the DRV2605L and MSP430F5510 devices, respectively. Table 8 lists the different supply configurations and supply voltages that the DRV2605L devices and MSP430 device could have.

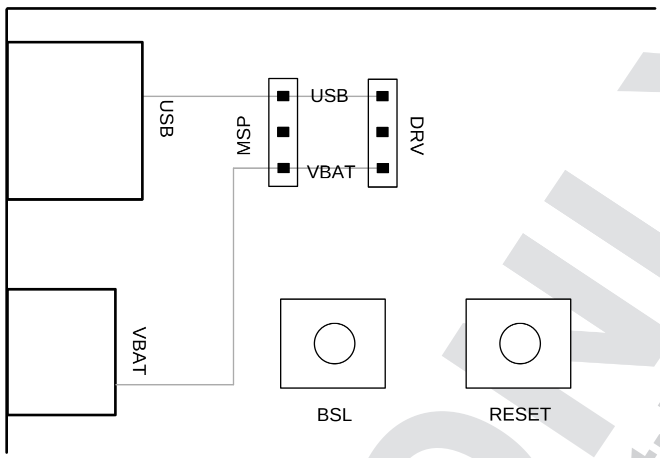


Figure 11. Power Jumper Selection

Table 8. Power Jumper Selection Options

SUPPLY CONFIGURATION	DRV	MSP	DRV2605L SUPPLY VOLTAGE
USB – both	USB	USB	5-V USB
DRV2605L external supply, MSP430 USB	VBAT	USB	VBAT
DRV2605L USB, MSP430 external supply	USB	VBAT	5-V USB
External Supply - both	VBAT	VBAT	VBAT

Because USB protocol allows for 500 mA per port, a conservative estimate allows two to three actuators and drivers to be operated with USB power (150 to 200 mA worst case per driver or actuator, depending on the actuator). If more actuators are required, use the VBAT terminal to ensure adequate power for the entire system.

8 Typical Usage Examples

8.1 Play a Waveform or Waveform Sequence from ROM Memory

1. Configure the TCA9554 channels as output ports and enable the appropriate DRV2605L devices by asserting the output pin (logic high).
2. Configure the TCA9548A device to select the appropriate channel that is connected to the desired DRV2605L I^{2}C data and clock lines.
3. Initialize the DRV2605L device as listed in the *Initialization Procedure* section of the DRV2605L datasheet, .
4. Select the desired MODE[2:0] bit value of 0 (internal trigger), 1 (external edge trigger), or 2 (external level trigger) in the MODE register (address 0x01). If the STANDBY bit was previously asserted then it should be de-asserted (logic low) at this time. If register 0x01 already holds the desired value and the STANDBY bit is low, the user can skip this step.
5. Select the waveform index to be played and write it to address 0x04. Alternatively, a sequence of waveform indices can be written to register 0x04 through 0x0B. See the *Waveform Sequencer* section of the DRV2605L data sheet for details.

6. If using the internal trigger mode, set the Go bit (in register 0x0C) to fire the effect or sequence of effects. If using an external trigger mode, send an appropriate trigger pulse to the IN/TRIG pin. See the *Waveform Triggers* section of the DRV2605L datasheet for details.
7. If desired, the user can repeat step 5 to figure the effect or sequence again.
8. Put the device in low-power mode by deasserting the EN pin through the TCA9554 device to set the STANDBY bit.

NOTE: To send the same commands to multiple DRV2605L devices at the same time, configure the TCA9554 and TCA9548A devices to the appropriate channel selections. I^{2}C write functions can be sent to multiple DRV2605L device, but I^{2}C read functions for each DRV2605L device must be read individually. One issue with write functions is the inability to properly determine whether multiple DRV2605L devices are ACK (acknowledge) or NACK (not acknowledge) if the same command was sent, however writing actual bytes to the DRV2605L is not a problem. The bus acts as an *AND* bus and logic zero takes priority.

Table 9 lists examples of the I^{2}C transactions that are required to play a triple click (100%) waveform using driver 1 in LRA, closed-loop mode. The yellow highlighted rows indicate auto-calibration mode and obtaining the results for the auto-calibration compensation and back-EMF results (if required to be performed for the first time).

Table 9. I^{2}C Transaction Example of Playing a Triple Click Waveform Using Driver1 in LRA, Closed Loop mode

	I^{2}C ACTION	DEVICE	SLAVE ADDRESS (7-BIT)	REGISTER	VALUE	DESCRIPTION
1	Write	TCA9554	0x20	0x03	0xFE	Configures IO expander for output port at channel 1
2	Write	TCA9554	0x20	0x01	0x01	Sends a high signal to output channel 1
3	Write	TCA9548A	0x70	N/A	0x01	Configures I^{2}C switch to connect channel 1 I^{2}C lines
4	Write	DRV2605L	0x5A	0x16	0x53	Set rated voltage (2 V_{RMS})
5	Write	DRV2605L	0x5A	0x17	0xA4	Set overdrive clamp voltage (3.6-V peak)
6	Write	DRV2605L	0x5A	0x01	0x07	Change mode to AutoCalibration
7	Write	DRV2605L	0x5A	0x1E	0x20	Set AutoCalTime to 500 ms
8	Write	DRV2605L	0x5A	0x0C	0x01	Set GO Bit
9	Read	DRV2605L	0x5A	0x0C		Poll GO Bit until it clears t0
12	Write	DRV2605L	0x5A	0x1A	0xB6	Set feedback control register
13	Write	DRV2605L	0x5A	0x1B	0x93	Set control 1 register
14	Write	DRV2605L	0x5A	0x1C	0xF5	Set control 2 register
15	Write	DRV2605L	0x5A	0x1D	0x80	Set control 3 register
16	Write	DRV2605L	0x5A	0x01	0x00	Set mode to internal trigger
17	Write	DRV2605L	0x5A	0x04	0x0C	Set waveform sequence 1 as triple-click waveform
18	Write	DRV2605L	0x5A	0x05	0x00	Indicator that there is only one waveform that should be played
19	Write	DRV2605L	0x5A	0x0C	0x01	Set GO bit
20	Read	DRV2605L	0x5A	0x0C		Poll GO bit until it clears to 0
21	Write	TCA9554	0x20	0x00	0x00	Deassert the EN pin for driver 1
22	Write	TCA9548A	0x70	N/A	0x00	No driver I^{2}C channels connected

