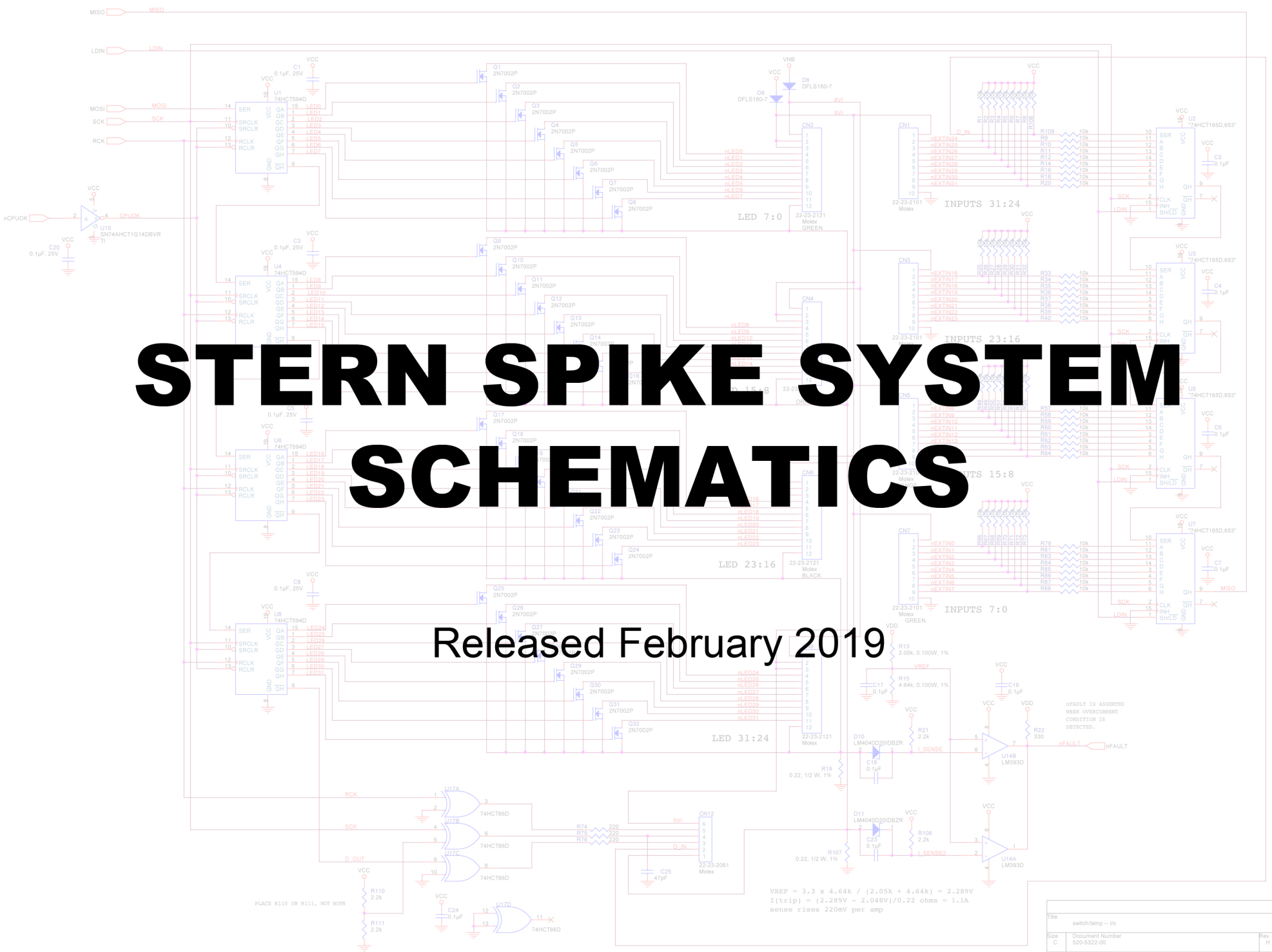


STERN SPIKE SYSTEM SCHEMATICS

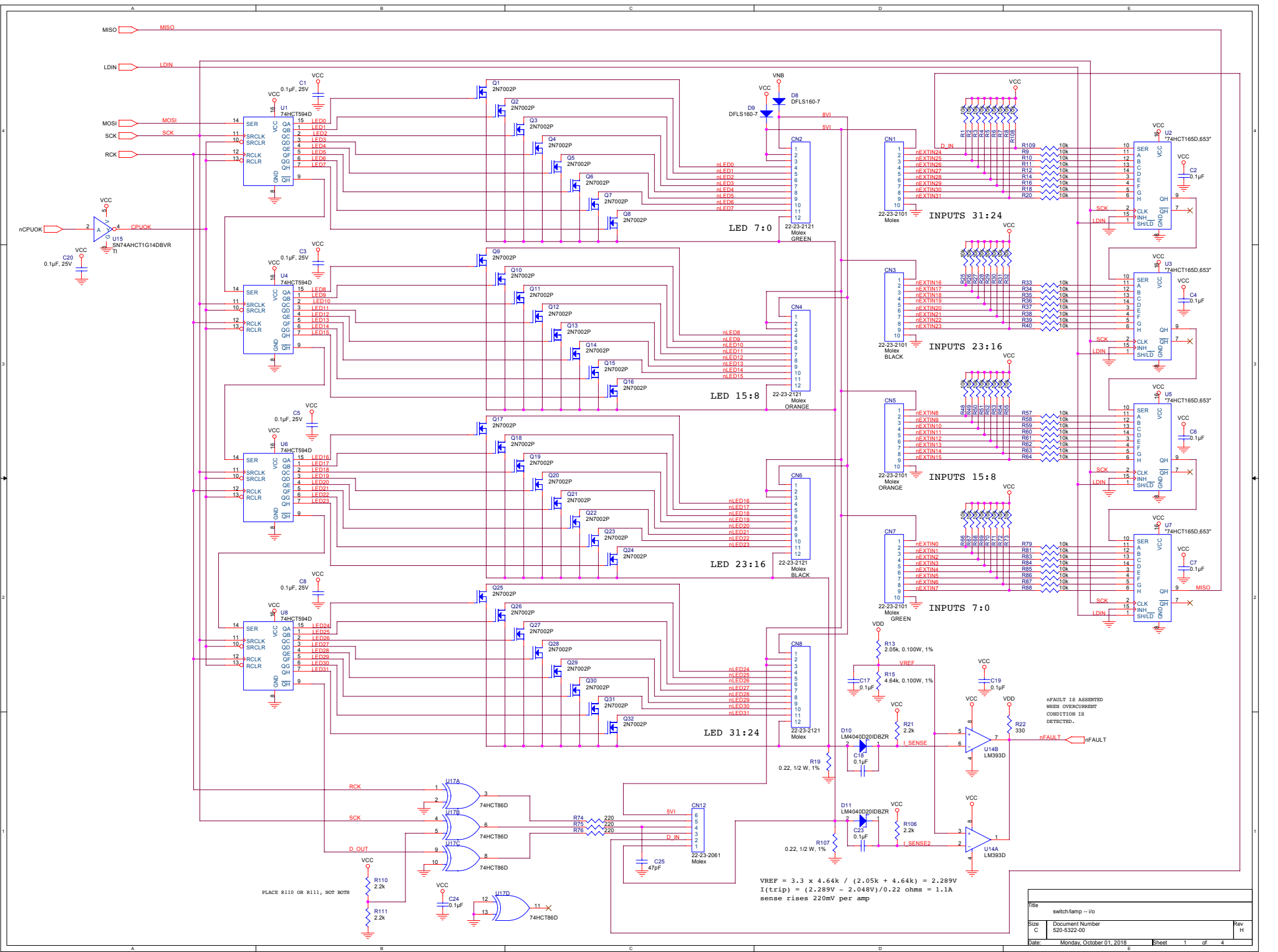
Released February 2019



$$VREF = 3.3 \times 4.64k / (2.05k + 4.64k) = 2.89V$$
$$I_{(trip)} = (2.89V - 2.048V) / 0.22 \text{ ohms} = 1.1A$$

sense rises 220mV per amp

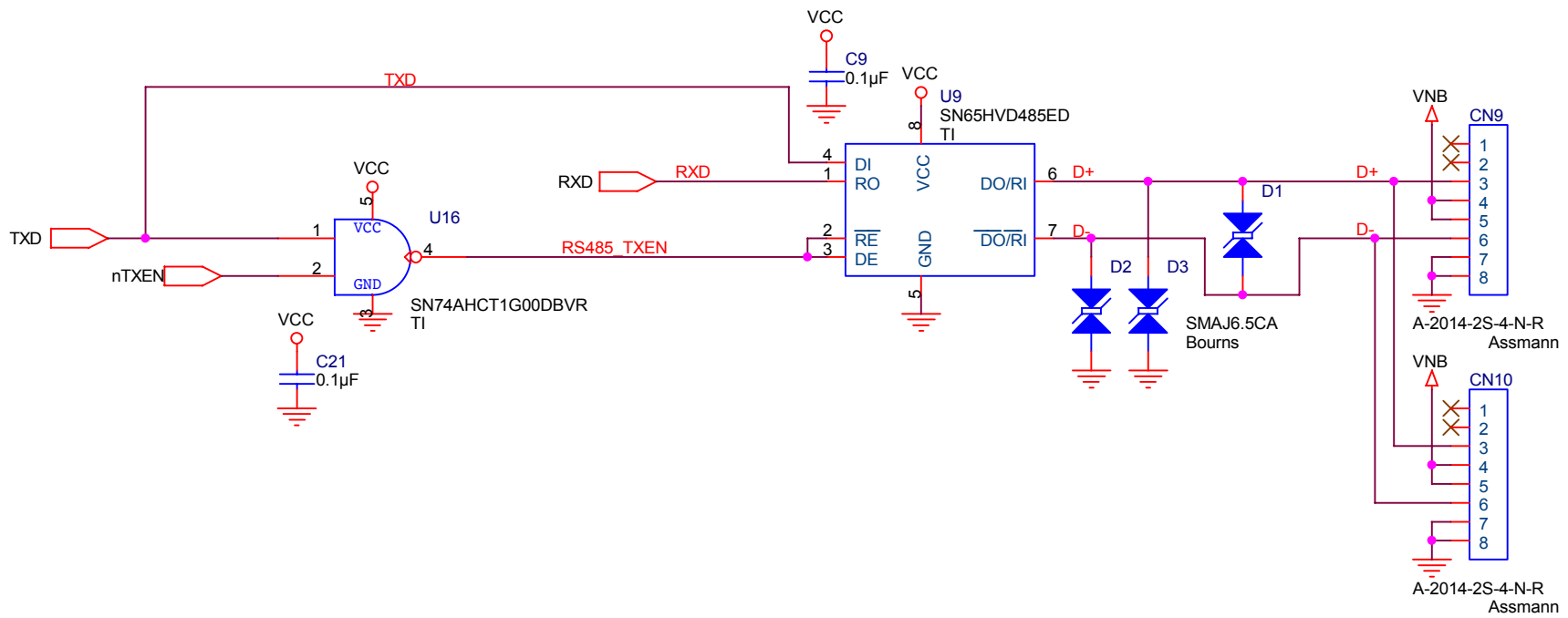
Rev	switch/lamp - io	Rev	H
Size	Document Number		
C	520-532-00		
Date:	Monday, October 01, 2018	Sheet	1 of 4



$VREF = 3.3 \times 4.64k / (2.05k + 4.64k) = 2.289V$
 $I(trip) = (2.289V - 2.048V) / 0.22 \text{ ohms} = 1.1A$
 sense rises 220mV per amp

PLACE R110 OR R111, NOT BOTH

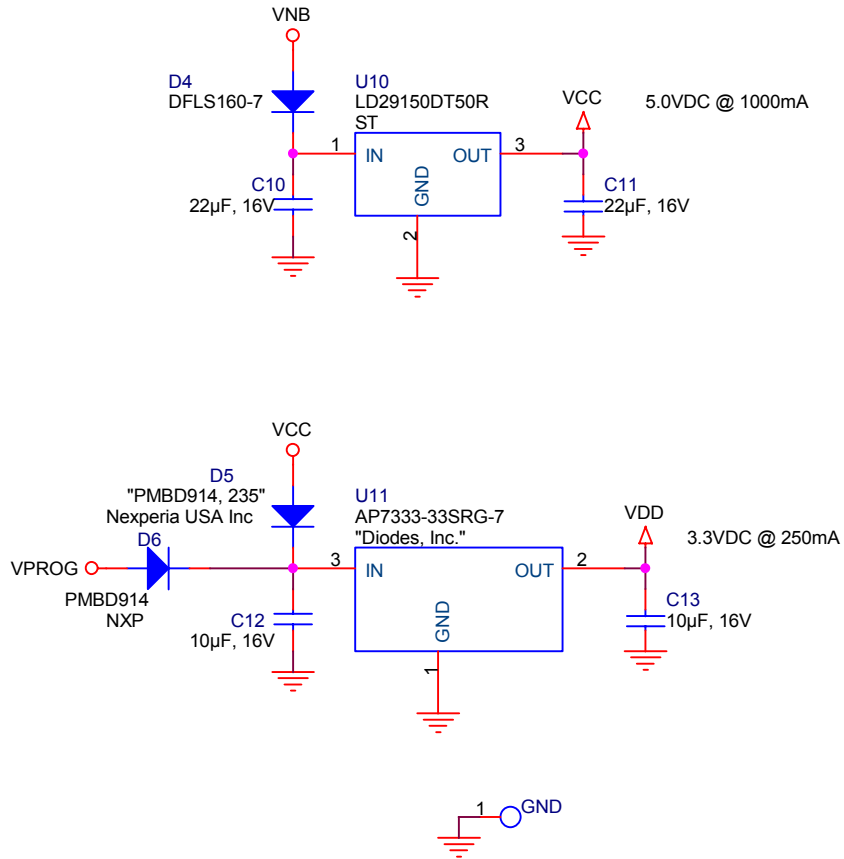
Title	switch/lamp - i/o	Rev	H
Size	Document Number		
C	520-5322-00		
Date:	Monday, October 01, 2018	Sheet	1 of 4



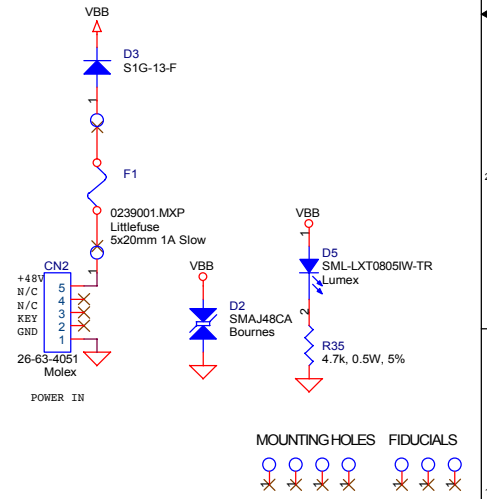
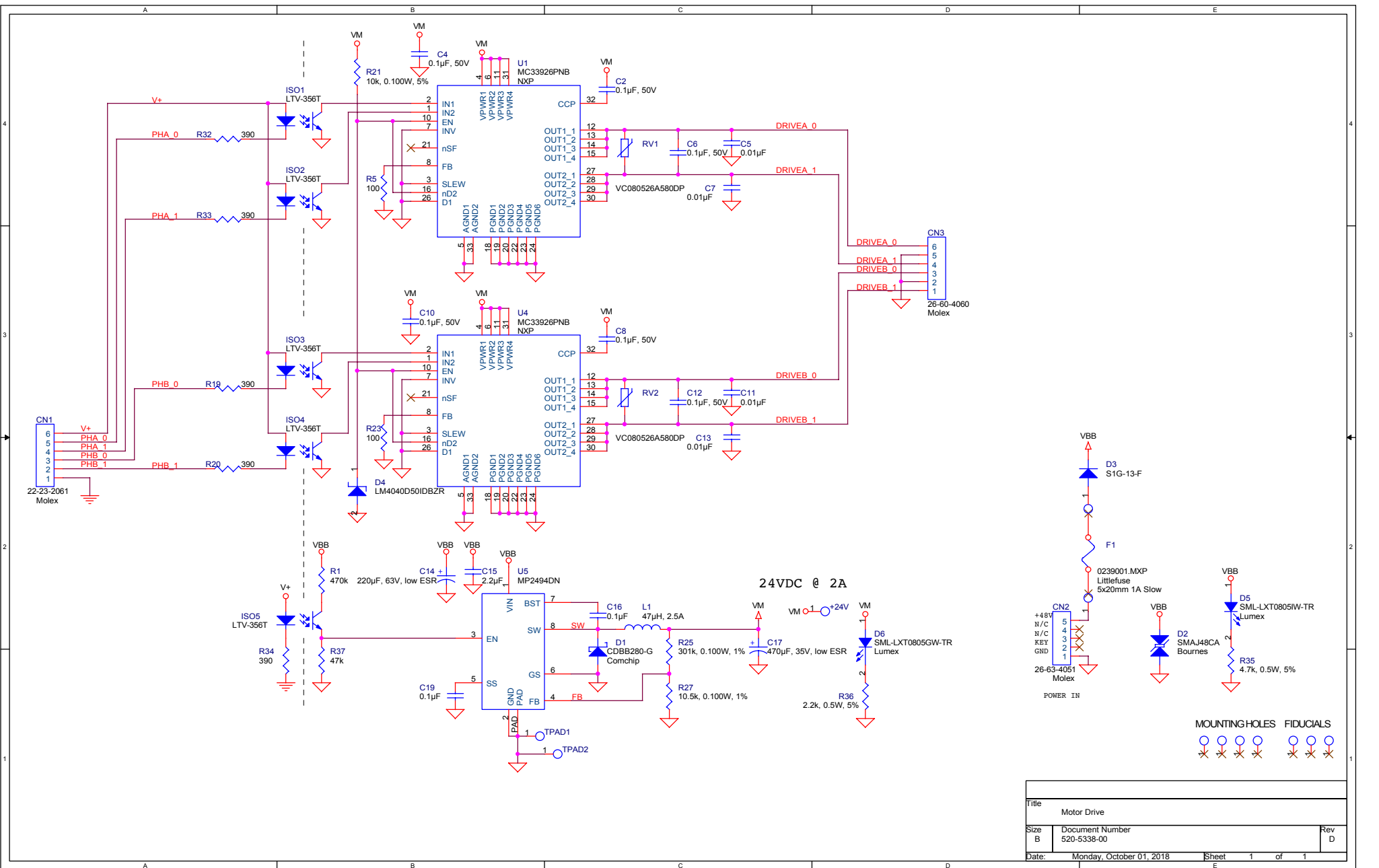
Title		
switch/lamp -- communication		
Size	Document Number	Rev
A	520-5322-00	H
Date:	Monday, October 01, 2018	Sheet 2 of 4

STATUS LED (D7, YELLOW)

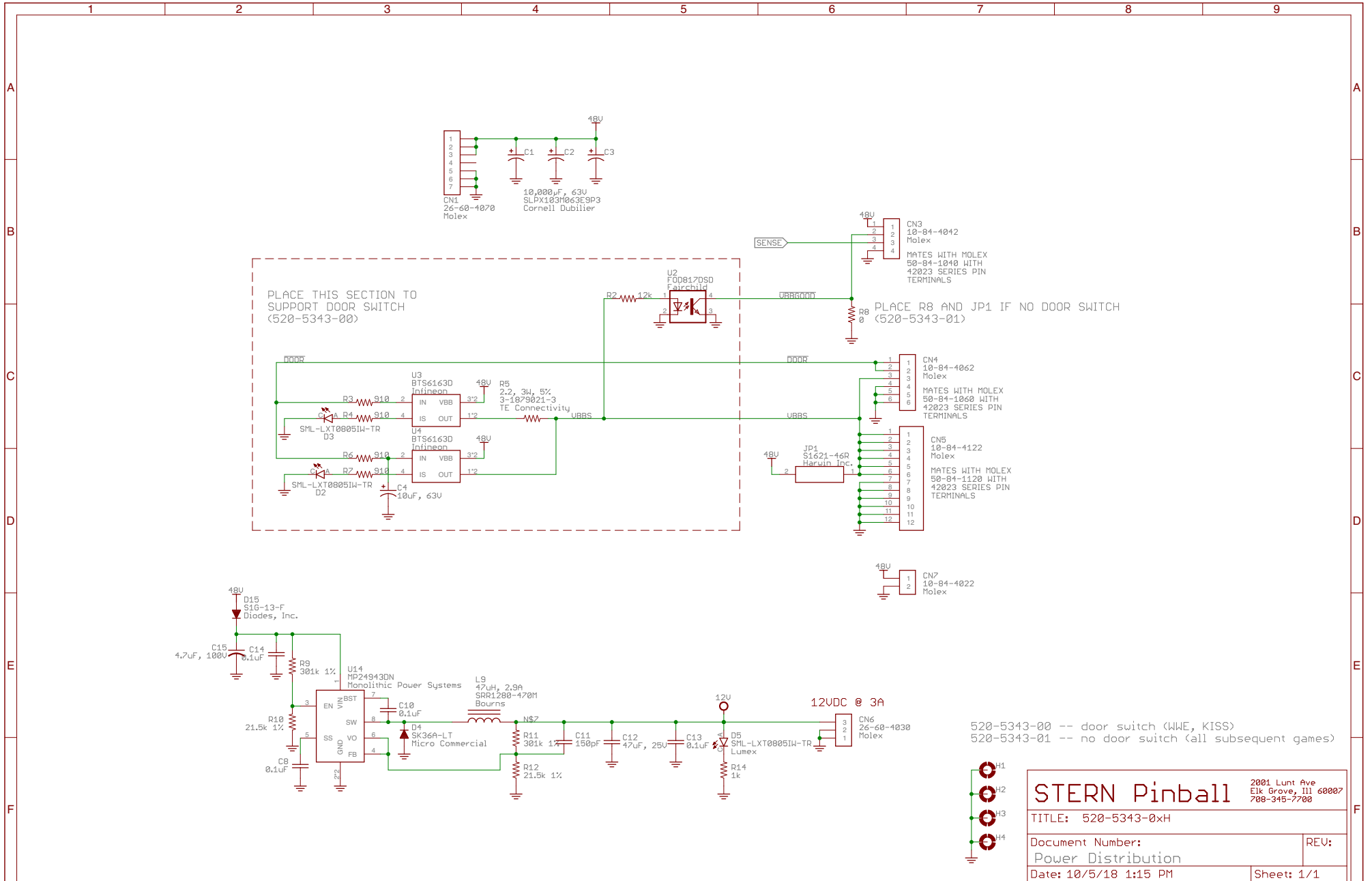
10Hz 50% power okay, processor in boot mode waiting for runtime update: check node cable, ensure other nodes are communicating, check communication interface
 1Hz 90% power okay, processor in runtime mode but not receiving from CPU: check node cable, ensure other nodes are communicating, check communication interface
 flickering power okay, processor communicating and operating correctly



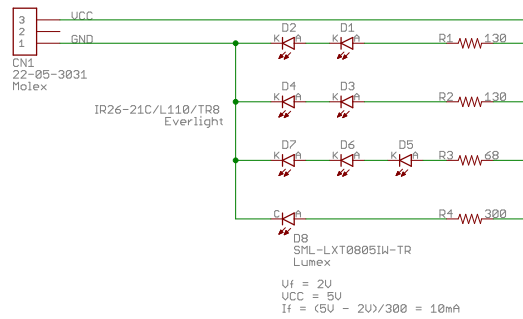
Title		
switch/lamp -- power supply		
Size	Document Number	Rev
A	520-5322-00	H
Date:	Monday, October 01, 2018	Sheet 3 of 4



Title		
Motor Drive		
Size	Document Number	Rev
B	520-5338-00	D
Date:	Monday, October 01, 2018	Sheet 1 of 1

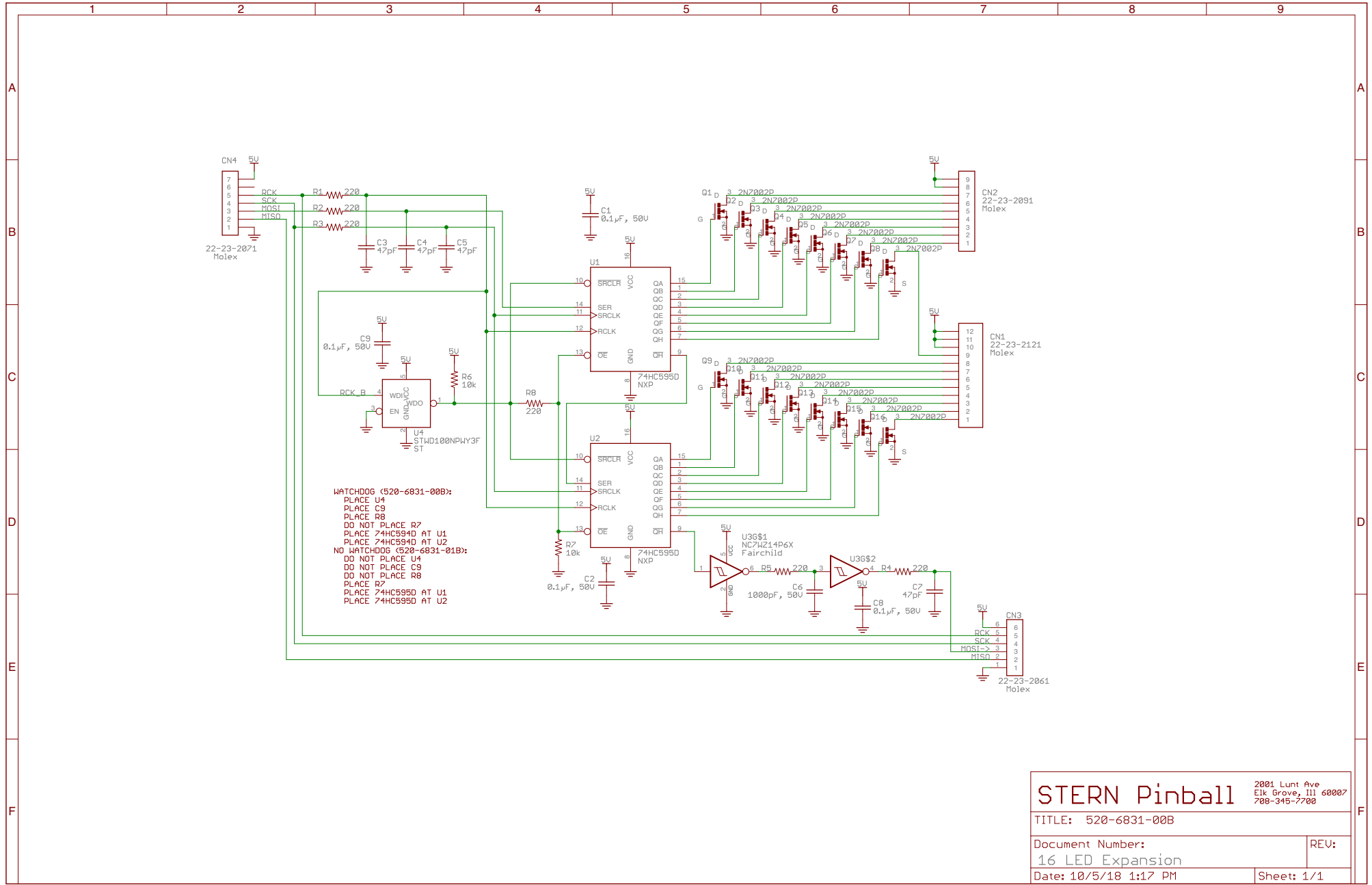


STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-5343-0xH			
Document Number:		REV:	
Power Distribution			
Date: 10/5/18 1:15 PM		Sheet: 1/1	

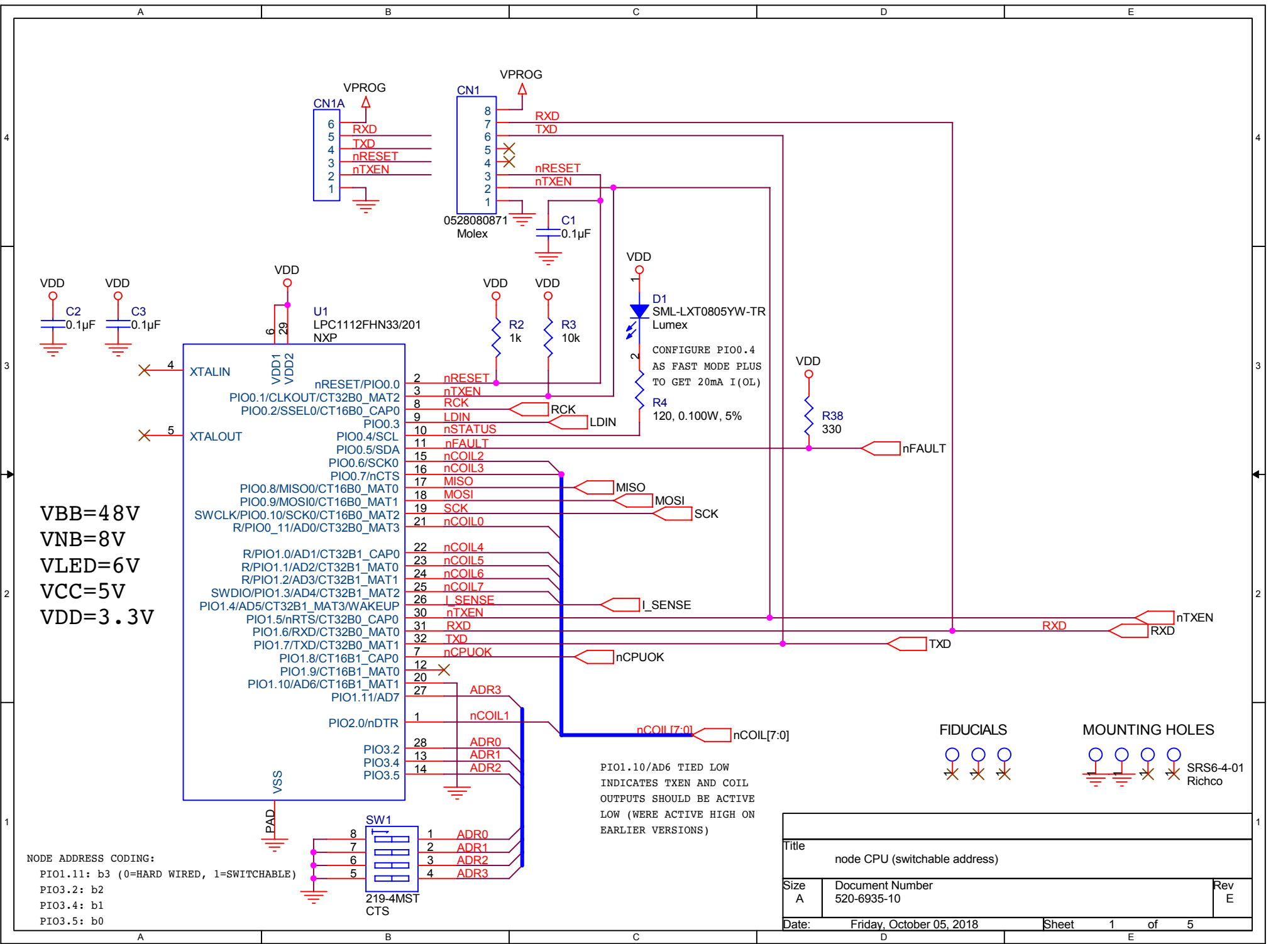


$V_f = 1.2V$
 $UCC = 5V$
 $I_f = 20mA$
 two LEDs: $R = (5V - (2 \times 1.2V)) / 130\Omega = 20mA$
 three LEDs: $R = (5V - (3 \times 1.2V)) / 68\Omega = 20mA$

