PGF-SP CDR
Part Three

Prepared by: Bionetics

Date:09/10/2002

Agenda

Part Three

- Electronics and Software
  - Electronics
  - Software

Electronics and Software Design

Electronic Modules for the PGF-SP

Prepared by

The LSSC Flight Experiments Development Group

August 15 2002

Microcontroller Modules

- The concept of this design is to allow fail-safe procedures to be executed and for the experimental plant growth to continue in event of a partial hardware failure
- This has been accomplished by controlling devices such as fans, blowers solenoid valves and pumps with individual modules each with its own microcontroller on board
- Each module is responsible for monitoring the temperature of the device it is controlling as well as sensing changes in temperature on the PCB itself.

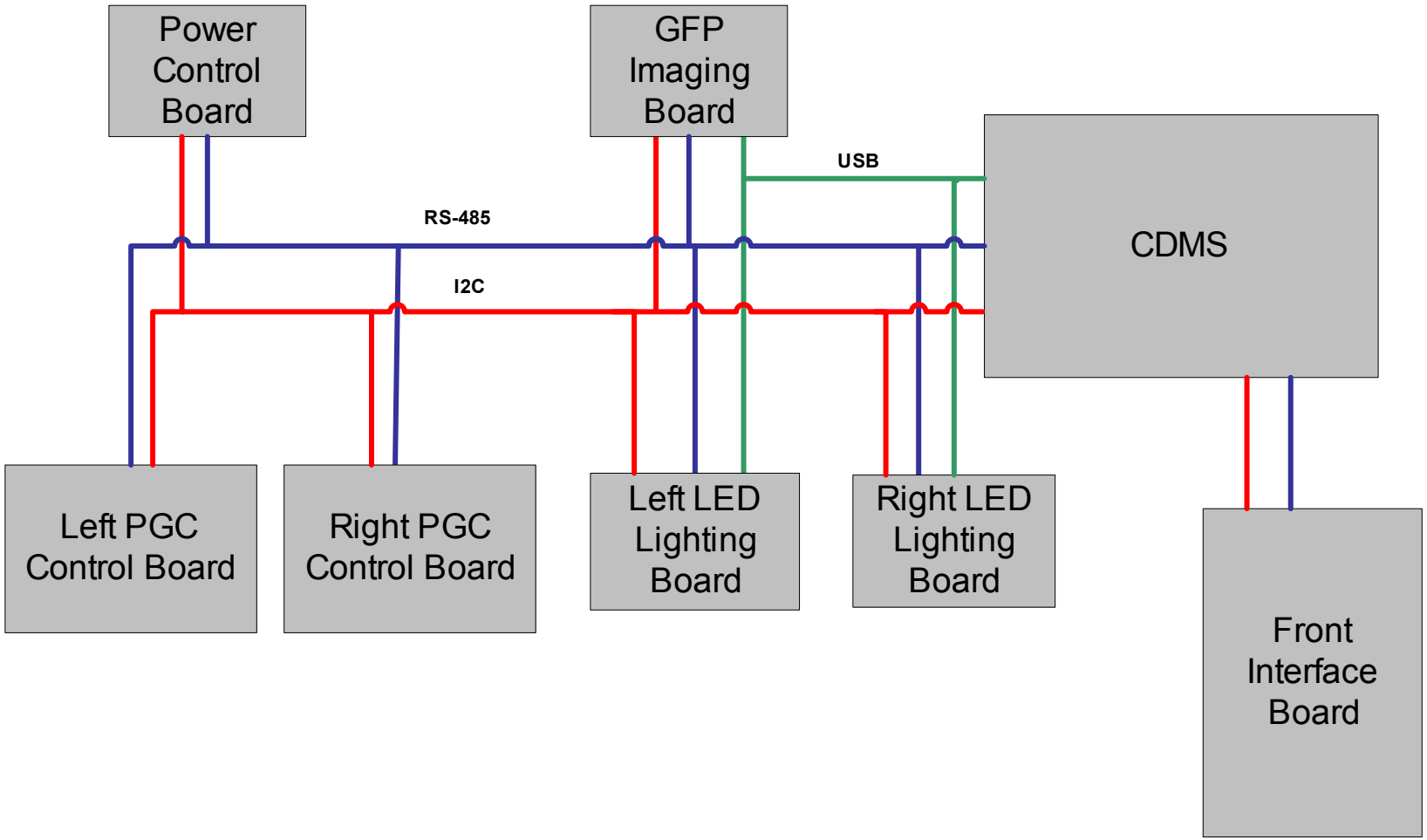
Microcontroller Modules (cont)

- Provisions have been made for monitoring the current consumption of each controlled device

If a change in temperature or current consumption is detected the module can take the appropriate steps to go into a fail safe mode and report its actions including time stamping back to the CDMS

- The use of the satellite modules allows for extensive set of sensors to be implemented in the system without the addition of wiring complexity
- Flash Programmable for ease of software updates

Controller Functional Block Diagram



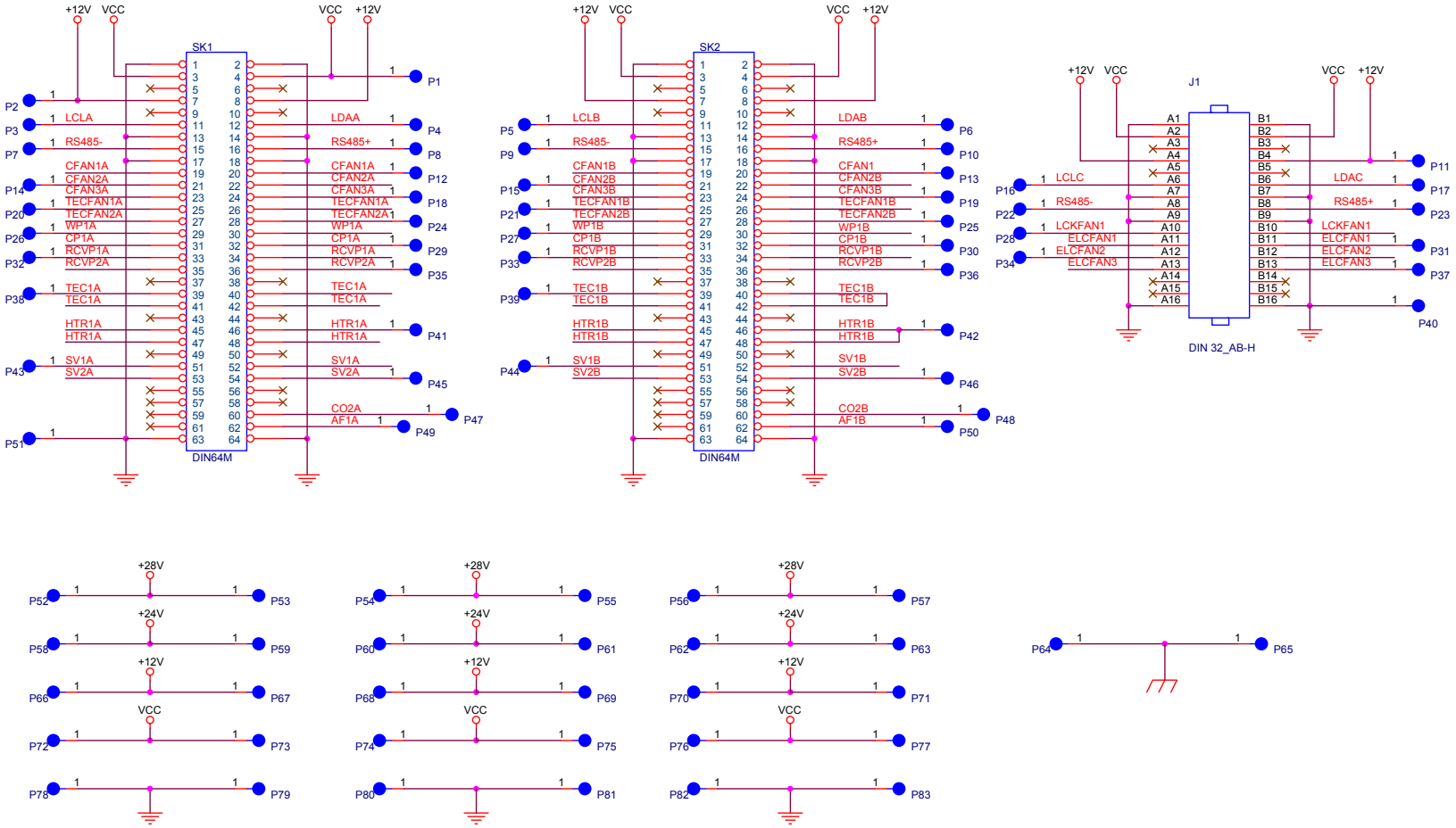
PGF Controller Boards

- PIC Microcontroller boards control and monitor system temperatures, relative humidity, light levels and imaging
- Each controller board is interfaced to CDMS through an RS-485 and an I2C data bus
- Data buses provide data and command capability from CDMS to each controller board
- Current monitors on actuators
- I2C EEPROMS store set-points and some data
- Watchdog timers on each PIC controller
- Operates autonomously if CDMS control lost

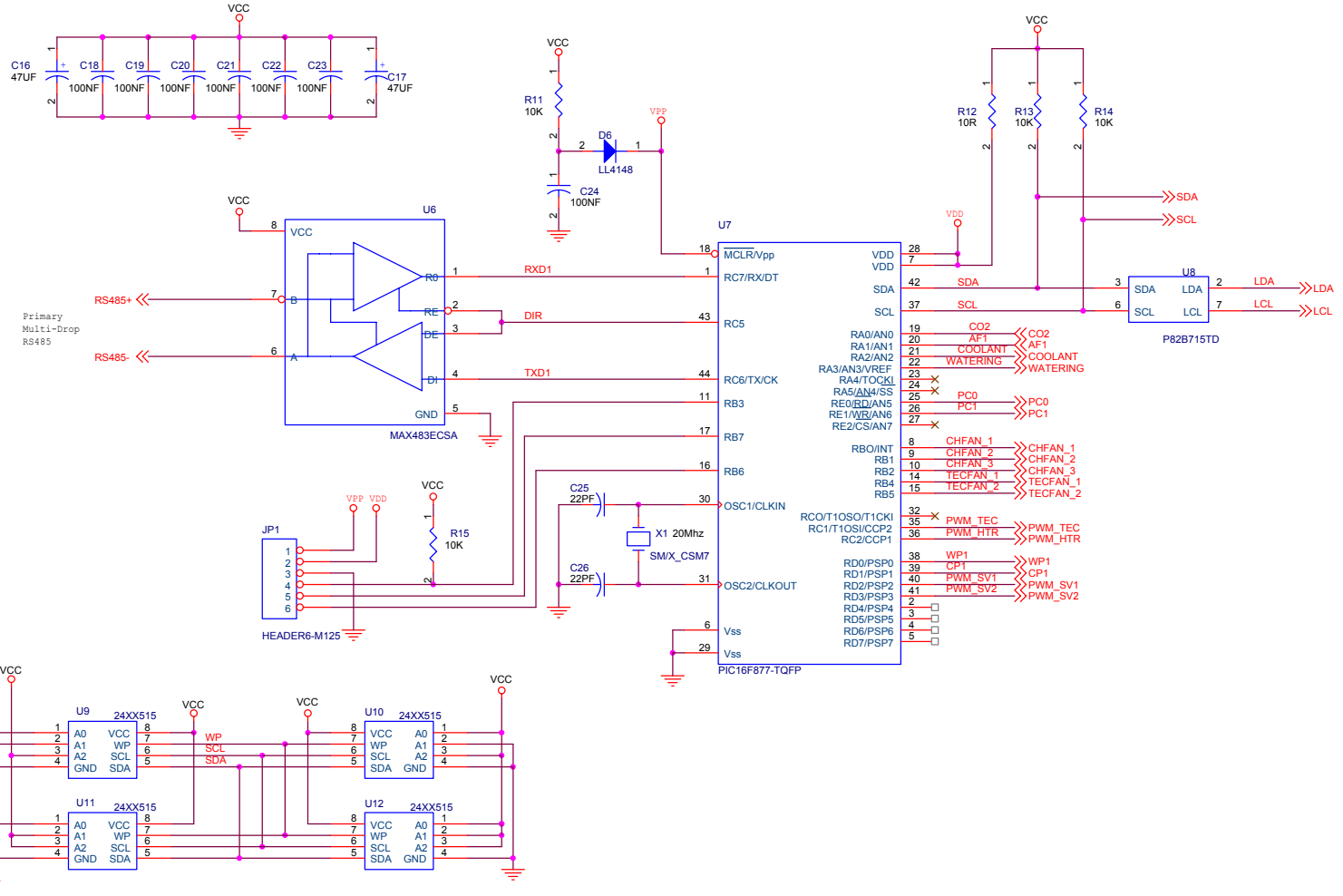
Right/Left PGC Controller Board

- Controls PGC temperatures, relative humidity and CO2 level and recovers condensate
- Similar in design to prototype PGC controllers
- Heater is Pulse Width Modulation (PWM) controlled
- Thermal Electric Cooler (TEC) is PWM controlled
- TEC and air flow fans are on/off controlled
- Water pump and solenoids are on/off controlled
- Recovery pump is two-way reversible
- Sensors are I2C interfaced

