Freescale Semiconductor
Application Note

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Design of an Electrically Isolated USB Interface

A How-To Guide

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1 Introduction

In many electronic systems involving motor control or power inversion, very high voltages are being controlled. It is not uncommon if these levels are in the hundreds of volts. The systems are controlled by a microprocessor that typically runs at under 5 volts.

During the development stage, a personal computer is attached to the MCU system to program and debug the code. Some form of isolation between the MCU system and the PC would be desirable as this can often be a quite dangerous situation.

Other applications may also involve medical systems where isolation between the electronic medical apparatus and the PC is desirable, and is often the case, mandatory.

This How-To document describes a galvanometric USB adapter that isolates the USB port of a PC from the target system, thus protecting the PC from potential damage from high voltages.

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Figure 1. Prototype Isolated USB Interface

2 Overview

Figure 2 shows USB Isolated Board System.

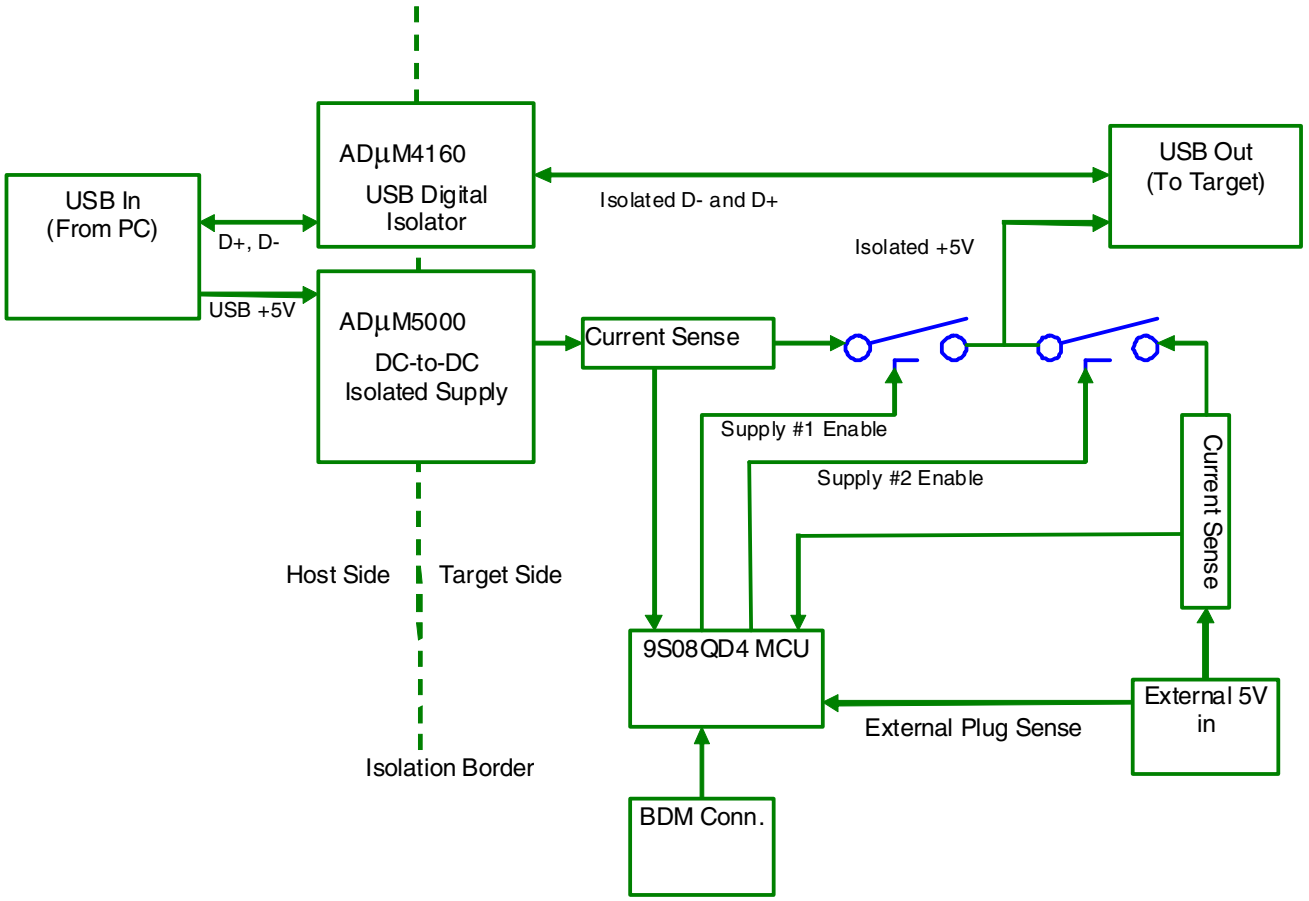

Figure 2. USB Isolated Board System

The dotted line represents the galvanometric border between the two halves of the power supplies. The left side attaches to a PC and the right side attaches to the target system, which might contain high voltages.

The two LEDs that indicate the selected power source are not shown.

The USB isolation is performed by an Analog Device ADμM4160 Full/Low Speed USB Digital Isolator. This device provides up to 5000V RMS isolation.

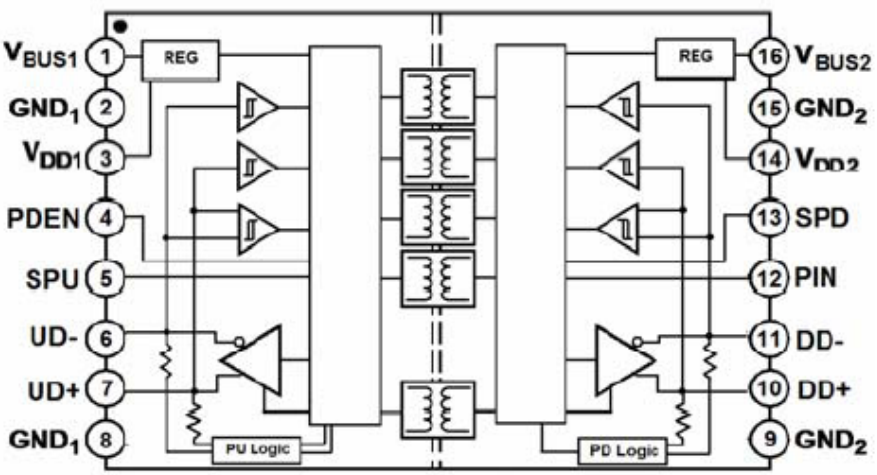

Figure 3. ADμM4160

Power is provided by two sources. One is the PC side USB. In this case, an Analog Device ADμM5000 Isolated DC-to-DC Converter is used. This converter provides up to 100mA of current to the target. Since the USB specification supports 500mA of current, a second power supply is available which is provided by an external 5V source.