STERN Pinball 2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700		TITLE: 520-5344-00E
Date: 10/5/18 1:16 PM		Sheet: 1/1



STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6831-00B		
Document Number:	REV:	
16 LED Expansion		
Date: 10/5/18 1:17 PM	Sheet: 1/1	

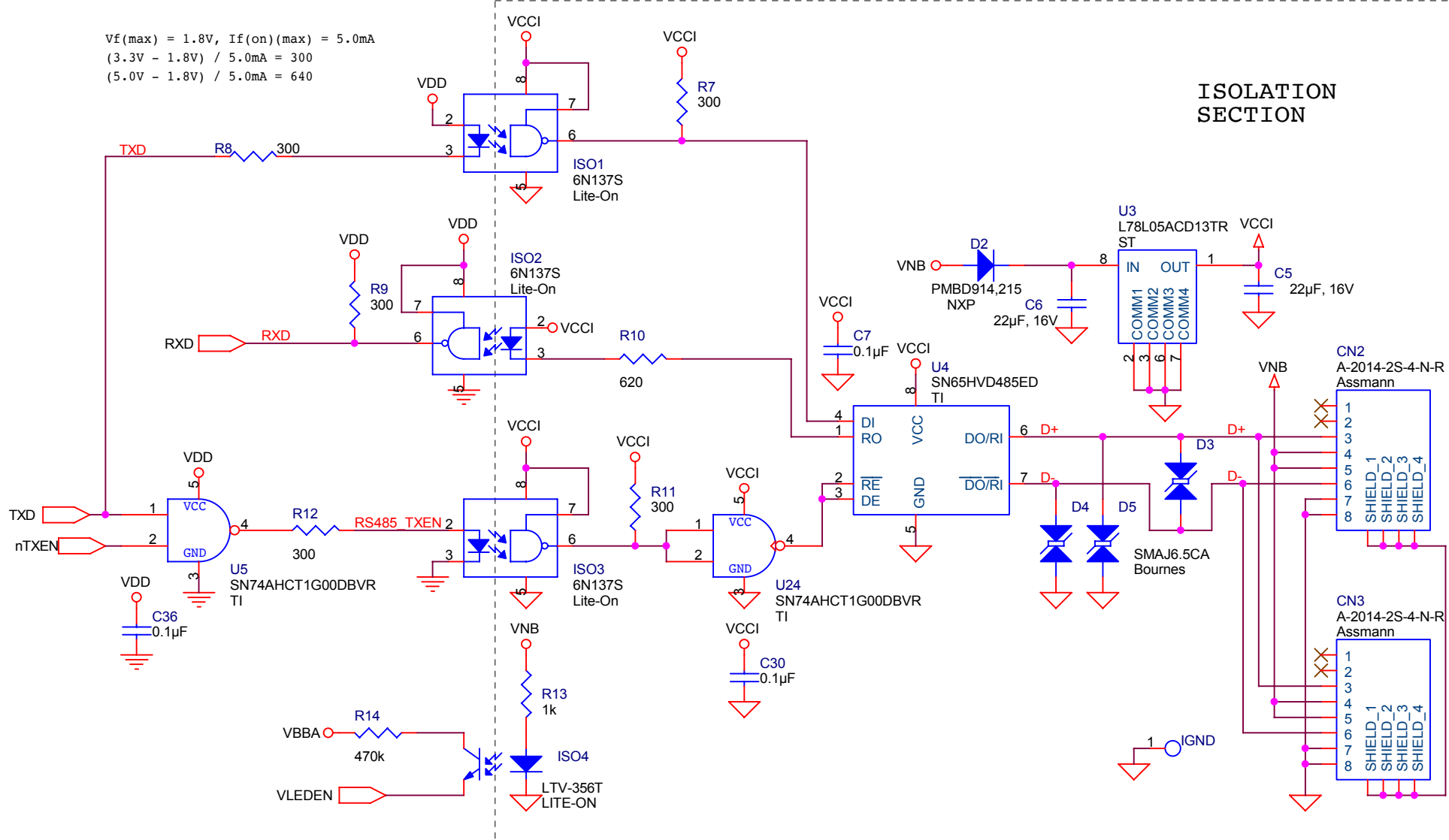


NODE ADDRESS CODING:
 PIO1.11: b3 (0=HARD WIRED, 1=SWITCHABLE)
 PIO3.2: b2
 PIO3.4: b1
 PIO3.5: b0

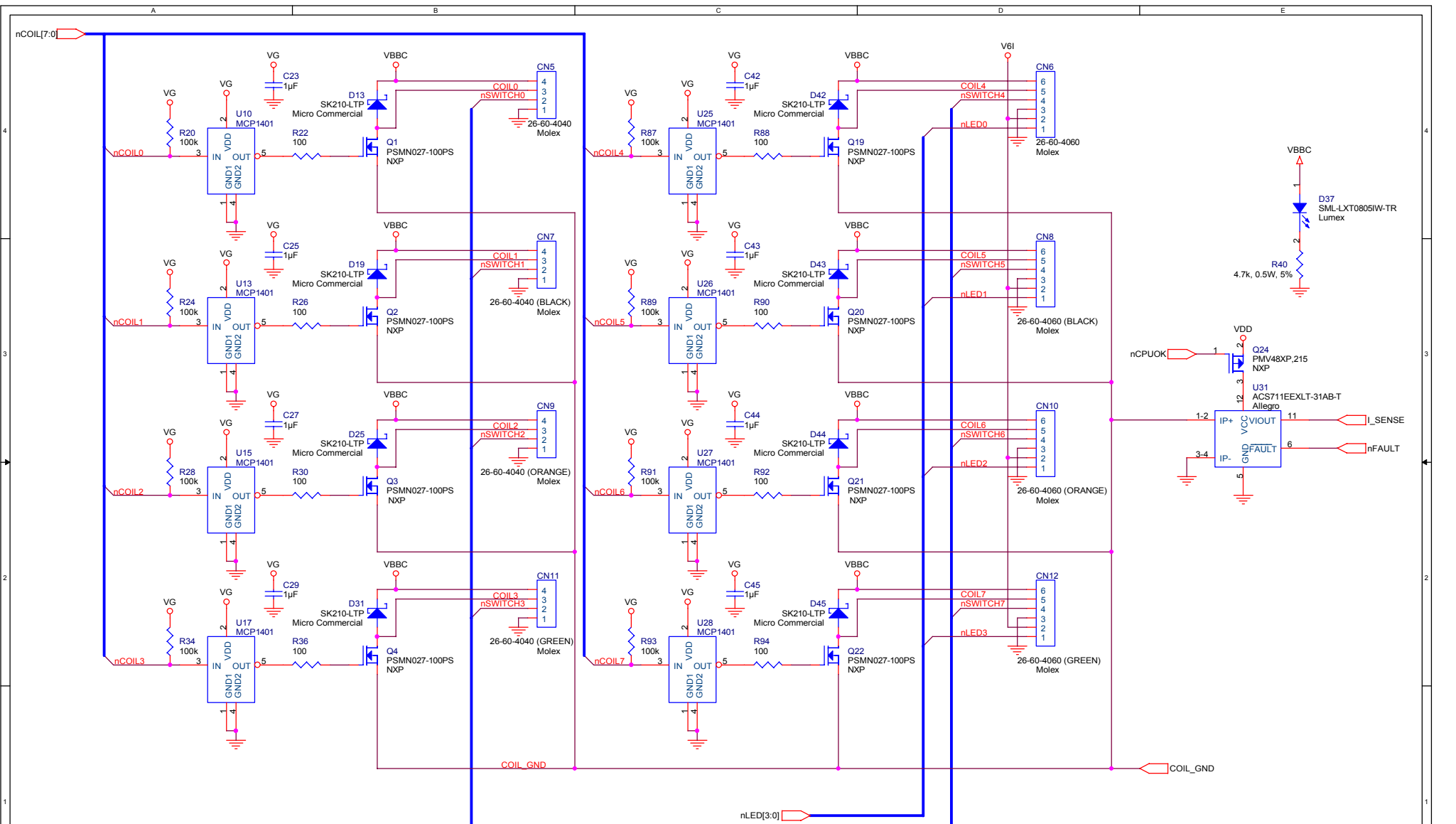
Title		
node CPU (switchable address)		
Size	Document Number	Rev
A	520-6935-10	E
Date:	Friday, October 05, 2018	Sheet 1 of 5

$V_f(\max) = 1.8V$, $I_f(\text{on})(\max) = 5.0mA$
 $(3.3V - 1.8V) / 5.0mA = 300$
 $(5.0V - 1.8V) / 5.0mA = 640$

ISOLATION SECTION



Title		
communication -- isolated		
Size	Document Number	Rev
A	520-6935-10	E
Date:	Friday, October 05, 2018	Sheet 2 of 5



I_SENSE rises 33mV/A from its idle voltage of 1.225V. ADC should idle at about 380 (10-bit) and will rise by 10.24 per amp as coil current increases (e.g, 10A coil current should read 380 + 10 x 10.24 = 482).

$$I_SENSE = 1.225V + I(\text{coil}) \times 0.033 \text{ ohms}$$

$$VREF = 5.00V \times 4.64k / (5.49k + 4.64k) = 2.290V$$

$$I(\text{trip}) = (2.290V - 1.225V) / 0.033 \text{ ohms} = 32A$$

Title		
coils		
Size	Document Number	Rev
B	520-6935-10	E
Date:	Friday, October 05, 2018	Sheet 4 of 5

LED STATUS TABLE

48V 6V MCU STATUS

D37 D10 D1

RED GREEN YELLOW

OFF OFF OFF

48V not present: check that system is connected and powered

ON OFF OFF

48V present, no 6V: node bus is powered off by CPU, node bus cable is unplugged, or 6V supply is overloaded (shorted) or damaged

ON ON OFF

48V present, 6V present, processor not running: check 5V and 3.3V supplies

ON ON 10Hz 50%

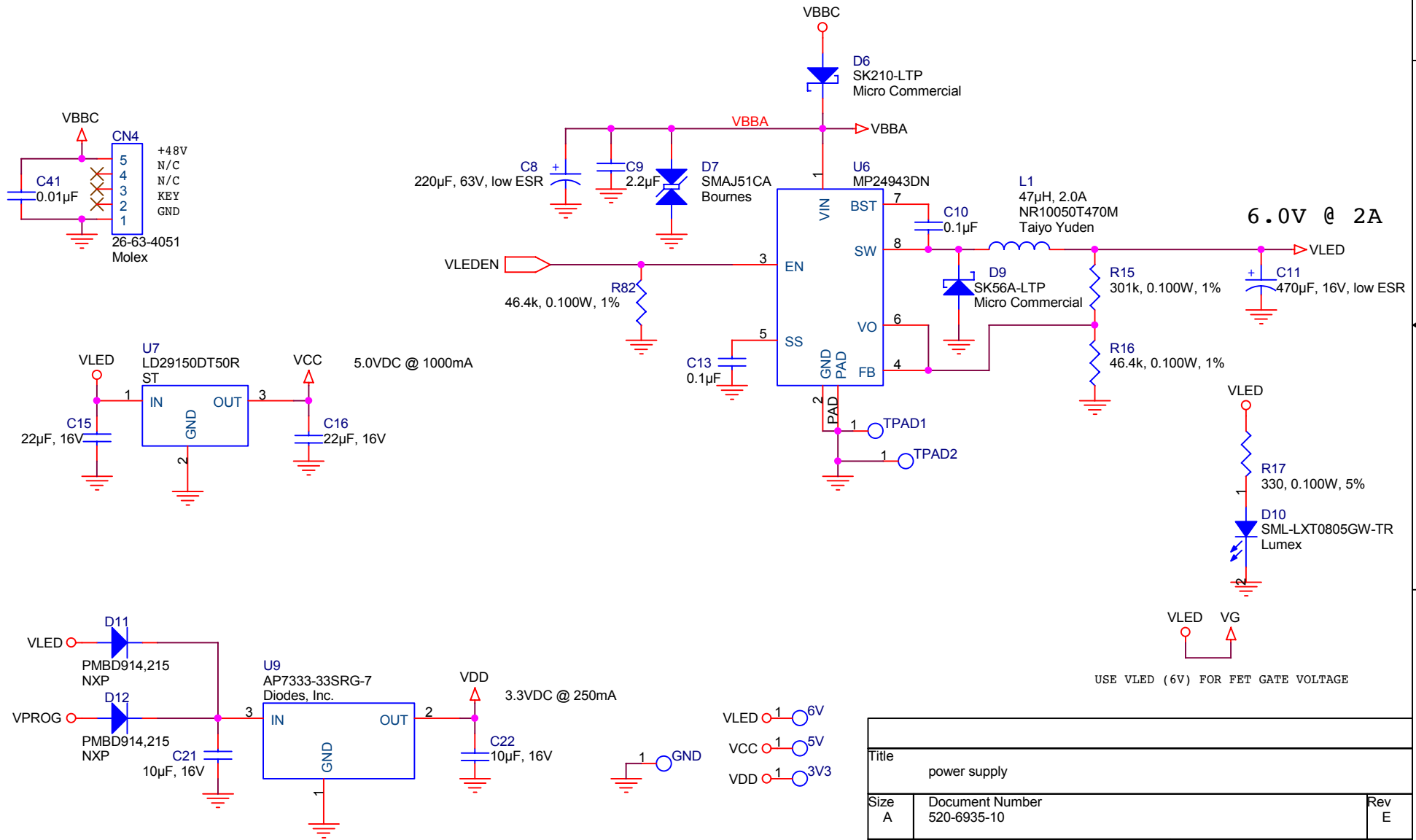
power okay, processor in boot mode waiting for runtime update: check node cable, ensure other nodes are communicating, check communication interface

ON ON 1Hz 90%

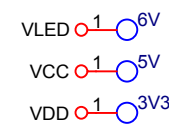
power okay, processor in runtime mode but not receiving from CPU: check node cable, ensure other nodes are communicating, check communication interface

ON ON flickering

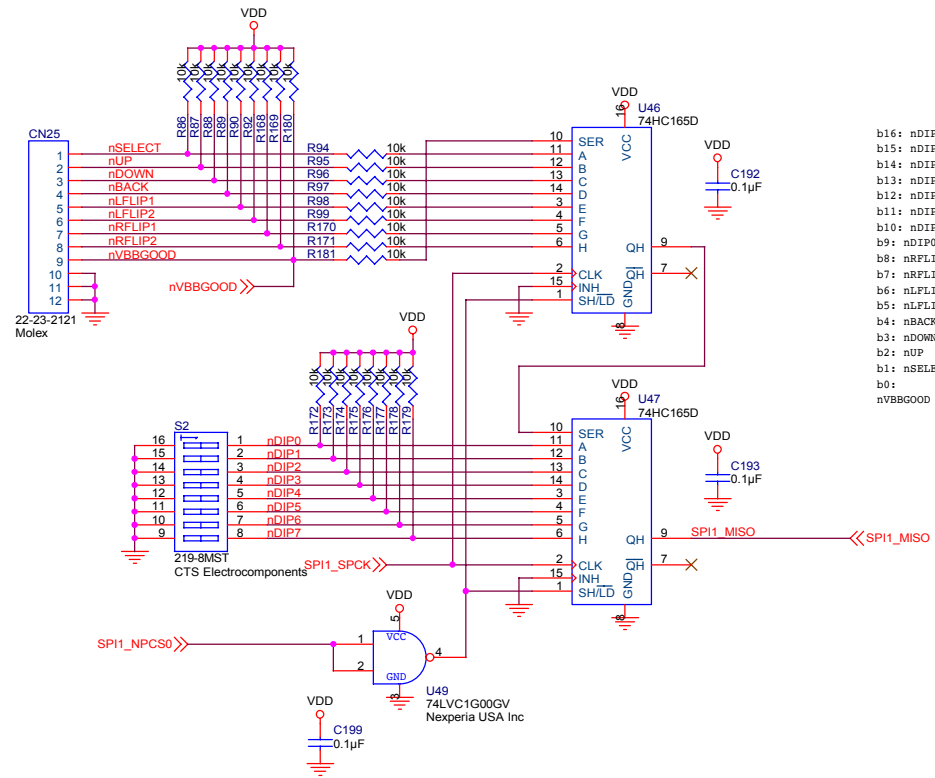
power okay, processor communicating and operating correctly



USE VLED (6V) FOR FET GATE VOLTAGE

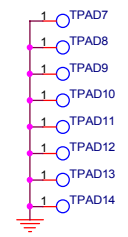
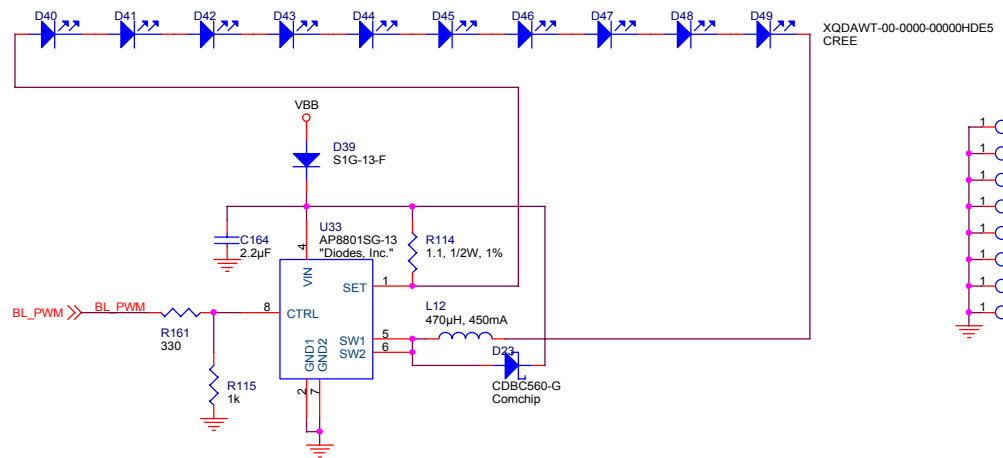


Title power supply		
Size A	Document Number 520-6935-10	Rev E
Date: Friday, October 05, 2018	Sheet 3	of 5



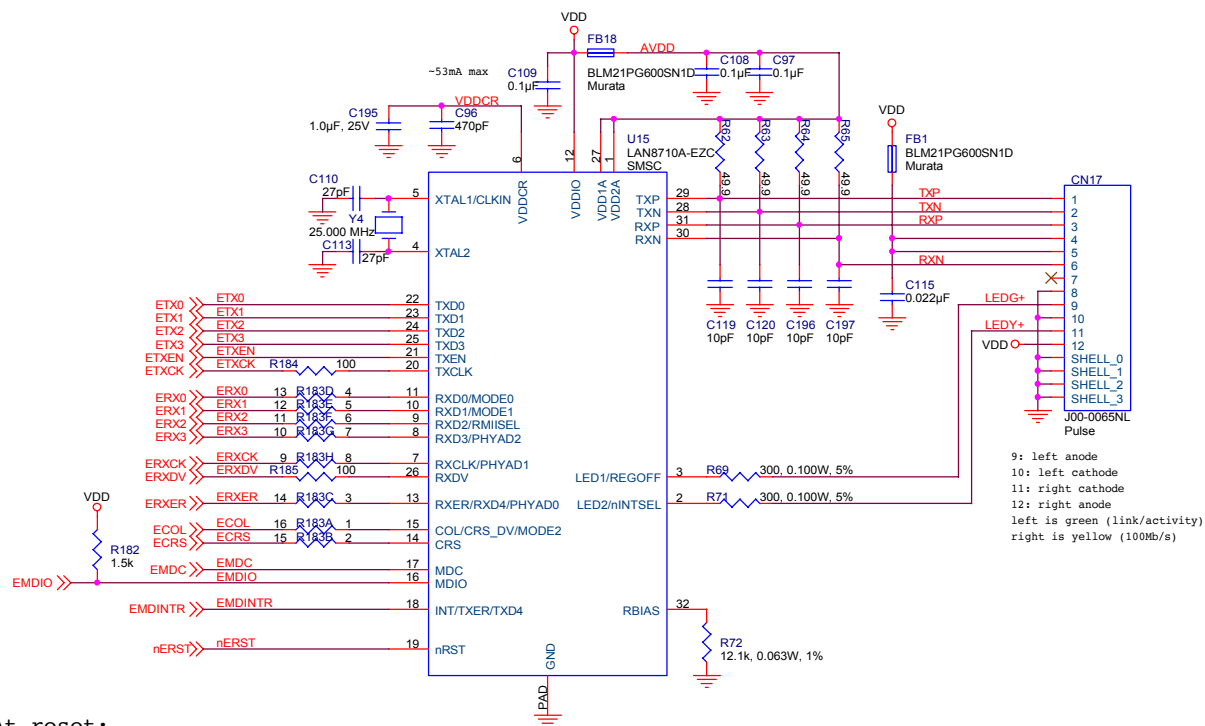
- b16: nDIP7
- b15: nDIP6
- b14: nDIP5
- b13: nDIP4
- b12: nDIP3
- b11: nDIP2
- b10: nDIP1
- b9: nDIP0
- b8: nRFLIP2
- b7: nRFLIP1
- b6: nLFLIP2
- b5: nLFLIP1
- b4: nBACK
- b3: nDOWN
- b2: nUP
- b1: nSELECT
- b0: nVBBGOOD

Title		
Stern Pinball CPU -- switch inputs		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 2 of 8



$V_{thd} = 200 \text{ mV}$
 $V_{ref} = 1.25\text{V}$
 $I_{led} = V_{ctrl} / V_{ref} \times V_{thd} / R_{set}$
 $V_{ctrl} = 3.3 \times 1\text{k} / (330 + 1\text{k}) = 2.48\text{V}$
 $I_{led} (\text{target}) = 350 \text{ mA}$
 $R_{set} = V_{ctrl} / V_{ref} \times V_{thd} / I_{led} = 2.48\text{V} / 1.25\text{V} \times 200\text{mV} / 350\text{mA} = 1.13 \text{ ohms}$
 $R_{set} = 1.1 \text{ ohms}$
 $I_{led} = 2.48 / 1.25 \times 200\text{mV} / 1.1 \text{ ohms} = 360 \text{ mA}$
 Power across Rset is $(I^2)R = (360\text{mA})^2 \times 1.1 \text{ ohms} = 143\text{mW}$

Title		
backlight		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 4 of 8

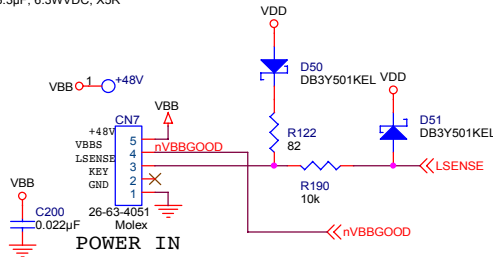
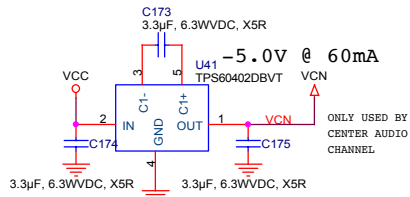
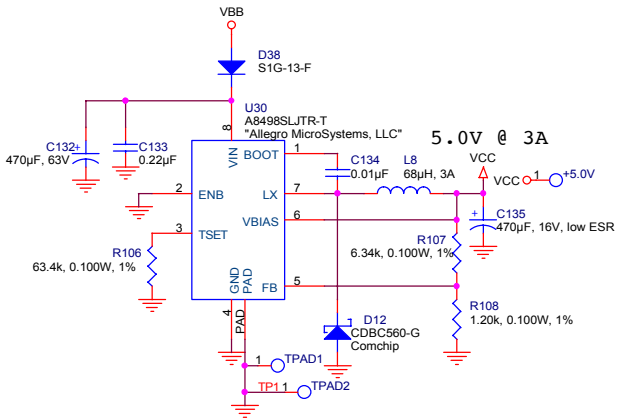
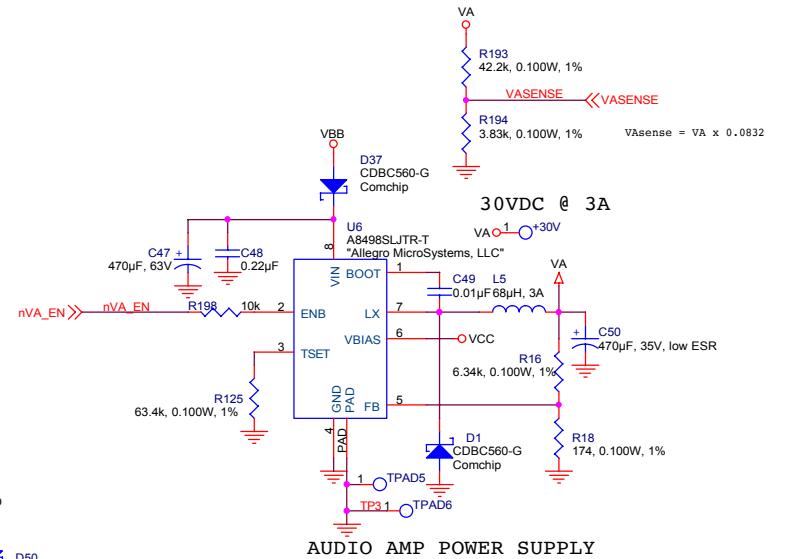
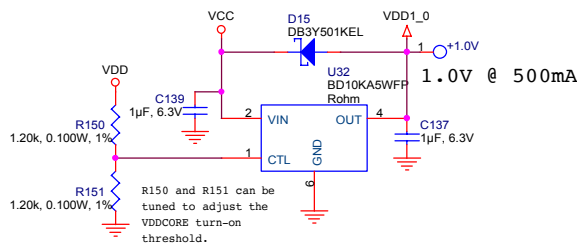
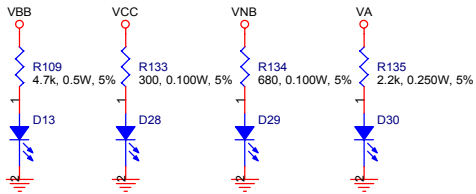
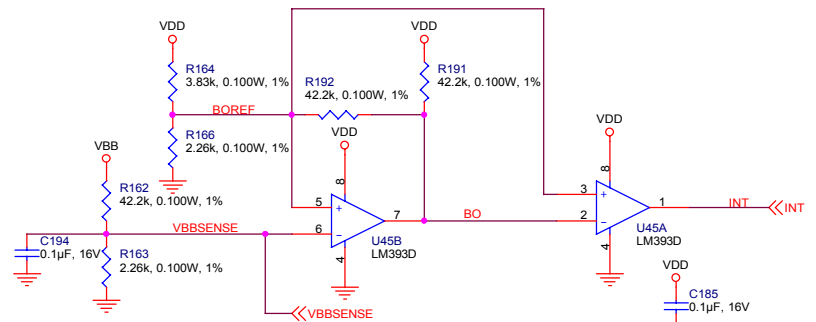
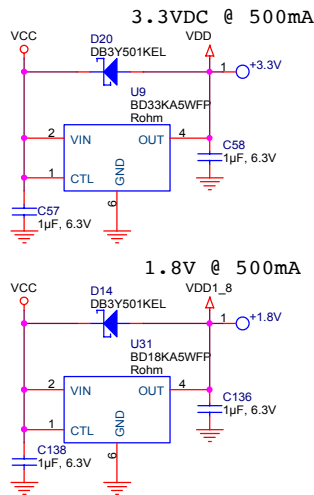
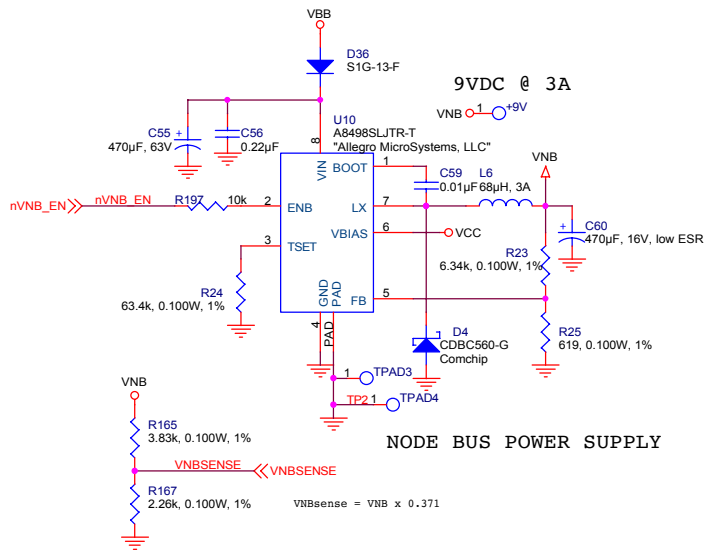


