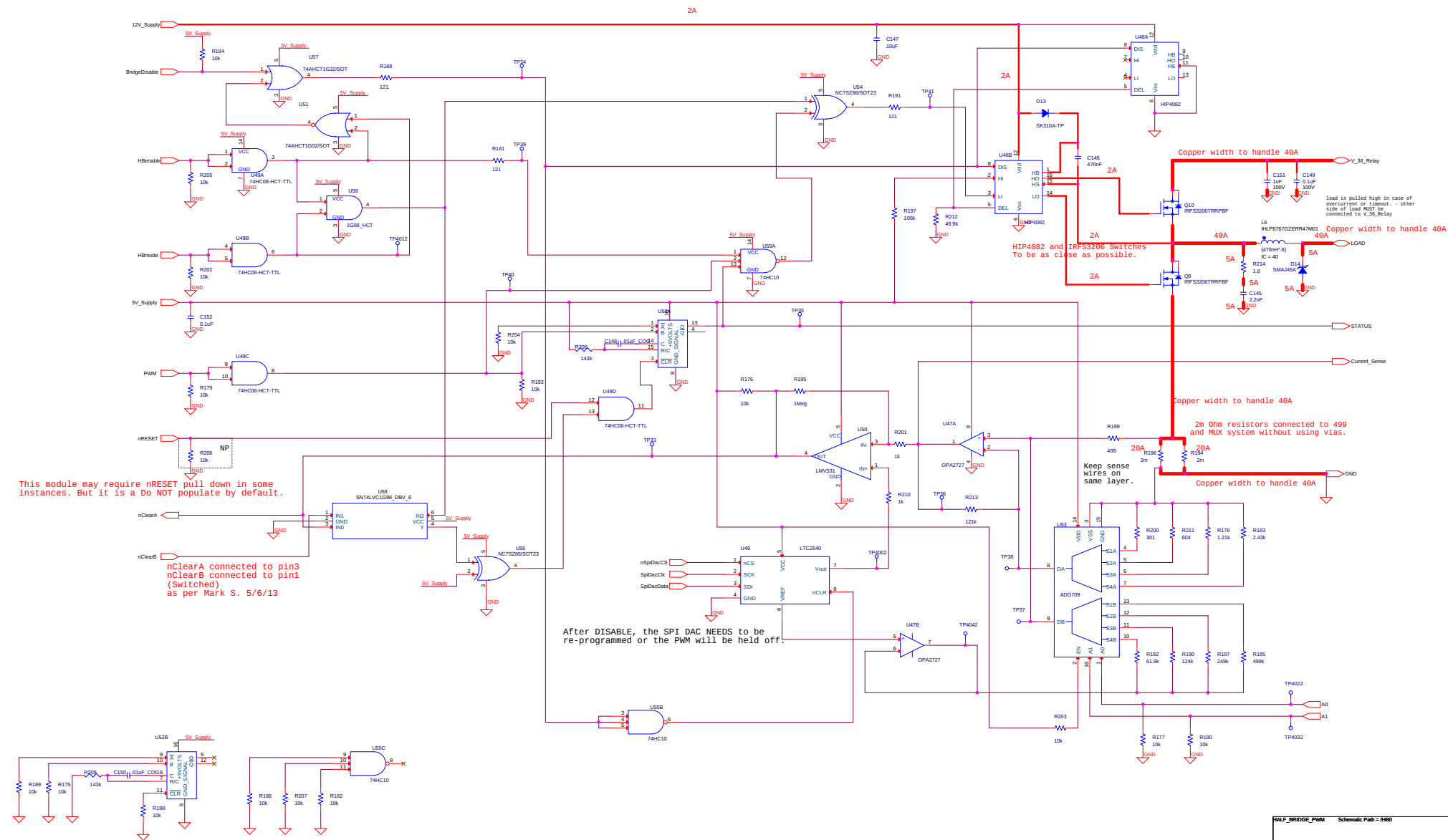
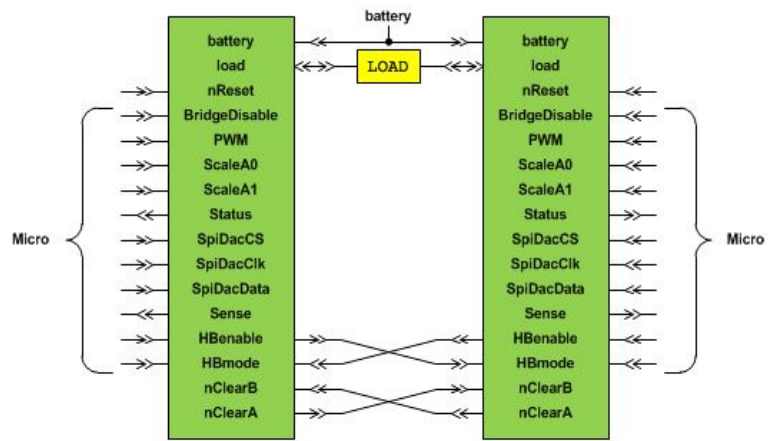


LAYOUT NOTES

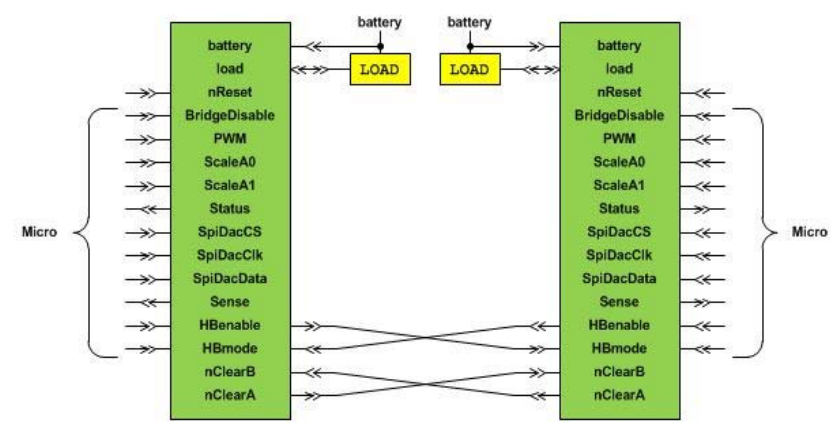
- 1) Cu 250mils wide. ~ 10A capability. Need ~40A capability @ 1 oz Cu. May change for 2 oz Cu.
- 2) All Resistors at 1% Except 1Meg ohm Resistors can be 5% if no 1% available.
- 3) 2m Ohm resistors tied directly to 499 ohms on TOP LEVEL before via to ground. USE MANY VIAS to ground out this node.
- 4) To minimize ringing in the bootstrap circuit, keep the PCB traces from the HIP4082 to the external bootstrap capacitor and MOSFETs as short as possible. The bypass capacitor should be located as close as possible to the IC. Ceramic dielectric is the best choice for bypass and bootstrap capacitors.



