

# ***DRV2511Q1EVM Haptic Solenoid Driver Evaluation Kit***

## **ABSTRACT**

The DRV2511-Q1 is an automotive qualified, high-efficiency, haptic solenoid driver that can provide up to 8 A of output current drive. The driver simplifies the design of solenoid control for haptic effects and reduces the total solution size. This evaluation kit provides an easy way to test any solenoid with pre-loaded or customizable waveforms to achieve different haptic effects. The EVM board includes the following:

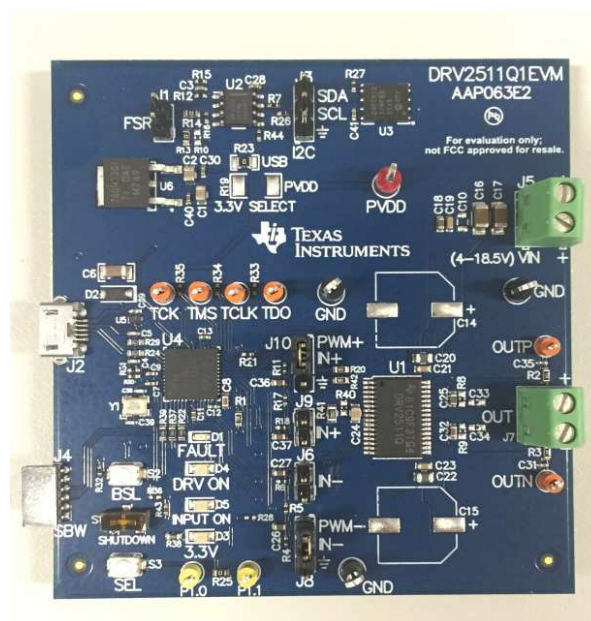
- MSP430 MCU
- On-board EEPROM
- Selectable external analog inputs or pre-loaded/customizable PWM waveforms
- EMC Filter
- Small footprint (70 mm × 75 mm)

Evaluation Kit Contents:

- DRV2511Q1EVM evaluation board
- Firmware preloaded onto on-board EEPROM
- Downloadable Haptics Control Console to control EVM
- Micro USB cable

The following is required for programming and advanced configuration:

- Code Composer Studio™ (CCS) or IAR Embedded Workbench IDE for MSP430
- MSP430 LaunchPad (MSP-EXP430G2), or MSP430-FET430UIF hardware programming tool
- DRV2511Q1EVM firmware available on DRV2511Q1EVM tool folder



**Figure 1. DRV2511Q1EVM Board**

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**WARNING: EXPORT NOTICE**

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US ECCN: 3E991

EU ECCN: EAR99

Technology may also require export or re-export license for shipping it in compliance with the applicable regulations of certain countries.

## Cautions and Warnings



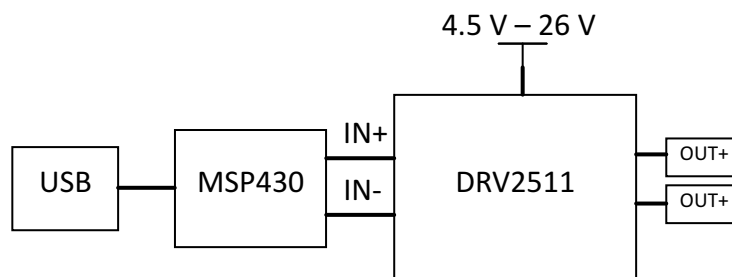
**Warning! Do not leave EVM powered when unattended.**



**Warning Hot Surface! Contact may cause burns. Do not touch. Please take the proper precautions when operating.**

### 1 Getting Started

The DRV2511Q1EVM provides an evaluation of platform for different solenoids and driving waveforms. It can also be used as a demonstration board allowing access to both the MSP430 and DRV2511-Q1 through multiple test points. Input type can be controlled using the Haptics Control Console for the DRV2511Q1EVM. The input is generated by an MSP430F5510 by using PWM signals. The EVM also has the option for the DRV2511-Q1 to receive inputs externally through the jumpers available on the board if necessary. [Figure 2](#) below is the block diagram:



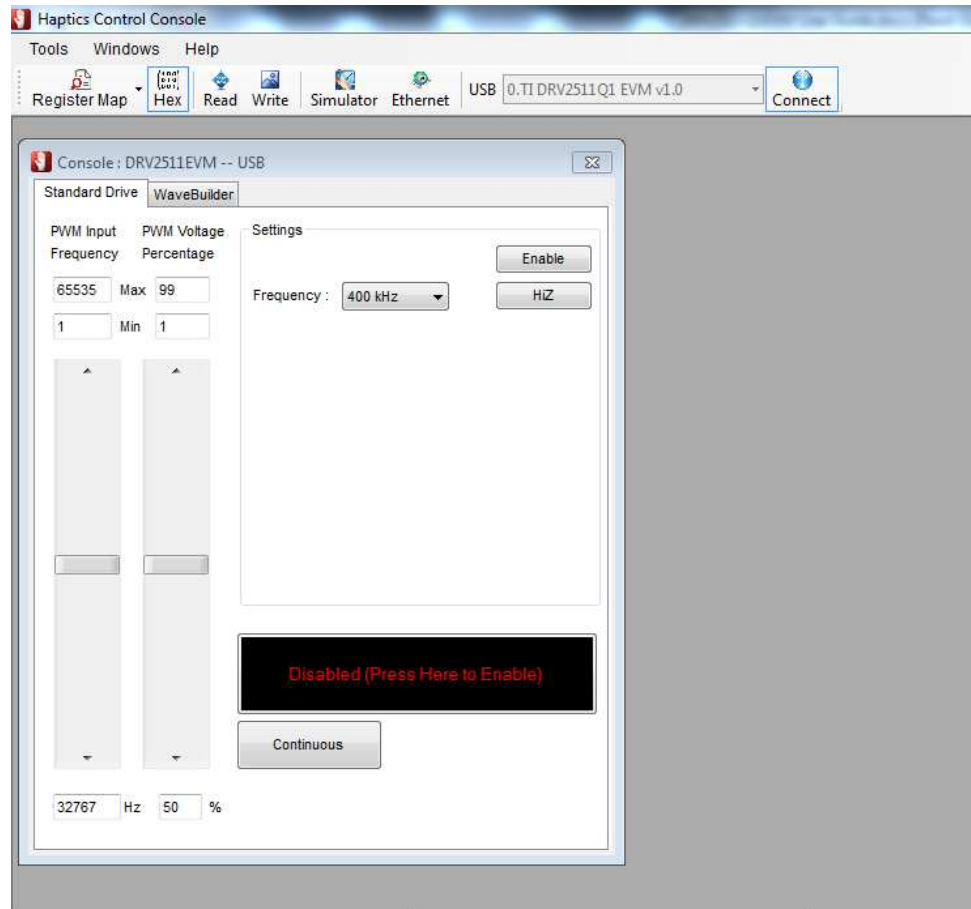
**Figure 2. EVM System Block Diagram**

## 1.1 Powering the Board

To power the board, connect the DRV2511Q1EVM to an available USB port on your computer using the included Micro-USB cable. When USB power is applied, the TL760M33Q will take the 5-V supply voltage down to a regulated 3.3 V. The green 3.3-V LED will turn on and the MSP430 will be powered on. To power the DRV2511-Q1, external power must be supplied through header J5. The driver will power on when the external power supply provides at least 4.5 V.

## 1.2 Quick Start Board Setup

The DRV2511Q1EVM comes preprogrammed to use with Haptics Control Console. [Figure 3](#) below is a screenshot of Haptics Control Console:



**Figure 3. Haptics Control Console**

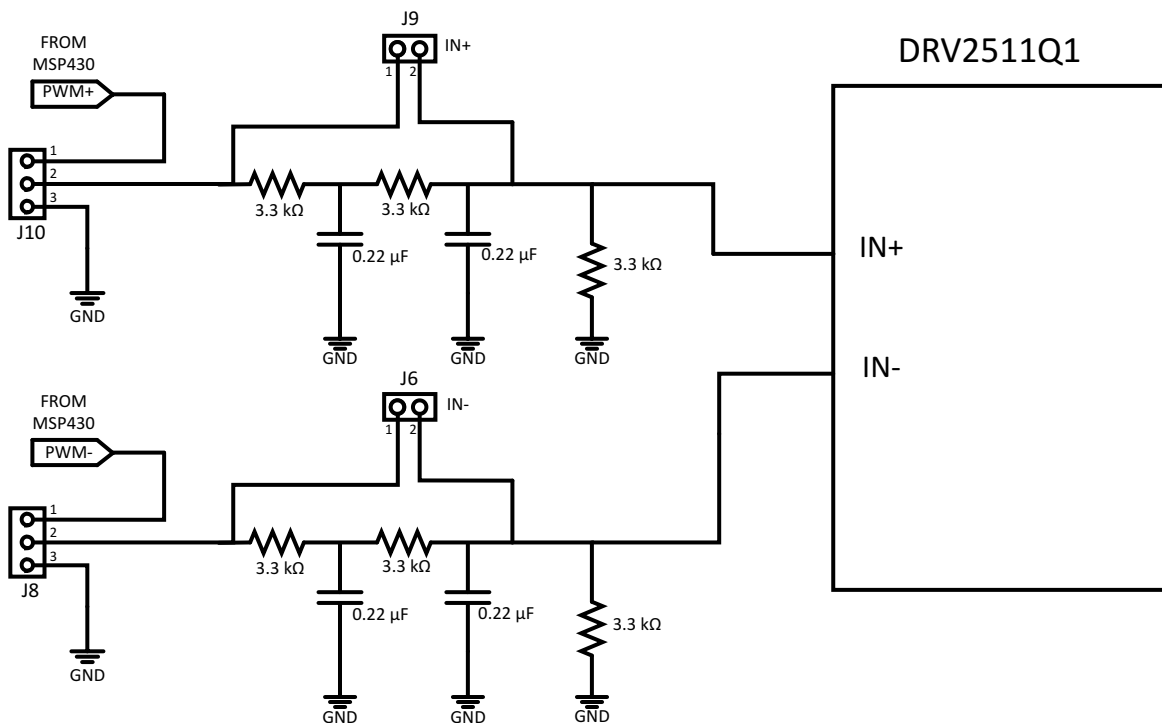
1. Out of the box, the on-board MSP430 is set to receive commands from Haptics Control Console through the USB.
2. Use the included Micro-USB cable to connect the DRV2511Q1EVM board to an available USB port on a computer. The green 3.3-V LED will turn on and the MSP430 will be powered.
3. Once the latest version of Haptics Control Console has opened, and the device is connected to your computer, you will see that the USB tab will read out '0.TI DRV2511Q1 EVM v1.[version]'. When Haptics Control Console has recognized the DRV2511Q1EVM, press 'Connect' to access the device Console window.

### 1.3 Configuring the Input

Out of the box, the jumpers are set to connect a USB cable for microcontroller power, and drive the DRV2511-Q1 inputs from an MSP430 through a 2<sup>nd</sup> order low pass filter. [Table 1](#) shows the summary of the possible configurations for the input signal:

**Table 1. Input Jumper Configurations**

Jumper	Default Position	Description
J9	Open	(+) bypass 2 <sup>nd</sup> order filter (When Shorted)
J6	Open	(-) bypass 2 <sup>nd</sup> order filter (When Shorted)
J10	Short Pin 1-2	(+) PWM from MSP430
J8	Short Pin 1-2	(-) PWM from MSP430



**Figure 4. Input 2<sup>nd</sup> Order Filter**

As seen above in [Figure 4](#), J9 & J6 provide the user the option to filter the input signal (IN+ or IN-) coming from either the MSP430 or external source. If an external input is used, remove the jumper that is connected to the MSP430 (Pin 1 on J10 & J8) in order to avoid potential damage to the MCU.

When using an external input, the 2<sup>nd</sup> order filter is utilized by connecting the input signal to Pin 2 of J10 & J8 (assuming J9 and J6 are open). To bypass the 2<sup>nd</sup> order filter, connect the external input signal directly to Pin 2 of J9 & J6, or connect the external input signal to Pin 2 of J10 & J8, and short jumpers J9 and J6.

### 1.4 Connecting a Load

To begin, caution is advised as the DRV2511-Q1 is a high-current device that can provide up to 8 A of output current drive. Also, solenoids can become hot after extended use. Be conscious of the current and temperature ratings of the solenoid, as application of pulses and waveforms for an extended period can cause damage to the solenoids.