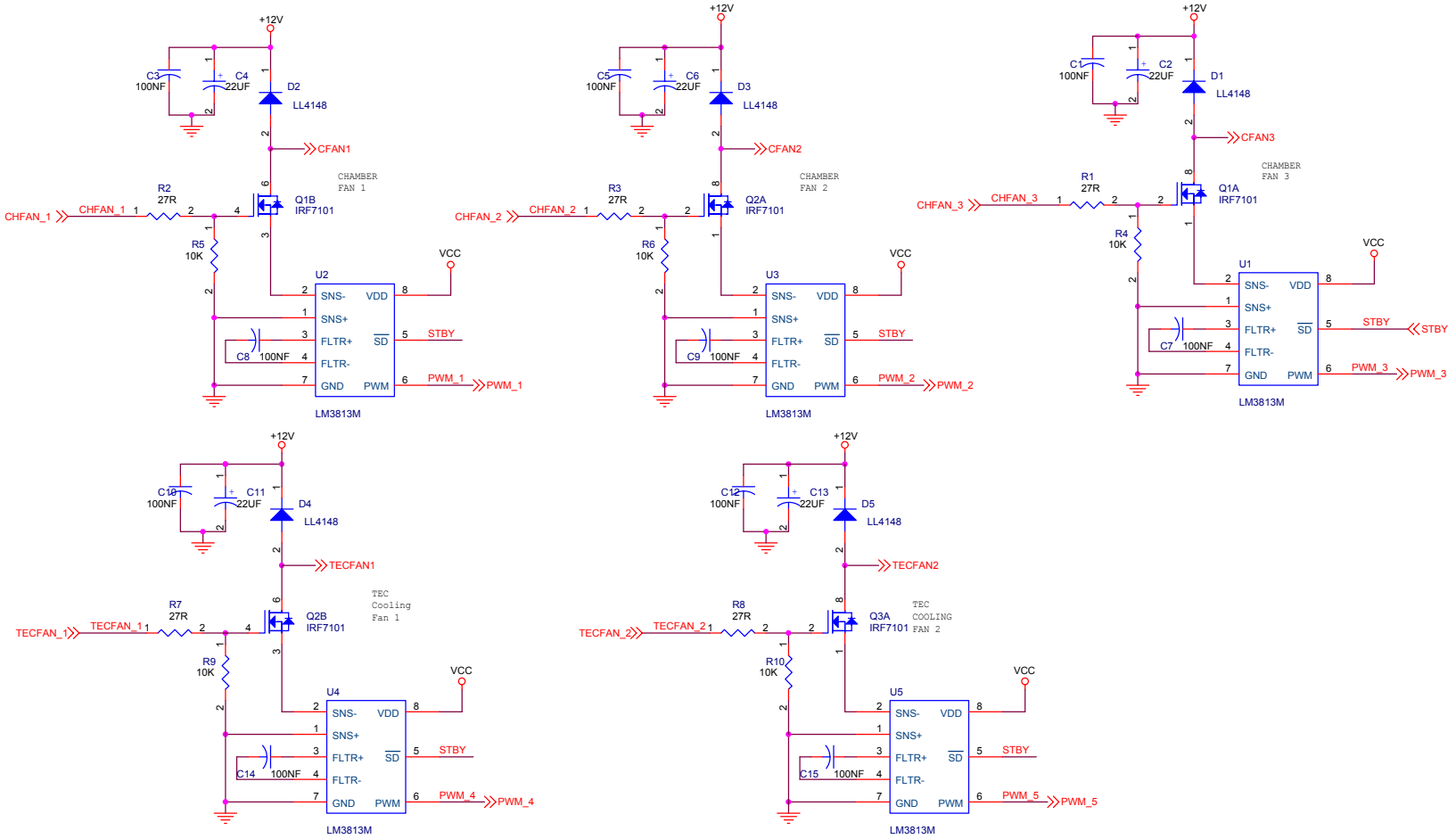
Main Interconnect board



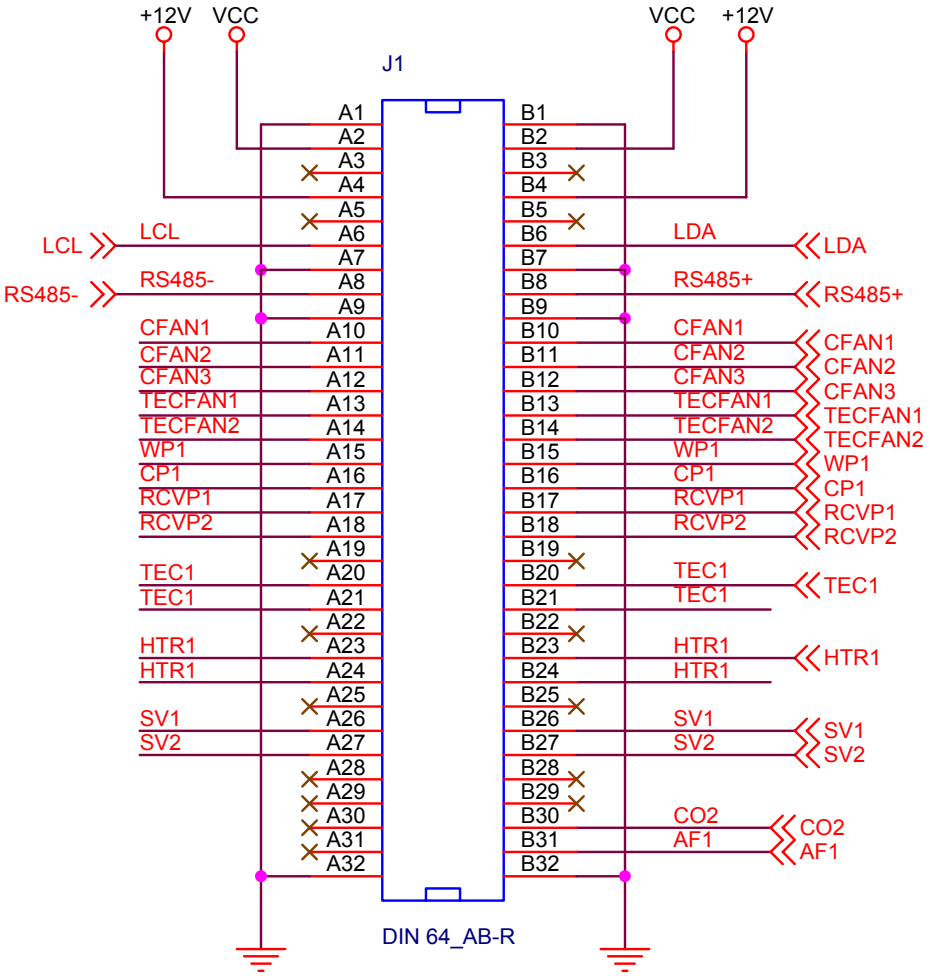
Microcontroller PGC



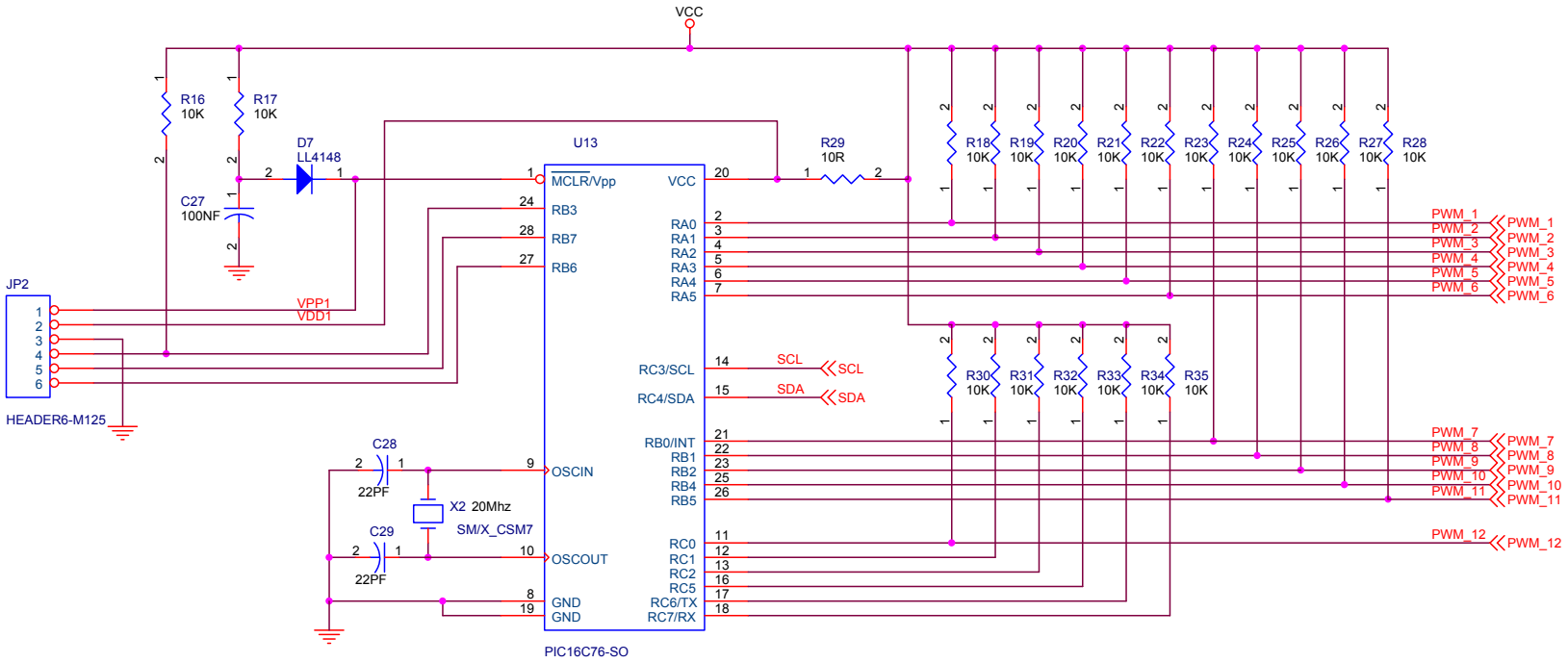
Fan Control & Monitoring



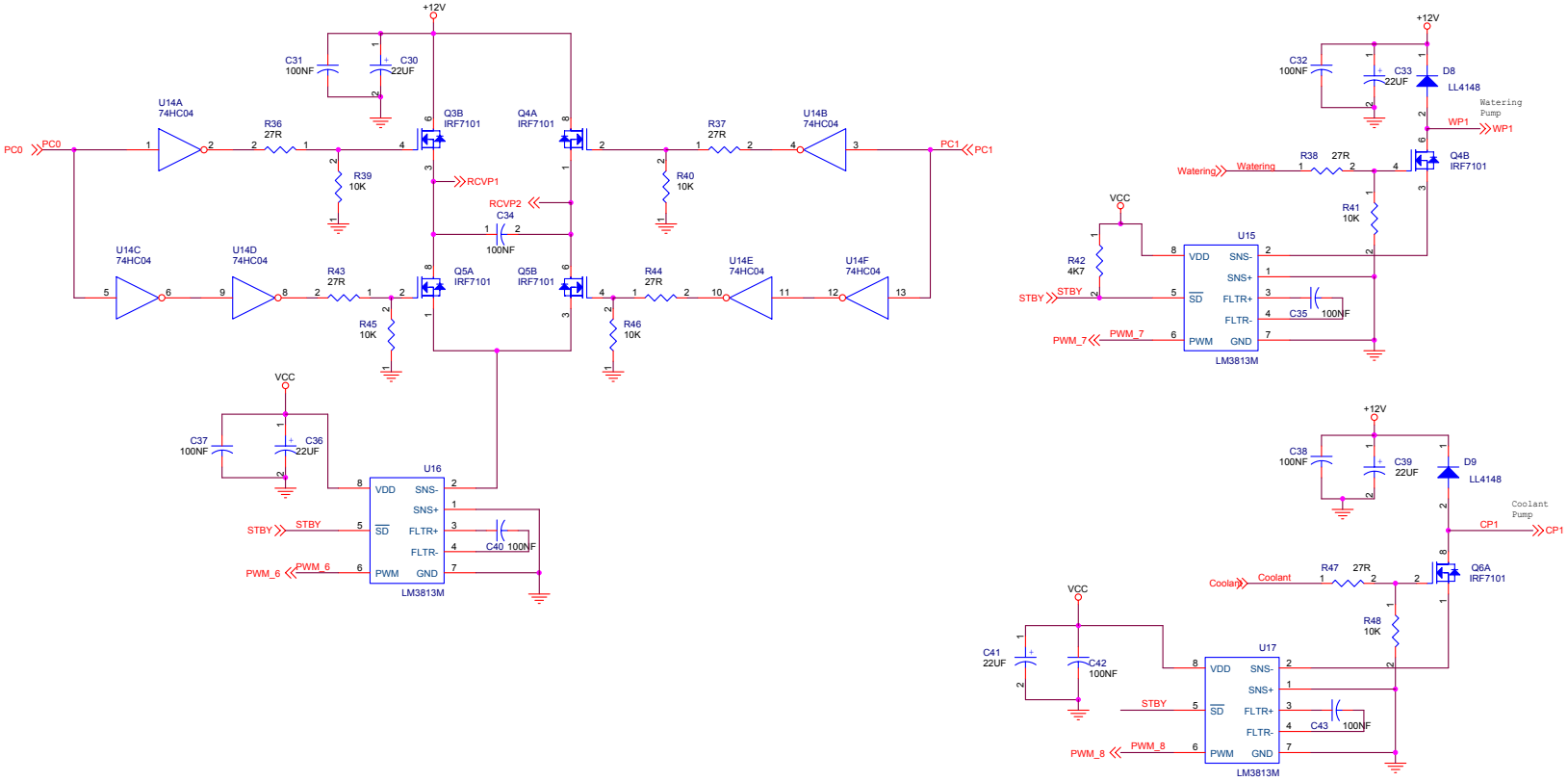
Interconnect



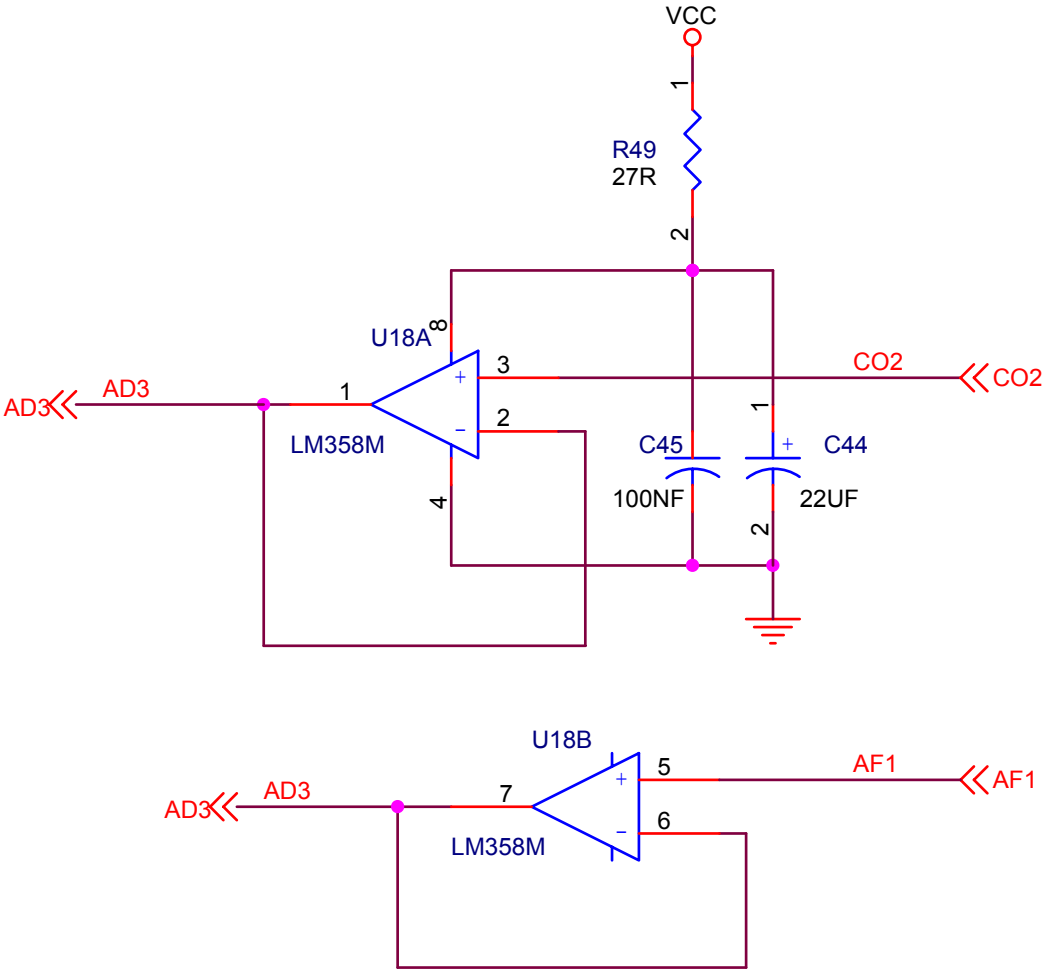
Monitoring Microcontroller



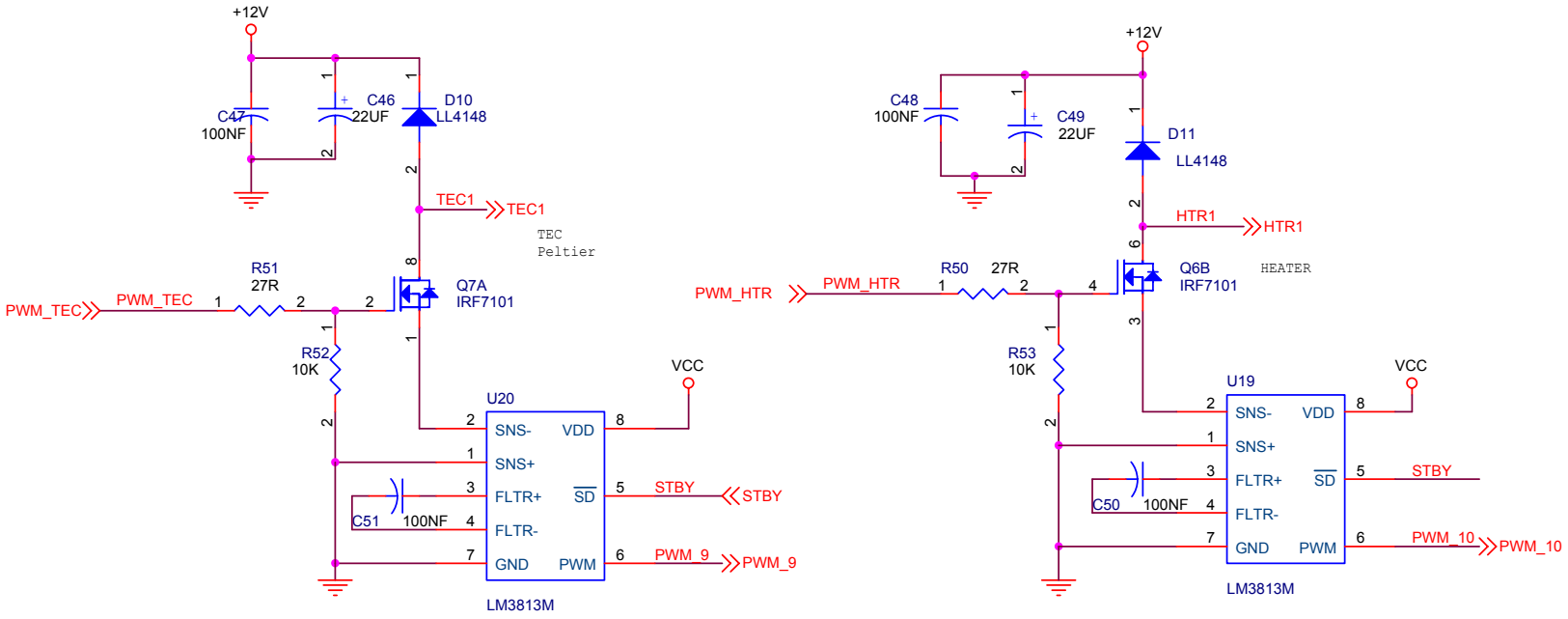
Valve Control & Monitoring



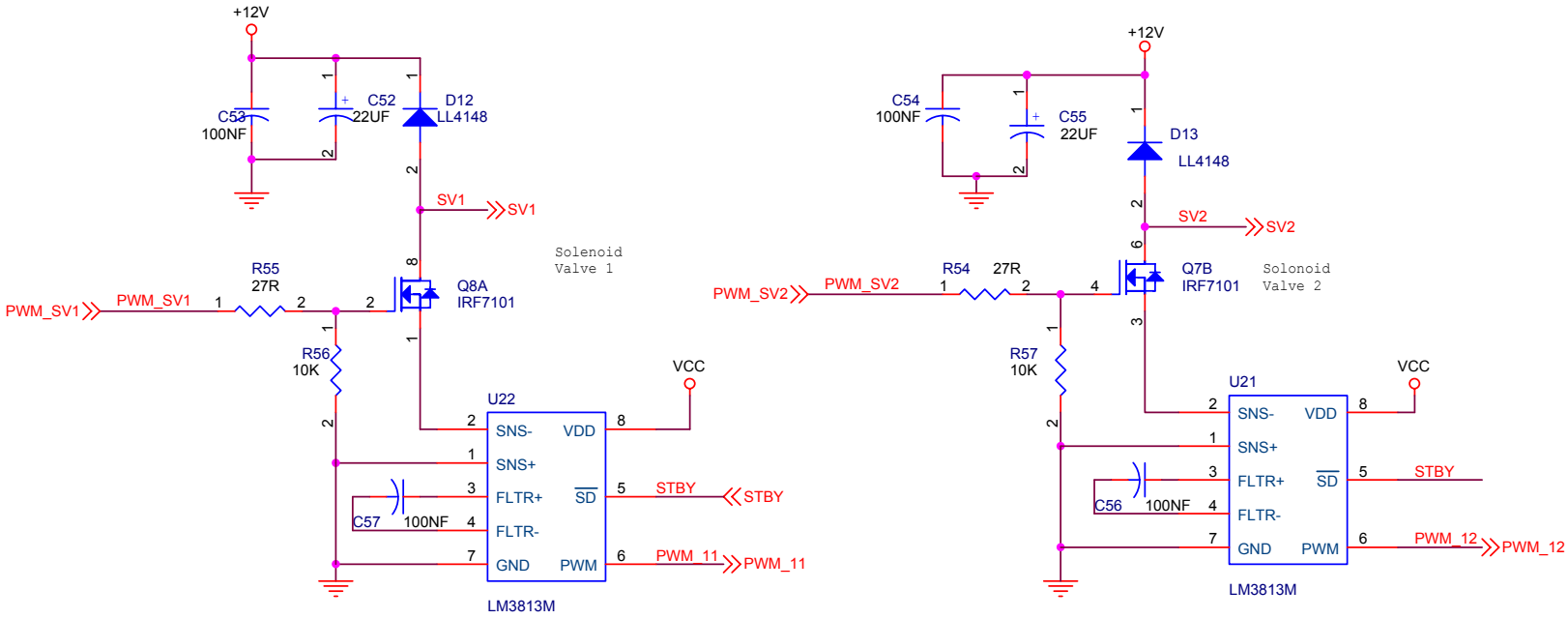
CO2 Sensor Interface



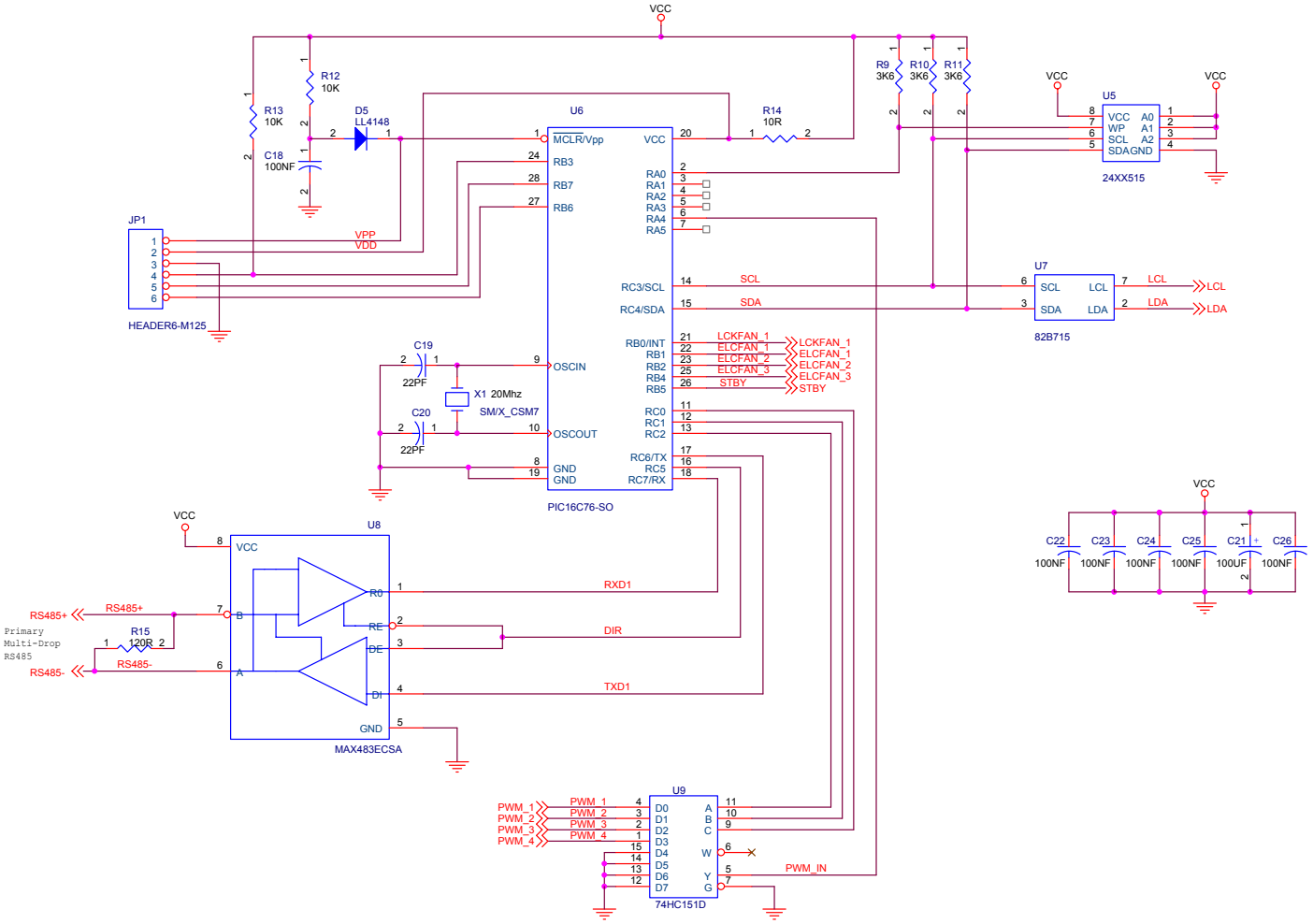
TEC Control & Monitoring