APP NOTES

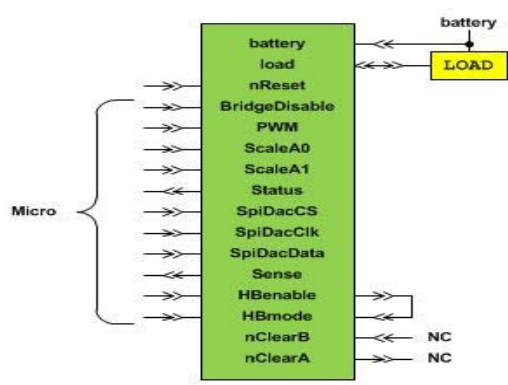


H-Bridge Application



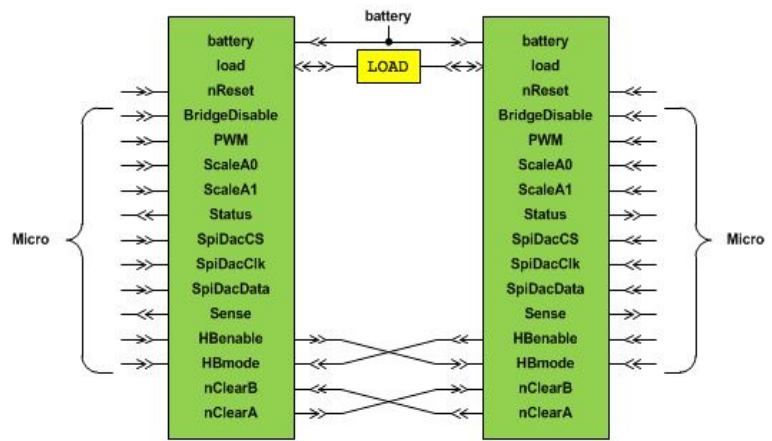
2 Half Bridge Application

Update: BridgeDisable Pull up to 5V to solve Startup issues. 9-19-13

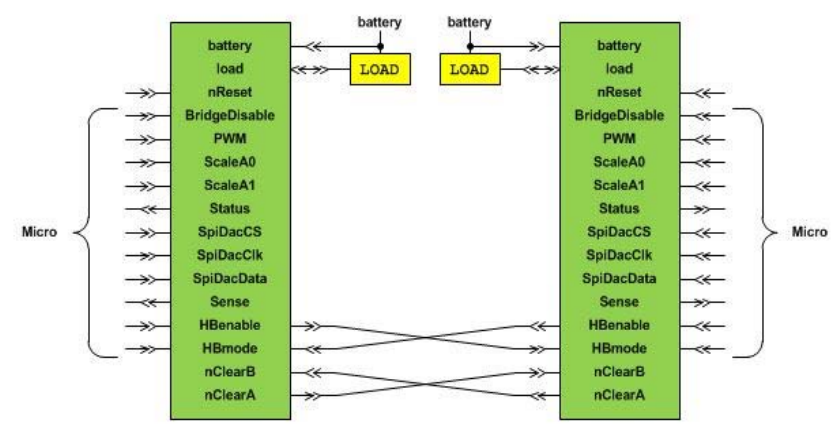


Half-Bridge Application

APP NOTES

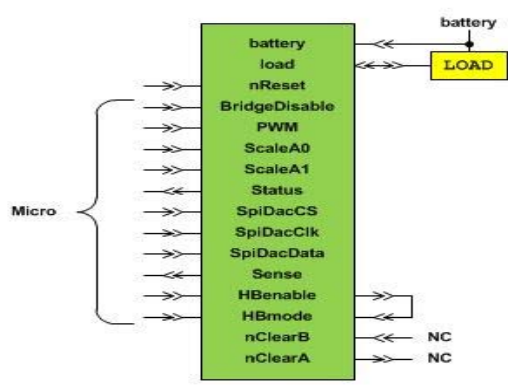


H-Bridge Application



2 Half Bridge Application

Update: BridgeDisable Pull up to 5V to solve Startup issues. 9-19-13



Half-Bridge Application



Rev B - Changes :

- 1) added GND pin to 4 - Power Supplies Page.
- 2) Changed VDD_3V3 to VDD_3p3V on 3Phase Motor Control Page.

Rev C - Changes :

- 1) An issue was found with the off page reference connectors. They were all adjusted to fix this issue
- 2) ACTUATOR_HB0_HBENABLE and ACTUATOR_HB1_HBENABLE replace former ACTUATOR_DIRECTION_A and ACTUATOR_DIRECTION_B pins for Half Bridge
- 3) Populate the CAN 0 Ohm RESISTOR AND 47nF CAPACITOR.
- 4) Changed the Half Bridge Pin nClear A from Bidirectional to Output only.

Rev D - Changes :

- 1) Changed Diodes in Low Side Driver (LSD) circuits to make for better room and routing in layout.

Rev E - Changes :

- 1) JTAG for the 3 Phase Motor Circuit Female PCB connector is compatible with our current tools.

Rev F - Changes :

- 1) JTAG footprints added.
- 2) Resistor duplicate fixed.

Rev G - Changes :

- 1) Correct Reference to the D3 Motor. REV_B

Rev H - Changes :

- 1) Correct pins on Micro

Rev J - Changes :

- 1) Correct pins on Micro
- 2) Corrected Footprints
- 3) Added missing 3.3 to JTAG

Rev K - 4/1/14 Changes :

- 1) fixed diode on sheet 3 D3

TENNANT			
Title			
Thunderbolt: Side Scrub Board			
Size	Document Number	Rev	
C	<Doc>	K	
Date:	Thursday, February 06, 2014	Sheet	1 of 15