9 Programming the MSP430

9.1 Bootstrap Loader Method

The following items are required to program the board using the bootstrap loading (BSL) method:

- Mini USB cable
- MSP430 USB firmware upgrade which is found in the MSP430 USB developers package (www.ti.com/tool/msp430usbdevpack)
- Code Composer Studios (CCS)

  Use the following steps to program the board using the BSL method:

  1. Open the firmware project in CCS and go to the build menu of the properties window as shown in Figure 12.
  2. Under the *Steps* tab of the build menu and in the *Apply Predefined Step* drop-down, select *Create flash image: TI-TXT* as shown in Figure 12.

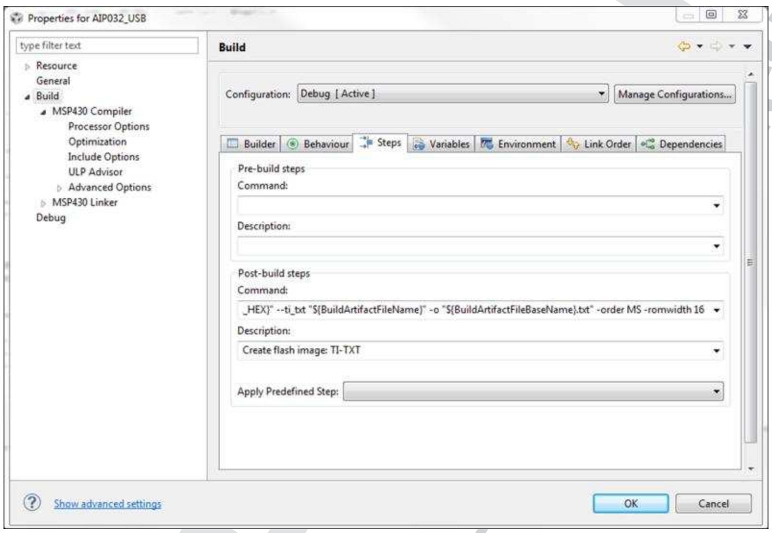


Figure 12. CCS Create Flash Image

3. Rebuild the project. The text image file can be found in debug folder with the name AIP032.txt
4. Hold the BSL button on the DRV2605LEVM-MD and connect the EVM to the computer through the USB mini cable to initiate it as a USB device.
5. Open up the MSP430 USB Firmware Uploader. If it does not say *ready* on the screen then retry the BSL powerup sequence again.
6. Go to *file* and select *open user firmware* to locate the text image file (Figure 13 shows an example of a successful firmware update process).
7. Cycle the power on the board to restart the firmware.

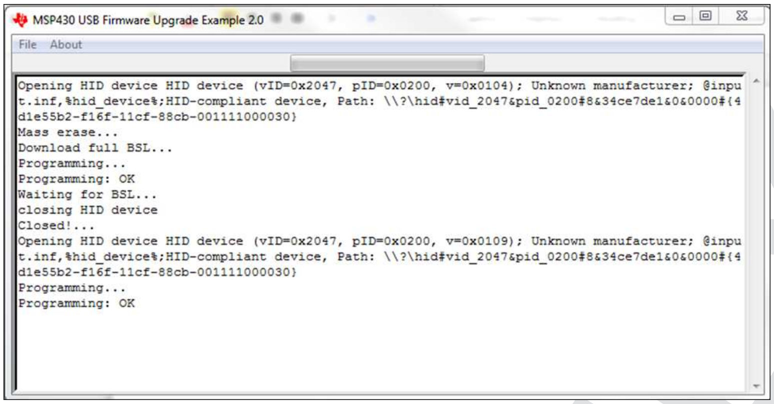


Figure 13. MSP430 USB Firmware Uploader Programming Sequence

9.2 Spy-By-Wire Method

The following items are required to program the board using the spy-by-wire (SBW) method.

- Mini USB cable
- MSP-JTAG2SBW Adapter
- MSP-FET430UIF Hardware Debugging Interface
- Code Composer Studios (CCS)

Use the following steps to program the board using the SBW method:

1. Connect the MSP-JTAG2SBW adapter to the SBW connector on the board
2. Connect the MSP-FET430UIF to the MSP-JTAG2SBW adapter.
3. Open up the firmware project in CCS.
4. Verify that the general-build properties are set as shown in Figure 14.
5. Right click on the project title folder under the *project explorer* and click *build project* to ensure that no errors exist.
6. If no errors exist, select *RUN* → *DEBUG* in the title bar.
7. Exit the debugger when the firmware has been uploaded to the board.