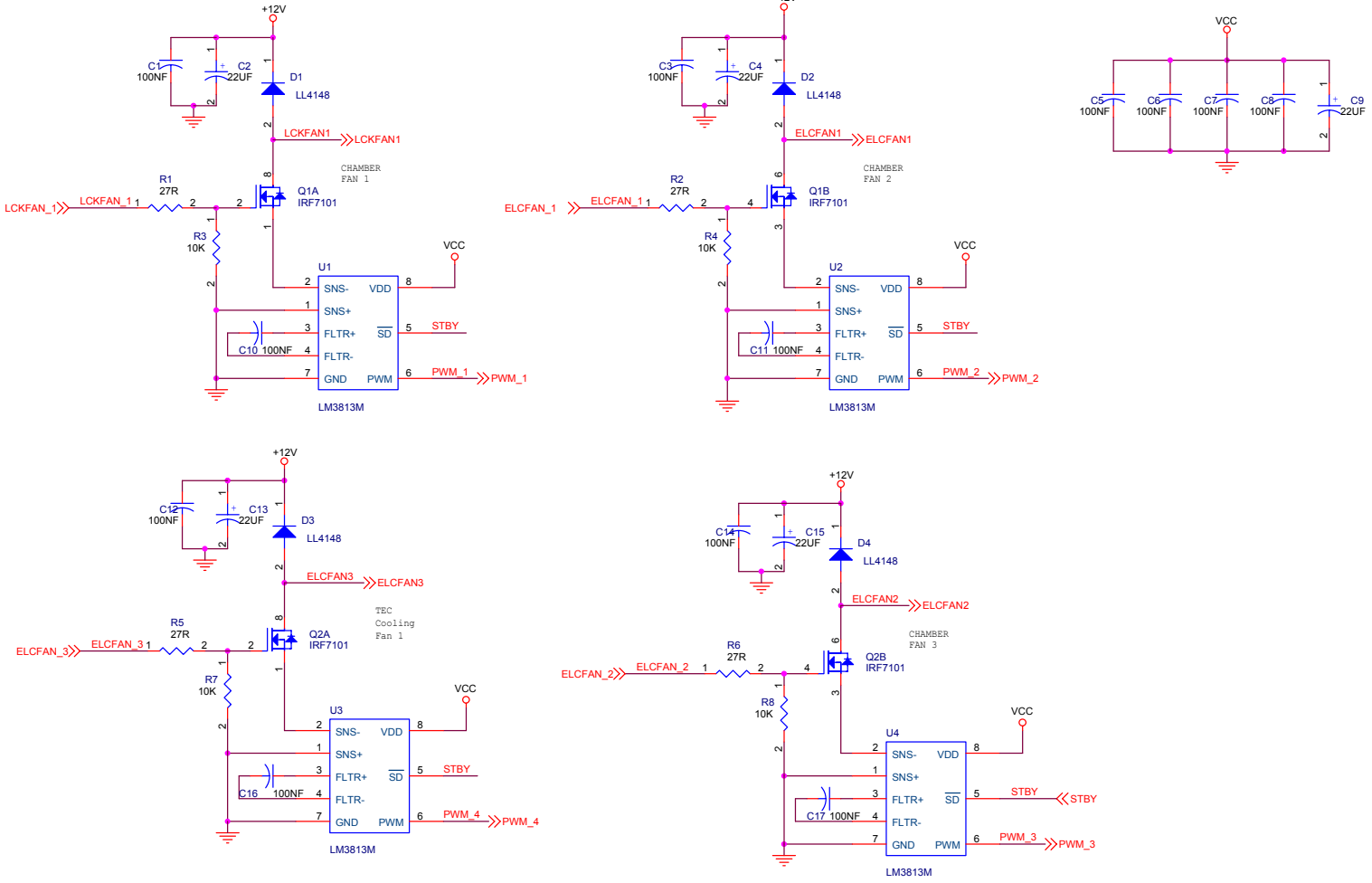
Solenoid Valve Control & Monitoring



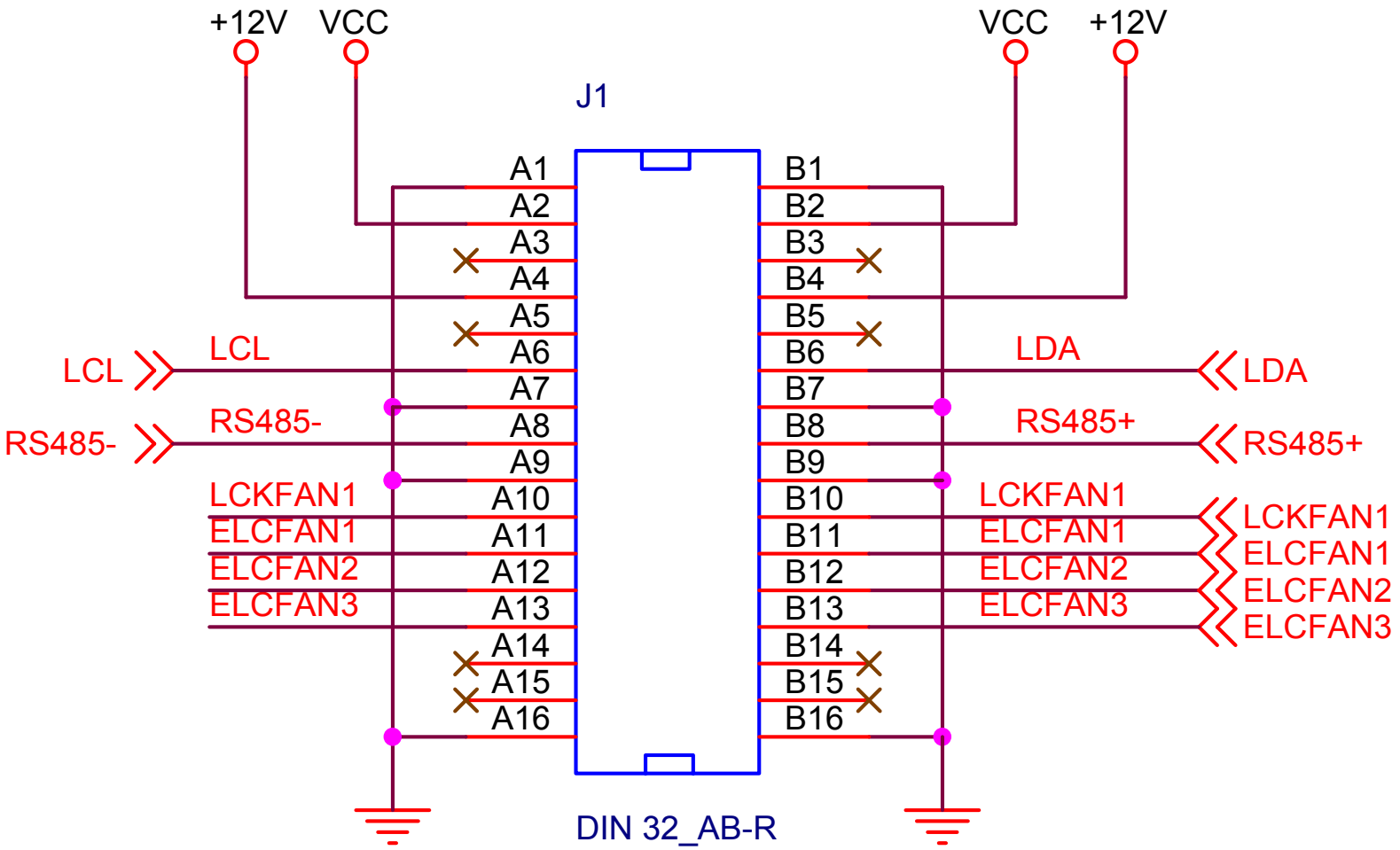
Locker Microcontroller



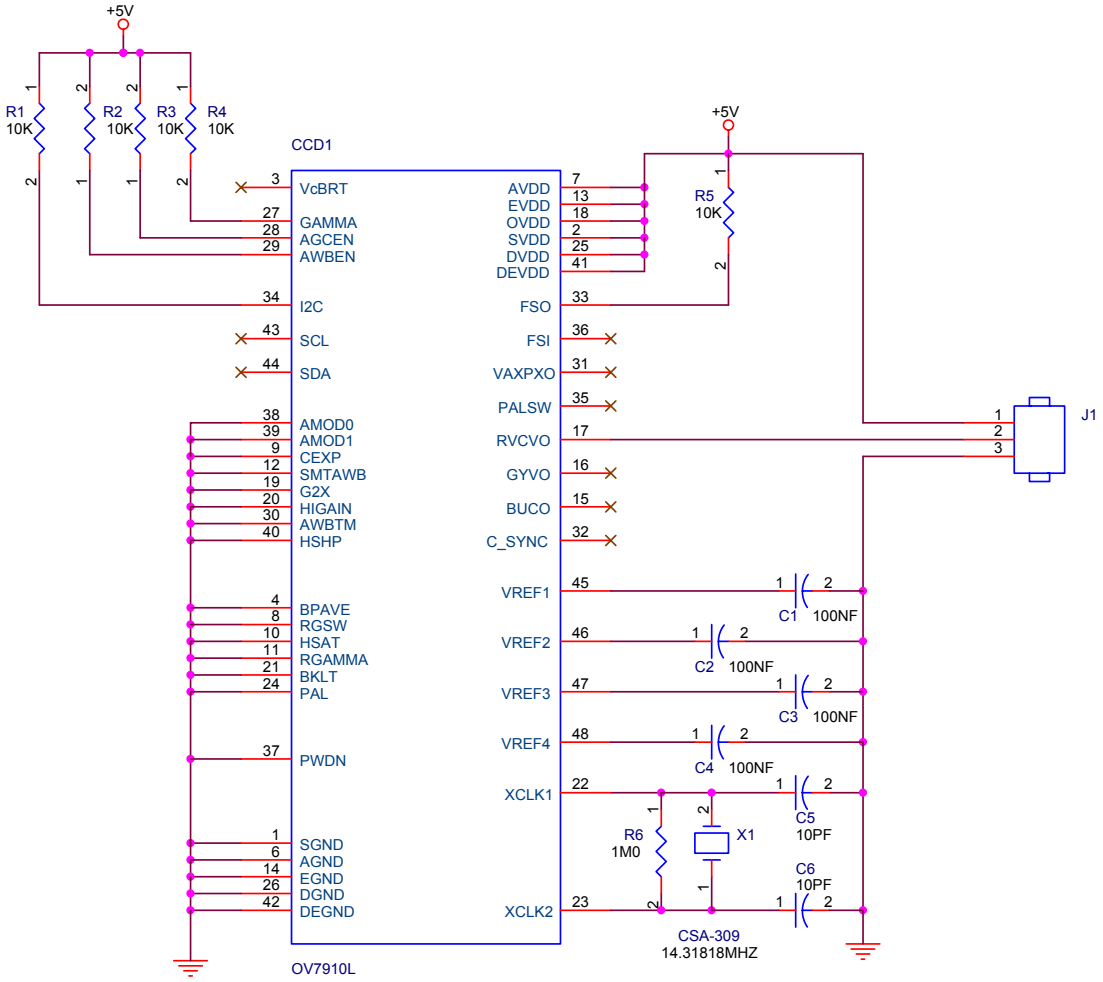
Locker Fan Control Circuit



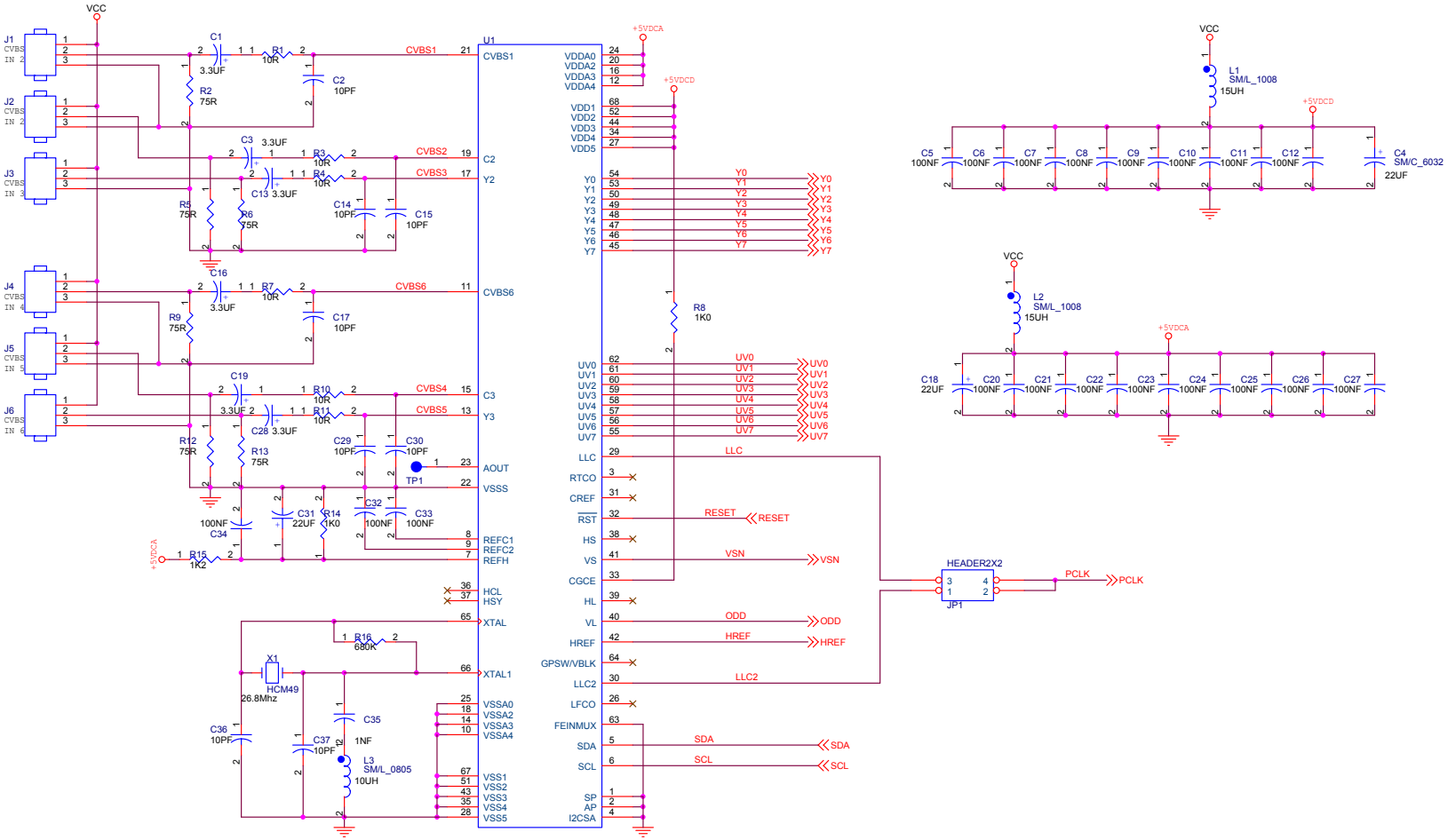
Locker Control Interconnect



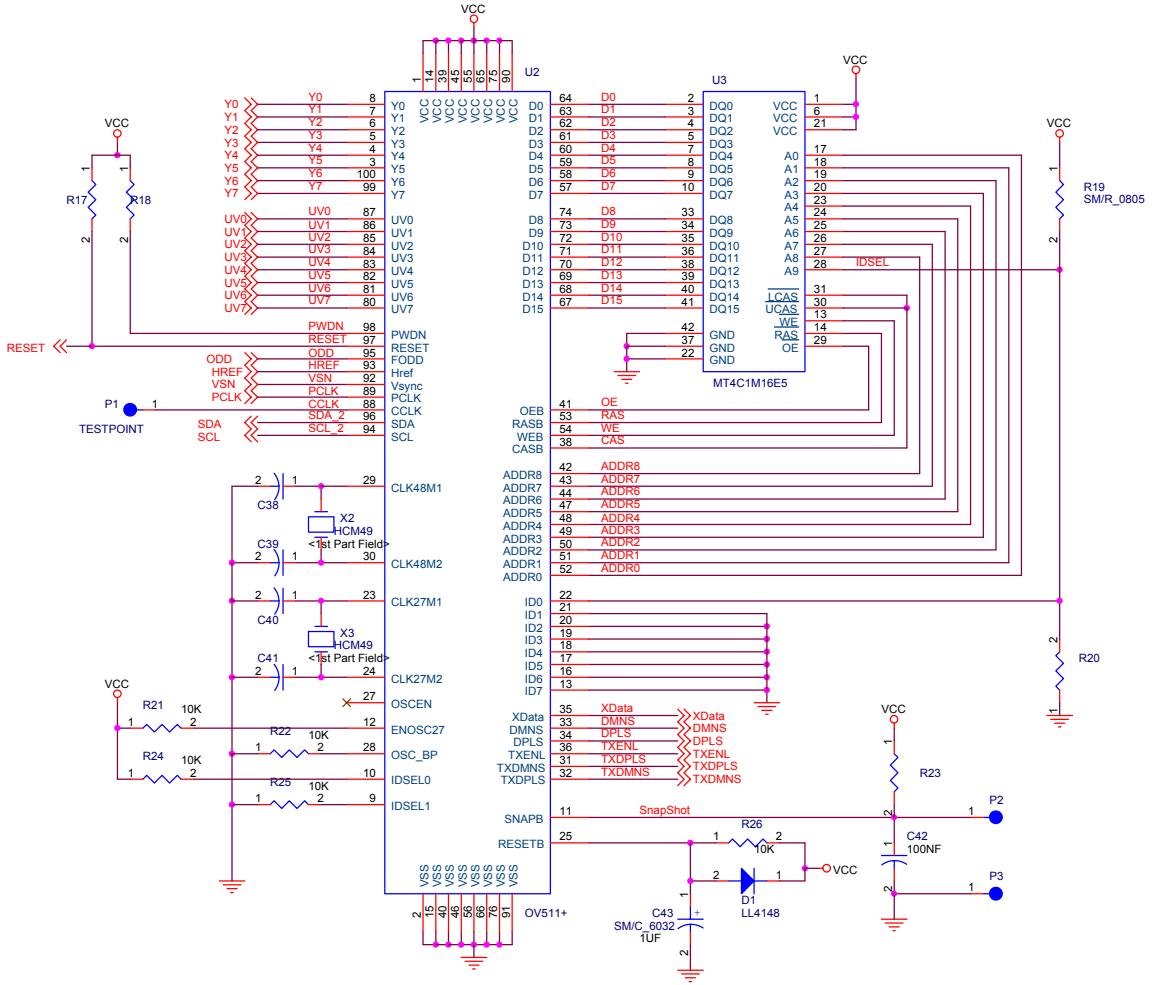
Locker Camera (1 of 6)



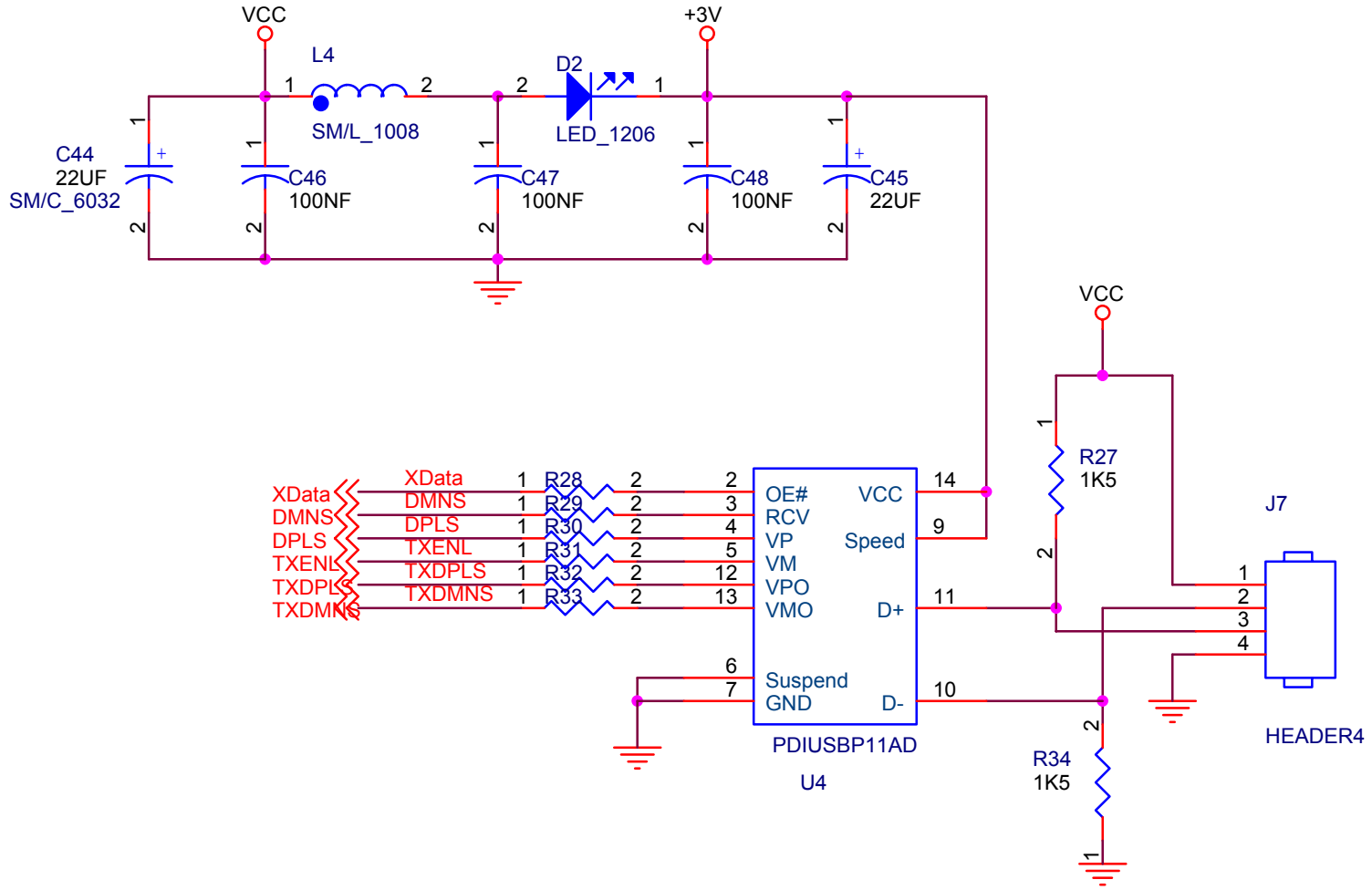
Locker Camera Interface



Locker Camera Interface



Locker Camera Interface



LED Light Module

The LED subsystem is composed of the following components and capabilities:

LED Board

- **RED 660nm LED's**
- **BLUE 470nm LED's**
- **WHITE LED's**

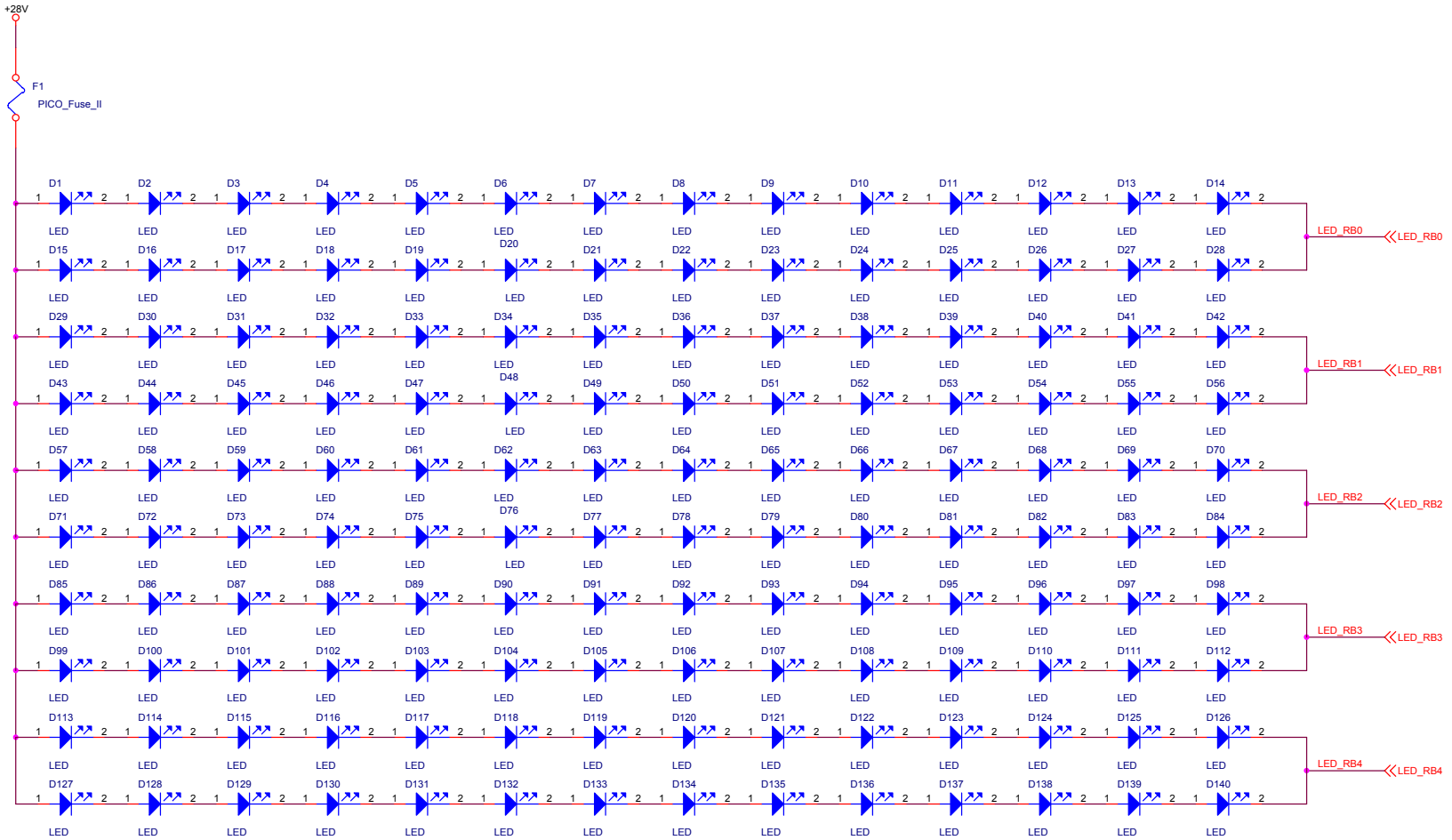
Separate outer housing for LED and Control Boards

- **Provide heat sinking and EMI shielding**

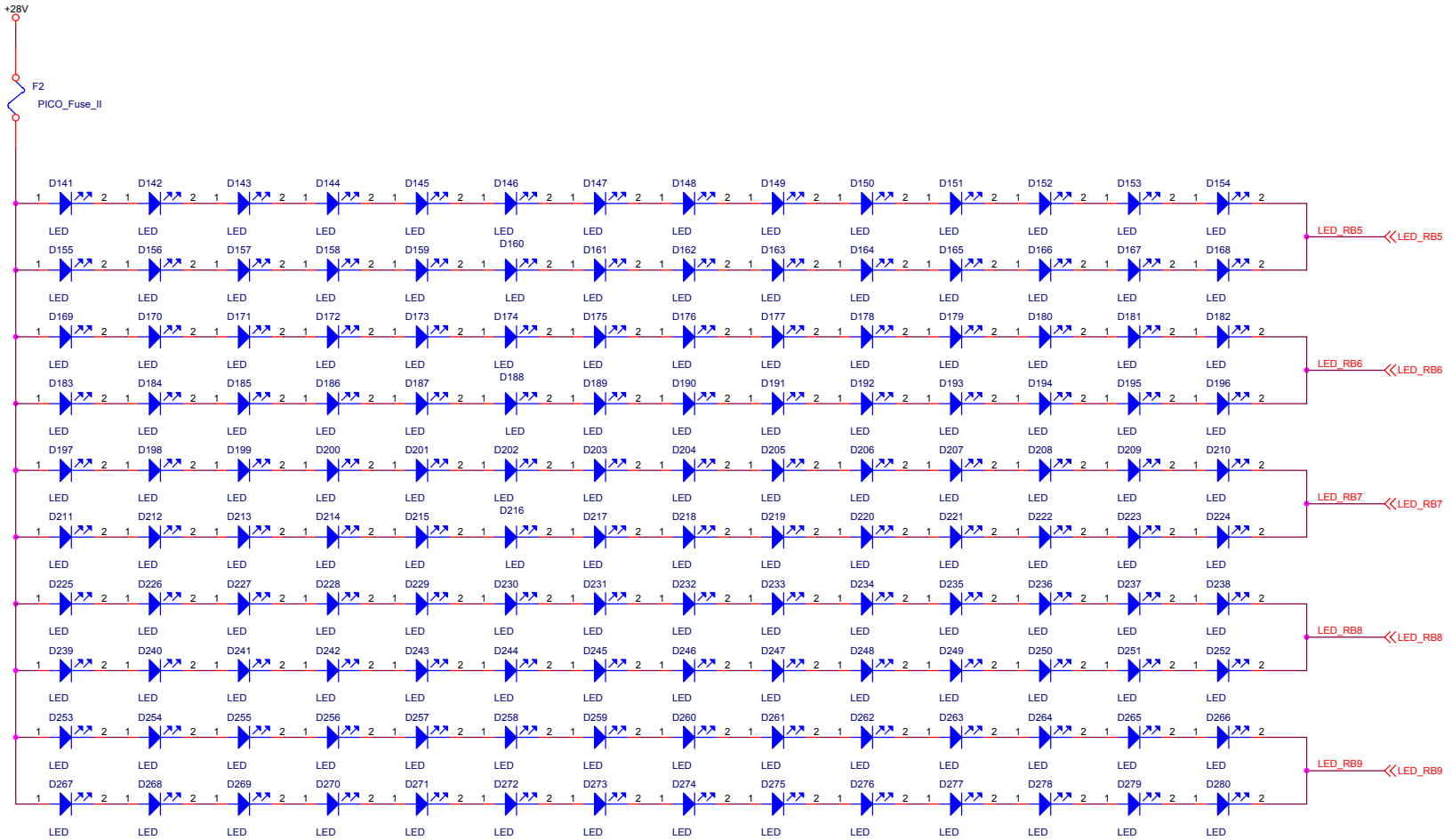
Right/Left Lighting Board

- 4 banks of LEDs that are PWM controlled when images are not being taken
- 4 cameras per board that are multiplexed to the USB bus
- Light sensors to monitor chamber light levels
- Interrupt switch to turn LEDs off when chamber is opened