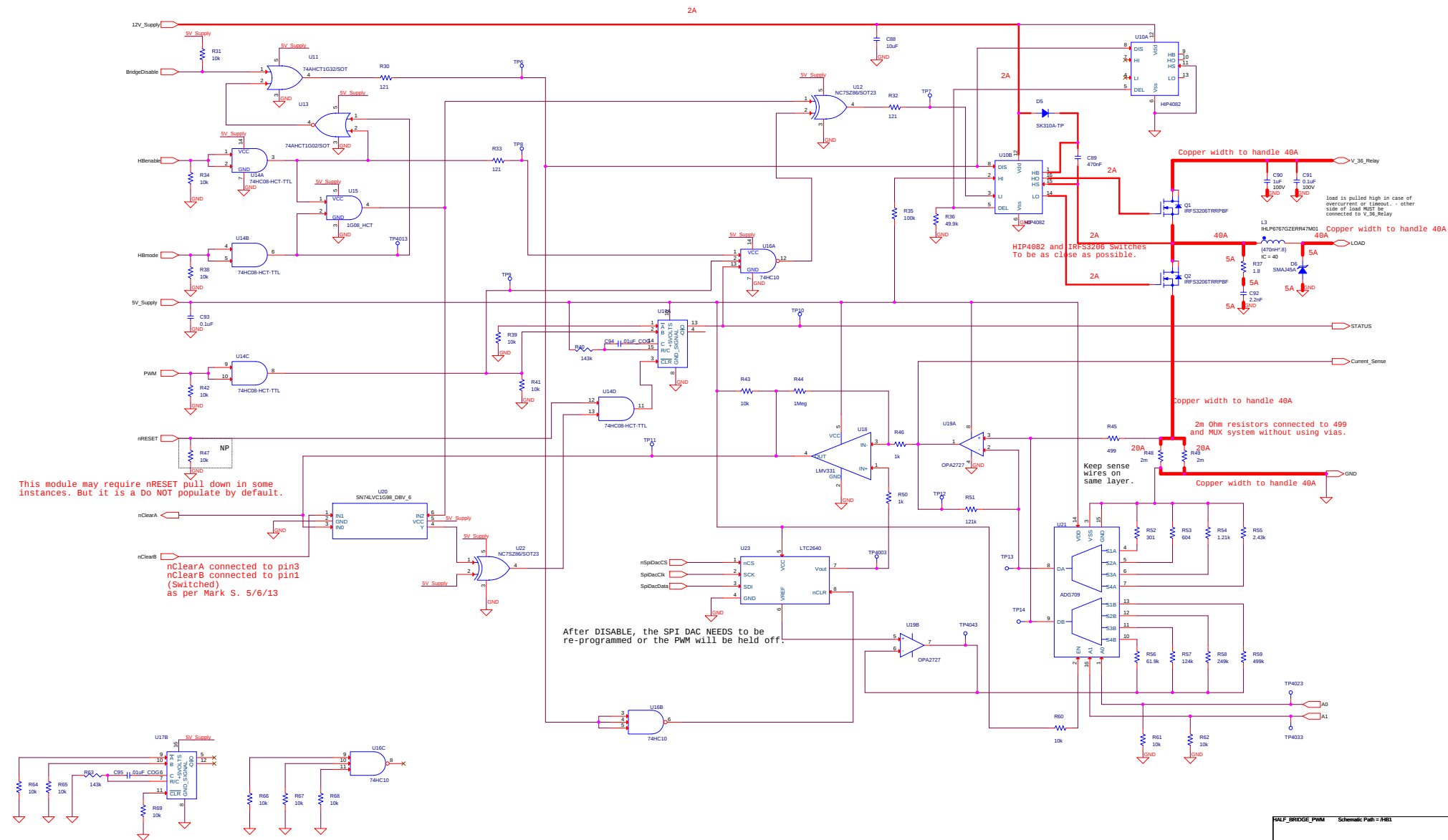
REV_B: Changes -

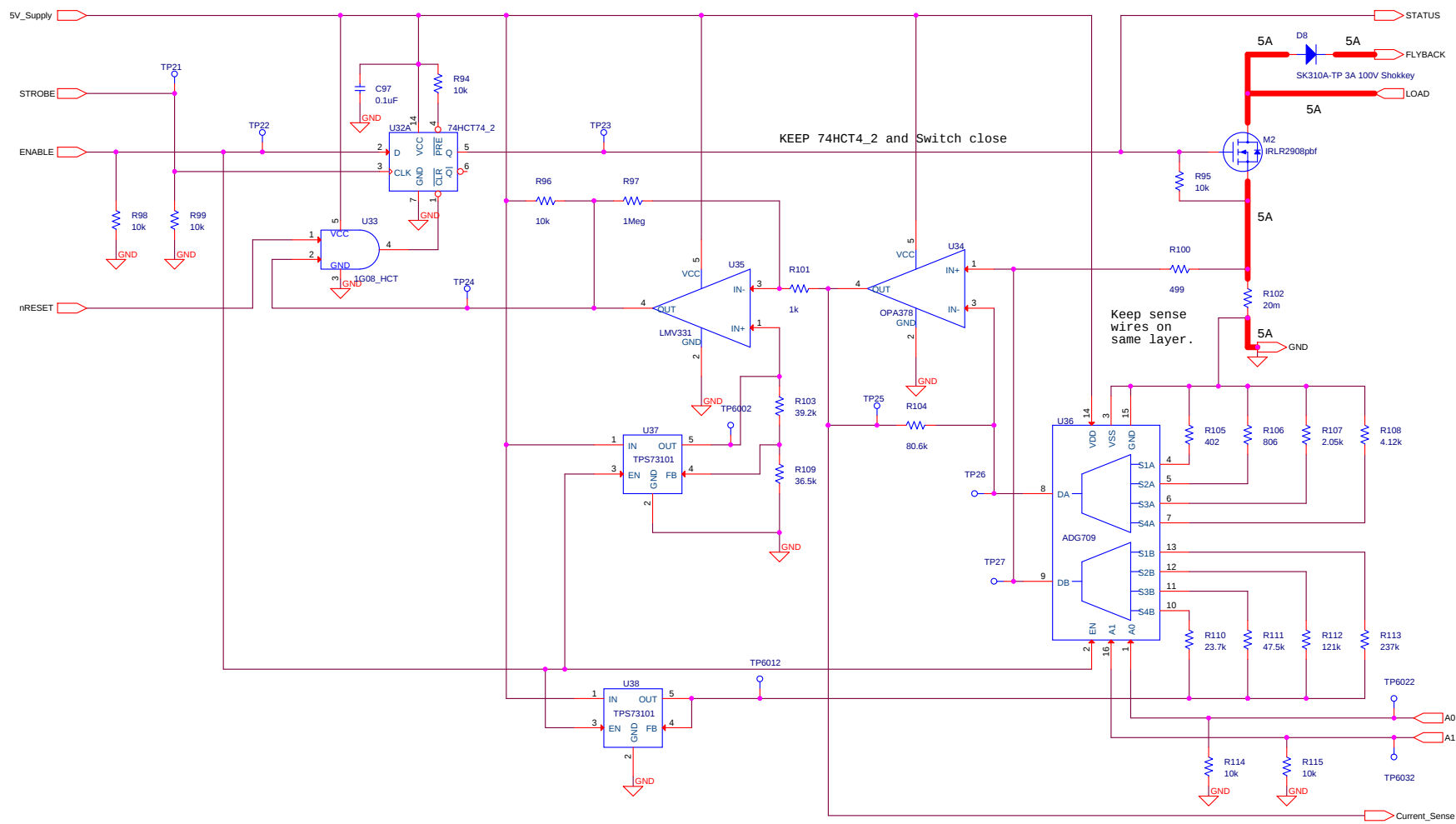
- 1) Removed I2C tie to 3p3V supply. Placed on top levels.
- 2) Switched 2 pins on Current Sense Circuit as per D3 review.
- 3) Changed 10k resistor to 4.99k resistor on Current Sense Circuit as per D3 review.
- 4) Added 1k ohm pull down resistor to Motor Control Circuit as per D3 review.
- 5) Removed the Bulk Capacitors from this design. They are added to the top level.
- 6) Changed Current limit resistor to 6.81k

D3_MOTOR_DRIVE Schematic Path = /BP_MD_1			
TENNANT			
Title Thunderbolt: D3 - COVER			
Size	Document Number	Rev	
C	<Doc>	B	
Date:	Monday, July 08, 2013	Sheet	1 of 15

LAYOUT NOTES

- 1) Cu 250mils wide. ~ 10A capability. Need ~40A capability @ 1 oz Cu. May change for 2 oz Cu.
- 2) All Resistors at 1% Except 1Meg ohm Resistors can be 5% if no 1% available.
- 3) 2m Ohm resistors tied directly to 499 ohms on TOP LEVEL before via to ground. USE MANY VIAS to ground out this node.
- 4) To minimize ringing in the bootstrap circuit, keep the PCB traces from the HIP4082 to the external bootstrap capacitor and MOSFETs as short as possible. The bypass capacitor should be located as close as possible to the IC. Ceramic dielectric is the best choice for bypass and bootstrap capacitors.





