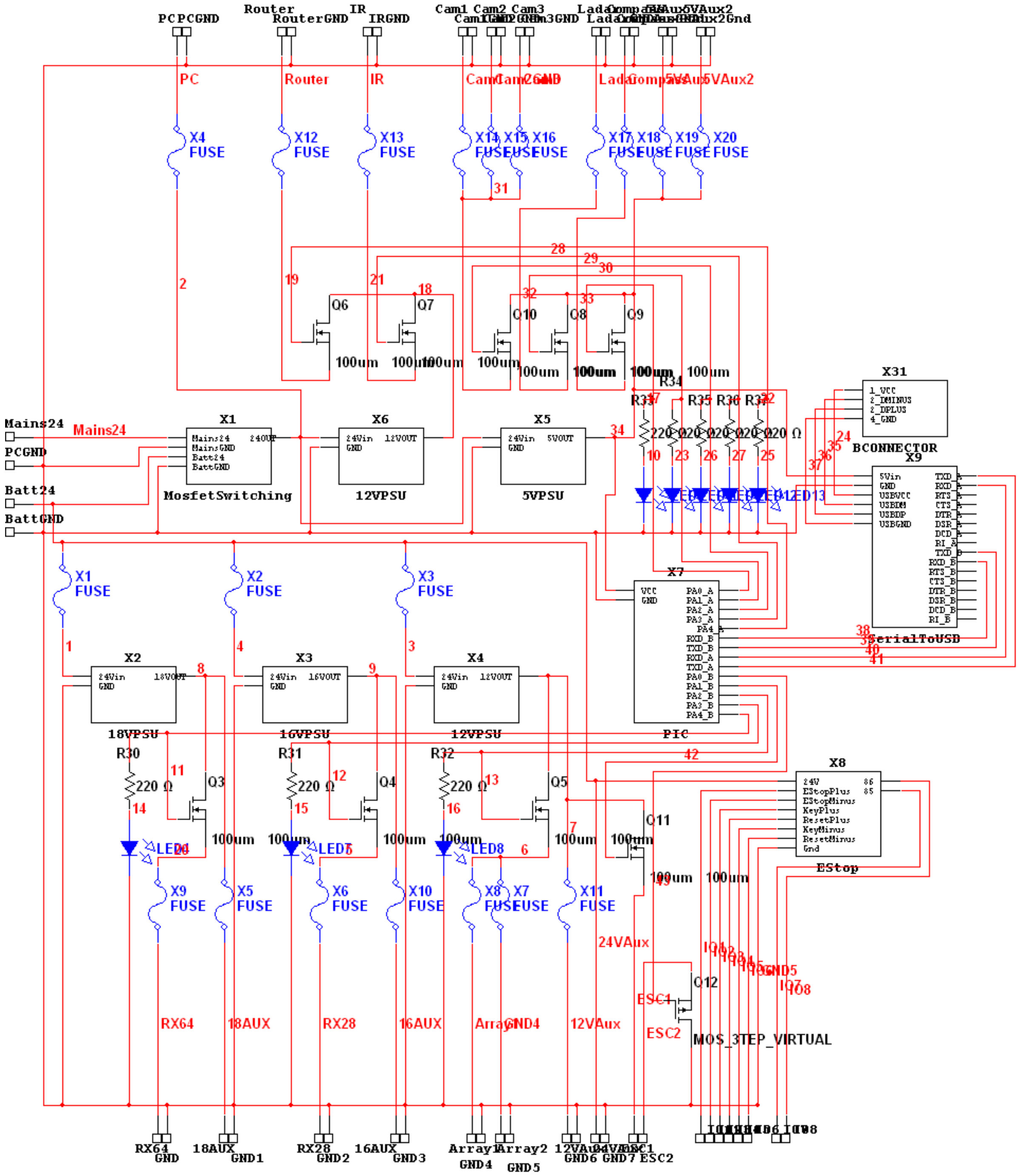
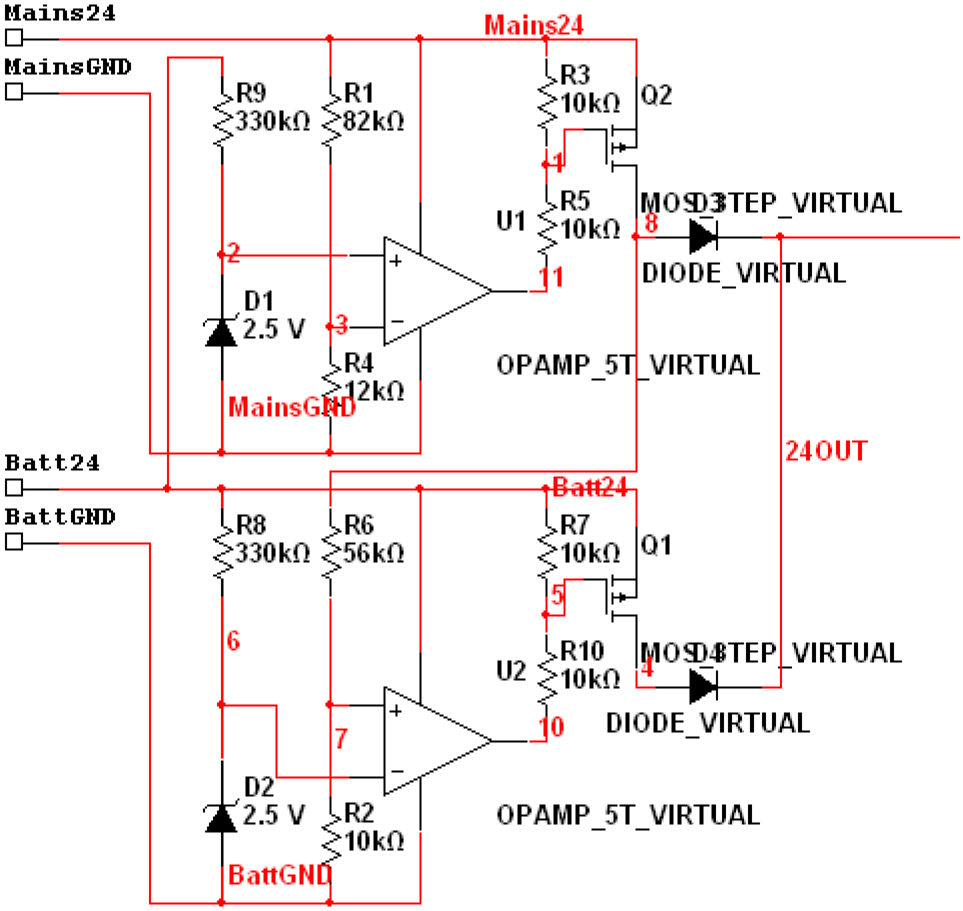
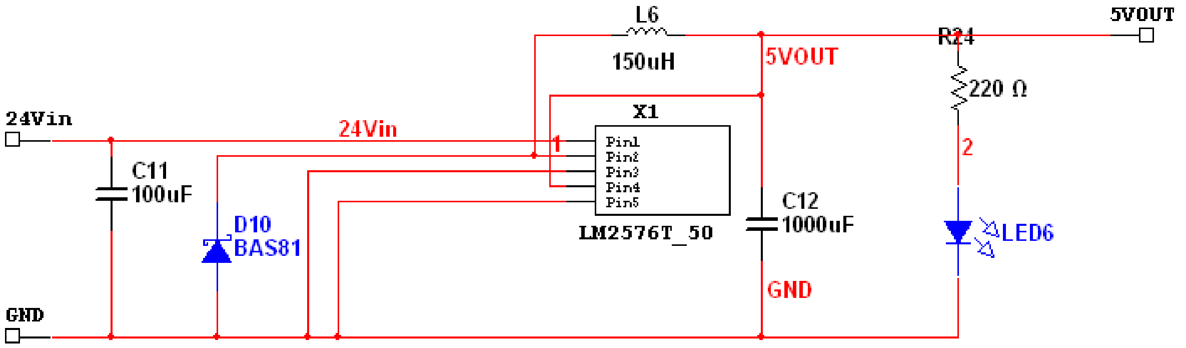
15.7 ELECTRONICS APPENDIX E