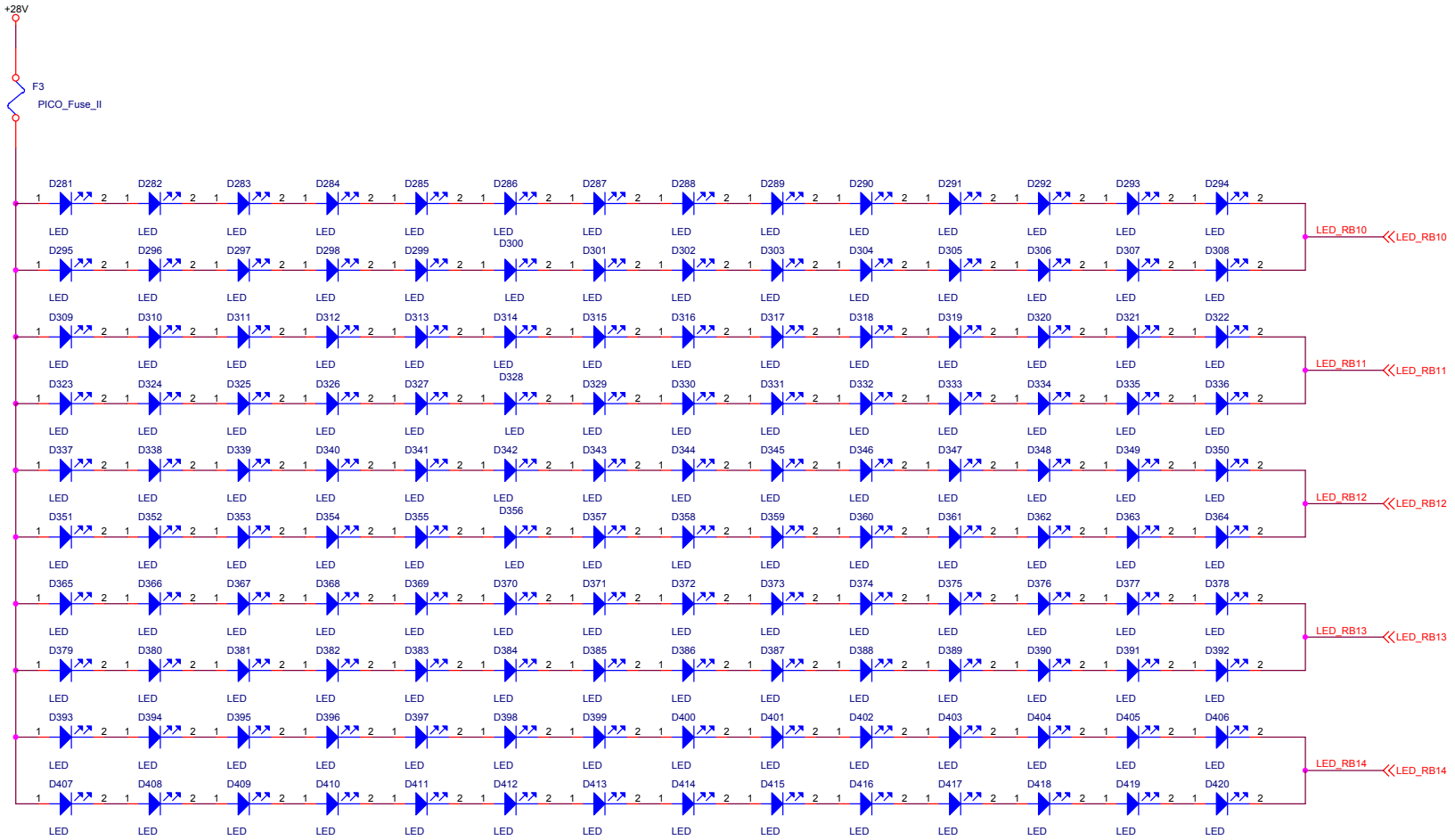
Growth Chamber RED LED's



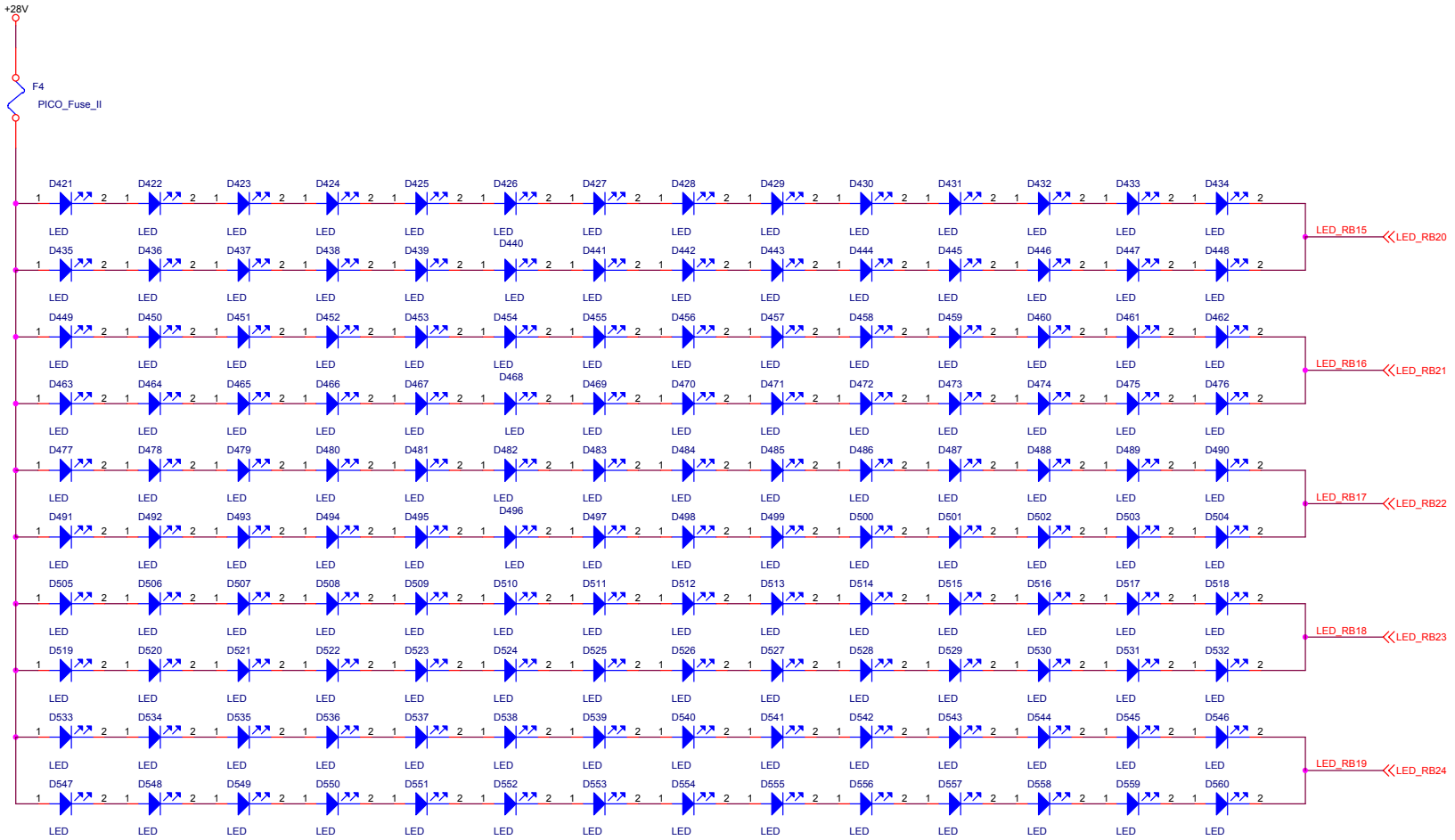
Growth Chamber RED LED's



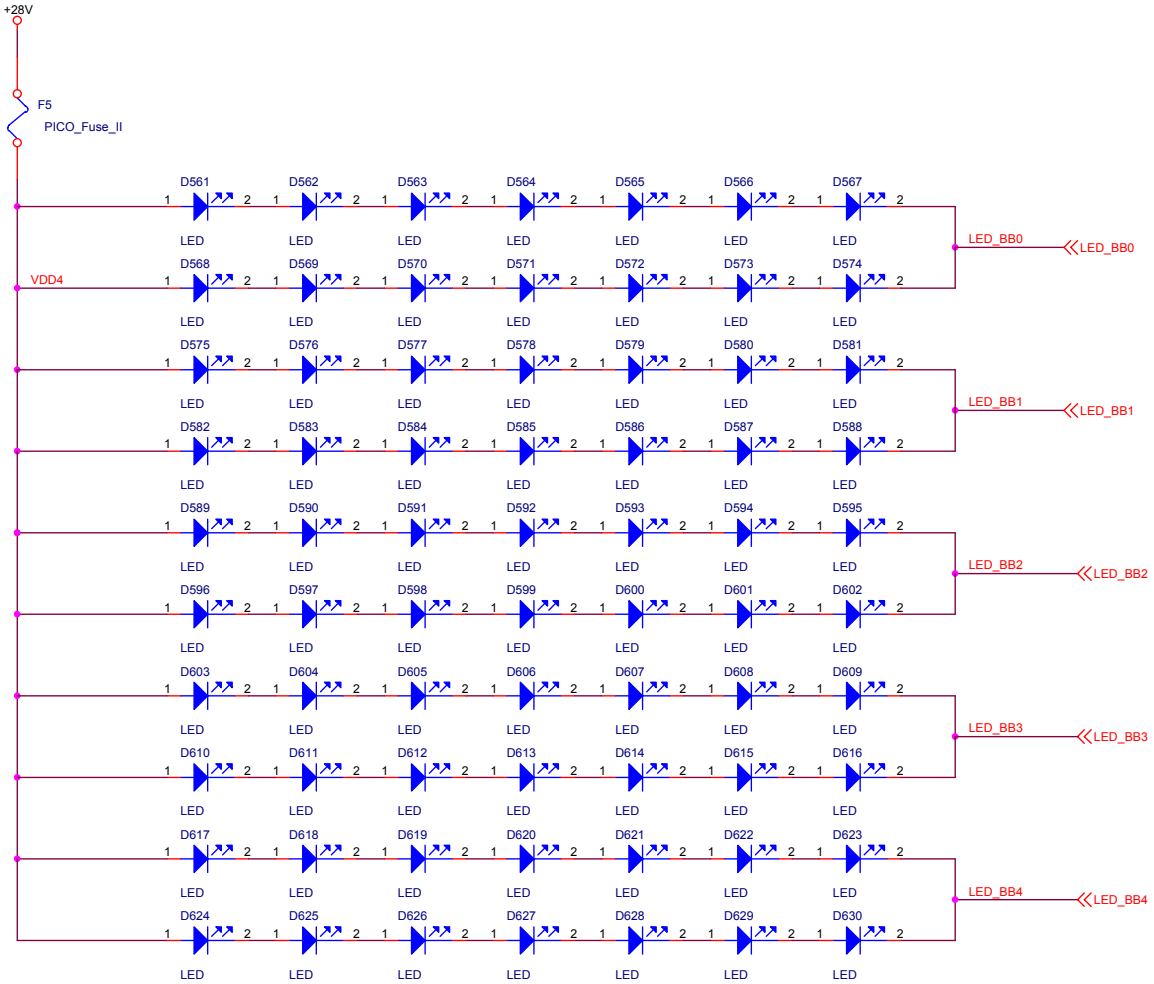
Growth Chamber RED LED's



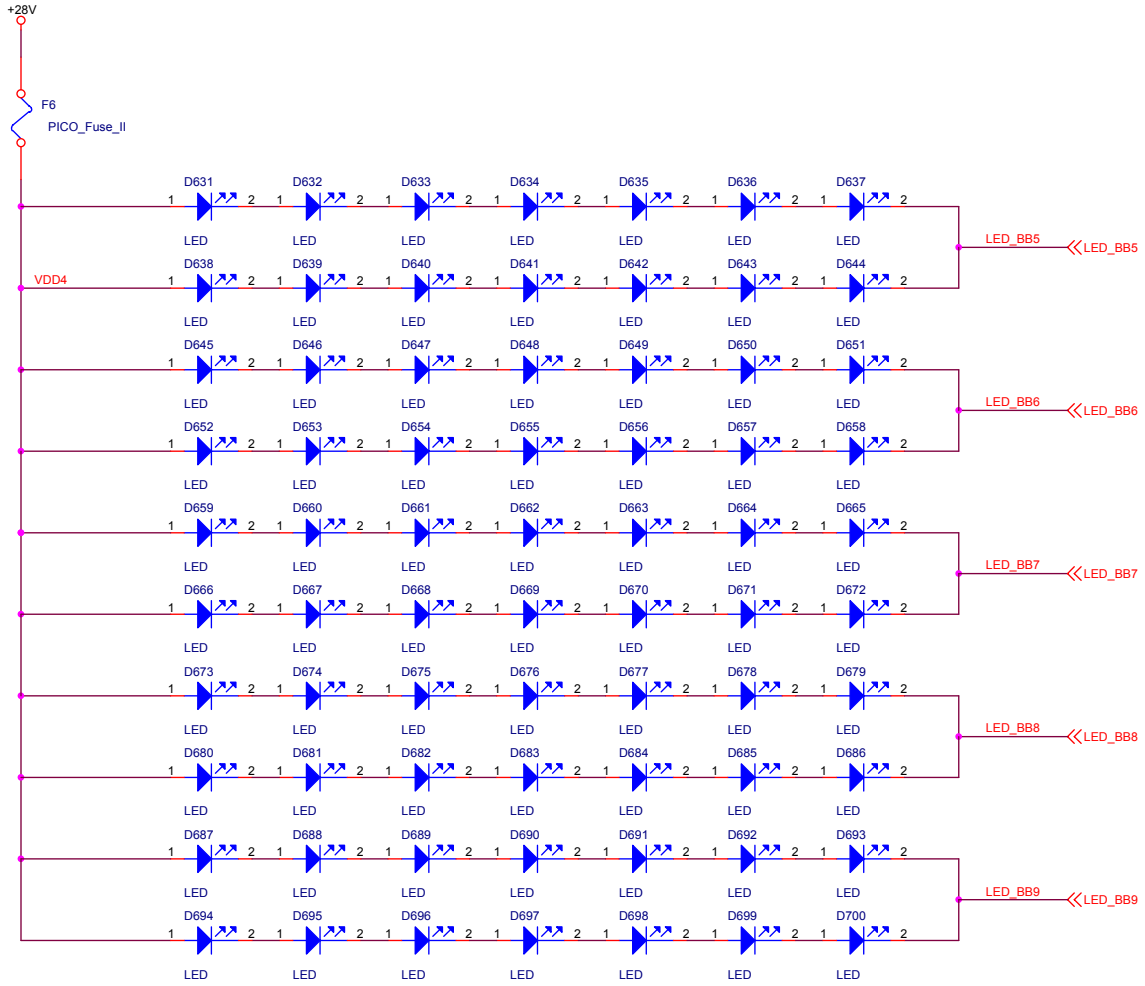
Growth Chamber RED LED's



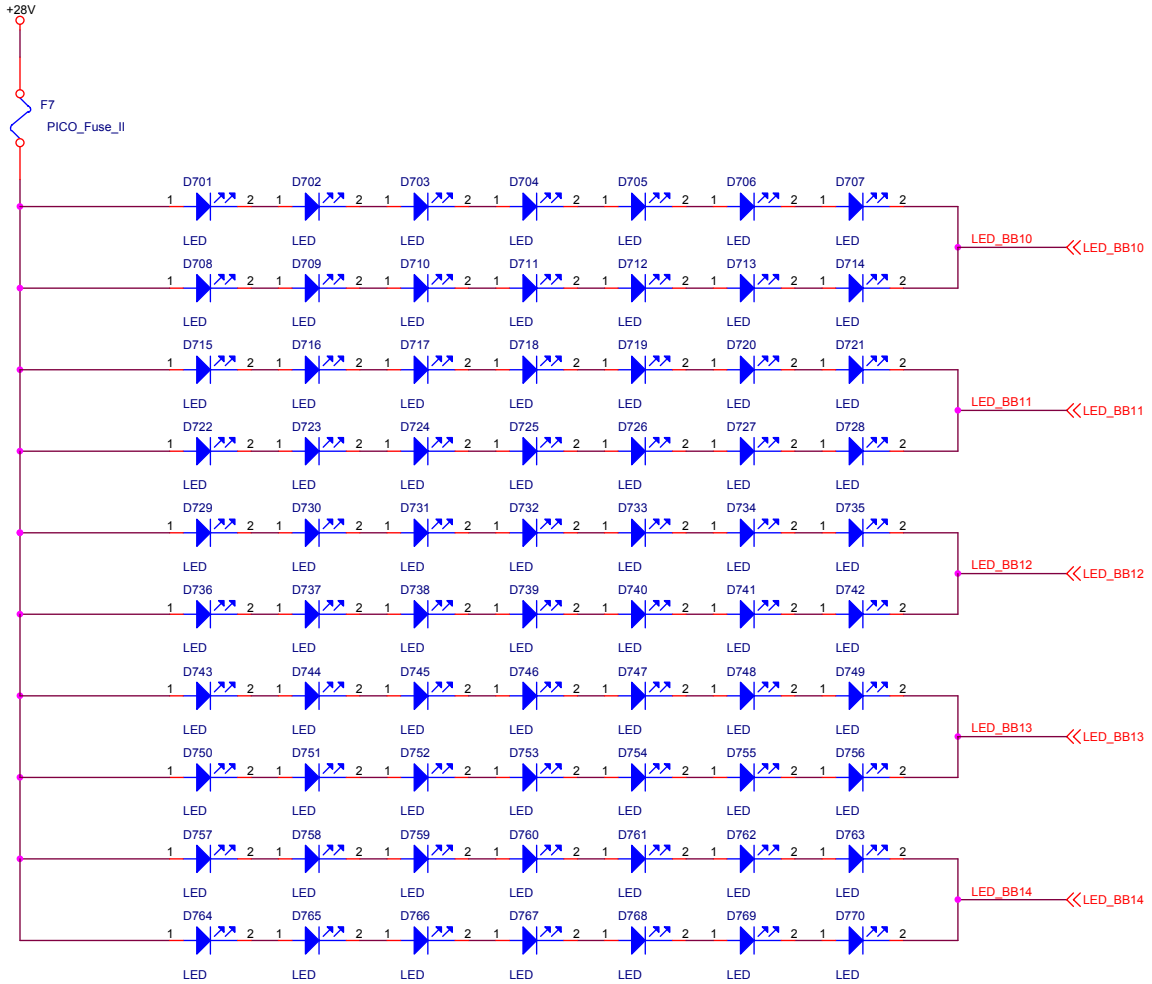
Growth Chamber Blue LED's



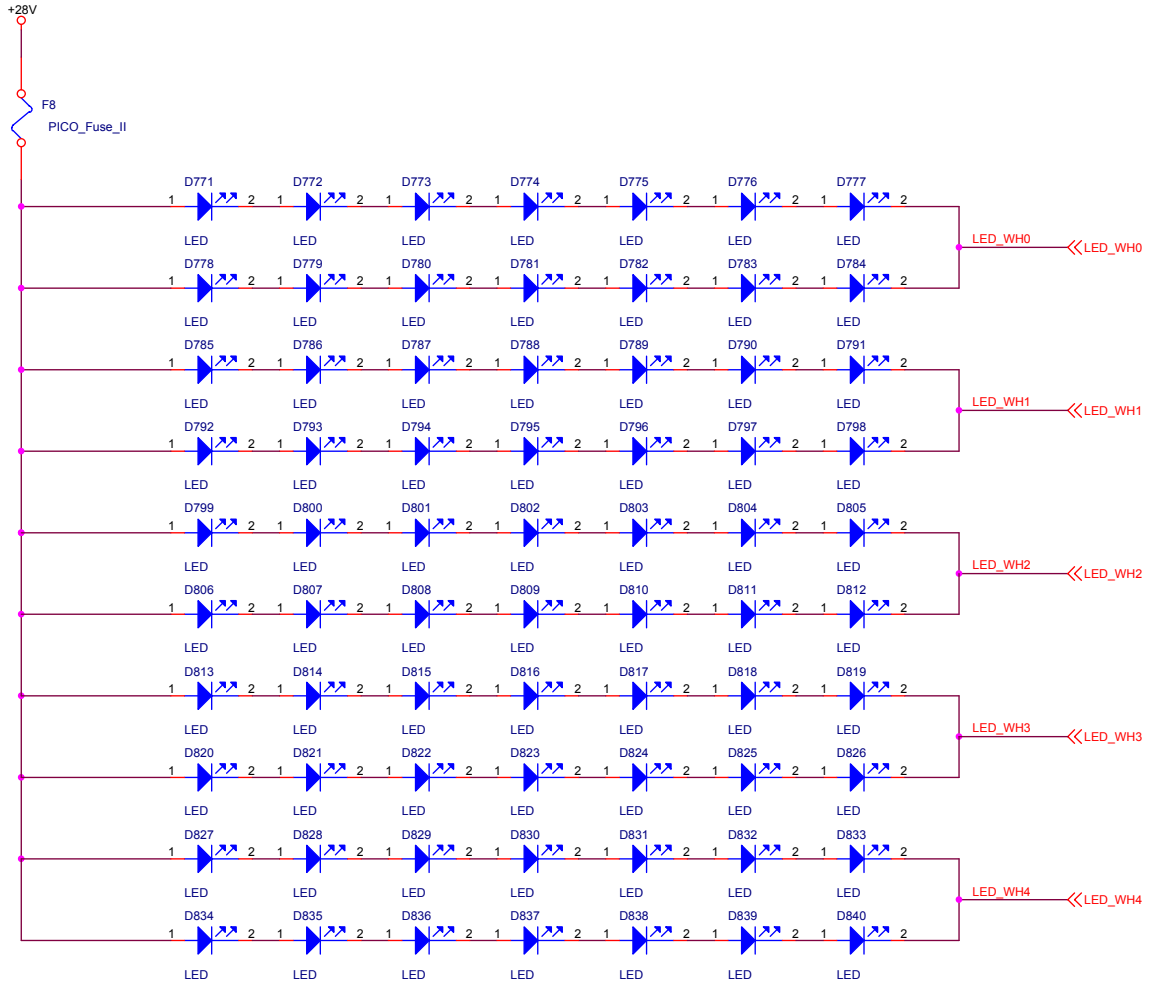
Growth Chamber Blue LED's



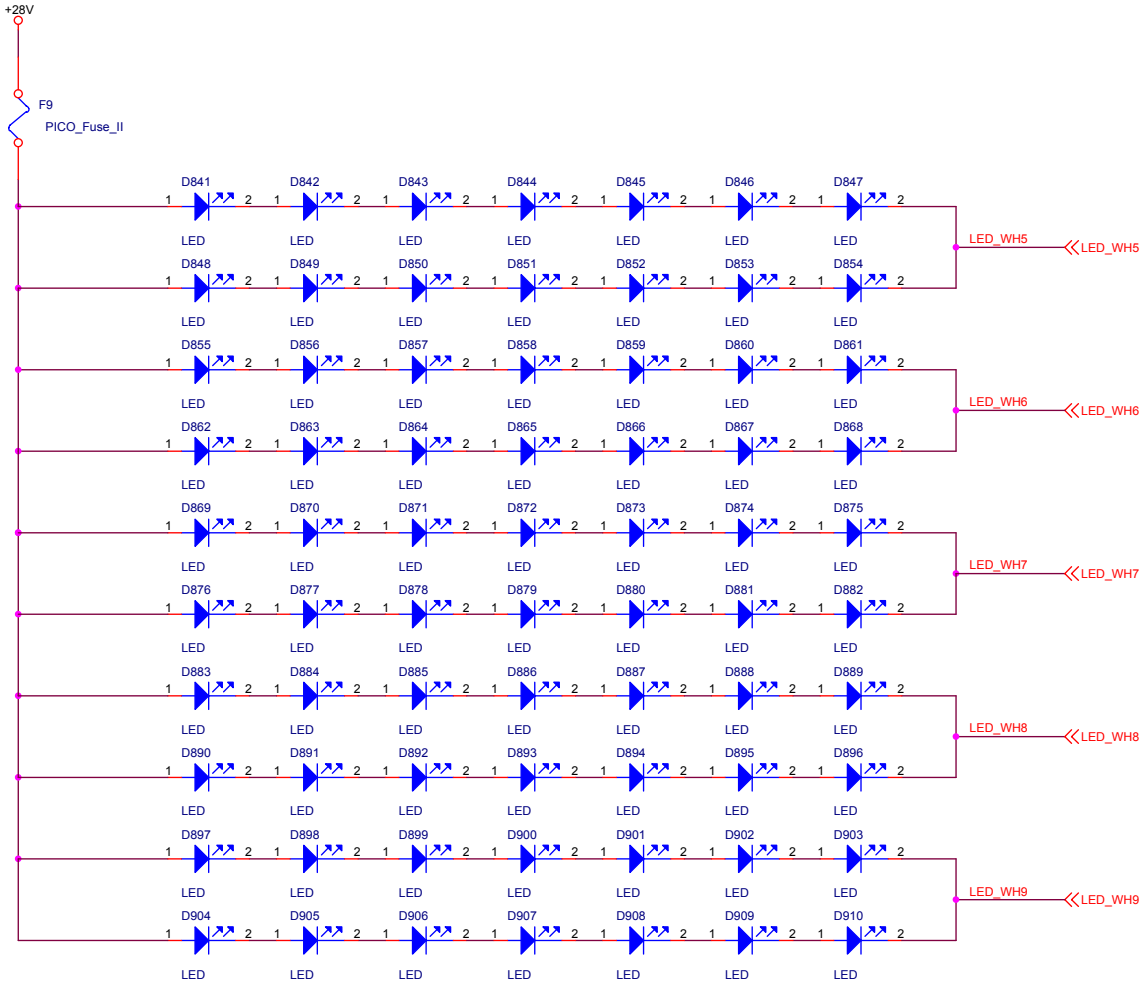
Growth Chamber Blue LED's



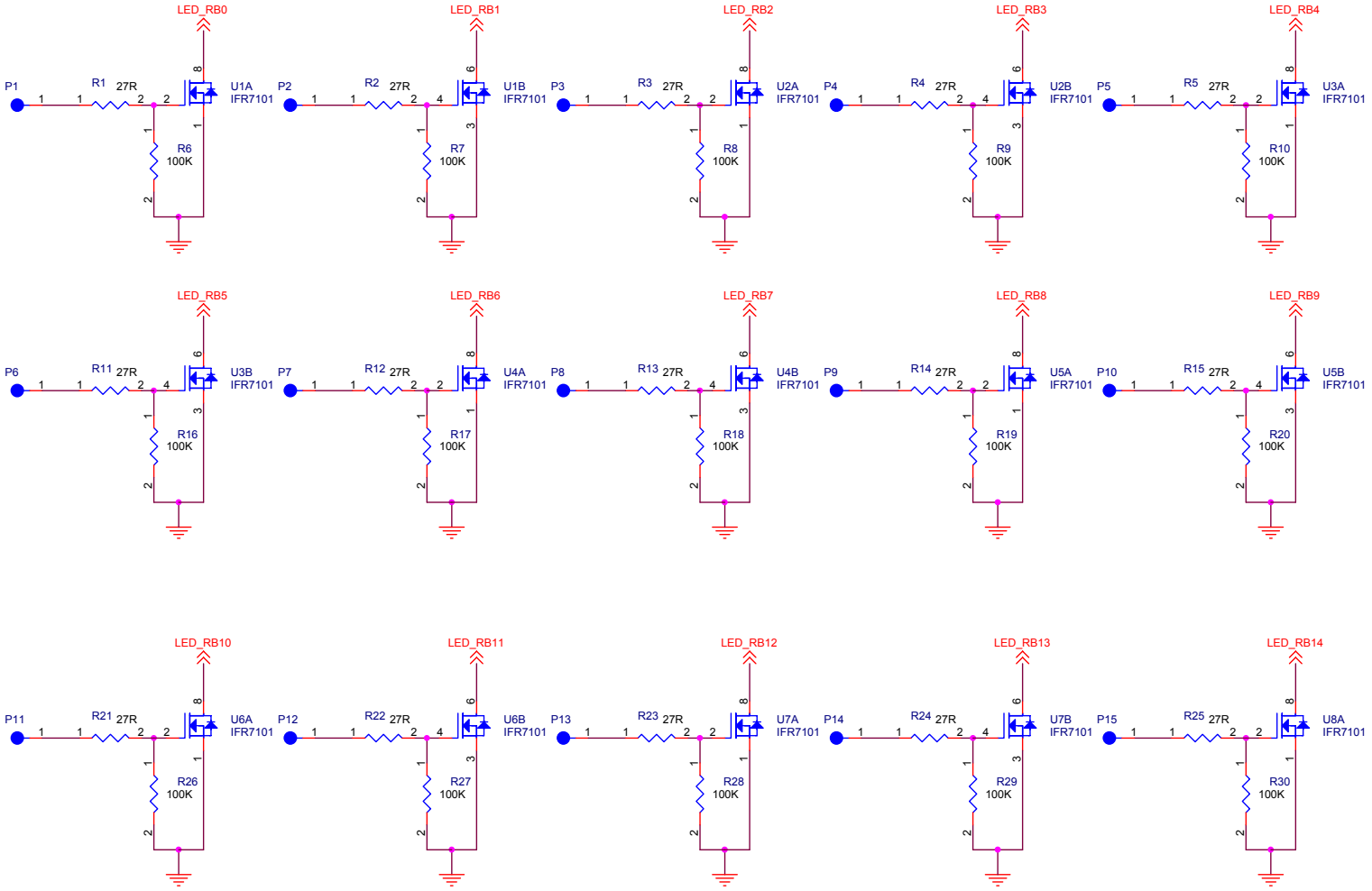
Growth Chamber White LED's



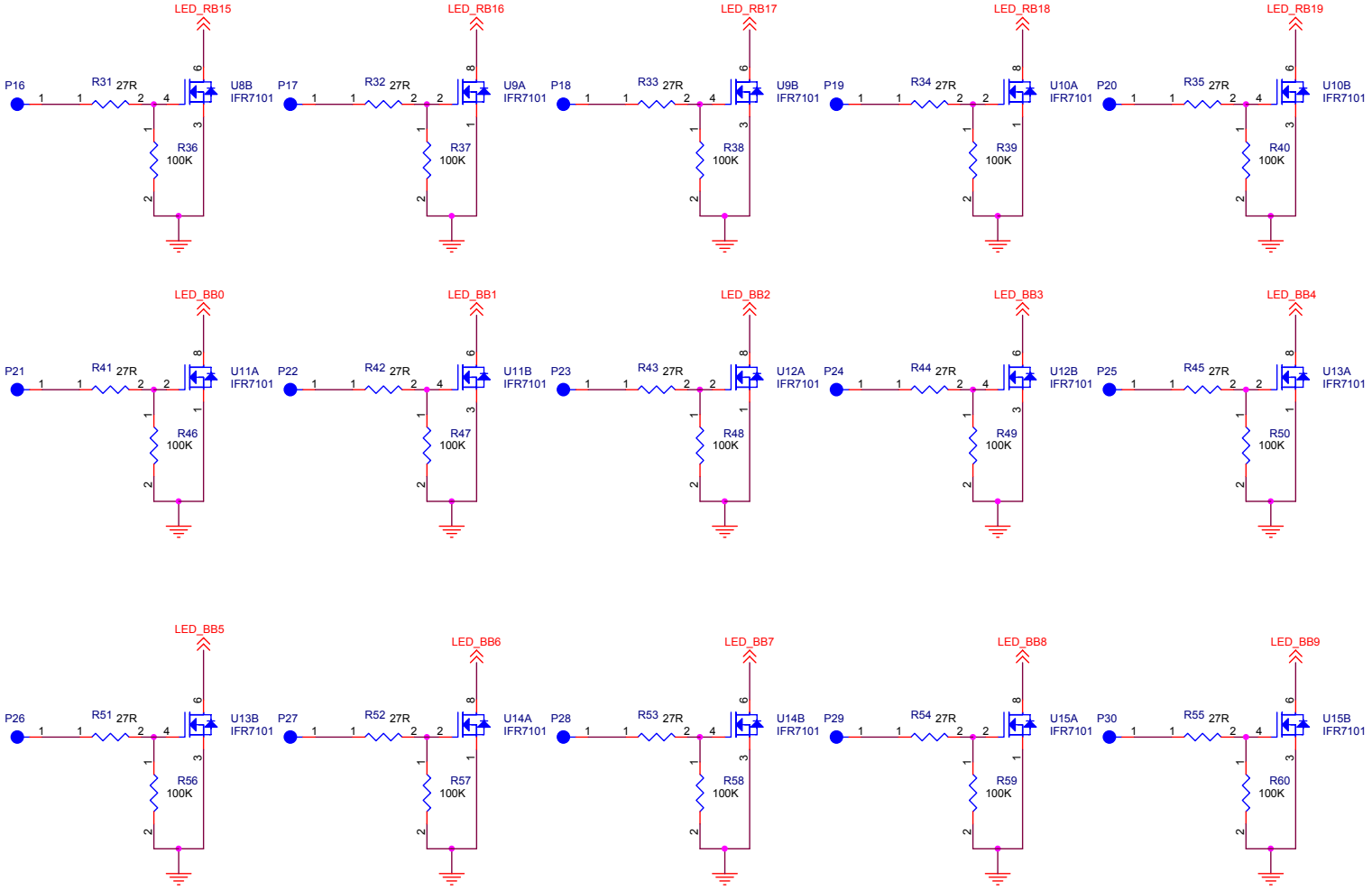
Growth Chamber White LED's



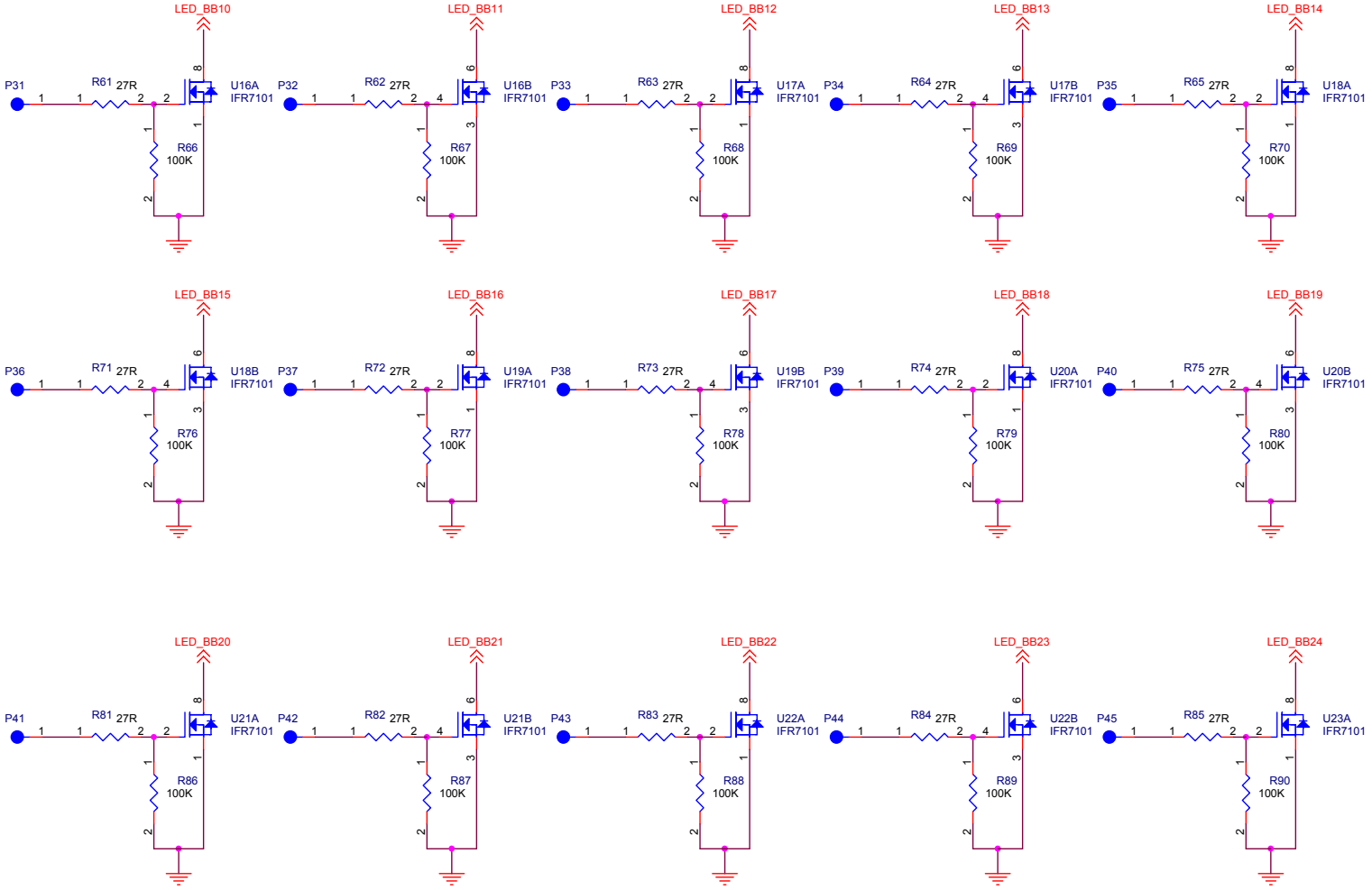
Growth Chamber LED Driver's



Growth Chamber LED Driver's



Growth Chamber LED Drivers



Growth & Imaging LED Driver

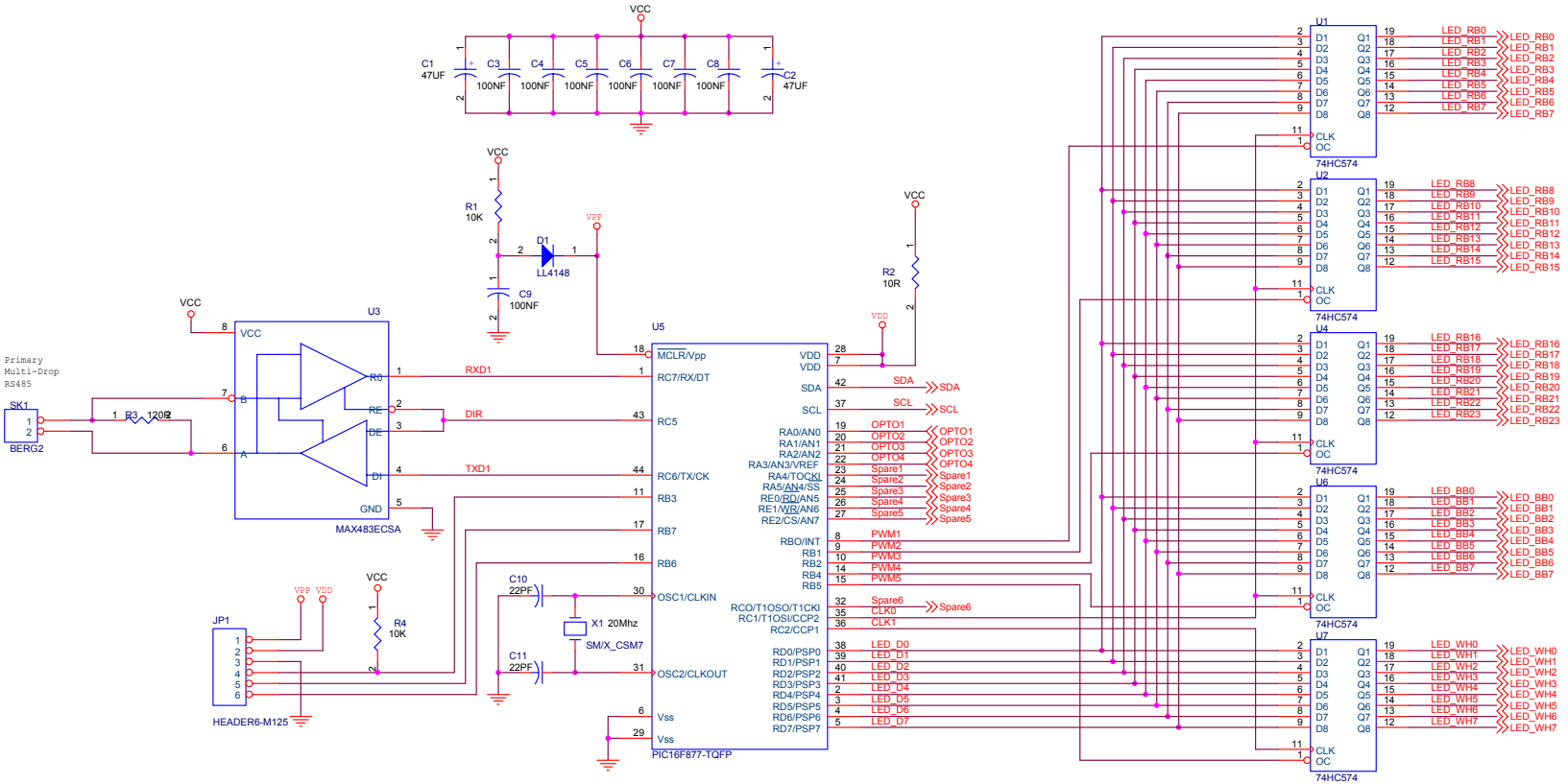
PWM Driver and Controller Board

- PIC16F877 Microcontroller
- Pulse width modulation Multiplexed Drivers for setting up different Light Levels.
- RED, WHITE and BLUE LEDS individually switched for Growth and Imaging as dictated by the Science
- White light for Imaging system can be controlled independently for time lapse.

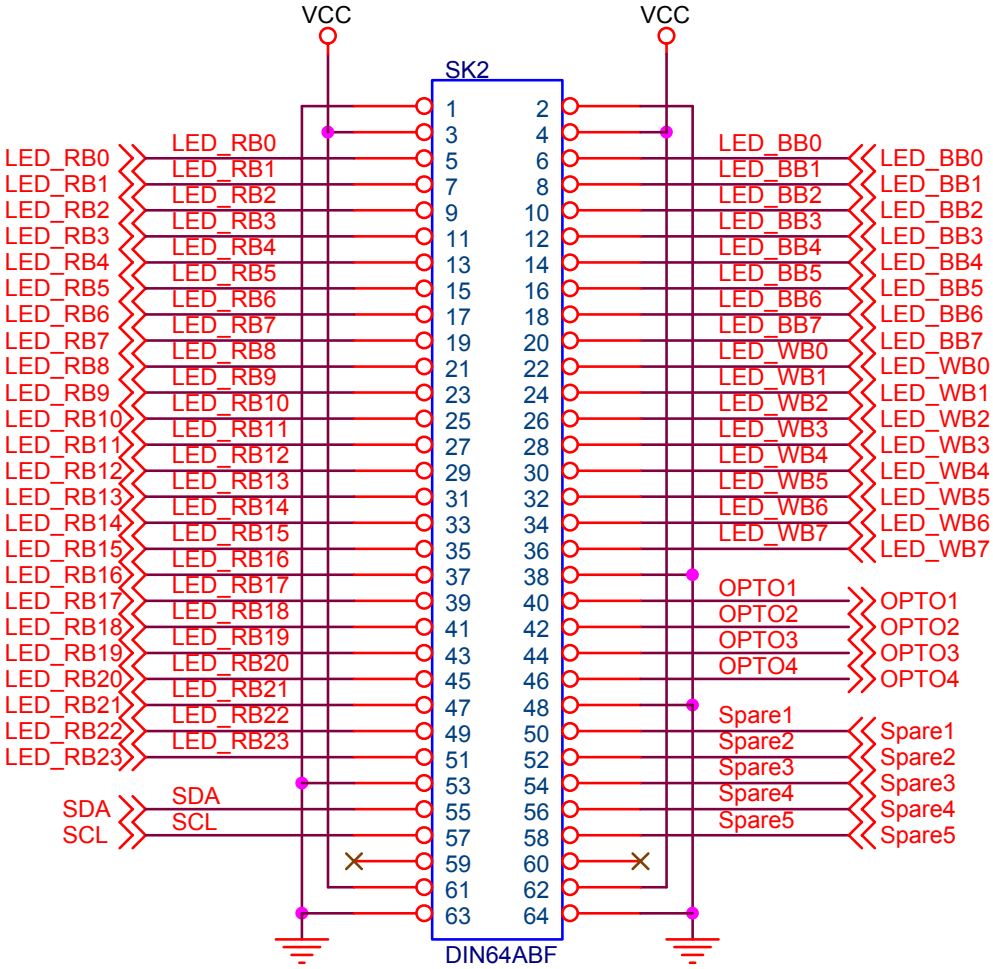
GFP Imaging Board

- Multiplexes four cameras onto USB
- I2C camera control
- LEDs PWM controlled

LED PWM Controller



LED PWM Controller Interconnect



Power Conditioning Module

The PCM subsystem is composed of the following components and capabilities:

- DC-DC Converters
  - Provide power to various of electronic components
  - Enable to PGF-SP to operate within NSTS 21000-IDD-MDK, REV B specifications