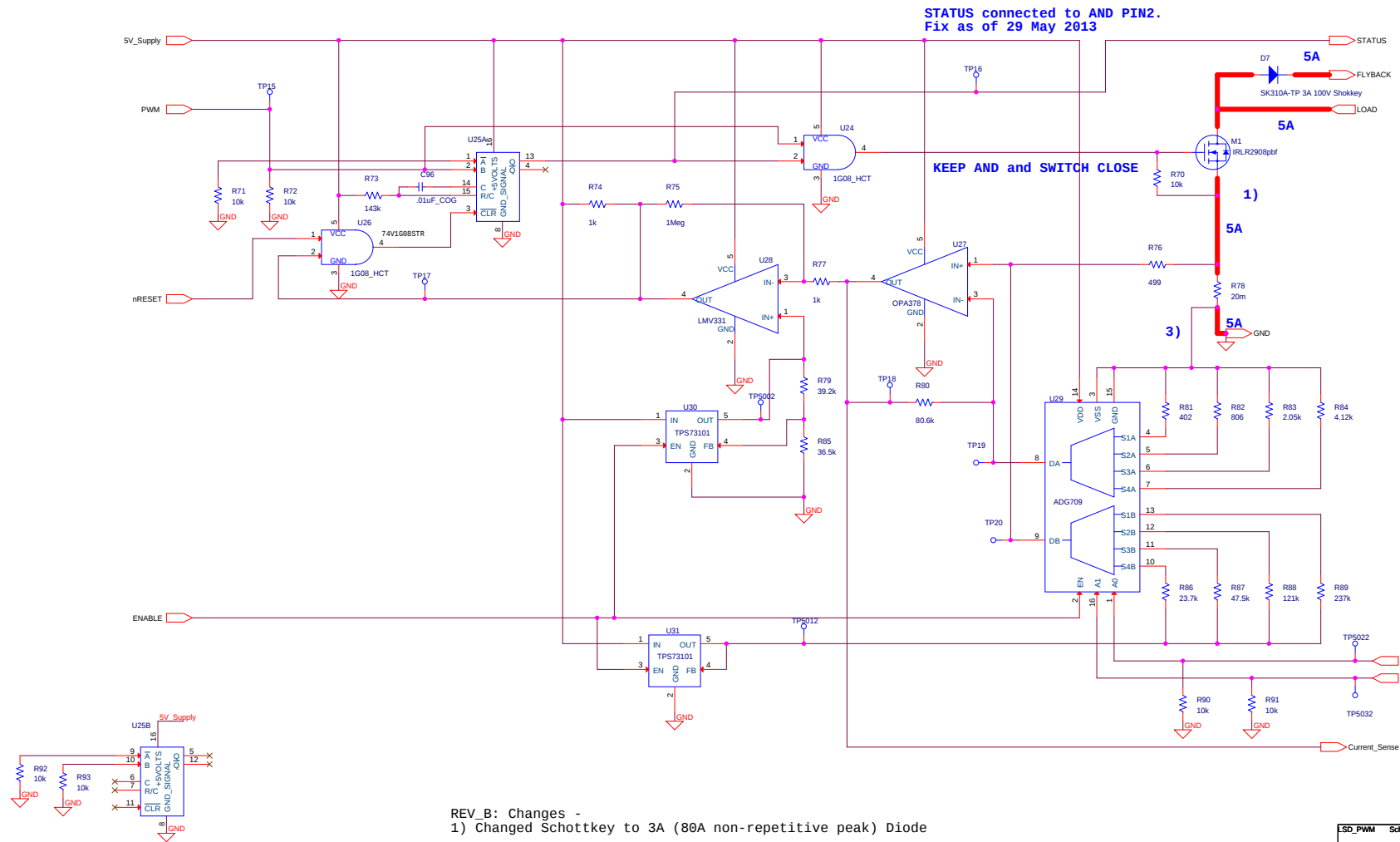
REV_B: Changes -
1) Changed Schottkey to 3A (80A non-repetitive peak) Diode

LS0 Schematic Path = /LS00
Low Side Driver Circuit
<OrigAddr1>
<OrigAddr2>
<OrigAddr3>
<OrigAddr4>

Size	Document Number	Rev
CustomerDoc =		B
Date:	Monday, September 23, 2013	Sheet 1 of 15

LAYOUT NOTES

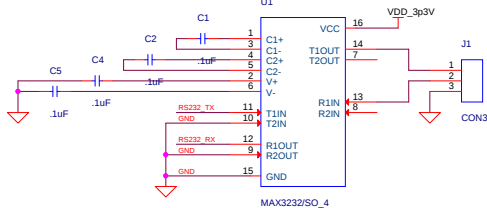
- 1) Cu 250mils wide. ~ 10A capability
- 2) All Resistors at 1% Except 1Meg and 10k ohm Resistors can be 5%
- 3) R5-R8 tied directly to R3 on TOP LEVEL before via to ground. USE MANY VIAS to ground out this node.



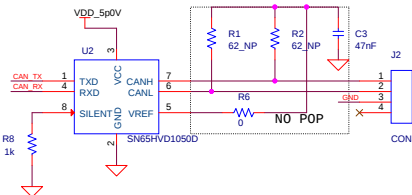
LSD_PWM Schematic Path = /ASDP0	
Low Side Driver with PWM Circuit	
Size	Document Number
Custom	Doc
Date	Thursday, December 05, 2013
Sheet	1 of 15
Rev	B

Thunderbolt Board SIDE SCRUB

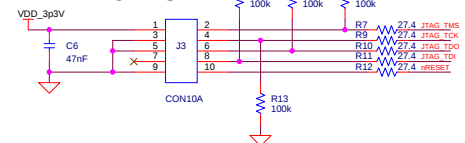
RS-232 SERIAL PORT



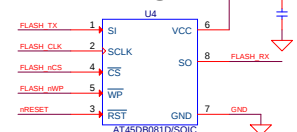
CAN COMMUNICATIONS



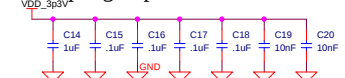
JTAG



FLASH



Decoupling Capacitors for the Micro.



U3A

LM4F232H5QD_PGE_144

U3B

LM4F232H5QD_PGE_144

U3C

LM4F232H5QD_PGE_144

U3D

LM4F232H5QD_PGE_144

U3E

LM4F232H5QD_PGE_144

U3F

LM4F232H5QD_PGE_144

U3G

LM4F232H5QD_PGE_144

U3H

LM4F232H5QD_PGE_144

U3I

LM4F232H5QD_PGE_144

U3J

LM4F232H5QD_PGE_144

U3K

LM4F232H5QD_PGE_144

U3L

LM4F232H5QD_PGE_144

U3M

LM4F232H5QD_PGE_144

U3N

LM4F232H5QD_PGE_144

U3O

LM4F232H5QD_PGE_144

U3P

LM4F232H5QD_PGE_144

U3Q

LM4F232H5QD_PGE_144

U3R

LM4F232H5QD_PGE_144

U3S

LM4F232H5QD_PGE_144

U3T

LM4F232H5QD_PGE_144

U3U

LM4F232H5QD_PGE_144

U3V

LM4F232H5QD_PGE_144

U3W

LM4F232H5QD_PGE_144

U3X

LM4F232H5QD_PGE_144

U3Y

LM4F232H5QD_PGE_144

U3Z

LM4F232H5QD_PGE_144

U3A

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U3B

LM4F232H5QD_PGE_144

U3C

LM4F232H5QD_PGE_144

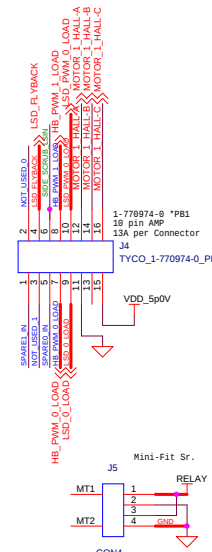
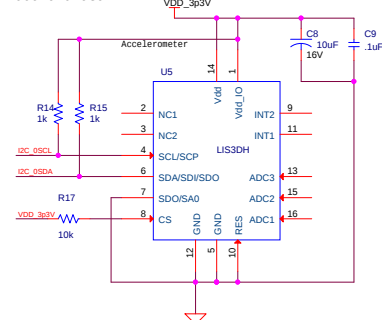
U3D