15.7.1 APPENDIX E1: ORIGINAL POWER CONTROL PCB

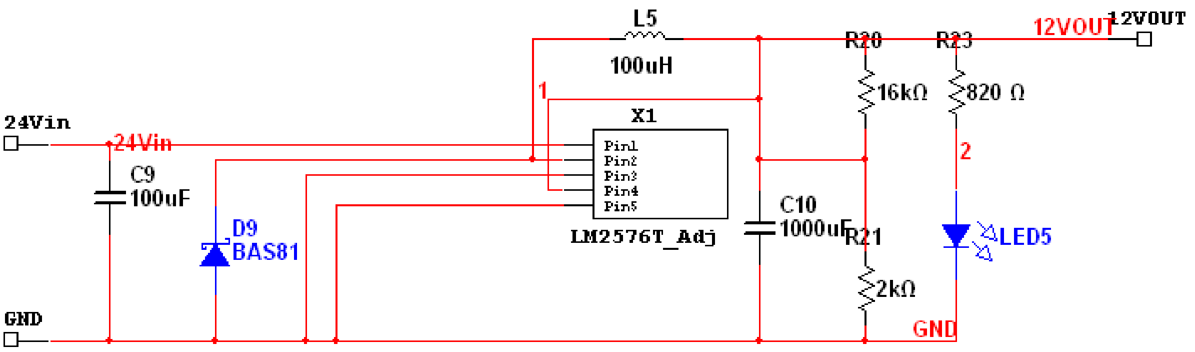



Mains24
MainsGND
Batt24
BattGND
R9 330kΩ
R1 82kΩ
R3 10kΩ
Q2
R5 10kΩ
U1
MOSSTEP_VIRTUAL
D3
DIODE_VIRTUAL
D1 2.5 V
R4 12kΩ
OPAMP_5T_VIRTUAL
24OUT
R8 330kΩ
R6 56kΩ
R7 10kΩ
Q1
R10 10kΩ
U2
D4
D2 2.5 V
R2 10kΩ

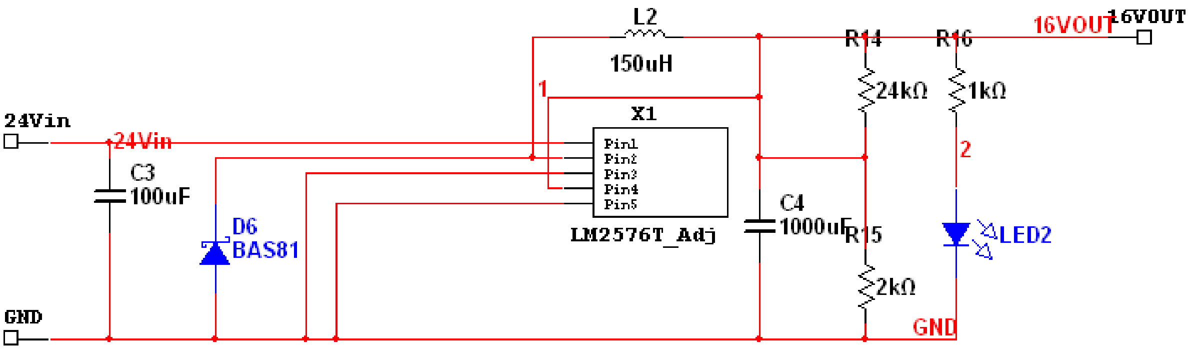
15.7.3 APPENDIX E3: 5 V VOLTAGE REGULATOR SUB-CIRCUIT



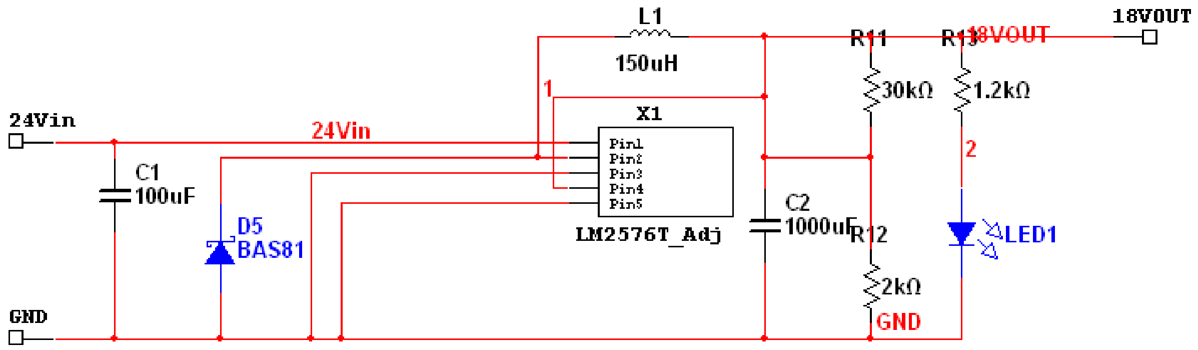
15.7.4 APPENDIX E4: 12 V VOLTAGE REGULATOR SUB-CIRCUIT



