

TI Designs: TIDA-01373

DRV10983, DRV10975, DRV10983-Q1, and DRV10987 EEPROM Programming Tool Reference Design



Description

The TIDA-01373 is a reference hardware and software example of a scalable programming tool for the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 integrated BLDC motor drivers. These devices feature configurable EEPROM registers that must be set to motor-specific parameters. This reference design provides details on how to program up to eight EEPROM registers of a motor driver device with user-specified motor parameter values.

Resources

Design Folder

[TIDA-01373](#)

Product Folders

DRV10983	DRV10975	DRV10983-Q1	DRV10987
MSP430G2553	TCA9548A	TPS630701	TPD3S014
LP5907-3.3	SN74LV4T125	DCP010505B	ISO1541DR
LM3478	TPD8E003		

Features

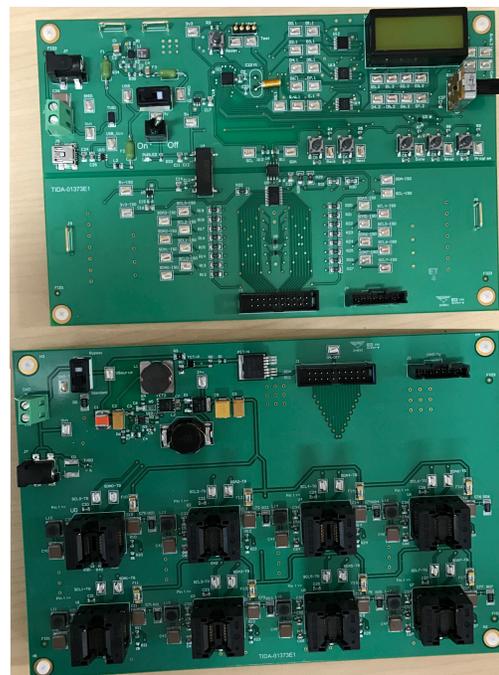
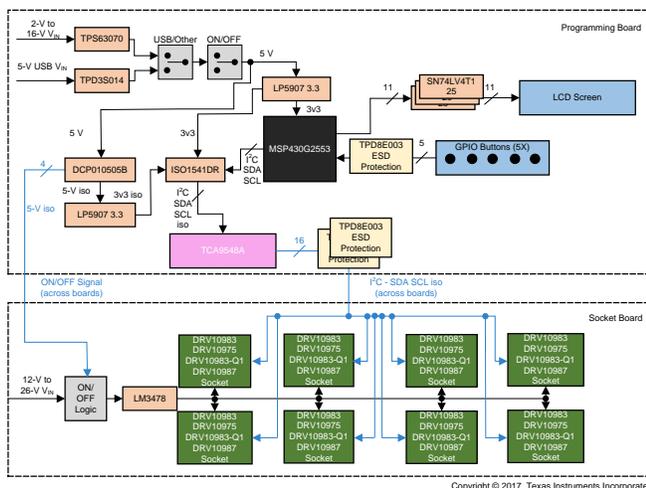
- Software and Hardware Support up to Eight Devices
- User-Configurable EEPROM Settings
- Single ON and OFF Switch
- Overvoltage Protection
- Power Supply Isolation
- Two-Wire JTAG Interface to MCU
- DRV10983, DRV10975, DRV10983-Q1, and DRV10987 EEPROM Software Examples
- LCD Screen for User to Read Back Verification
- ESD Protection for GPIO and I²C Interfaces

Applications

- [EEPROM Programming Tool](#)



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1 System Description

The DRV10983, DRV10975, DRV10983-Q1, and DRV10987 are integrated brushless DC (BLDC) motor drivers with configurable, electrically erasable programmable read-only memory (EEPROM) registers that must be set to motor-specific parameters. The EEPROM registers can be written to and read from through I²C protocol.

The TIDA-01373 is a hardware and software reference design for a DRV10983, DRV10975, DRV10983-Q1, and DRV10987 programming tool. The design is intended to be used as an example of how a scalable programming tool may be built to program the configurable registers of the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 devices through the I²C protocol described in the *I²C Serial Interface* sections of the respective device data sheet [1] [2] [3].

The TIDA-01373 hardware consists of two separate printed-circuit boards (PCBs). The first board is referred to as the programming board and the second board is referred to as the socket board. The programming board consists of power management, whole system ON and OFF switch, microcontroller (MCU), I²C multiplexer (MUX), liquid-crystal display (LCD), buttons, and isolation. The socket board consists of power management and eight sockets in which the DRV10983, DRV10975, DRV10983-Q1, or DRV10987 motor driver is placed. The two boards are connected through two ribbon wires: one for the I²C communication lines as well as an ON and OFF signal and one for a ground connection. Overvoltage protection is built into both boards as well as isolation to protect both the motor drivers and the MCU in the system.

The design allows for a user to select custom motor parameter settings to program the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 EEPROM registers by editing a header file found in the source code. The user manually inputs the parameters with the desired values that are generated when the motor has been tuned. The source code is then compiled and flashed to the MSP430G2553 MCU on the programming board. The design offers a two-wire JTAG interface to the MCU to reduce the pin count. When the MCU is flashed the TIDA-01373 is a stand-alone system. The LCD on the programming board allows for user-friendly operation of the design.

The TIDA-01373 has three general functions during operation. The first function reads back to the user the values that are to be programmed into the EEPROM registers of the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 devices for the motor parameters. These values correspond to the values entered by the user into the header file in the source code. The second function reads the DRV10983, DRV10975, DRV10983-Q1, or DRV10987 devices that are in the system and verifies that the EEPROM registers in each of the devices match the desired values in the header file. This function indicates which devices have EEPROM registers that match and which ones do not. The third function is the general programming routine. This function writes the desired motor parameter values that the user has specified in the header file to the EEPROM registers in each of the populated DRV10983, DRV10975, DRV10983-Q1, or DRV10987 motor drivers on the socket board. This function then verifies that all of the devices have been properly programmed and indicates back to the user if any errors occur.

1.1 System Benefits

- *Scalability*
 - Hardware example can be used to scale up to more than eight motor drivers
 - Software examples can be used to scale up to more than eight motor drivers
- *Software examples*
 - Example I²C routines to communicate with the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 devices
 - Example routines for users to learn how to read from the DRV10983, DRV10975, DRV10983-Q1, and DRV10987
 - Example routines for users to learn how to write to the configuration registers on the DRV10983, DRV10975, DRV10983-Q1, and DRV10987
 - Validation feedback given immediately after programming is completed
- *Highly integrated*
 - Stand-alone system requires no computer in *General Operation Mode*
 - Solution allows user to simultaneously program up to eight devices increasing programming times
 - JTAG interface allows quick MCU-flashing capabilities for a complete software and hardware solution
- *Fully protected*
 - Overvoltage protection integrated into both boards through transient voltage suppression (TVS) diodes
 - I²C software protection for unpopulated sockets; allows user to verify proper population of devices
 - ESD protection for both general port input/output (GPIO) buttons and I²C communication
 - Single ON and OFF switch for easy operation with minimal interference