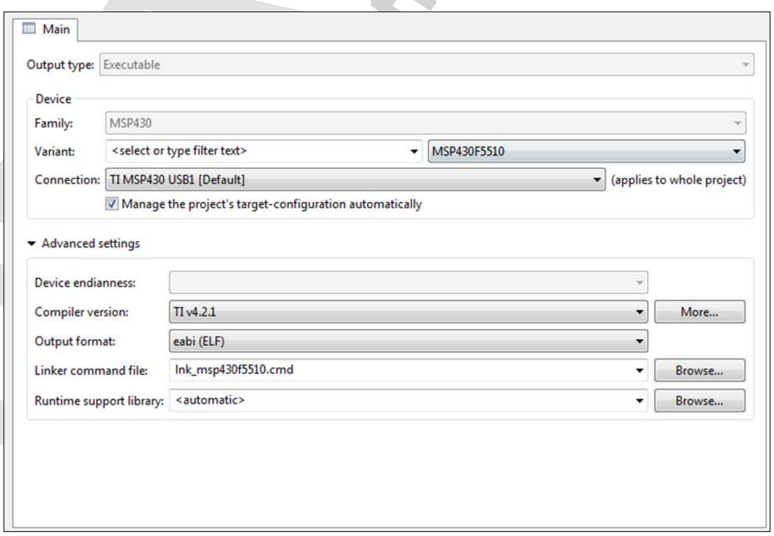


Figure 14. Build Properties of Firmware Project

9.3 MSP430 Pinout

Table 10 lists the pin functions the MSP430F5510 device. The yellow highlighted rows indicate pins that are used by the board. The non-highlighted rows indicate unused pins. All GPIO pins that are not highlighted are broken out to standard 100-mil pitch headers for prototype development and evaluation.

Table 10. Used and Unused Pins on the MSP430F5510

PIN		DESCRIPTION
NO.	NAME	
1	P6.0/CB0/A0	Button 1
2	P6.1/CB1/A1	Button 2
3	P6.2/CB2/A2	
4	P6.3/CB3/A3	
5	P6.4/CB4/A4	
6	P6.5/CB5/A5	
7	P6.6/CB6/A6	
8	P6.7/CB7/A7	
9	P5.0/A8	
10	P5.1/A9	
11	AVCC1	3.3 V
12	P5.4/XIN	XIN, 32.768-kHz crystal
13	P5.5/XOUT	XOUT, 32.768-kHz crystal
14	AVSS1	GND
15	DVCC1	3.3 V
16	DVSS1	GND
17	VCORE	Decoupling capacitor for VCore
18	P1.0/TA0CLK	
19	P1.1/TA0.0	
20	P1.2/TA0.1	
21	P1.3/TA0.2	
22	P1.4/TA0.3	
23	P1.5/TA0.4	
24	P1.6/TA1CLK/CBOUT	COMP_OUT, Feedback from B1 and B2 captouch
25	P1.7/TA1.0	
26	P2.0/TA1.1	
27	P2.1/TA1.2	
28	P2.2/TA2CLK/SMCLK	
29	P2.3/TA2.0	
30	P2.4/TA2.1	PWM, can be disconnected
31	P2.5/TA2.2	
32	P2.6/RTCCLK/DMAE0	
33	P2.7/UCB0STE/UCA0CLK	
34	P3.0/UCB0SIMO/UCB0SDA	
35	P3.1/UCB0SOMI/UCB0SCL	
36	P3.2/UCB0CLK/UCA0STE	
37	P3.3/UCA0TXD/UCA0SIMO	
38	P3.4/UCA0RXD/UCA0SOMI	
39	DVSS2	GND
40	DVCC2	3.3 V
41	P4.0/PM_UCB1STE/PM_UCA1CLK	
42	P4.1/PM_UCB1SIMO/PM_UCB1SDA	SDA_IN
43	P4.2/PM_UCB1SOMI/PM_UCB1SCL	SCL_IN
44	P4.3/PM_UCB1CLK/PM_UCA1STE	
45	P4.4/PM_UCA1TXD/PM_UCA1SIMO	
46	P4.5/PM_UCA1RXD/PM_UCA1SOMI	

Table 10. Used and Unused Pins on the MSP430F5510 (continued)

PIN		DESCRIPTION
NO.	NAME	
47	P4.6/PM_NONE	
48	P4.7/PM_NONE	
49	VSSU	GND
50	PU.0/DP	USB_DP, data+
51	PUR	PUR, BSL switch
56	AVSS2	GND
57	P5.2/XT2IN	XT2IN, 24-MHz oscillator
58	P5.3/XT2OUT	XT2OUT, 24-MHz oscillator
59	TEST/SBWTCK	SBWTCK, SBW programmer conn.
60	PJ.0/TDO	B1LED
61	PJ.1/TDI/TCLK	B2LED
62	PJ.2/TMS	USER LED1, can be disconnected
63	PJ.3/TCK	USER LED2, can be disconnected
64	nRST/NMI/SBWTDIO	ResistorET button, SBW programmer
65	QFN PAD	GND