At reset:

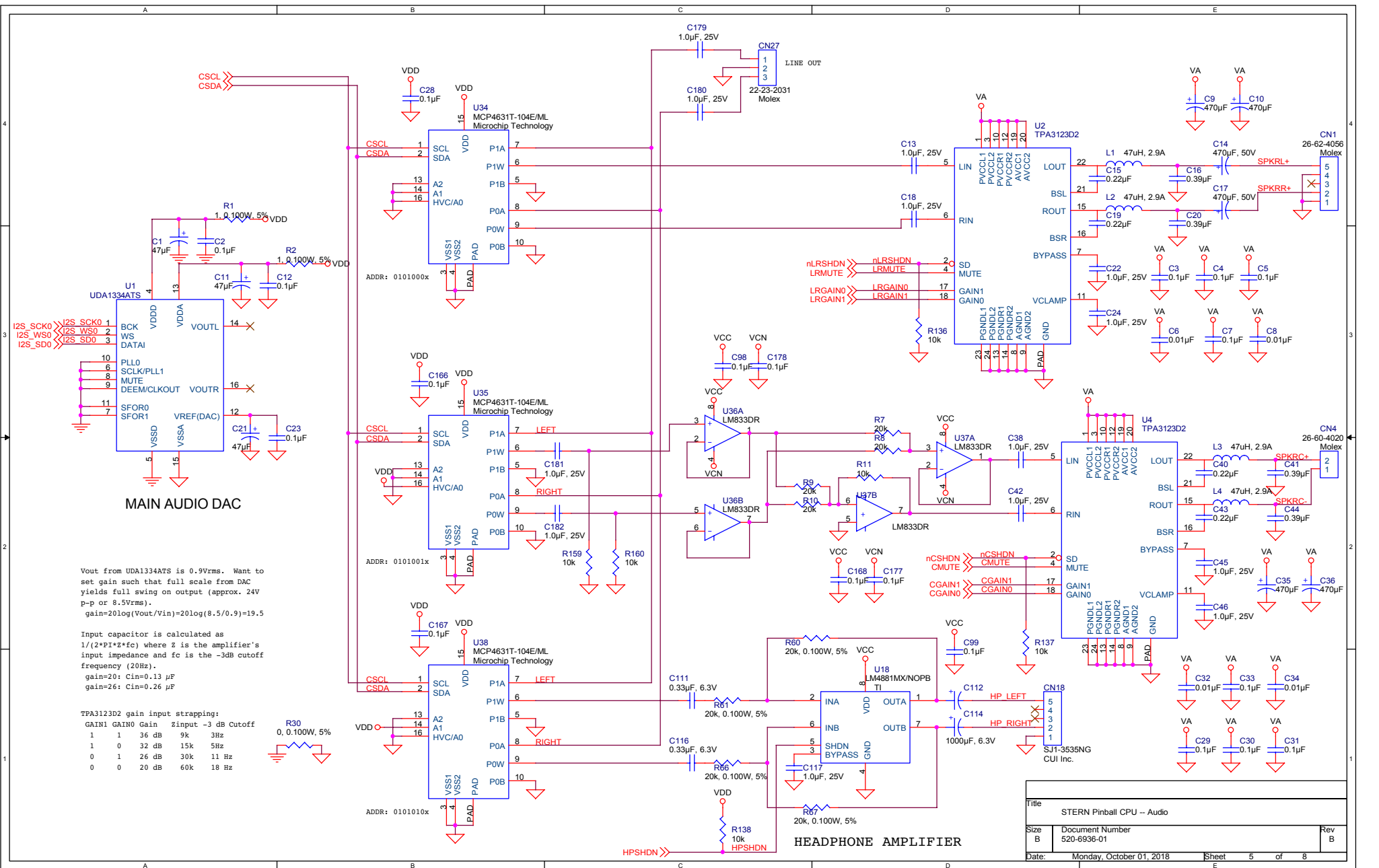
PHYAD[2:0] should be driven low
 MODE[2:0] should be driven high
 RMIISEL should be driven low

From the boot loader drive nERST low, set the various configuration pins, drive nERST high, then set the pins back to inputs pulled high. nERST is PA31.

Title			Ethernet interface		
Size	Document Number				Rev
B	520-6936-01				B
Date:	Monday, October 01, 2018	Sheet	7	of	8



Title		
STERN Pinball CPU -- power supply		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 6 of 8



MAIN AUDIO DAC

Vout from UDA1334ATS is 0.9Vrms. Want to set gain such that full scale from DAC yields full swing on output (approx. 24V p-p or 8.5Vrms).
 $gain = 20 \log(V_{out}/V_{in}) = 20 \log(8.5/0.9) = 19.5$

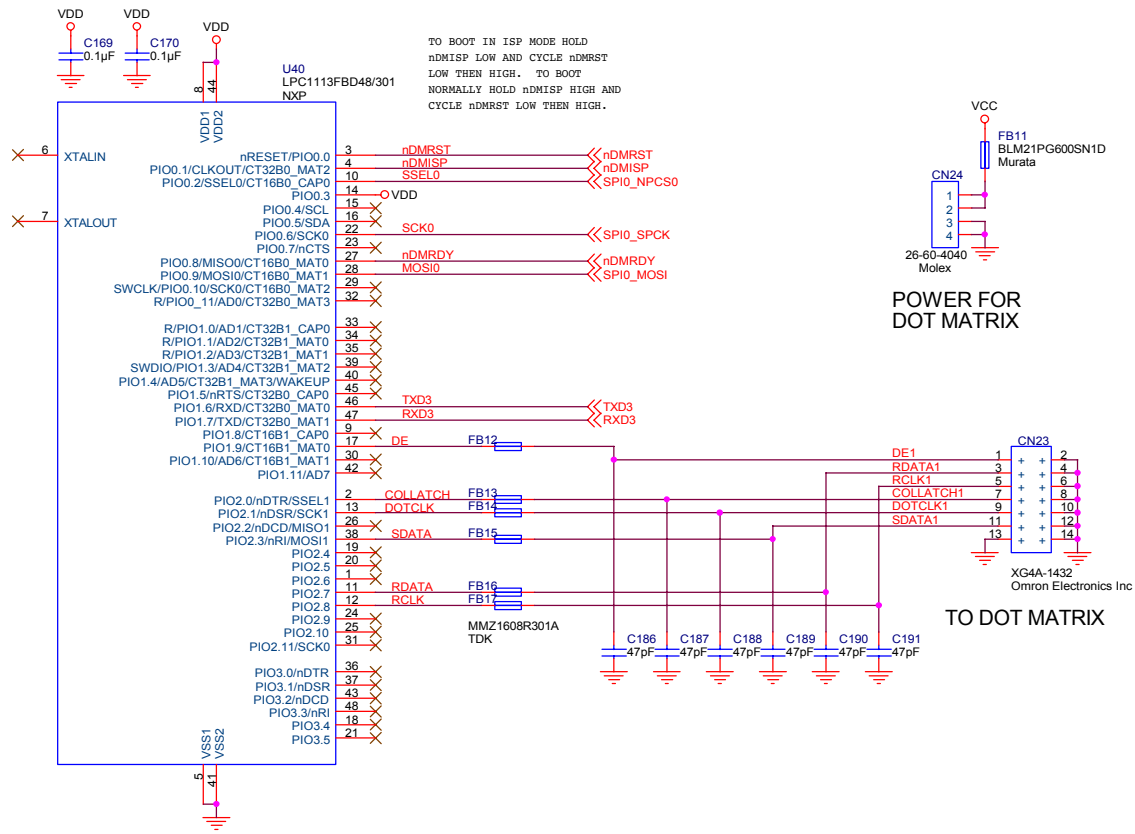
Input capacitor is calculated as $1/(2 * \pi * Z * f_c)$ where Z is the amplifier's input impedance and f_c is the -3dB cutoff frequency (20Hz).
 $gain = 20; C_{in} = 0.13 \mu F$
 $gain = 26; C_{in} = 0.26 \mu F$

TPA3123D2 gain input strapping:

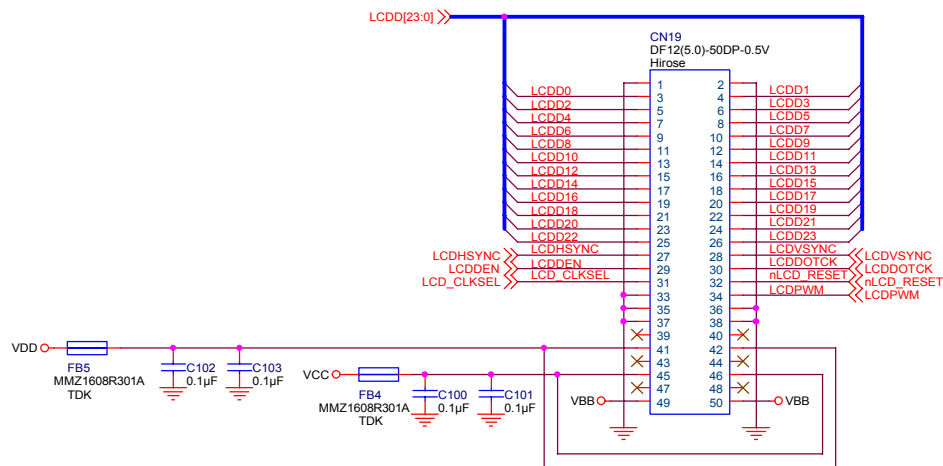
GAIN1	GAIN0	Gain	Z _{in}	-3 dB Cutoff
1	1	36 dB	9k	3Hz
1	0	32 dB	15k	5Hz
0	1	26 dB	30k	11 Hz
0	0	20 dB	60k	18 Hz

HEADPHONE AMPLIFIER

Title		
STERN Pinball CPU - Audio		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 5 of 8



Title		
dot matrix display interface		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 8 of 8



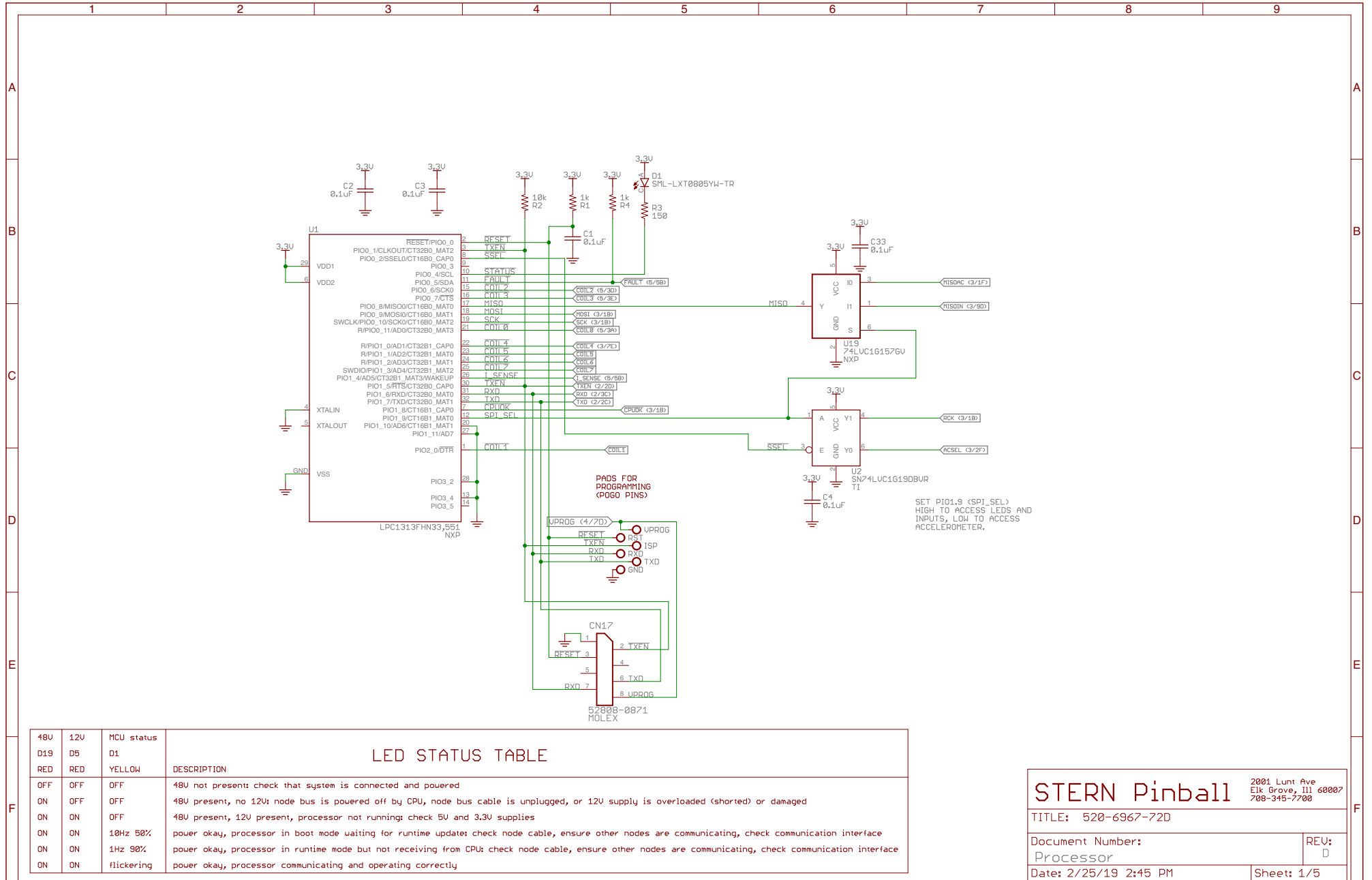
USE KEYSTONE 24390 5.0mm M3
SPACER OR EQUIVALENT



LCDD7:0 = RED
LCDD15:8 = GREEN
LCDD23:16 = BLUE

COLOR DATA IS ALWAYS TOP-JUSTIFIED
(e.g., IF ONLY FIVE BITS OF RED ARE
USED THEY ARE MAPPED TO LCDD7:3)

Title		
video interface		
Size	Document Number	Rev
B	520-6936-01	B
Date:	Monday, October 01, 2018	Sheet 3 of 8

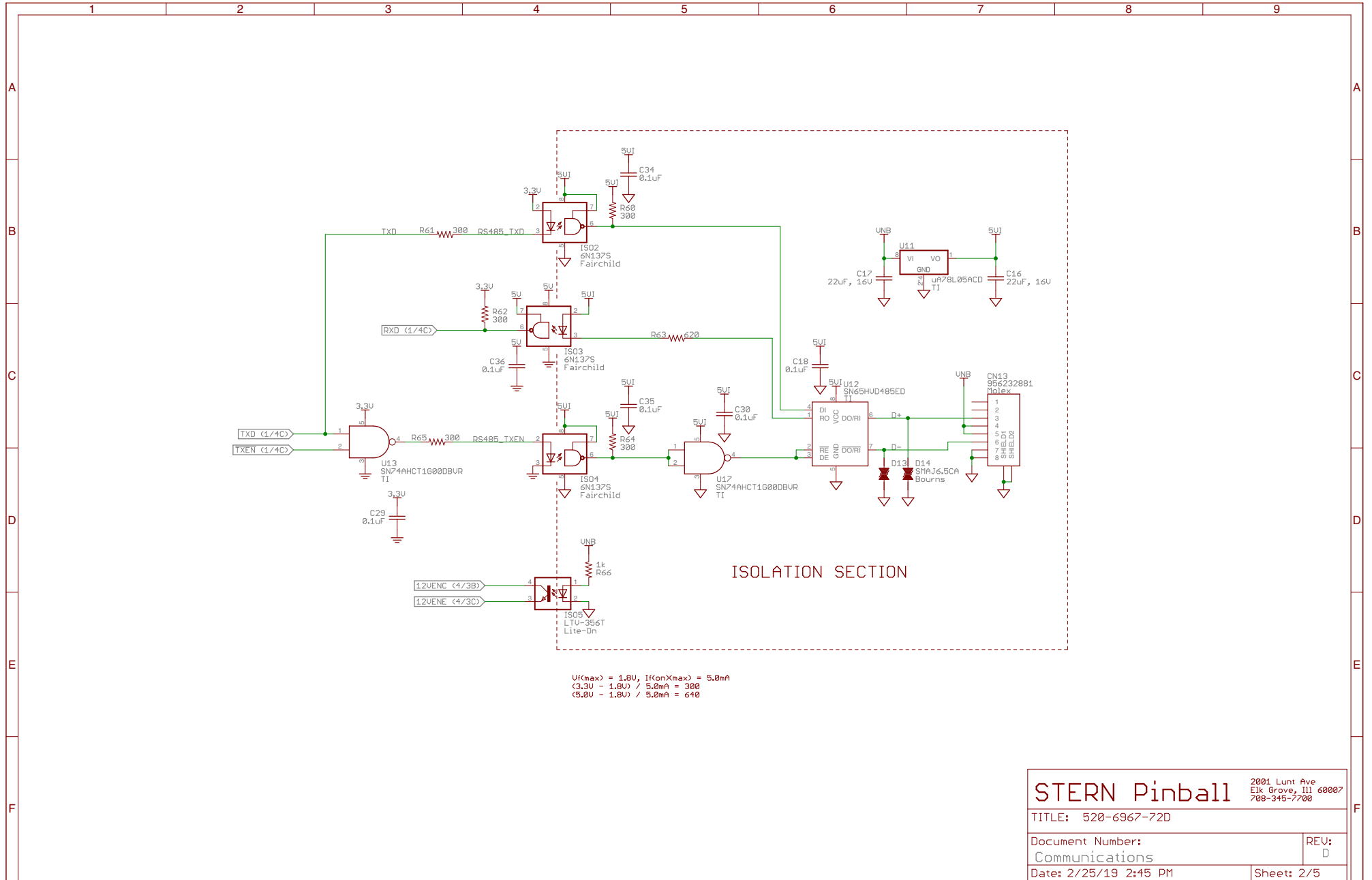


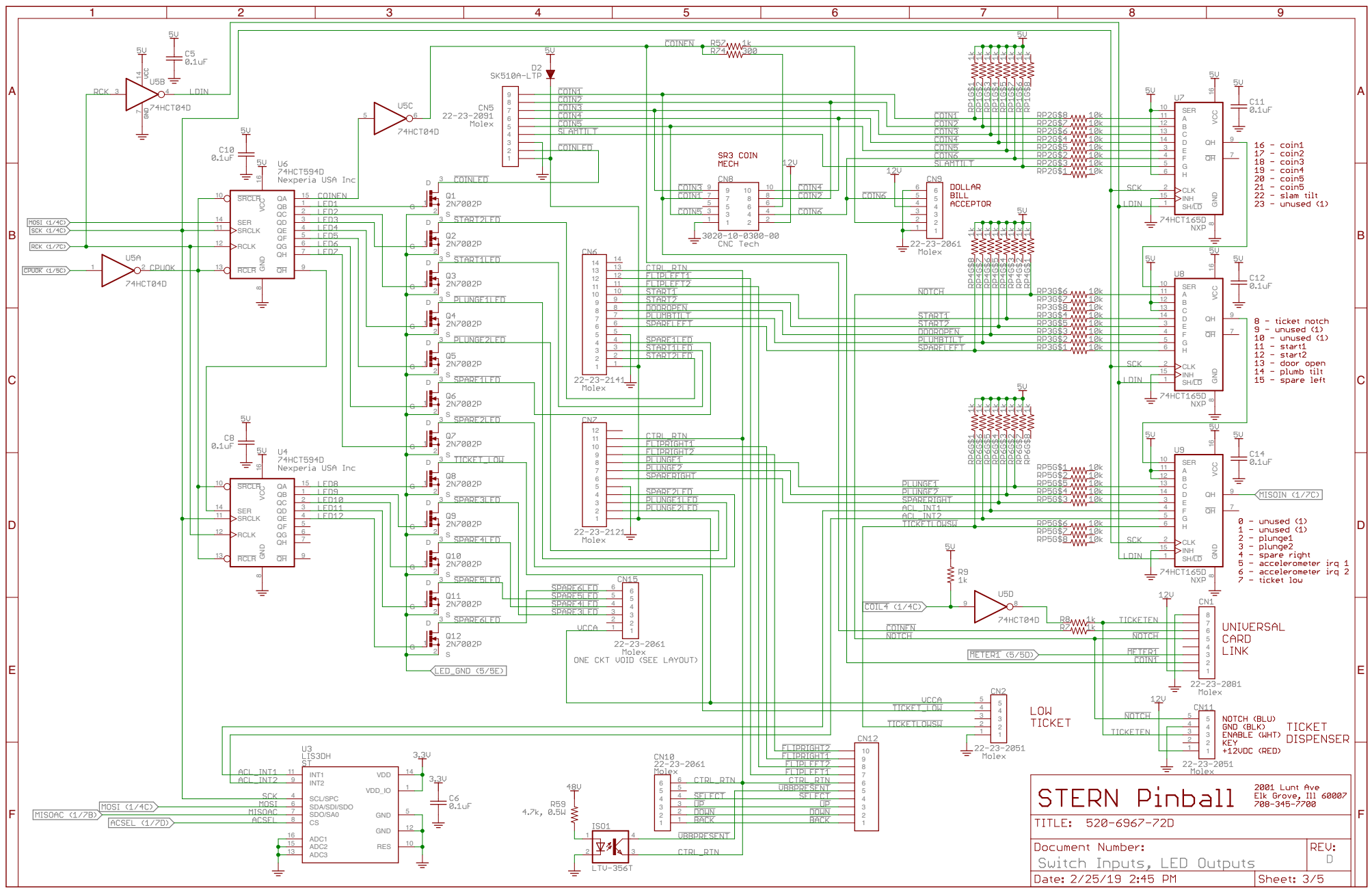
STERN Pinball 2001 Lunt Ave
Elk Grove, Ill 60007
708-345-7700

TITLE: 520-6967-72D

Document Number: Processor REV: D

Date: 2/25/19 2:45 PM Sheet: 1/5





- 16 - coin1
- 17 - coin2
- 18 - coin3
- 19 - coin4
- 20 - coin5
- 21 - coin5
- 22 - slam tilt
- 23 - unused (1)

- 8 - ticket notch
- 9 - unused (1)
- 10 - unused (1)
- 11 - start1
- 12 - start2
- 13 - door open
- 14 - plumb left
- 15 - spare left

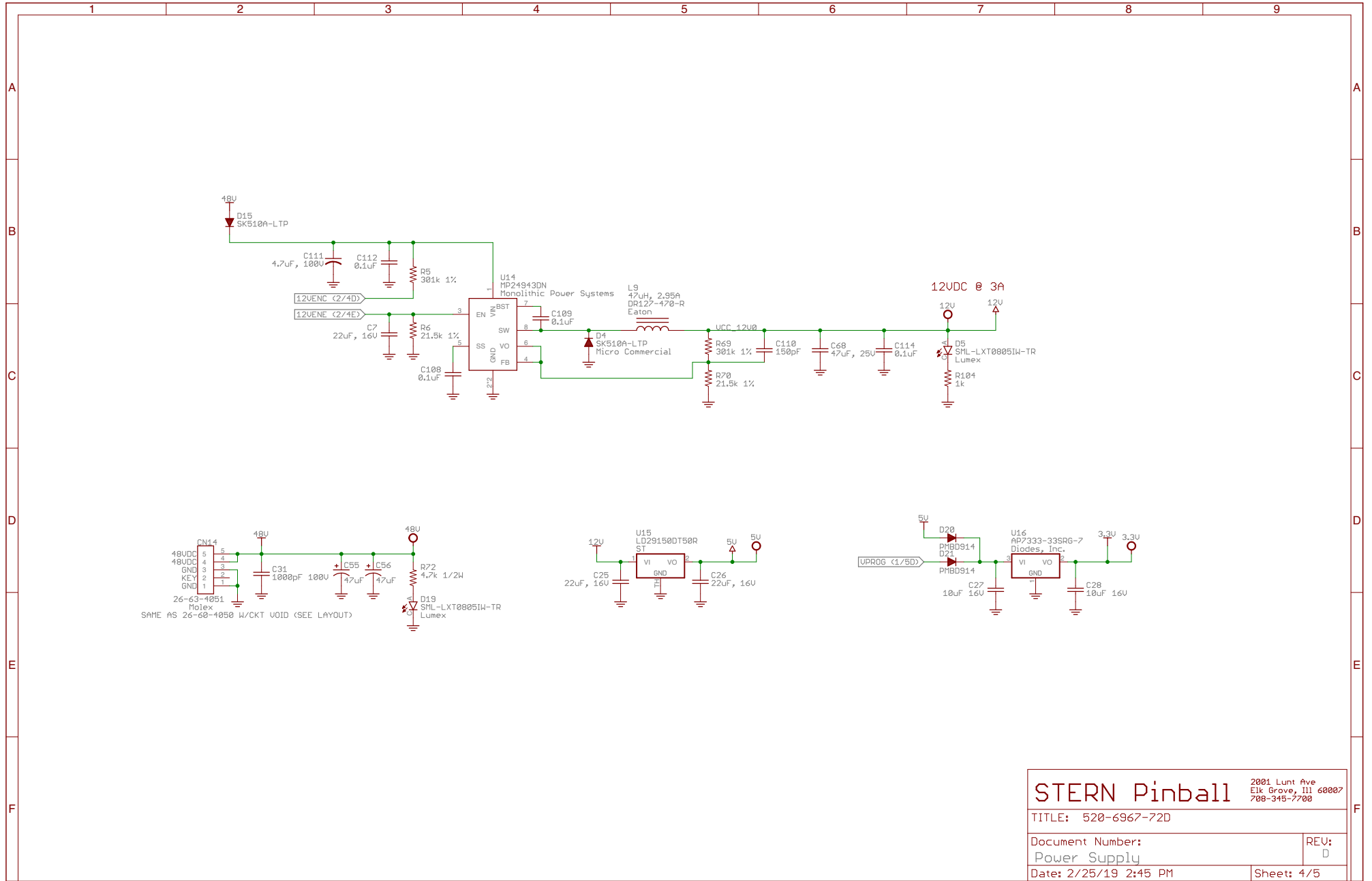
- 0 - unused (1)
- 1 - unused (1)
- 2 - plunge1
- 3 - plunge2
- 4 - spare right
- 5 - accelerometer irq 1
- 6 - accelerometer irq 2
- 7 - ticket low

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Elk Grove, Ill 60007
708-345-7700

