

ZUIHO
Specification

- Version 0.1 -

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Research Institute for Secure Systems,
National Institute of Advanced Industrial Science and Technology

Table of Contents

1. Overview	3
2. Operational Instructions.....	5
2.1. Power Circuit.....	7
2.2. Voltage Calibration	7
2.3. Power-On Sequences	8
2.4. Configuration.....	8
2.5. Clock System	8
2.6. Measurement Points	8
2.7. Connectors	9
2.8. Switches	12
3. I/O Assignments	13
3.1. FPGA #1 (Spartan-3A)	13
3.2. FPGA #2 (Spartan-3AN)	17
3.3. FPGA Interconnects	19
4. Parts List, Schematic, and Board Layout	20

1. Overview

The ZUIHO is designed for evaluation and training of Side-Channel Attack and Physical Unclonable Function (PUF). The ZUIHO is suitable for research and educational use relevant to such area of hardware security because the board has old 90-nm Spartan-3A FPGA device for cryptographic process, which enables a measurement easier than the previous evaluation board SASEBO-GII.

The basic features of ZUIHO are as follows:

- 200 mm x 150 mm x 1.6mm, FR-4, 4 layers.
- Two Xilinx FPGAs
 - Cryptographic FPGA: Spartan-3A XC3S1400A-4FGG484C
 - Control FPGA: Spartan-3AN XC3S50AN-4TQG144C
- External power source supplies the on-board power regulators and the FPGAs with 5.0 V.
- Shunt resistor is provided to insert on the core VCC line of the cryptographic FPGA for measuring power traces.
- The host PC controls and communicates with the board via the USB 2.0 port.

Table 1 : Specification

FPGA #1	FPGA	Xilinx Spartan-3A XC3S1400A-4FGG484C
	Configuration ROM	8Mbit SPI Flash Memory AT45DB081D
	Configuration Mode	Configuration from SPI Flash: <ul style="list-style-type: none"> •Master SPI (from Configuration ROM) Configuration from FPGA #2: <ul style="list-style-type: none"> •Master Serial •Slave Serial •Slave Parallel (SelectMAP)
	Clock	24MHz Oscillator
	User LED	10bit
	User Switch	DIP Switch 8bit / Push Switch 2bit
	3.3V User GPIO	<ul style="list-style-type: none"> •64bit SASEBO-W Compatible Header •4bit Header •SMA 2pairs (Differential, Clock Capable)
	USB I/F	FTDI FT2232H (Channel A)
	Measurement point	High side of VCCINT (Core)
FPGA #2	FPGA	Xilinx Spartan-3AN XC3S50AN-4TQG144C
	Configuration ROM	FPGA Internal Flash Memory
	Clock	24MHz Oscillator
	User LED	4bit
	User Switch	DIP Switch 4bit / Push Switch 2bit
	3.3V User GPIO	<ul style="list-style-type: none"> •Header 10bit •SMA 2pairs (Differential, Clock Capable)
	USB I/F	FTDI FT2232H (Channel B)
FPGA Interconnect	22 pin	
Rated board voltage	•5V ±5%	
Rated board current	<ul style="list-style-type: none"> •USB bus power : 0.5A (Protected by fuse) •External power input : 6A (Rated by switch) 	
Substrate	4 Layers, FR-4, 1.6t	
Dimensions	150mm × 200mm	

2. Operational Instructions

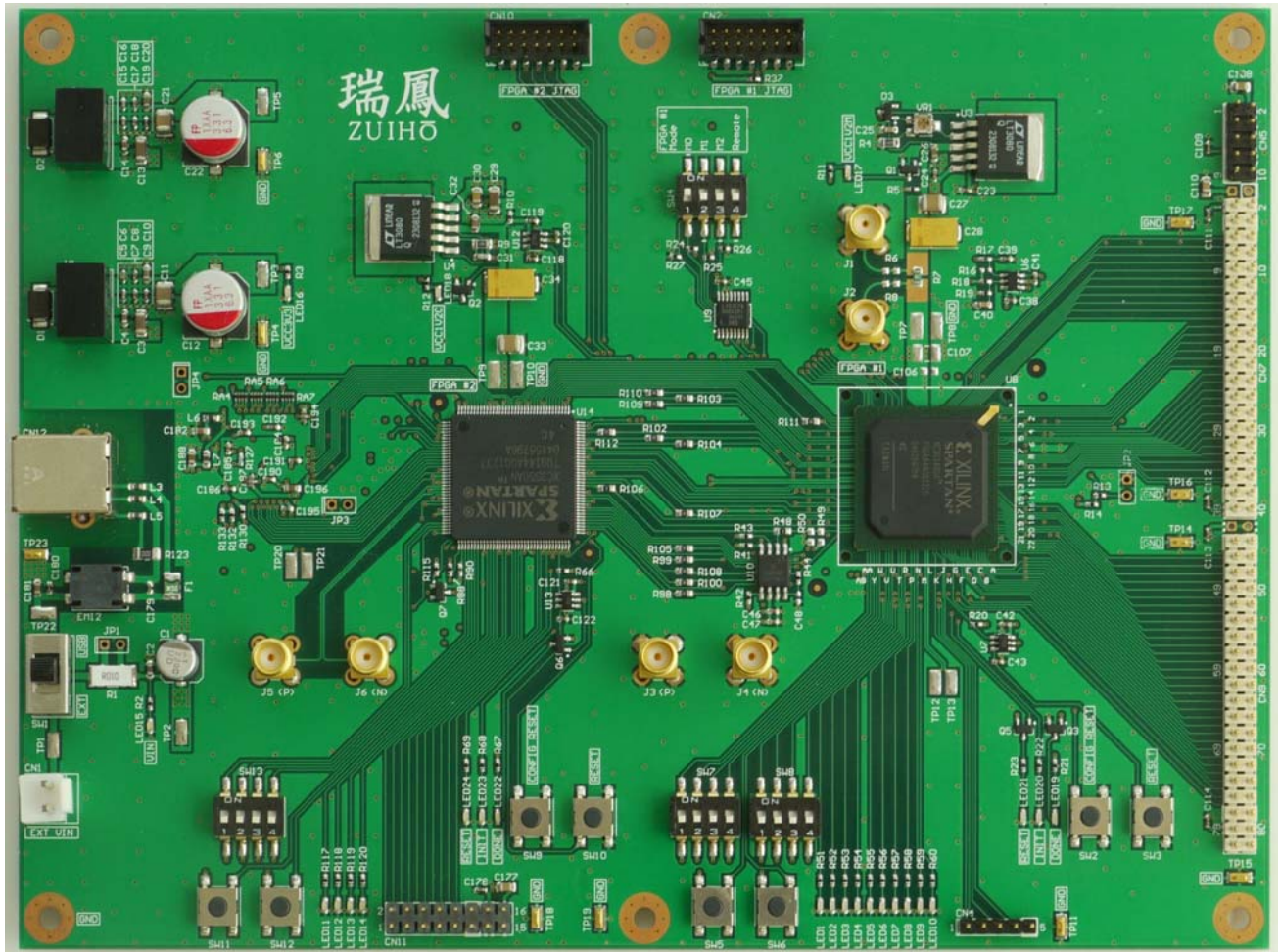


Figure 1 : ZUIHO Top View

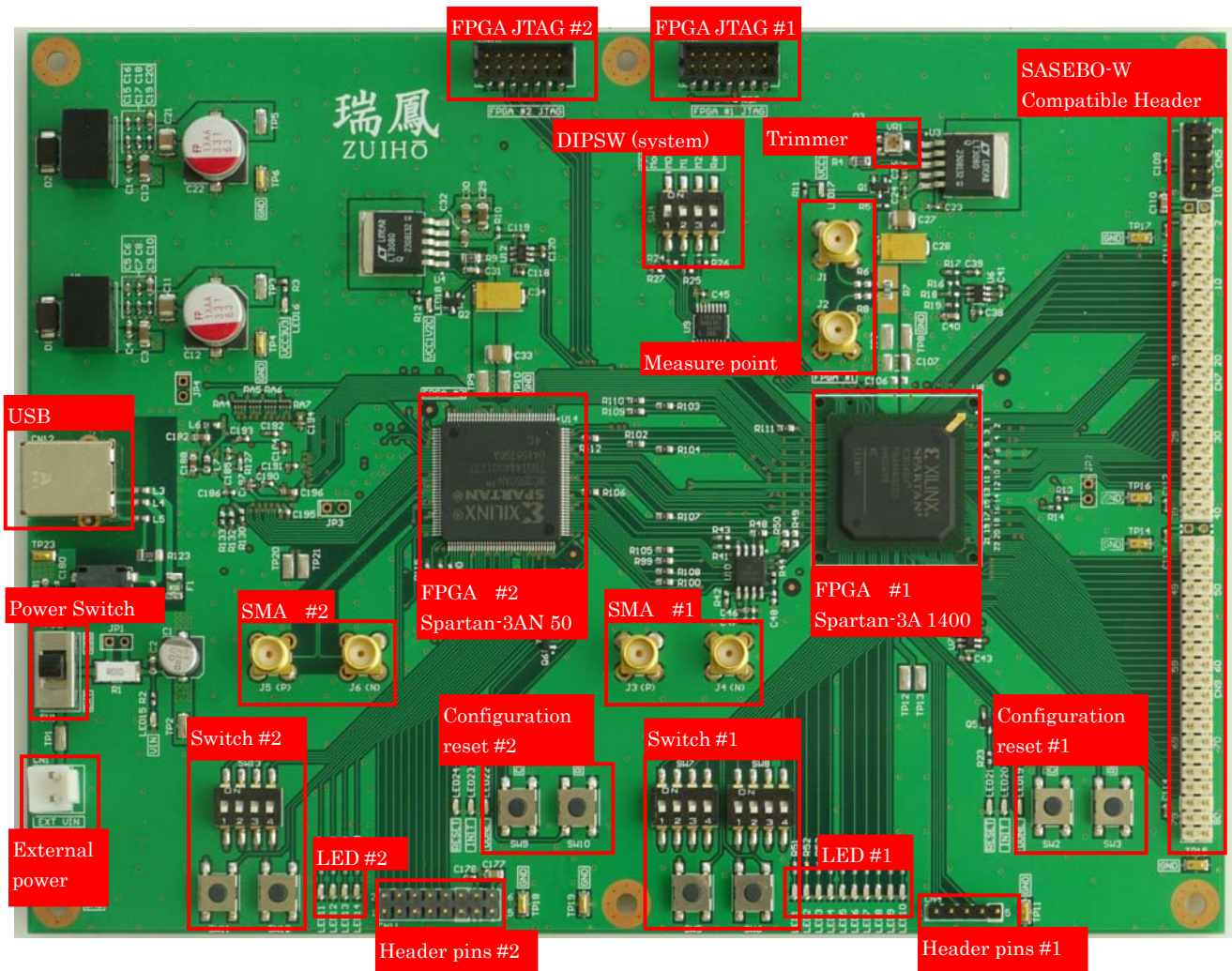


Figure 2 : ZUIHO Board Functions

2.1. Power Circuit

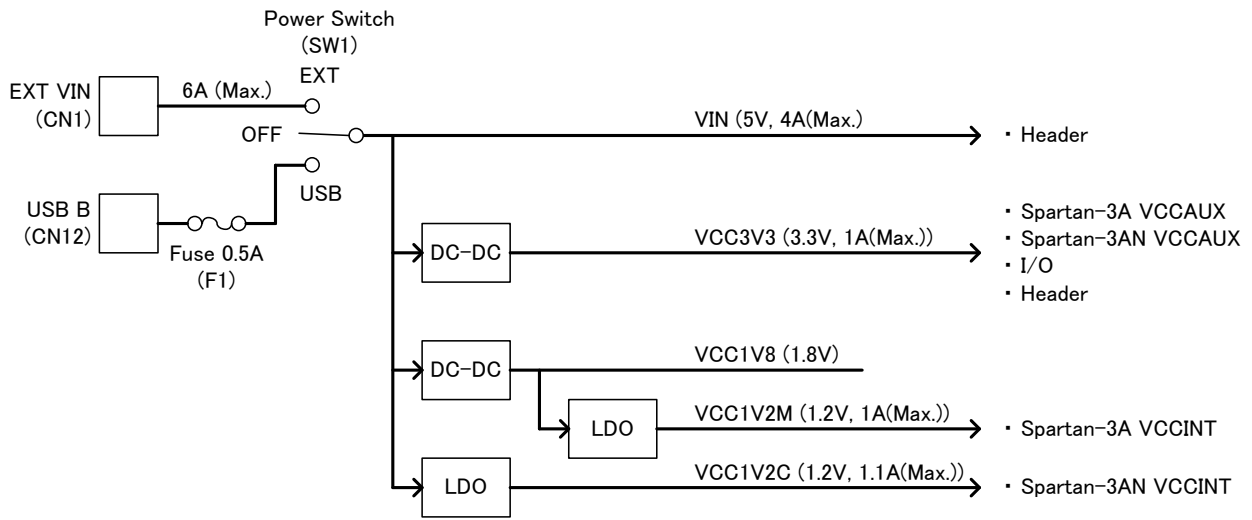


Figure 3 : Power Circuit

2.2. Voltage Calibration

The following voltage can be calibrated by trimmer.