  - 24 VDC converter
  - 12 VDC converter
  - 5 VDC converter

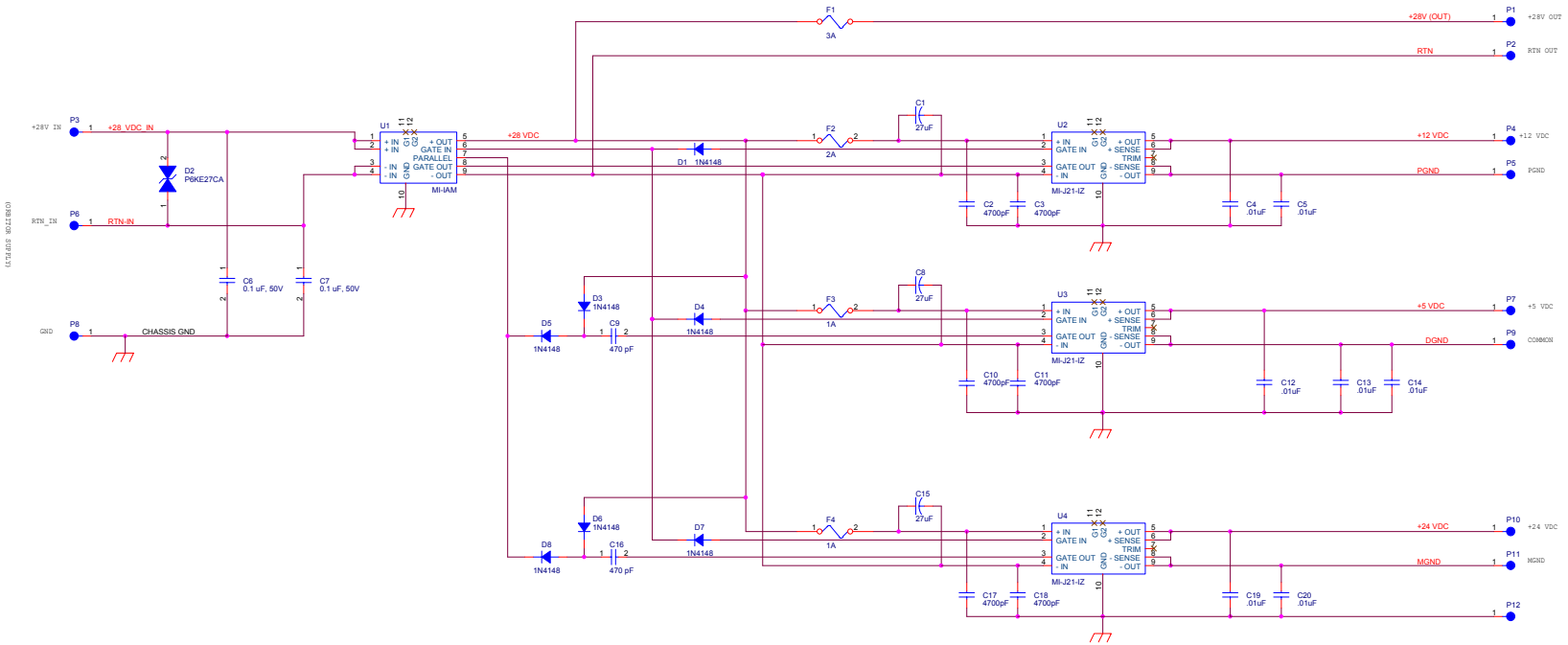
Power Control Board

- Monitors inlet/outlet temperature and relative humidity
- Limits:
  - Inlet 31 degrees C
  - Outlet 40 degrees C
  - Humidity delta between inlet and outlet
- Monitors current on fans cooling locker and electronics
- Off nominal conditions will cause an alert to be sent to CDMS to send system into stand-by mode

Power Control Board

- **Monitors inlet/outlet temperature and relative humidity**
- **Provides fan cooling of locker and electronics**

POWER CONDITIONING MODULE



Front Panel Control Board

- Serves as a back-up watchdog to CDMS
- If communication with CDMS is broken, will poll controller boards for status and provide RTC
- Illuminates front panel LEDs from commanding by CDMS or standalone

Front Panel Control Board

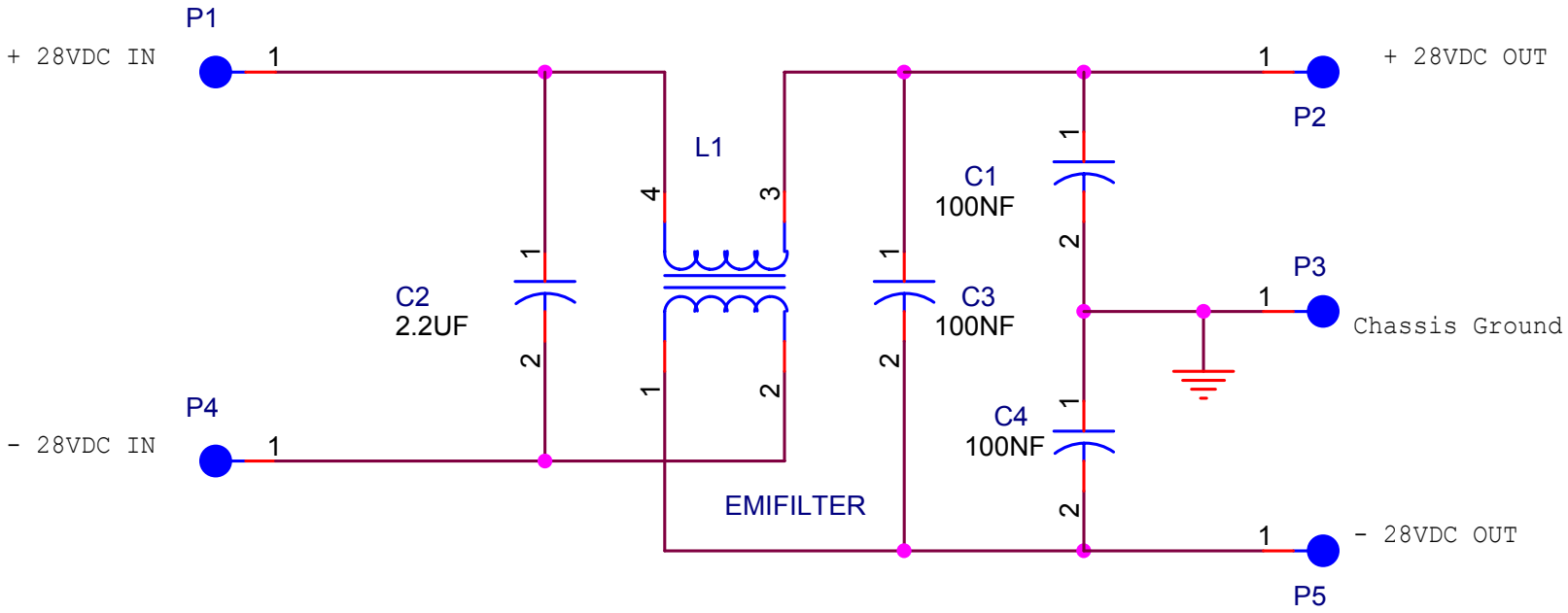
- Provides interface to outside
- USB to RS232 translation
- Serial interface
- Ethernet interface
- 6 LEDs
    - Power on
    - CDMS heartbeat
    - Status
    - Park mode
    - Stand-by
    - Experiment mode
- Polls other controller boards, provides RTC, in case of CDMS Failure

EMI – EMC - RFI

EMI suppression

- Suppress and or eliminate Electro Magnetic Interference to meet IDD requirements.
- Suppress Radio Frequency Interference to below the acceptable limits imposed by the IDD.
- Meet Requirements for Electro Magnetic Compatibility
- Ensure we have no Susceptibility issues from other pieces of equipment outside our control.