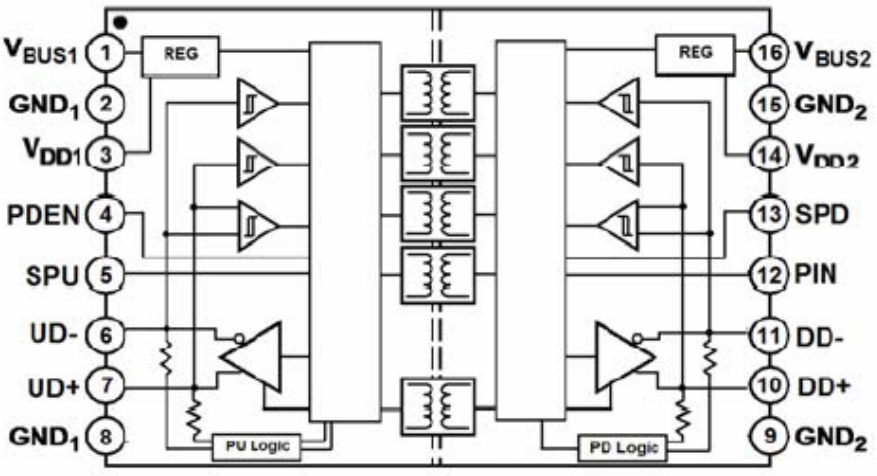

Figure 4. ADμM5000

A Freescale MC9S08QD4 8-bit microcontroller is used to control which power source is used. It also monitors the current provided by both power sources and shuts down the isolated power supply if the cur-

rent exceeds 100mA, and disables the external supply if the current exceeds 500mA.

Normally, the ADµM5000 provides power to the MCU and up to 100mA of current to the isolated USB jack. When a +5V external power is connected via the jack, the MCU senses the voltage, disables power from the ADµM5000 and switches to the external power source.

3 Operating Instructions

All the electronics and connectors are mounted on a small double-side printed circuit card.

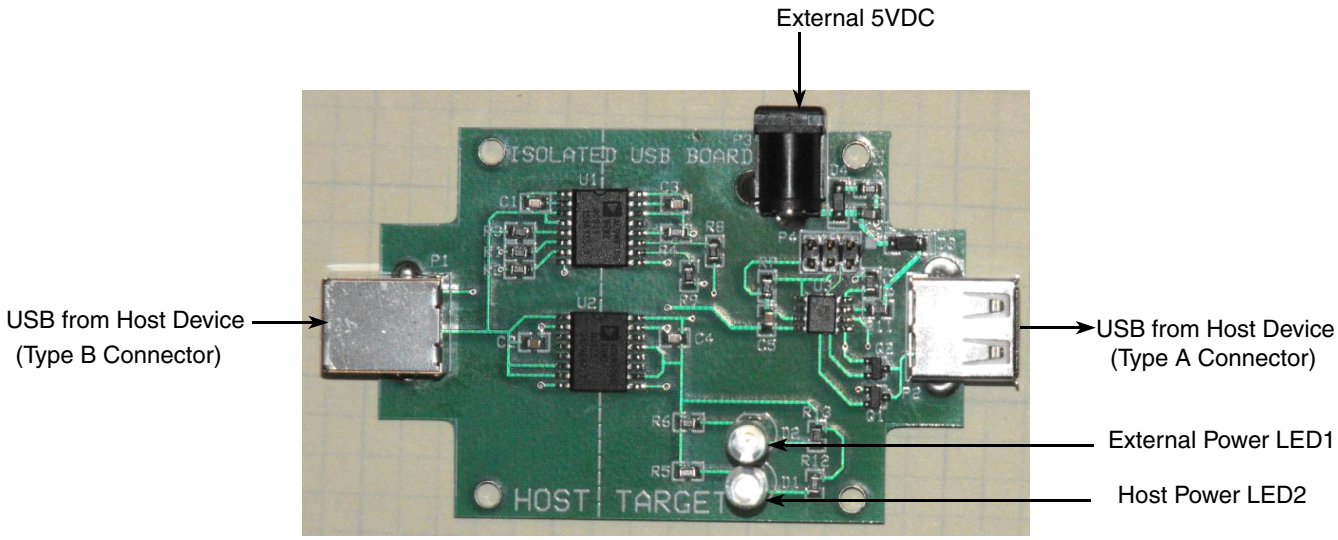

Figure 5. Operating Instructions For USB Isolated Board

The device is powered by one of two sources:

1. Power from external 5 VDC supply and is indicated by LED1. (limit of 500mA).
2. Power from Host USB and is indicated by LED2 (limit of 100mA).

NOTE

Both LEDs are never allowed to be on at the same time.

The 9S08QD4 microprocessor monitors both sources and automatically selects the preferred source.