1. With the power supply off, connect either  $\pm$  terminals on header J7 of the DRV2511Q1EVM to the solenoid. Polarity only matters if you are using a polarized solenoid. Typical solenoids are not polarized.

2. Once the connection is made and no interrupts have been triggered, inputs can be applied. Refer to the solenoids datasheet to operate within the recommended specifications.

## 2 Overview of EVM

This section provides a description of each of the blocks identified in the diagram from [Figure 2](#).

### 2.1 DRV2511-Q1

The DRV2511-Q1 is an automotive qualified high-current haptic driver, specifically designed for inductive loads. Please see the DRV2511-Q1 datasheet for more in depth information.

### 2.2 MSP430F5510

An onboard MSP430F5510 is used to control input signals to the DRV2511-Q1 and the as well as communicate through USB to Haptics Control Console. See the Haptics Control Console section for more information about the interface.

### 2.3 TL760M33Q

This automotive-grade, fixed-output LDO converts the incoming 5 V from USB down to 3.3 V for the MSP430.

### 2.4 Haptics Control Console

Haptics Control Console allows the user to control the inputs to the DRV2511-Q1 using the on-board MSP430. The user can also control the DRV2511-Q1 enable pin, standby pin, and output switching frequency.

As seen in [Figure 5](#) below, the console contains a set of controls to manipulate the PWM Input Frequency, PWM Voltage Percentage, and duration of the PWM signal.

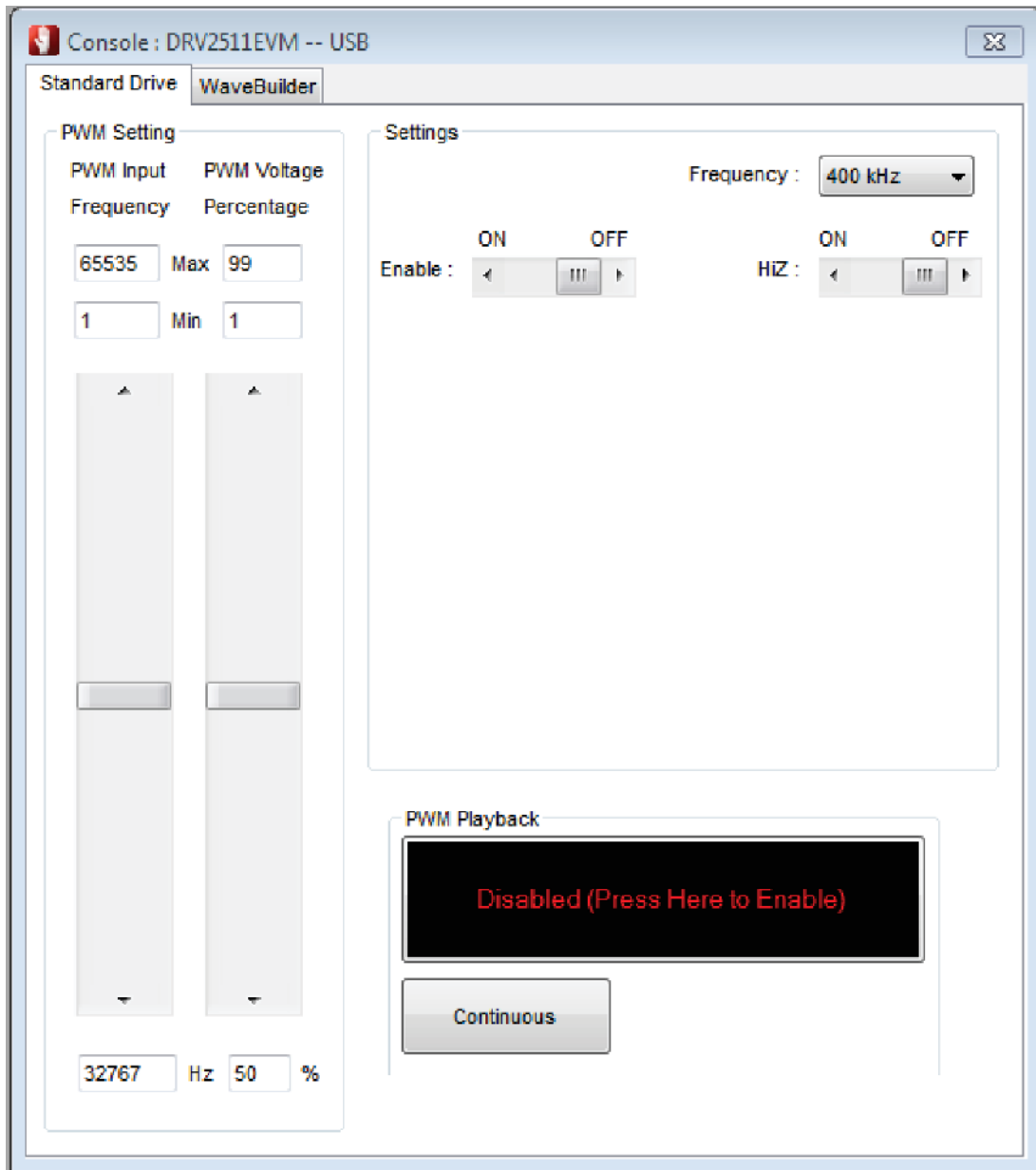


Figure 5. DRV2511Q1EVM Haptics Control Console

### 2.4.1 PWM Input Frequency

In the Standard Drive tab, the PWM input frequency can be changed using either a slider bar or by manually entering a frequency value. The minimum frequency is 1 Hz and the maximum frequency can be up to 65 kHz. The optimum frequency for solenoid operation is less than 200 Hz.

### 2.4.2 PWM Voltage Percentage

PWM Voltage Percentage selects the max input range to the DRV2511-Q1. The full scale output voltage of the MSP430 is in the range of 3.3 V.

### 2.4.3 PWM Signal Control

Located below the input Enable/Disable on the bottom right of [Figure 5](#), the user has the ability to select duration of the PWM input signal coming from the MSP430. The PWM signal can be driven continuously, in pulses (with control of on and off time), or with a single pulse (with control of the pulse duration). The control mode can be changed by clicking on the "continuous" button that will dynamically change to the type of signal control selected.