LM4F232H5QD_PGE_144

U3E

LM4F232H5QD_PGE_144

PLACE HOLDER for Accelerometer



R225 and C160 ADDED 07/03/13 CAH

U3A

LM4F232H5QD_PGE_144

U3B

LM4F232H5QD_PGE_144

U3C

LM4F232H5QD_PGE_144

U3D

LM4F232H5QD_PGE_144

U3E

LM4F232H5QD_PGE_144

U3F

LM4F232H5QD_PGE_144

U3G

LM4F232H5QD_PGE_144

U3H

LM4F232H5QD_PGE_144

U3I

LM4F232H5QD_PGE_144

U3J

LM4F232H5QD_PGE_144

U3K

LM4F232H5QD_PGE_144

U3L

LM4F232H5QD_PGE_144

U3M

LM4F232H5QD_PGE_144

U3N

LM4F232H5QD_PGE_144

U3O

LM4F232H5QD_PGE_144

U3P

LM4F232H5QD_PGE_144

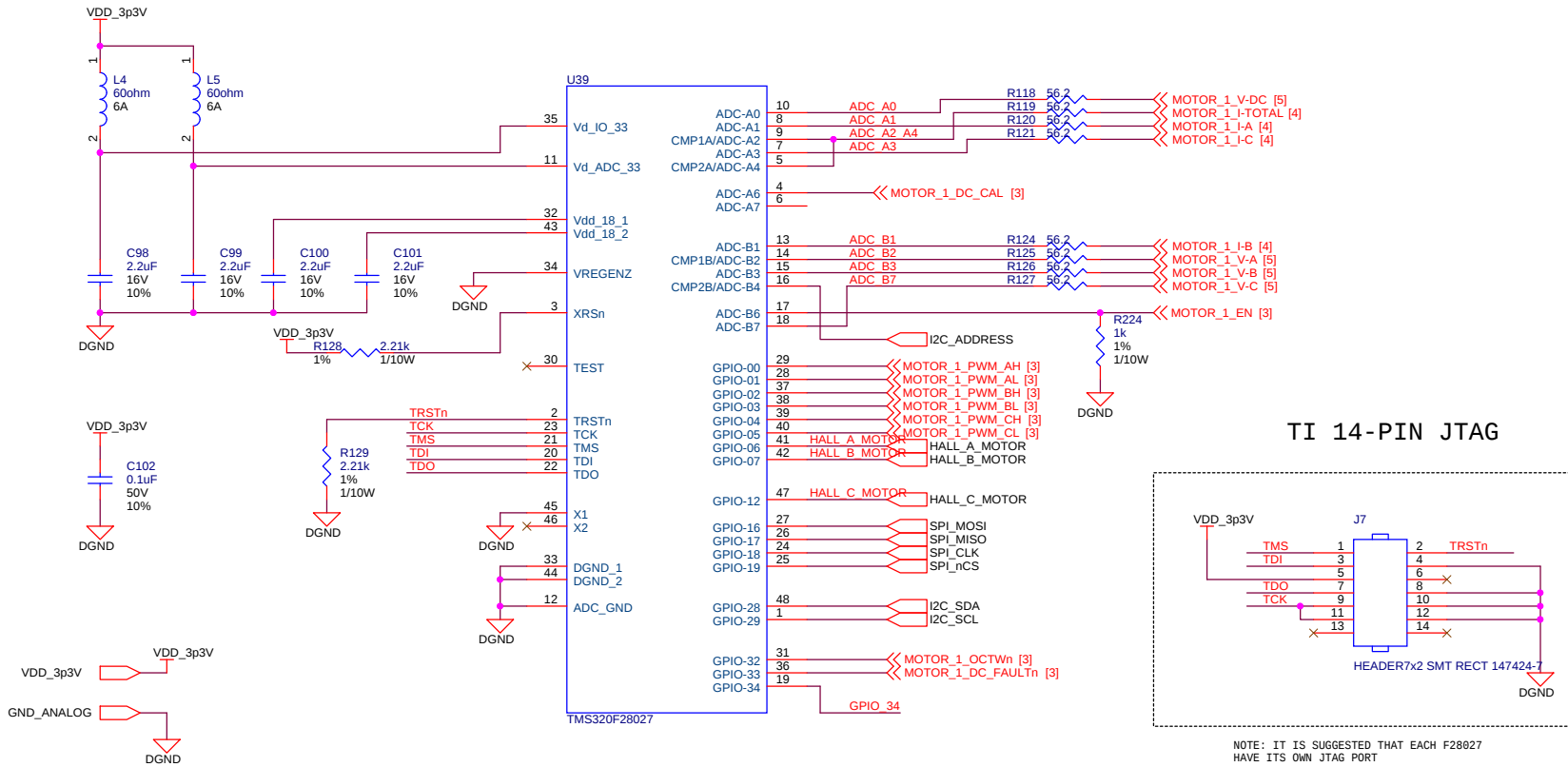
U3Q

LM4F232H5QD_PGE_144

TENNANT			
File	Thunderbolt: Side Scrub Board		
Size	Document Number		Rev K
Customer Doc#			
Date	Thursday, February 06, 2014	Sheet	2 of 15

Thunderbolt Board

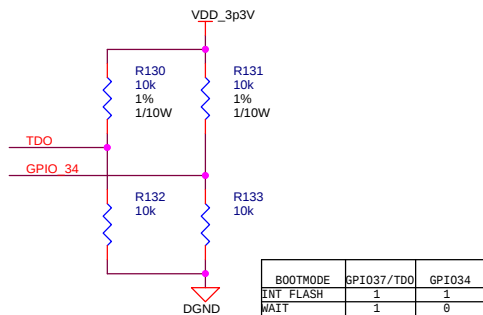
3-Phase Motor Control



TI 14-PIN JTAG

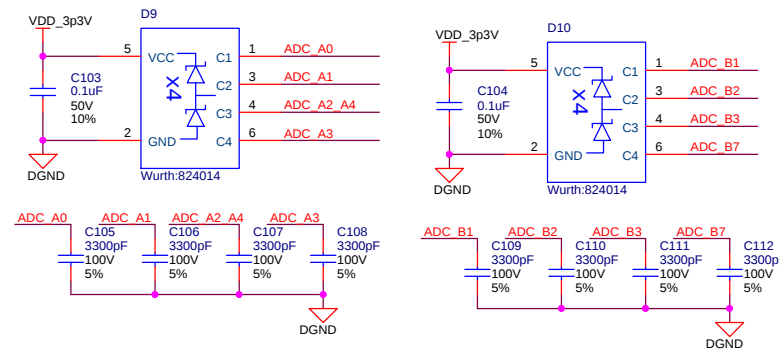
NOTE: IT IS SUGGESTED THAT EACH F28027 HAVE ITS OWN JTAG PORT

Boot-mode Selection



NOTE: WAIT STATE IS USED IF DEBUGGING WITH CODE SECURITY TURNED ON IS NEEDED

NOTE: JTAG WILL ASSERT TRSTn PIN TO ENTER EMU BOOT MODE (SEE PAGE 24 OF 28027 DATASHEET)



D3_MOTOR_DRIVE Schematic Path = /3P_MD_1

TENNANT

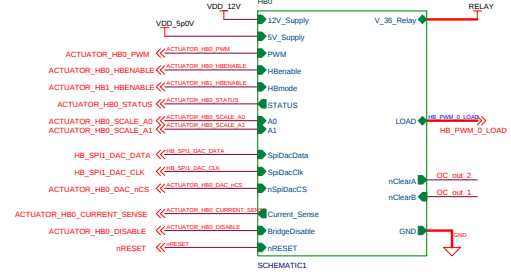
Title
Thunderbolt: D3 - MOTOR CONTROL DSP

Size Document Number
Custom<Doc>

Rev
B

Date: Wednesday, September 25, 2013 Sheet 2 of 15

The diagram shows a 12V input connected to a 3.3V regulator. The output of the regulator is connected to the VDD_3p3V pin of the relay module. The relay module also has pins for RELAY, VDD_5p0V, and GND.