The power provided by the host is electrically isolated and is limited to approximately 100mA. If this current is exceeded, the system will shut down and reset. If the over-current condition continues, then the LED will go on and off approximately once every three seconds. This is a fault condition and should be avoided.

If more than 100mA is required by the slave device, then it is must to use an external power supply. To insure electrical isolation between the host and slave, make certain that the 5V source is provided by the slave side.

NOTE

When running on power provided by host, there are cases when a device is improperly powered and Windows reports a problem. The common reason for this is that the USB port may be a hub device. This is common with lap top PCs. Try using another USB port or use an external +5 VDC source.

NOTE

This device only supports USB 2 HS (12 mega-bits-per-second). It is NOT compatible with Full Speed USB FS or Low Speed USB (V1.1 LS)

4 Circuit Description

Refer to schematic in Section Appendix A, “Circuit Schematic.

The PC side USB connector is a Type B (P1). The +5V (VDD Host), ground (Host Gnd), and the two signal lines are routed to the USB Isolation IC (U1) and to the isolated DC-to-DC converter (U2).

The right side two-thirds of the schematic refer to the target side. This has a ground signal (Target Gnd) that is electrically isolated from Host Gnd. U2 provides +5V to the target side (VDD Target) which is electrically isolated from VDD Host.

The isolated D- and D+ outputs from U1 are connected to the target side Type “A” USB connector (P2).

External power is applied to J3. The Zener Diode D4 limits the voltage to approximately 5.1 volts, although it is recommended that a 5V regulated supply be used. It also acts as a protection diode in case the polarity is reversed.

The Schottkey diode D3 offers further protection against reversed polarity. It will drop the input voltage by approximately 400mV and may be removed and replaced by a 0 ohm resistor, if necessary.

Power from either U2 or from the external jack (P3) is supplied to the target USB connector by two p-channel MOSFETs (Q1 & Q2) manufactured by International Rectifier (IRLML6401). The gates of these MOSFETs are connected to the Freescale MC9S08QD4 MCU. On reset, both of these lines are pulled up to VDD Target via R5 & R6, thereby turning the MOSFETs to an off state. Lowering these lines turns on the corresponding MOSFET and lights up the LED (D1 & D2) to indicate which supply is being used.

Table 1. Power Supply Input to the USB Isolated Board

	Power supply
LED1	Isolated power supply
LED2	External Supply

The current sense resistors, R10 & R11, produce a small voltage drop that can be read by the A/D converter in the MCU.