### 2.4.4 Settings

In the settings section, the user can control the internal oscillator frequency, enable pin, and Hi-Z pin. To operate the device be sure to have the enable pin high and Hi-Z pin low.

## 3 Hardware Configuration

The DRV2511Q1EVM can be used to completely evaluate the DRV2511-Q1. The following sections list the various hardware configurations.

### 3.1 Input, Output, & Communication Overview

The DRV2511Q1EVM allows complete evaluation of the DRV2511-Q1 through test points, jacks, and connectors. [Table 2](#) provides a brief description of the hardware.

**Table 2. Hardware Overview**

Signal	Description	I/O
VIN	External Supply Power (4.5 V - 26 V)	Input
USB	USB power (5 V)	Input
IN+/IN-	J10 (Pin2) Positive differential input; J9 bypass 2 <sup>nd</sup> order filter (When shorted) J8 (Pin2) Negative differential input; J6 bypass 2 <sup>nd</sup> order filter (When shorted)	Input
OUT+/OUT-	J7 Output to Inductive Load	Output
OUTP/OUTN	Output test points for observation, connect to oscilloscope or measurement equipment	Output
FSR	Force Sensing Resistor Input	Input
I2C	MSP430 I2C bus	Input/Output
SBW	MSP430 programming header	Input/Output
TDO	JTAG data output	Output
TCLK	System input clock	Input
TMS	Signal to control the JTAG state machine	Input
TCK	JTAG clock input	Input
FAULT	General fault reporting: Over-temp, DC Detect, Open Drain Fault = High, normal operation; Fault = Low, Fault Condition	LED
DRVON	DRV Enable = LED On; DRV Disable = LED Off	LED
INPUT ON	MSP430 PWM input enabled = LED On MSP430 PWM input disabled = LED Off	LED
3.3 V	MSP430 Powered On/Off	LED

### 3.2 Power Supply Overview

The DRV2511Q1EVM relies on USB and an external power supply to operate completely. Refer to [Table 3](#) for the power supply configurations.

**Table 3. Power Supply Configuration**

Parameter	Source	Supply Voltage Range
MSP430	Micro-USB	5.0 V (LDO drops it down to 3.3 V)
DRV2511-Q1	J5 Terminal Block	4.5 V to 26 V



### 3.3 PWM, Analog and Single-Ended Inputs

By default, the DRV2511Q1EVM uses the MSP430 PWM input mode with a 2<sup>nd</sup> order low-pass filter. This section describes each input mode and the modifications necessary for operation of each.

The DRV2511Q1EVM supports two input modes for driving the DRV2511-Q1:

- PWM input using MSP430: In this mode, the onboard MSP430 generates a PWM waveform that is sent through the 2<sup>nd</sup> order low-pass input filter to the DRV2511-Q1.
- External analog input: An external source supplies an analog waveform to the INPUT header. The low-pass input filter can be bypassed as described in [Section 1.3](#).
  - Single Ended Inputs: Connect the external analog input to either Pin 2 of J8 or J10. Refer to [Section 1.3](#) for more detailed input configuration.
  - Differential Input: Connect the external analog inputs across J8 and J10 using Pin 2 on each jumper. Refer to [Section 1.3](#) for more detailed input configuration.

### 3.4 Gain Setting and Master / Slave

The gain of the DRV2511-Q1 is set by the voltage divider connected to the GAIN control pin. An internal ADC is used to detect the four input states. The four states set the DRV2511-Q1 with gains of 20 dB, 26 dB, 32 dB, and 36 dB respectively. The gain setting is latched during power-up and cannot be changed while the device is powered. [Table 4](#) shows the recommended resistor values for each mode and gain combination:

**Table 4. Gain Settings**

GAIN	R40 (to VREG) <sup>(1)(2)</sup>	R41 (to GND) <sup>(1)(3)</sup>	INPUT IMPEDANCE
20 dB	OPEN	20 k $\Omega$	60 k $\Omega$
26 dB	100 k $\Omega$	20 k $\Omega$	30 k $\Omega$
32 dB	100 k $\Omega$	39 k $\Omega$	15 k $\Omega$
36 dB	75 k $\Omega$	47 k $\Omega$	9 k $\Omega$

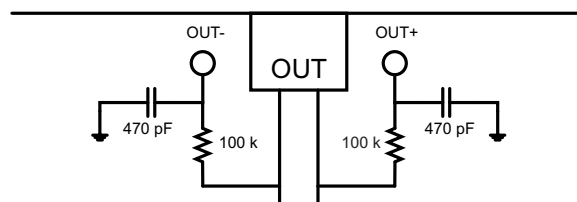
<sup>(1)</sup> Resistor tolerance should be 5% or better.

<sup>(2)</sup> R40 resistor is 0603

<sup>(3)</sup> R41 resistor is 0805

## 4 Measurement and Analysis

The DRV2511-Q1 uses PWM modulation to create the output signal for both solenoids and voice coils. To measure the output signals, connect an oscilloscope or other measurement equipment to the filtered output test points, “OUT+” and “OUT-”.



**Figure 6. Terminal Blocks and Test Points**

The DRV2511-Q1 PWM modulation frequency is set by default at 400 kHz. Solenoids and voice coils do not operate at this high of frequencies and will only be affected by the modulated output waveform. For measurement purposes, the output waveform needs to pass through a low-pass filter with a cutoff frequency around 3.38 kHz. If the DRV2511Q1EVM filter is not used, TI recommends using a first-order, low-pass filter with a cutoff between 1 kHz and 3.5 kHz.

## 5 Reference

This section includes the DRV2511Q1EVM schematic, PCB Layout, and bill of materials.