NOTE: GROUND RETURN PATHS ON AVDD, GVDD, DVDD
ARE VERY IMPORTANT. SEE TI APP NOTE: SLVA552



Thunderbolt Board 3-Phase Gate Drive

GAIN: (DIFF-AMP GAIN)
LOW = 10V/V
HIGH = 40V/V

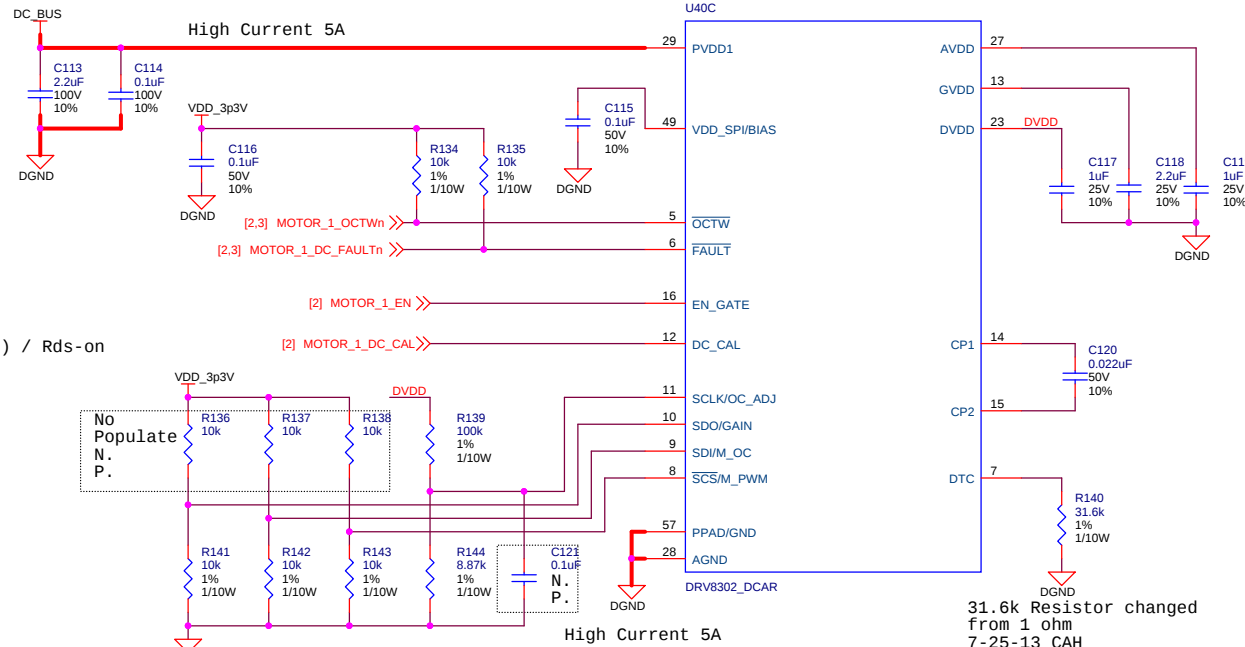
M_OC: (OVER-CURRENT PROTECTION)
LOW = CYCLE-BY-CYLCE
HIGH = LATCHED FAULT

M_PWM: (PWM MODE)
LOW = 6 - INPUT
HIGH = 3 - INPUT

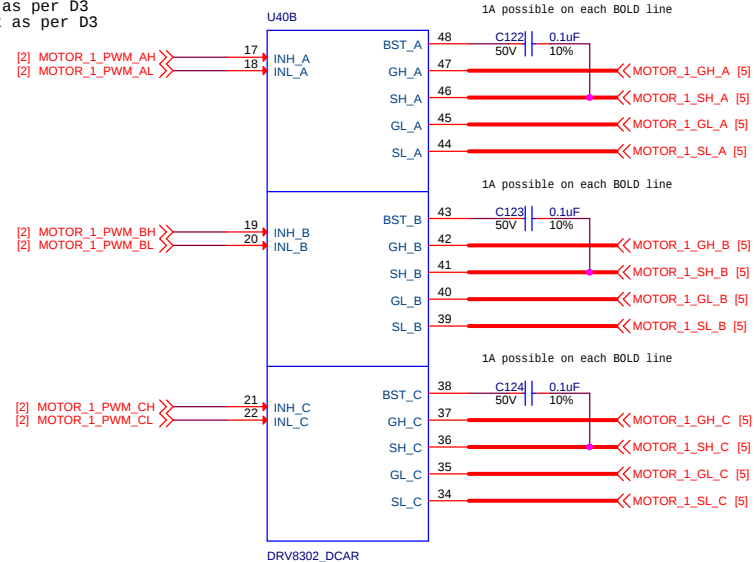
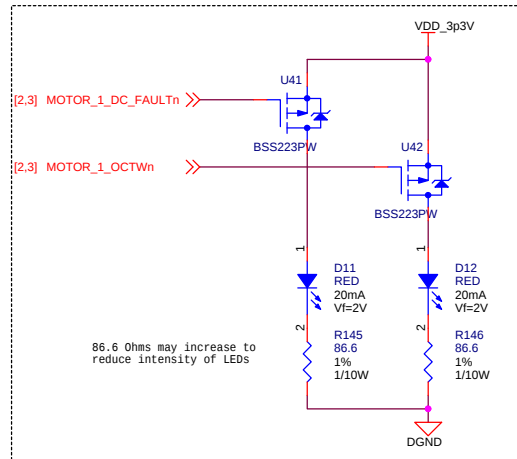
DVDD = 3.3V

M_OC = $(3.3V (19.6k / (100k + 19.6k))) / R_{ds-on}$

NOTE: GROUND RETURN PATHS ON AVDD, GVDD, DVDD
ARE VERY IMPORTANT. SEE TI APP NOTE: SLVA552



OPTIONAL FAULT INDICATION LEADS



D3_MOTOR_DRIVE Schematic Path = /3P_MD_1

TENNANT

Thunderbolt: D3 - GATE DRIVE

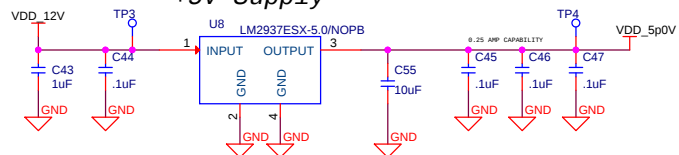
Size Document Number
Custom-Doc>

Rev B

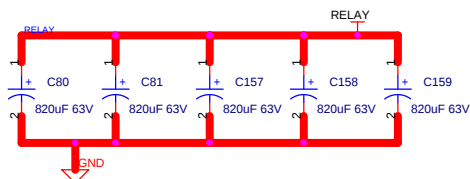
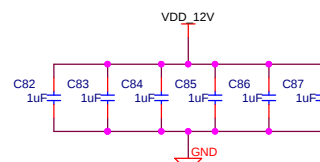
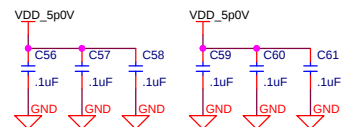
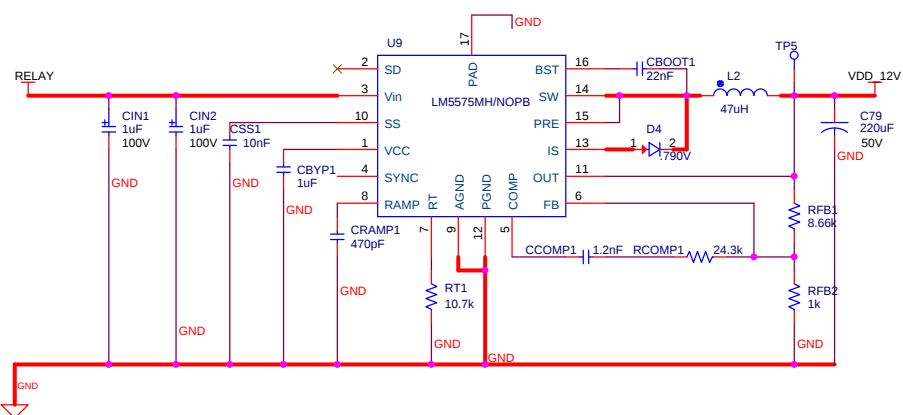
Date: Wednesday, September 25, 2013 Sheet 3 of 15