1.2 Key System Specifications

Table 1. Key System Specifications—Programming Board

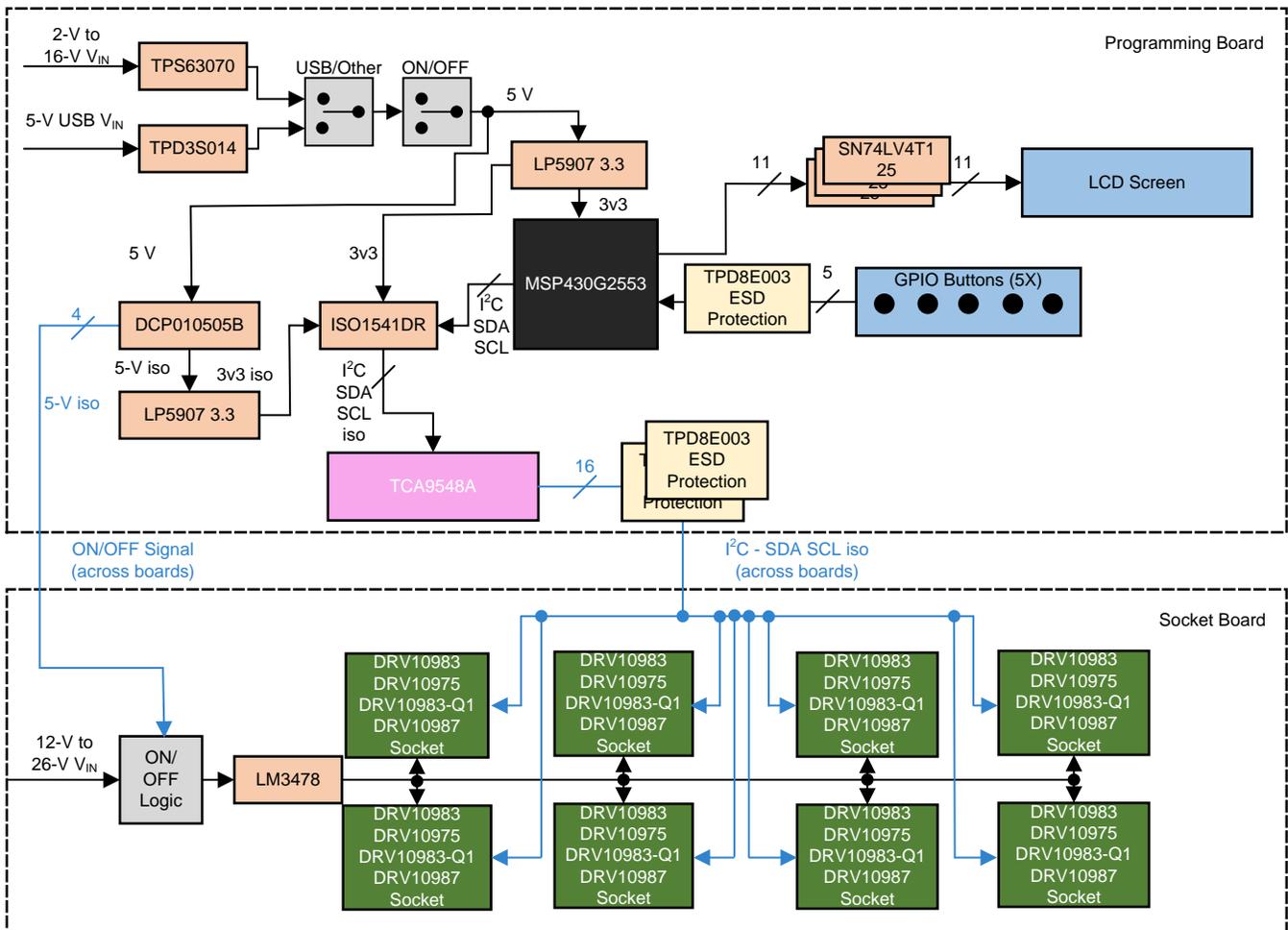
PARAMETER	DESCRIPTION	SPECIFICATION
V _{IN}	V _{IN} from DC power supply	2 V to 16 V
USB_V _{IN}	USB input voltage	4.8 V to 5.2 V
Test	Test pin used in two-wire JTAG	3.3 V
Reset	Reset pin used in two-wire JTAG	3.3 V

Table 2. Key System Specifications—Socket Board

PARAMETER	DESCRIPTION	SPECIFICATION
V _{IN}	V _{IN} from DC power supply	12 V to 26 V
Cable length	I ² C ribbon cable length	6 in

2 System Overview

2.1 Block Diagram



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Figure 1. TIDA-01373 Block Diagram

2.2 Highlighted Products

The key features of the highlighted devices are available in their respective data sheets. The following subsections provide high-level details of the highlighted products used in the TIDA-01373 reference design.

2.2.1 DRV10983

DRV10983 is a three-phase sensorless motor driver with integrated power MOSFETs, which can provide continuous drive current up to 2 A. The device is specifically designed for cost-sensitive, low-noise, and low-external-component count applications.

The DRV10983 uses a proprietary, sensorless control scheme to provide continuous sinusoidal drive, which significantly reduces the pure tone acoustics that typically occur as a result of commutation. The interface to the device is designed to be simple and flexible. The motor can be controlled directly through pulse-width modulation (PWM), analog, or I²C inputs. Motor speed feedback is available through either the FG pin or I²C.

The DRV10983 features an integrated buck and linear regulator to efficiently step down the supply voltage to either 5 V or 3.3 V for powering both internal and external circuits. The device is available in either a sleep mode or standby mode version to conserve power when the motor is not running. The standby mode version (3 mA) leaves the regulator running and the sleep mode version (180 μ A) shuts it off. Use the standby mode version in applications where the regulator is used to power an external MCU [1].

An I²C interface allows the user to reprogram specific motor parameters in registers and program the EEPROM to help optimize the performance for a given application. The DRV10983 is available in a thermally-efficient HTSSOP, 24-pin package with an exposed thermal pad. The operating temperature is specified from -40°C to 125°C .

2.2.2 DRV10975

The DRV10975 is a three-phase sensorless motor driver with integrated power MOSFETs, which can provide continuous drive current up to 1.5 A. The device is specifically designed for cost-sensitive, low-noise and low-external-component count applications.

The DRV10975 uses a proprietary, sensorless control scheme to provide continuous sinusoidal drive, which significantly reduces the pure tone acoustics that typically occur as a result of commutation. The interface to the device is designed to be simple and flexible. The motor can be controlled directly through PWM, analog, or I²C inputs. Motor speed feedback is available through either the FG pin or I²C.

The DRV10975 features an integrated buck and linear regulator to efficiently step down the supply voltage to either 5 V or 3.3 V for powering both internal and external circuits. The device is available in either a sleep mode or a standby mode version to conserve power when the motor is not running. The standby mode version (4.5 mA) leaves the regulator running and the sleep mode version (80 μ A) shuts it off. Use the standby mode version in applications where the regulator is used to power an external MCU.

An I²C interface allows the user to reprogram specific motor parameters in registers and program the EEPROM to help optimize the performance for a given application. The DRV10975 is available in a thermally-efficient HTSSOP, 24-pin package with an exposed thermal pad. The operating temperature is specified from -40°C to 125°C [2].

2.2.3 DRV10983-Q1

The DRV10983-Q1 device is a three-phase sensorless motor driver with integrated power MOSFETs, which can provide continuous drive current up to 2 A. The device is specifically designed for cost-sensitive, low noise, low-external-component-count fan and pump applications.

The DRV10983-Q1 device protects the nonvolatile memory down to 4.5 V and delivers current to the motor with a supply voltage as low as 6.2 V. If the power supply voltage is higher than 28 V, the device stops driving the motor and protects the DRV10983-Q1 circuitry. This function is able to handle a load dump condition up to 45 V [3].

2.2.4 DRV10987

The DRV10987 device is a three-phase, sensorless, 180° sinusoidal motor driver with integrated power MOSFETs which can provide continuous drive current up to 2 A. The device is specifically designed for cost-sensitive, low-noise, low-external-component-count fan and pump applications.

The DRV10987 device delivers current to the motor with a supply voltage as low as 6.2 V. If the power supply voltage is higher than 28 V, the device stops driving the motor and protects the DRV10987 circuitry.

2.2.5 MSP430G2553

The Texas Instruments MSP430™ family of ultra-low-power microcontrollers consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency.

The digitally controlled oscillator (DCO) allows wakeup from low-power modes to active mode in less than 1 μ s. The MSP430G2x13 and MSP430G2x53 series are ultra-low-power, mixed-signal MCUs with built-in 16-bit timers, up to 24 I/O capacitive-touch enabled pins, a versatile analog comparator, and built-in communication capability using the universal serial communication interface. In addition, the MSP430G2x53 family members have a 10-bit analog-to-digital converter (ADC). Typical applications include low-cost sensor systems that capture analog signals, convert them to digital values, and then process the data for display or for transmission to a host system [5].

2.2.6 TCA9548A

The TCA9548A device has eight bidirectional translating switches that can be controlled through the I²C bus. The SCL/SDA upstream pair fans out to eight downstream pairs, or channels. Any individual SCn/SDn channel or combination of channels can be selected, which is determined by the contents of the programmable control register. These downstream channels can be used to resolve I²C slave address conflicts. For example, if eight identical digital temperature sensors are required in the application, one sensor can be connected at each channel: 0-7. The system master can reset the TCA9548A device in the event of a time-out or other improper operation by asserting a low in the RESET input. Similarly, the power-on reset deselects all channels and initializes the I²C (SMBus) state machine. Asserting RESET causes the same reset and initialization to occur without powering down the part. This feature allows recovery if one of the downstream I²C buses get stuck in a low state. The pass gates of the switches are constructed so that the VCC pin can be used to limit the maximum high voltage, which is passed by the TCA9548A device. Limiting the maximum high voltage allows the use of different bus voltages on each pair, so that 1.8-V, 2.5-V or 3.3-V parts can communicate with 5-V parts without any additional protection. External pullup resistors pull the bus up to the desired voltage level for each channel. All I/O pins are 5-V tolerant [6].

2.2.7 TPS63070

The TPS6307x is a high-efficiency, low-quiescent current, buck-boost converter suitable for applications where the input voltage can be higher or lower than the output voltage. Output currents can go as high as 2 A in boost mode and in buck mode. The buck-boost converter is based on a fixed-frequency PWM controller using synchronous rectification to obtain maximum efficiency. At low load currents, the converter enters power save mode to maintain high efficiency over a wide-load current range. The converter can be disabled to minimize battery drain. During shutdown, the load is disconnected from the battery. The device is available in a 2.5x3-mm QFN package [7].

2.2.8 TPD3S014

The TPD3S0x4 series of integrated devices feature a current-limited load switch and a two-channel, TVS-based, electrostatic discharge (ESD) protection diode array for USB interfaces.