### 5.1 Schematics

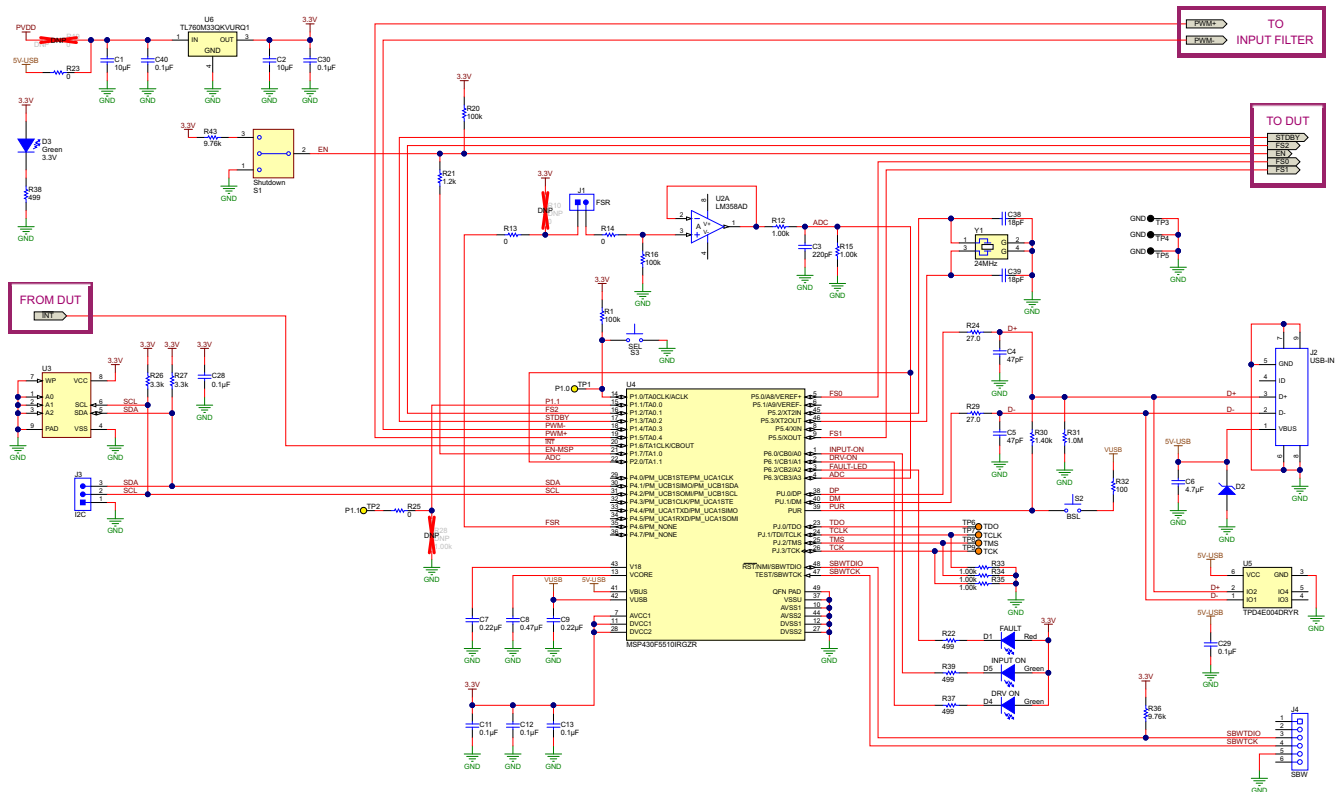


Figure 7. DRV2511-Q1 Schematic 1

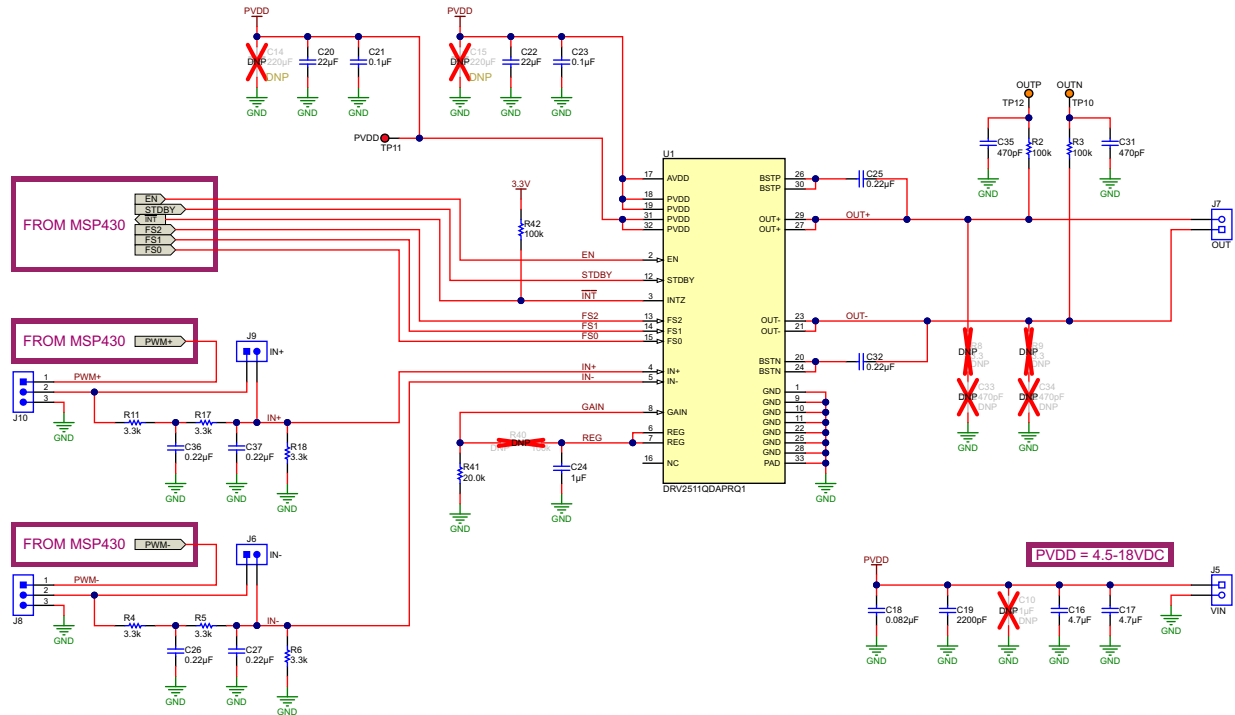
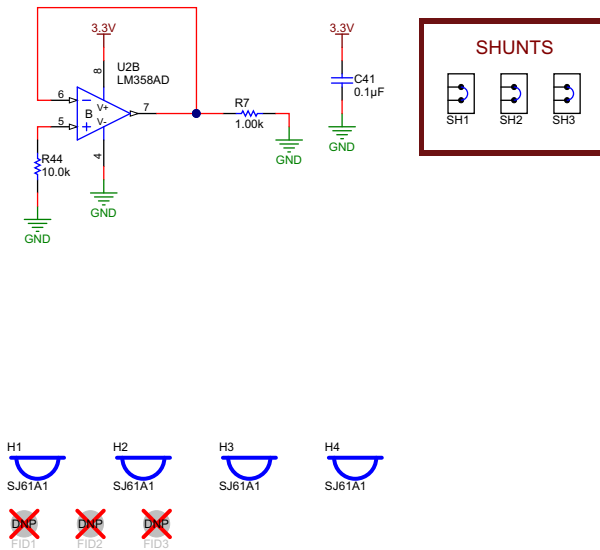