5V

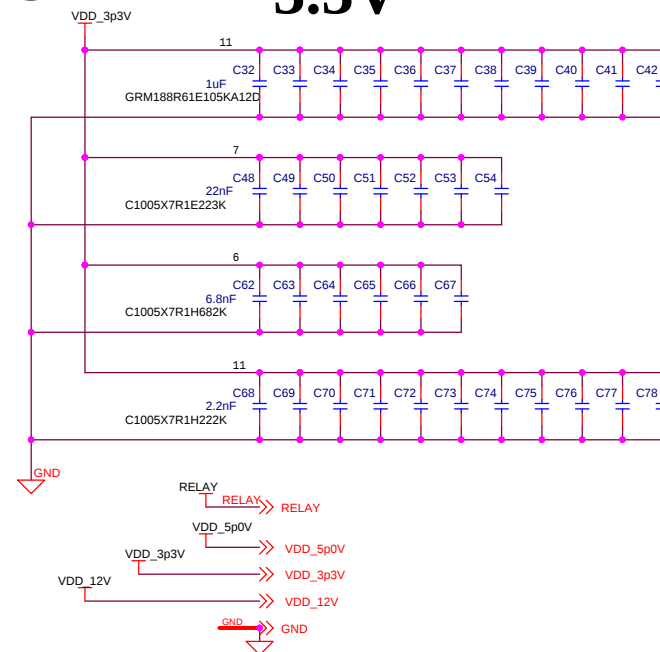
+5V Supply



12.0V



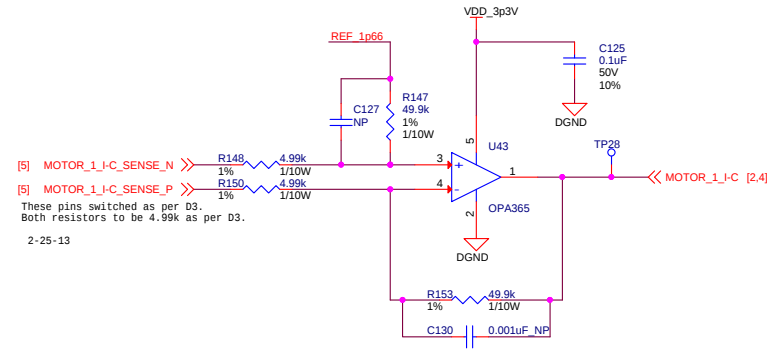
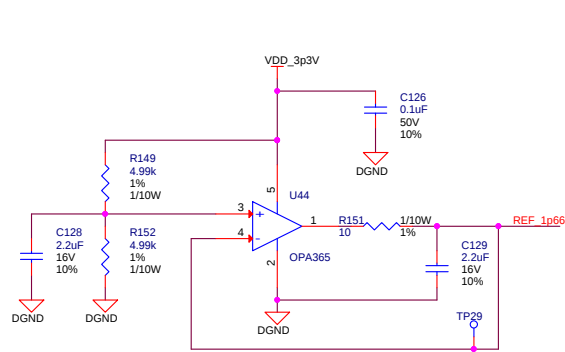
3.3V



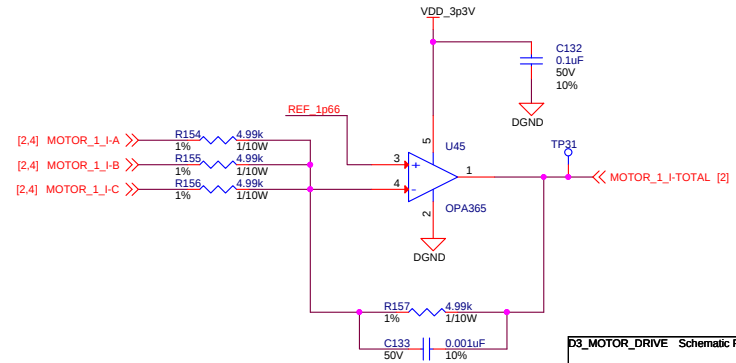
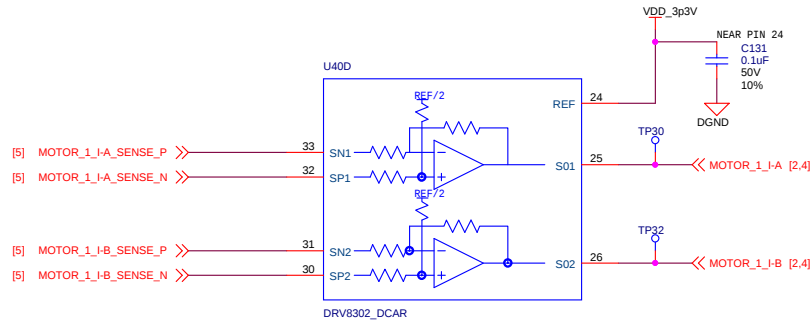
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Title Thunderbolt: Side Scrub Board - Power Supplies			
Size Custom	Document Number <Doc>		Rev K
Date:	Wednesday, May 08, 2013	Sheet	4 of 15