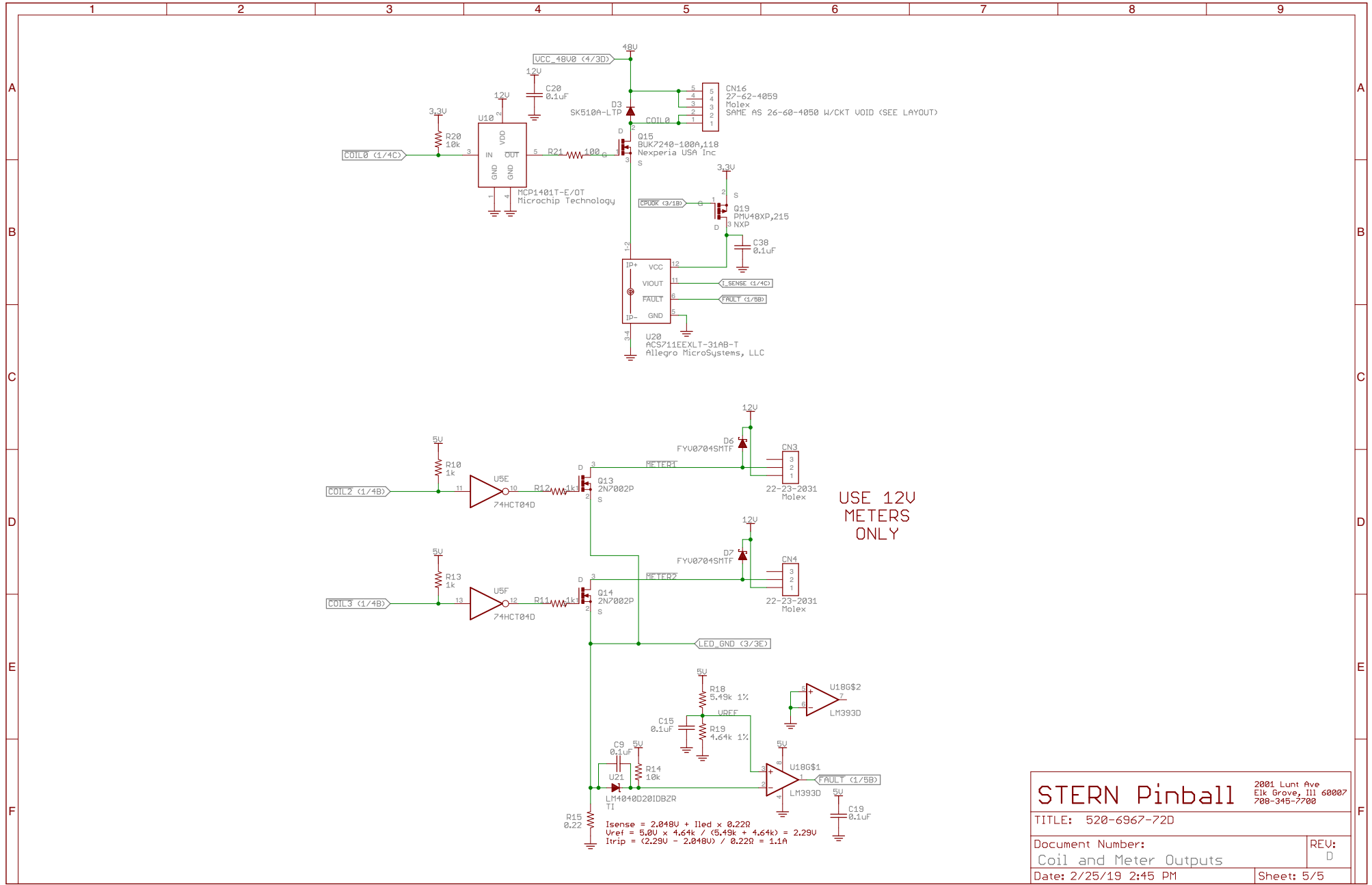
TITLE: 520-6967-72D

Document Number: _____ REV: _____
Switch Inputs, LED Outputs _____ D

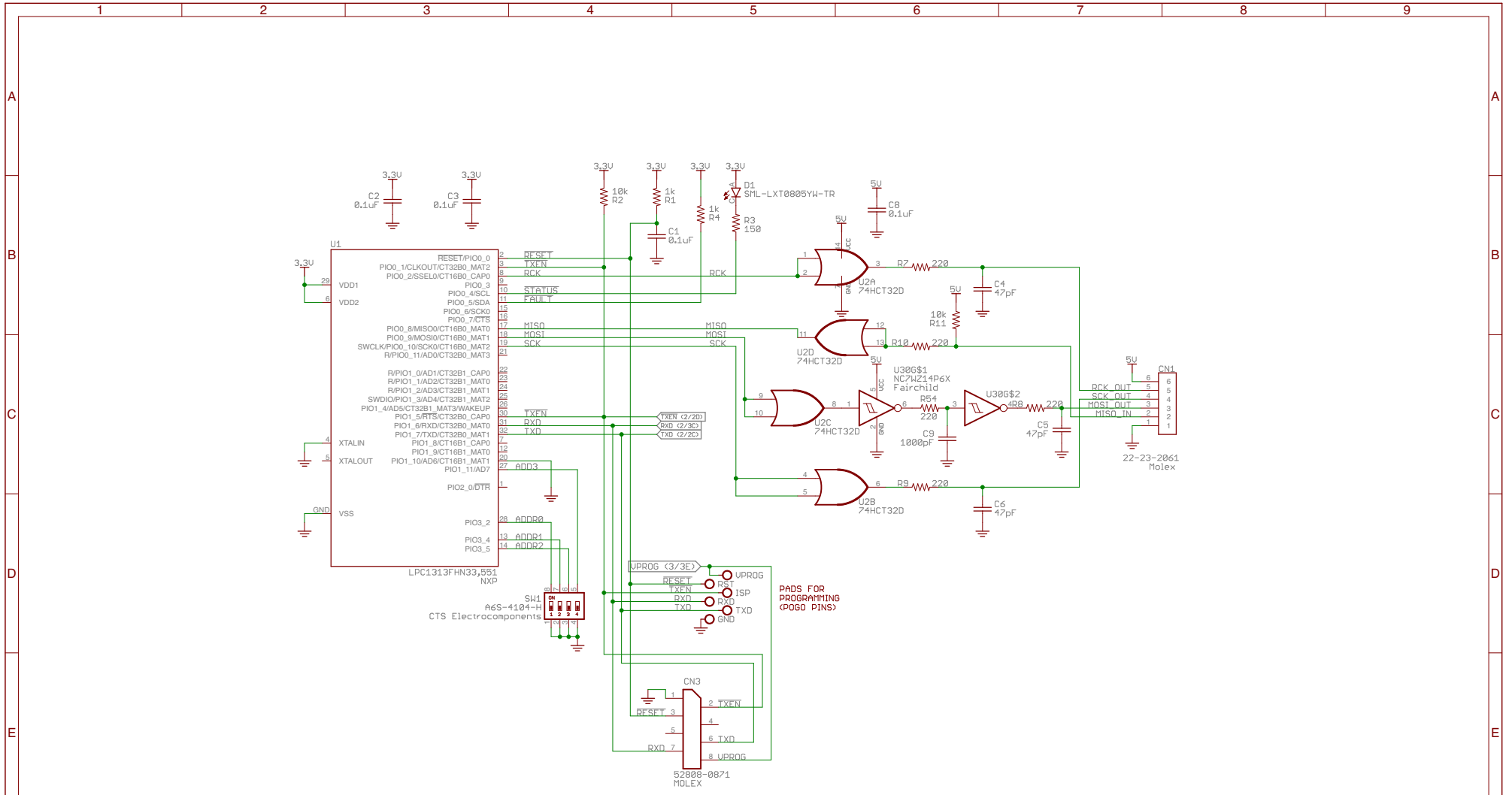
Date: 2/25/19 2:45 PM Sheet: 3/5



STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-6967-72D			
Document Number: Power Supply			REV: D
Date: 2/25/19 2:45 PM			Sheet: 4/5



STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6967-72D		
Document Number:		REV: D
Coil and Meter Outputs		
Date: 2/25/19 2:45 PM		Sheet: 5/5



LED STATUS TABLE

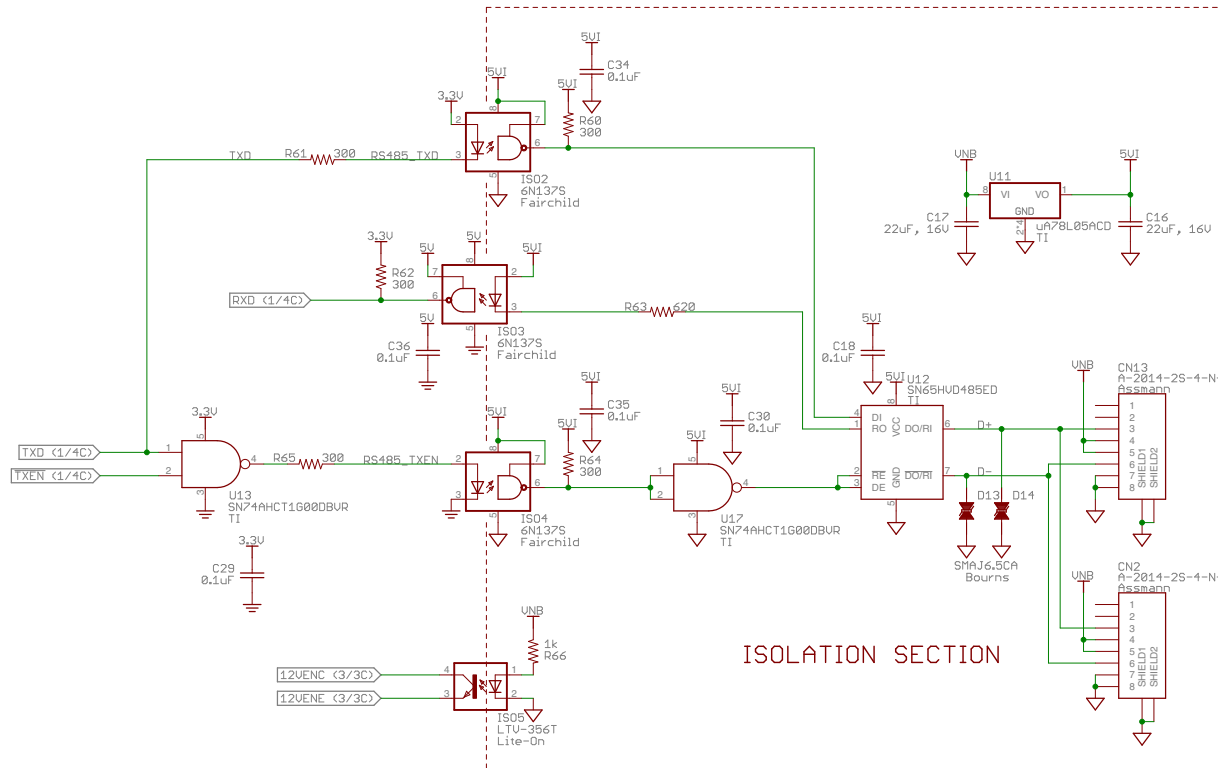
48V	5V	MCU status	DESCRIPTION
D19	D5	D1	
RED	RED	YELLOW	
OFF	OFF	OFF	48V not present: check that system is connected and powered
ON	OFF	OFF	48V present, no 5V: node bus is powered off by CPU, node bus cable is unplugged, or 5V supply is overloaded (shorted) or damaged
ON	ON	OFF	48V present, 5V present, processor not running: check 3.3V supply
ON	ON	10Hz 50%	power okay, processor in boot node waiting for runtime update: check node cable, ensure other nodes are communicating, check communication interface
ON	ON	1Hz 90%	power okay, processor in runtime mode but not receiving from CPU: check node cable, ensure other nodes are communicating, check communication interface
ON	ON	flickering	power okay, processor communicating and operating correctly

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TITLE: 520-6976-72A

Document Number: _____ REV: _____

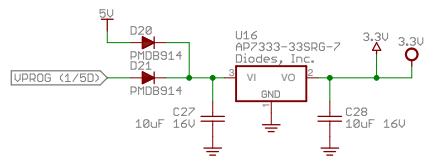
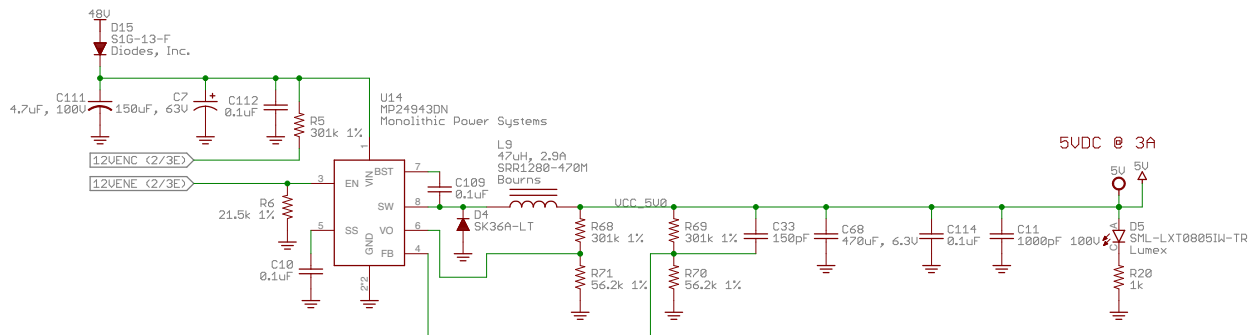
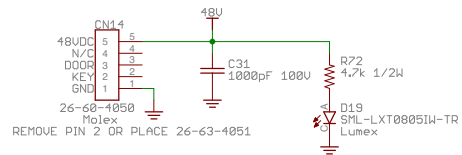
Date: 2/25/19 2:58 PM Sheet: 1/3



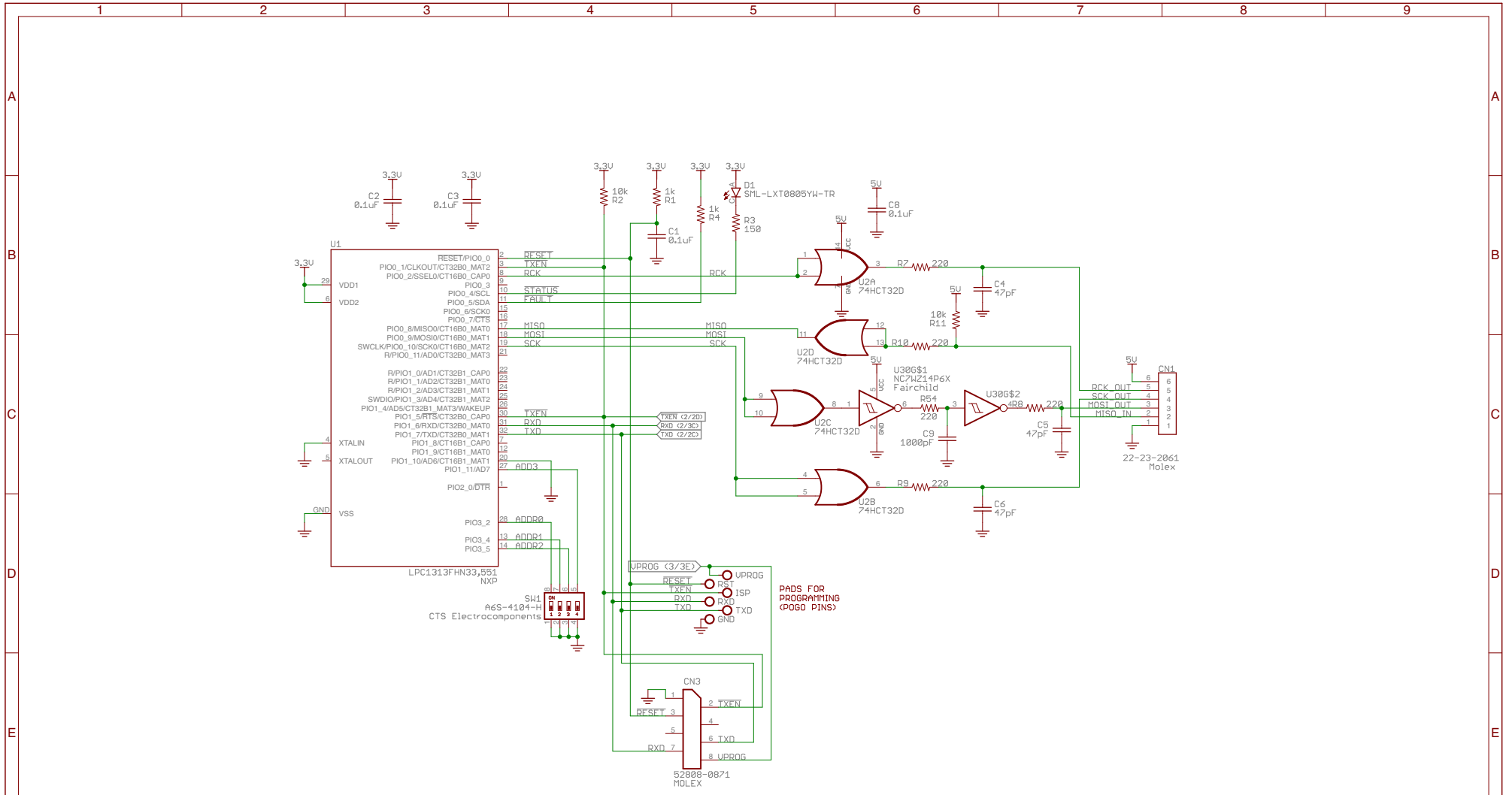
ISOLATION SECTION

$U_{I(max)} = 1.8U$, $I_{f(con)X(max)} = 5.0mA$
 $(3.3V - 1.8U) / 5.0mA = 300$
 $(5.0V - 1.8U) / 5.0mA = 640$

STERN Pinball TITLE: 520-6976-72A		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
		Document Number: Communication	REV:
Date: 2/25/19 2:58 PM		Sheet: 2/3	



STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6976-72A		
Document Number:	REV:	
Power Supply		
Date: 2/25/19 2:58 PM	Sheet: 3/3	



LED STATUS TABLE

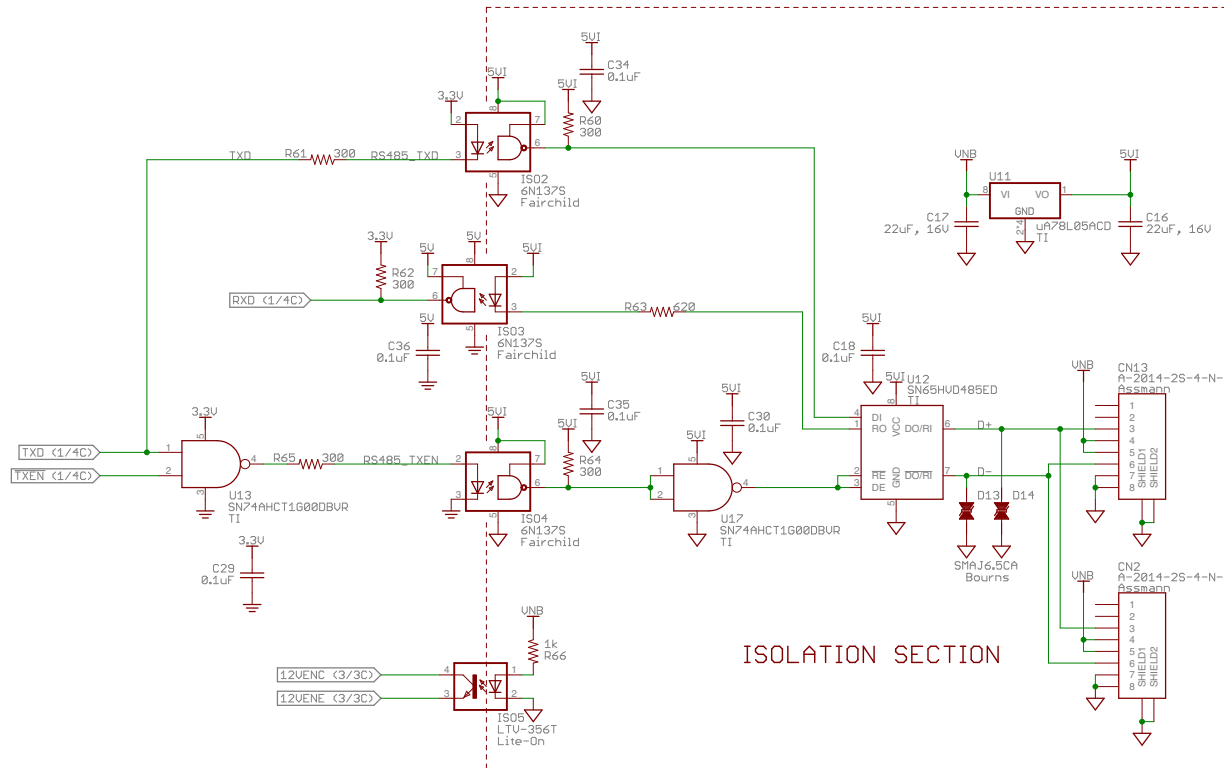
48U	5U	MCU status	DESCRIPTION
D19	D5	D1	
RED	RED	YELLOW	
OFF	OFF	OFF	48U not present: check that system is connected and powered
ON	OFF	OFF	48U present, no 5U: node bus is powered off by CPU, node bus cable is unplugged, or 5U supply is overloaded (shorted) or damaged
ON	ON	OFF	48U present, 5U present, processor not running: check 3.3U supply
ON	ON	10Hz 50%	power okay, processor in boot node waiting for runtime update: check node cable, ensure other nodes are communicating, check communication interface
ON	ON	1Hz 90%	power okay, processor in runtime mode but not receiving from CPU: check node cable, ensure other nodes are communicating, check communication interface
ON	ON	flickering	power okay, processor communicating and operating correctly

STERN Pinball 2001 Lunt Ave
Elk Grove, Ill 60007
708-345-7700

TITLE: 520-6976-72A

Document Number: _____ REV: _____

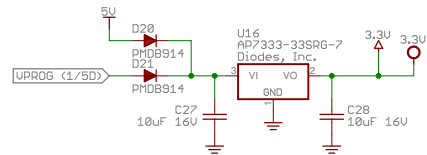
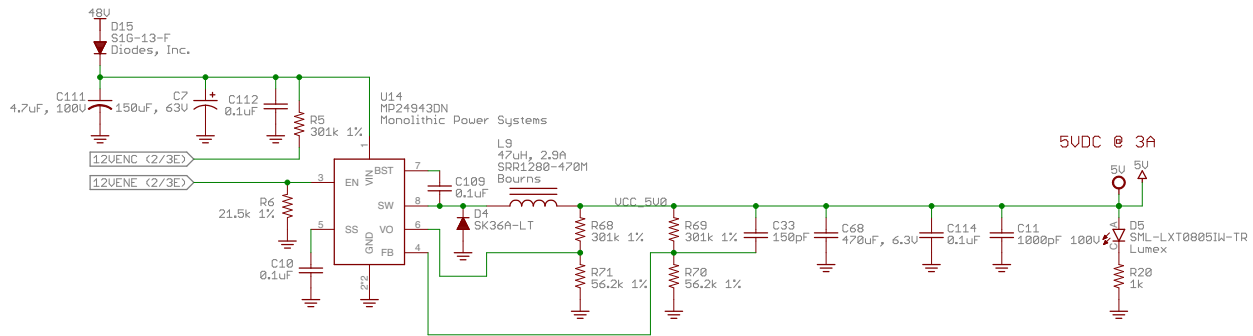
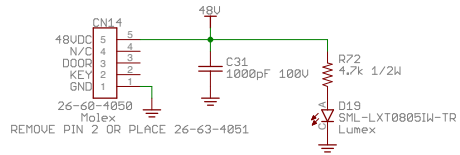
Date: 2/25/19 2:58 PM Sheet: 1/3



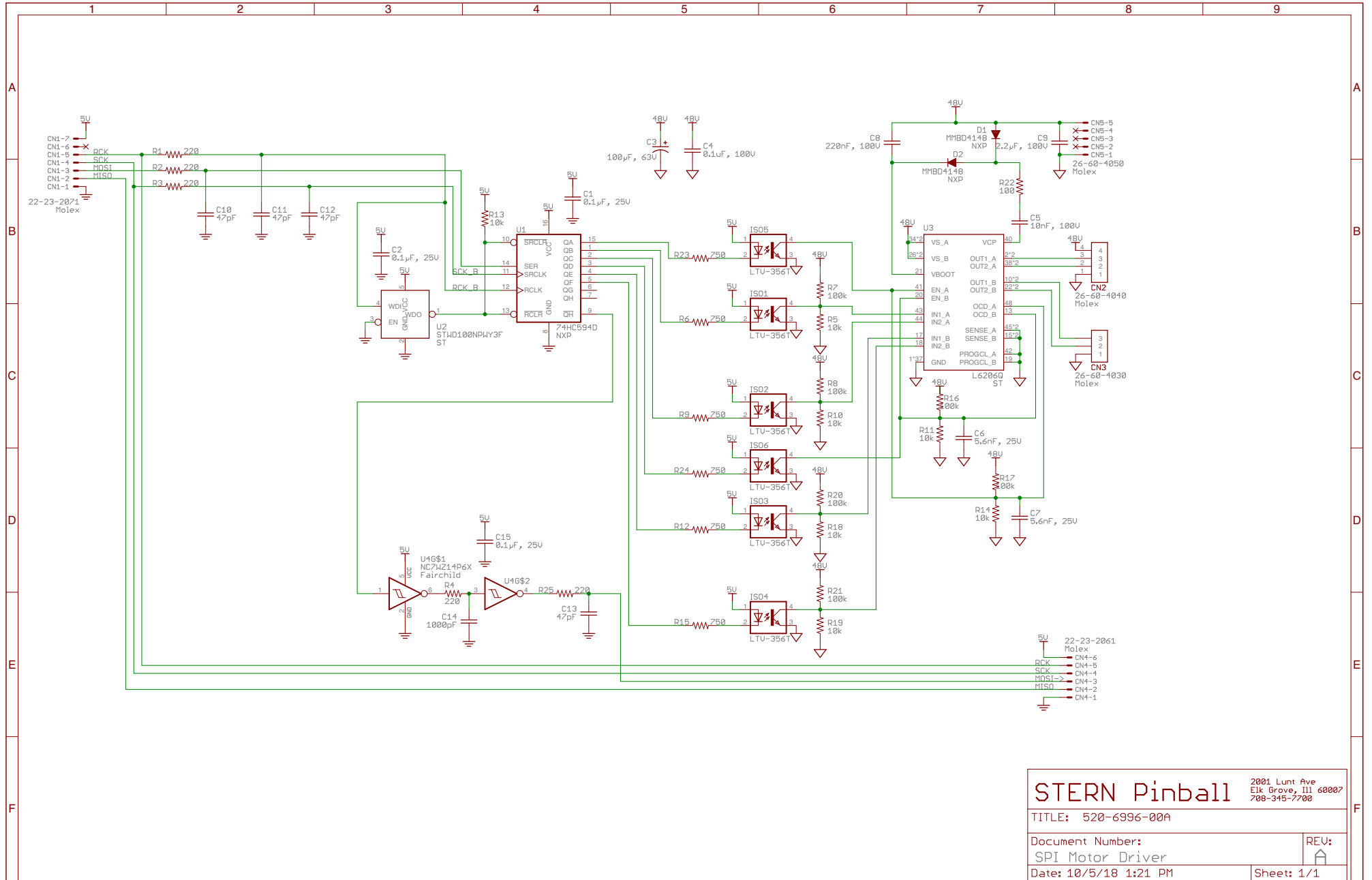
ISOLATION SECTION

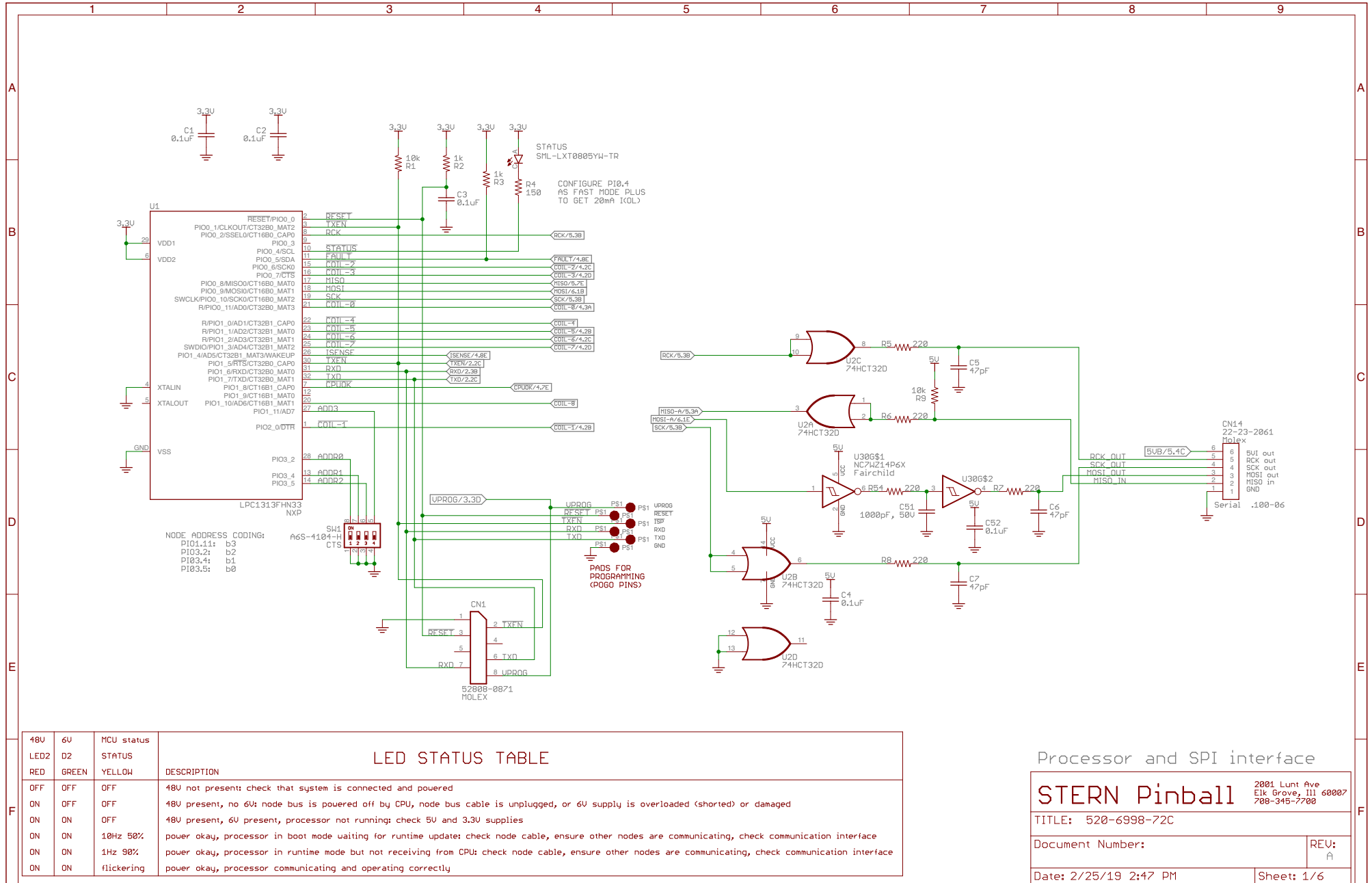
$U_{I(max)} = 1.8U$, $I_{f(con)X(max)} = 5.0mA$
 $(3.3V - 1.8U) / 5.0mA = 300$
 $(5.0V - 1.8U) / 5.0mA = 640$