EMI – EMC FILTER BOARD



Sensor List

Name	Location/Component	Qty per module	Extended
Assembly, Tray Insert			
Temperature Sensor	Inlet	1	1
Temperature Sensor	Exhaust	1	1
Temperature Sensor	Inside Locker Rear	3	3
Current Sensor	Main Input Power 28VDC	1	1
Current Sensor	Exhaust Fan	1	1
Assembly, PGC			
Hycal, Temp. & RH Sensor	PGC	1	2
Light Intensity Sensor	PGC	1	2
Temperature Sensor	TEC Cold Plate	1	2
Temperature Sensor	Dehumidifier Cold Plate	1	2
Temperature Sensor	Exhaust	2	4
Temperature Sensor	Root Zone	1	2
Current Sensor	Dehumidifier	1	2
Current Sensor	TEC	1	2
Current Sensor	DC Muffin Fans	3	6
Current Sensor	Micro Pump	1	2
Pressure Sensor	Dehumidifier	1	2
Assembly, FLM			
Temperature Sensor	FLM	1	2
Temperature Sensor	Ballast Assembly	1	2
Current Sensor	Ballast Assembly	1	2
Current Sensor	DC Muffin Fans	2	4
Assembly, CDMS			
Temperature Sensor	CDMS Assembly	1	1
Assembly, Filtration System			
CO2 Sensor	PGC CO2 Detector	1	2
Current Sensor	Pump	1	2
Current Sensor	Solenoid	3	6
Flow Sensor	CO2 & VOC	1	2
Assembly, Power Conditioning Module			
Temperature Sensor	PCM Assembly	1	1
Total			**59**

Update Data

CDMS

- Provides commanding of set-points for environmental control and imaging
- Receives and logs data and errors from controller boards
- Based on a Pentium DIMM PC CPU board on a custom carrier board (133 MHz)
- Provides I2C, USB, ethernet and RS-485 bus control
- Watchdog timer to guard against lockups
- IDE Hard drives (30 GB)

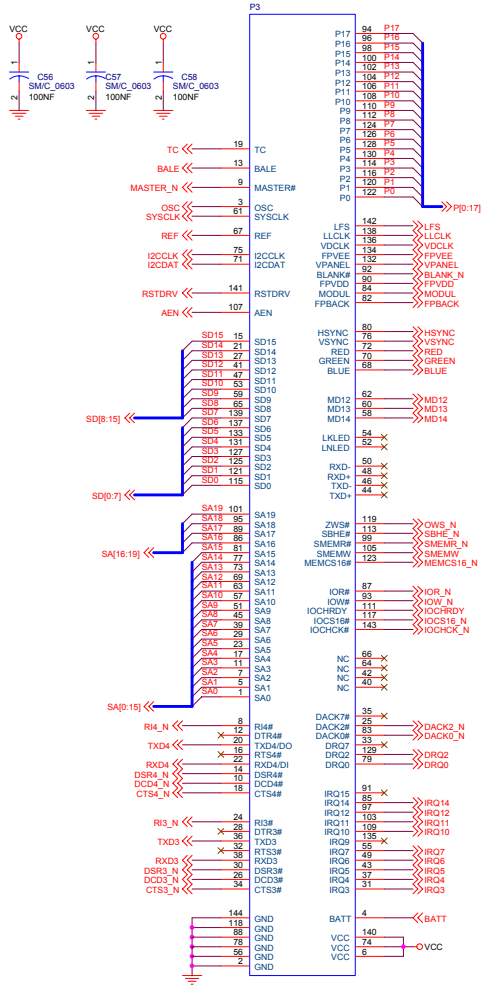
CDMS (cont)

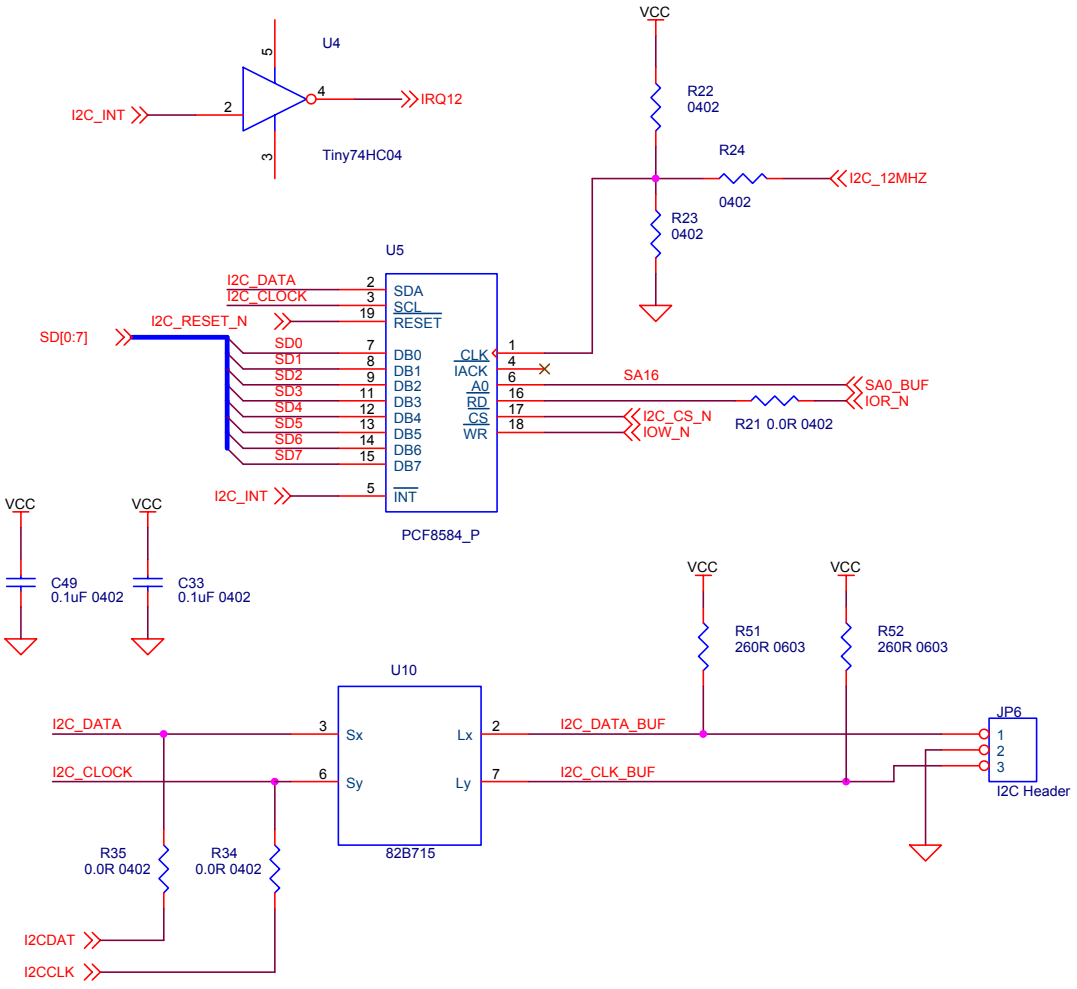
- Communication to Handheld Visual indication Unit with RS-485 interface
- Communication to ISS via LAN
- Communication to Laptop on Orbiter is achieved with a RS-232C interface

Mass Storage Device

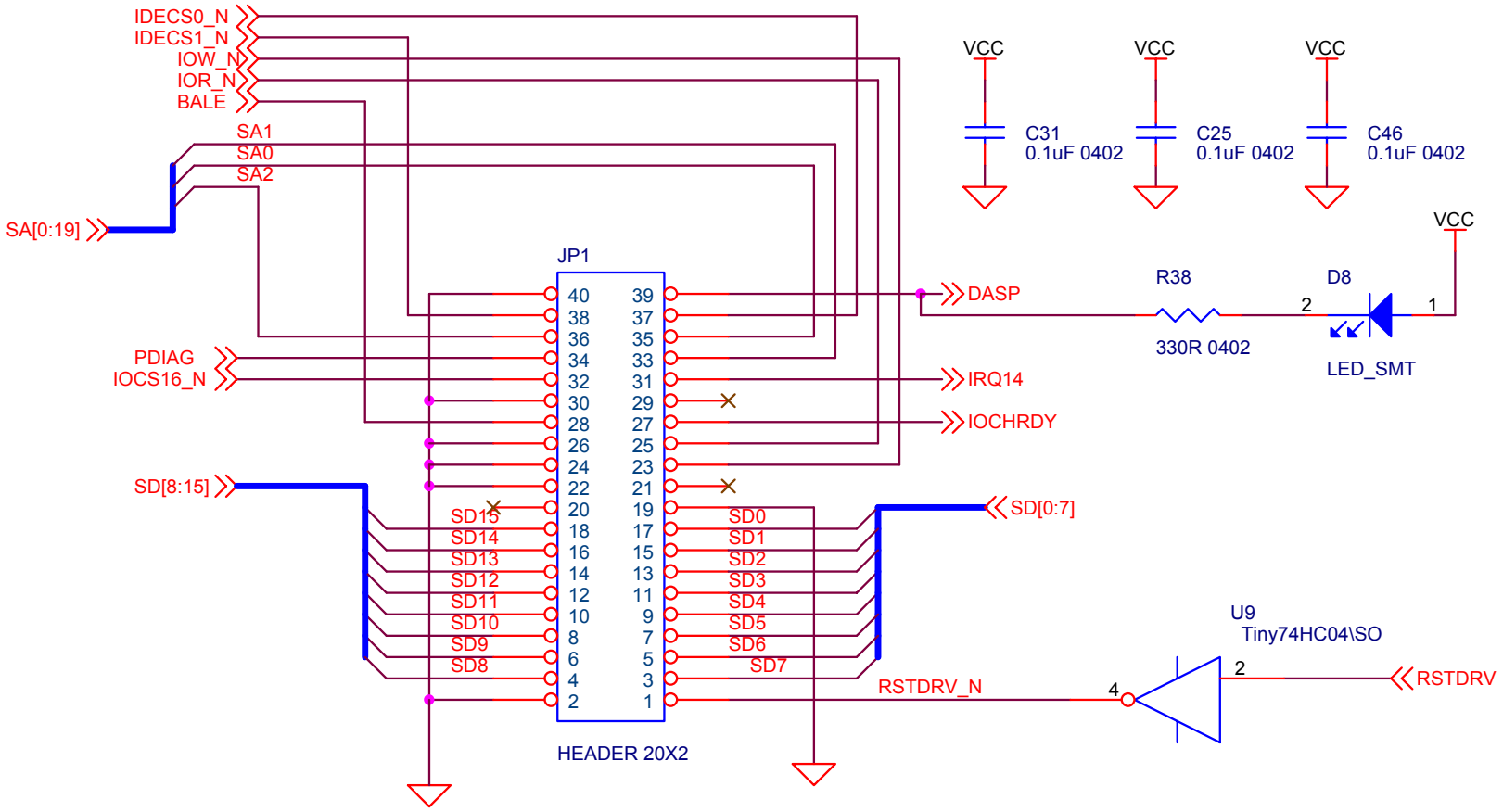
IBM Hard Drive (2 units)

- Hard drives, Capable of storing 10 Giga bytes of data each.
- Capable of storing at least 16,000 images per hard drive, uncompressed.

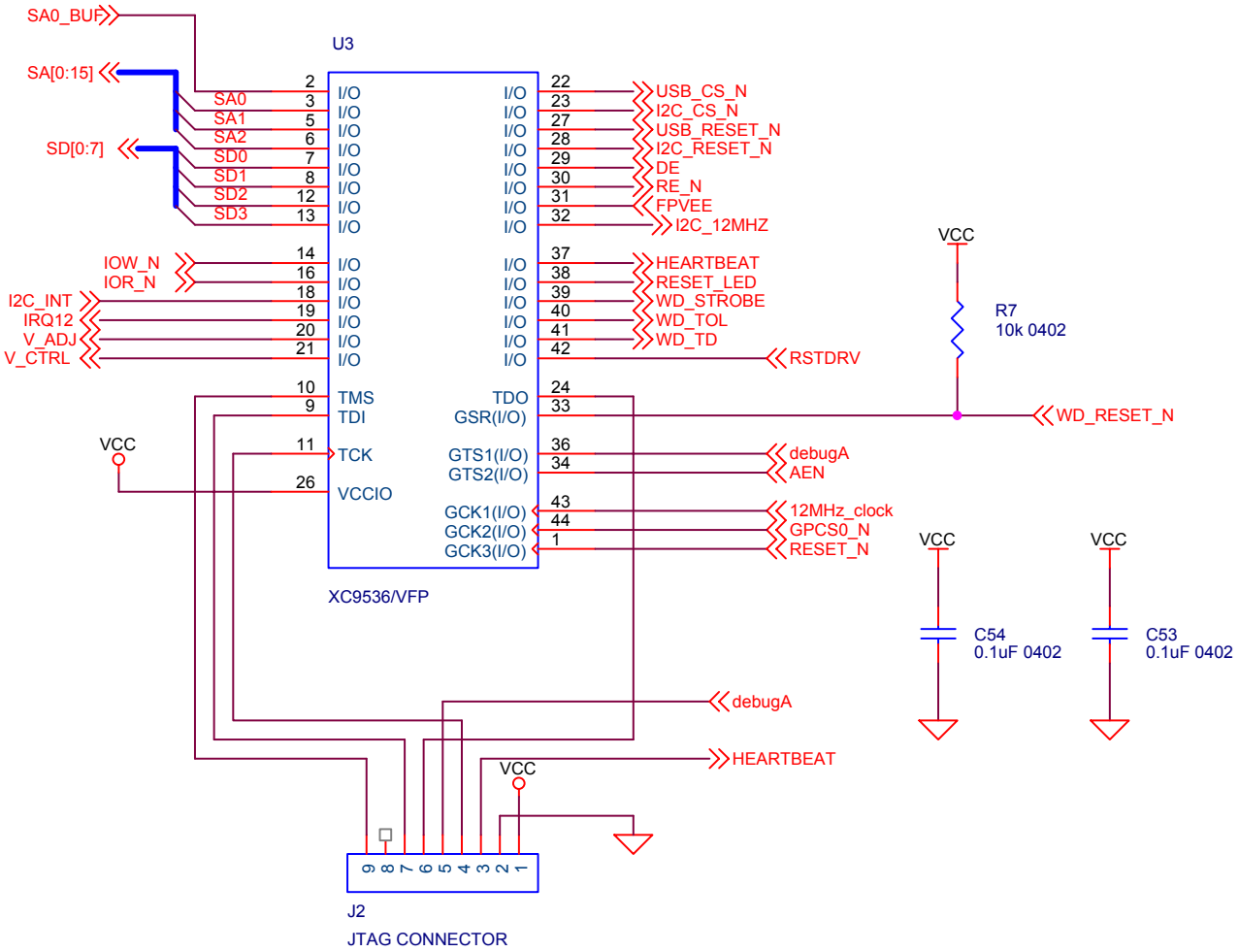

P3
VCC
VCC
VCC
C56
SM/C_0603
100NF
C57
SM/C_0603
100NF
C58
SM/C_0603
100NF
TC
BALE
MASTER_N
OSC
SYSCLK
REF
I2CCLK
I2CDAT
RSTDRV
AEN
SD[8:15]
SD[0:7]
SA[16:19]
SA[0:15]
RI4_N
TXD4
RXD4
DSR4_N
DCD4_N
CTS4_N
RI3_N
TXD3
RXD3
DSR3_N
DCD3_N
CTS3_N
P[0:17]
LFS
LLCLK
VDCLK
FPVEE
VPANEL
BLANK#
FPVDD
MODUL
FPBACK
HSYNC
VSYNC
RED
GREEN
BLUE
MD12
MD13
MD14
LKLED
LNLED
RXD-
RXD+
TXD-
TXD+
ZWS#
SBHE#
SMEMR#
SMEMW
MEMCS16#
IOR#
IOW#
IOCHRDY
IOCS16#
IOCHCK#
NC
DACK7#
DACK2#
DACK0#
DRQ7
DRQ2
DRQ0
IRQ15
IRQ14
IRQ12
IRQ11
IRQ10
IRQ9
IRQ7
IRQ6
IRQ5
IRQ4
IRQ3
BATT
GND
VCC


U4
Tiny74HC04
I2C_INT
IRQ12
VCC
R22
0402
R24
0402
I2C_12MHZ
R23
0402
U5
PCF8584_P
I2C_DATA
I2C_CLOCK
I2C_RESET_N
SD[0:7]
SDA
SCL
RESET
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
INT
CLK
IACK
A0
RD
CS
WR
SA16
SA0_BUF
IOR_N
I2C_CS_N
IOW_N
R21 0.0R 0402
C49
0.1uF 0402
C33
0.1uF 0402
R51
260R 0603
R52
260R 0603
U10
82B715
Sx
Sy
Lx
Ly
I2C_DATA_BUF
I2C_CLK_BUF
JP6
I2C Header
R35
0.0R 0402
R34
0.0R 0402
I2CDAT
I2CCLK

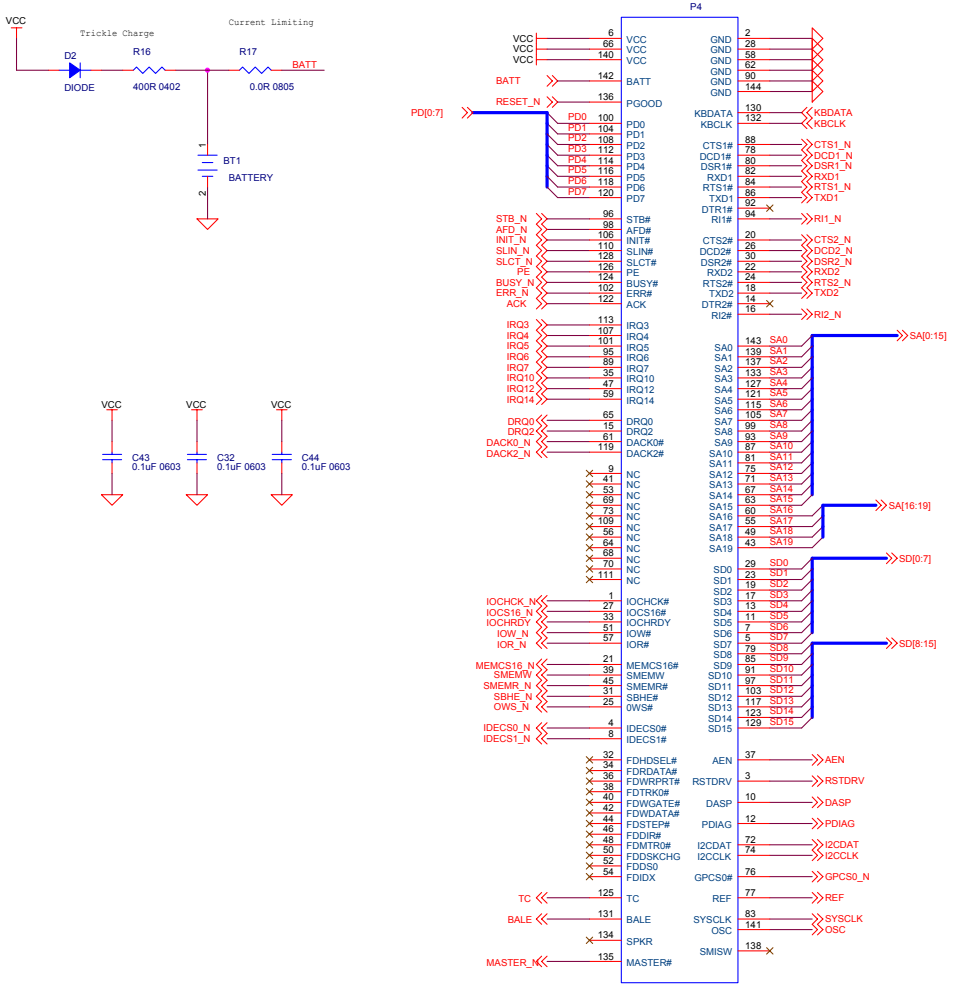
IDE INTERFACE



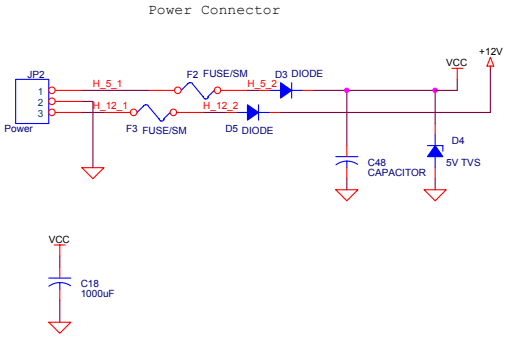
I/O DECODE

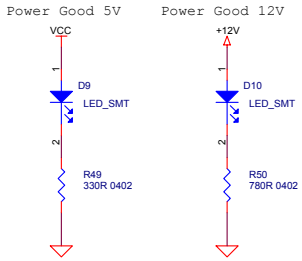

SA0_BUF
SA[0:15]
SD[0:7]
U3
SA0
SA1
SA2
SD0
SD1
SD2
SD3
IOW_N
IOR_N
I2C_INT
IRQ12
V_ADJ
V_CTRL
TMS
TDI
TCK
VCCIO
TDO
GSR(I/O)
GTS1(I/O)
GTS2(I/O)
GCK1(I/O)
GCK2(I/O)
GCK3(I/O)
USB_CS_N
I2C_CS_N
USB_RESET_N
I2C_RESET_N
DE
RE_N
FPVEE
I2C_12MHZ
HEARTBEAT
RESET_LED
WD_STROBE
WD_TOL
WD_TD
RSTDRV
debugA
AEN
12MHz_clock
GPCS0_N
RESET_N
XC9536/VFP
VCC
R7
10k 0402
WD_RESET_N
C54
0.1uF 0402
C53
0.1uF 0402
HEARTBEAT
J2
JTAG CONNECTOR

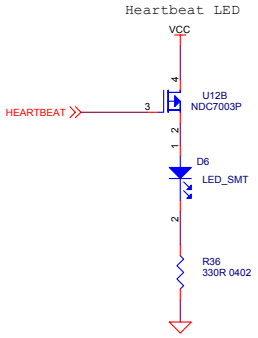
MASTER CPU

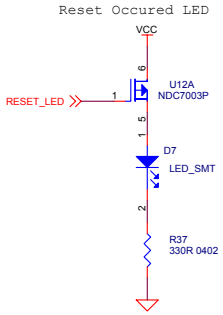

VCC
Trickle Charge
Current Limiting
D2
DIODE
R16
400R 0402
R17
0.0R 0805
BATT
BT1
BATTERY
C43
0.1uF 0603
C32
0.1uF 0603
C44
0.1uF 0603
P4
PD[0:7]
SA[0:15]
SA[16:19]
SD[0:7]
SD[8:15]