Figure 8. DRV2511-Q1 Schematic 2

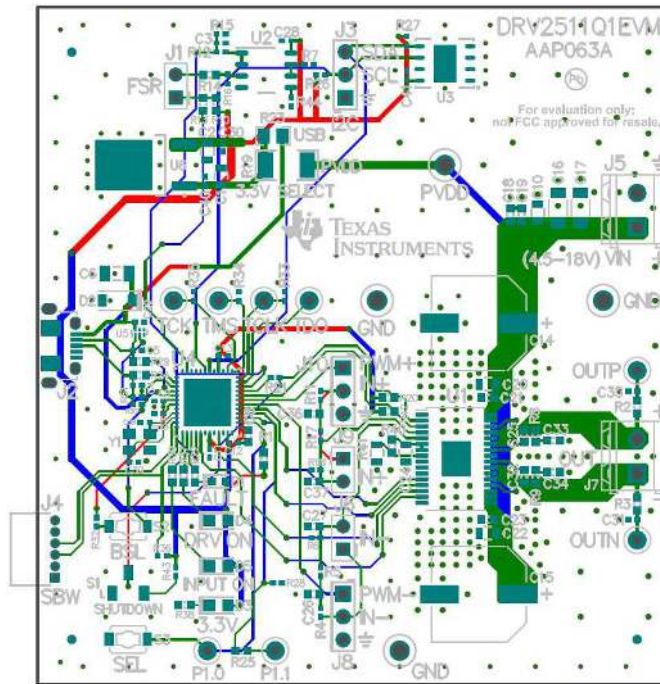


PCB Number: AAP063  
PCB Rev: A

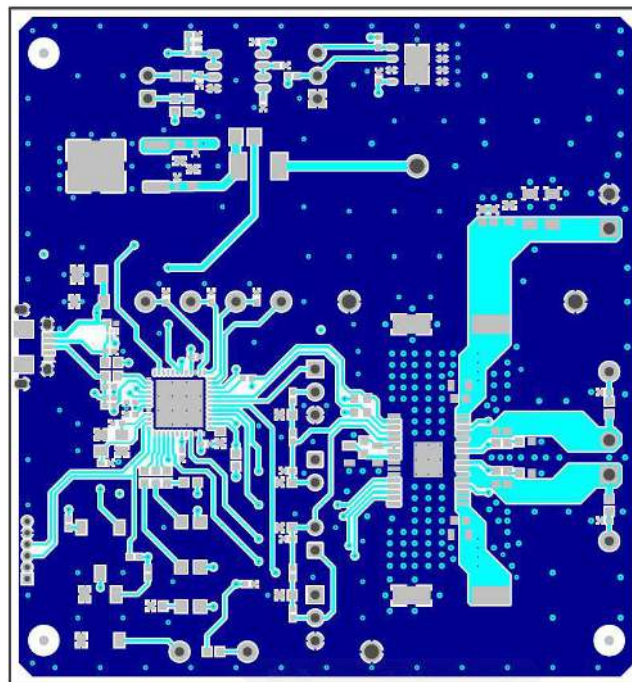
- ZZ1  
Assembly Note  
These assemblies are ESD sensitive, ESD precautions shall be observed.
- ZZ2  
Assembly Note  
These assemblies must be clean and free from flux and all contaminants. Use of no clean flux is not acceptable.
- ZZ3  
Assembly Note  
These assemblies must comply with workmanship standards IPC-A-610 Class 2, unless otherwise specified.