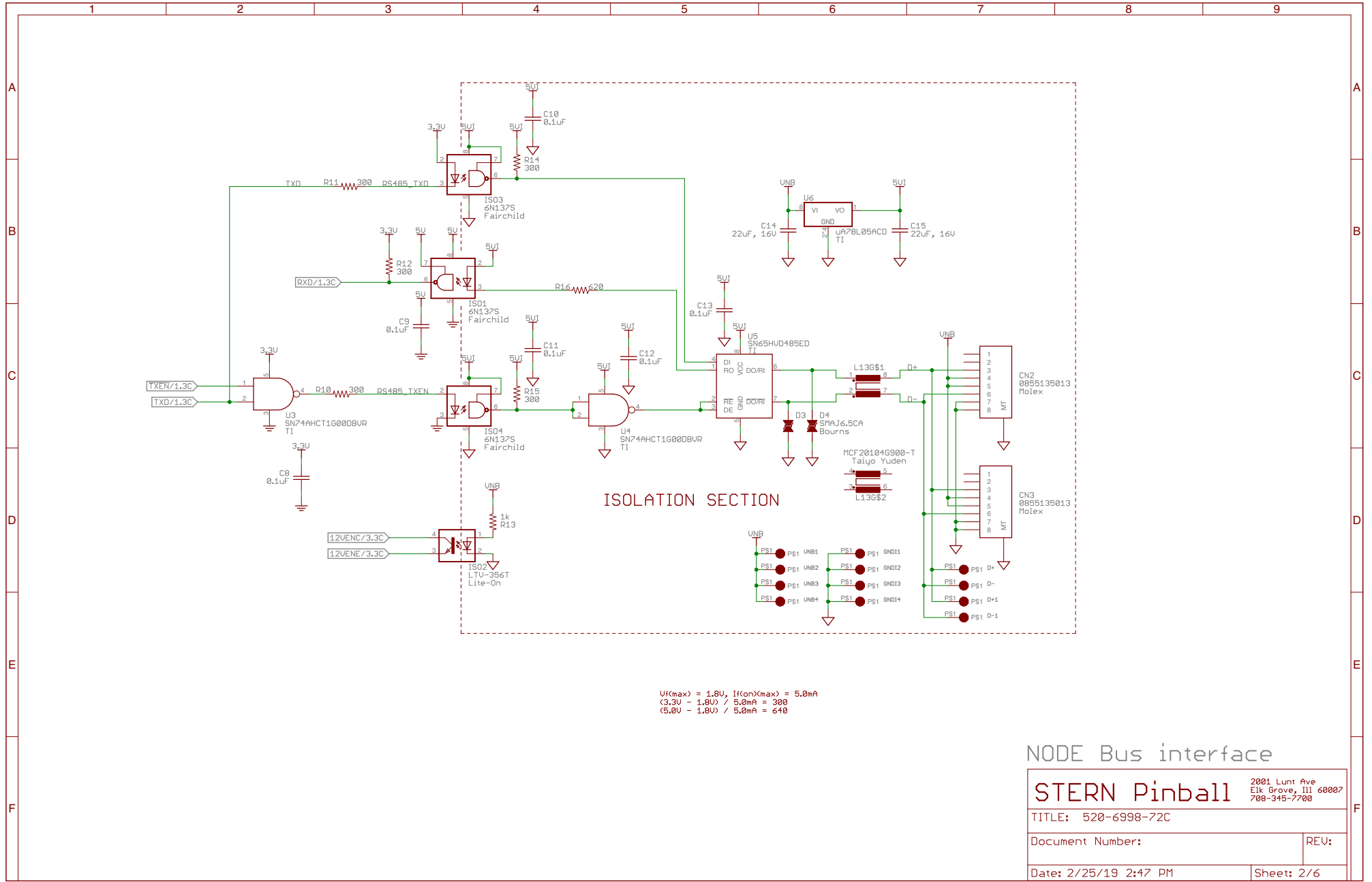
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6976-72A		
Document Number:	REV:	
Communication		
Date: 2/25/19 2:58 PM	Sheet: 2/3	



STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6976-72A		
Document Number:	REV:	
Power Supply		
Date: 2/25/19 2:58 PM	Sheet: 3/3	

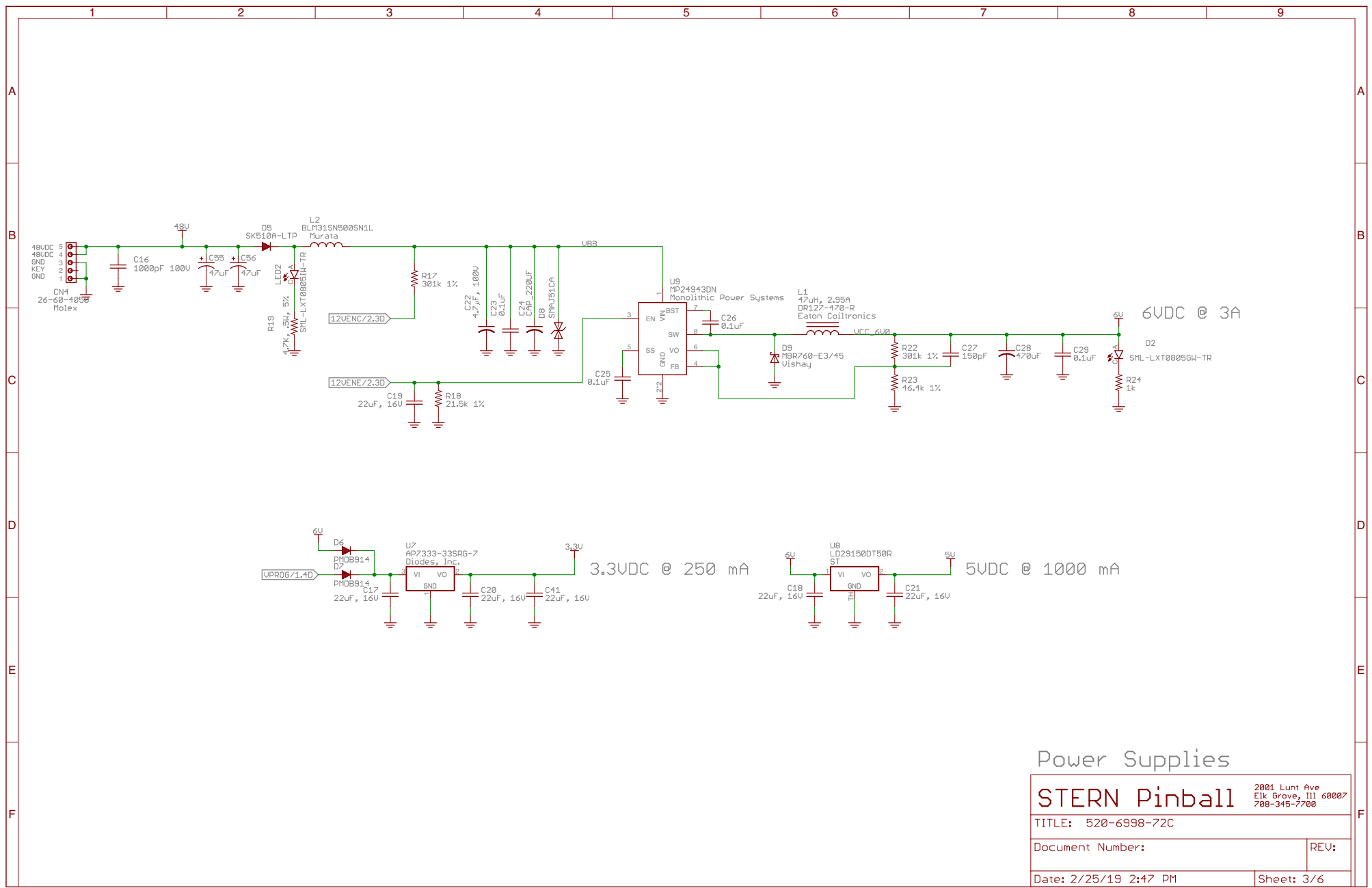






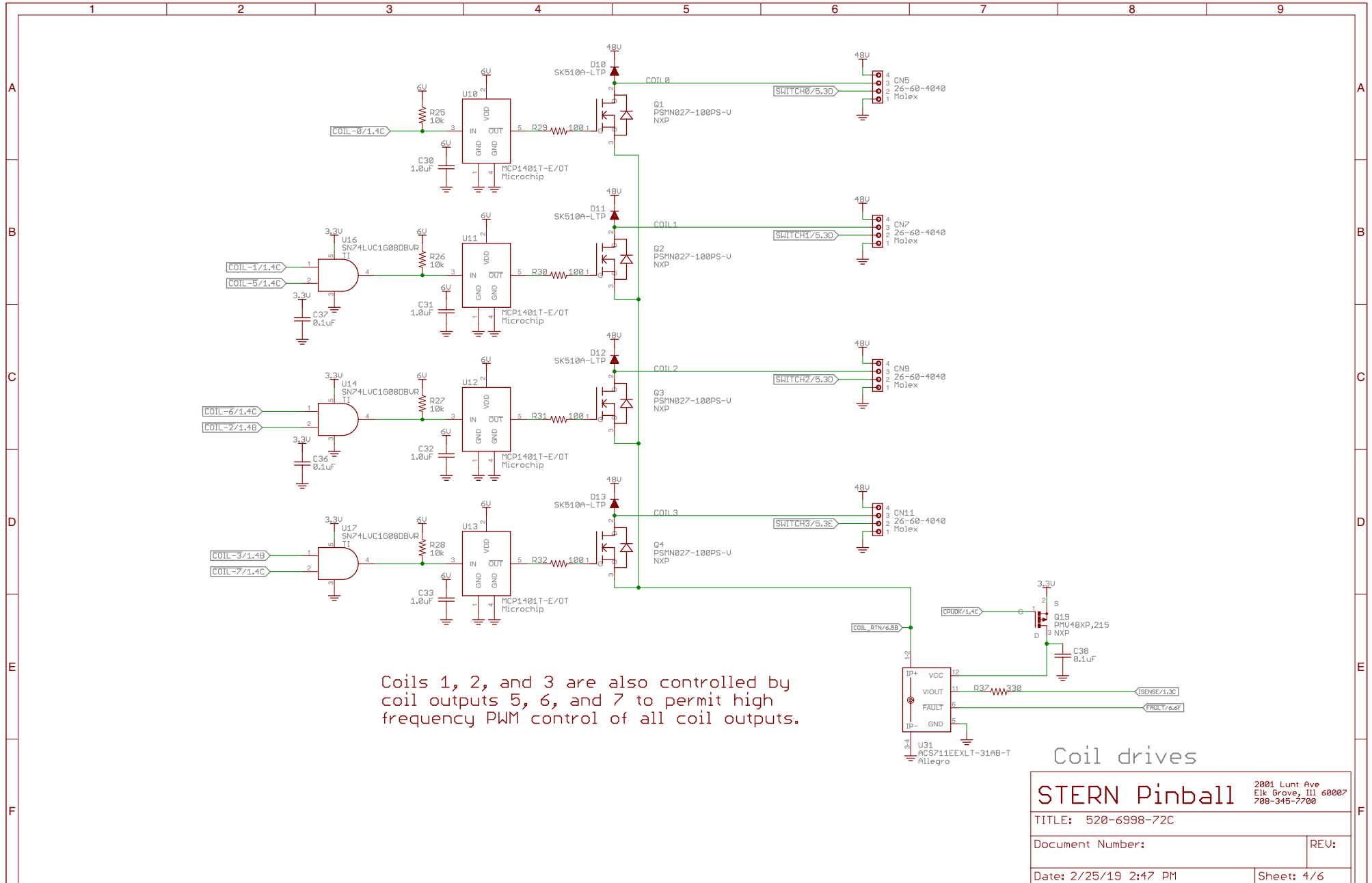
NODE Bus interface

STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-6998-72C			
Document Number:			REV:
Date: 2/25/19 2:47 PM			Sheet: 2/6



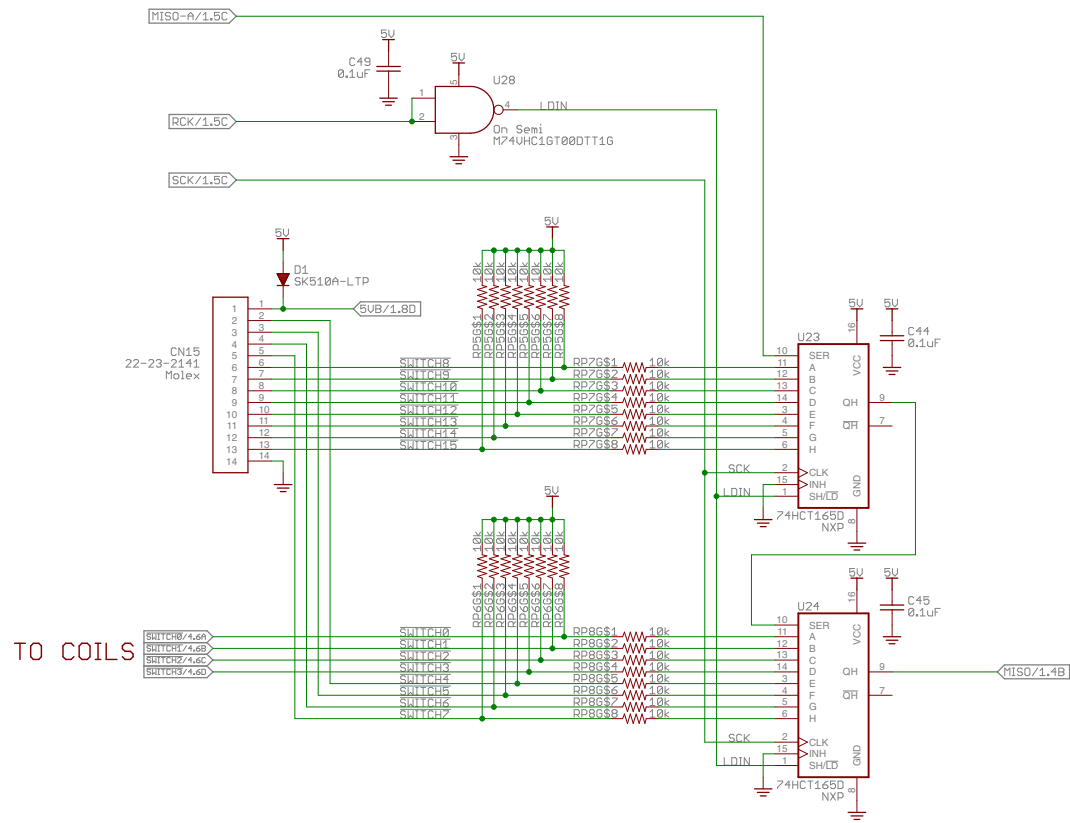
Power Supplies

STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-6998-72C			
Document Number:			REV:
Date: 2/25/19 2:47 PM			Sheet: 3/6



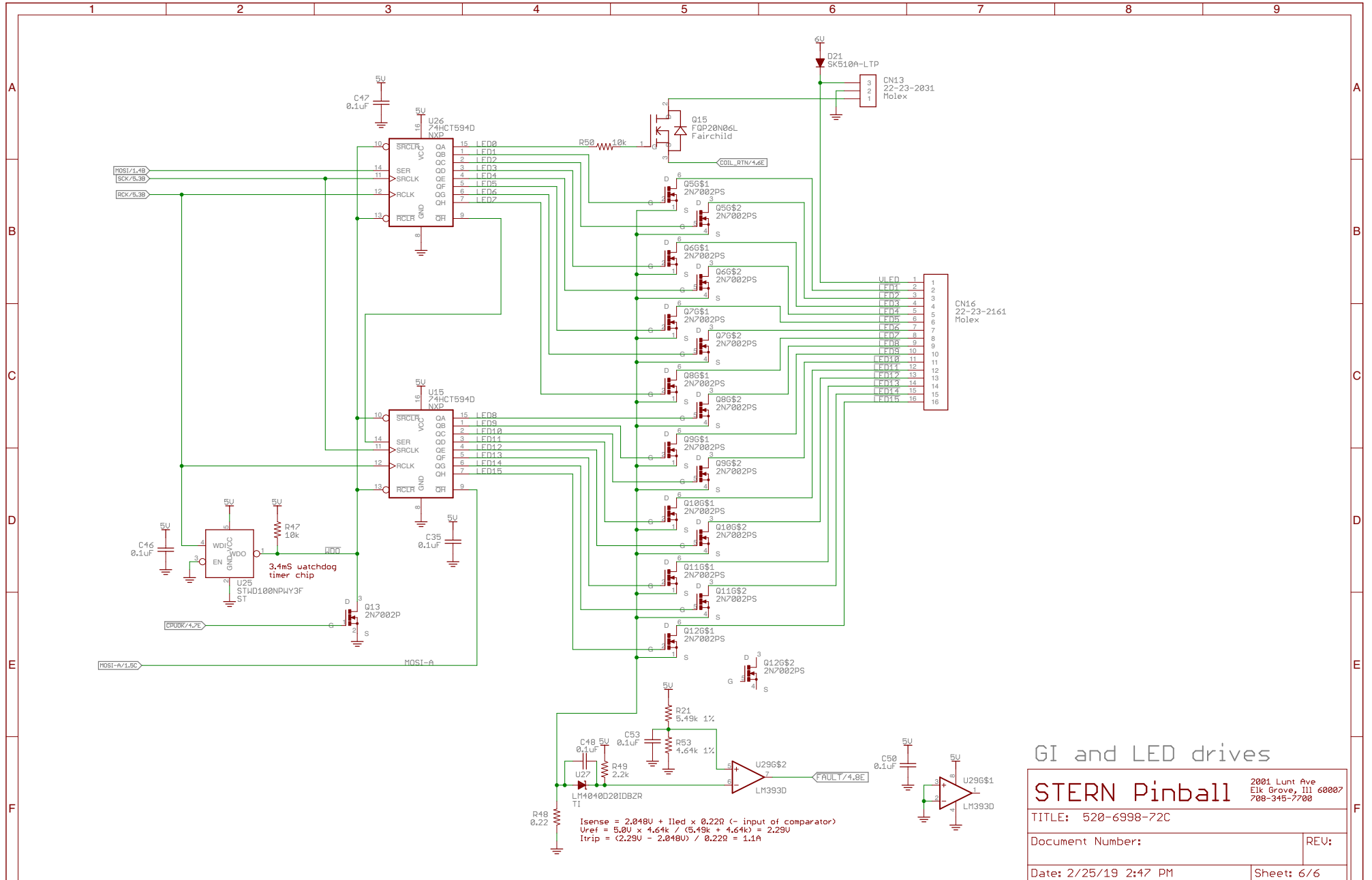
Coil drives

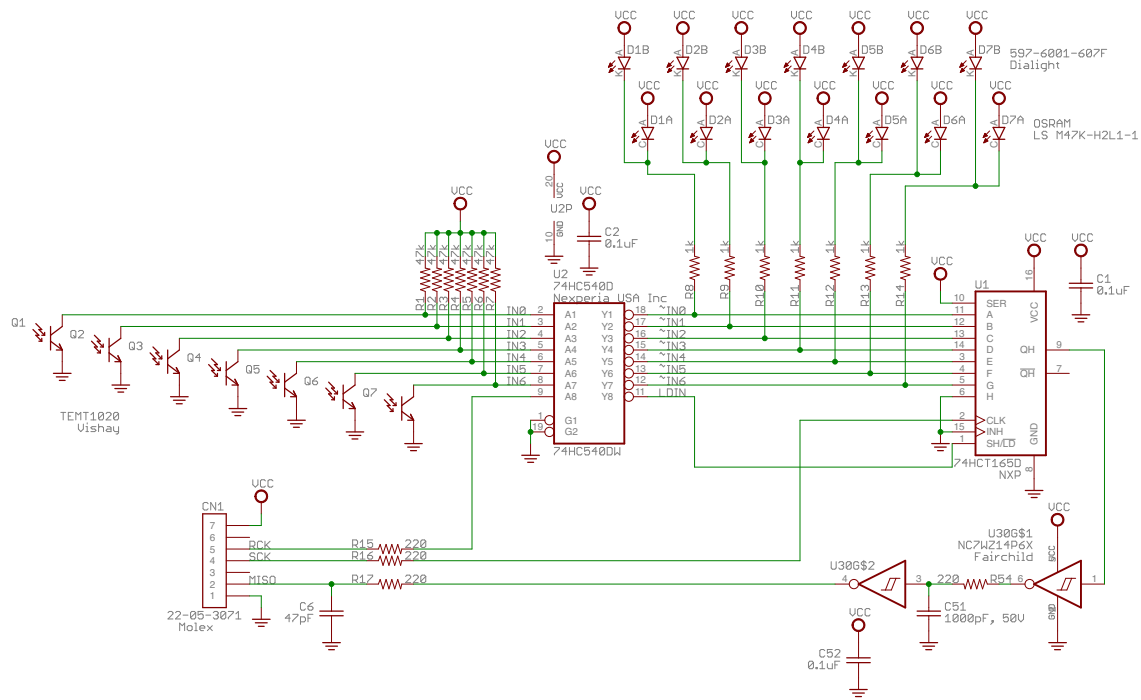
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6998-72C		
Document Number:		REV:
Date: 2/25/19 2:47 PM		Sheet: 4/6



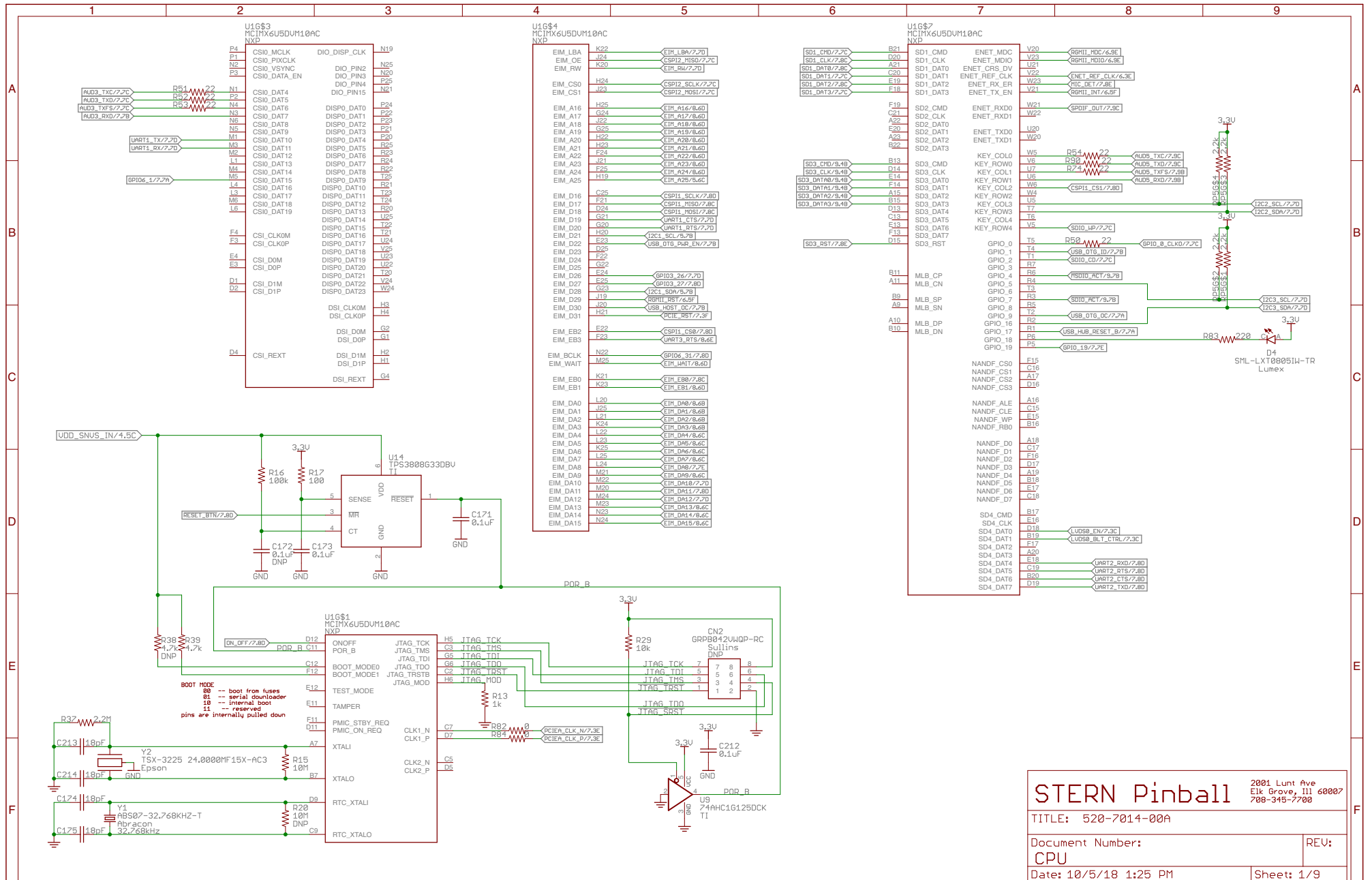
Switch Inputs

STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-6998-72C		
Document Number:	REV:	
Date: 2/25/19 2:47 PM	Sheet: 5/6	

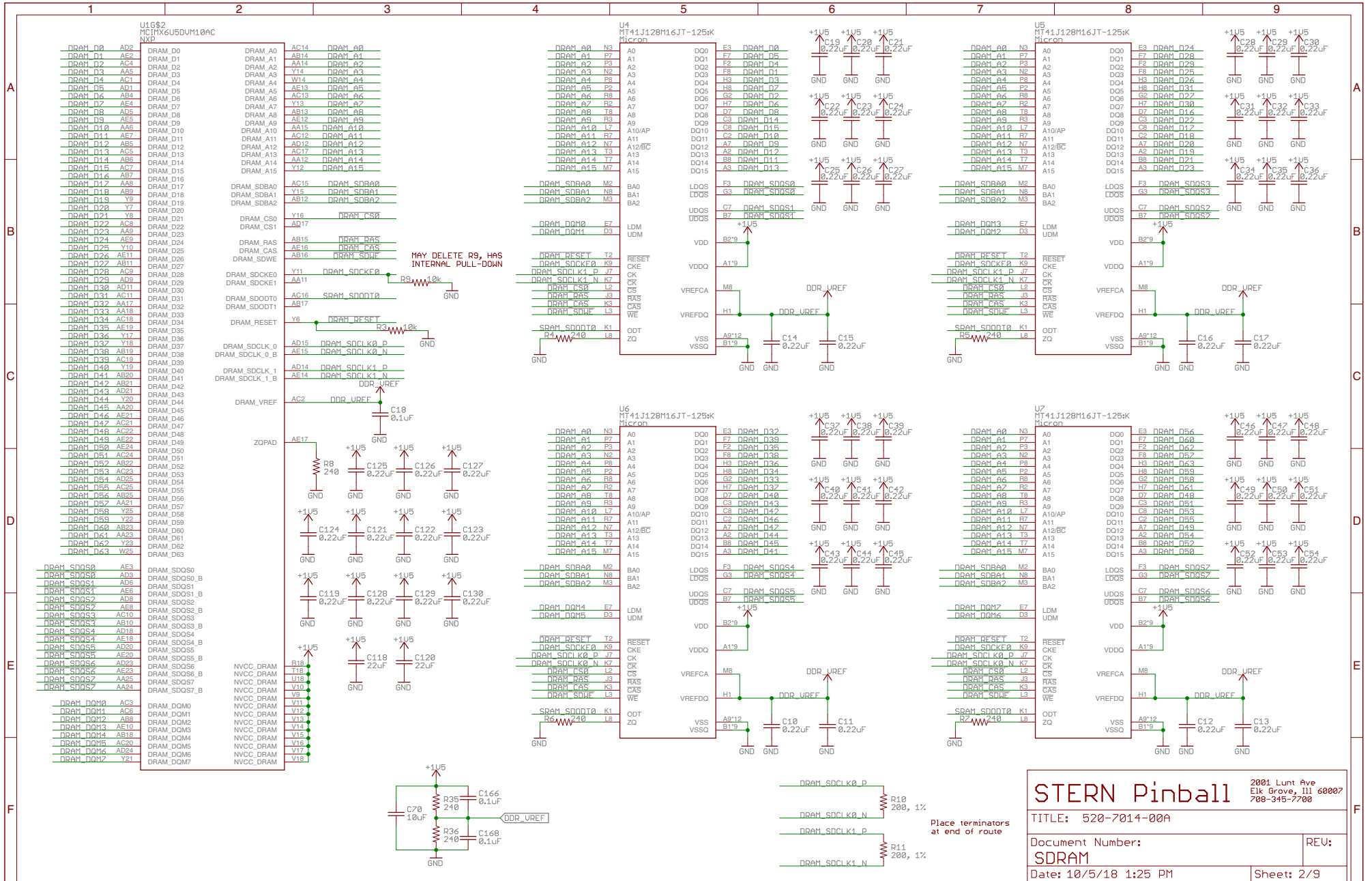




STERN Pinball TITLE: 520-7001-00A		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
		Document Number:	REV:
Date: 10/5/18 1:24 PM		Sheet: 1/1	



STERN Pinball 2001 Lunt Ave
 Elk Grove, Ill 60007
 708-345-7700
 TITLE: 520-7014-00A
 Document Number: CPU
 Date: 10/5/18 1:25 PM
 REV: 1
 Sheet: 1/9