Table 2 : Voltage Calibration Point

Trimmer	Voltage
VR1	FPGA Spartan-3A 1400 VCCINT (Core) 1.2V (1.1~1.3V)

2.3. Power-On Sequences

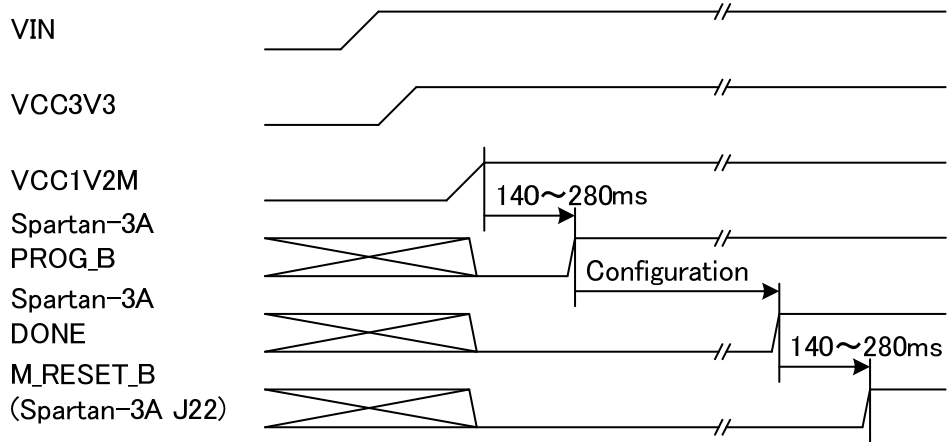


Figure 4 : FPGA #1 (Spartan-3A) Reset Sequence

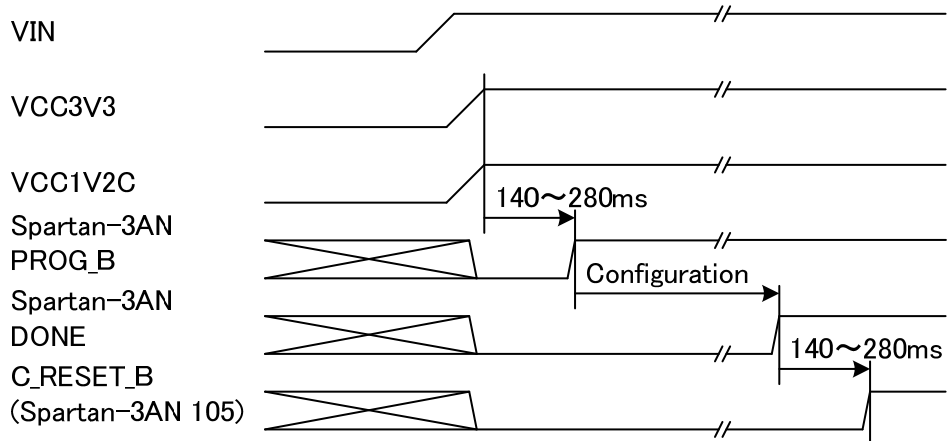


Figure 5 : FPGA #2 (Spartan-3AN) Reset Sequence

2.4. Configuration

(TBD)

2.5. Clock System

(TBD)

2.6. Measurement Points

(TBD)

2.7. Connectors

Table 3 : Abstract of connectors

Connector	Function
CN1	External Power Supply (5V)
CN2	FPGA #1 (Spartan-3A) JTAG
CN3	Unused
CN4	FPGA #1 (Spartan-3A) GPIO
CN5	FPGA #1 SASEBO-W Compatible Header
CN6	Unused
CN7	FPGA #1 SASEBO-W Compatible Header
CN8	Unused
CN9	FPGA #1 SASEBO-W Compatible Header
CN10	FPGA #2 (Spartan-3AN) JTAG
CN11	FPGA #2 (Spartan-3AN) GPIO
CN12	USB B

Table 4 : CN1, external power supply (5.0V)

Pin	Function
1 (▲)	VIN (5.0V)
2	GND

Table 5 : CN2 FPGA #1 (Spartan-3A) JTAG

Pin	Function
1	GND
2	3.3V
3	GND
4	TMS
5	GND
6	TCK
7	GND
8	TDO
9	GND
10	TDI
11	GND
12	N.C.

13	GND
14	N.C.

Table 6 : CN4 FPGA #1 GPIO

Pin	Function
1	IO0
2	IO1
3	IO2
4	IO3
5	GND

Table 7 : CN5 FPGA #1 (Spartan-3A) SASEBO-W Compatible Header

Pin	Function
1	GND
2	VIN (5V)
3	GND
4	VIN (5V)
5	GND
6	N.C.
7	GND
8	VCC3V3 (3.3V)
9	GND
10	VCC3V3 (3.3V)

Table 8 : CN7, CN9 FPGA #1 (Spartan-3A) SASEBO-W Compatible Header

Pin (Silk)	Function
1	VCC3V3 (3.3V)
2	VCC3V3 (3.3V)
3	GND
4	GND
5~36	IO0~IO31
37	GND
38	GND
39	VCC3V3 (3.3V)
40	VCC3V3 (3.3V)
41	VCC3V3 (3.3V)

42	VCC3V3 (3.3V)
43	GND
44	GND
45~76	IO32~IO63
77	GND
78	GND
79	VCC3V3 (3.3V)
80	VCC3V3 (3.3V)

Table 9 : CN10 FPGA #2 (Spartan-3AN) JTAG

Pin	Function
1	GND
2	3.3V
3	GND
4	TMS
5	GND
6	TCK
7	GND
8	TDO
9	GND
10	TDI
11	GND
12	N.C.
13	GND
14	N.C.

Table 10 : CN11 Spartan-6 GPIO

Pin (Silk)	Function
1~10	IO0~IO9
11	GND
12	GND
13	VCC3V3 (3.3V)
14	VCC3V3 (3.3V)
15	VIN (5V)
16	VIN (5V)

2.8. Switches

Table 11 : Abstract of switches

Switch	Function
SW1	Power
SW2	FPGA #1 (Spartan-3A) Configuration Reset
SW3	FPGA #1 (Spartan-3A) System Reset
SW4	System Settings
SW5	FPGA #1 (Spartan-3A) User Push Switch
SW6	FPGA #1 (Spartan-3A) User Push Switch
SW7	FPGA #1 (Spartan-3A) User DIP Switch
SW8	FPGA #1 (Spartan-3A) User DIP Switch
SW9	FPGA #2 (Spartan-3AN) Configuration Reset
SW10	FPGA #2 (Spartan-3AN) System Reset
SW11	FPGA #2 (Spartan-3AN) User Push Switch
SW12	FPGA #2 (Spartan-3AN) User Push Switch
SW13	FPGA #2 (Spartan-3AN) User DIP Switch

Table 12 : SW1 Power

	Function
USB	VIN power supply via USB (CN12)
OFF	Off
EXT	VIN power supply via EXT5V (CN1)

Table 13 : SW4 System Settings

Pin	Function	On	Off
1	M0	M0=1 (*)	M0=0
2	M1	M1=1	M1=0 (*)
3	M2	M2=1	M2=0 (*)
4	M[2:0] are connected to FPGA #2	Yes	No (*)

(*) Default Settings

3. I/O Assignments

3.1. FPGA #1 (Spartan-3A)

Table 14 : FPGA #1 (Spartan-3A) Clock and Reset

Signal Name	FPGA #1 (U8) Pin	Destination	Voltage
M_CLK_OSC	C12	U5.3	3.3
M_CLK_INH_B	C11	U5.1	3.3
M_CLK_EXT0_N	AB12	J4	3.3
M_CLK_EXT0_P	AA12	J3	3.3
M_RESET_B	J22	U7.1	3.3

Table 15 : FPGA #1 (Spartan-3A) Configuration

Signal Name	FPGA #1 (U8) Pin	FPGA #2 (U14) Pin	Flash (U10) Signal	Voltage
M_JTAG_TDI	F5			3.3
M_JTAG_TMS	D4			3.3
M_JTAG_TCK	A21			3.3
M_JTAG_TDO	E19			3.3
M_PROG_B	C4	112 (*)		3.3
M_DONE	Y19	110 (*)		3.3
M_M2	W4	102 (*)		3.3
M_M1	V6	103 (*)		3.3
M_M0	W5	104 (*)		3.3
M_CCLK_R0	AA20	124 (*)	SCK	3.3
M_INIT_B	V13	111 (*)		3.3
M_CSO_B	Y4	15 (*)	/CS	3.3
M_DOUT	AA15	114 (*)		3.3
M_MOSI_CSI_B	AB14	121 (*)	SI	3.3
M_D7	Y9	4 (*)		3.3
M_D6	AB9	3 (*)		3.3
M_D5	Y11	5 (*)		3.3
M_D4	AB11	138 (*)		3.3
M_D3	U13	139 (*)		3.3
M_D2	AA17	127 (*)		3.3
M_D1	Y17	116 (*)		3.3

M_MISO_D0	AB20	113 (*)	SO	3.3
M_RDWR_B	V9	141 (*)		3.3

(*) : Small resistor (100Ω or 22Ω) is inserted.

Table 16 : FPGA #1 (Spartan-3A) Switch

Signal Name	FPGA #1 (U8) Pin	Destination	Voltage
M_DIPSW_0	AA22	SW7.1	3.3
M_DIPSW_1	Y21	SW7.2	3.3
M_DIPSW_2	Y22	SW7.3	3.3
M_DIPSW_3	W21	SW7.4	3.3
M_DIPSW_4	V22	SW8.1	3.3
M_DIPSW_5	U21	SW8.2	3.3
M_DIPSW_6	U22	SW8.3	3.3
M_DIPSW_7	T20	SW8.4	3.3
M_PUSHSW_0	W22	SW5	3.3
M_PUSHSW_1	V20	SW6	3.3

Table 17 : FPGA #1 (Spartan-3A) SASEBO-W Compatible Header

Signal Name	FPGA #1 (U8) Pin	CN7, CN9 Pin (Silk)	Voltage
M_MEZZANINE_0	J21	5	3.3
M_MEZZANINE_1	J20	6	3.3
M_MEZZANINE_2	H22	7	3.3
M_MEZZANINE_3	H19	8	3.3
M_MEZZANINE_4	H21	9	3.3
M_MEZZANINE_5	G22	10	3.3
M_MEZZANINE_6	F22	11	3.3
M_MEZZANINE_7	F21	12	3.3
M_MEZZANINE_8	E22	13	3.3
M_MEZZANINE_9	D22	14	3.3
M_MEZZANINE_10	D21	15	3.3
M_MEZZANINE_11	H20	16	3.3
M_MEZZANINE_12	C22	17	3.3
M_MEZZANINE_13	G20	18	3.3
M_MEZZANINE_14	C21	19	3.3
M_MEZZANINE_15	E20	20	3.3
M_MEZZANINE_16	B22	21	3.3
M_MEZZANINE_17	D20	22	3.3

M_MEZZANINE_18	B21	23	3.3
M_MEZZANINE_19	B20	24	3.3
M_MEZZANINE_20	A20	25	3.3
M_MEZZANINE_21	B19	26	3.3
M_MEZZANINE_22	A19	27	3.3
M_MEZZANINE_23	A18	28	3.3
M_MEZZANINE_24	C18	29	3.3
M_MEZZANINE_25	B17	30	3.3
M_MEZZANINE_26	A17	31	3.3
M_MEZZANINE_27	A16	32	3.3
M_MEZZANINE_28	B15	33	3.3
M_MEZZANINE_29	A15	34	3.3
M_MEZZANINE_30	A14	35	3.3
M_MEZZANINE_31	B13	36	3.3
M_MEZZANINE_32	A13	45	3.3
M_MEZZANINE_33	A12 (CC)	46	3.3
M_MEZZANINE_34	A11 (CC)	47	3.3
M_MEZZANINE_35	B11 (CC)	48	3.3
M_MEZZANINE_36	A10	49	3.3
M_MEZZANINE_37	A9	50	3.3
M_MEZZANINE_38	B9	51	3.3
M_MEZZANINE_39	A8	52	3.3
M_MEZZANINE_40	B8	53	3.3
M_MEZZANINE_41	A7	54	3.3
M_MEZZANINE_42	A6	55	3.3
M_MEZZANINE_43	B6	56	3.3
M_MEZZANINE_44	A5	57	3.3
M_MEZZANINE_45	C9	58	3.3
M_MEZZANINE_46	A4	59	3.3
M_MEZZANINE_47	A3	60	3.3
M_MEZZANINE_48	C8	61	3.3
M_MEZZANINE_49	B3	62	3.3
M_MEZZANINE_50	B2	63	3.3
M_MEZZANINE_51	B1	64	3.3
M_MEZZANINE_52	C2	65	3.3
M_MEZZANINE_53	C1	66	3.3

M_MEZZANINE_54	D2	67	3.3
M_MEZZANINE_55	D1	68	3.3
M_MEZZANINE_56	E1	69	3.3
M_MEZZANINE_57	F2	70	3.3
M_MEZZANINE_58	F1	71	3.3
M_MEZZANINE_59	G3	72	3.3
M_MEZZANINE_60	G1	73	3.3
M_MEZZANINE_61	H2	74	3.3
M_MEZZANINE_62	H1	75	3.3
M_MEZZANINE_63	J1	76	3.3

Table 18 : FPGA #1 (Spartan-3A) GPIO

Signal Name	FPGA #1 (U8) Pin	Destination	Voltage
M_HEADER_0	L21 (CC)	CN4.1	3.3
M_HEADER_1	L20 (CC)	CN4.2	3.3
M_HEADER_2	K20 (CC)	CN4.3	3.3
M_HEADER_3	K22	CN4.4	3.3

(CC): Clock Capable pin

Table 19 : FPGA #1 (Spartan-3A) LED

Signal Name	FPGA #1 (U8) Pin	Destination	Voltage
M_LED_0	U20	LED1	3.3
M_LED_1	T22	LED2	3.3
M_LED_2	R21	LED3	3.3
M_LED_3	R22	LED4	3.3
M_LED_4	P20	LED5	3.3
M_LED_5	N19	LED6	3.3
M_LED_6	P22	LED7	3.3
M_LED_7	N21	LED8	3.3
M_LED_8	N22	LED9	3.3
M_LED_9	N20	LED10	3.3

Table 20 : FPGA #1 (Spartan-3A) FTDI

Signal Name	FPGA #1 (U8) Pin	FTDI (U16) Pin	Voltage
M_FTDI_ACBUS0_RXF_B	V1	26	3.3
M_FTDI_ACBUS1_TXE_B	W1	27	3.3
M_FTDI_ACBUS2_RD_B	Y1	28	3.3

M_FTDI_ACBUS3_WR_B	AA1	29	3.3
M_FTDI_ACBUS4_SIWUA	AA2	30	3.3
M_FTDI_ACBUS5_CLKOUT	K1	32	3.3
M_FTDI_ACBUS6_OE_B	T3	33	3.3
M_FTDI_ACBUS7	P3	34	3.3
M_FTDI_ADBUS0_D0	D3	16	3.3
M_FTDI_ADBUS1_D1	E3	17	3.3
M_FTDI_ADBUS2_D2	F3	18	3.3
M_FTDI_ADBUS3_D3	J3	19	3.3
M_FTDI_ADBUS4_D4	L3	21	3.3
M_FTDI_ADBUS5_D5	R1	22	3.3
M_FTDI_ADBUS6_D6	T1	23	3.3
M_FTDI_ADBUS7_D7	U1	24	3.3