10 Layout

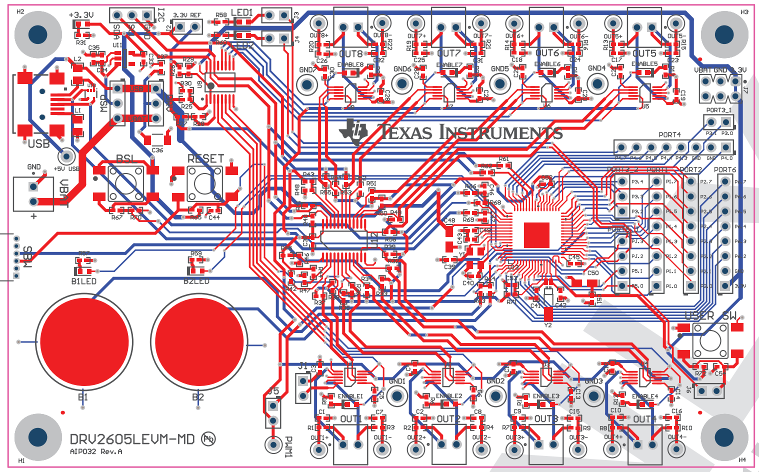


Figure 15. Xray Image of Top and Bottom Layer Traces

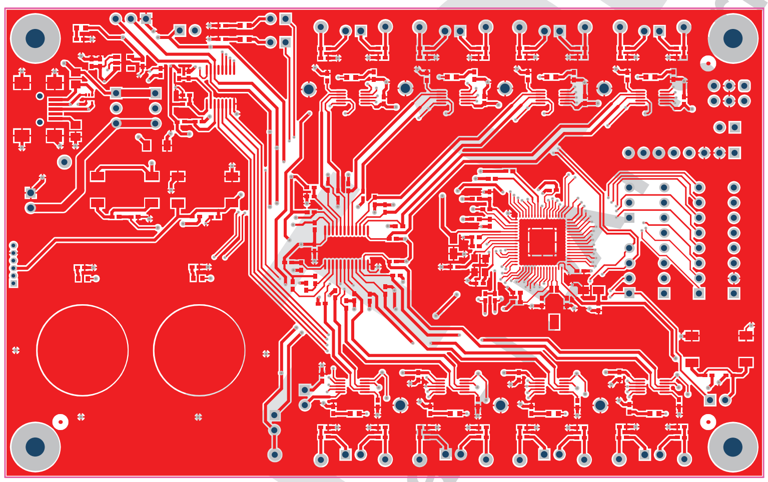


Figure 16. Top Layer

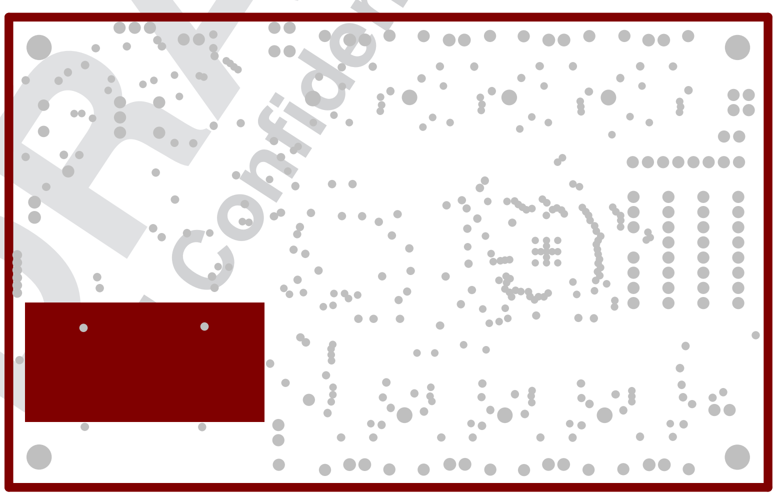