STERN Pinball 2001 Lunt Ave
Elk Grove, Ill 60007
708-345-7700

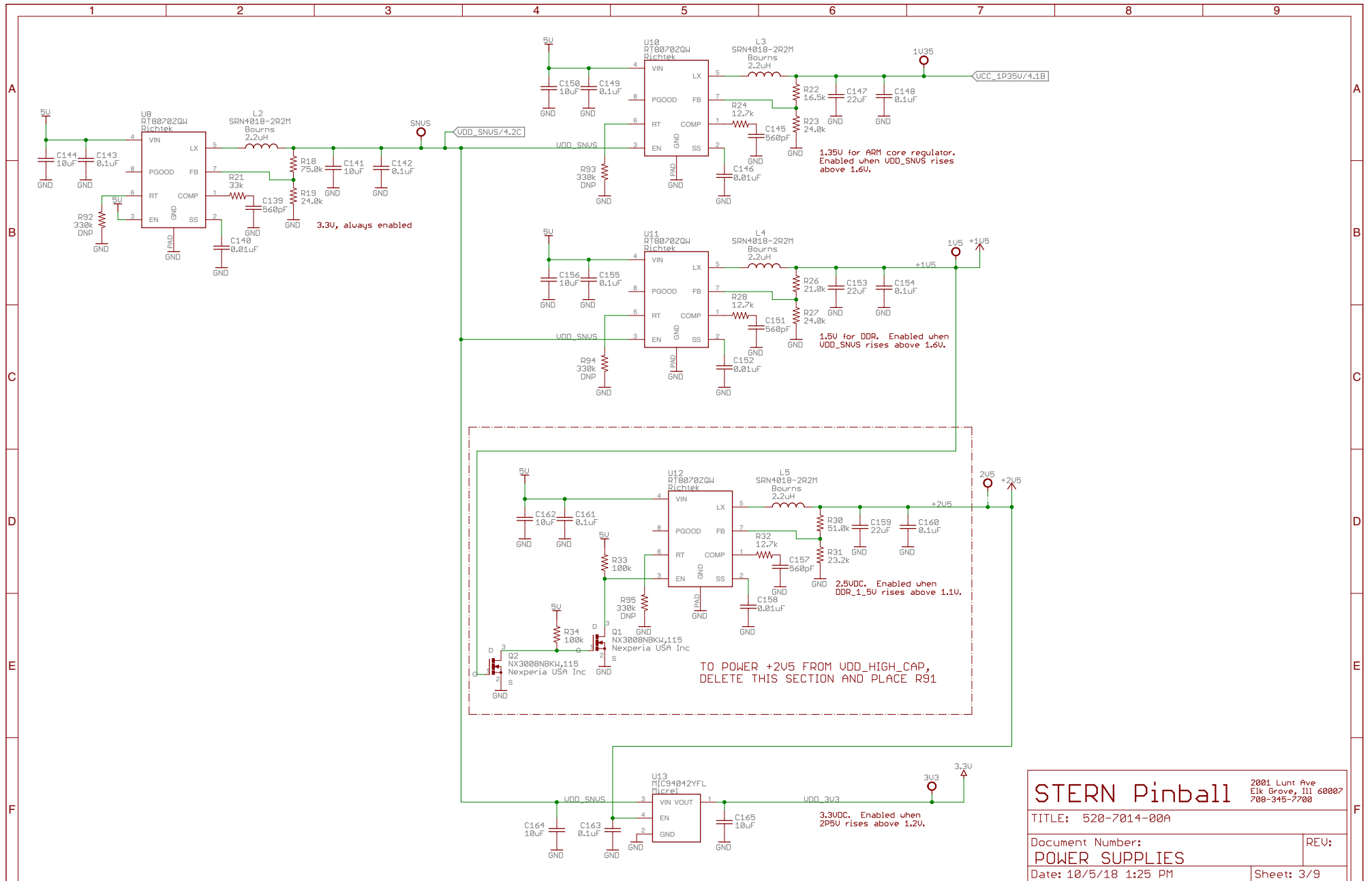
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Document Number: SDRAM

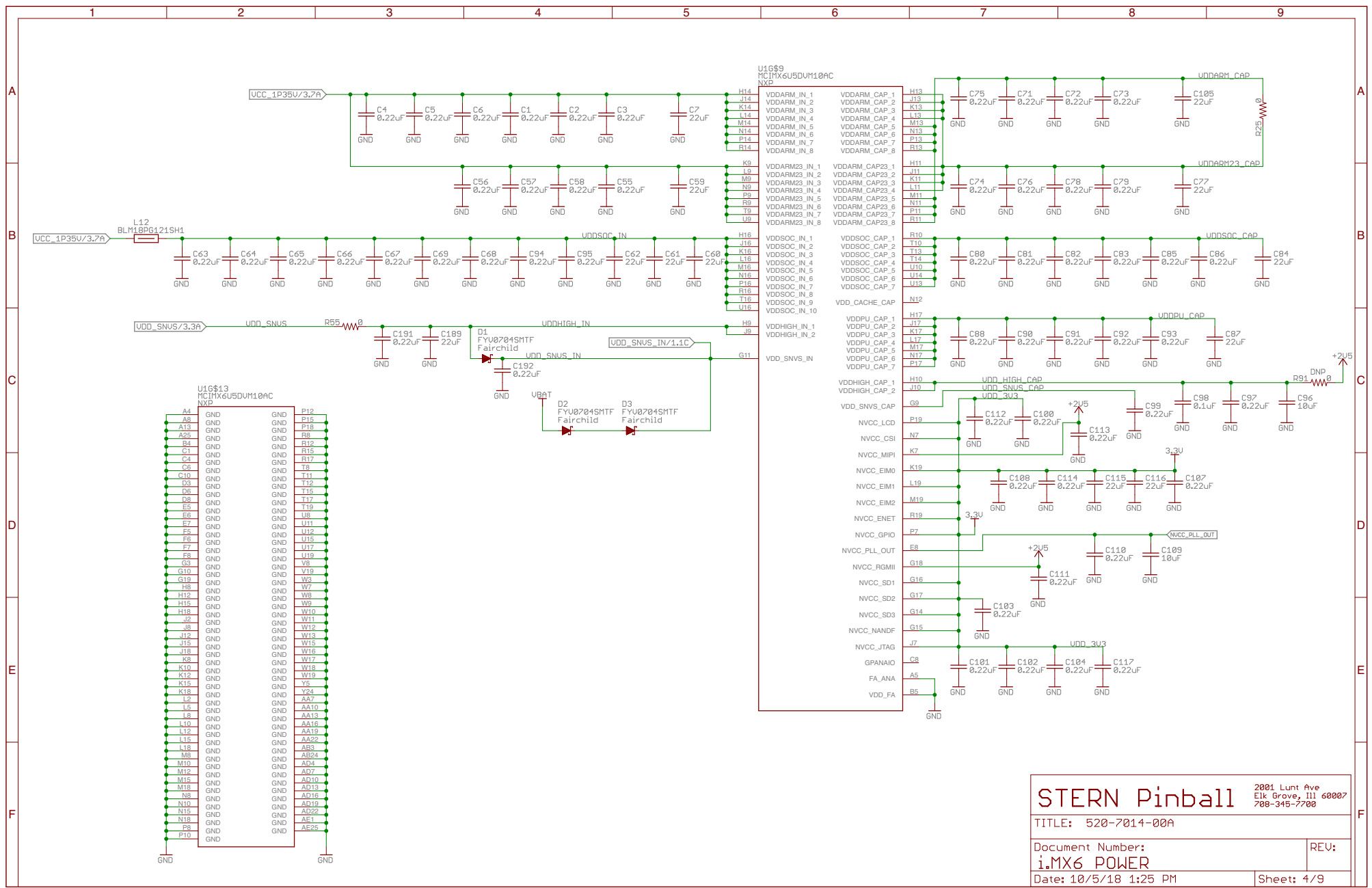
Date: 10/5/18 1:25 PM

REV: _____

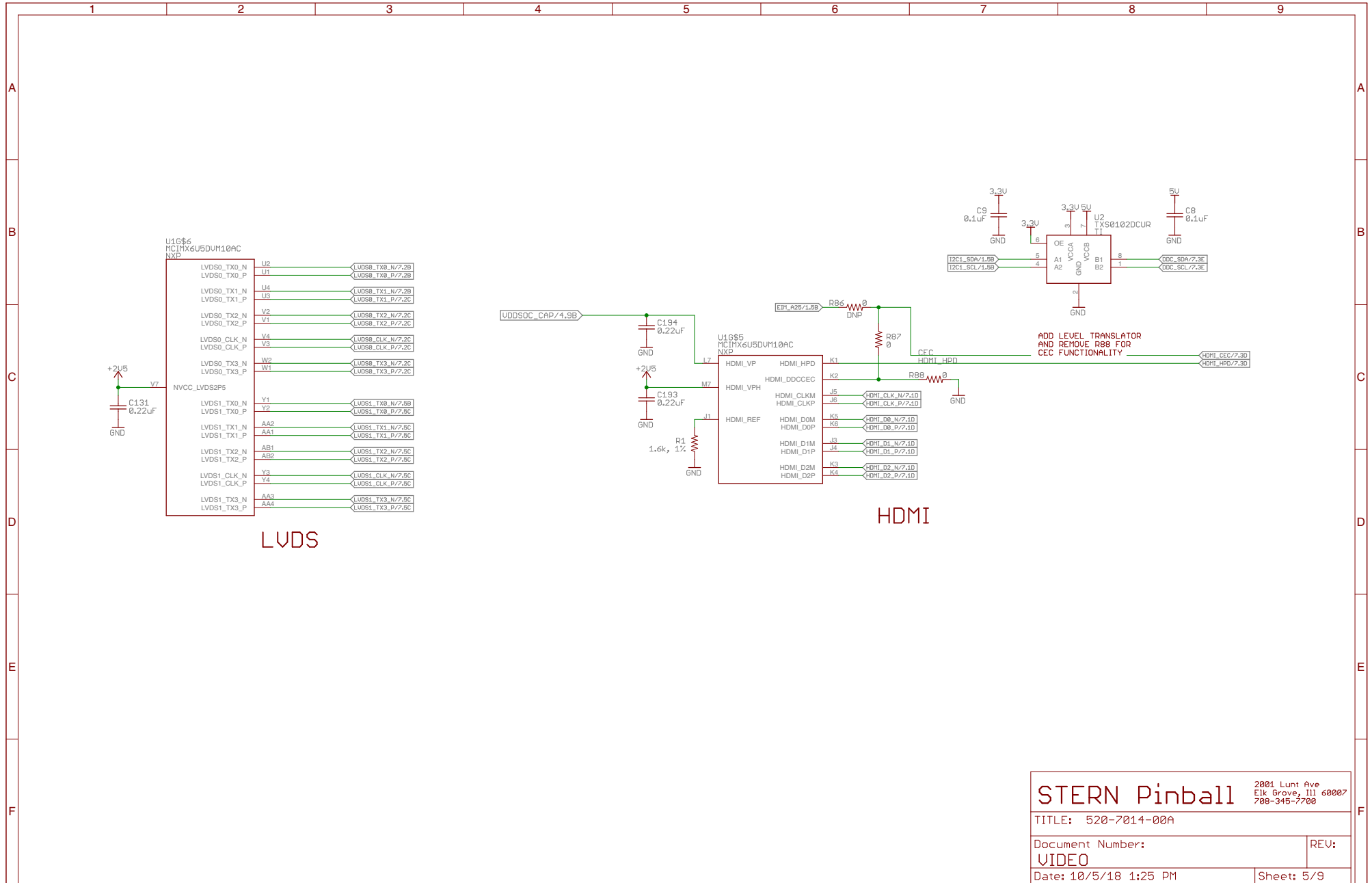
Sheet: 2/9



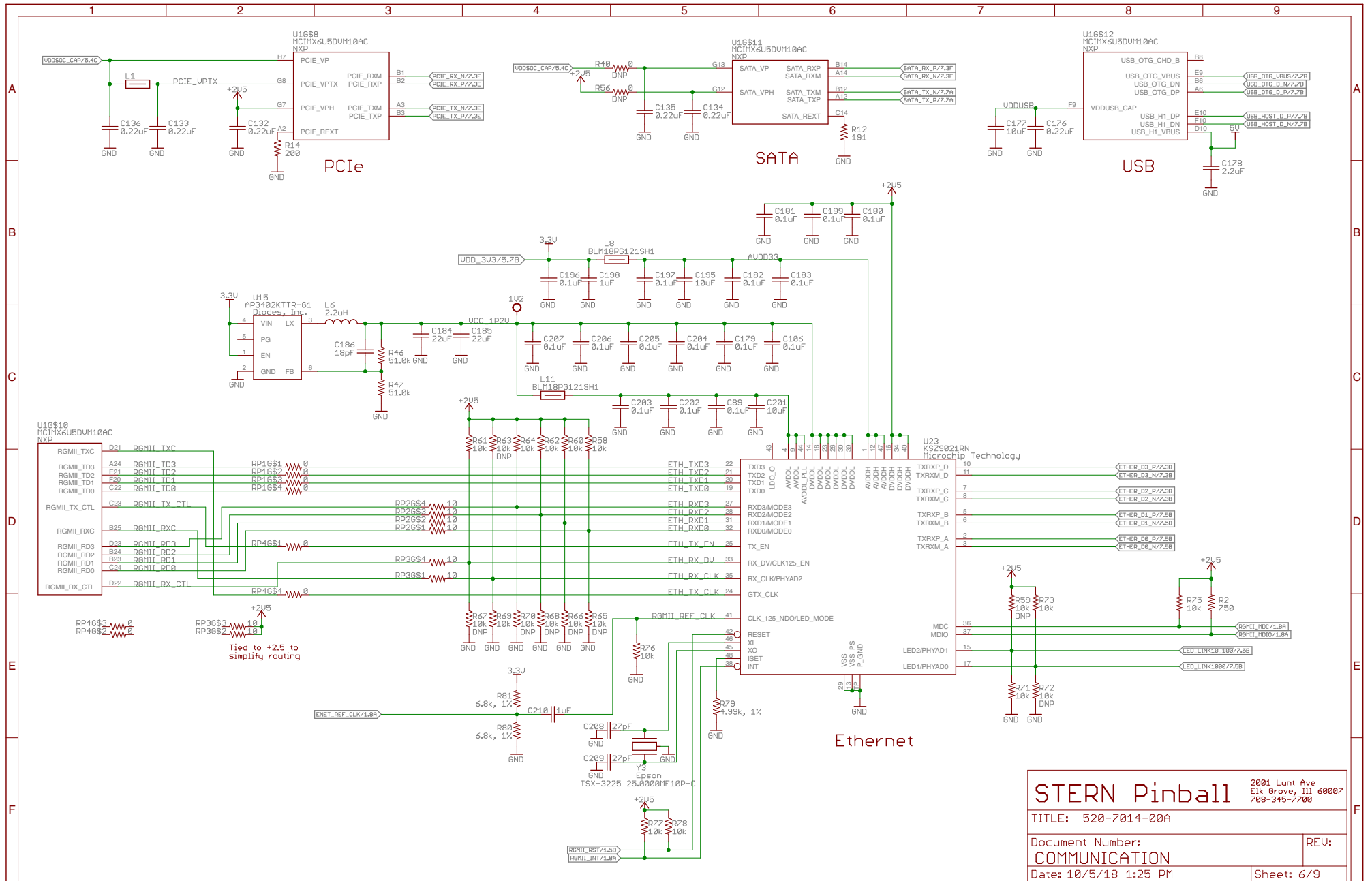
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7014-00A		
Document Number:	REV:	
POWER SUPPLIES		
Date: 10/5/18 1:25 PM	Sheet: 3/9	



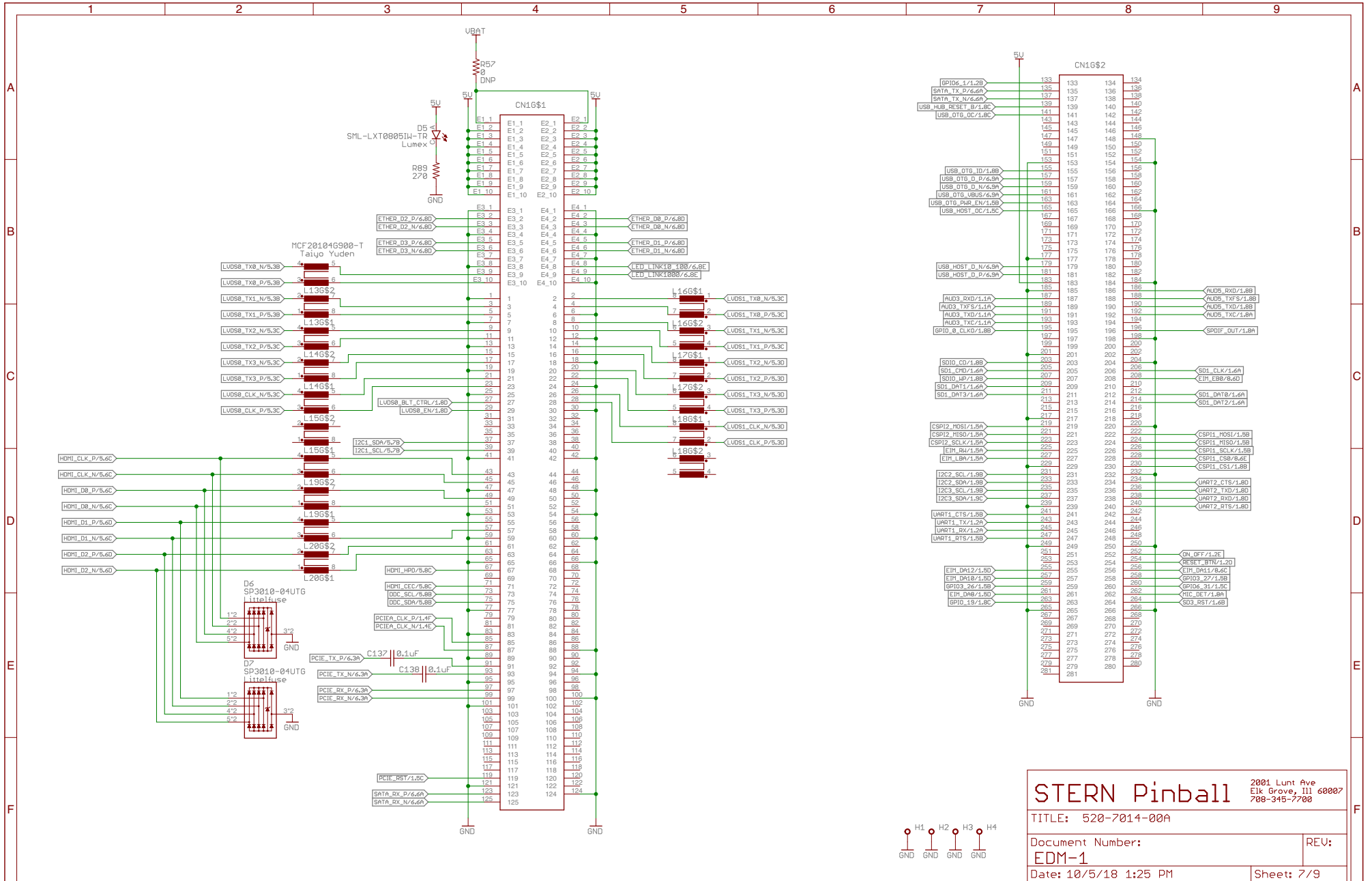
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7014-00A		
Document Number: i.MX6 POWER	REV:	
Date: 10/5/18 1:25 PM	Sheet: 4/9	

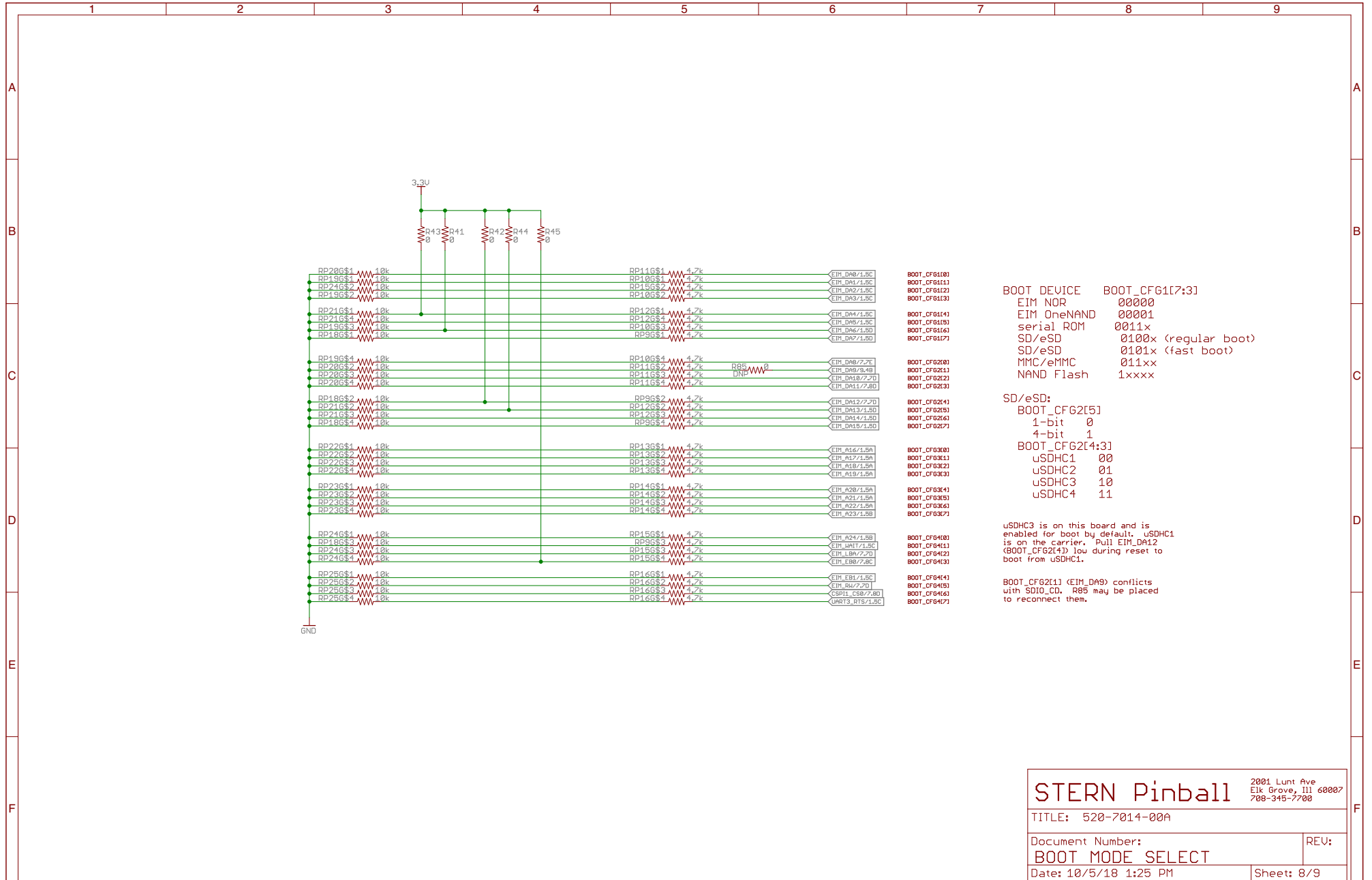


STERN Pinball 2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
Document Number:	REV:
VIDEO	Date: 10/5/18 1:25 PM
Sheet: 5/9	

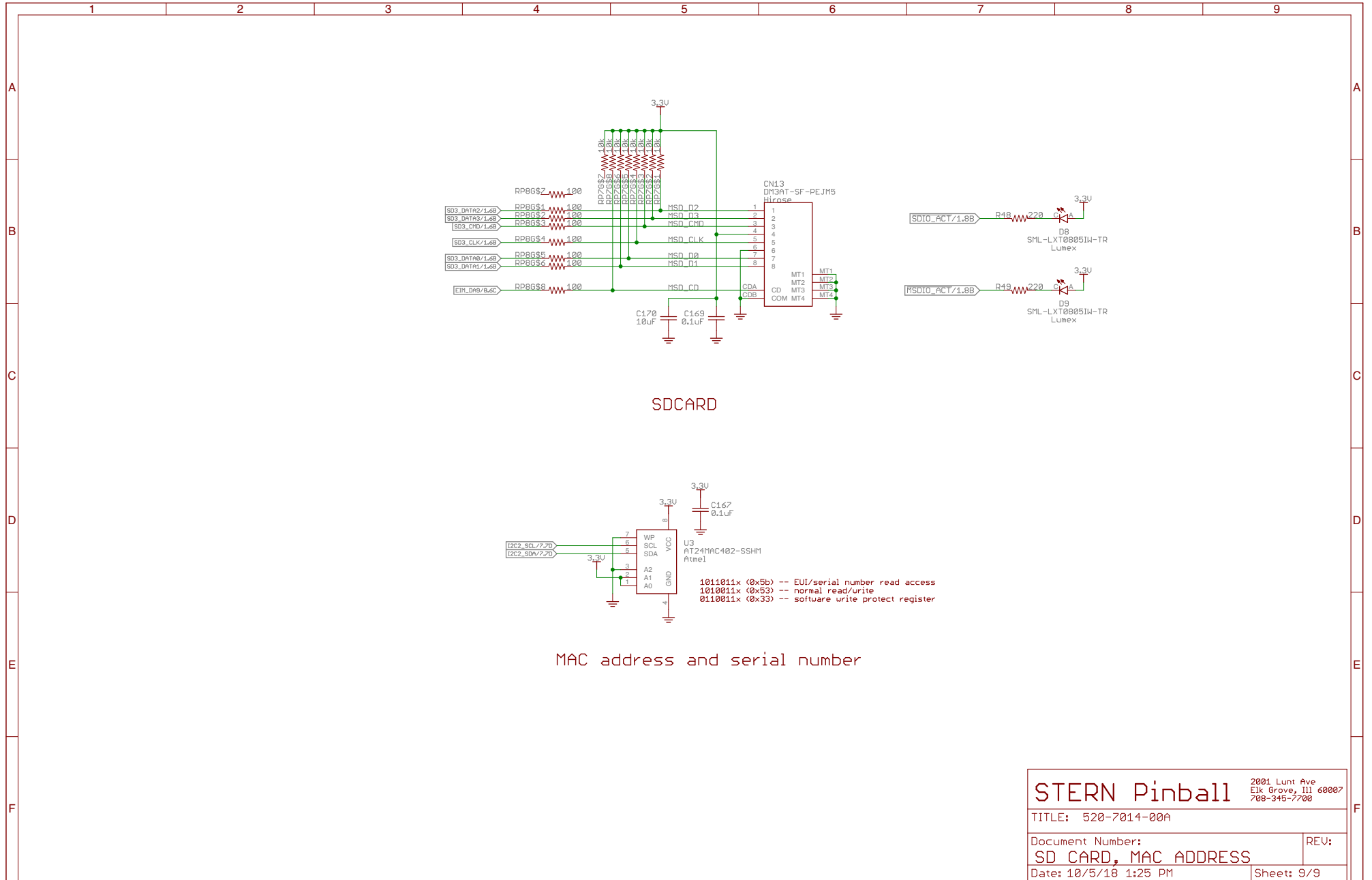


STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-7014-00A			
Document Number:			REV:
COMMUNICATION			
Date: 10/5/18 1:25 PM			Sheet: 6/9

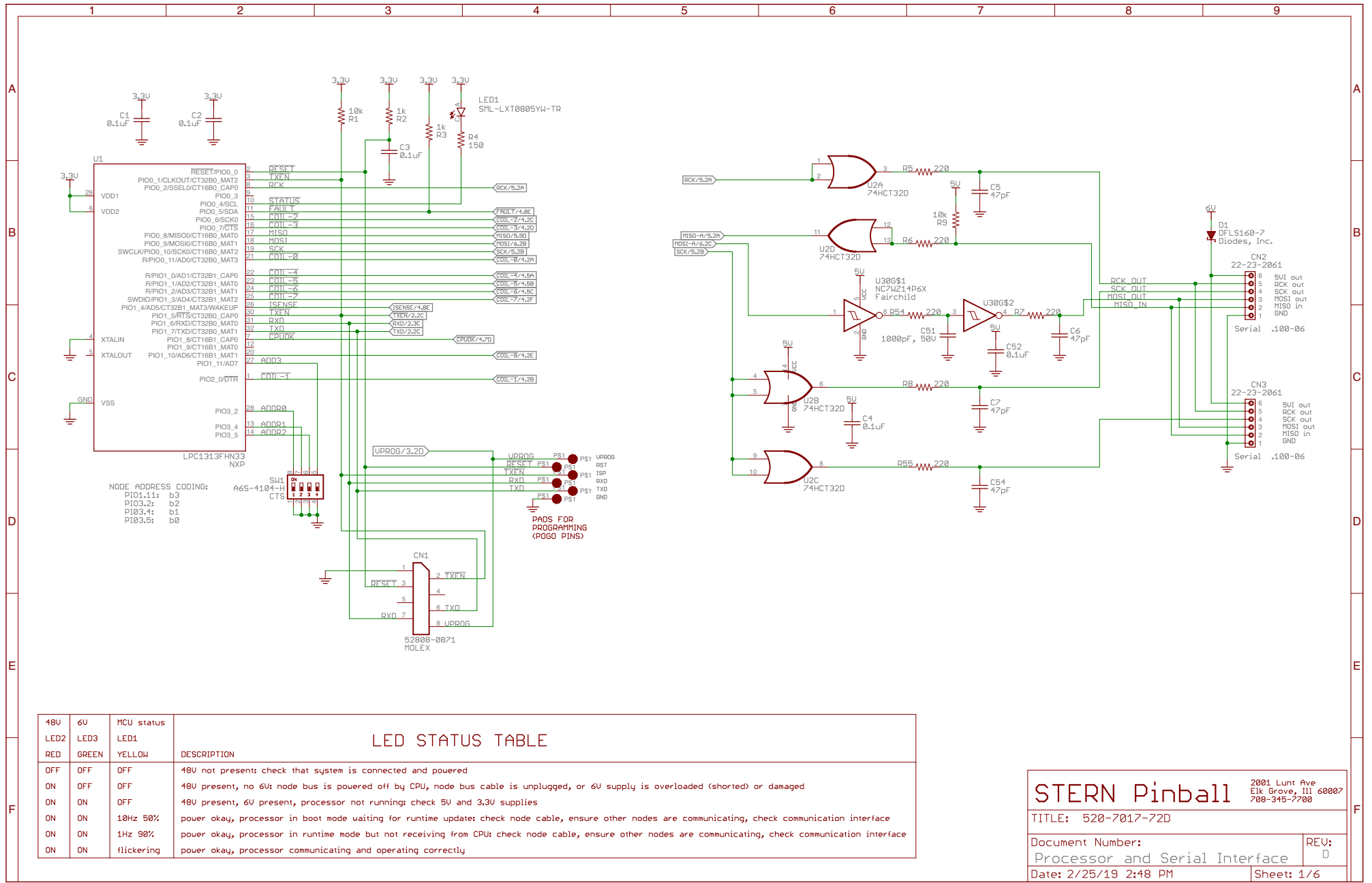




STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7014-00A		
Document Number:	REV:	
BOOT MODE SELECT		
Date: 10/5/18 1:25 PM	Sheet: 8/9	