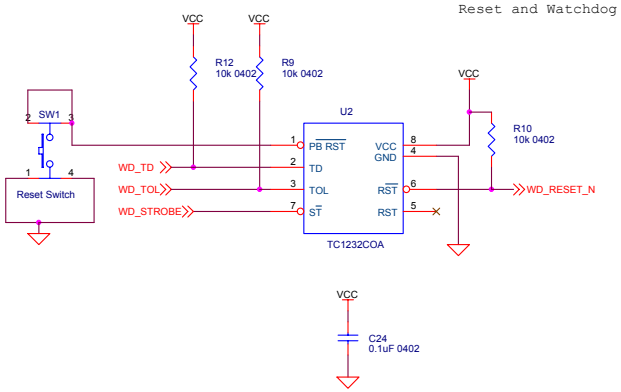
WATCHDOG TIMER





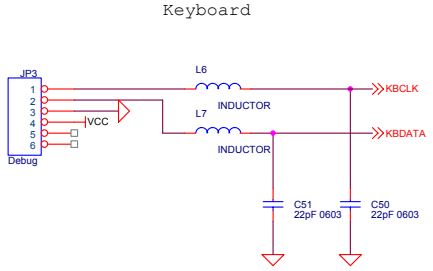




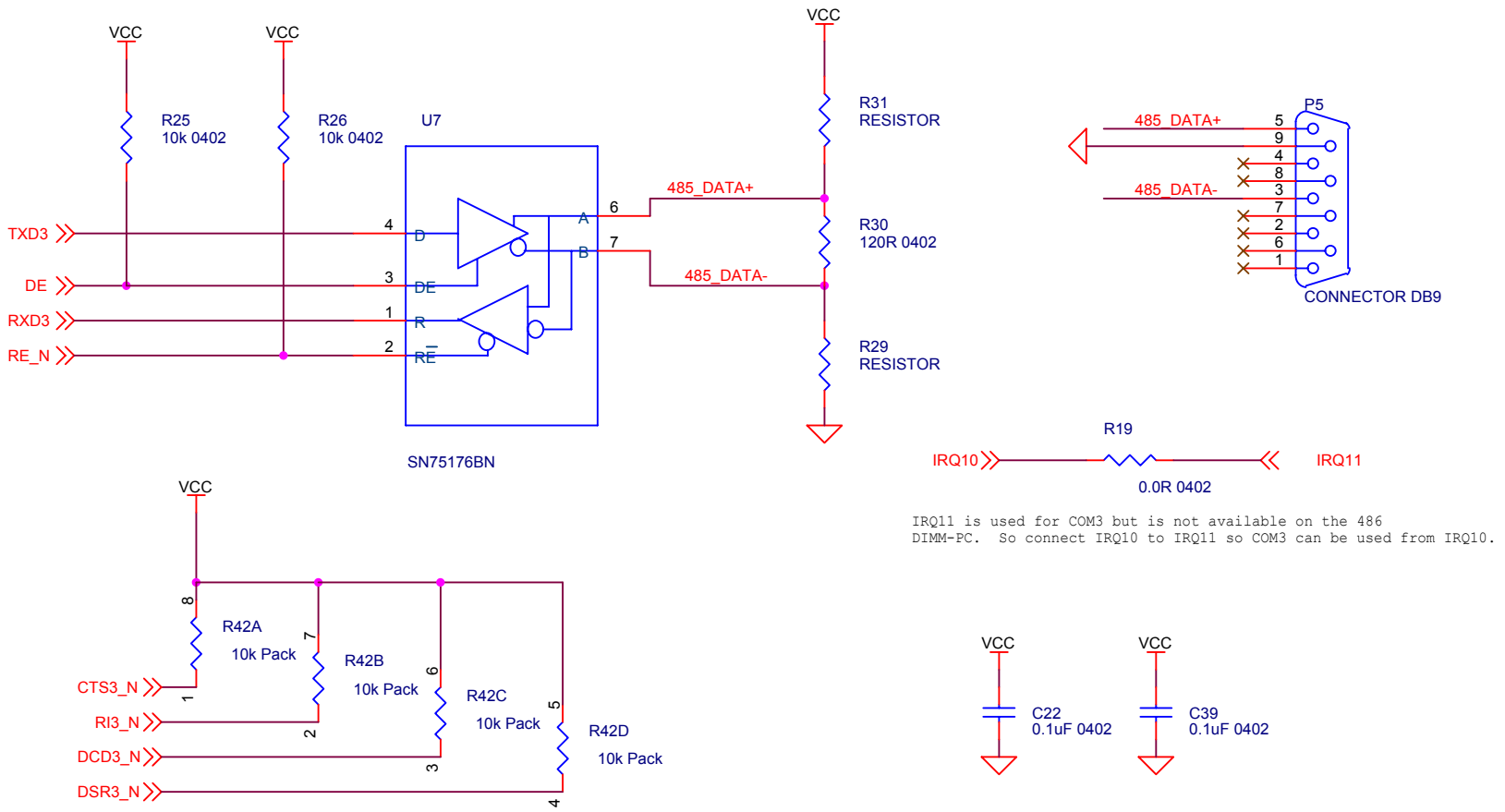


JP4, TD: Watchdog time delay set.
TD = 0V, Timeout = 150mS
TD = Float, Timeout = 600mS
TD = 5V, Timeout = 1.2 Sec

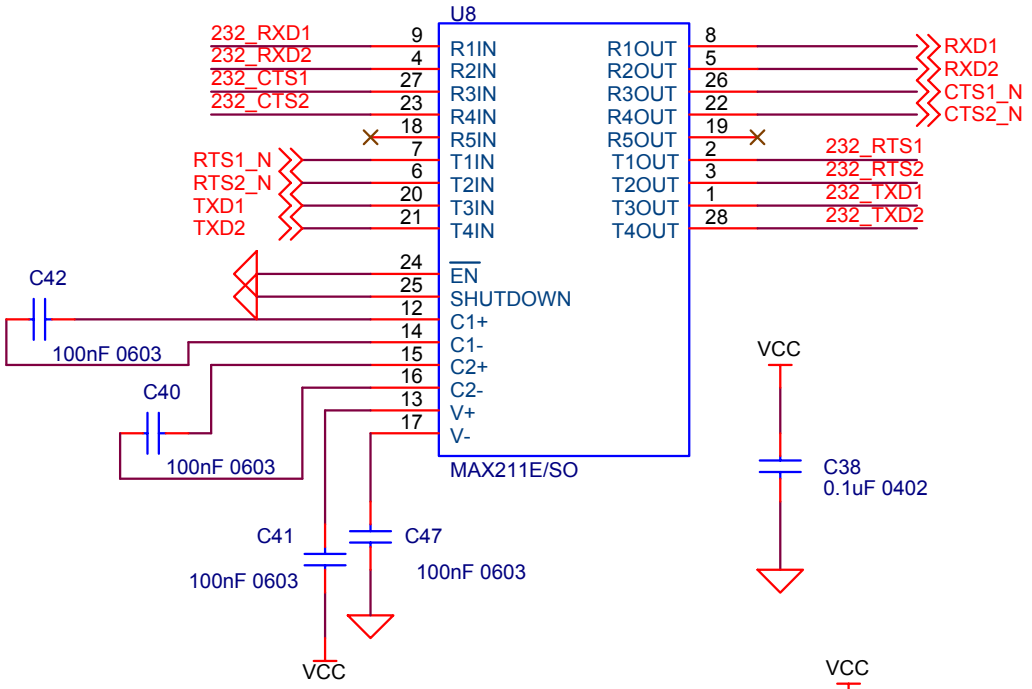
JP5, TOL: Power Supply Tolerance select
TOL = 0V for 5% tolerance
TOL = 5V, for 10% Tolerance

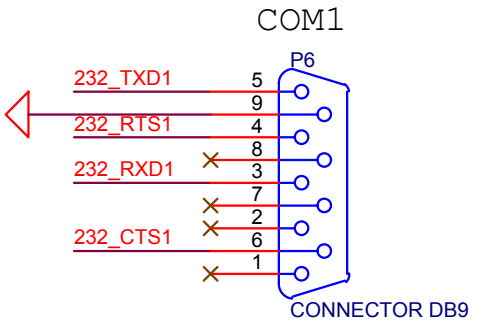


RS485 Interface

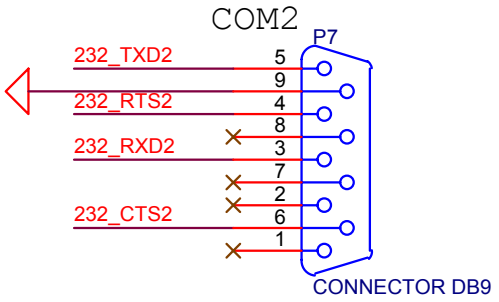


RS232 INTERFACE

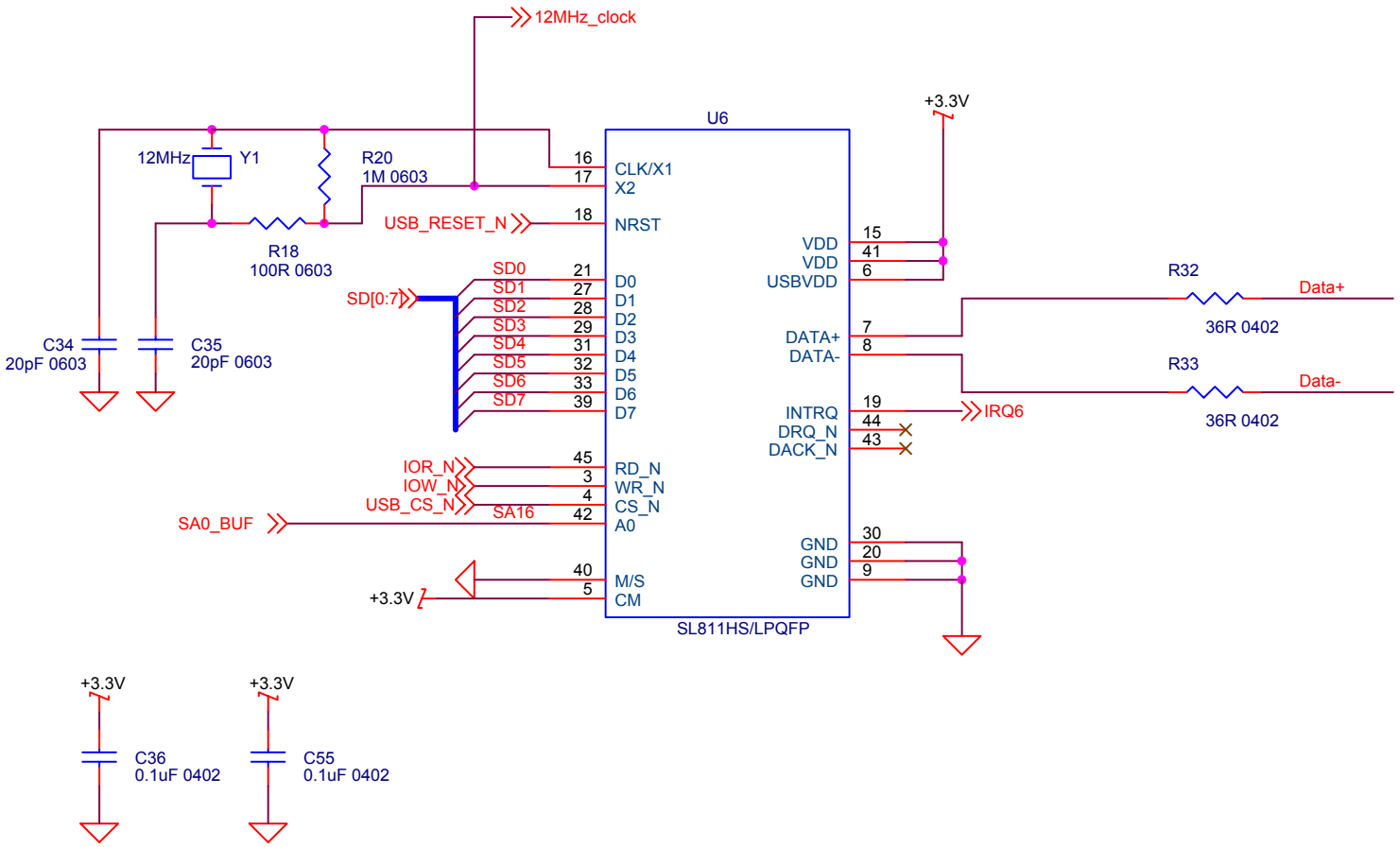


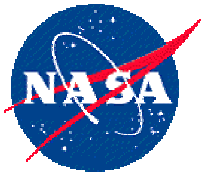


Connectors wired for dual row 0.100 in header



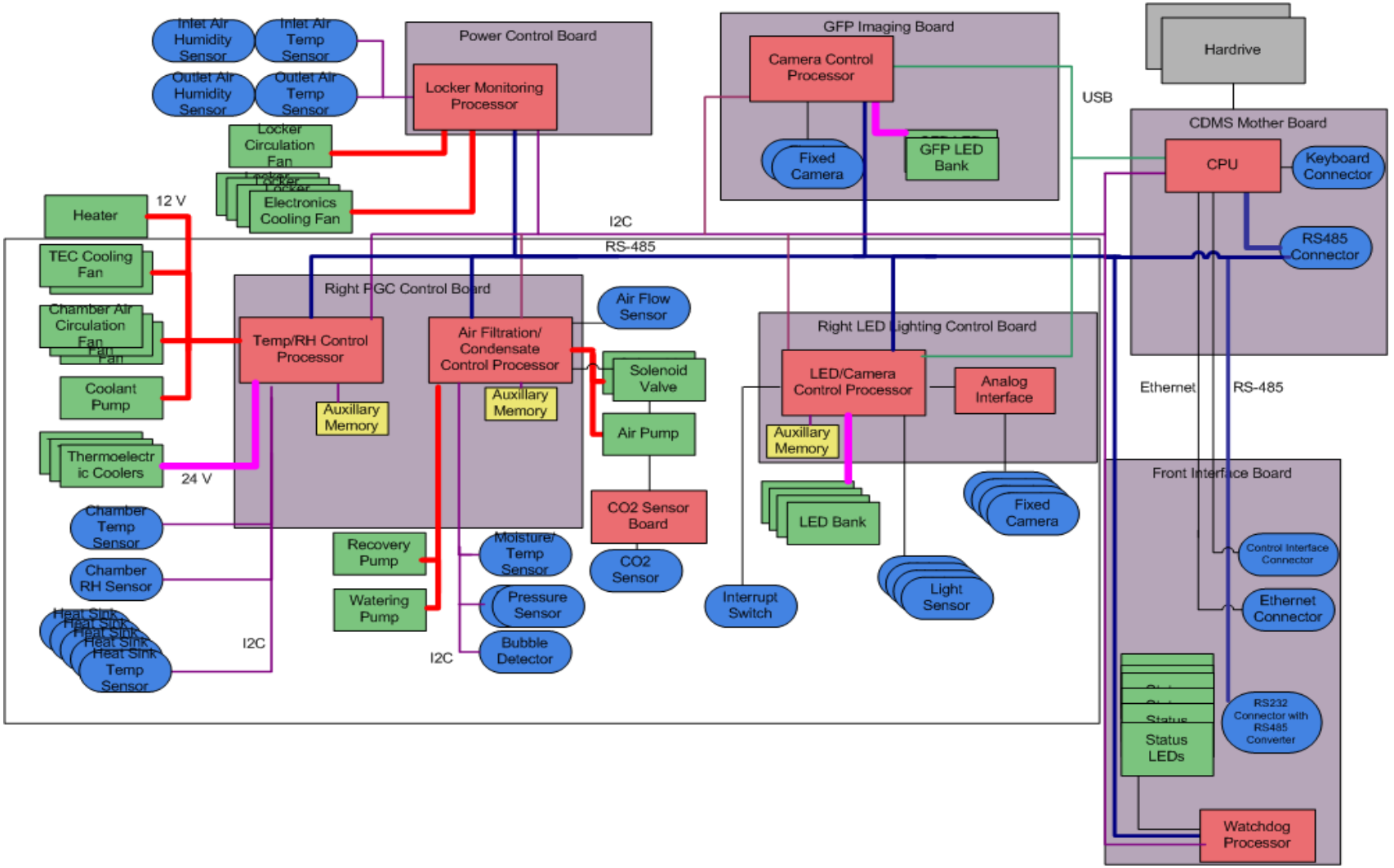
USB INTERFACE





PGF-SP Software

Controller Functional Block Diagram



PGC Controller Board Software

- Controls PGC temperatures, relative humidity and CO2 level and recovers condensate
- Temperature control is based on Proportional, Integral, Derivative (PID) control loop
  - A set-point will be issued through CDMS command
  - Receives sensor data feedback to determine how much cooling or heating required to maintain set-point
- PWM control of Heater and Thermal Electric Cooler (TEC)
- Fans, valves and water pump are on/off control
- Recovery pump is two-way reversible
- Sensors are read by I2C

PGC Controller Board Software (cont.)

- The Heater is open loop PWM control based on light-bank and humidity settings
  - If lights on, no more heat is needed
  - Take error between set-point and current temp.
  - Determine if too hot or too cold and run system accordingly
- TEC cools to dehumidify
  - Slow fans to add heat (maybe for 5 minutes)
  - Turn on full speed (1 minute) to clear water off heat sink
- Bang-bang control of fans also to control temperature
- Condensate Recovery
  - Monitor pressure and bubble detector
  - Adjust with recovery pump (bi-directional)
- Coolant pump is on all the time, monitor current
- Valves control air flow through CO2 scrubber if needed

Right/Left Lighting Board Software

- 4 banks of LEDs are PWM controlled by a set-point when images are not being taken
- When images are being taken, red and blue LEDs are turned off so only white LEDs are illuminating
- 4 cameras per board that are multiplexed to the USB bus
- A mux selects camera video output to USB
- Light sensors to monitor chamber light levels (A/D conversions)
- Interrupt switch to turn LEDs off when chamber is opened (safety feature)
    - Read a switch, if open, turn off LEDs

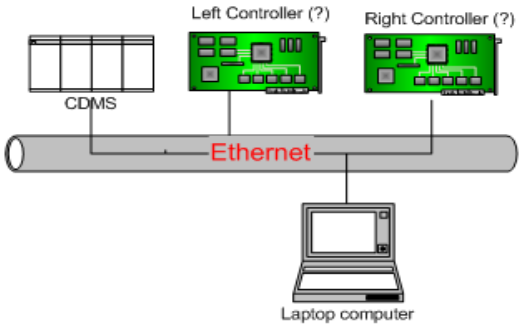
GFP Imaging Board Software

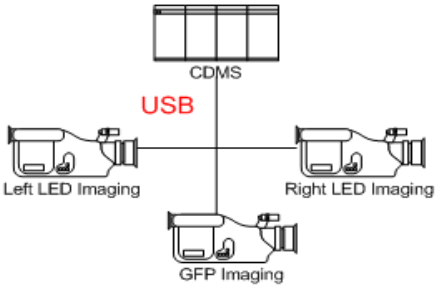
- Multiplexes four cameras onto USB when commanded by CDMS
- I2C camera control, sets up cameras, writes camera setup to EEPROM
- Open loop PWM of LED bank

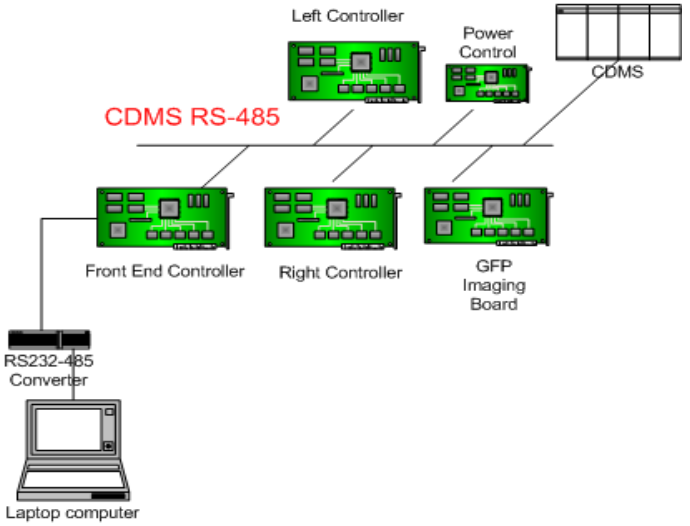
CDMS Software

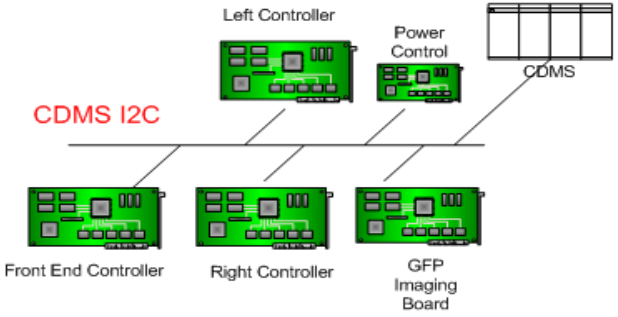
- Collect and log data per EIS spec:
  - Maximum: 10 samples/min
  - Minimum: 1 sample/hour
  - Nominal: 1 sample/10 min
  - Store image data
- All data stored to IDE hard drives
- Provide serial interface to display control screen
- Provide Ethernet, I2C, USB and RS-485 bus control
- Watchdog timer implemented to guard against lockups (< 30 second update)

CDMS Networks









CDMS Operating System Trade-Off

Operating System	MS Windows Embedded CE	MS Windows Embedded XP	Embedded Linux	DOS
Cost			X	X
Features		X		
Small Footprint	X		X	X
Ease of programming				X
Software tools	X	X		
GUI interface without add-ons	X	X		
Ease of Networking	X	X		
Reliability			X	
Near real-time performance			X	
Technical support			X	

CDMS Operating System

- Linux chosen as operating system
- Currently being used on PTIM-WONDER
- Small footprint
- Reliable
- ANSI-C code capability