The TPD3S0x4 devices are intended for applications such as USB where heavy capacitive loads and short circuits are likely to be encountered; TPD3S0x4 devices provide short-circuit protection and overcurrent protection. The TPD3S0x4 limits the output current to a safe level by operating in constant current mode when the output load exceeds the current limit threshold. The fast overload response eases the burden on the main 5-V power supply by quickly regulating the power when the output is shorted. The rise and fall times for the current limit switch are controlled to minimize current surges when turning the device on and off.

The TPD3S014 and TPD3S044 allow 0.5 A and 1.5 A of continuous current, respectively. The TVS diode array is rated to dissipate ESD strikes above the maximum level specified in the IEC 61000-4-2 international standard.

The high level of integration, combined with its easy-to-route DBV package, allows this device to provide great circuit protection for USB interfaces in applications like laptops, high-definition digital TVs, set-top boxes, and electronic point-of-sale equipment [8].

2.2.9 LP5907-3.3

The LP5907 is a low-noise linear-dropout regulator (LDO) that can supply up to 250 mA of output current. Designed to meet the requirements of RF and analog circuits, the LP5907 device provides low noise, high power supply rejection ratio (PSRR), low quiescent current, and low line or load transient response figures. Using new innovative design techniques, the LP5907 offers class-leading noise performance without a noise bypass capacitor and the ability for remote output capacitor placement. The device is designed to work with a 1- μ F input and a 1- μ F output ceramic capacitor and does not require a separate noise bypass capacitor. This device is available with fixed output voltages from 1.2 V to 4.5 V in 25-mV steps [9].

2.2.10 SN74LV4T125

SN74LV4T125 is a low-voltage complementary metal-oxide-semiconductor (CMOS) buffer gate which operates at a wider voltage range for portable, telecom, industrial, and automotive applications. The output level is referenced to the supply voltage and is able to support 1.8-V, 2.5-V, 3.3-V, and 5-V CMOS levels.

The input is designed with a lower threshold circuit to match 1.8-V input logic at $V_{CC} = 3.3$ V and can be used in 1.8-V to 3.3-V level-up translation. In addition, the 5-V tolerant input pins enable down translation (for example, 3.3-V to 2.5-V output at $V_{CC} = 2.5$ V). The wide V_{CC} range of 1.8 V to 5.5 V allows the generation of desired output levels to connect to controllers or processors.

The SN74LV4T125 device is designed with current-drive capability of 8 mA to reduce line reflections, overshoot, and undershoot caused by high-drive outputs [10].

2.2.11 DCP010505B

The DCP01B series is a family of 1-W, isolated, unregulated DC-DC converter modules. Requiring a minimum of external components and including on-chip device protection, the DCP01B series of devices provide extra features such as output disable and synchronization of switching frequencies.

This combination of features and small size makes the DCP01B series of devices suitable for a wide range of applications and is an easy-to-use solution in applications requiring signal path isolation [11].

2.2.12 ISO1541DR

The ISO1540 and ISO1541 devices are low-power, bidirectional isolators that are compatible with I²C interfaces. These devices have logic input and output buffers that are separated by Texas Instrument's capacitive isolation technology using a silicon dioxide (SiO₂) barrier. When used with isolated power supplies, these devices block high voltages, isolate grounds, and prevent noise currents from entering the local ground and interfering with or damaging sensitive circuitry.

This isolation technology provides for function, performance, size, and power consumption advantages when compared to optocouplers. The ISO1540 and ISO1541 devices enable a complete isolated I²C interface to be implemented within a small form factor.

The ISO1540 has two isolated bidirectional channels for clock and data lines while the ISO1541 has a bidirectional data and a unidirectional clock channel. The ISO1541 is useful in applications that have a single master while the ISO1540 is suitable for multi-master applications. For applications where clock stretching by the slave is possible, the ISO1540 device should be used.

Isolated bidirectional communication is accomplished within these devices by offsetting the low-level output voltage on side 1 to a value greater than the high-level input voltage on side 1, thus preventing an internal logic latch that otherwise would occur with standard digital isolators [12].

2.2.13 LM3478

The LM3478 is a versatile low-side, N-Channel MOSFET controller for switching regulators. The controller is suitable for use in topologies requiring a low-side MOSFET, such as boost, flyback, single-ended primary-inductor converter (SEPIC), and so forth. Moreover, the LM3478 can be operated at an extremely-high switching frequency to reduce the overall solution size. The switching frequency of the LM3478 can be adjusted to any value between 100 kHz and 1 MHz by using a single external resistor. Current mode control provides superior bandwidth and transient response, besides cycle-by-cycle current limiting. Output current can be programmed with a single external resistor.

The LM3478 has built-in features such as thermal shutdown, short-circuit protection, overvoltage protection, and so forth. Power-saving shutdown mode reduces the total supply current to 5 μ A and allows power supply sequencing. An internal soft-start limits the inrush current at start-up [13].

2.2.14 TPD8E003

The TPD8E003 device is a unidirectional, TVS-based, ESD protection diode array. The TPD8E003 is rated to dissipate ESD strikes above the maximum level specified in the IEC 61000-4-2 international standard (level 4). This device provides eight channels of ESD protection in a space-saving WSON package. Typical applications for the TPD8E003 include keypad, GPIO, resistive touchscreen, and low-speed memory interfaces. See the TPD2E2U06 and TPD4E05U06 for two- and four-channel ESD protection solutions, respectively [14].

3 Hardware, Software, and Test Results

3.1 Required Hardware and Software

This section outlines the required hardware and software that make up the TIDA-01373 reference design

3.1.1 Hardware

To get started with using the hardware, see the TIDA-01373 *Quick Start User's Guide* [4].

3.1.1.1 Programming Board

The programming board consists of a power management and a system ON and OFF switch, MCU, I²C multiplexer (MUX), LCD, buttons, and isolation.

3.1.1.1.1 Power Stage

The power stage of the programming board provides many different options for the user to power the board:

- 6-V to 12-V wall socket (barrel power connector)
- External power supply with clips (test-point connection)
- External power supply using wires (screw terminal block)
- USB power interface (micro-USB port)

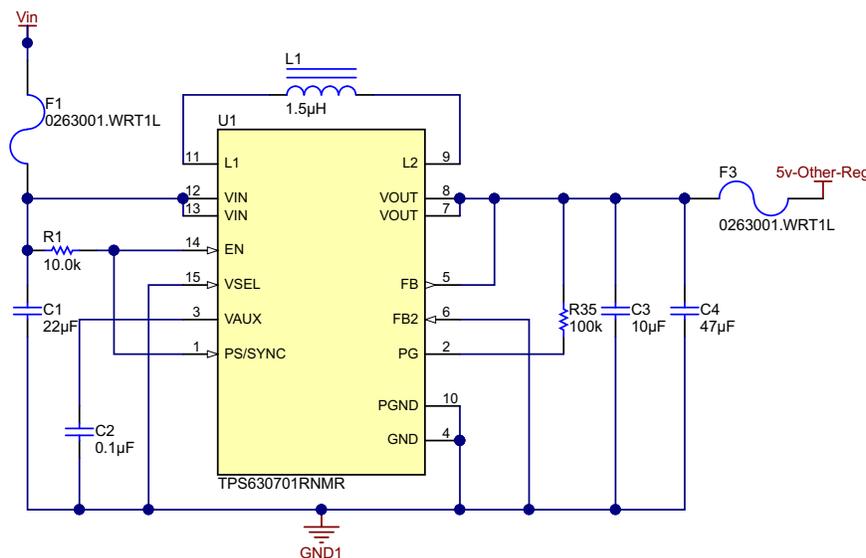
Because of the additional USB power interface, two different regulators have been built into the system: one for the USB power interface and one for all other possible power supply options. The user must select which option with which to power the system through a control switch.

In addition to these regulators, the design also features a built-in 3V3 LDO that bucks the 5-V regulated rail from the power supply down to 3.3 V to supply the onboard MCU.

The following subsections outline the design considerations for the three different regulators as well as the control switches.

3.1.1.1.1.1 TPS630

Figure 2 shows the configuration of the TPS630701 5-V regulator in the TIDA-01373 system. This regulator is responsible for regulating an external DC power supply other than a USB input.



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Figure 2. TPS630701 Configuration

The TPS6307x series of buck-boost converter features internal loop compensation; therefore, the external L-C filter has to be selected according to the internal compensation. One important factor to consider is that the effective inductance, due to inductor tolerance and current derating, can vary between 20% and –30%. The same consideration applies for the capacitance of the output filter: The effective capacitance can vary between 20% and –80% of the specified data sheet value, due to capacitor tolerance and bias voltage.

Programming the output voltage

While the output voltage of the TPS63070 is adjustable, the TPS630701 is set to a fixed voltage. For fixed-output versions, the FB pin must be connected to the output directly.