Figure 17. Middle Power Layer

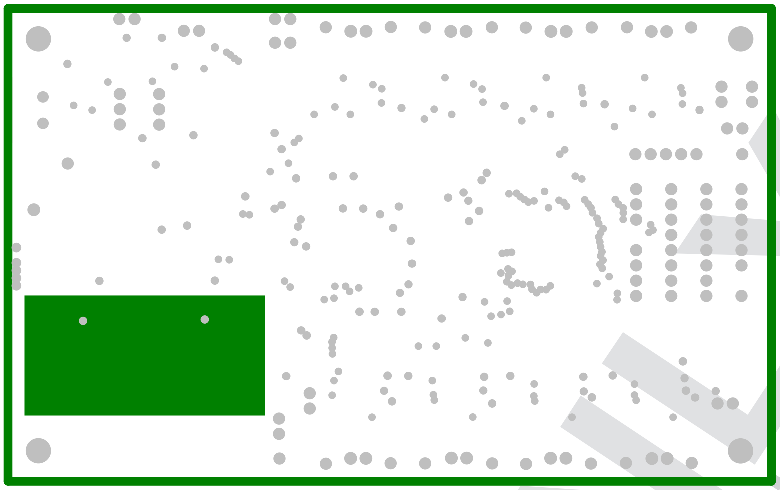


Figure 18. Middle Ground Layer

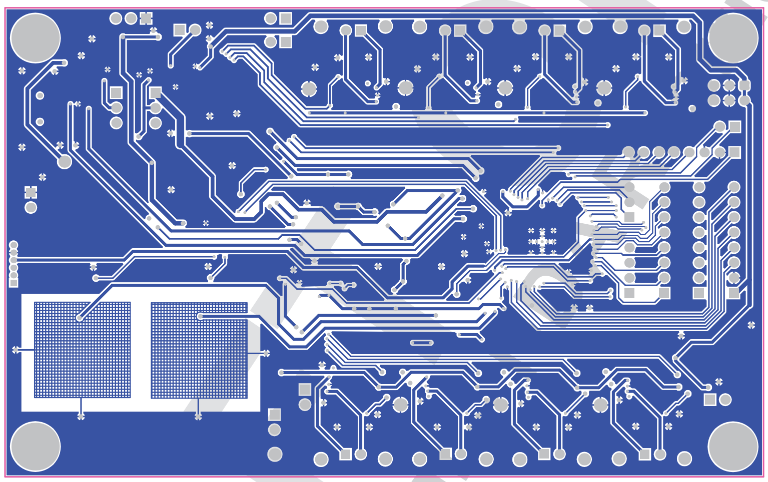


Figure 19. Bottom Layer

11 Schematic