3.2. FPGA #2 (Spartan-3AN)

Table 21 : FPGA #2 (Spartan-3AN) Clock and Reset

Signal Name	FPGA #2 (U14) Pin	Destination	Voltage
C_CLK_OSC	54	U11.3	3.3
C_CLK_INH_B	63	U11.1	3.3
C_CLK_EXT0_N	59	J6	3.3
C_CLK_EXT0_P	57	J5	3.3
C_RESET_B	105	U13.1	3.3

Table 22 : FPGA #2 (Spartan-3AN) Switch

Signal Name	FPGA #2 (U14) Pin	Destination	Voltage
C_DIPSW_0	69	SW13.1	3.3
C_DIPSW_1	70	SW13.2	3.3
C_DIPSW_2	75	SW13.3	3.3
C_DIPSW_3	76	SW13.4	3.3
C_PUSHSW_0	77	SW11	3.3
C_PUSHSW_1	78	SW12	3.3

Table 23 : FPGA #2 (Spartan-3AN) GPIO

Signal Name	FPGA #2 (U14) Pin	Destination	Voltage
C_HEADER_0	85 (CC)	CN11.1	3.3

C_HEADER_1	87 (CC)	CN11.2	3.3
C_HEADER_2	88 (CC)	CN11.3	3.3
C_HEADER_3	90 (CC)	CN11.4	3.3
C_HEADER_4	91 (CC)	CN11.5	3.3
C_HEADER_5	92 (CC)	CN11.6	3.3
C_HEADER_6	93 (CC)	CN11.7	3.3
C_HEADER_7	98	CN11.8	3.3
C_HEADER_8	99	CN11.9	3.3
C_HEADER_9	101	CN11.10	3.3

(CC): Clock Capable pin

Table 24 : FPGA #2 (Spartan-3AN) LED

Signal Name	FPGA #2 (U14) Pin	Destination	Voltage
C_LED_0	79	LED11	3.3
C_LED_1	82	LED12	3.3
C_LED_2	83	LED13	3.3
C_LED_3	84	LED14	3.3

Table 25 : FPGA #2 (Spartan-3AN) FTDI

Signal Name	FPGA #2 (U14) Pin	FTDI (U16) Pin	Voltage
C_FTDI_BCBUS0_RXF_B	42	48	3.3
C_FTDI_BCBUS1_TXE_B	46	52	3.3
C_FTDI_BCBUS2_RD_B	47	53	3.3
C_FTDI_BCBUS3_WR_B	48	54	3.3
C_FTDI_BCBUS4_SIWUB	49	55	3.3
C_FTDI_BCBUS5	50	57	3.3
C_FTDI_BCBUS6	51	58	3.3
C_FTDI_BCBUS7_PWRSV	55	59	3.3
C_FTDI_BDBUS0_D0	21	38	3.3
C_FTDI_BDBUS1_D1	25	39	3.3
C_FTDI_BDBUS2_D2	27	40	3.3
C_FTDI_BDBUS3_D3	28	41	3.3
C_FTDI_BDBUS4_D4	29	43	3.3
C_FTDI_BDBUS5_D5	30	44	3.3
C_FTDI_BDBUS6_D6	31	45	3.3
C_FTDI_BDBUS7_D7	32	46	3.3
C_FTDI_PWREN_B	53	60	3.3

C_FTDI_RESET_B	20	14	3.3
C_FTDI_SUSPEND_B	33	36	3.3

3.3. FPGA Interconnects

Table 26 : FPGA Interconnects

Signal Name	FPGA #1 (U8) Pin	FPGA #2 (U14) Pin	Voltage
MC_IC_D0	AB2	19 (CC)	3.3
MC_IC_D1	AA3	18 (CC)	3.3
MC_IC_D2	AB3	16 (CC)	3.3
MC_IC_D3	AB4	13 (CC)	3.3
MC_IC_D4	AB5	12 (CC)	3.3
MC_IC_D5	AA6	11	3.3
MC_IC_D6	AB6	10	3.3
MC_IC_D7	AB7	8	3.3
MC_IC_D8	AA8	7	3.3
MC_IC_D9	AB8	6	3.3
MC_IC_D10	AB10	142	3.3
MC_IC_D11	Y12 (CC)	135	3.3
MC_IC_D12	AB13	134	3.3
MC_IC_D13	W12 (CC)	132 (CC)	3.3
MC_IC_D14	AB15	131 (CC)	3.3
MC_IC_D15	AB16	130 (CC)	3.3
MC_IC_D16	AB17	129 (CC)	3.3
MC_IC_D17	AB18	126 (CC)	3.3
MC_IC_D18	AB19	125 (CC)	3.3
MC_IC_D19	Y14	120	3.3
MC_IC_D20	Y16	117	3.3
MC_IC_D21	Y18	115	3.3

(CC) Clock Capable pin

4. Parts List, Schematic, and Board Layout

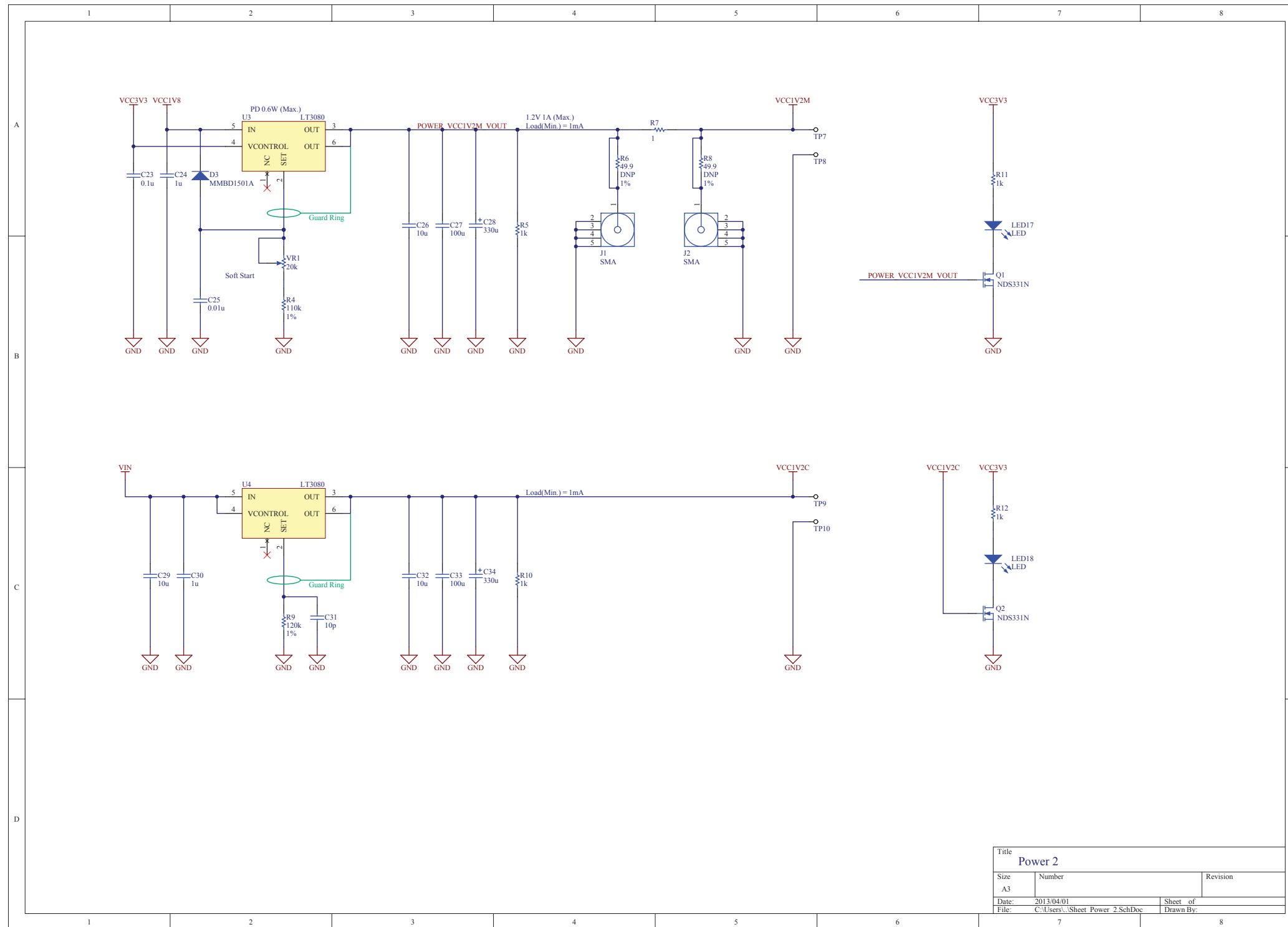
Table 27 : Parts List

Description	Part Number	Maker	Reference Designator	Spec.
Capacitor	UUD1C221MCL1GS	Nichicon	C1	220u
Capacitor	GRM188B11E104K	Murata	C2, C4, C14	0.1u
Capacitor	C3216X5R1C106KT	TDK	C3, C13, C29	10u
Capacitor	GRM155B11E103K	Murata	C5, C6, C15, C16, C35, C55, C56, C57, C63, C64, C65, C72, C73, C74, C80, C81, C82, C83, C84, C90, C91, C115, C132, C133, C138, C139, C145, C146, C151, C152, C153, C154, C155, C156, C165, C166, C167, C168	0.01u
Capacitor	GRM155B11A104K	Murata	C7, C8, C17, C18, C23, C38, C39, C41, C42, C43, C44, C45, C46, C52, C53, C54, C60, C61, C62, C69, C70, C71, C77, C78, C79, C85, C86, C92, C93, C118, C119, C120, C121, C122, C123, C130, C131, C136, C137, C143, C144, C149, C150, C157, C158, C159, C160, C169, C170, C171, C172, C179, C180, C184, C185, C186, C190, C191, C192, C193, C195, C199	0.1u
Capacitor	GRM155B30J105K	Murata	C9, C19, C24, C47, C51, C59, C68, C76, C87, C94, C109, C111, C112, C113, C114, C129, C135, C142, C148, C161, C162, C173, C174, C178	1u
Capacitor	C1608X5R0J106MT	TDK	C10, C20, C26, C32, C37, C50, C58, C67, C75, C88, C95, C117, C128, C134, C141, C147, C163, C175, C181, C182, C188, C196	10u
Capacitor	GRM32ER60J107ME20L	Murata	C11, C21, C27, C33, C49, C66, C89, C127, C140, C164, C176	100u
Capacitor	RPS0J331MCN1GS	Nichicon	C12, C22	330u
Capacitor	GRM188B11H103K	Murata	C25	0.01u
Capacitor	T520V337M2R5ATE025	Kemet	C28, C34	330u
Capacitor	GRM21BB11C105K	Murata	C30, C108, C110, C177	1u

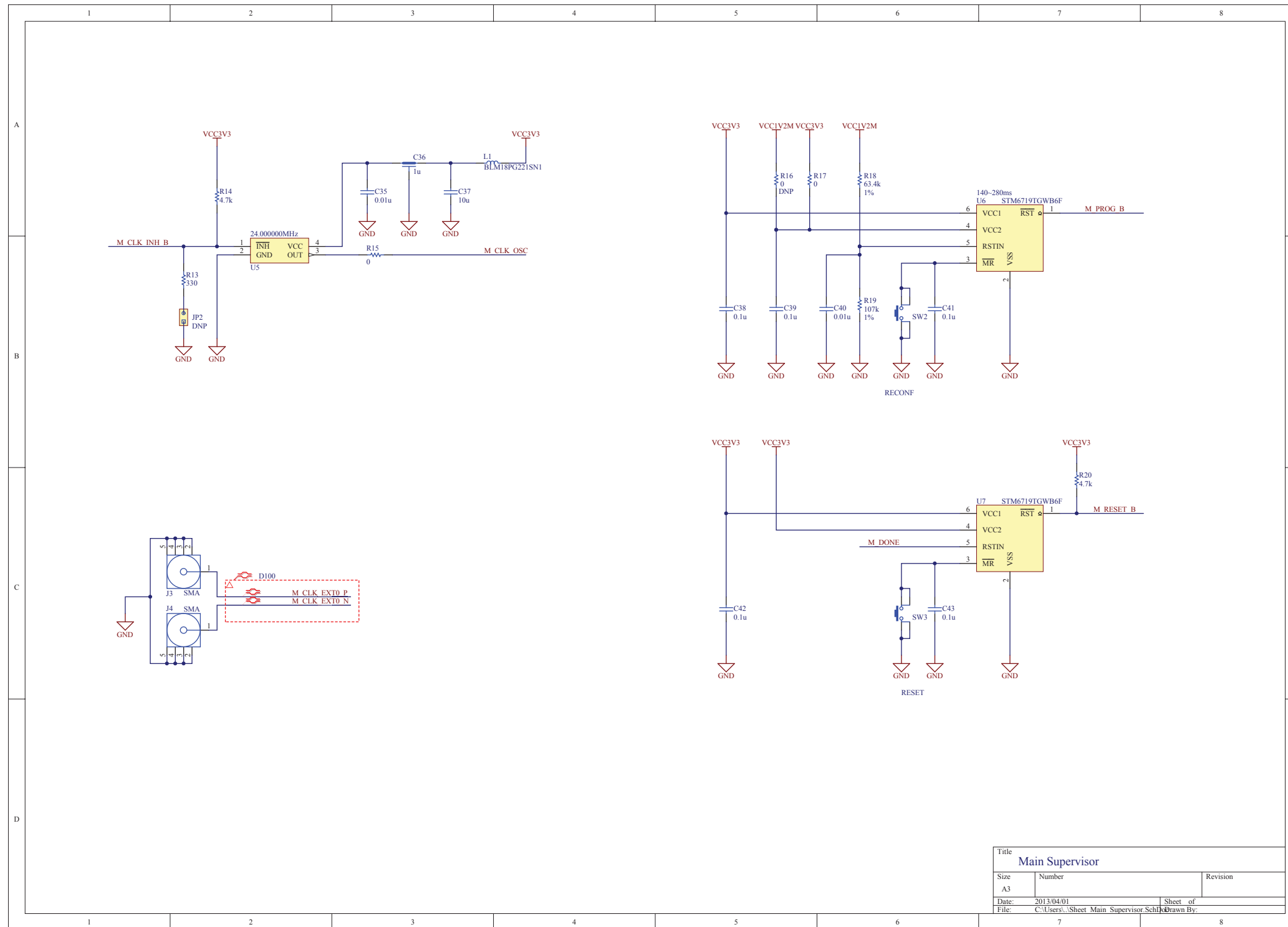
Capacitor	GRM1882C1H100J	Murata	C31	10p
Capacitor	NFM18PC105R0J3	Murata	C36, C116, C183, C187, C189, C194	1u
Capacitor	GRM188B11H103K	Murata	C40	0.01u
Capacitor	GRM1552C1H220J	Murata	C197, C198	22p
Connector	B2P-VH(LF)(SN)	JST	CN1	
Connector	87832-1420	Molex	CN2, CN10	
Header	68002-205HLF	FCI	CN4	
Header	M20-9760542	Harwin	CN5	
Header	M20-9762042	Harwin	CN7, CN9	
Header	M20-9760842	Harwin	CN11	
Connector	61729-0011BLF	FCI	CN12	
Diode	S2A	Fairchild	D1, D2	
Diode	MMBD1501A	Fairchild	D3	
EMI Filter	DLW21HN900SQ2	Murata	EMI1	
EMI Filter	ACM9070-701-2PL	TDK	EMI2	
Fuse	MICROSMD050F-2	TE	F1	
SMA Jack	0733910060	Molex	J1, J2, J3, J4, J5, J6	
Inductor	BLM18PG221SN1	Murata	L1, L2, L3, L4, L5, L6, L7	
LED	LS Q976-NR-1	OSRAM	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9, LED10, LED11, LED12, LED13, LED14, LED15, LED16, LED17, LED18, LED19, LED20, LED21, LED22, LED23, LED24	LED
FET	NDS331N	FAIRCHILD	Q1, Q2, Q3, Q6	
FET	NDS332P	FAIRCHILD	Q4, Q5, Q7, Q8	
Resistor	KRL3264-C-R010-F-T1	Susumu	R1	10m
Resistor	RK73B1ETTP222J	KOA	R2, R128, R129, R131	2.2k
Resistor	RK73B1ETTP102J	KOA	R3, R5, R10, R11, R12, R21, R22, R23, R24, R25, R26, R27, R28, R30, R32, R46, R47, R51, R52, R53, R54, R55, R56, R57, R58, R59, R60, R61, R62, R67, R68, R69, R73, R74, R76, R78, R80, R82, R96, R115, R117, R118, R119, R120, R121, R122, R126	1k
Resistor	ERJ-6ENF1103V	Panasonic	R4	110k
Resistor	RL1220S-1R0-F	Susumu	R7	1
Resistor	ERJ-6ENF1203V	Panasonic	R9	120k