Inductor selection

For high efficiencies, the inductor must have a low DC resistance to minimize conduction losses. The core material has a higher impact on efficiency, especially at high switching frequencies. When using small-chip inductors, the efficiency is reduced mainly due to higher inductor core losses, which must be taken into consideration when selecting the appropriate inductor. The inductor value determines the inductor ripple current. The larger the inductor value, the smaller the inductor ripple current and the lower the conduction losses of the converter. Conversely, larger inductor values cause a slower load transient response. To avoid saturation of the inductor, the peak current for the inductor in steady-state operation is calculated using Equation 1. Only the equation which defines the switch current in boost mode is shown, because this provides the highest value of current and represents the critical current value for selecting the right inductor.

$$\text{Duty Cycle Boost: } D = \frac{V_{\text{OUT}} - V_{\text{IN}}}{V_{\text{OUT}}}$$

$$I_{\text{PEAK}} = \frac{I_{\text{OUT}}}{\eta \times (1 - D)} + \frac{V_{\text{IN}} \times D}{2 \times f \times L} \quad (1)$$

Where:

- D = Duty cycle in boost mode,
- f = Converter switching frequency (typical 2.4 MHz),
- L = Selected inductor value,
- η = Estimated converter efficiency (use the number from the efficiency curves or 0.90 as an assumption).

NOTE: The calculation must be done for the minimum input voltage, which is possible to have in boost mode.

Input capacitor

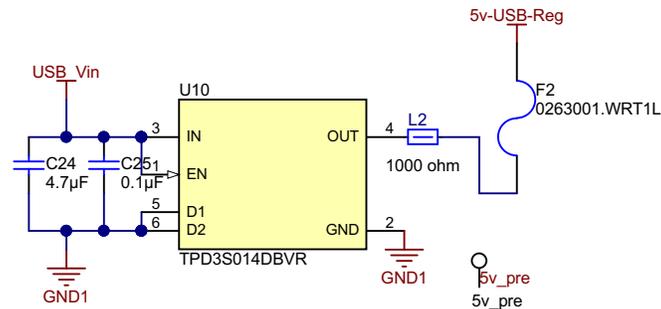
TI recommends to use a combination of capacitors on the input: a small-size ceramic capacitor as close as possible from the VIN pin to GND1 to block high-frequency noise and a larger one in parallel for the required capacitance for good transient behavior of the regulator. The use of X5R or X7R ceramic capacitors are recommended. The input capacitor must be large enough to avoid supply voltage dips shorter than 5 μs because the undervoltage lockout (UVLO) circuitry requires time to react.

Output capacitor

Same as the input, the output capacitor should be a combination of capacitors optimized for suppressing high-frequency noise and a larger capacitor for low-output voltage ripple and stable operation. The use of small X5R or X7R ceramic capacitors placed as close as possible to the VOUT and GND pins of the IC is recommended. The best configuration is a 0603-size capacitor close to the pins of the IC and as many 0805 capacitors as required to get the capacitance considering the output voltage and DC bias effect of the ceramic capacitors. Larger capacitors cause a lower-output voltage ripple as well as a lower-output voltage drop during load transients [7].

3.1.1.1.2 TPD3S014

Figure 3 shows the configuration of the TPD3S014 device in the TIDA-01373 system. The TPD3S014 is a regulator for a USB power supply input.



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Figure 3. TPD3S014 Configuration

TPD3S014 capacitor selection

Input and output capacitance improves the performance of the device; the actual capacitance should be optimized for the particular application. For all applications, a 0.1 µF or greater ceramic bypass capacitor between USB_IN and GND1 is recommended as close to the device as possible for local noise decoupling.

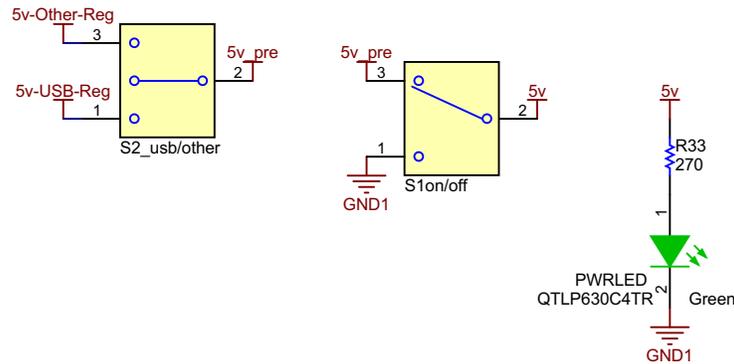
All protection circuits such as the TPD3S0x4s have the potential for input voltage overshoots and output voltage undershoots.

Input voltage overshoots can be caused by either of two effects. The first cause is an abrupt application of input voltage in conjunction with input power bus inductance and input capacitance when the IN terminal is high impedance (before turnon). Theoretically, the peak voltage is two times the applied voltage. The second cause is due to the abrupt reduction of output short-circuit current when the TPD3S0x4s turn off and energy stored in the input inductance drives the input voltage high. Input voltage droops may also occur with large load steps and as the TPD3S0x4s outputs are shorted. Applications with large input inductance (for example, connecting the evaluation board to the bench power supply through long cables) may require large input capacitance to reduce the voltage overshoot from exceeding the absolute maximum voltage of the device. The fast current-limit speed of the TPD3S0x4s to hard output short circuits isolates the input bus from faults. However, ceramic input capacitance in the range of 1 µF to 22 µF adjacent to the TPD3S0x4s inputs aids in both speeding the response time and limiting the transient seen on the input power bus. Momentary input transients to 6.5 V are permitted.

Output voltage undershoot is caused by the inductance of the output power bus just after a short has occurred and the TPD3S0x4s have abruptly reduced OUT current. Energy stored in the inductance drives the OUT voltage down and potentially to a negative value as it discharges. Applications with large output inductance (such as from a cable) benefit from use of a high-value output capacitor to control the voltage undershoot. When implementing USB standard applications, a 120-µF minimum output capacitance is required. Typically a 150-µF electrolytic capacitor is used, which is sufficient to control voltage undershoots. However, if the application does not require 120 µF of capacitance, and there is potential to drive the output negative, a minimum of 10-µF ceramic capacitance on the output is recommended. The voltage undershoot should be controlled to less than 1.5 V for 10 µs [8].

3.1.1.1.1.3 Control Switches

Figure 4 shows the control switches for the system



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Figure 4. TIDA-01373 System Control Switches—Programming Board

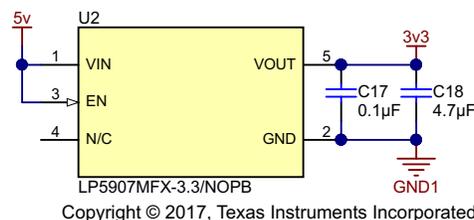
The control switches for the system consist of two switches: a USB or other switch and an ON and OFF switch. When initially setting up the design, the user must first select how they are going to power the programming board. If the user plans to use a USB power supply, they must flip the USB or other switch to the “USB” state, and if they are using another DC power supply, the user must flip the switch to the “Other” state.

The ON and OFF switch is used when the system is in general use. This switch can be flipped on and off per the instruction in the TIDA-01373 *Quick Start User’s Guide* [4]. The ON and OFF switch also sends a 5-V signal from the programming board to the socket board when turned on and a 0-V signal when turned off. Logic on the socket board allows this one switch to control the whole system.

3.1.1.1.1.4 LP5907 3v3 LDO

Figure 5 details the LDO in the system that provides power to the MCU and voltage levels for the logic as well as I²C communication lines.

Power for MCU and I²C



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Figure 5. LP5907 Configuration for 3V3 Rail

Output capacitance selection and placement

The LP5907 device requires at least a 1-µF capacitor at the OUT pin, but there are no strict requirements about the location of the capacitor in regards the OUT pin. In practical designs, the output capacitor may be located up to 10-cm away from the LDO.

Device power dissipation

The actual power being dissipated in the device can be represented by Equation 2 [9]:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} \tag{2}$$

3.1.1.1.2 MSP430G2553 Schematic

Figure 6 shows the schematic for the onboard MSP430™ MCU and JTAG connections.

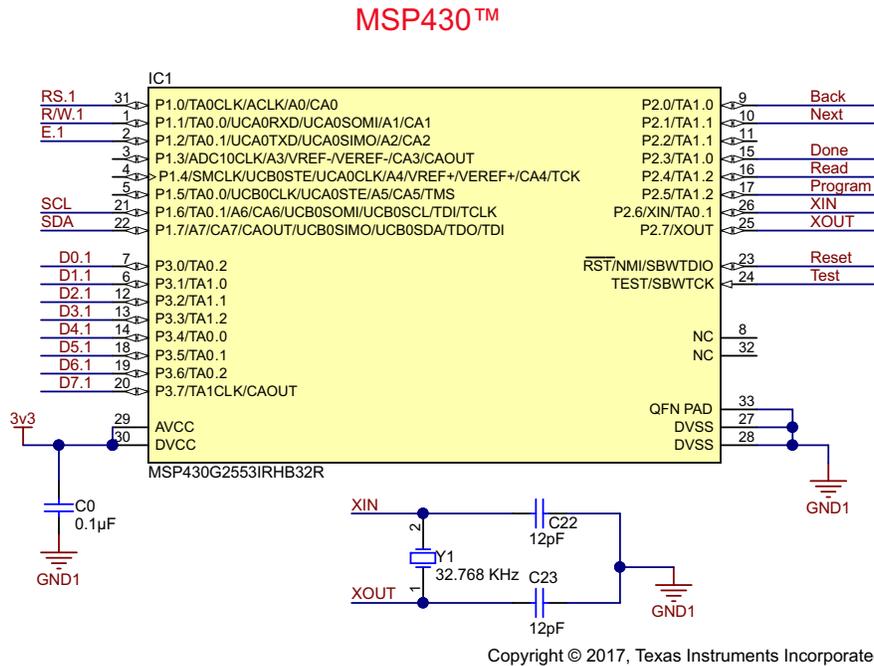


Figure 6. MSP430G2553 Schematic

For further details on the MCU layout, see the [MSP430G2553 product page](#).