Figure 9. DRV2511-Q1 Schematic 3

**5.2 PCB Layout**



**Figure 10. All Layers**



**Figure 11. Top Layer**

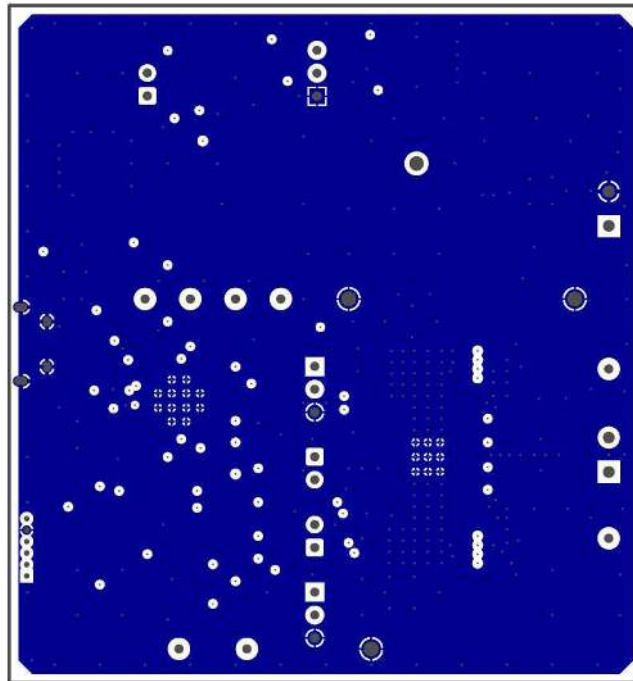


Figure 12. Signal Layer 1

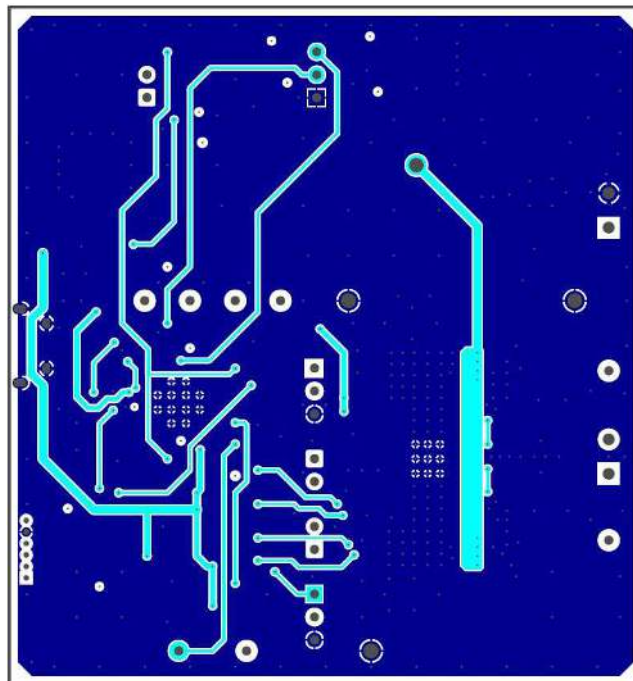
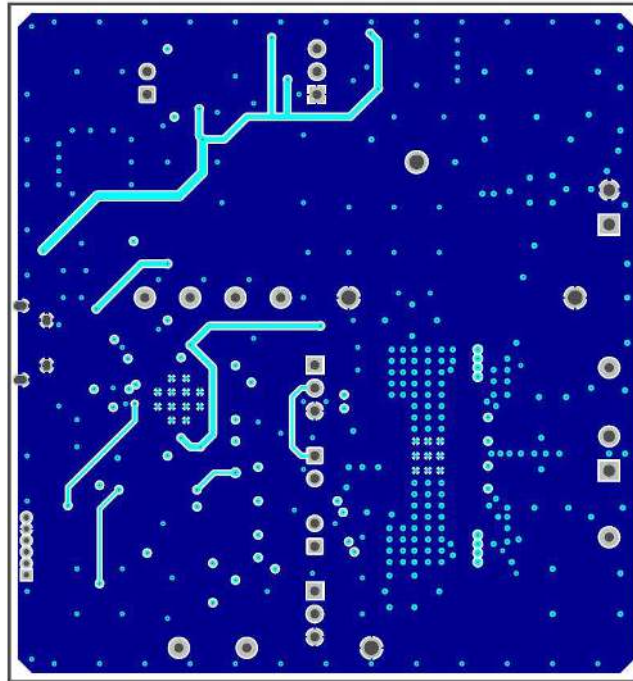


Figure 13. Signal Layer 2



**Figure 14. Bottom Layer**

### 5.3 Bill Of Materials

**Table 5. Bill of Materials**

Designator	Quantity	Value	Description	Package Reference	Part Number
!PCB1	1		Printed Circuit Board		AAP063
C1, C2	2	10 $\mu$ F	CAP, CERM, 10 $\mu$ F, 16 V, $\pm$ 20%, X5R, 0805	0805	0805YD106MAT2A
C3	1	220 pF	CAP, CERM, 220 pF, 50 V, $\pm$ 10%, X7R, 0402	0402	C1005X7R1H221K
C4, C5	2	47 pF	CAP, CERM, 47 pF, 50 V, $\pm$ 5%, C0G/NP0, 0402	0402	GRM1555C1H470JA01D
C6	1	4.7 $\mu$ F	CAP, CERM, 4.7 $\mu$ F, 25 V, $\pm$ 10%, X7R, 1206	1206	GRM31CR71E475KA88L
C7, C9	2	0.22 $\mu$ F	CAP, CERM, 0.22 $\mu$ F, 6.3 V, $\pm$ 10%, X6S, 0402	0402	GRM155C80J224KE01D
C8	1	0.47 $\mu$ F	CAP, CERM, 0.47 $\mu$ F, 10 V, $\pm$ 10%, X7R, 0603	0603	C0603C474K8RACTU
C11, C12, C13, C28, C29, C30, C40, C41	8	0.1 $\mu$ F	CAP, CERM, 0.1 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0402	0402	GRM155R71C104KA88D
C16, C17	2	4.7 $\mu$ F	CAP, CERM, 4.7 $\mu$ F, 50 V, $\pm$ 10%, X7R, 1206_190	1206_190	UMK316AB7475KL-T
C18	1	0.082 $\mu$ F	CAP, CERM, 0.082 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0603	0603	GRM188R71H823KA93D
C19	1	2200 pF	CAP, CERM, 2200 pF, 50 V, $\pm$ 10%, X7R, 0603	0603	GRM188R71H222KA01D
C20, C22	2	22 $\mu$ F	CAP, CERM, 22 $\mu$ F, 35 V, $\pm$ 20%, X5R, 0805	0805	C2012X5R1V226M125AC
C21, C23	2	0.1 $\mu$ F	CAP, CERM, 0.1 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0603	0603	GRM188R71H104KA93D
C24	1	1 $\mu$ F	CAP, CERM, 1 $\mu$ F, 25 V, $\pm$ 10%, X7R, 0805	0805	GRM21BR71E105KA99L
C25, C32	2	0.22 $\mu$ F	CAP, CERM, 0.22 $\mu$ F, 50 V, $\pm$ 10%, X7R, 0603	0603	C1608X7R1H224K080AB
C26, C27, C36, C37	4	0.22 $\mu$ F	CAP, CERM, 0.22 $\mu$ F, 25V, $\pm$ 10%, X7R, 0603	0603	GRM188R71E224KA88D
C31, C35	2	470 pF	CAP, CERM, 470 pF, 50 V, $\pm$ 10%, X7R, 0402	0402	GRM155R71H471KA01D
C38, C39	2	18 pF	CAP, CERM, 18 pF, 50 V, $\pm$ 5%, C0G/NP0, 0402	0402	GRM1555C1H180JA01D
D1	1	Red	LED, Red, SMD	Red LED, 1.6 mm $\times$ 0.8 mm $\times$ 0.8 mm	LTST-C190CKT