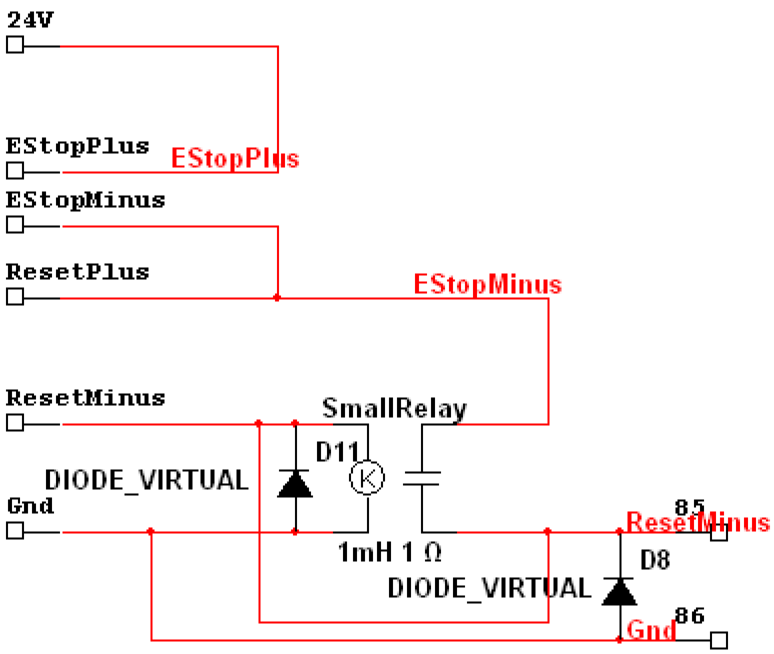
15.7.5 APPENDIX E5: 16 V VOLTAGE REGULATOR SUB-CIRCUIT



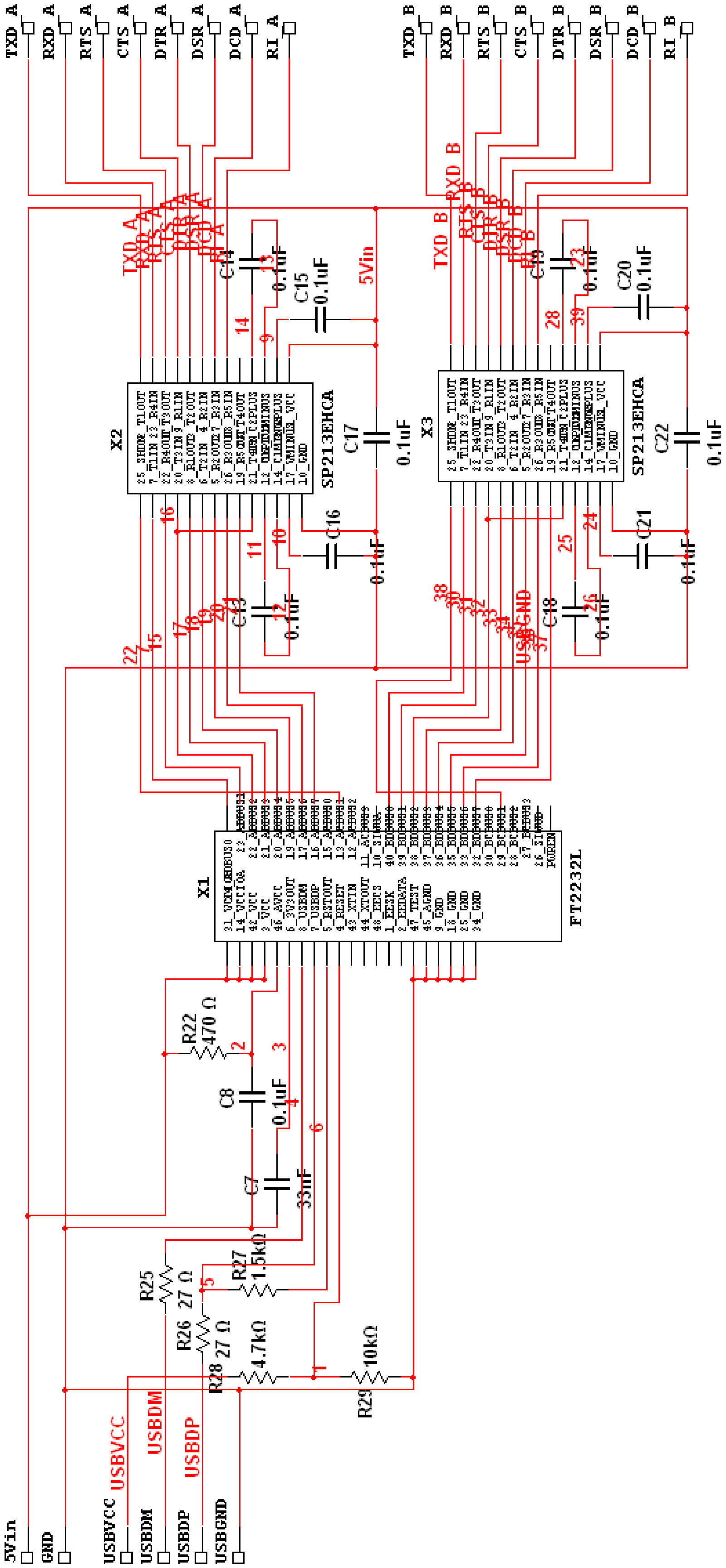
15.7.6 APPENDIX E6: 18 V VOLTAGE REGULATOR SUB-CIRCUIT