5 Firmware Flowchart

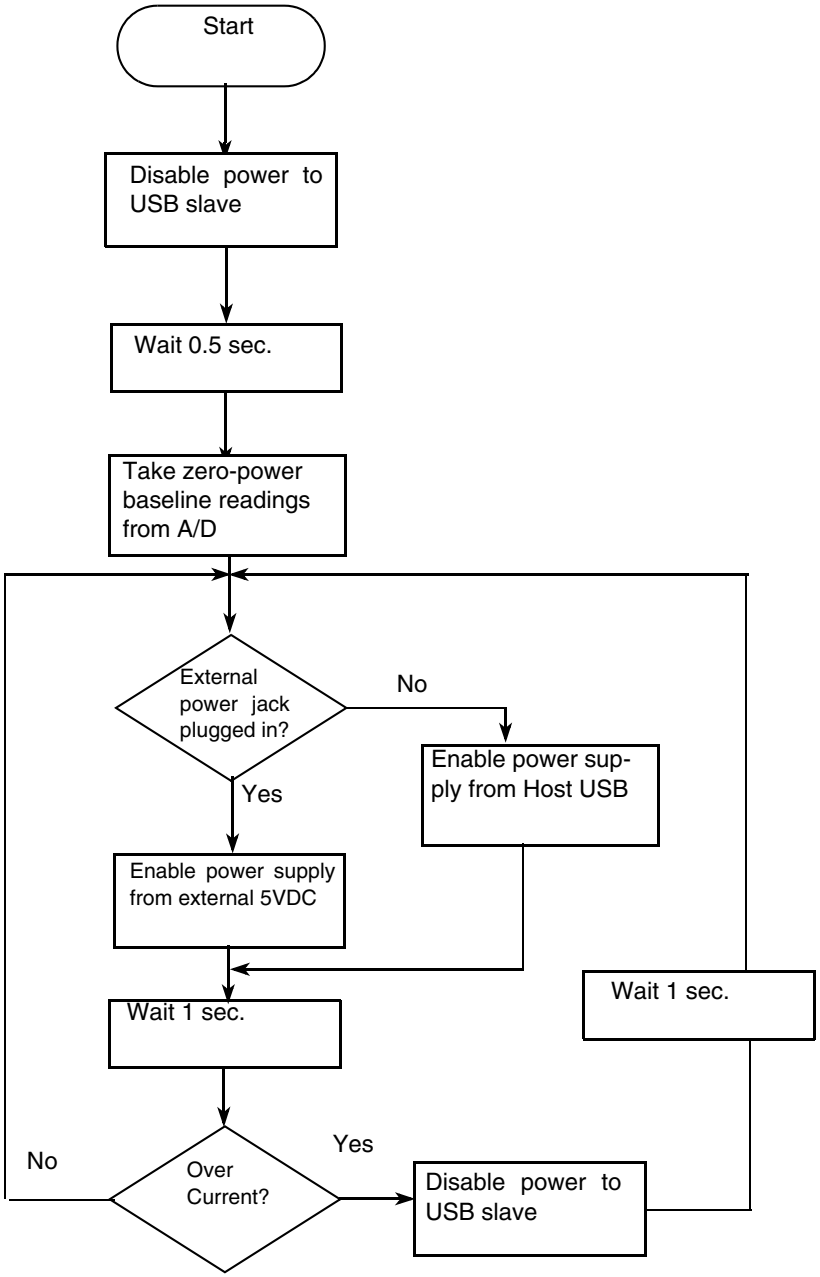

Figure 6. Software Flow for the USB Isolated Board

Appendix A Circuit Schematic

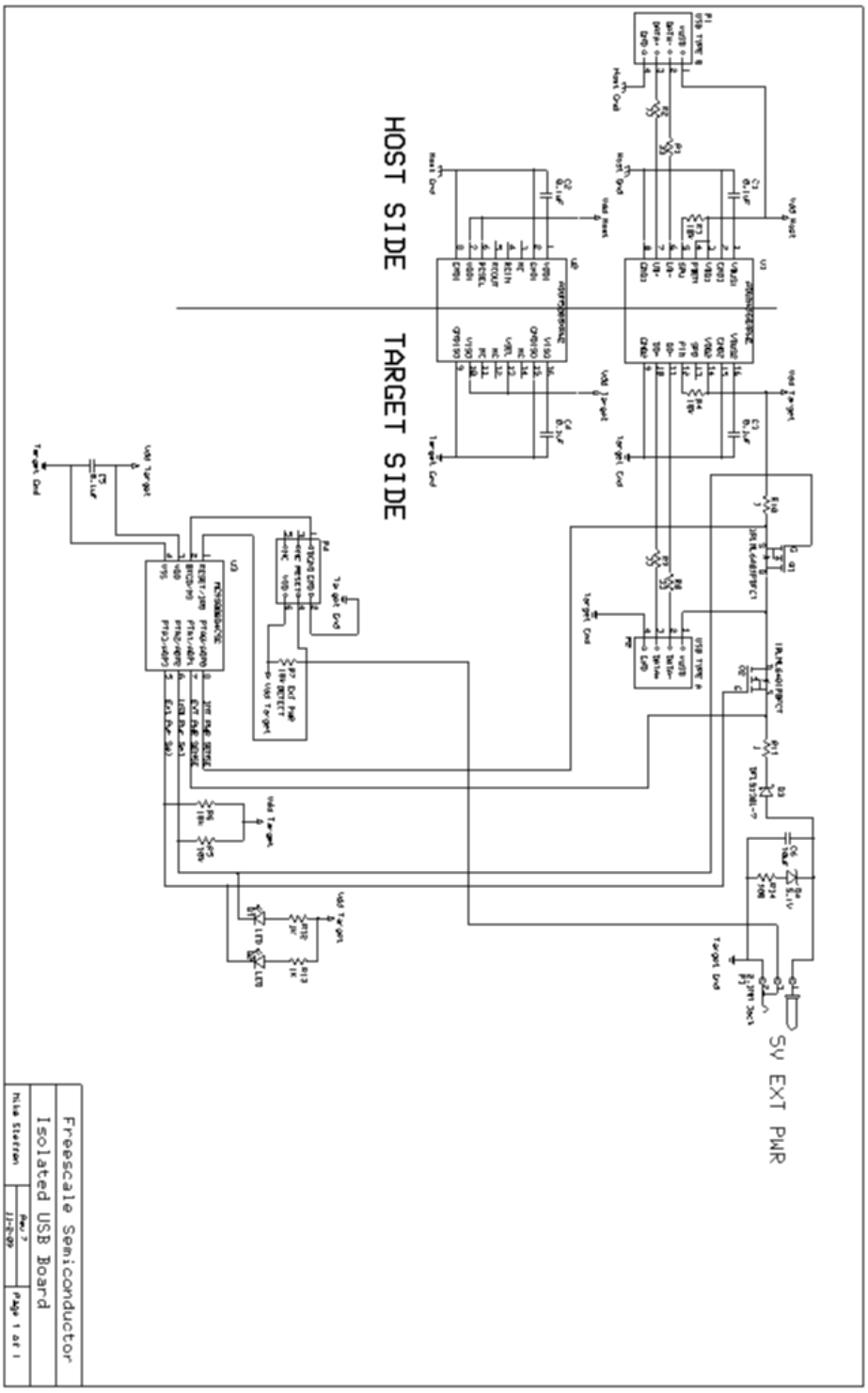

Figure 7. USB Isolated Circuit Board Schematic

Appendix B Circuit Board Layout

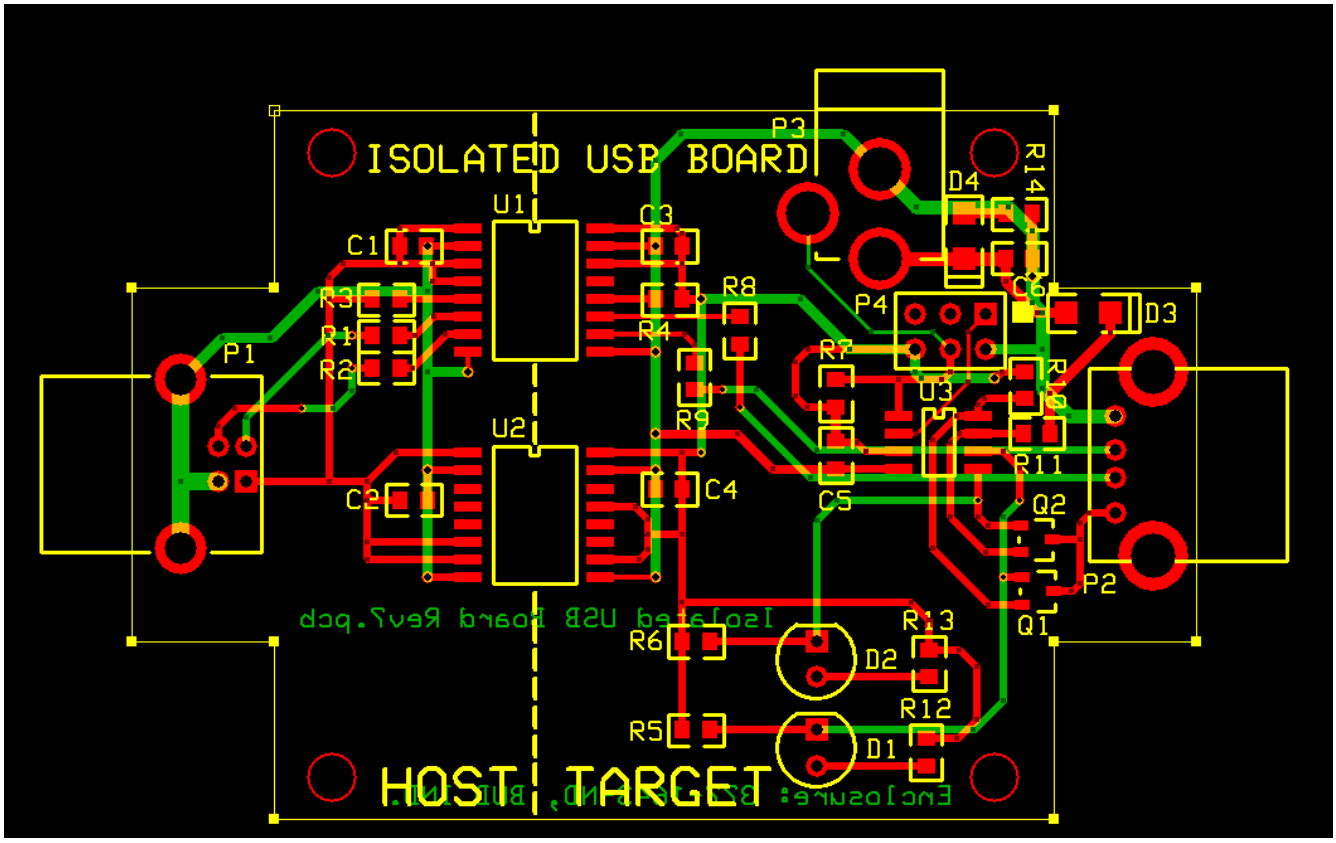

Figure 8. USB Isolated Circuit Board Layout

Appendix C Bill of Materials

Table 2. Bill of Materials