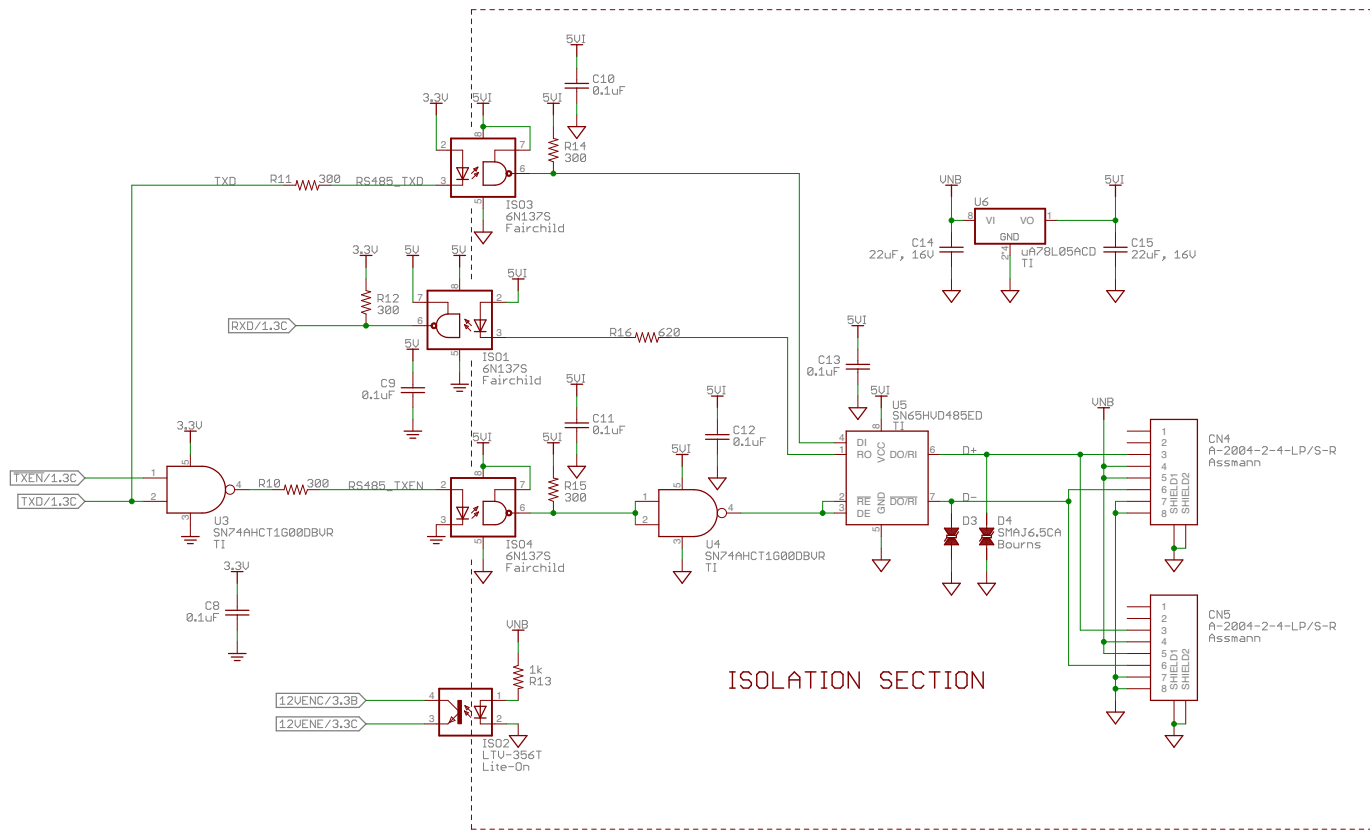
STERN Pinball 2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700		
		TITLE: 520-7014-00A
Document Number:	REV:	
SD CARD, MAC ADDRESS		
Date: 10/5/18 1:25 PM	Sheet: 9/9	



STERN Pinball 2001 Lunt Ave
Elk Grove, Ill 60007
708-345-7700

TITLE: 520-7017-72D

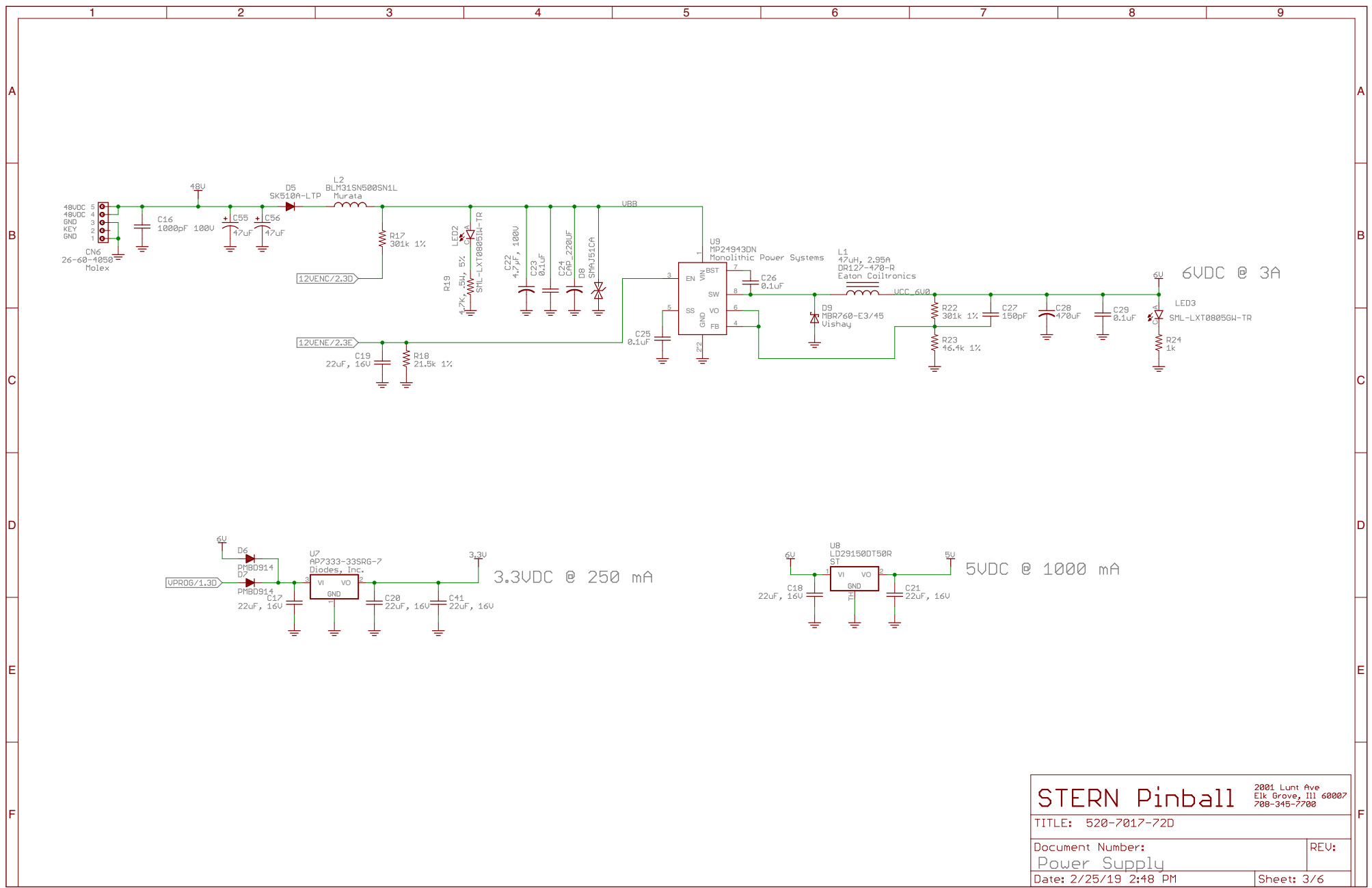
Document Number: Processor and Serial Interface REV: D
Date: 2/25/19 2:48 PM Sheet: 1/6



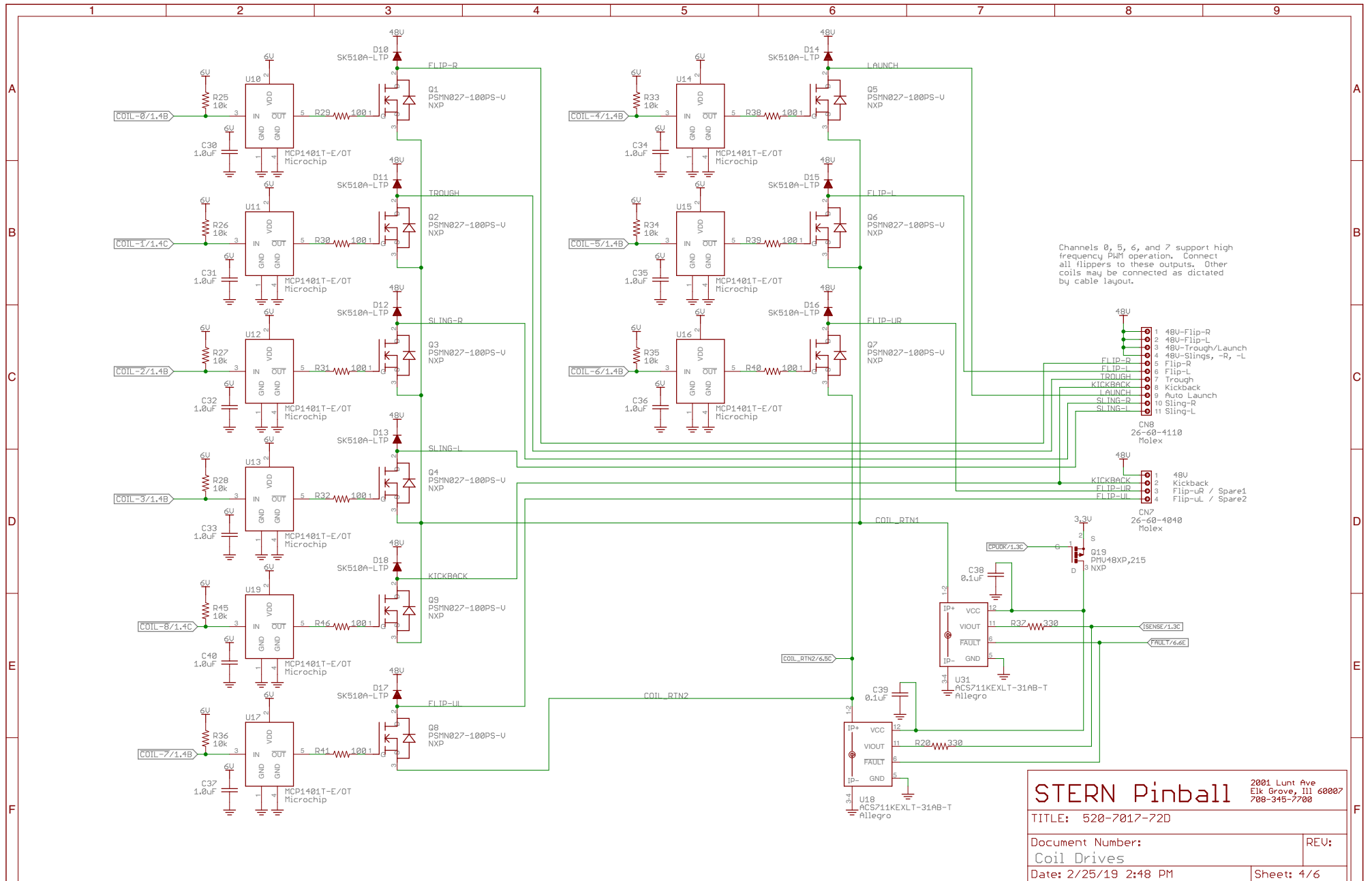
ISOLATION SECTION

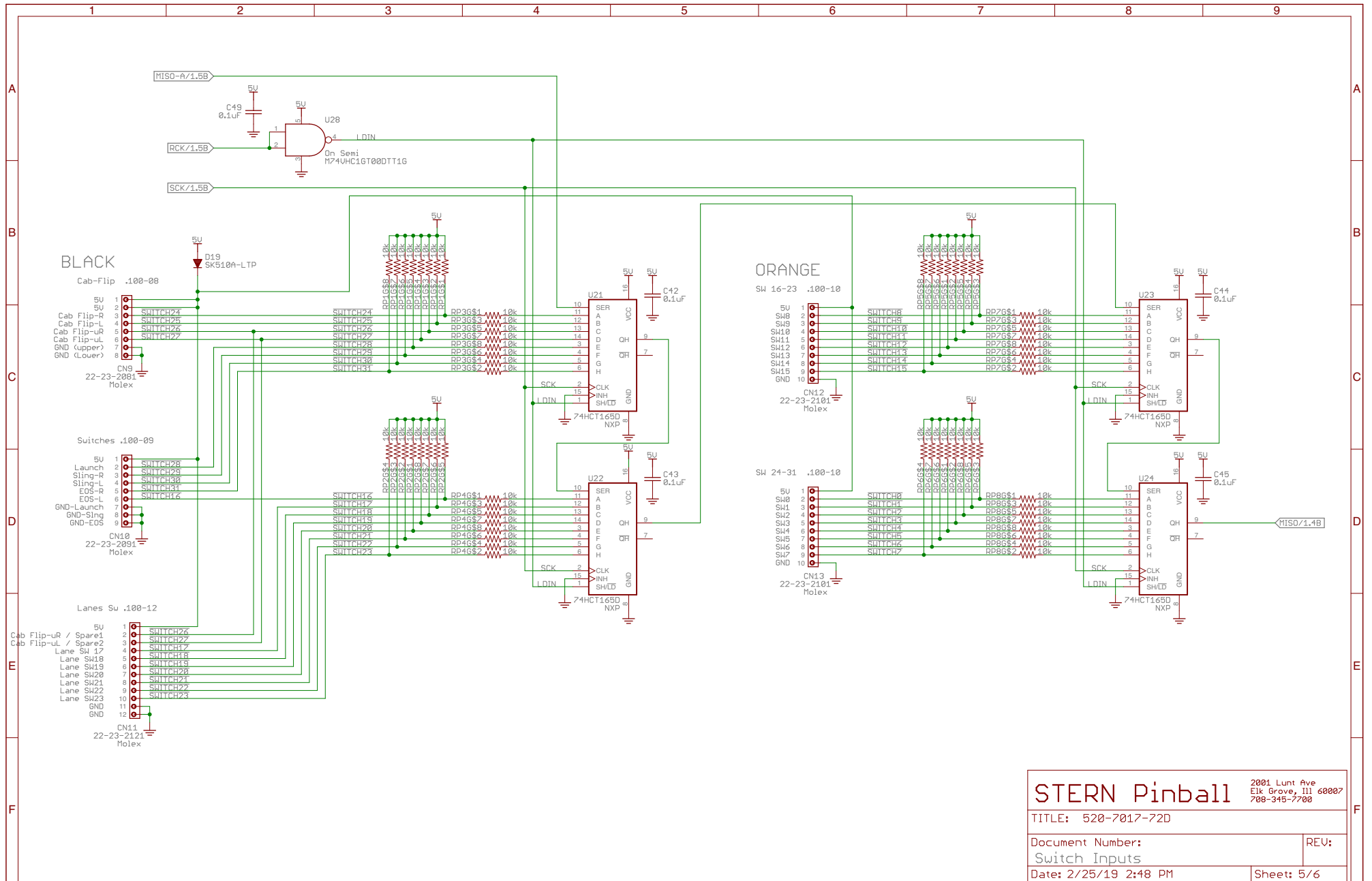
LED current limiting resistors:
 $V_f(\text{max}) = 1.8\text{V}$, $I_f(\text{con})(\text{max}) = 5.0\text{mA}$
 $(3.3\text{V} - 1.8\text{V}) / 5.0\text{mA} = 300\Omega$
 $(5.0\text{V} - 1.8\text{V}) / 5.0\text{mA} = 640\Omega$ (use 620 Ω)

STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7017-72D		
Document Number:	REV:	
Communication		
Date: 2/25/19 2:48 PM	Sheet: 2/6	

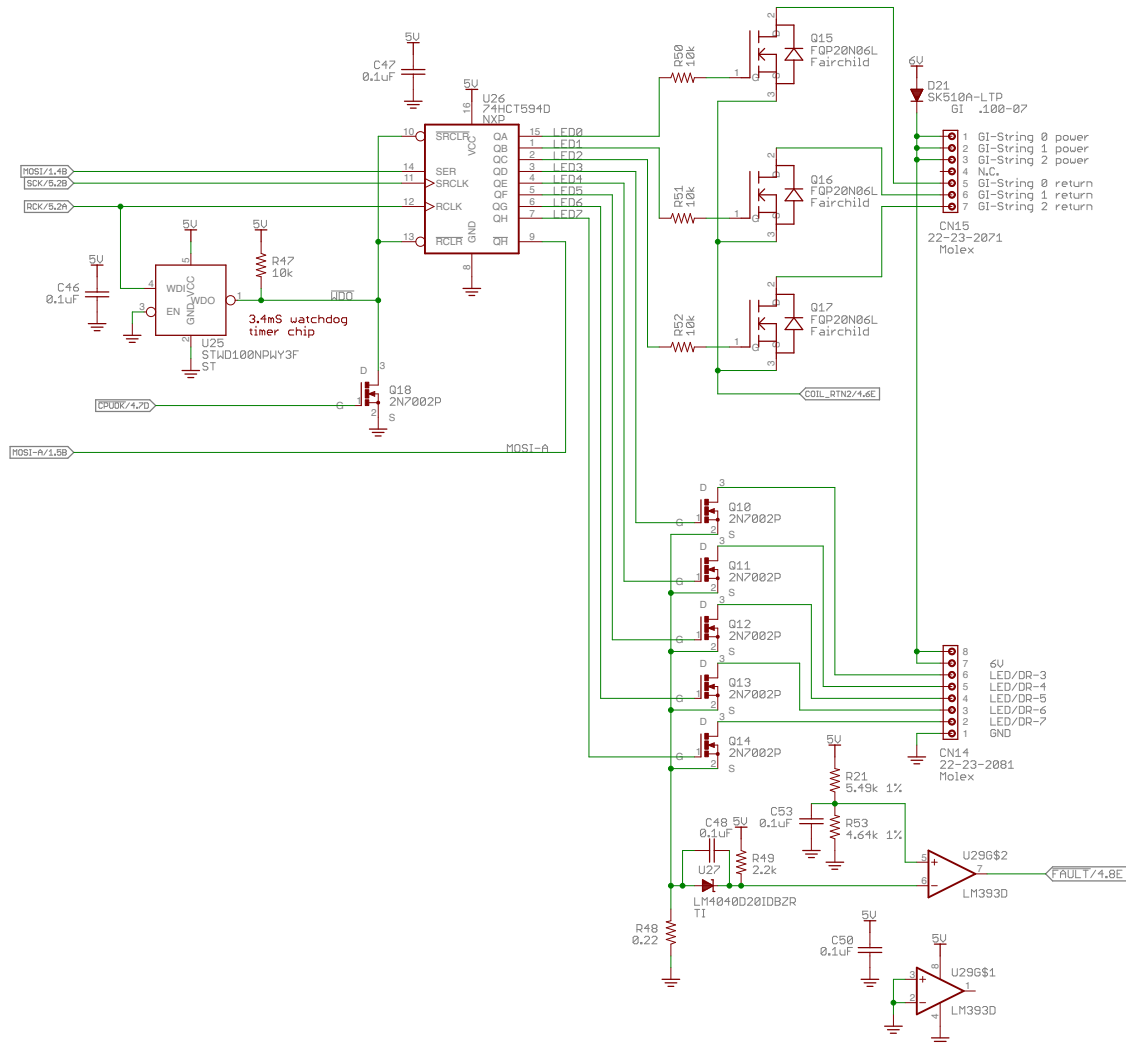


STERN Pinball TITLE: 520-7017-72D		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
		Document Number: Power Supply	REV:
Date: 2/25/19 2:48 PM		Sheet: 3/6	



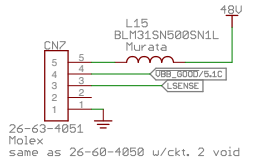
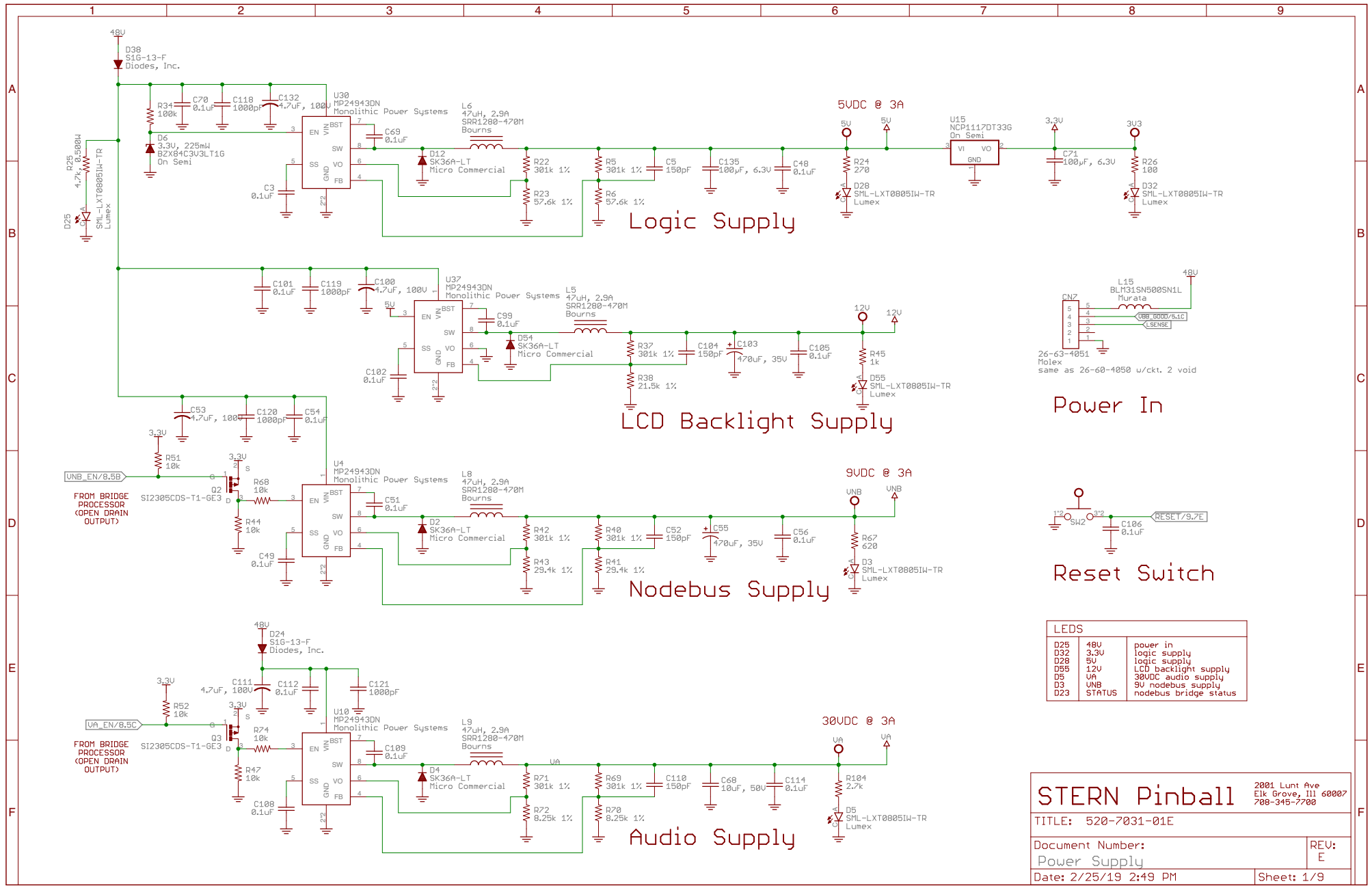


STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7017-72D		
Document Number:		REV:
Switch Inputs		
Date: 2/25/19 2:48 PM		Sheet: 5/6

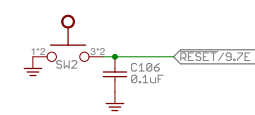


$I_{sense} = 2.048V + I_{led} \times 0.22\Omega$ (\leftarrow input of comparator)
 $U_{ref} = 5.0V \times 4.64k / (5.49k + 4.64k) = 2.29V$
 $I_{trip} = (2.29V - 2.048V) / 0.22\Omega = 1.1A$

STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7017-72D		
Document Number:	REV:	
GI and LED/General Drives		
Date: 2/25/19 2:48 PM	Sheet: 6/6	



Power In



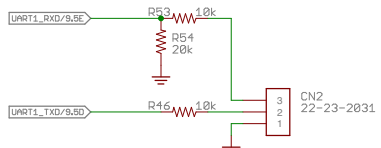
Reset Switch

LEDS		
D25	48U	power in
D32	3.3U	logic supply
D28	5U	logic supply
D55	12U	LCD backlight supply
D5	VA	30VDC audio supply
D3	UNB	5U nodebus supply
D23	STATUS	nodebus bridge status

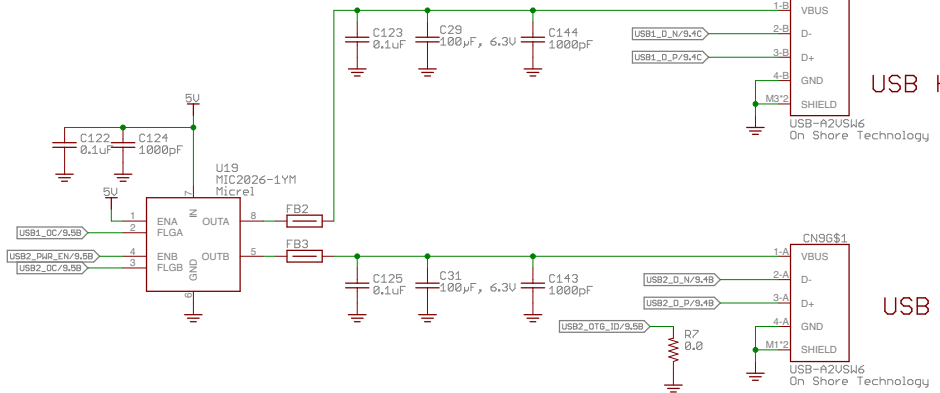
STERN Pinball 2001 Lunt Ave
Elk Grove, Ill 60007
708-345-7700