Thunderbolt Board

3-Phase Current Sense



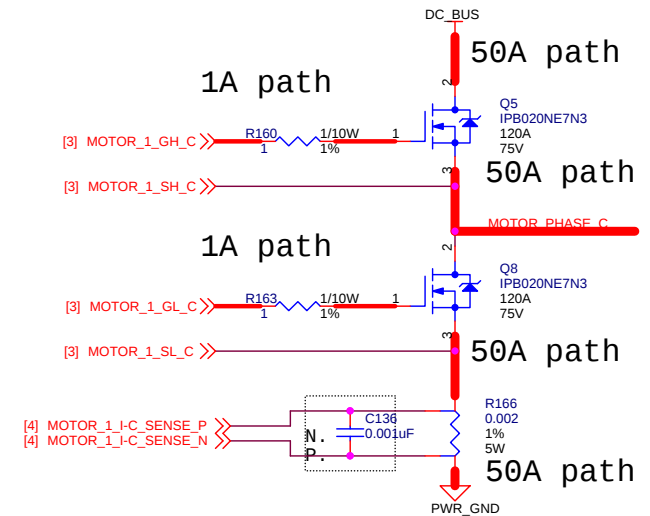
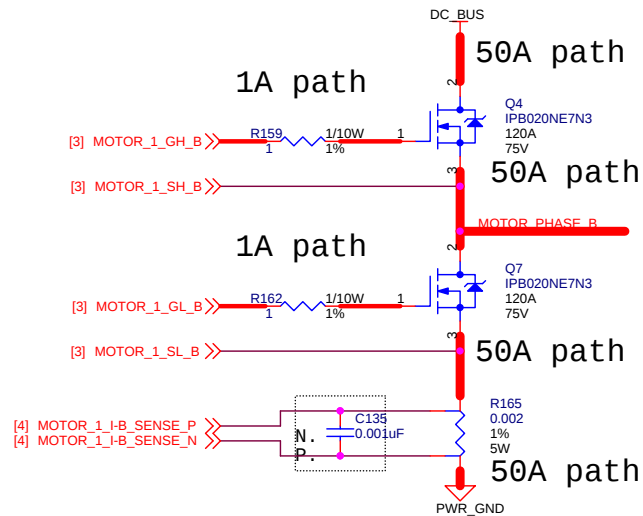
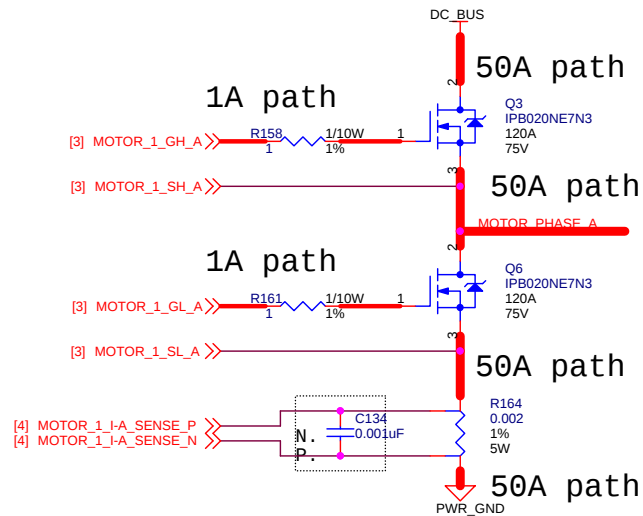
GAIN = 10 V/V



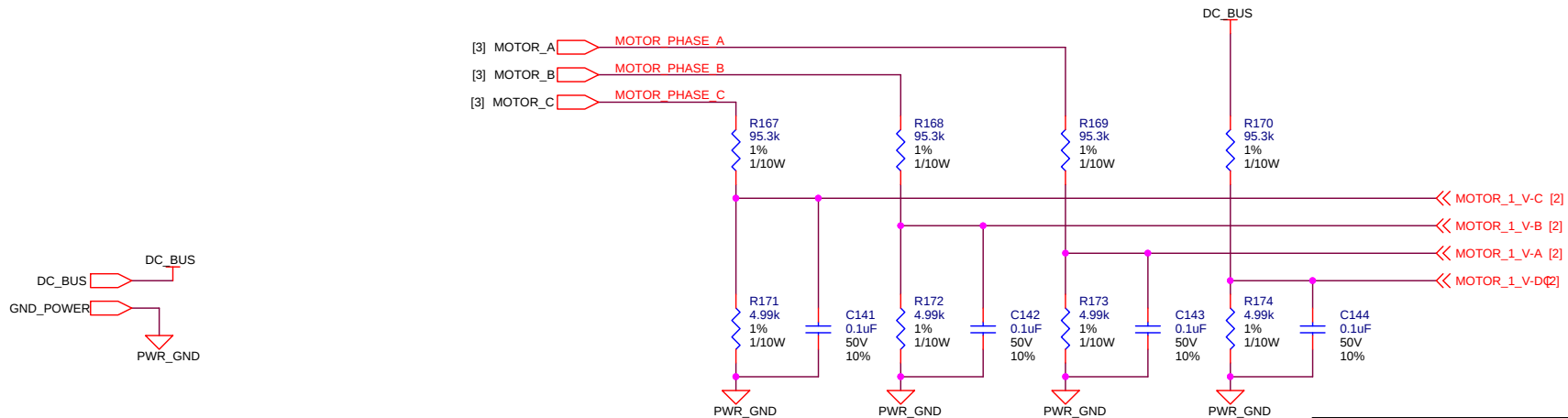
D3_MOTOR_DRIVE Schematic Path = /3P_MD_1			
TENNANT			
Title			
Thunderbolt: D3 - CURRENT SENSE			
Size	Document Number	Rev	
Custom	<Doc>	B	
Date:	Friday, September 20, 2013	Sheet	4 of 15

Thunderbolt Board

3-Phase Motor H-Bridge

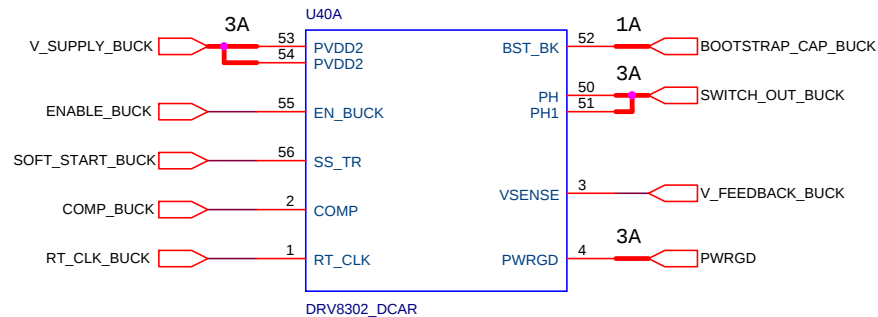


NOTE: KELVIN CONNECTIONS REQUIRED ON SENSE RESISTOR (3) PLCS



D3_MOTOR_DRIVE Schematic Path = /3P_MD_1		
TENNANT		
Title Thunderbolt: D3 - MOTOR H-BRIDGE		
Size Custom	Document Number	Rev B
Date: Friday, September 20, 2013	Sheet 5 of 15	

Can Be turned off



NOTE: DRV8302 HAS THE SAME BUCK
CONVERTER AS THE TPS54160

INFO TAKEN FROM DATA SHEET

RT_CLK 1 I Resistor timing and external clock for buck regulator. Resistor should connect to GND (power pad) with very short trace to reduce the potential clock jitter due to noise.

COMP 2 0 Buck error amplifier output and input to the output switch current comparator.

VSENSE 3 I Buck output voltage sense pin. Inverting node of error amplifier.

PWRGD 4 I An open drain output with external pull-up resistor required. Asserts low if buck output voltage is low due to thermal shutdown, dropout, over-voltage, or EN_BUCK shut down

BST_BK 52 P Bootstrap cap pin for buck converter

PVDD2 53,54 P Power supply pin for buck converter, PVDD2 cap should connect to GND.

EN_BUCK 55 I Enable buck converter. Internal pull-up current source. Pull below 1.2V to disable. Float to enable. Adjust the input undervoltage lockout with two resistors

SS_TR 56 I Buck soft-start and tracking. An external capacitor connected to this pin sets the output rise time. Since the voltage on this pin overrides the internal reference, it can be used for tracking and sequencing. Cap should connect to GND

GND 57 P GND pin. The exposed power pad must be electrically connected to ground plane through soldering to (POWER PCB for proper operation and connected to bottom side of PCB through vias for better thermal PAD) spreading.

D3_MOTOR_DRIVE Schematic Path = /3P_MD_1			
TENNANT			
Title Thunderbolt: D3 - POWER BUCK - OPTIONAL			
Size Custom	Document Number <Doc>		Rev B
Date:	Monday, July 22, 2013	Sheet	6 of 15

Hall Sensors Removed and placed on the Top Level
Schematic due to the fact that we have part of the
design needing 2 and part needing 1.

D3_MOTOR_DRIVE Schematic Path = /BP_MD_1	
TENNIANT	
Title	
Thunderbolt: D3 - Hall Sensors	
Size	Document Number
C	<Doc>
Date:	Monday, March 25, 2013
Sheet	6 of 7
1	