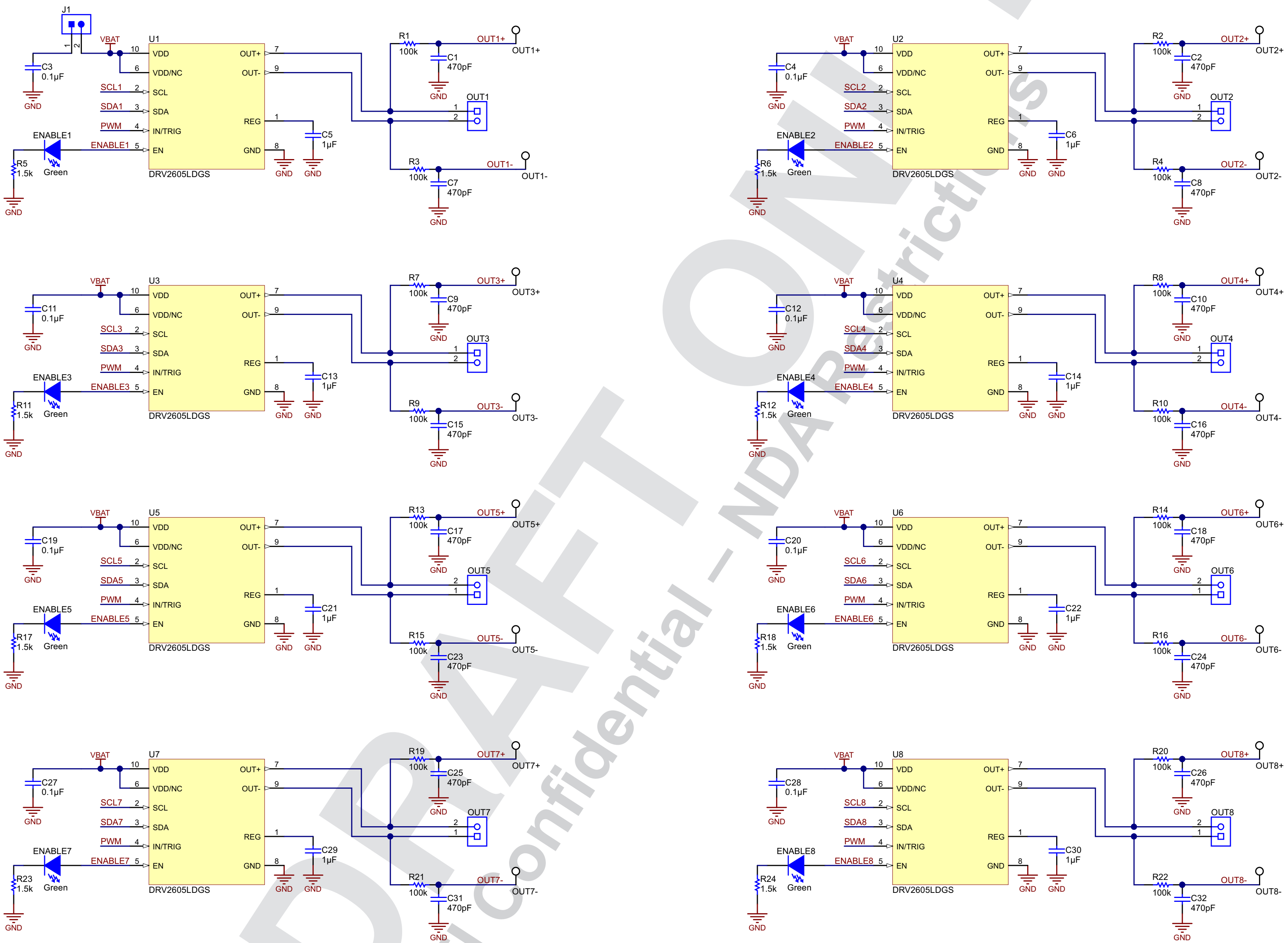


Figure 20. Schematic page 1

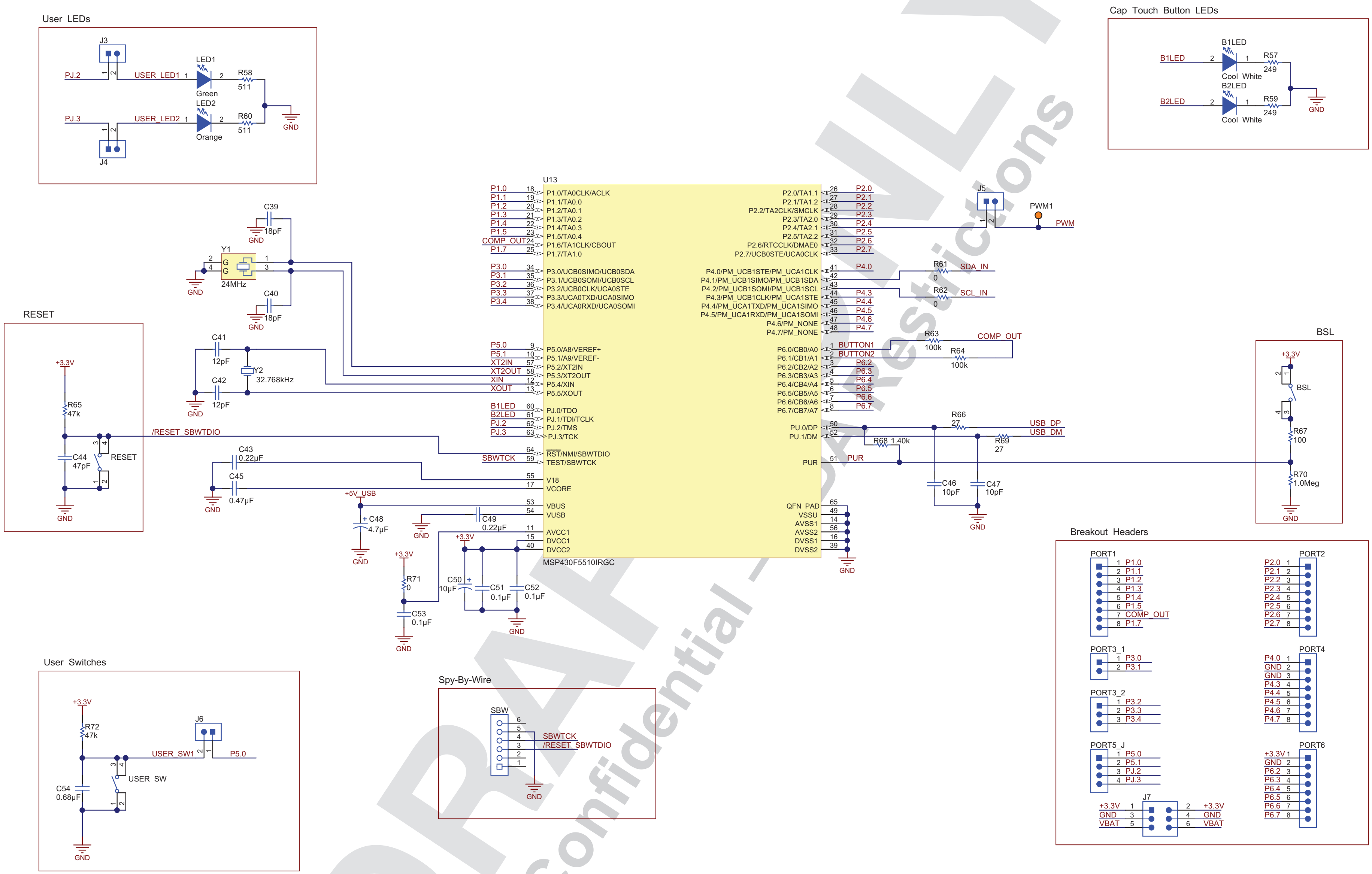
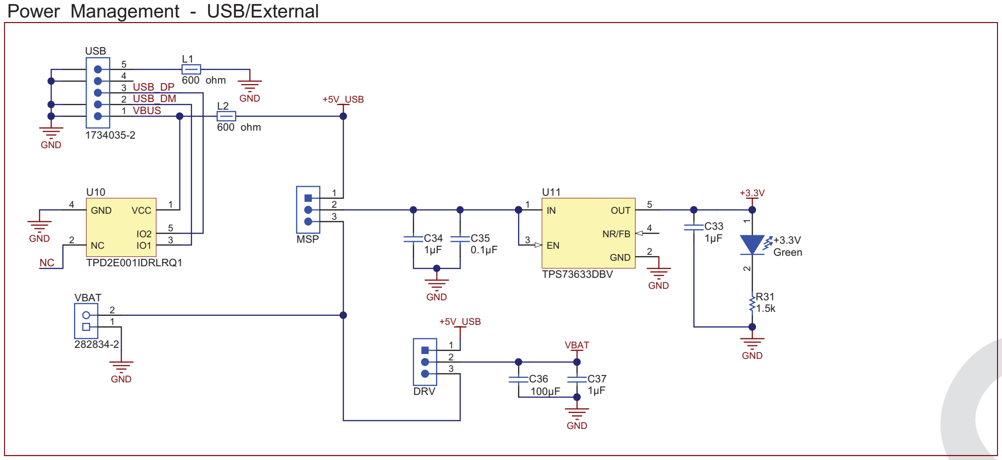
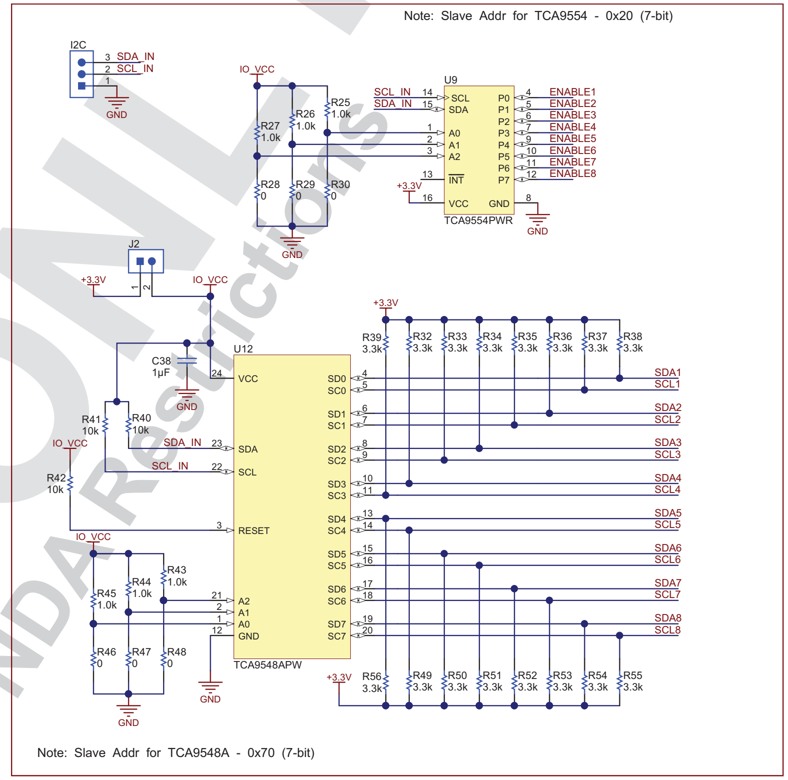