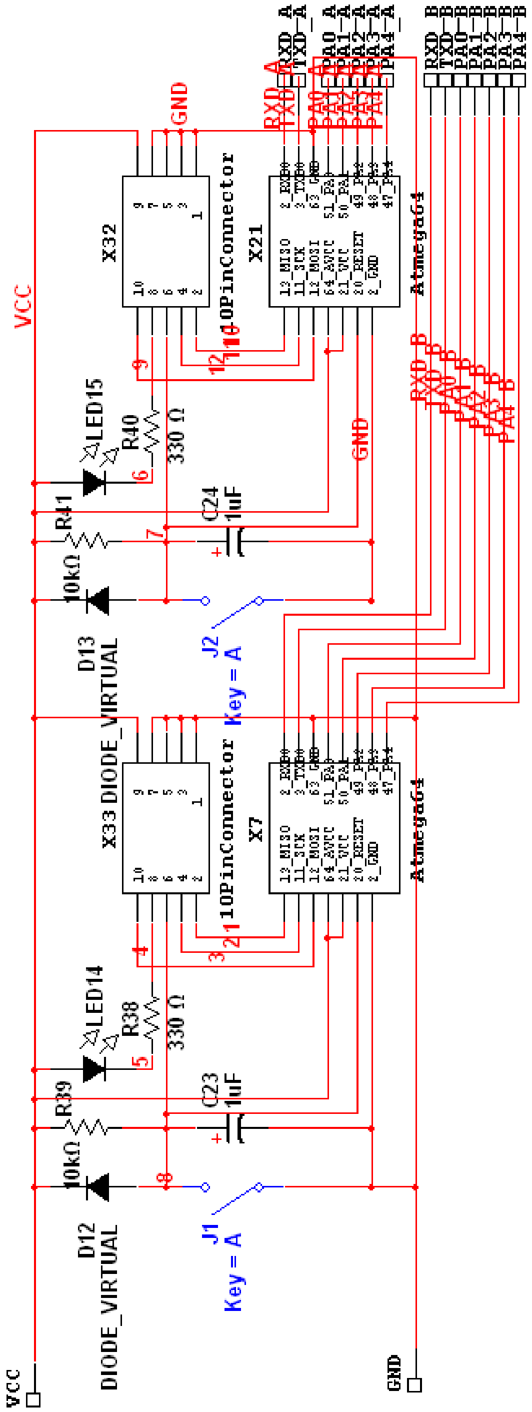
15.7.7 APPENDIX E7: EMERGENCY STOP SUB-CIRCUIT



15.7.8 APPENDIX E8: SERIAL TO USB CONVERSION SUB-CIRCUIT



15.7.9 APPENDIX E9: PIC SUB-CIRCUIT



15.7.10 APPENDIX E10: COMPARING IC VOLTAGE REGULATORS

The options for the voltage regulator are either a linear or switched regulator. These are compared below:

	LM317	LM2576
Type	Linear Regulator	Switched Regulator
Output Current	1.5 A	3A
Maximum Supply Voltage	40 V	60 V
Efficiency	60%	88%

The LM2576 is the better option, as it is a lot more efficient. This means it is likely to run at a lower temperature, which has positive implications on lifespan and size of heat sink required. It also has a higher maximum output current so will be able to take a greater load.

15.7.11 APPENDIX E11: VOLTAGE REGULATOR CALCULATIONS

The 5.0 V regulator is connected as shown on the datasheet. However, resistor values need to be calculated for the adjustable regulators to achieve the required voltage output. The following calculations assume that R1 is 2 kΩ and Vref is 1.23 V:

12 V Regulator

$$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

$$R2 = 2\left(\frac{12}{1.23} - 1\right)$$

$$R2 \approx 16\ k\Omega$$

16 V Regulator

$$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

$$R2 = 2\left(\frac{16}{1.23} - 1\right)$$

$$R2 \approx 24\ k\Omega$$

18 V Regulator

$$R2 = R1\left(\frac{V_{OUT}}{V_{REF}} - 1\right)$$

$$R2 = 2\left(\frac{18}{1.23} - 1\right)$$

$$R2 \approx 30\ k\Omega$$

15.7.12 APPENDIX E12: HEAT SINK CALCULATIONS

For the voltage regulators, the heat sink needs to have a minimum rating of:

$$P_D = V_{in} I_Q + \left(\frac{V_{OUT}}{V_{IN}}\right) I_{LOAD} V_{SAT}$$

$$P_D = (24 \times 0.01) + \left(\frac{18}{24}\right) \times 3 \times 1.2$$

$$P_D = 2.94$$

$$\Delta T_J = (P_D)(\theta_{JC} + \theta_{HEAT\ SINK})$$

$$\theta_{HEAT\ SINK} = \left(\frac{\Delta T_J}{P_D}\right) - \theta_{JC}$$

$$\theta_{HEAT\ SINK} = \left(\frac{110}{2.94}\right) - 2$$

$$\theta_{HEAT\ SINK} = 35.4°C/W$$

For the mospec diode, the heat sink needs to have a minimum rating of:

$$P_D = V_{in} I_Q + \left(\frac{V_{OUT}}{V_{IN}}\right) I_{LOAD} V_{SAT}$$

$$P_D = (24 \times 0.01) + \left(\frac{24}{24}\right) \times 10 \times 1.2$$

$$P_D = 12.24$$

$$\Delta T_J = (P_D)(\theta_{JC} + \theta_{HEAT\ SINK})$$

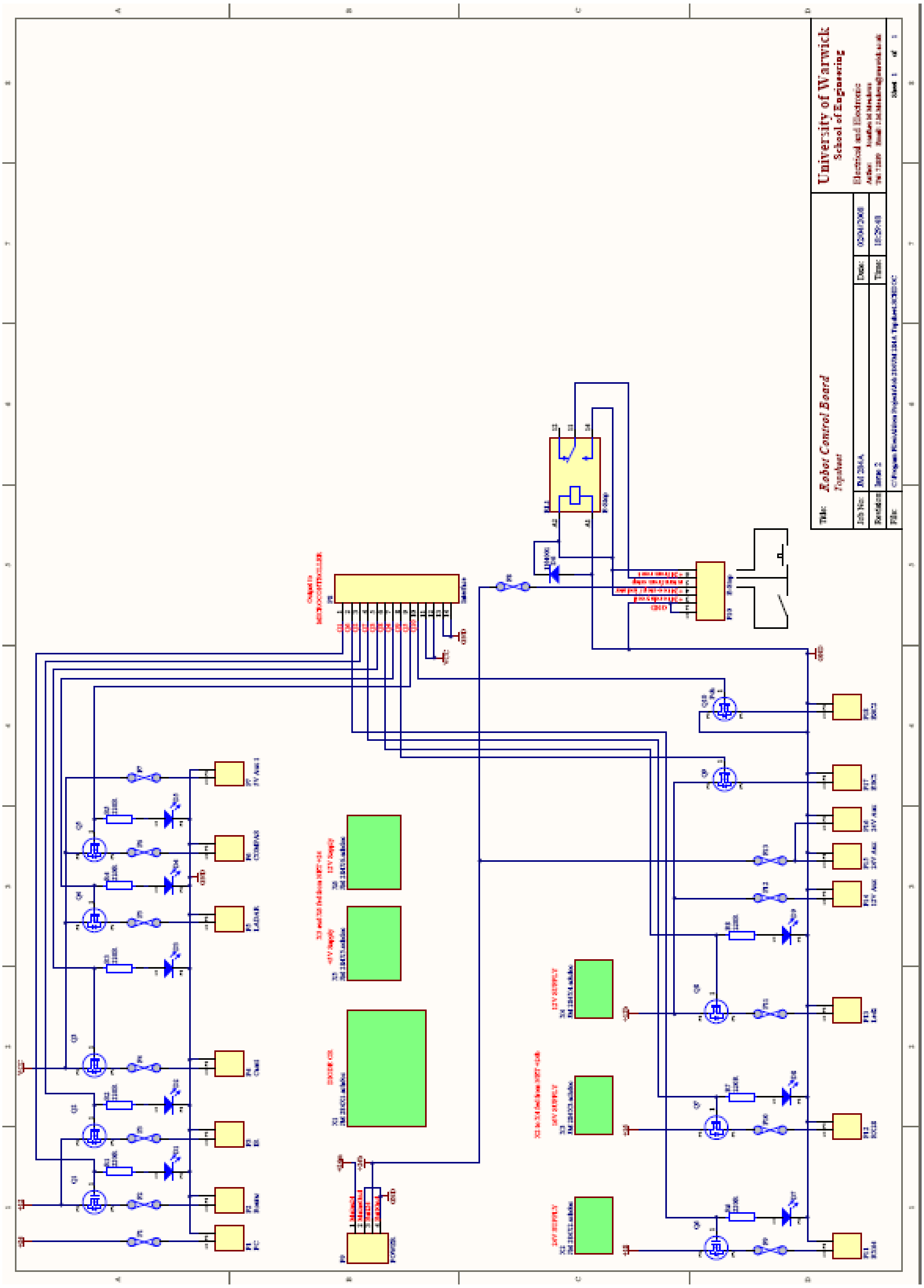
$$\theta_{HEAT\ SINK} = \left(\frac{\Delta T_J}{P_D}\right) - \theta_{JC}$$

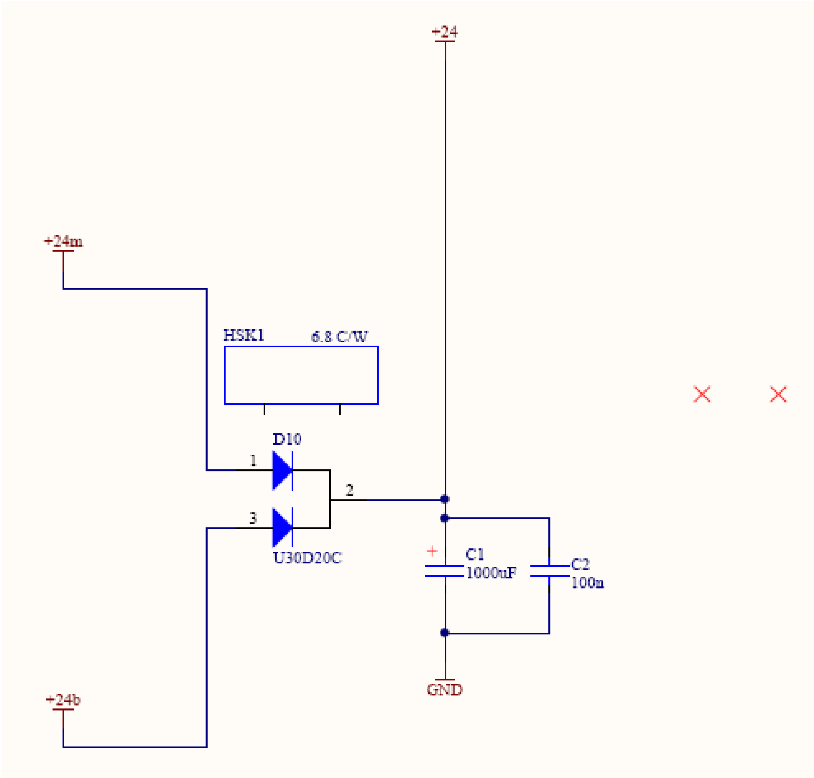
$$\theta_{HEAT\ SINK} = \left(\frac{110}{12.24}\right) - 2$$