TITLE: 520-7031-01E

Document Number: Power Supply	REV: E
Date: 2/25/19 2:49 PM	Sheet: 1/9

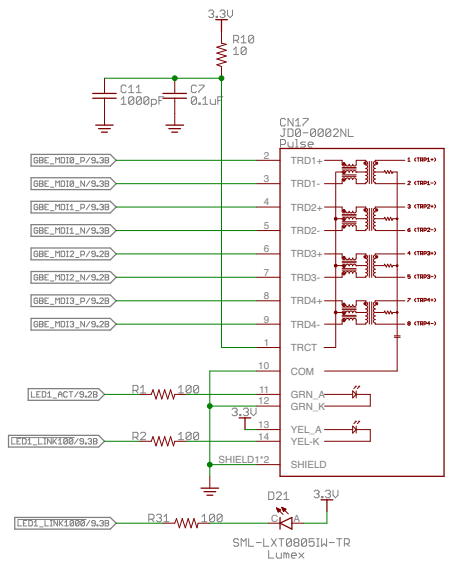


CONSOLE PORT

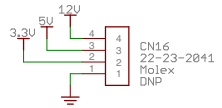


USB HOST PORT

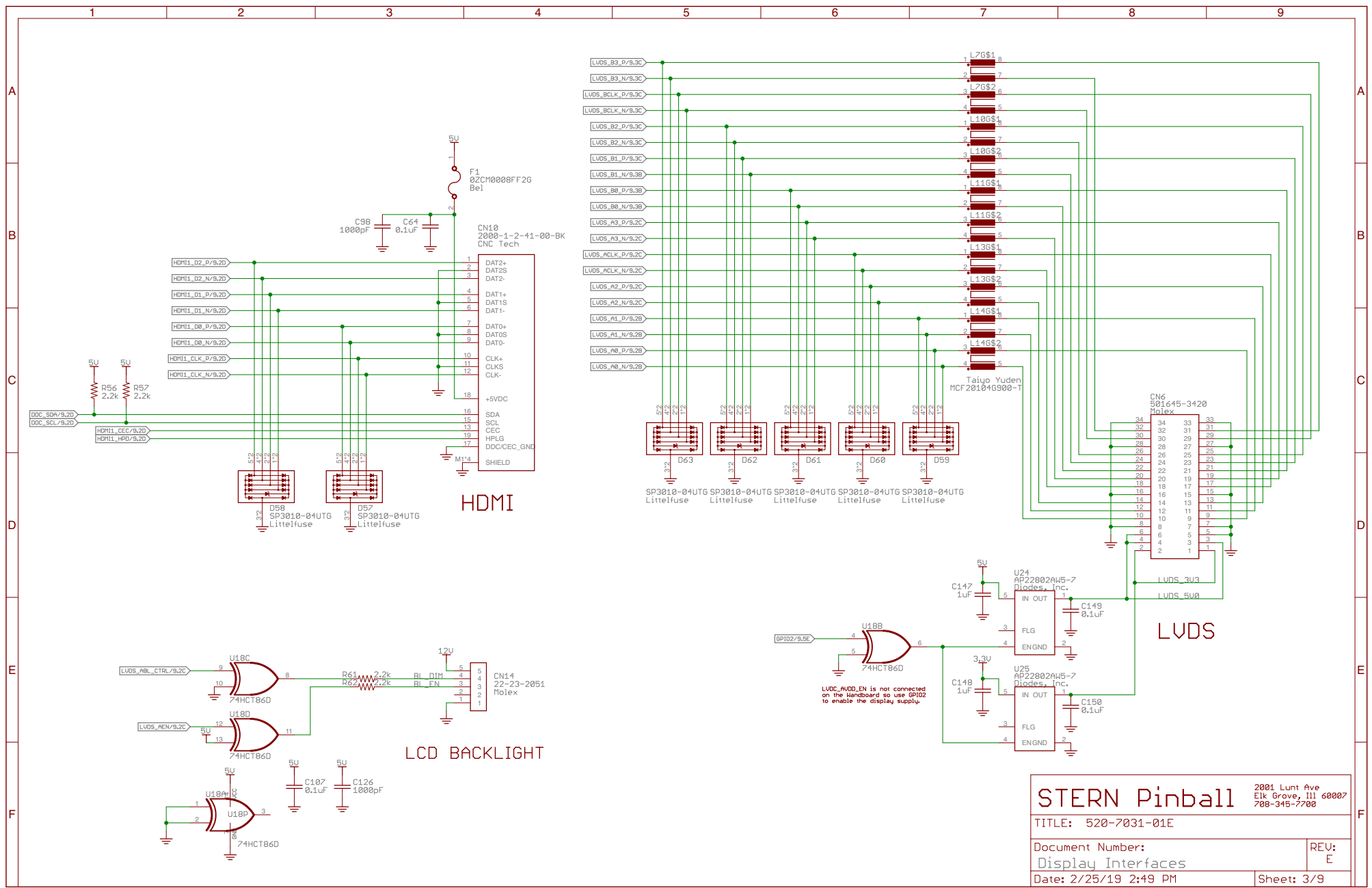
USB HOST PORT



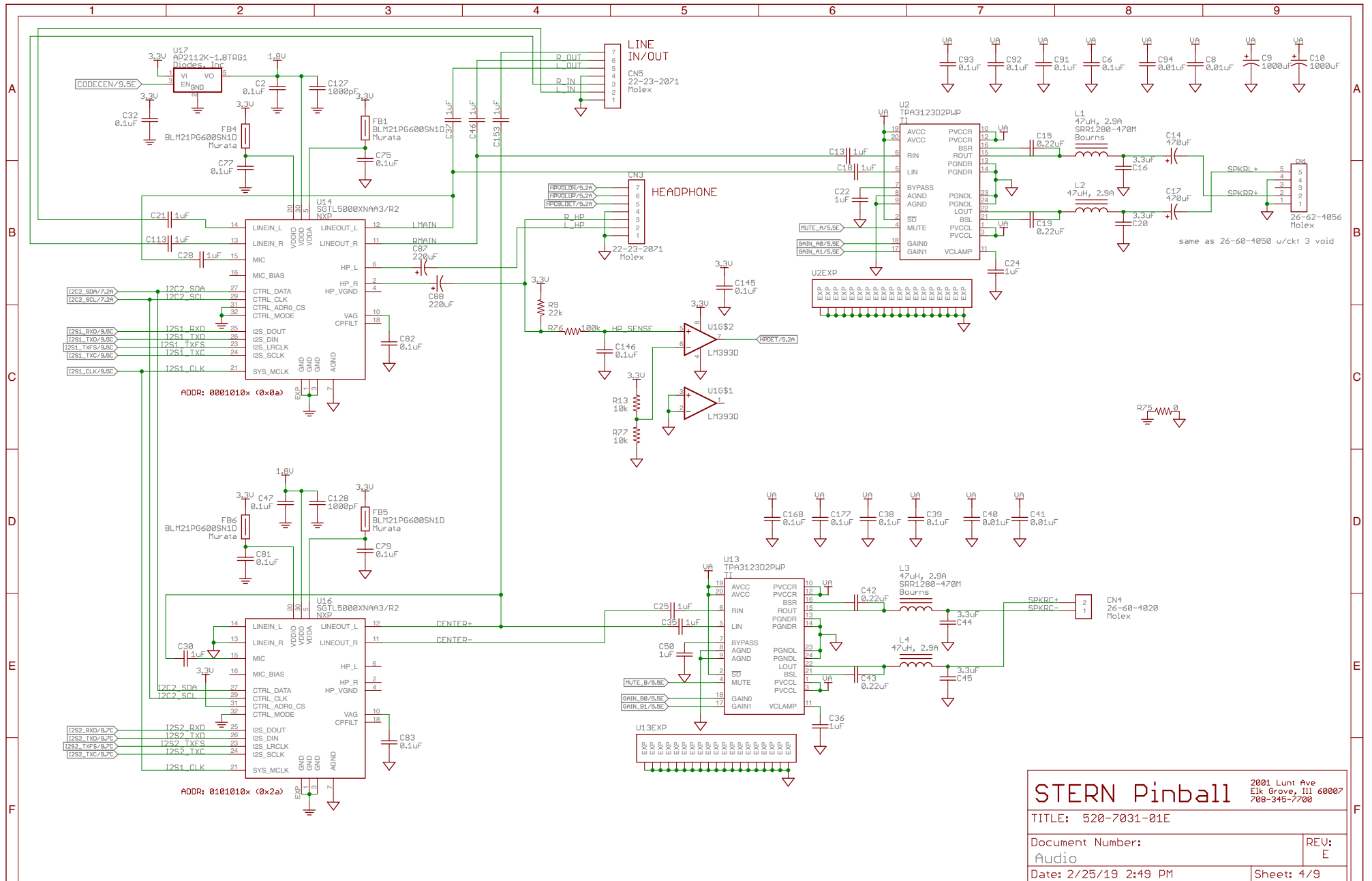
ETHERNET



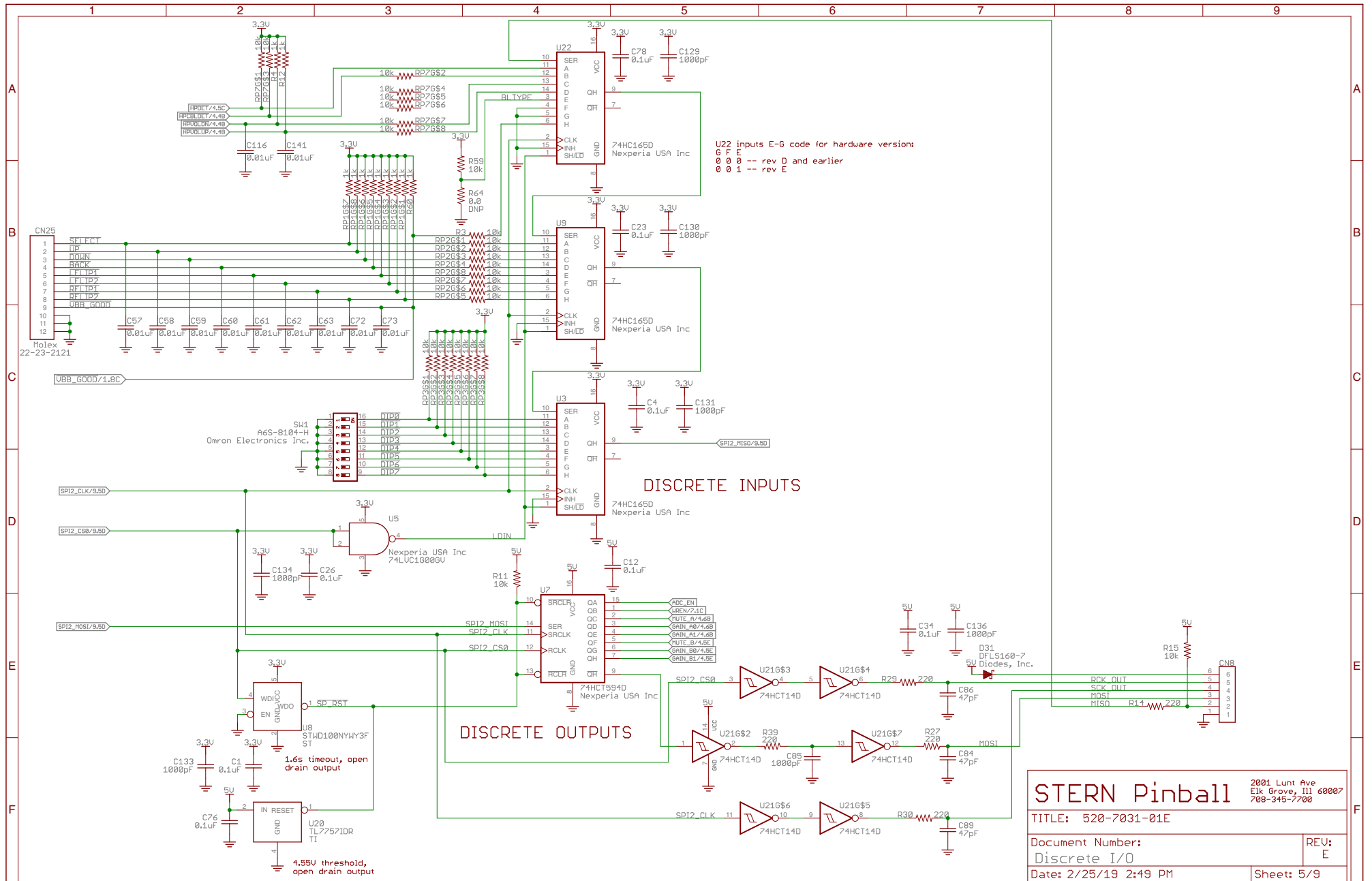
STERN Pinball 2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
Document Number: Communication Interfaces	REV: E
Date: 2/25/19 2:49 PM	Sheet: 2/9

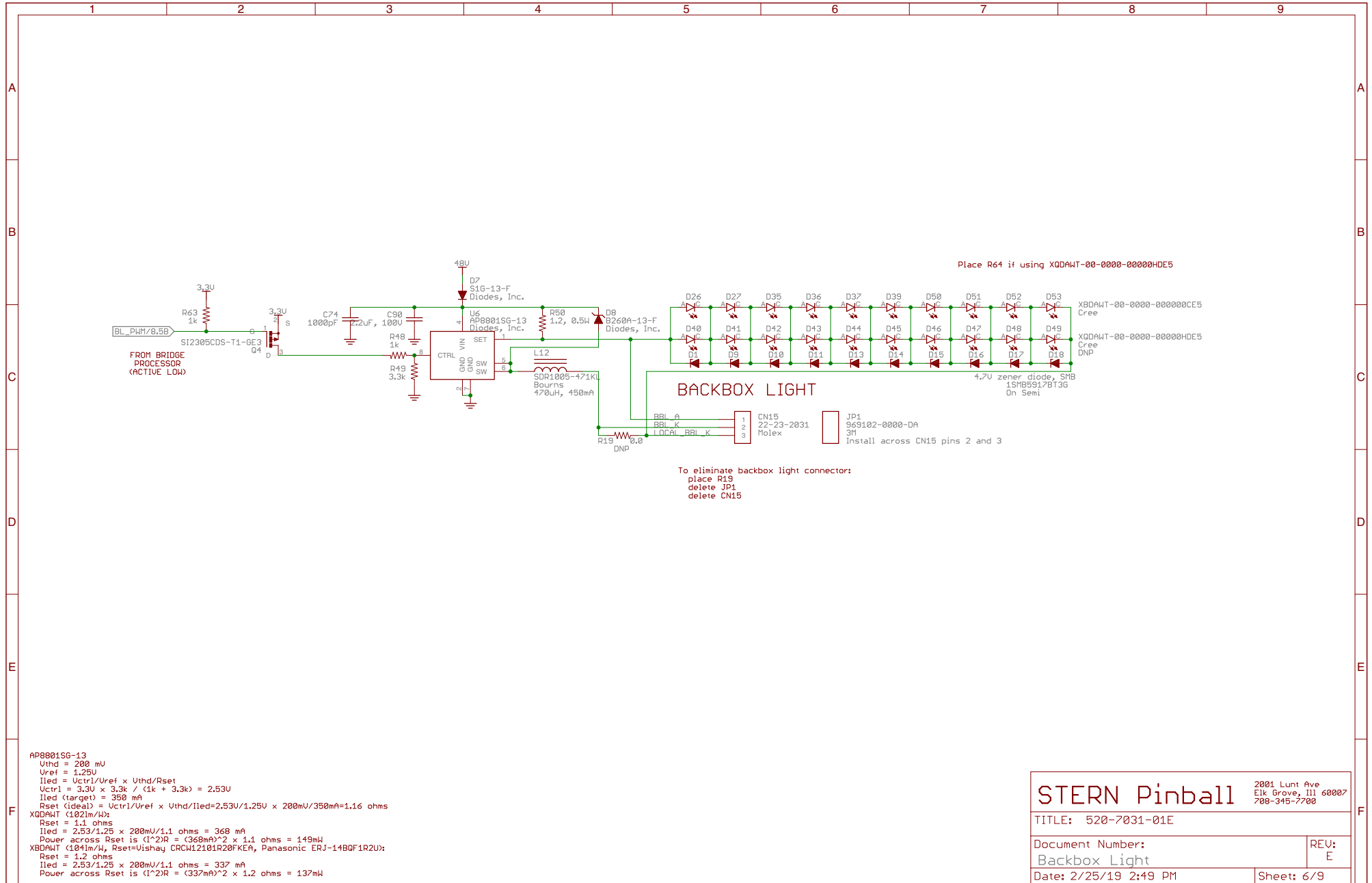


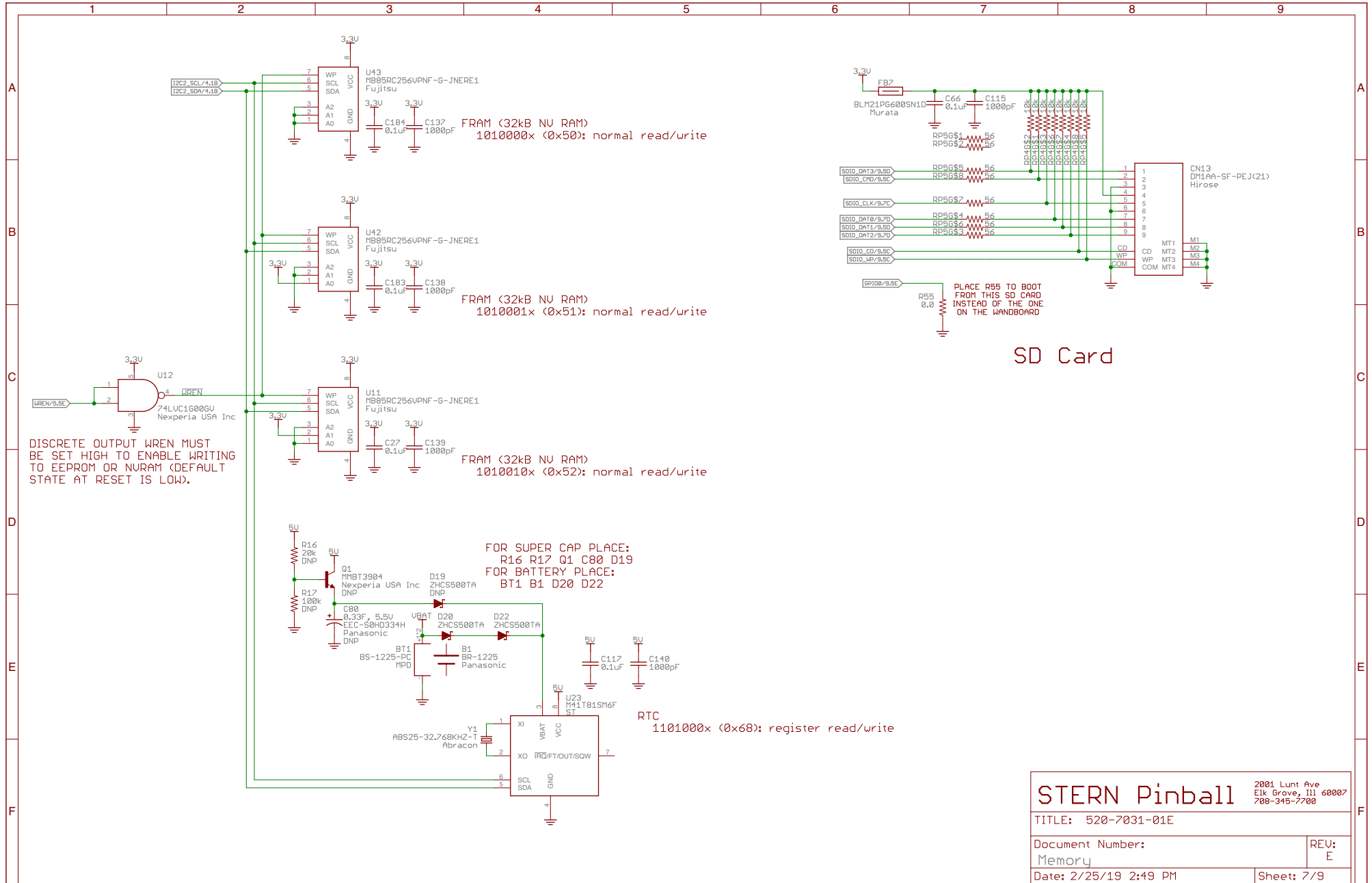
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700
TITLE: 520-7031-01E		
Document Number:	Display Interfaces	REV: E
Date: 2/25/19 2:49 PM	Sheet: 3/9	



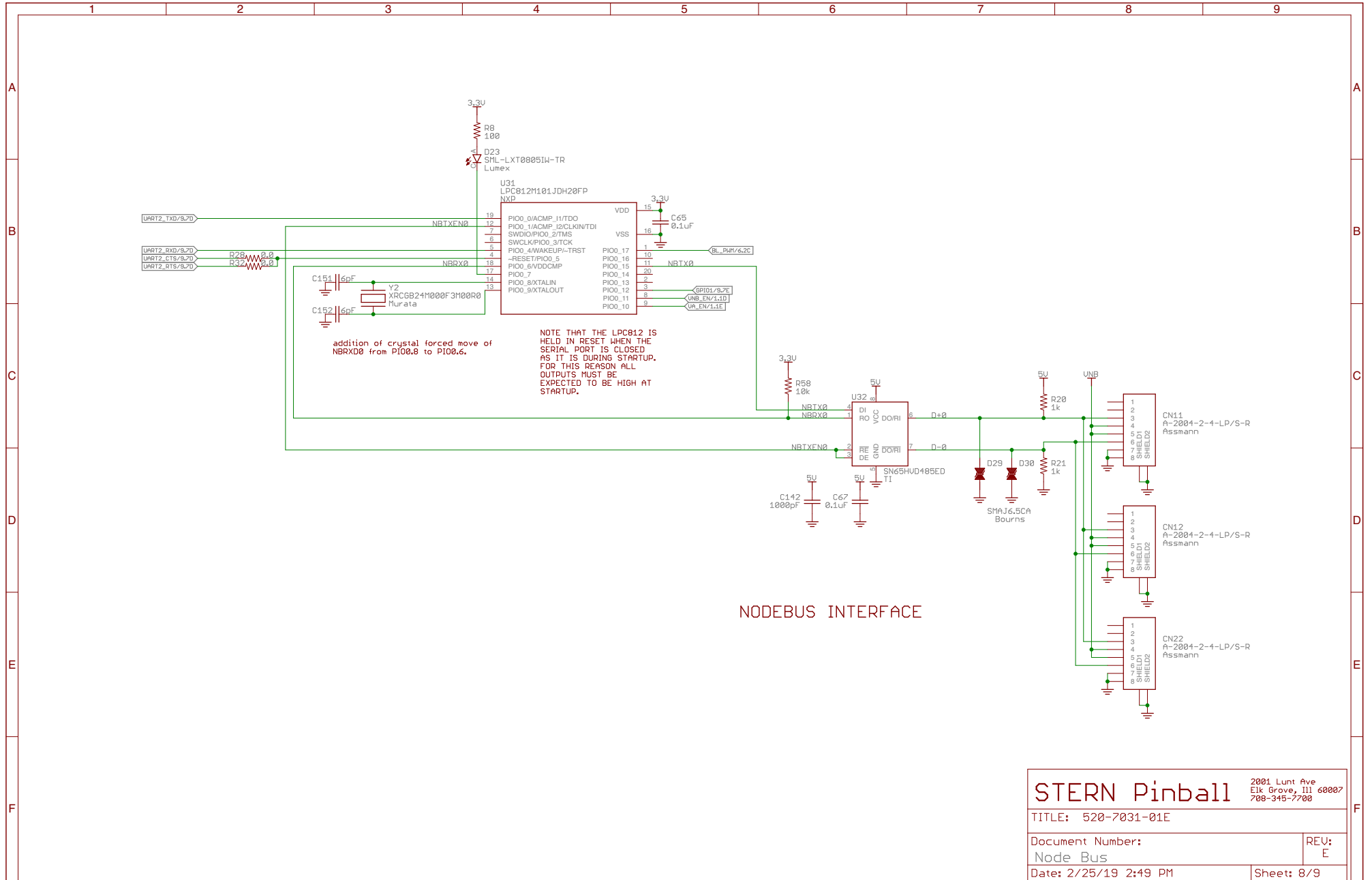
STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-7031-01E			
Document Number:		REV:	
Audio		E	
Date: 2/25/19 2:49 PM			Sheet: 4/9

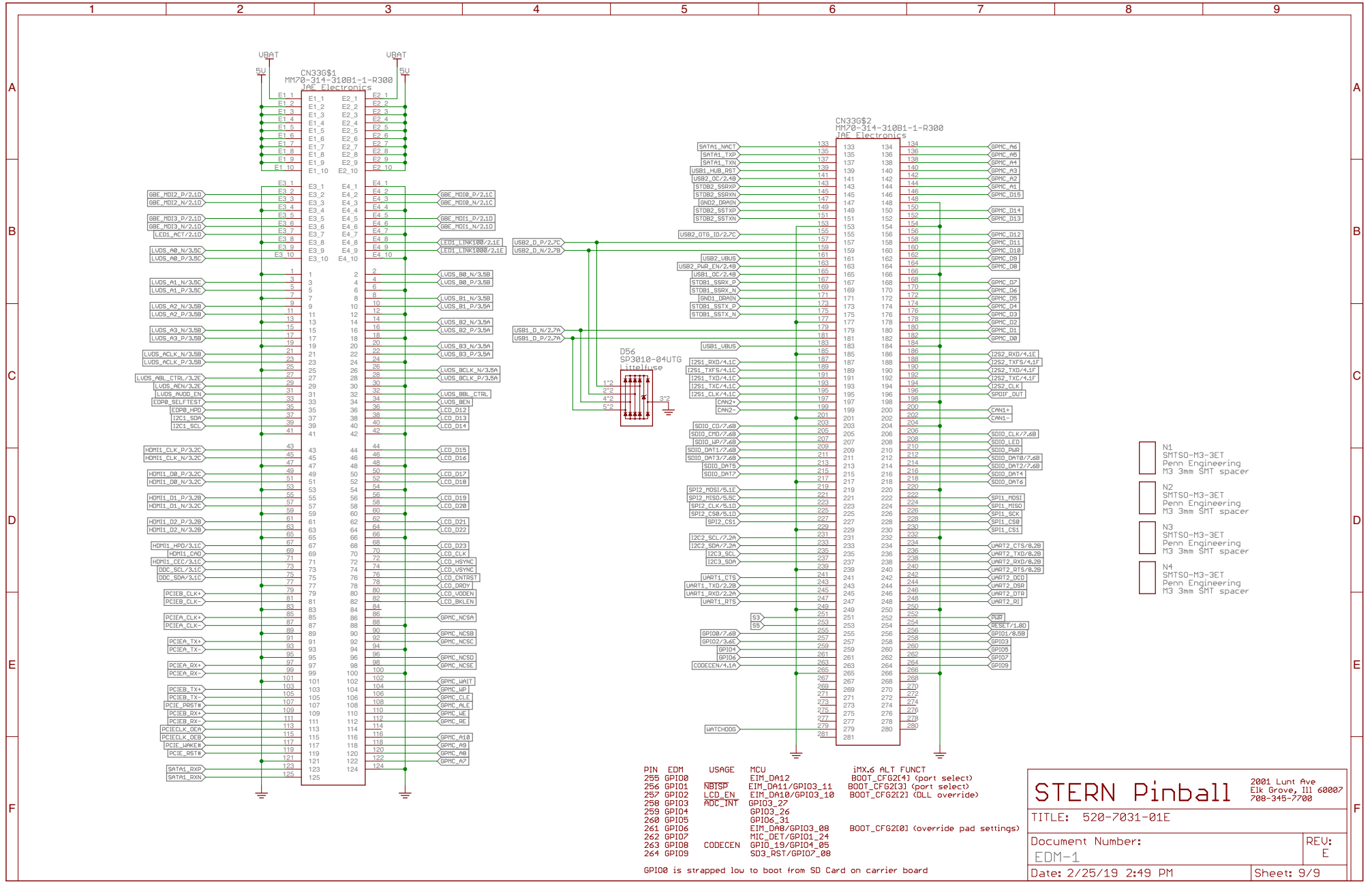


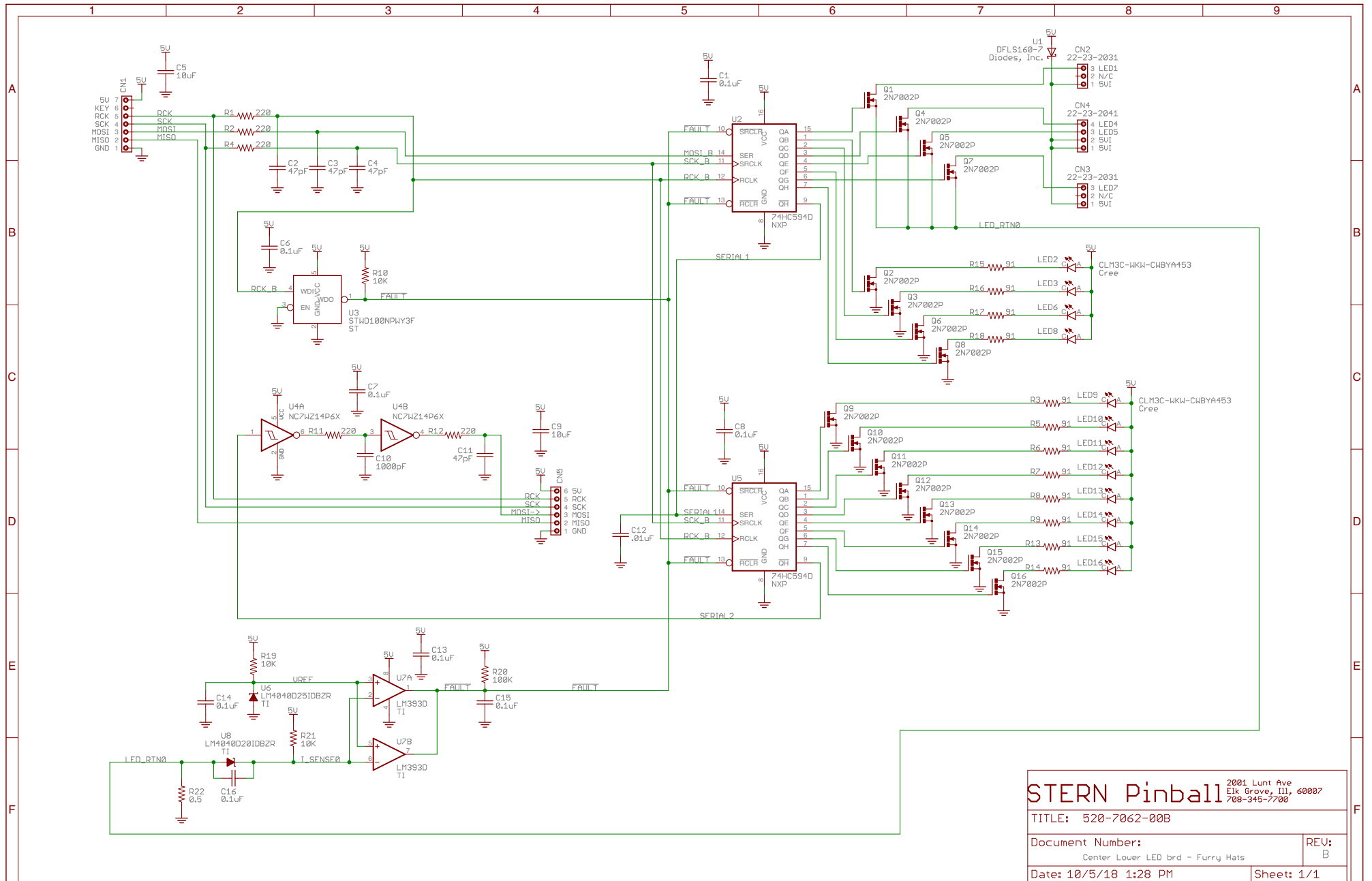




STERN Pinball		2001 Lunt Ave Elk Grove, Ill 60007 708-345-7700	
TITLE: 520-7031-01E			
Document Number:			REV: E
Date: 2/25/19 2:49 PM			Sheet: 7/9







STERN Pinball 2001 Lunt Ave Elk Grove, Ill, 60007 708-345-7700	
TITLE: 520-7062-00B	
Document Number: Center Lower LED brd - Furry Hats	REV: B
Date: 10/5/18 1:28 PM	Sheet: 1/1