Figure 21. Schematic page 2

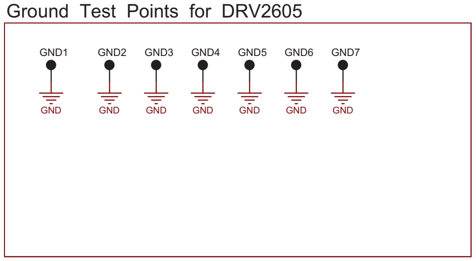
Power Management - USB/External



I2C Switch Interface



Ground Test Points for DRV2605



+5V USB Test Point

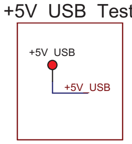


Figure 22. Schematic page 3

12 Bill Of Materials

DESIGNATOR	QTY.	VALUE	PART NUMBER	DESCRIPTION	PACKAGE	MANUFACTURER
+3.3V, ENABLE1, ENABLE2, ENABLE3, ENABLE4, ENABLE5, ENABLE6, ENABLE7, ENABLE8, LED1	10	Green	LTST-C190GKT	LED, green, SMD	1.6 × 0.8 × 0.8 mm	Lite-On
5 V USB	1	Red	5000	Test point, miniature, red, TH	Red miniature test point	Keystone
B1LED, B2LED	2	Cool White	LNJ037X8ARA	LED, cool white, SMD	0603 LED	Panasonic
BSL, ResistorET, USER SW	3		4-1437565-1	Switch, tactile, SPST-NO, 0.05-A, 12-V, SMT	SW, SPST 6 × 6 mm	TE Connectivity
C1, C2, C7, C8, C9, C10, C15, C16, C17, C18, C23, C24, C25, C26, C31, C32	16	470 pF	GRM155R71H471KA01D	Capacitor, ceramic, 470-pF, 50-V, ±10%, X7R, 0402	0402	MuRata
C3, C4, C11, C12, C19, C20, C27, C28, C51, C52, C53	11	0.1 µF	GRM155R61C104KA88D	Capacitor, ceramic, 0.1-µF, 16-V, ±10%, X5R, 0402	0402	MuRata
C5, C6, C13, C14, C21, C22, C29, C30, C38	9	1 µF	C1005X5R1E105K050BC	Capacitor, ceramic, 1-µF, 25V, ±10%, X5R, 0402	0402	TDK
C33, C34, C37	3	1 µF	GRM155R61A105KE15D	Capacitor, ceramic, 1-µF, 10-V, ±10%, X5R, 0402	0402	MuRata
C35	1	0.1 µF	GRM155R61A104KA01D	Capacitor, ceramic, 0.1-µF, 10-V, ±10%, X5R, 0402	0402	MuRata
C36	1	100 µF	C3216X5R1A107M160AC	Capacitor, ceramic, 100-µF, 10-V, ±20%, X5R, 1206_190	1206_190	TDK
C39, C40	2	18 pF	GRM1555C1H180JA01D	Capacitor, ceramic, 18-pF, 50-V, ±5%, C0G/NP0, 0402	0402	MuRata
C41, C42	2	12 pF	GRM1555C1H120JA01D	Capacitor, ceramic, 12-pF, 50-V, ±5%, C0G/NP0, 0402	0402	MuRata
C43, C49	2	0.22 µF	GRM155R71C224KA12D	Capacitor, ceramic, 0.22-µF, 16-V, ±10%, X7R, 0402	0402	MuRata
C44	1	47 pF	GRM1555C1H470JZ01	Capacitor, ceramic, 47-pF, 50-V, ±5%, C0G/NP0, 0402	0402	MuRata
C45	1	0.47 µF	GRM155R61C474KE01	Capacitor, ceramic, 0.47-µF, 16-V, ±10%, X5R, 0402	0402	MuRata
C46, C47	2	10 pF	GRM1555C1H100JA01D	Capacitor, ceramic, 10-pF, 50-V, ±5%, C0G/NP0, 0402	0402	MuRata
C48	1	4.7 µF	TPSA475K010R1400	Capacitor, TA, 4.7uF, 10-V, ±10%, 1.4 Ω, SMD	3216-18	AVX
C50	1	10 µF	TPSA106K010R0900	Capacitor, TA, 10-µF, 10-V, ±10%, 0.9 Ω, SMD	3216-18	AVX
C54	1	0.68 µF	GRM155R61A684KE15D	Capacitor, ceramic, 0.68-µF, 10-V, ±10%, X5R, 0402	0402	MuRata
DRV, I1, MSP, PORT3_2	4		5-146278-3	Header, 100-mil, 3 × 1, tin, TH	Header, 3 × 1, 100-mil, TH	TE Connectivity
GND1, GND2, GND3, GND4, GND5, GND6, GND7	7	Black	5011	Test point, multipurpose, black, TH	Black multipurpose test point	Keystone
H1, H2, H3, H4	4		NY PMS 440 0025 PH	Machine screw, round, #4-40 × 1/4, nylon, Philips panhead	Screw	B&F Fastener Supply
H5, H6, H7, H8	4		1902C	Standoff, hex, 0.5"L #4-40 nylon	Standoff	Keystone
J1, J2, J3, J4, J5, J6, PORT3_1	7		5-146278-2	Header, 100-mil, 2 × 1, Tin, TH	Header, 2 × 1, 100-mil, TH	TE Connectivity
J7	1		5-146254-3	Header, 100-mil, 3 × 2, Tin, TH	Header, 100-mil, 3 × 2, TH	TE Connectivity
L1, L2	2	600 Ω	MPZ2012S601A	Ferrite bead, 600-Ω at 100 MHz, 2-A, 0805	0805	TDK
LED2	1	Orange	LTST-C190KFKT	LED, orange, SMD	1.6 × 0.8 × 0.8 mm	Lite-On
OUT1+, OUT1-, OUT2+, OUT2-, OUT3+, OUT3-, OUT4+, OUT4-, OUT5+, OUT5-, OUT6+, OUT6-, OUT7+, OUT7-, OUT8+, OUT8-	16	White	5002	Test point, miniature, white, TH	White Miniature Testpoint	Keystone
OUT1, OUT2, OUT3, OUT4, OUT5, OUT6, OUT7, OUT8, VBAT	9		282834-2	Terminal block, 2 × 1, 2.54mm, TH	Terminal Block, 2 × 1, 2.54-mm, TH	TE Connectivity
PORT1, PORT2, PORT4, PORT6	4		5-146278-8	Header, 100-mil, 8 × 1, Tin, TH	Header, 8 × 1, 100-mil, TH	TE Connectivity
PORT5_J	1		5-146278-4	Header, 100-mil, 4 × 1, Tin, TH	Header, 4 × 1, 100-mil, TH	TE Connectivity