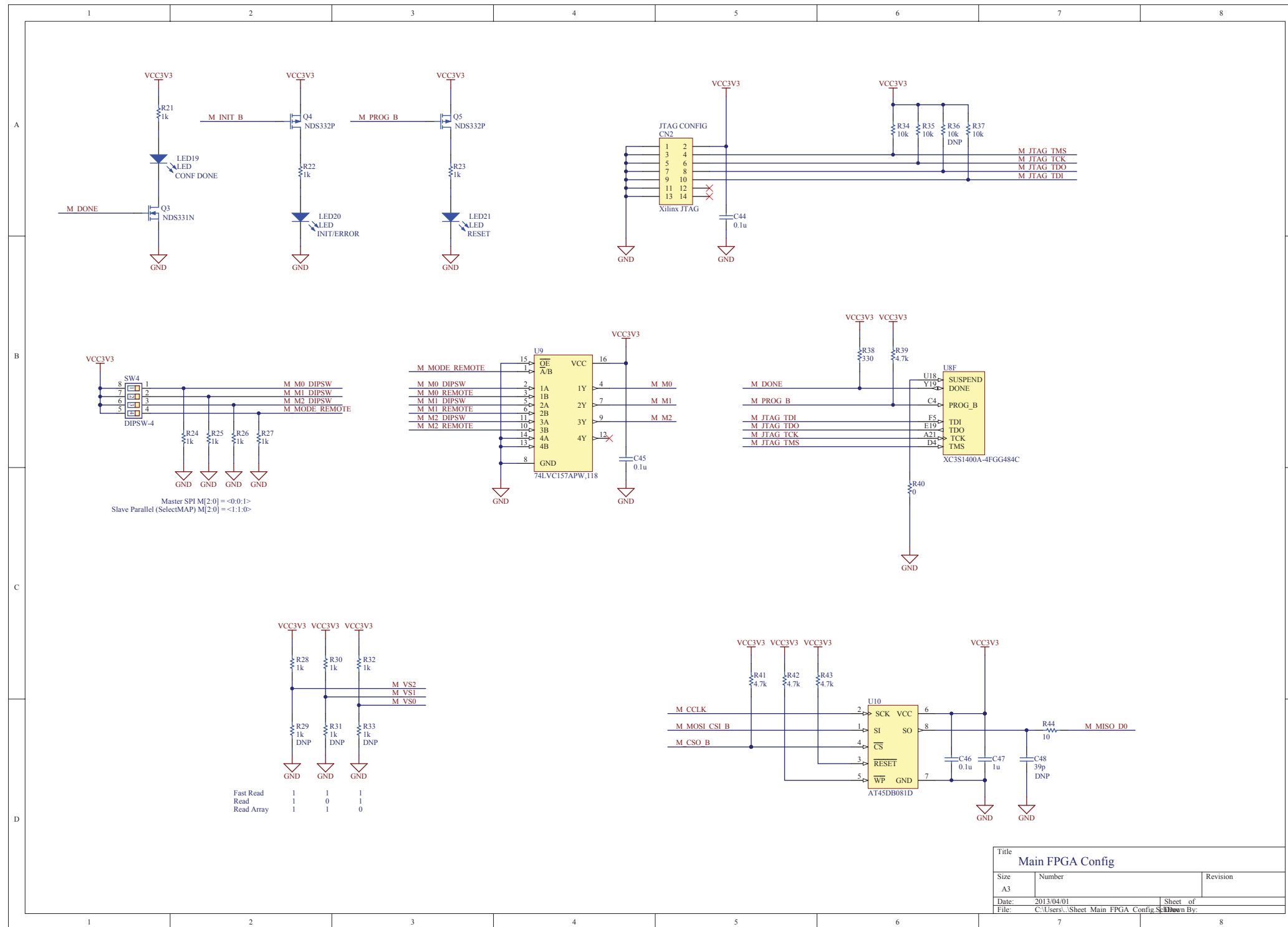
Resistor	RK73B1ETTP331J	KOA	R13, R38, R63, R88	330
Resistor	RK73B1ETTP472J	KOA	R14, R20, R39, R41, R42, R43, R64, R66, R89	4.7k
Resistor	RK73Z1ETTP	KOA	R15, R17, R40, R65, R71, R90	0
Resistor	ERJ-2RKF6342X	Panasonic	R18	63.4k
Resistor	ERJ-2RKF1073X	Panasonic	R19	107k
Resistor	RK73B1ETTP103J	KOA	R34, R35, R37, R84, R85, R87, R130, R132, R133	10k
Resistor	RK73B1ETTP100J	KOA	R44	10
Resistor	RK73Z1JTDD	KOA	R48, R106, R116	0
Resistor	RK73B1JTDD101J	KOA	R97, R98, R99, R100, R101, R102, R103, R104, R105, R107, R108, R109, R110, R111, R112	100
Resistor	RK73Z2BTDD	KOA	R123	0
Resistor	RK73H1ETTP1202F	KOA	R127	12.0k
Resistor Array	MNR04M0APJ102	Rohm	RA1, RA2, RA3	1k
Resistor Array	MNR04M0APJ222	Rohm	RA4, RA5, RA6, RA7, RA8, RA9, RA10, RA11	2.2k
Switch	MS-13AAP1	Nikkai	SW1	
Switch	B3FS-1000P	Omron	SW2, SW3, SW5, SW6, SW9, SW10, SW11, SW12	
Switch	A6S-4104-H	Omron	SW4, SW7, SW8, SW13	
Test Pin	HK-1-G	MAC8	TP4, TP6, TP11, TP14, TP15, TP16, TP17, TP18, TP19, TP23	
IC	R-783.3-1.0	Recom	U1	1A
IC	R-781.8-1.0	Recom	U2	1A
IC	LT3080EQ#PBF	LT	U3, U4	1.1A
Oscillator	ECS-3963-240-BN-TR	ECS	U5, U11	24MHz
IC	STM6719TGWB6F	STM	U6, U7, U12, U13	
FPGA	XC3S1400A-4FGG484C	Xilinx	U8	
IC	74LVC157APW,118	NXP	U9	
IC	AT45DB081D-SU	Atmel	U10	
FPGA	XC3S50AN-4TQG144C	Xilinx	U14	
IC	FT232HL-REEL	FTDI	U16	
Crystal Unit	CX3225GB12000D0HEQZ1	AVX	U17	12MHz
IC	AT93C46D-TH-B	Atmel	U18	

Variable Resistor	ST32ETA203	Copal Electronics	VR1	20k
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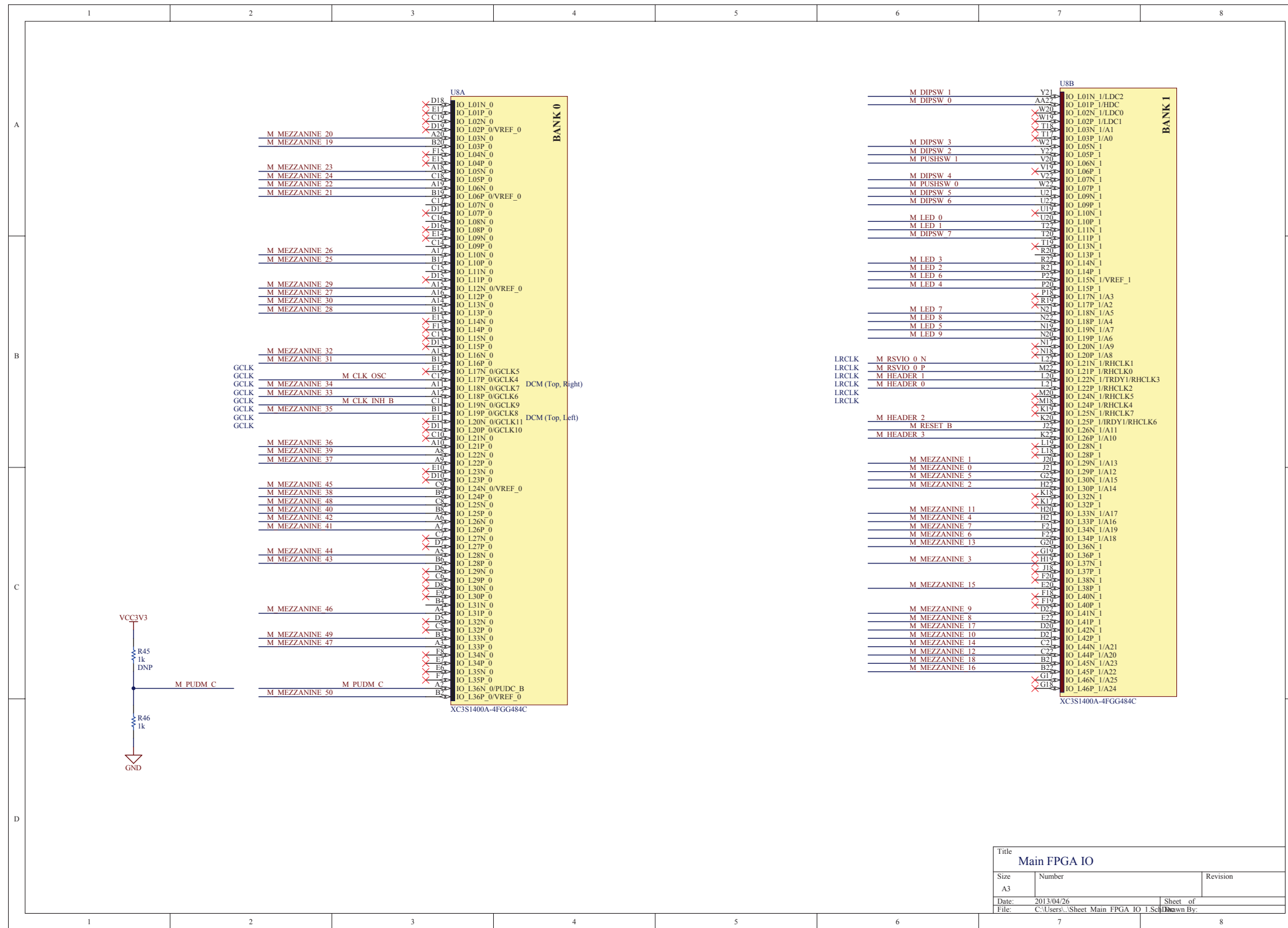