3.1.1.1.3 I²C Multiplexer

The system must have an I²C MUX to enable the onboard MCU to communicate with up to eight of the socketed motor driver devices through I²C communication. The TCA9548A is an eight-channel I²C MUX in which the channels are software-selectable through an I²C interface with the MUX itself. This device allows the system to talk to one motor driver device at a time through I²C even though all eight devices have the same I²C address.

Figure 7 shows the I²C multiplexer in the TIDA-01373 system.

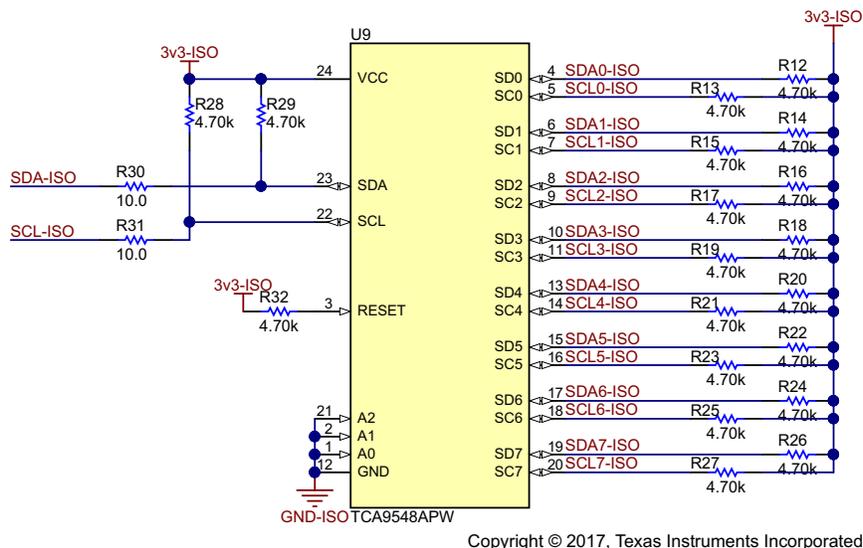


Figure 7. TCA9548A I²C Multiplexer Configuration

A typical application of the TCA9548A contains one or more data pullup voltages VDPUX: one for the master device (VDPUM) and one for each of the selectable slave channels (VDPU0 through VDPU7). In the event where the master device and all slave devices operate at the same voltage, then VDPUM = VDPUX = VCC. In an application where voltage translation is necessary, additional design requirements must be considered to determine an appropriate VCC voltage. In the TIDA-01373 design, the user does not require voltage translation.

The A0, A1, and A2 pins are hardware selectable to control the slave address of the TCA9548A device. These pins can be tied directly to GND or VCC in the application. For the TIDA-01373, the user only utilizes one I²C multiplexer and therefore can select any combination; in this case, the designer chose to pull all three of these pins to GND. If multiple slave channels are activated simultaneously in the application, then the total IOL from SCL/SDA to GND on the master side is the sum of the currents through all the pullup resistors: 4.70-k resistors are used for the TIDA-01373. The DRV10983-Q1 device requires a 100-kHz I²C interface and therefore the pass-gate transistors of the TCA9548A are constructed such that the VCC voltage can be used to limit the maximum voltage that is passed from one I²C bus to another [6].

3.1.1.1.4 LCD Interface

Figure 8 shows the LCD schematic.

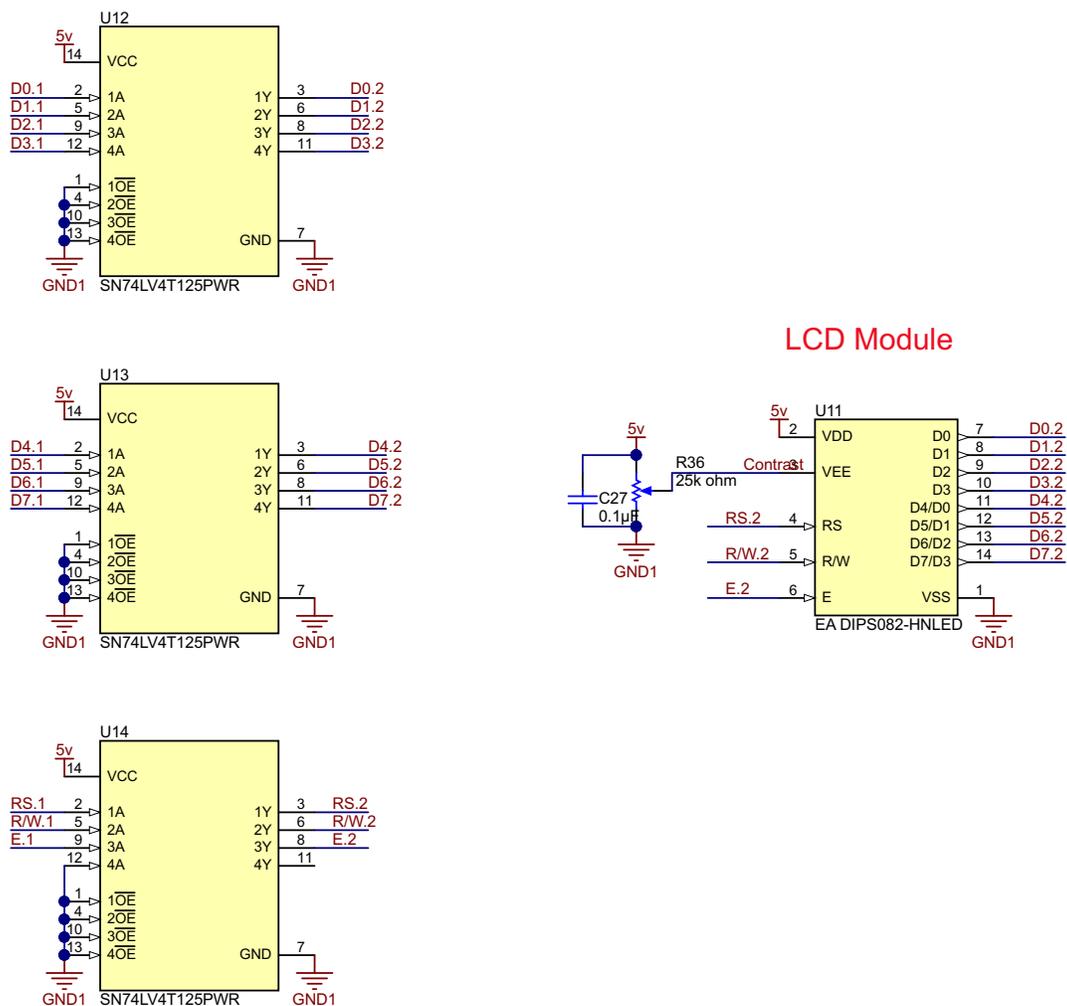


Figure 8. TIDA-01373 LCD Interface

Because the onboard LCD requires 5 V of power as well as logic, the TIDA-01373 incorporates three level shifters in the design so that the MCU can properly communicate with the LCD.

3.1.1.1.5 Button Interface

Figure 9 shows the schematic layout of the GPIO buttons for the TIDA-01373 system.