DESIGNATOR	QTY.	VALUE	PART NUMBER	DESCRIPTION	PACKAGE	MANUFACTURER
PWM1	1	Orange	5003	Test point, miniature, orange, TH	Orange miniature testpoint	Keystone
R1, R2, R3, R4, R7, R8, R9, R10, R13, R14, R15, R16, R19, R20, R21, R22, R63, R64	18	100 kΩ	CRCW0402100KJNED	Resistor, 100-kΩ, 5%, 0.063 W, 0402	0402	Vishay-Dale
R5, R6, R11, R12, R17, R18, R23, R24, R31	9	1.5 kΩ	CRCW04021K50JNED	Resistor, 1.5-kΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
R25, R26, R27, R43, R44, R45	0	1 kΩ	CRCW04021K00JNED	Resistor, 1-kΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
R28, R29, R30, R46, R47, R48, R61, R62, R71	9	0	CRCW04020000Z0ED	Resistor, 0-Ω, 5%, 0.063-W, 0402	0402	Vishay-Dale
R32, R33, R34, R35, R36, R37, R38, R39, R49, R50, R51, R52, R53, R54, R55, R56	16	3.3 kΩ	CRCW04023K30JNED	Resistor, 3.3-kΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
R40, R41, R42	3	10 kΩ	CRCW040210K0JNED	Resistor, 10-kΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
R57, R59	2	249 Ω	CRCW0402249RFKED	Resistor, 249-Ω, 1%, 0.063-W, 0402	0402	Vishay-Dale
R58, R60	2	511 Ω	CRCW0402511RFKED	Resistor, 511-Ω, 1%, 0.063-W, 0402	0402	Vishay-Dale
R65, R72	2	47 kΩ	CRCW040247K0JNED	Resistor, 47-kΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
R66, R69	2	27 Ω	CRCW040227R0JNED	Resistor, 27-Ω, 5%, 0.063-W, 0402	0402	Vishay-Dale
R67	1	100 Ω	CRCW0402100RJNED	Resistor, 100-Ω, 5%, 0.063-W, 0402	0402	Vishay-Dale
R68	1	1.4 kΩ	CRCW04021K40FKED	Resistor, 1.4-kΩ, 1%, 0.063-W, 0402	0402	Vishay-Dale
R70	1	1 MΩ	CRCW04021M00JNED	Resistor, 1-MΩ, 5%, 0.063-W, 0402	0402	Vishay-Dale
SBW	1		LPPB061NGCN-RC	Receptacle, 50-mil, 6 × 1, R/A, TH	6 × 1 receptacle	Sullins Connector Solutions
U1, U2, U3, U4, U5, U6, U7, U8	8		DRV2605LDGS	DRV2605LDGS, DGS0010A	DGS0010A	Texas Instruments
U9	1		TCA9554PWR	Remote 8-bit I^2C and SMBus I/expander, 1.65 to 5.5-V, –40 to 85°C, 16-pin TSSOP (PW), green (RoHS & nSb/Br)	PW0016A	Texas Instruments
U10	1		TPD2E001IDRLRQ1	Automotive catalog low-capacitance ±15-kV ESD-protection array for high-speed data inter, 2 channels, –40 to 85°C, 5-pin SOT (DRL), Green (RoHS & nSb/Br)	DRL0005A	Texas Instruments
U11	1		TPS73633DBV	Capacitor-free, NMOS, 400-mA low-dropout regulator with reverse current protection, DBV0005A	DBV0005A	Texas Instruments
U12	1		TCA9548APW	Low voltage 8-channel I^2C switch with reset, PW0024A	PW0024A	Texas Instruments
U13	1		MSP430F5510IRGC	Mixed signal microcontroller, RGC0064B	RGC0064B	Texas Instruments
USB	1		1734035-2	Connector, receptacle, mini-USB type B, R/A, top mount SMT	USB mini type B	TE Connectivity
Y1	1		ABM8-24.000MHZ-B2-T	Crystal, 24-MHz, 18-pF, SMD	3.2 × 0.8 × 2.5-mm	Abracon Corportation
Y2	1		MS3V-T1R 32.768KHZ ±20PPM 12.5PF	Crystal, 32.768-kHz, 12.5-pF, SMD	1.4 × 1.4 × 5-mm SMD	MicrCrystal AG

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