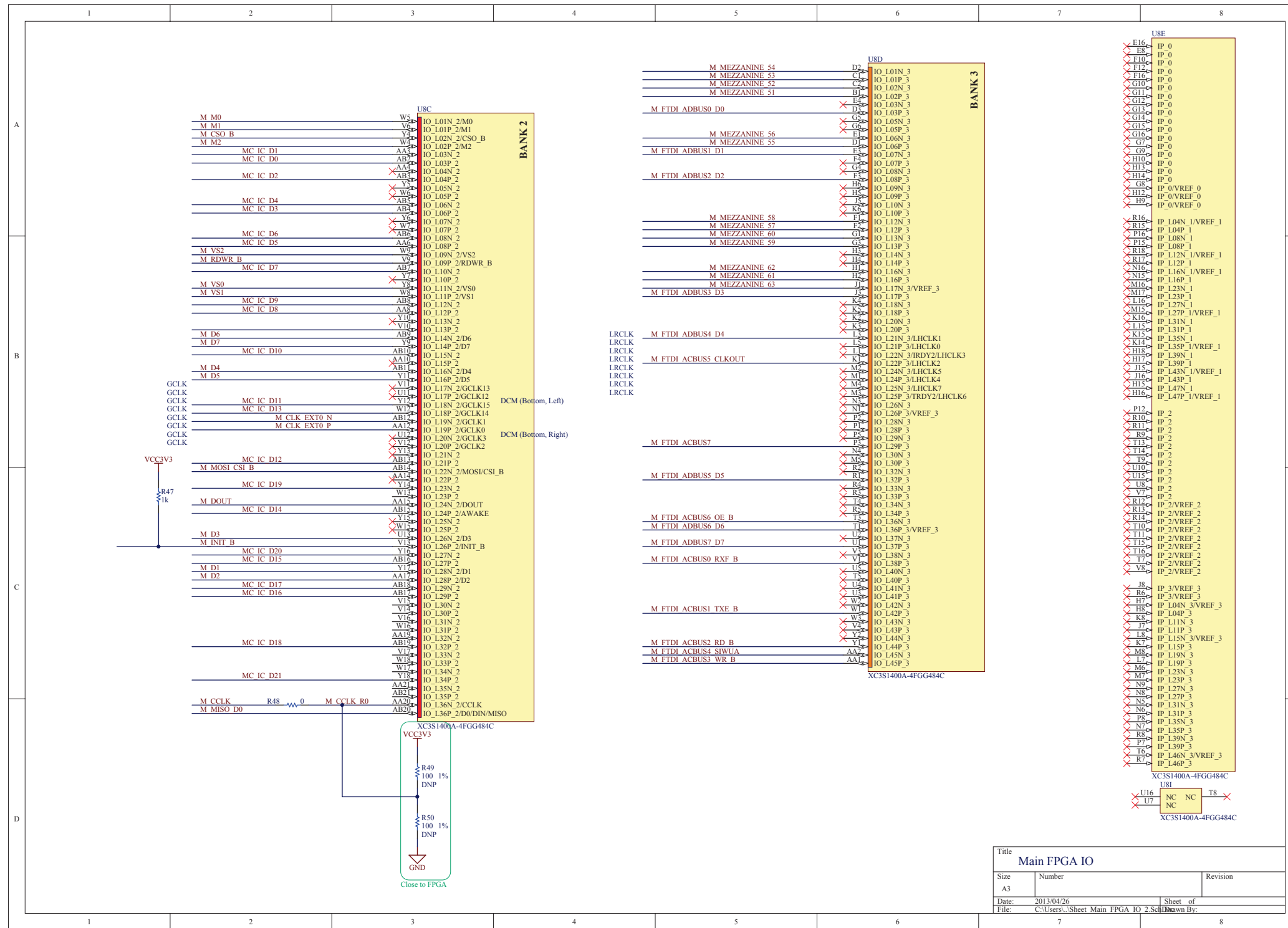
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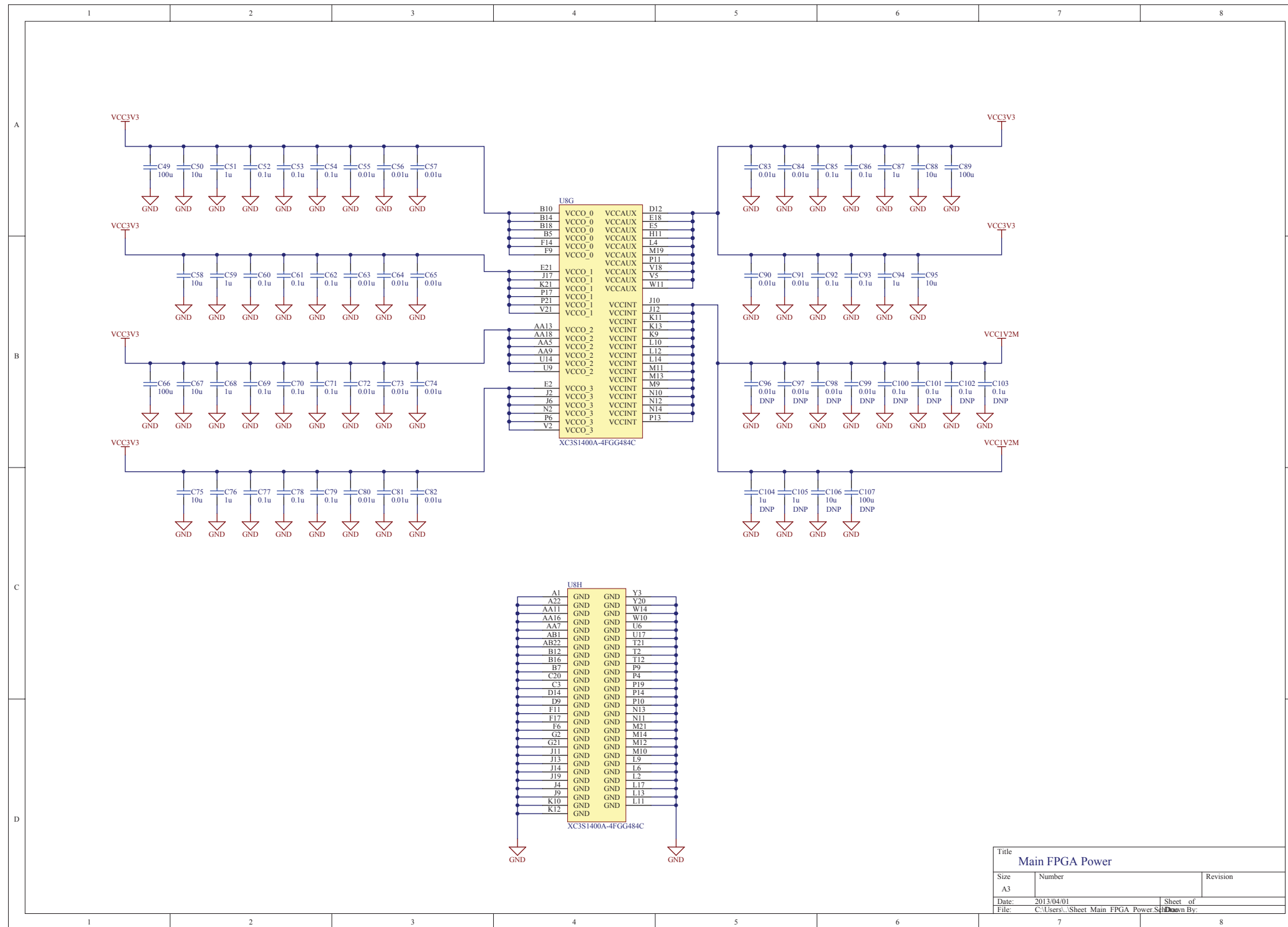




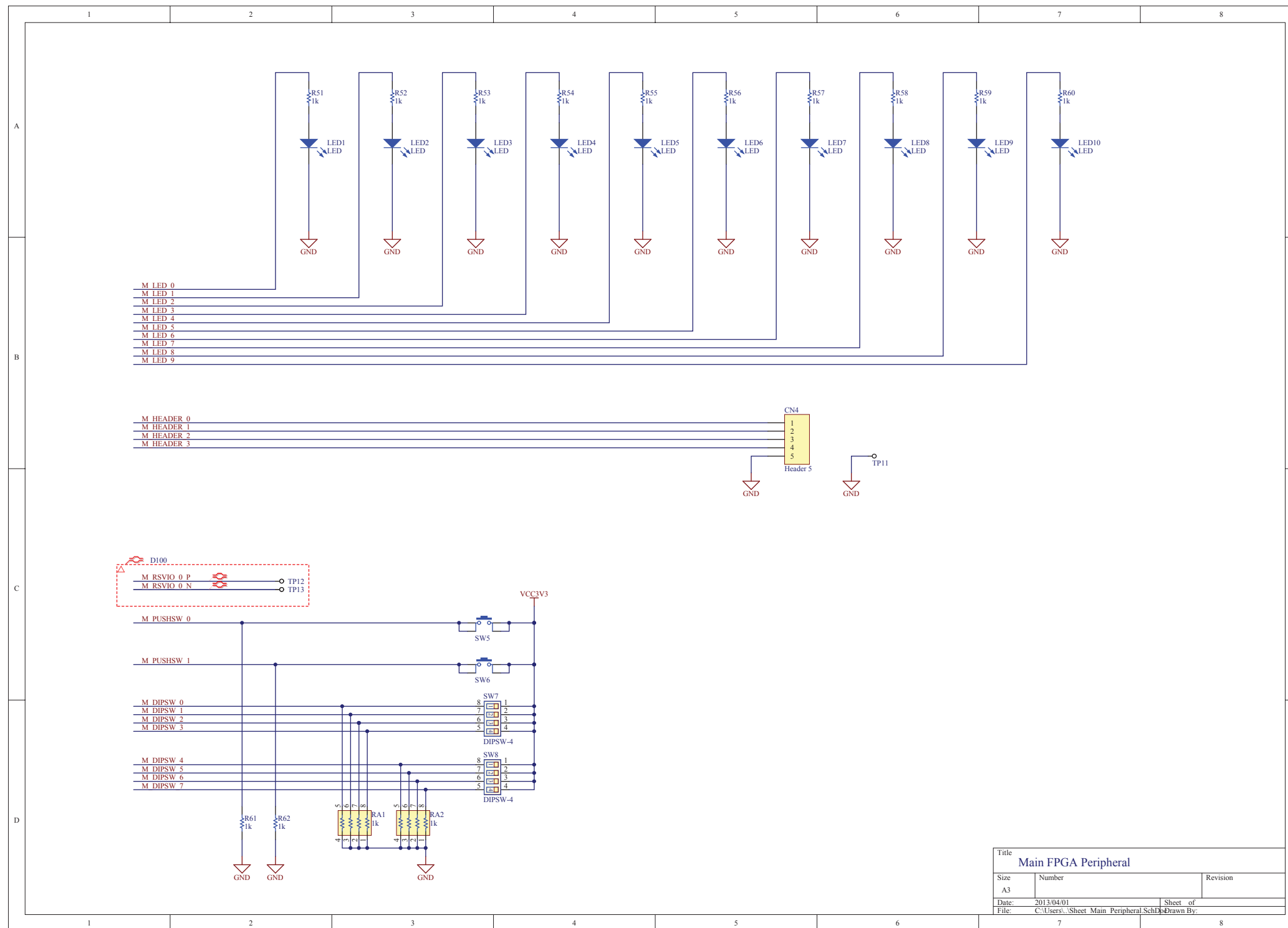
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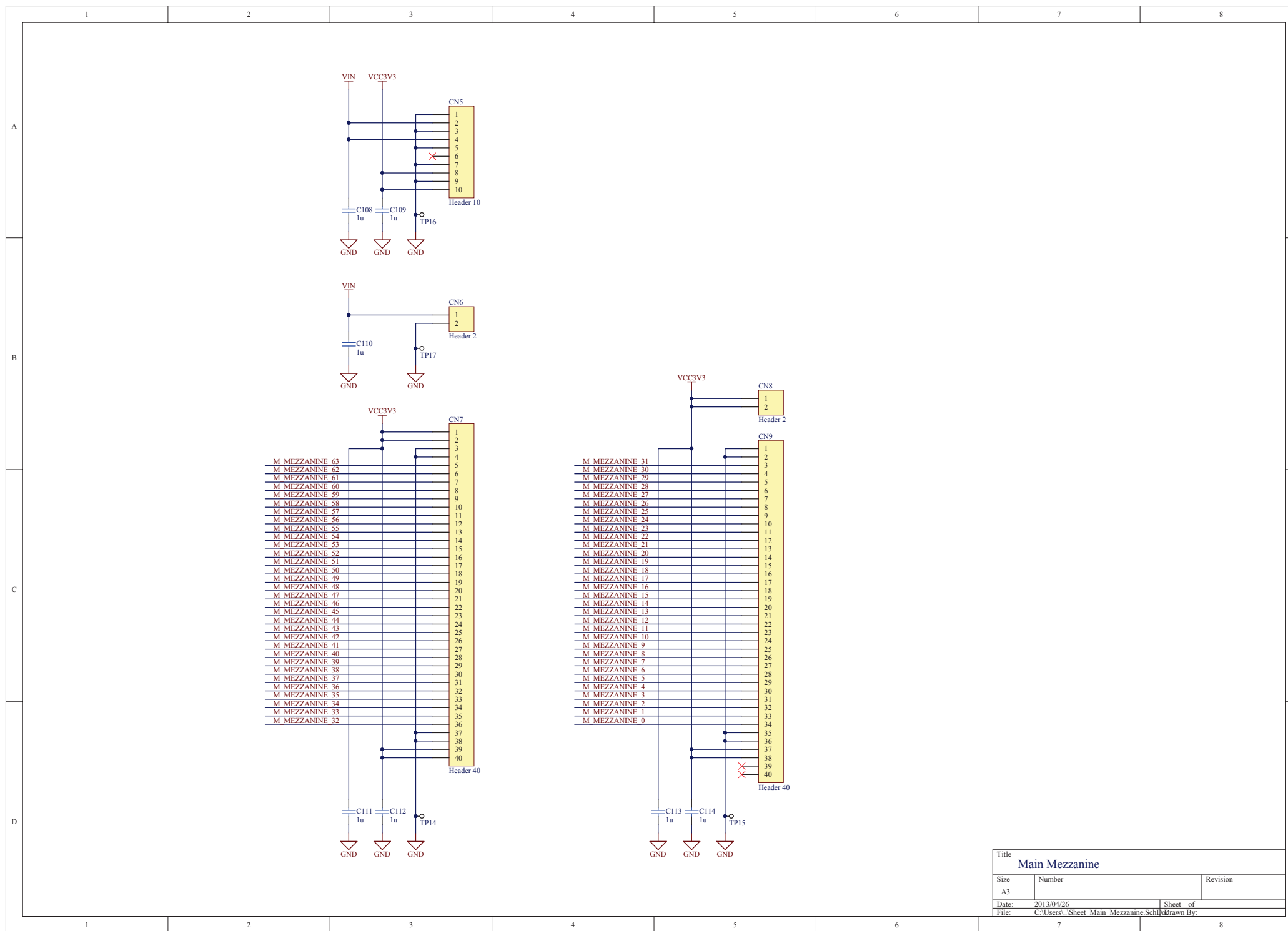