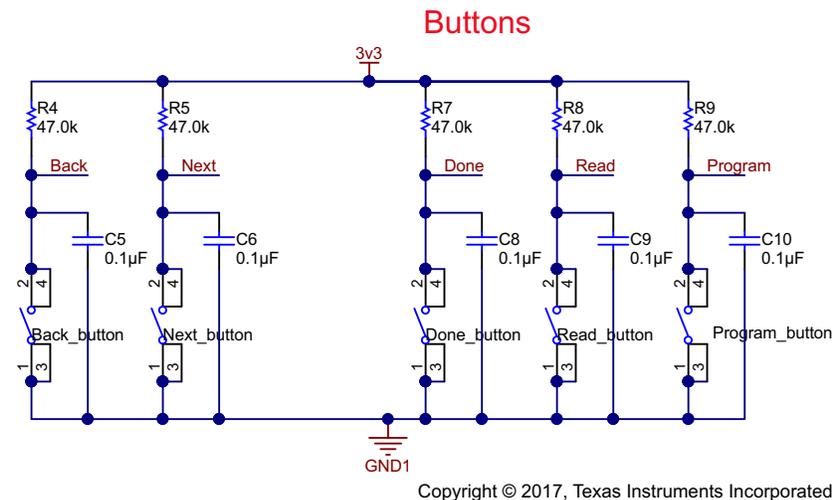


Figure 9. Button Layout

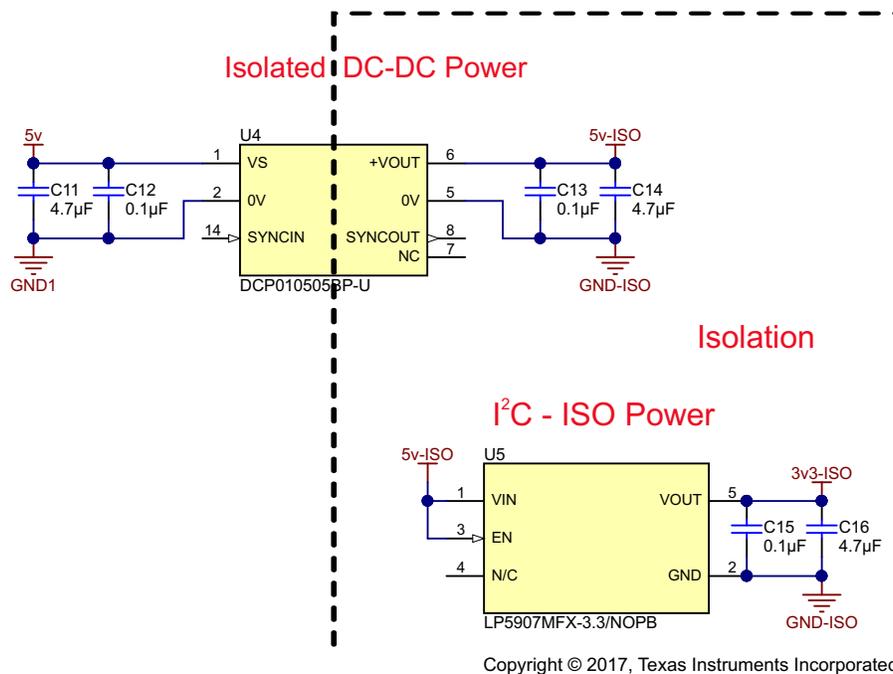
The buttons for the system are open-drain (active low) logic. When a button is pressed, the input to the MCU is low. The RC time constant of the system can be calculated with the 0.1-µF capacitor and the 47.0-kΩ resistor.

3.1.1.1.6 Isolation

Because the TIDA-01373 is a two-board solution and requires two separate power supplies, there is no guarantee that both power supplies will have the same ground reference. Due to this uncertainty, the TIDA-01373 has built-in isolation to prevent shoot-through and damage to either the DRV10983, DRV10975, DRV10983-Q1, or DRV10987 devices or the onboard MCU as well as all of the other peripheral components. A second LP5907 LDO on the isolated side exists to provide a 3V3 rail, the circuitry is the same as the previously mentioned LP5907 LDO.

3.1.1.1.6.1 Power Isolation

Figure 10 details the power isolation circuitry on the programming board.


Figure 10. Power Isolation Circuitry—Programming Board

Ripple reduction

For any DCP01B design, select a 1.0- μ F low-ESR ceramic output capacitor to reduce output ripple.

Sync pin

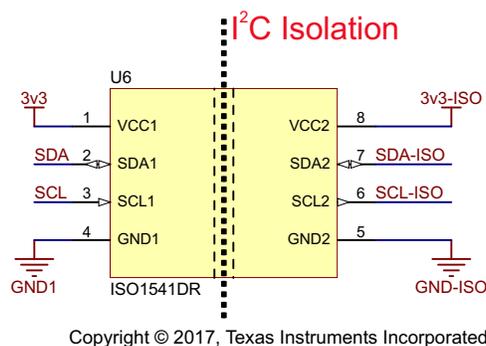
In a stand-alone application, leave the SYNCIN pin floating.

Layout considerations

The copper losses (resistance and inductance) can be minimized by the use of mutual ground and power planes (tracks) where possible. If this type of layout is not possible, use wide tracks to reduce the losses. If several devices are being powered from a common power source, a star-connected system for the track must be deployed. Do not connect the devices in series, because that type of connection cascades the resistive losses. The position of the decoupling capacitors is important [11].

3.1.1.1.6.2 I²C Isolation

Figure 11 shows the I²C isolation circuitry of the TIDA-01373.


Figure 11. I²C Isolation

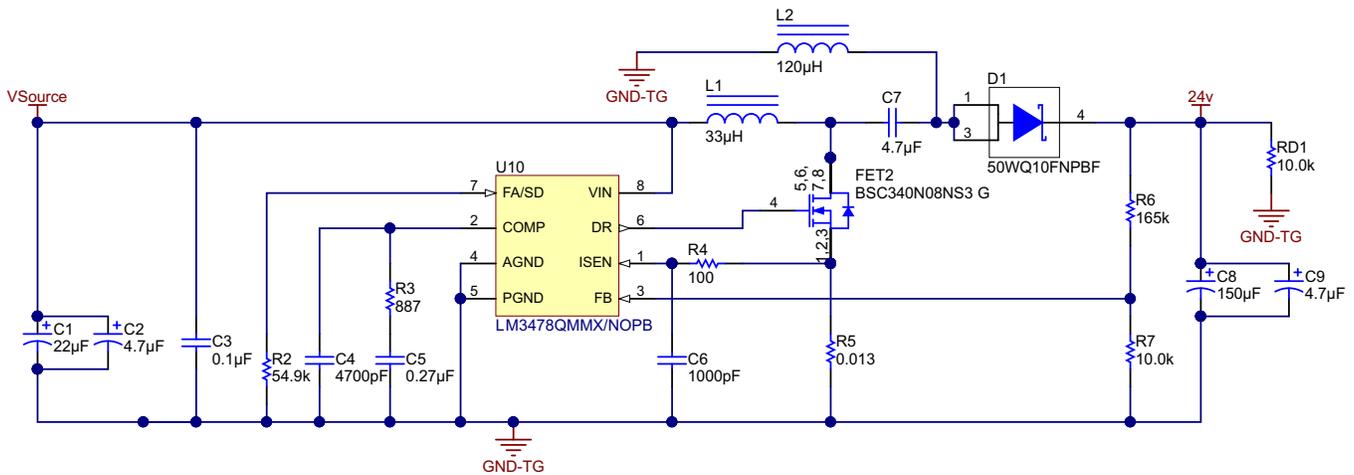
Due to the fact that the MCU and DRV10x devices are isolated from each other, the TIDA-01373 must incorporate an I²C isolation IC for the MCU to communicate with the motor drivers.

3.1.1.2 Socket Board

The socket board consists of power management, the system ON and OFF logic, and eight sockets in which the DRV10983, DRV10975, DRV10983-Q1, and DRV10987 device is placed.

3.1.1.2.1 Power Stage

Figure 12 shows the schematic of the power stage of the socket board.



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Figure 12. LM3478 SEPIC Configuration

Because the LM3478 device controls a low-side N-Channel MOSFET, it can also be used in SEPIC applications. The SEPIC uses two inductors to step up or step down the input voltage. The inductors L1 and L2 can be two discrete inductors or two windings of a coupled inductor because equal voltages are applied across the inductor throughout the switching cycle. Using two discrete inductors allows the use of catalog magnetics as opposed to a custom inductor. The input ripple can be reduced along with size by using the coupled windings for L1 and L2.

Due to the presence of the inductor L1 at the input, the SEPIC inherits all the benefits of a boost converter. One main advantage of a SEPIC over a boost converter is the inherent input-to-output isolation. The capacitor CS isolates the input from the output and provides protection against a shorted or malfunctioning load. Hence, the SEPIC is useful for replacing boost circuits when true shutdown is required, which means that the output voltage falls to 0 V when the switch is turned OFF. In a boost converter, the output can only fall to the input voltage minus a diode drop.

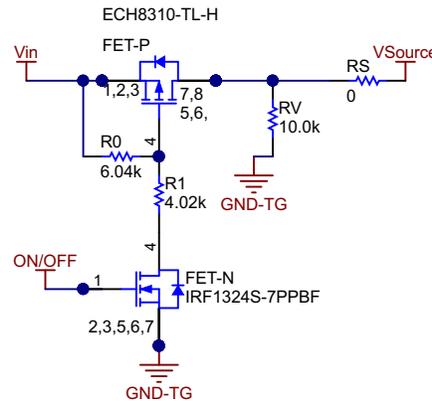
The duty cycle of a SEPIC is provided using Equation 3:

$$D = \frac{V_{OUT} + V_{DIODE}}{V_{OUT} + V_{IN} - V_Q + V_{DIODE}} \quad (3)$$

For greater detail on how to best design the SEPIC configuration, see the [LM3478 High Efficiency Low-Side N-Channel Controller for Switching Reg \[13\]](#).

3.1.1.2.2 ON and OFF Logic

Figure 13 shows the ON and OFF logic of the socket board.



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Figure 13. Socket Board ON and OFF Logic

The ON and OFF logic on the socket board allows for the single ON and OFF switch located on the programming board to control the entire TIDA-01373 system.