**Table 5. Bill of Materials (continued)**

Designator	Quantity	Value	Description	Package Reference	Part Number
D2	1	5.6 V	Diode, Zener, 5.6 V, 500 mW, SOD-123	SOD-123	MMSZ5232B-7-F
D3, D4, D5	3	Green	LED, Green, SMD	LED_0805	LTST-C171GKT
H1, H2, H3, H4	4		Bumpon, Cylindrical, 0.312 × 0.200, Black	Black Bumpon	SJ61A1
J1, J6, J9	3		Header, 100 mil, 2 × 1, Tin, TH	Header, 2 PIN, 100 mil, Tin	PEC02SAAN
J2	1		Connector, Receptacle, Micro-USB Type AB, R/A, Bottom Mount SMT	Connector, USB Micro AB	DX4R205JJAR1800
J3, J8, J10	3		Header, 100 mil, 3 × 1, Tin, TH	Header, 3 × 1, 100 mil, TH	5-146278-3
J4	1		Receptacle, 50 mil, 6 × 1, Gold, R/A, TH	6 × 1 Receptacle	LPPB061NGCN-RC
J5, J7	2		Terminal Block, 2 × 1, 3.81 mm, 24-16 AWG, 10 A, 300 VAC, TH	2 × 1 Terminal Block	691214310002
R1, R2, R3, R20, R42	5	100 k	RES, 100 k, 0.1%, 0.063 W, 0603	0603	CPF0603B100KE
R4, R5, R6, R11, R17, R18, R26, R27	8	3.3 k	RES, 3.3 k, 5%, 0.063 W, 0402	0402	CRCW04023K30JNED
R7, R12, R15, R33, R34, R35	6	1.00 k	RES, 1.00 k, 1%, 0.063 W, 0402	0402	CRCW04021K00FKED
R13, R14, R25	3	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL
R16	1	100 k	RES, 100 k, 5%, 0.063 W, 0402	0402	CRCW0402100KJNED
R21	1	1.2 k	RES, 1.2 k, 5%, 0.063 W, 0402	0402	CRCW04021K20JNED
R22, R37, R38, R39	4	499	RES, 499 Ω, 1%, 0.1W, 0603	0603	CRCW0603499RFKEA
R23	1	0	RES, 0, 5%, 0.125 W, 0805	0805	CRCW08050000Z0EA
R24, R29	2	27	RES, 27.0, 1%, 0.1 W, 0603	0603	RC0603FR-0727RL
R30	1	1.40 k	RES, 1.40 k, 1%, 0.063 W, 0402	0402	CRCW04021K40FKED
R32	1	100	RES, 100, 1%, 0.063 W, 0402	0402	CRCW0402100RFKED
R36, R43	2	9.76 k	RES, 9.76 k, 1%, 0.063 W, 0402	0402	CRCW04029K76FKED
R41	1	20.0 k	RES, 20.0 k, 1%, 0.125 W, 0805	0805	CRCW080520K0FKEA



**Table 5. Bill of Materials (continued)**

Designator	Quantity	Value	Description	Package Reference	Part Number
S1	1		Slide SW, SPDT 0.1 A 50 VDC	SW, 3.1 mm × 2.5 mm × 6 mm	CJS-1201TA
S2, S3	2		Switch, Tactile, SPST-NO, 0.05A, 12V, SMT	Switch, 4.4 mm × 2 mm × 2.9 mm	TL1015AF160QG
TP1, TP2	2	Yellow	Test Point, Miniature, Yellow, TH	Yellow Miniature Testpoint	5004
TP3, TP4, TP5	3		Test Point, Multipurpose, Black, TH	Black Multipurpose Testpoint	5011
TP6, TP7, TP8, TP9, TP10, TP12	6	Orange	Test Point, Miniature, Orange, TH	Orange Miniature Testpoint	5003
TP11	1		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010
U1	1		8 A Automotive Haptic Driver for Solenoids and Voice Coils, DAP0032C	DAP0032C	DRV2511QDAPRQ1
U2	1		Dual Low Power Op Amp, D0008A	D0008A	LM358AD
U3	1		512K I2C Serial EEPROM, DFN-8	DFN-8	24FC512-I/MF
U4	1		25 MHz Mixed Signal Microcontroller with 32 KB Flash, 4096 B SRAM and 47 GPIOs, -40 to 85 degC, 48-pin QFN (RGC), Green (RoHS& no Sb/Br)	RGZ0048A	MSP430F5510IRGZR
U5	1		ESD-Protection Array for High-Speed Data Interfaces, 4 Channels, -40 to +85 degC, 6-pin SON (DRY), Green (RoHS& no Sb/Br)	DRY0006A	TPD4E004DRYR
U6	1		Single Output Automotive LDO, 500 mA, Fixed 3.3 V Output, 3.8 to 26 V Input, 3-pin PFM (KVU), -40 to 125 degC, Green (RoHS& no Sb/Br)	KVU0003A	TL760M33QKVURQ1
Y1	1		Crystal, 24.000MHz, 18pF, SMD	3.2 mm × 0.8 mm × 2.5 mm	ABM8-24.000MHZ-B2-T
C10	0	1 uF	CAP, CERM, 1 uF, 25 V, ± 10%, X7R, 0805	0805	GRM21BR71E105KA99L
C14, C15	0	220 uF	CAP, AL, 220 uF, 50 V, ± 20%, 0.3 Ω, SMD	SMT Radial G	EEE-FC1H221P

**Table 5. Bill of Materials (continued)**

<b>Designator</b>	<b>Quantity</b>	<b>Value</b>	<b>Description</b>	<b>Package Reference</b>	<b>Part Number</b>
C33, C34	0	470 pF	CAP, CERM, 470 pF, 50 V, $\pm$ 5%, C0G/NP0, 0603	0603	06035A471JAT2A
FID1, FID2, FID3	0		Fiducial mark. There is nothing to buy or mount.	Fiducial	N/A
R8, R9	0	3.3	RES, 3.3, 5%, 0.1 W, 0603	0603	CRCW06033R30JNEA
R10	0	0	RES, 0, 5%, 0.1 W, 0603	0603	RC0603JR-070RL
R19	0	0	RES, 0, 5%, 0.75 W, 2010	2010	CRCW20100000Z0EF
R28	0	1.00 k	RES, 1.00 k, 1%, 0.063 W, 0402	0402	CRCW04021K00FKED
R40	0	100 k	RES, 100 k, 0.1%, 0.063 W, 0603	0603	CPF0603B100KE

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