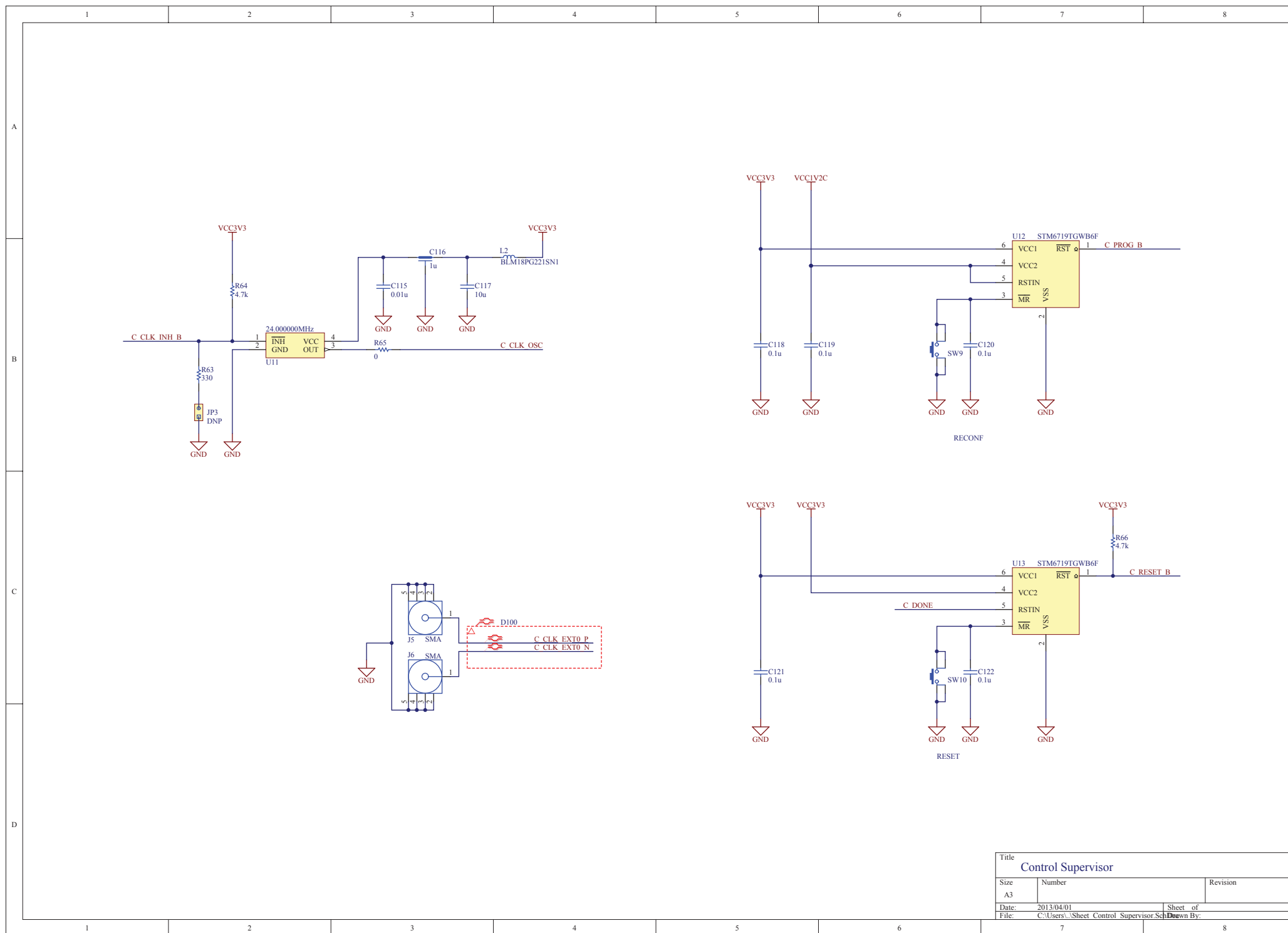
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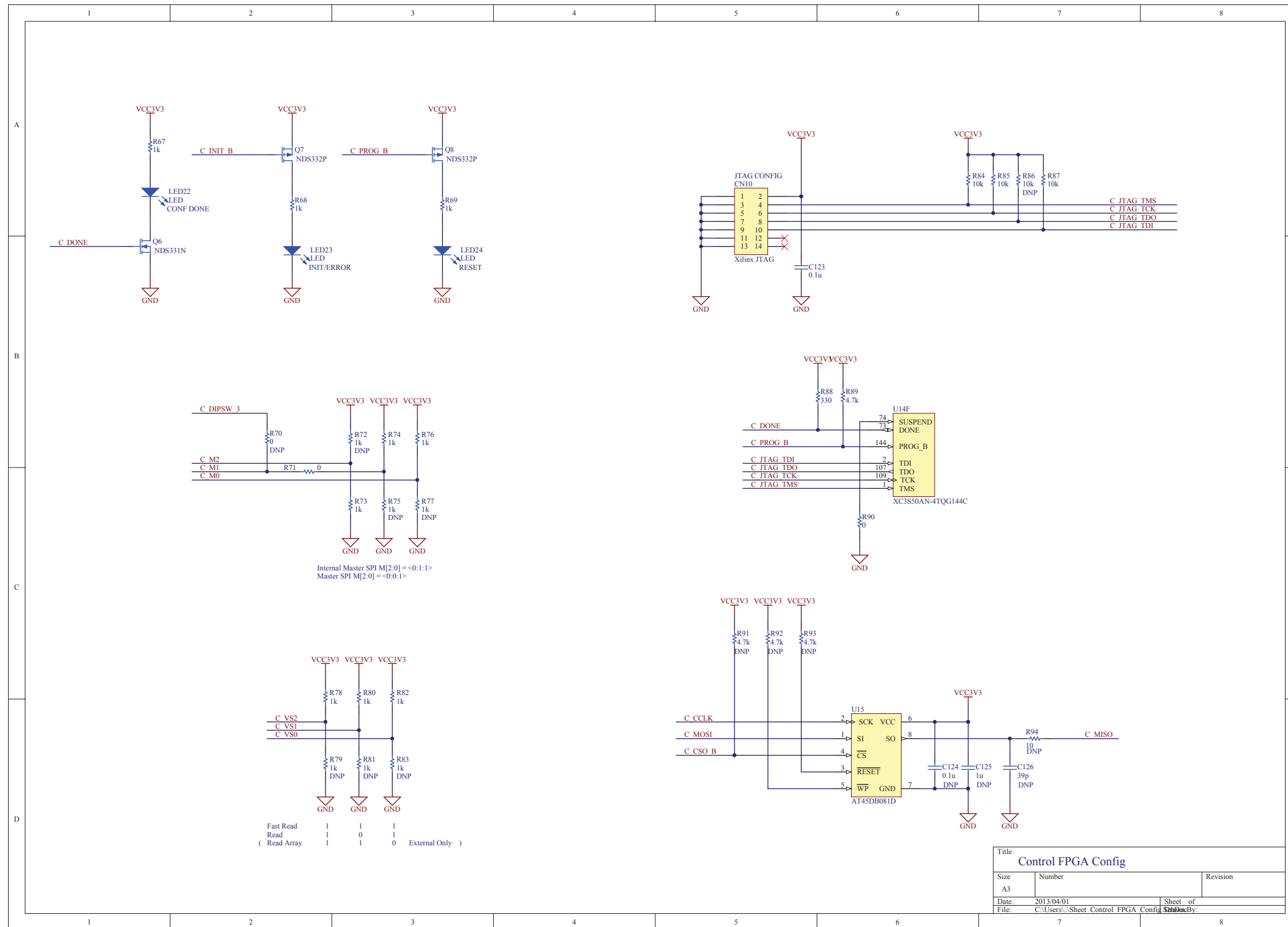


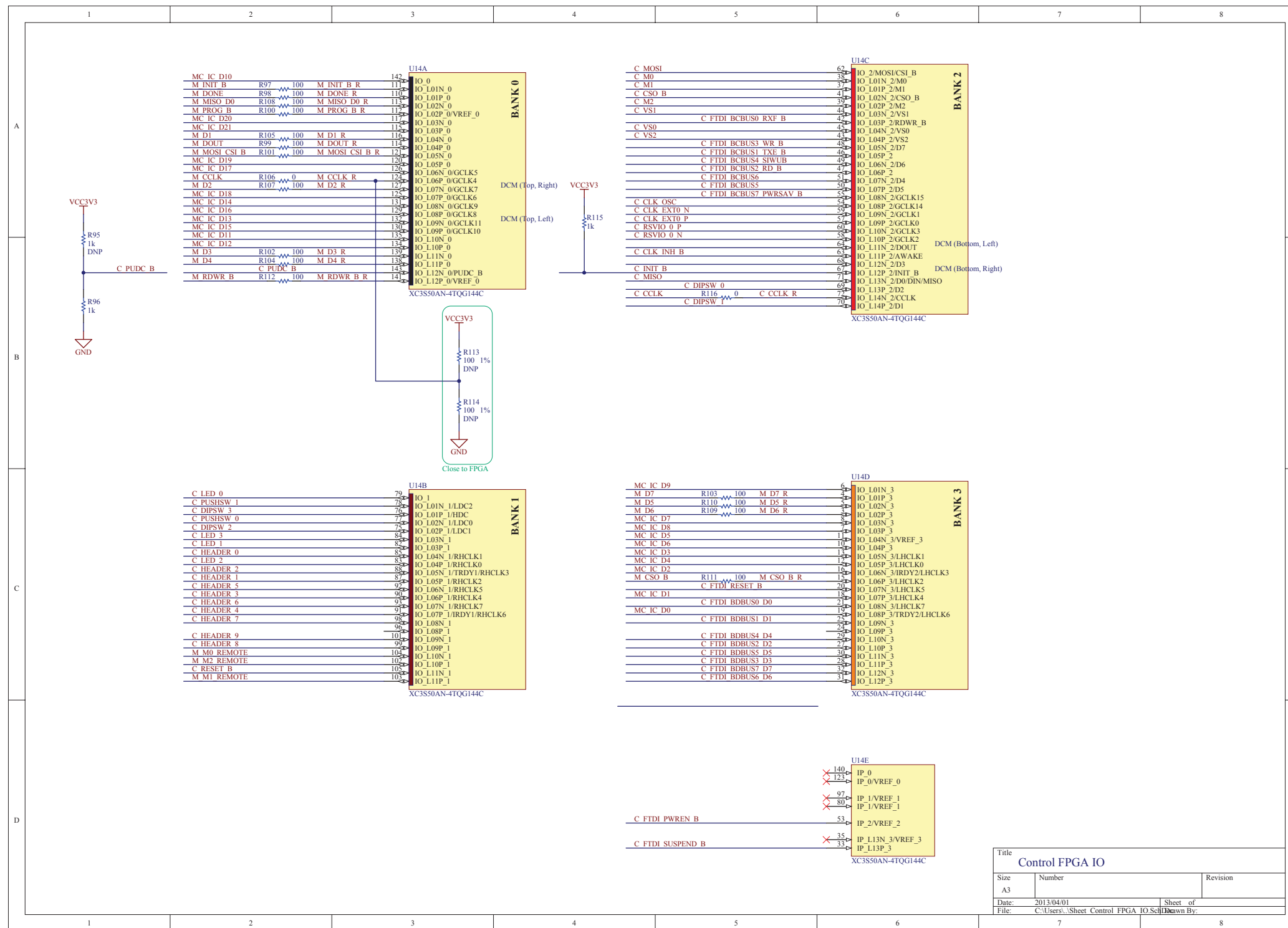
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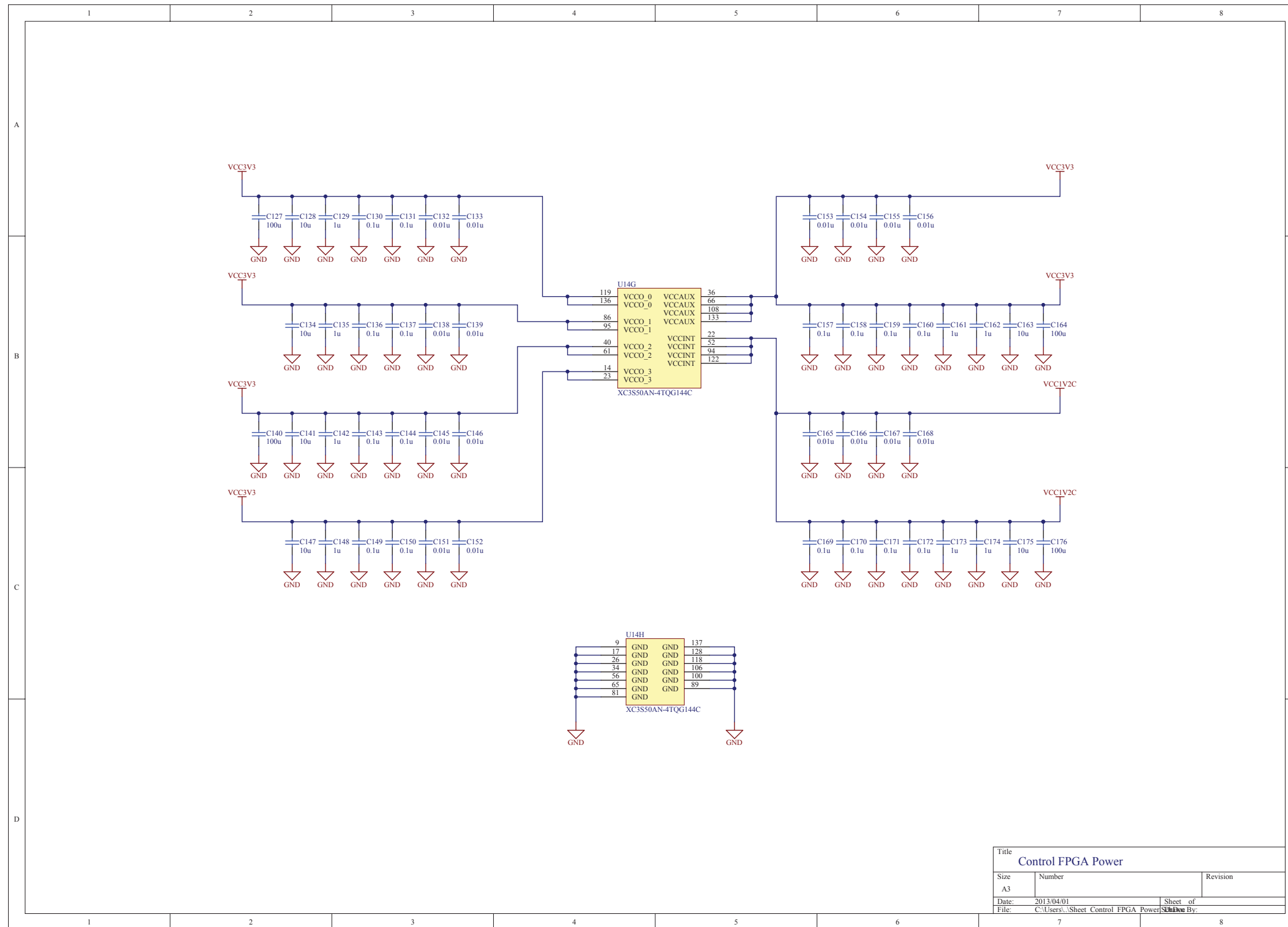