When the ON and OFF switch on the programming board is in the 'off' state, the ON and OFF signal sent to the socket board is 0 V. The 0-V signal corresponds to the gate voltage of the N-Type FET in the ON and OFF logic of the socket board. The 0-V gate voltage on the N-Type FET turns the FET "off", which means that no current flows from V_{IN} to GND-TG. This action, in turn, creates no voltage drop across the R0 and R1 resistors. With no voltage drop across these resistors, the gate voltage of the P-Type FET in the logic is then pulled high to V_{IN} . This high voltage on the P-Type FET turns this FET "off" as well, which means that no current flows from V_{IN} to GND-TG through the RV resistor. This action results in VSource being pulled to GND-TG. The sockets on the socket board receive no power in this state.

When the ON and OFF switch on the programming board is in the 'on' state, the ON and OFF signal sent to the socket board is 5 V. The 5-V signal corresponds to the gate voltage of the N-Type FET in the ON and OFF logic of the socket board. The 5-V gate voltage on the N-Type FET turns the FET "on", which means that the current now flows from V_{IN} to GND-TG. When current flows from V_{IN} to GND-TG across the R0 and R1 resistors there is a voltage drop. The R0 and R1 resistors act as a voltage divider for the gate voltage for the P-Type FET in the systems logic. Now the voltage at the gate V_g is 40% of the V_{IN} voltage, that is, $V_g \ll V_{IN}$ and the P-Type FET turns "on" and current flows from V_{IN} to GND-TG through the RV resistor. Now VSource is approximate to V_{IN} after subtracting a small voltage drop across the FET. In this state, the VSource feeds the LM3478 boost converter and the sockets now receive power.

3.1.1.2.3 Socket Schematic

Figure 14 shows the schematic for the sockets for the DRV10983-Q1 device. Note that adjustments must be made if the user desires to use the TIDA-01373 device to program the DRV10983, DRV10975, or DRV10987 devices, for which more information can be found in the TIDA-01373 *Quick Start Users Guide* [4].

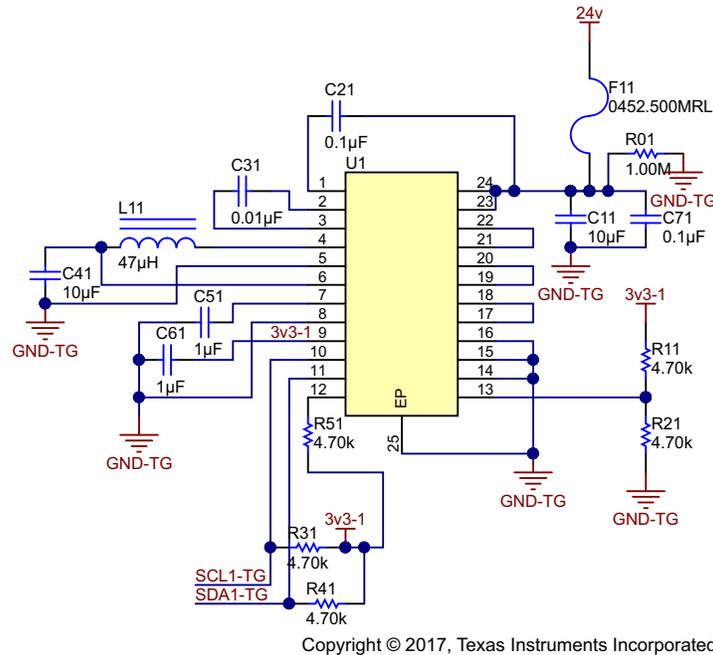


Figure 14. DRV10983-Q1 Socket Schematic

This schematic follows the design guidelines in the DRV10983-Q1 data sheet [3].

3.1.2 Software

The software consists of fourteen C source files (.c), all of which work together to complete the three functions of the TIDA-01373 device. The three functions are as follows:

1. Read the desired EEPROM values back to the user from the edited header file.
2. Read the eight DRV10983, DRV10975, DRV10983-Q1, or DRV10987 device EEPROM registers and compare them to the desired EEPROM values from the edited header file.
3. Program the eight DRV10983, DRV10975, DRV10983-Q1, or DRV10987 device EEPROM registers with the desired EEPROM values from the edited header file.

To get started using the software, see the TIDA-01373 *Quick Start Users Guide* [4].

To learn more about programming the DRV10983-Q1, see the *DRV10983-Q1 Programming Guide*.

3.2 Testing and Results

3.2.1 Test Setup

1. Power to programming board: USB
2. Power to socket board: 12-V wall socket

3.2.2 Test Procedure

1. Set switches to proper settings designated in the *Quick Start Users Guide* [4]
2. Capture the following waveforms in [Section 3.2.3](#) of the different power rails to indicate proper start-up
 1. 5 V (programming board) see [Figure 15](#)
 2. 3V3 (programming board) see [Figure 16](#)
 3. VSource (socket board) see [Figure 17](#)
 4. 24 V (socket board) see [Figure 18](#)