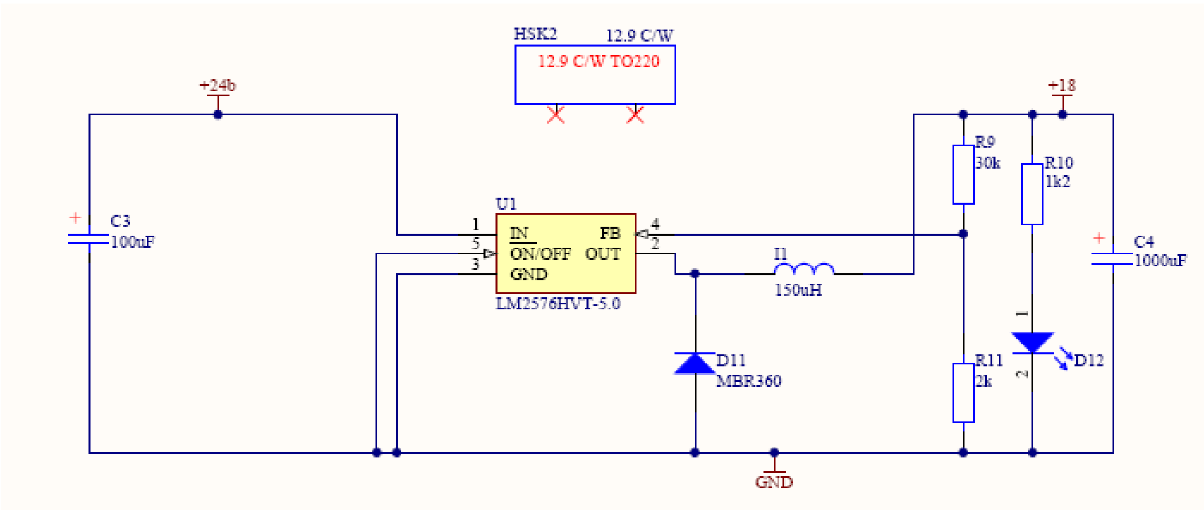
$$\theta_{HEAT\ SINK} = 6.98°C/W$$

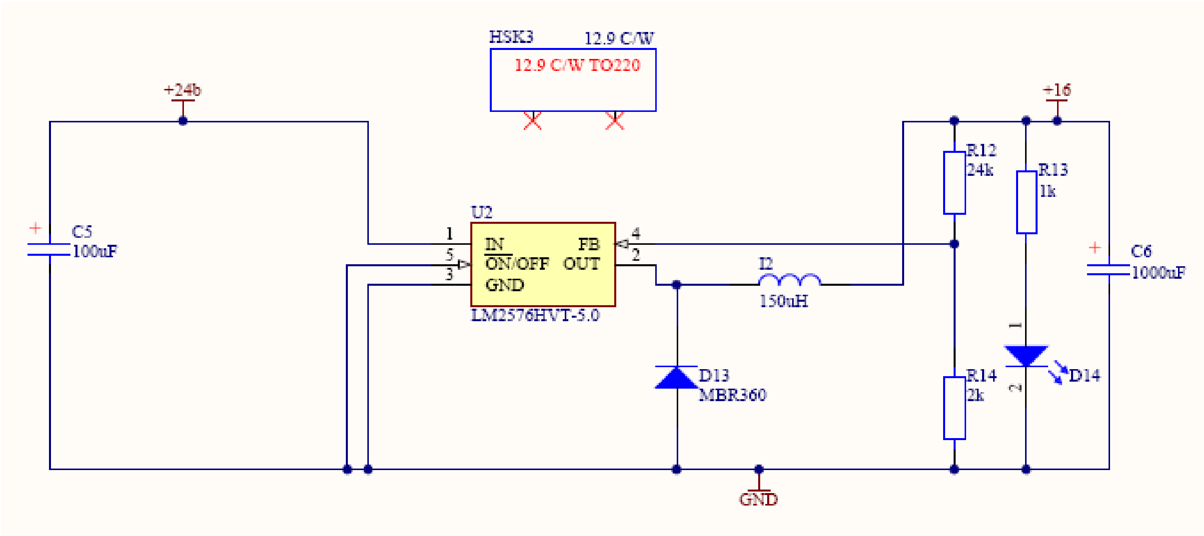
From these calculations, it is acceptable to use a 5°C/W heat sink for the U30D20C diode and a 12.9 °C/W sink for each of the LM2576 voltage regulators.