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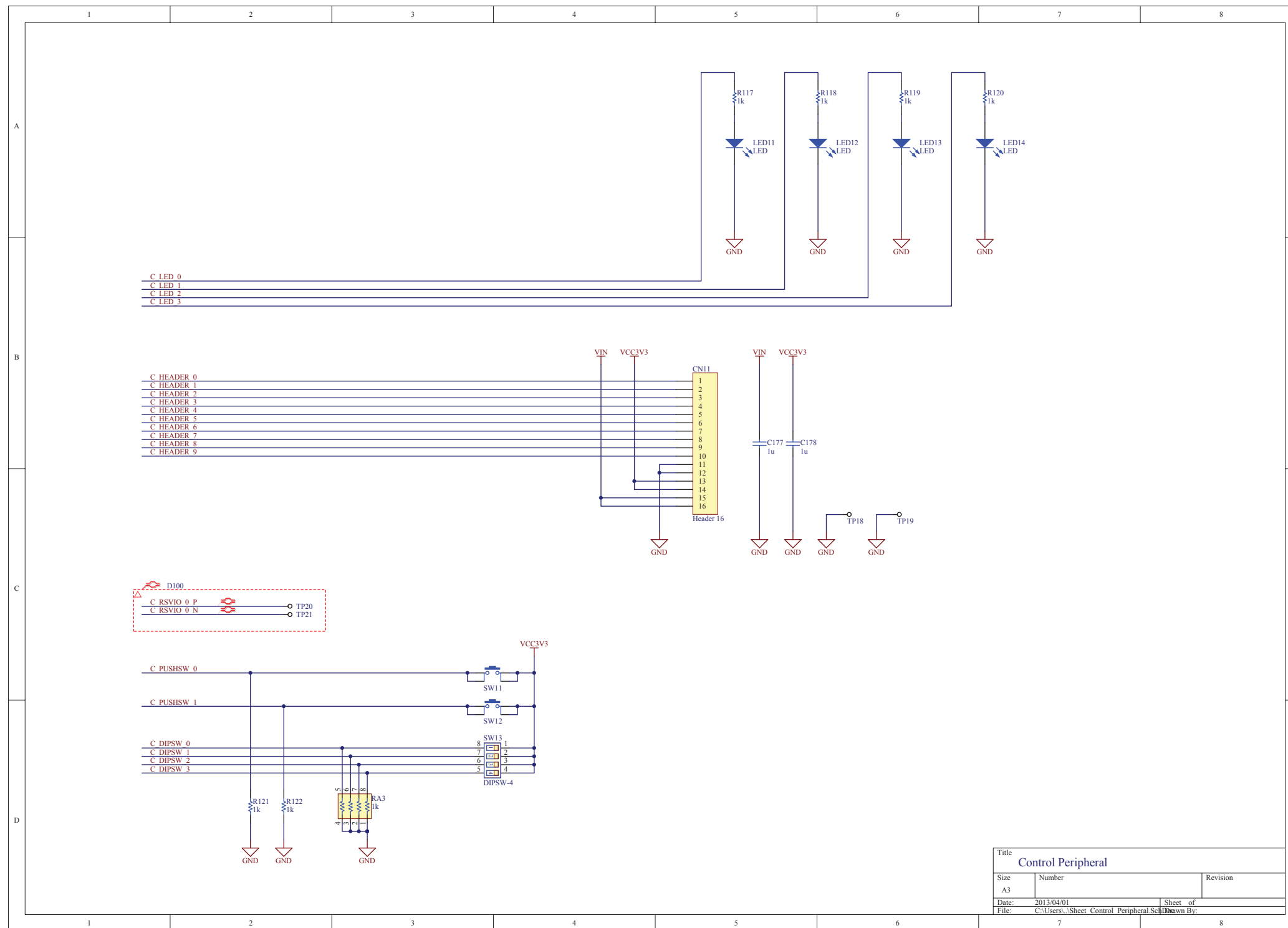




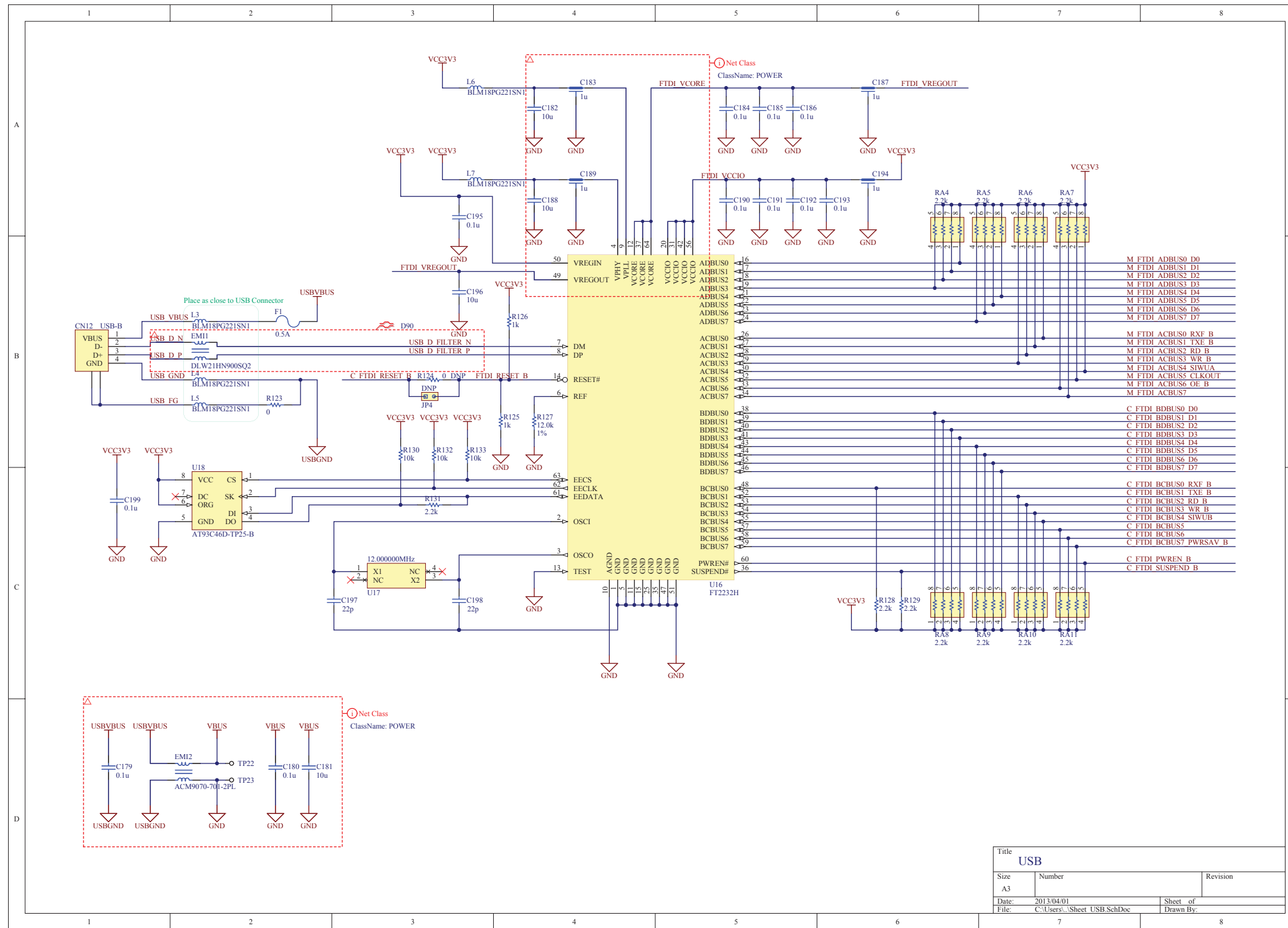




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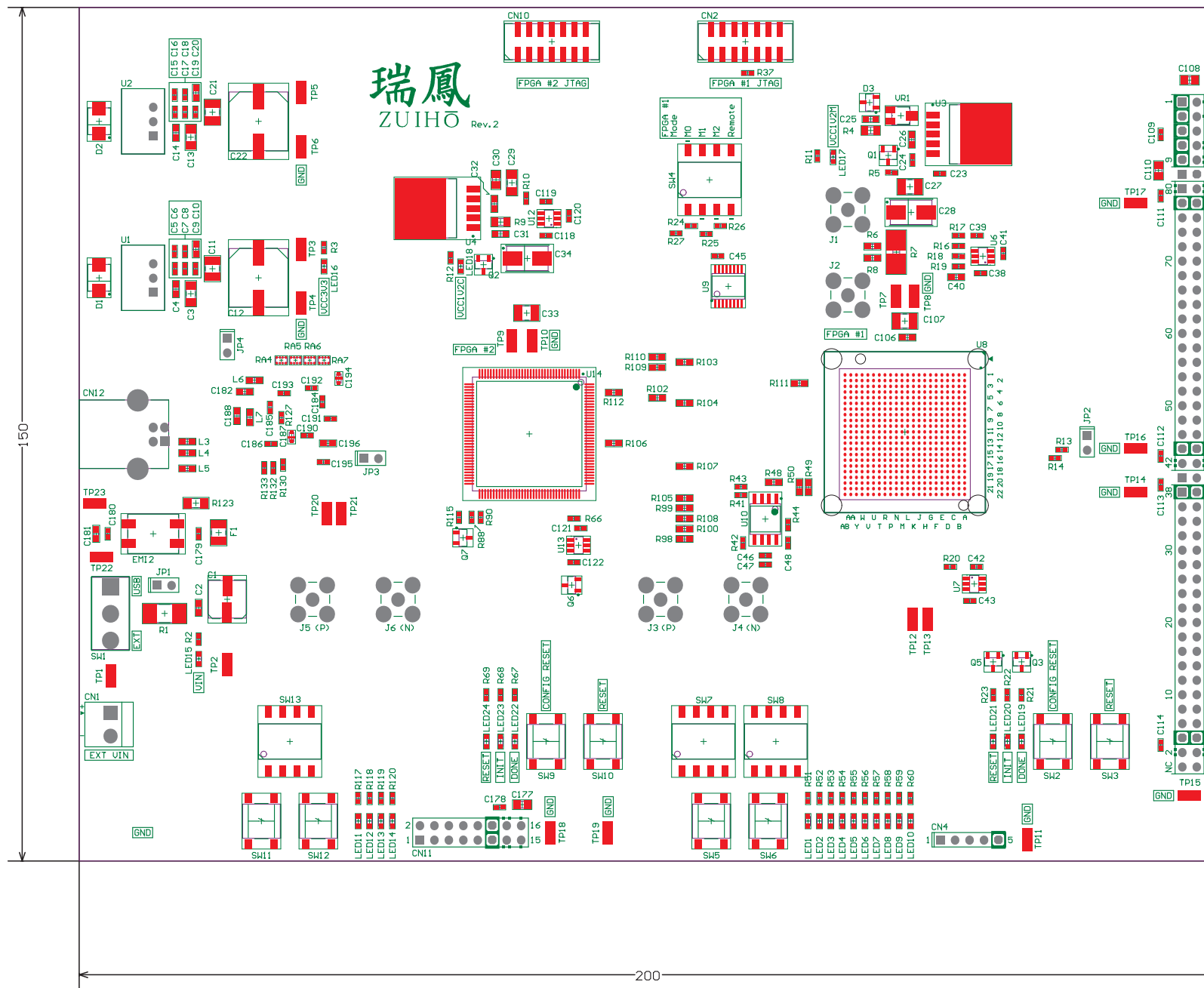