3.2.3 Test Results

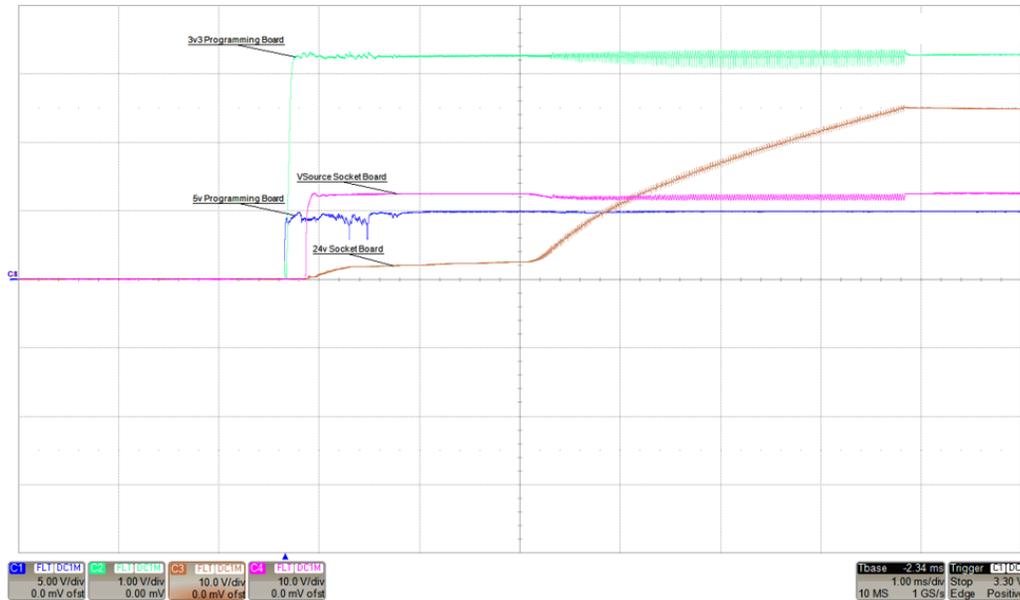


Figure 15. Start-up Overview

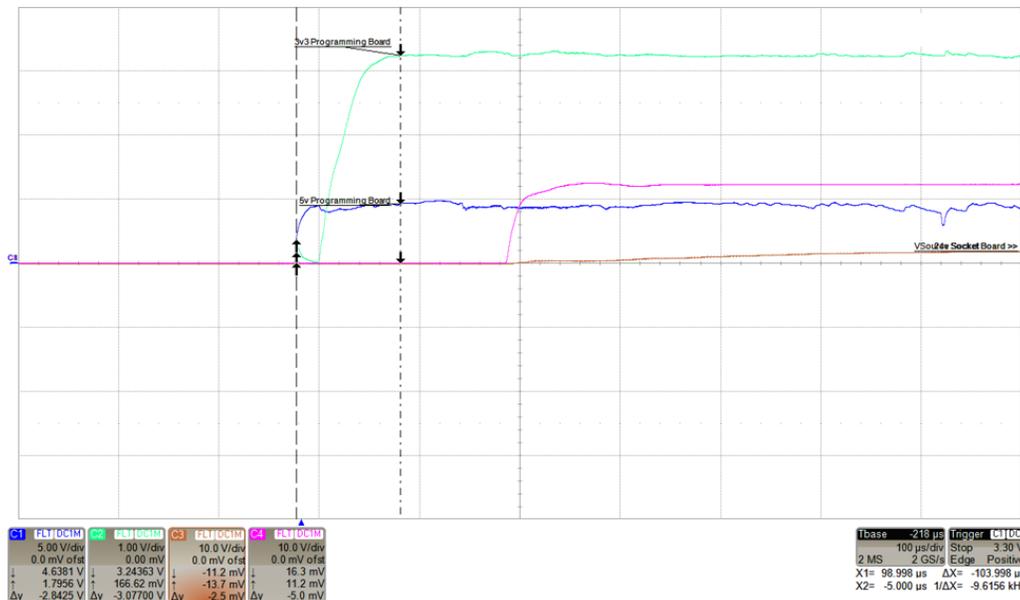


Figure 16. 3V3 Programming Board Start-up Time: 104 μ s

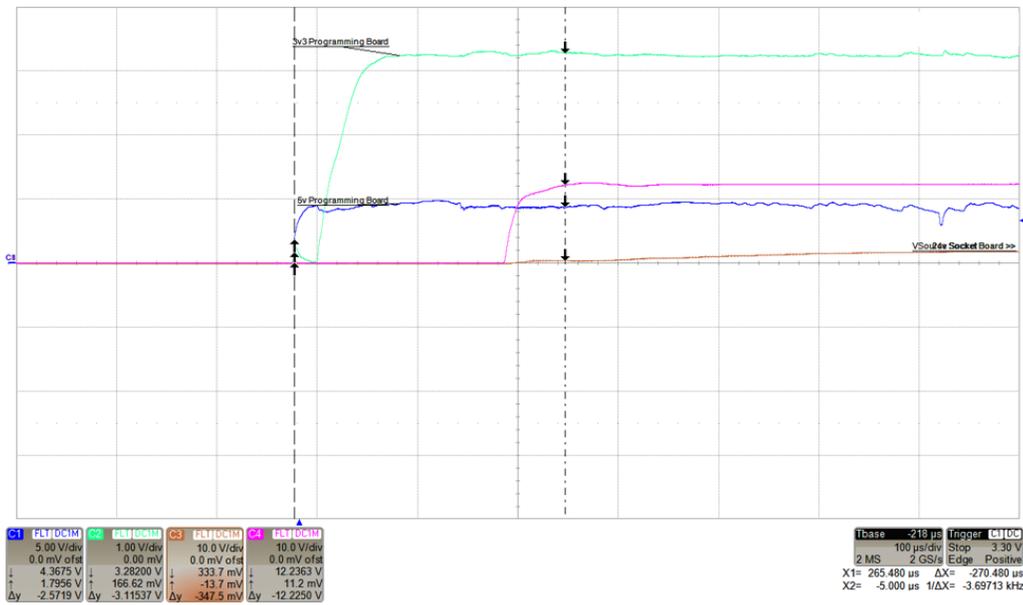


Figure 17. VSource Socket Board Start-up Time: 270 μ s

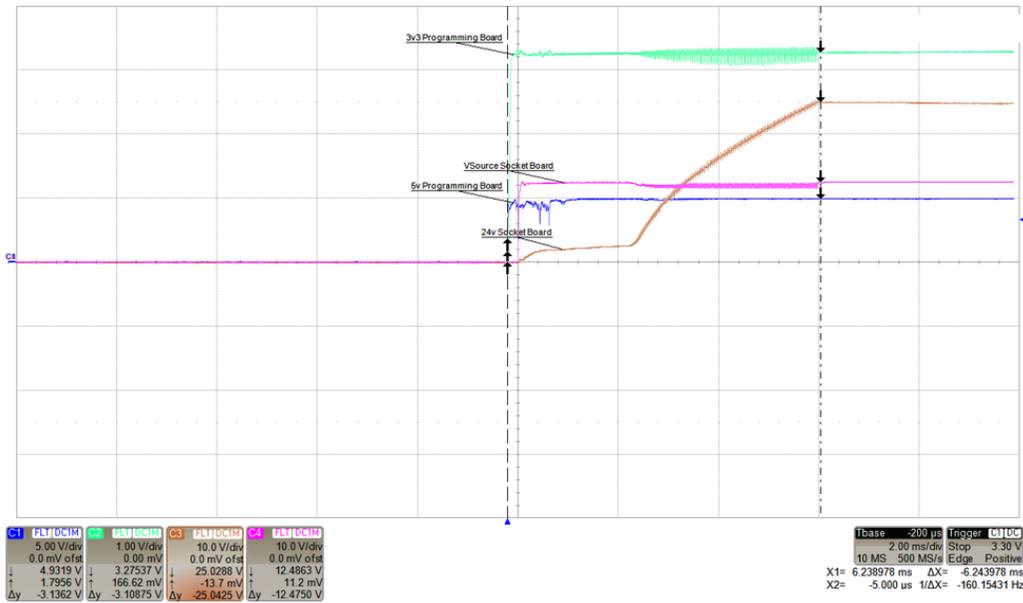


Figure 18. 24-V Socket Board Startup Time: 6.24 ms

4 Design Files

4.1 Schematics

To download the schematics, see the design files at [TIDA-01373](#).

4.2 Bill of Materials

To download the bill of materials (BOM), see the design files at [TIDA-01373](#).

4.3 PCB Layout Prints

To download the layer plots, see the design files at [TIDA-01373](#).

4.4 Altium Project

To download the Altium project files, see the design files at [TIDA-01373](#).

4.5 Gerber Files

To download the Gerber files, see the design files at [TIDA-01373](#).

4.6 Assembly Drawings

To download the assembly drawings, see the design files at [TIDA-01373](#).

5 Software Files

To download the software files, see the design files at [TIDA-01373](#).

6 Related Documentation

1. Texas Instruments, [DRV10983 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver](#), DRV10983 Data Sheet (SLVSCP6)
2. Texas Instruments, [DRV10975 12-V, Three-Phase, Sensorless BLDC Motor Driver](#), DRV10975 Data Sheet (SLVSCP2)
3. Texas Instruments, [DRV10983-Q1 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver](#), DRV10983-Q1 Data Sheet (SLVSD14)
4. Texas Instruments, [DRV10987 12- to 24-V, Three-Phase, Sensorless BLDC Motor Driver](#), DRV10987 Data Sheet (SLVSE89)
5. Texas Instruments, [Quick Start User's Guide](#), TIDA-01373 User's Guide (SLVUB30)
6. Texas Instruments, [MSP430G2553 Mixed Signal Microcontroller](#), MSP430G2553 Data Sheet (SLAS735)
7. Texas Instruments, [TCA9548A Low-Voltage 8-Channel I²C Switch With Reset](#), TCA9548A Data Sheet (SCPS207)
8. Texas Instruments, [TPS63070 Wide Input Voltage \(2V-16V\) Buck-Boost Converter](#), TPS63070 Data Sheet (SLVSC58)
9. Texas Instruments, [TPD3S014 Current-Limit Switch and D+/D- ESD Protection for USB Host Ports](#), TPD3S014 Data Sheet (SLVSCP4)
10. Texas Instruments, [LP5907 250-mA Ultra-Low-Noise, Low-IQ LDO](#), LP5907 Data Sheet (SNVS798)
11. Texas Instruments, [SN74LV4T125 Single Power Supply Quadruple Buffer GATE w/ 3-State Output CMOS Logic Level Shifter](#), SN74LV4T125 Data Sheet (SCLS749)
12. Texas Instruments, [DCP010505B Miniature, 1W Isolated Unregulated DC/DC Converters](#), DCP010505B Data Sheet (SBVS012)
13. Texas Instruments, [ISO1541 2.5 kVrms Isolated Unidirectional Clock, Bidirectional I²C Isolators](#), ISO1541 Data Sheet (SLLSEB6)

14. Texas Instruments, [LM3478x/-Q1 High-Efficiency Low-Side N-Channel Controller for Switching Regulator](#), LM3478/LM3478Q-Q1 Data Sheet (SNVS085)
15. Texas Instruments, [TPD8E003 8-Channel ESD Array For Portable Space-Saving Applications](#), TPD8E003 Data Sheet (SLLSE38)

6.1 Trademarks

MSP430 is a trademark of Texas Instruments.

7 Terminology

ADC— Analog-to-digital converter

BLDC— Brushless DC

DCO— Digitally-controlled oscillator

EEPROM — Electrically erasable programmable read-only memory

ESD— Electrostatic discharge

ESR— Equivalent series resistance

GPIO — General port input output

GND— Ground

JTAG— Joint Test Action Group

LDO— Linear dropout regulator

MOSFET— Metal-oxide-semiconductor field-effect transistor

MCU— Microcontroller

MUX— Multiplexer

PWM— Pulse-width modulation

TVS— Transient voltage suppressor

USB— Universal serial bus

8 About the Author

MICHAEL THOMAS SCHNEIDER is a Motor Driver Applications Associate in the Applications Rotation Program at Texas Instruments, where he is responsible for developing reference design solutions and supporting the DRV10x family of devices. Michael brings to this team his knowledge of mixed signal system level designs as well as electric motor drives in order to continue to build collateral material for the DRV10x family. Michael earned his Bachelor of Science in Electrical Engineering (BSEE) at the University of Texas at Austin.

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (March 2017) to A Revision	Page
• Updated title from <i>DRV10983, DRV10975, and DRV10983Q1 EEPROM Programming Tool Reference Design</i> to <i>DRV10983, DRV10975, DRV10983-Q1, and DRV10987 EEPROM Programming Tool Reference Design</i>	1
• Added DRV10987 to Resources and to overall design to complement DRV10983, DRV10983-Q1, and DRV10975	1
• Added DRV10987 to Highlighted Products	5
• Added DRV10987 data sheet (SLVSE89) to Related Documentation	22

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