Reference Designator	Value/Description	Part Number (Digikey)
C1	0.1uF	399-1170-1-ND
C2	0.1uF	399-1170-1-ND
C3	0.1uF	399-1170-1-ND
C4	0.1uF	399-1170-1-ND
C5	0.1uF	399-1170-1-ND
C6	10uF	490-3347-6-ND
D1	LED	160-1167-1-ND
D2	LED	160-1167-1-ND
D3	DFLS130L-7	
D4	5.1V	MMSZ4689CT-ND
P1	USB TYPE B	609-1039-ND
P2	USB TYPE A	AE9923-ND
P3	2.1MM Jack	CP-202A-ND
P4		A26528-40-ND
Q1	IRLML6401PBFCT	IRLML6401PBFCT-ND
Q2	IRLML6401PBFCT	IRLML6401PBFCT-ND
R1	33	311-33.0CRCT-ND
R2	33	311-33.0CRCT-ND
R3	10k	311-10KARCT-ND
R4	10k	311-10KARCT-ND
R5	10k	311-10KARCT-ND
R6	10k	311-10KARCT-ND
R7	10k	311-10KARCT-ND
R8	33	311-33.0CRCT-ND
R9	33	311-33.0CRCT-ND
R10	1	P1.0CT-ND
R11	1	P1.0CT-ND
R12	1K	311-1.00KCRCT-ND
R13	1K	311-1.00KCRCT-ND
R14	100	311-100ARCT-ND
U1		ADUM4160XRWZ
U2		ADUM5000XRWZ
U3	Freescale MCU	MC9S08QD4CSC

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