15.7.13 APPENDIX E13: NEW POWER CONTROL PCB SCHEMATICS

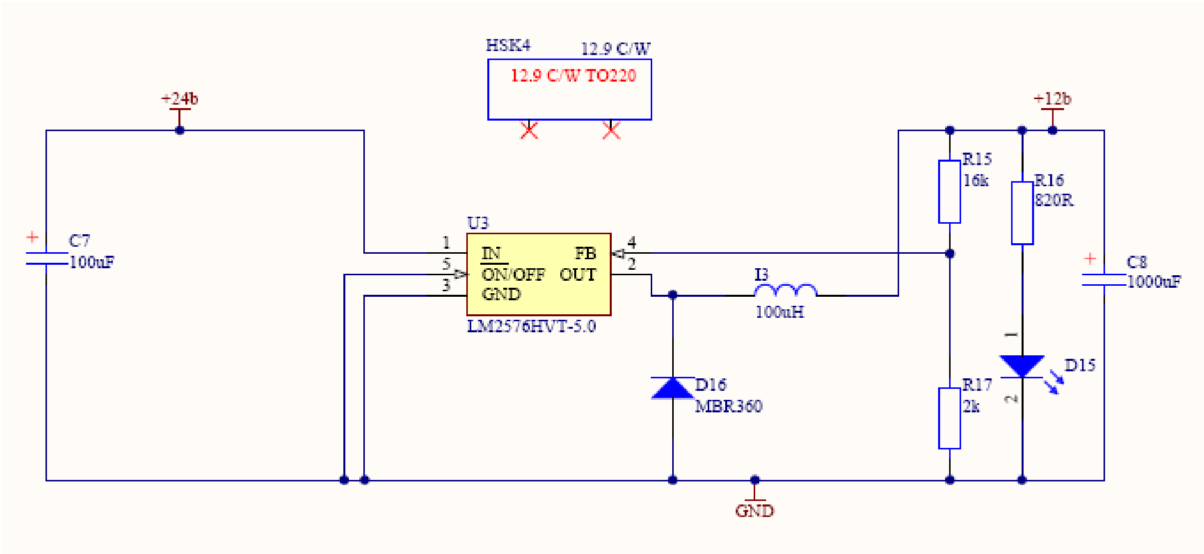



+24
+24m
HSK1
6.8 C/W
D10
1
2
3
U30D20C
C1
1000uF
C2
100n
GND
+24b

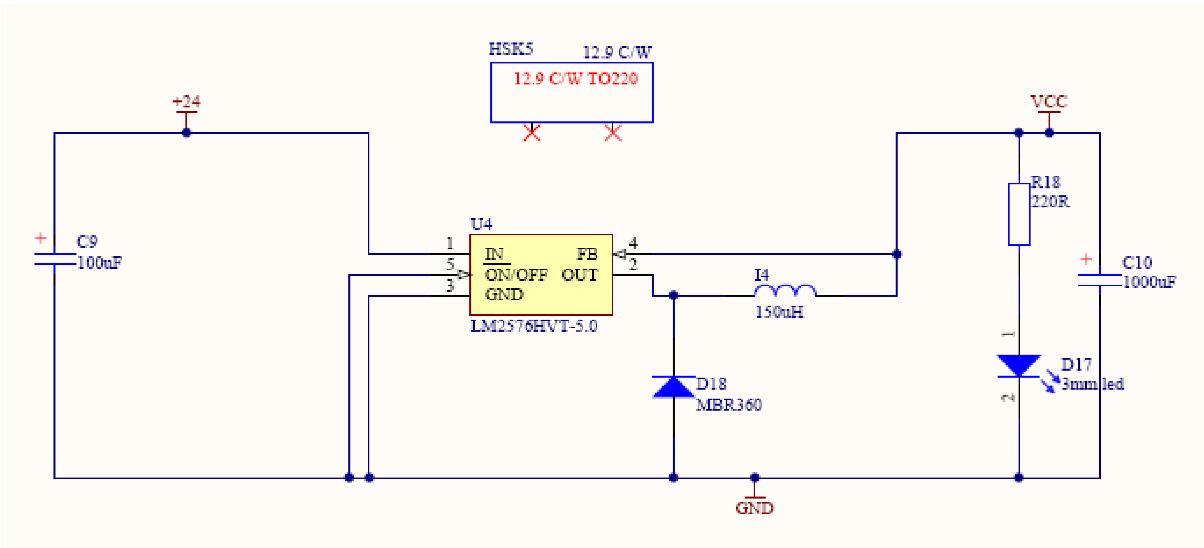

HSK2
12.9 C/W
12.9 C/W TO220
+24b
+18
R9
30k
R10
1k2
U1
C3
100uF
IN
FB
ON/OFF
OUT
GND
LM2576HVT-5.0
I1
150uH
C4
1000uF
D11
MBR360
R11
2k
D12
GND



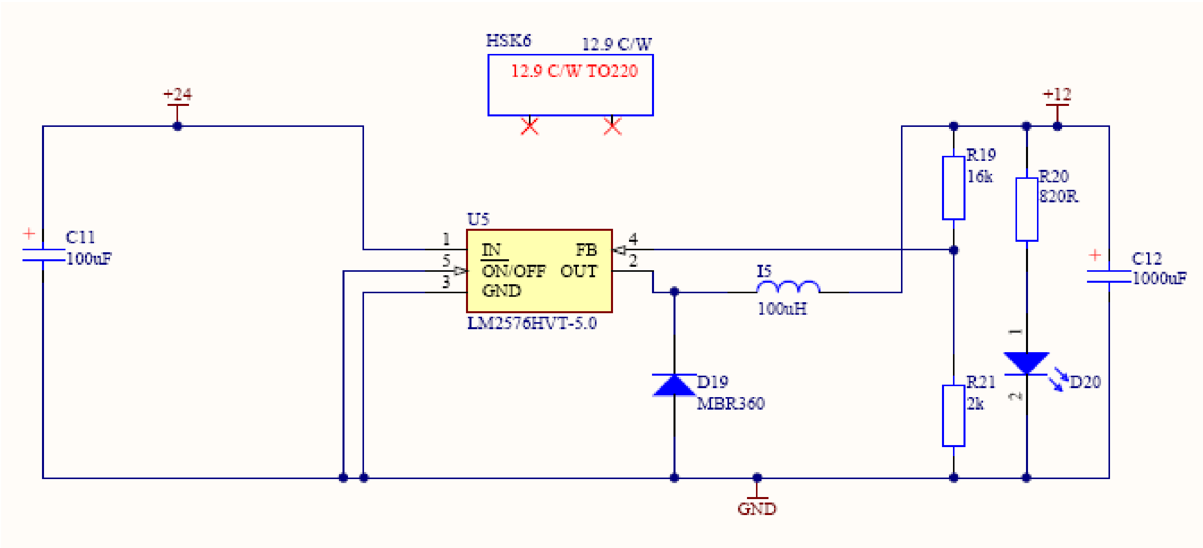
HSK3
12.9 C/W
12.9 C/W TO220
+24b
+16
C5
100uF
U2
IN
ON/OFF
GND
FB
OUT
LM2576HVT-5.0
I2
150uH
D13
MBR360
R12
24k
R13
1k
R14
2k
D14
C6
1000uF
GND



HSK4
12.9 C/W
12.9 C/W TO220
+24b
+12b
C7
100uF
U3
IN
ON/OFF
GND
FB
OUT
LM2576HVT-5.0
I3
100uH
D16
MBR360
R15
16k
R16
820R
R17
2k
D15
C8
1000uF
GND