Figure 6 : L1 Assembly Image

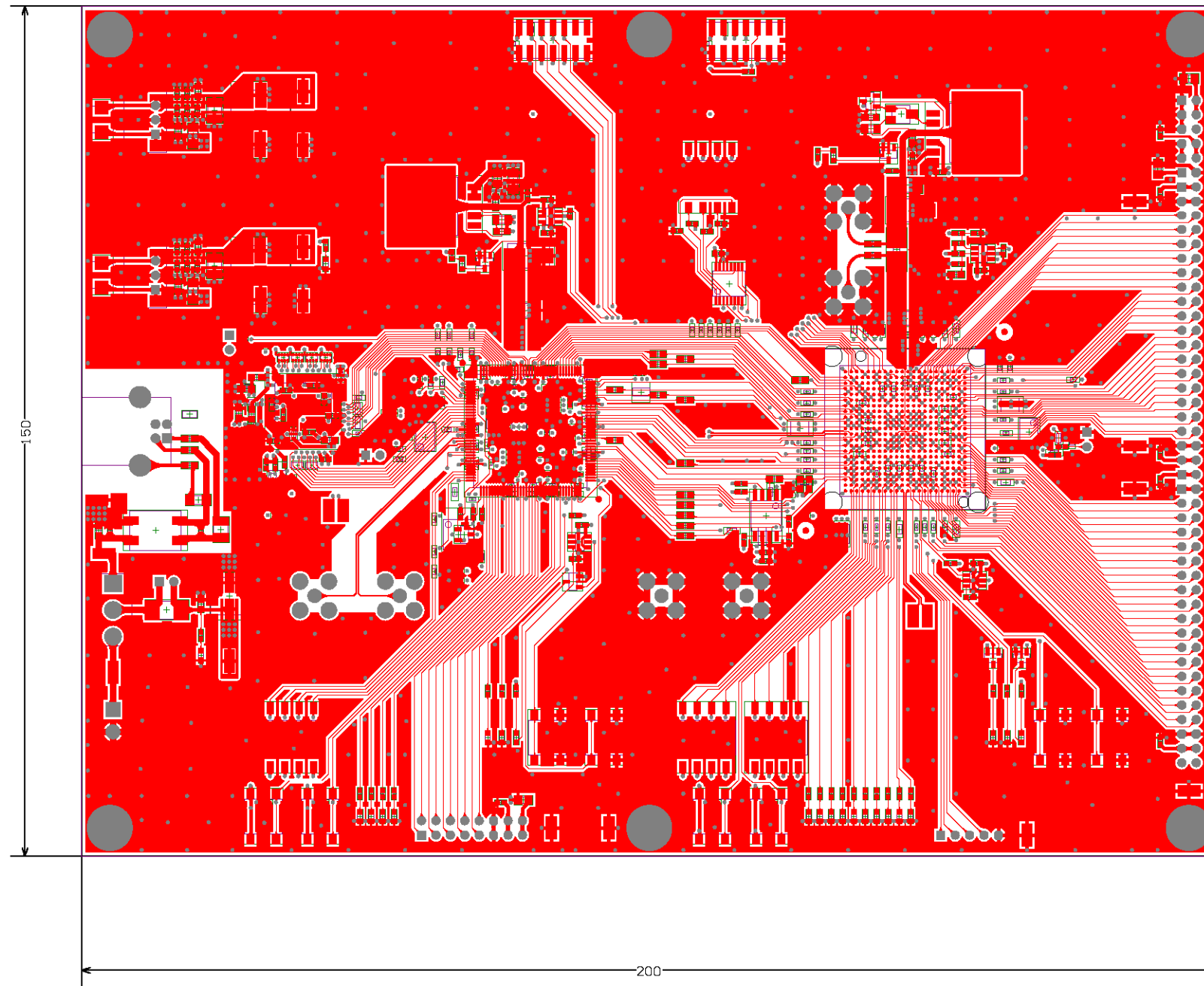


Figure 8 : L1 Pattern

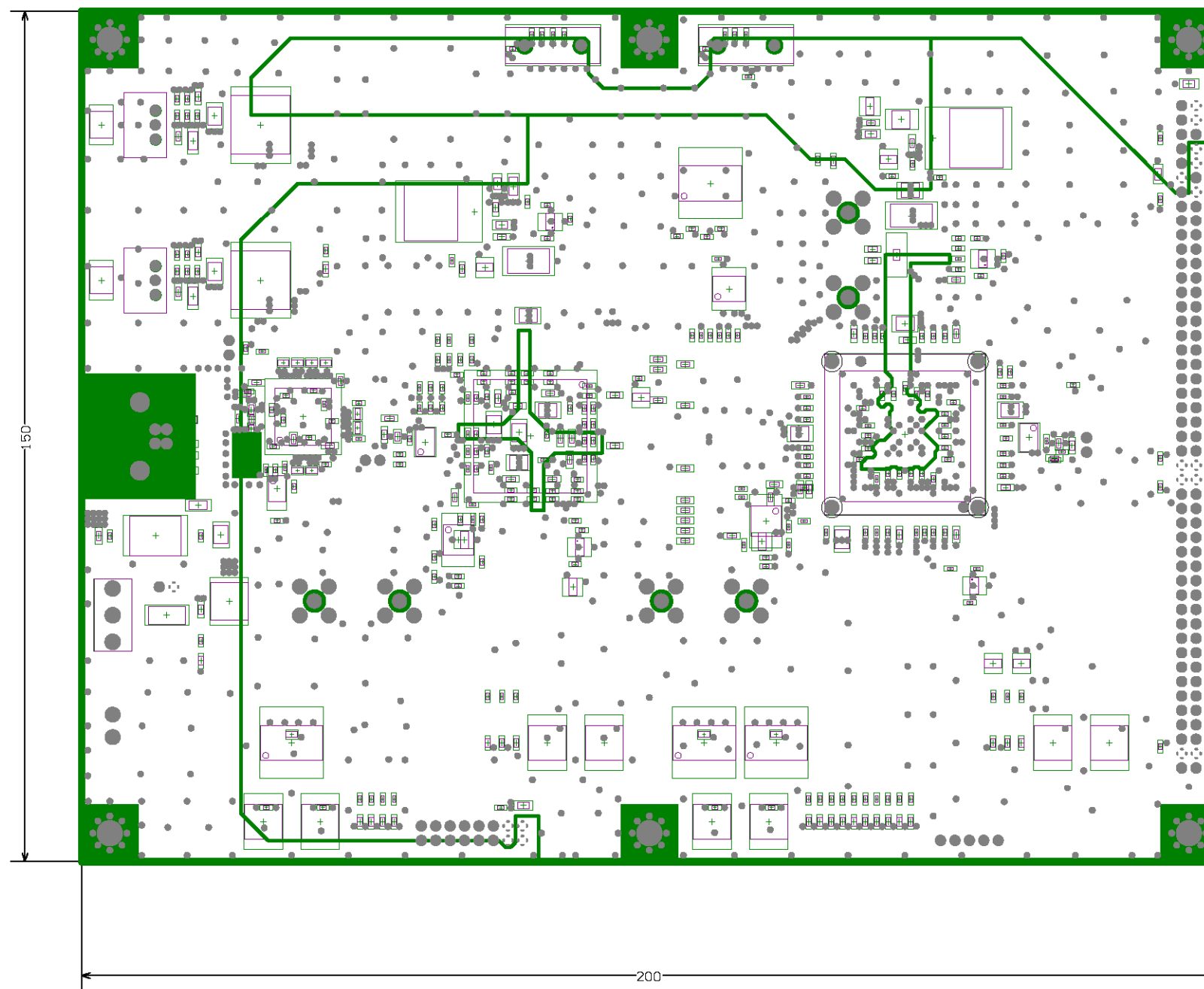


Figure 9 : L2 Cut Pattern

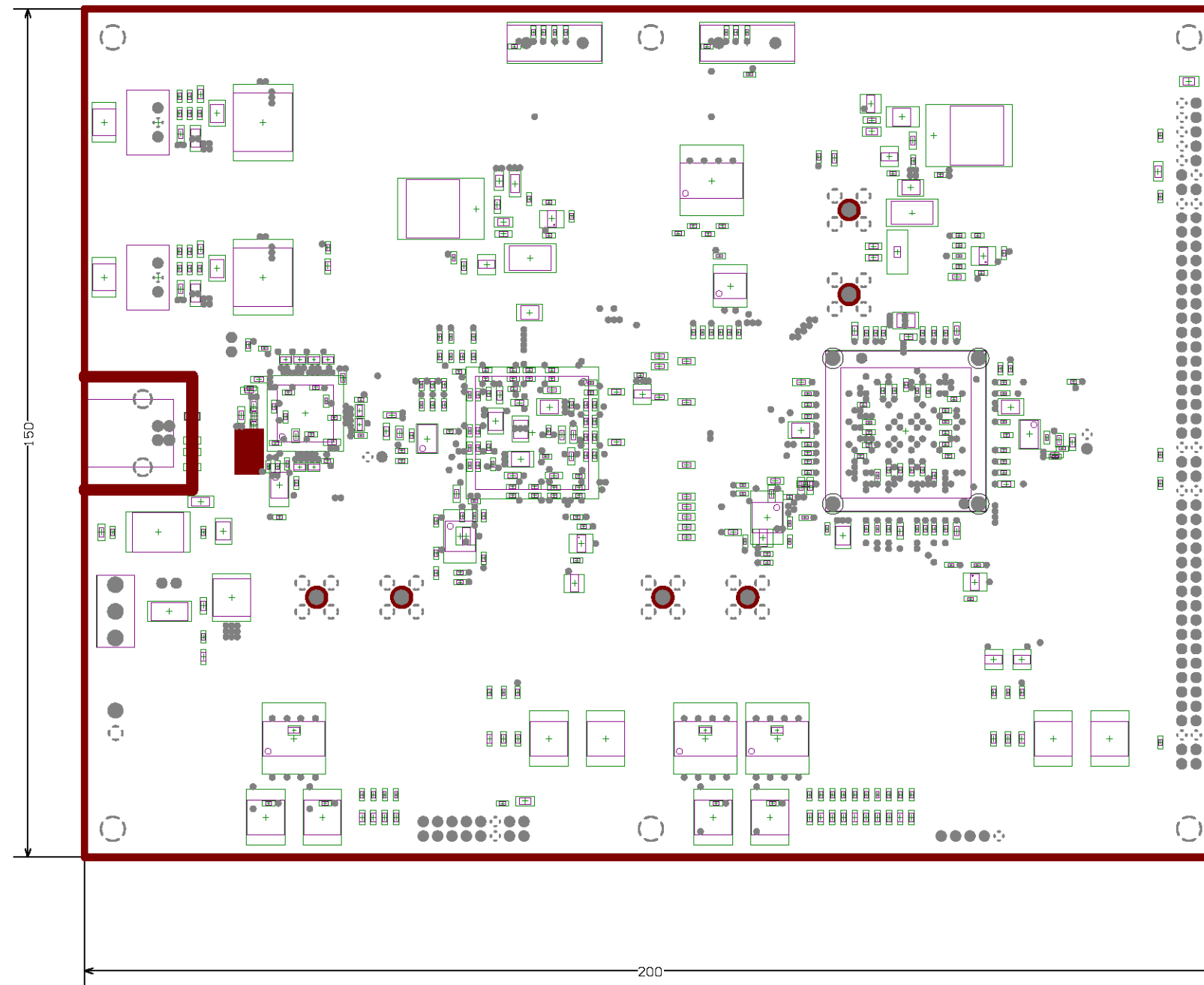


Figure 10 : L3 Cut Pattern

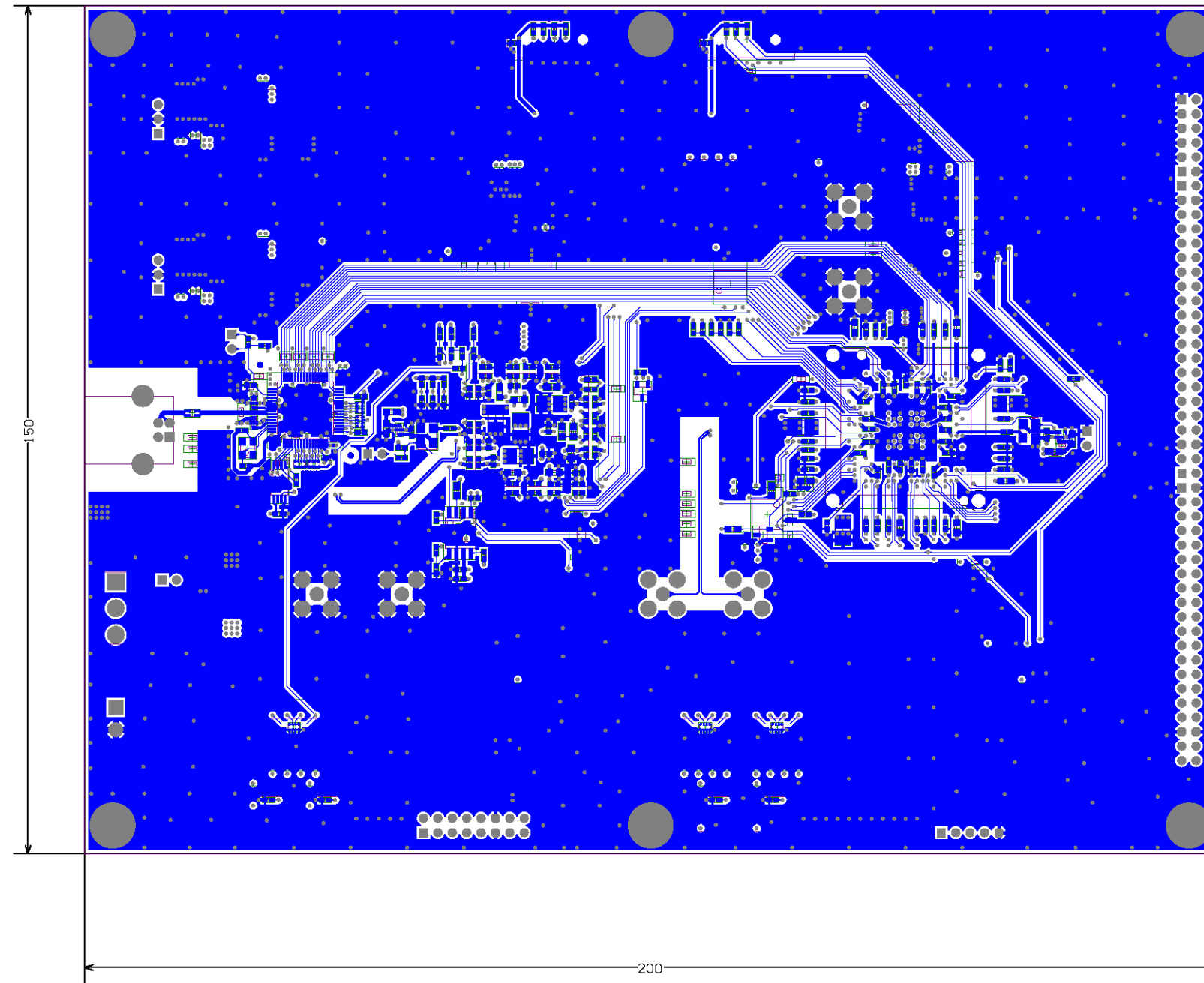


Figure 11 : L4 Pattern

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