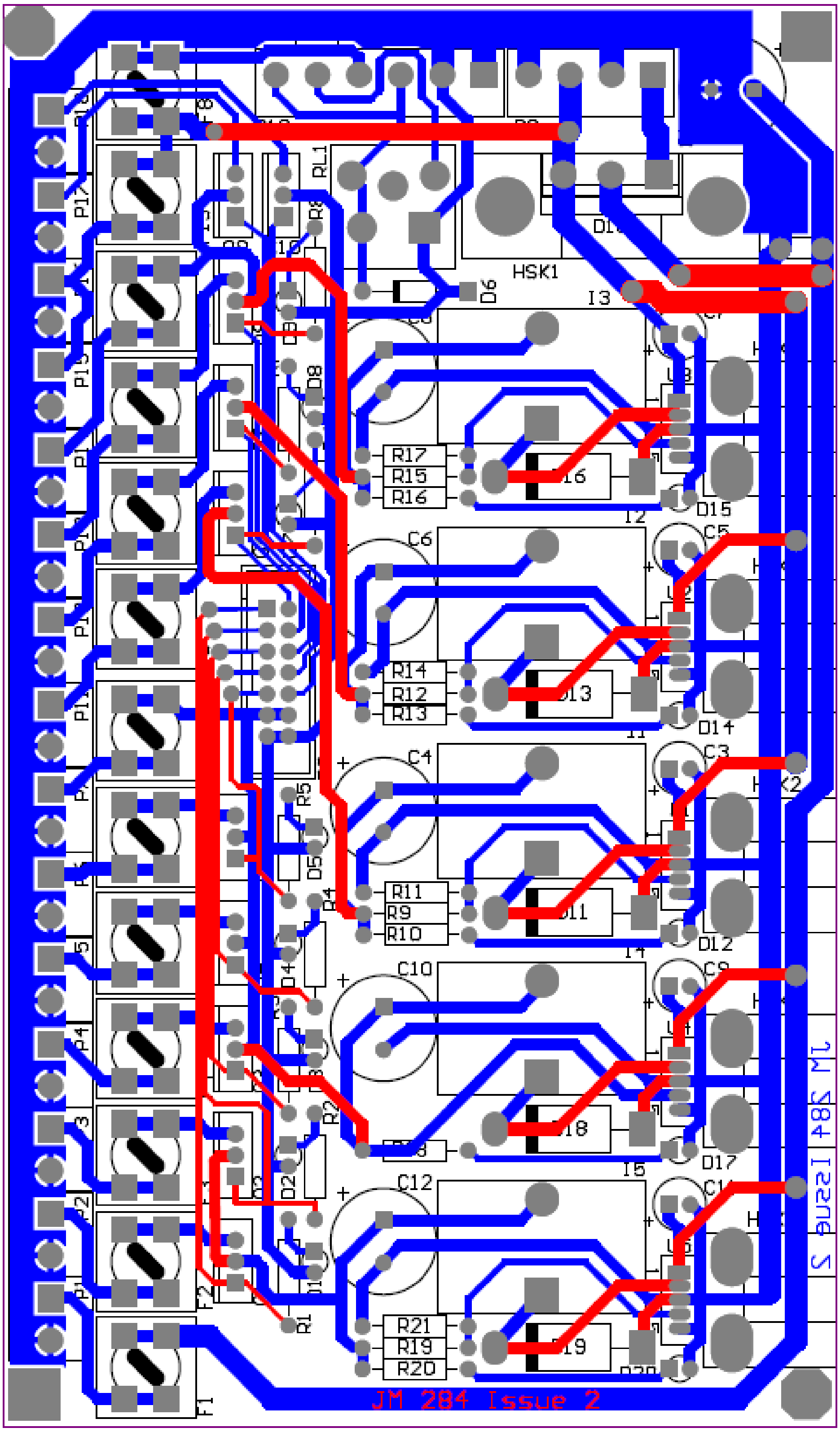


HSK5
12.9 C/W
12.9 C/W TO220
+24
VCC
C9
100uF
U4
IN
ON/OFF
GND
FB
OUT
LM2576HVT-5.0
I4
150uH
D18
MBR360
R18
220R
C10
1000uF
D17
3mm led
GND



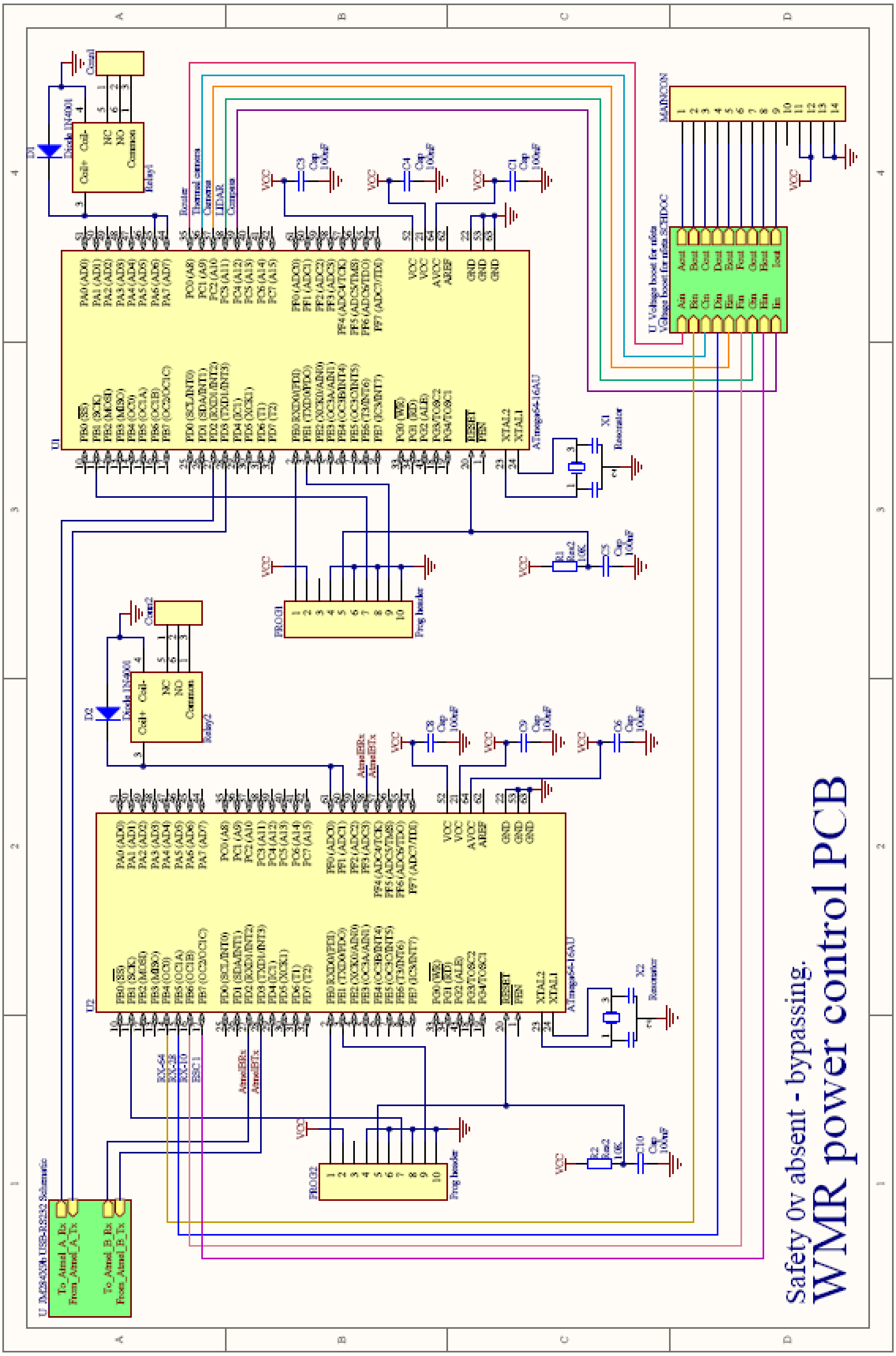
Note: Schematics above drawn by Mr Jonathan Meadows

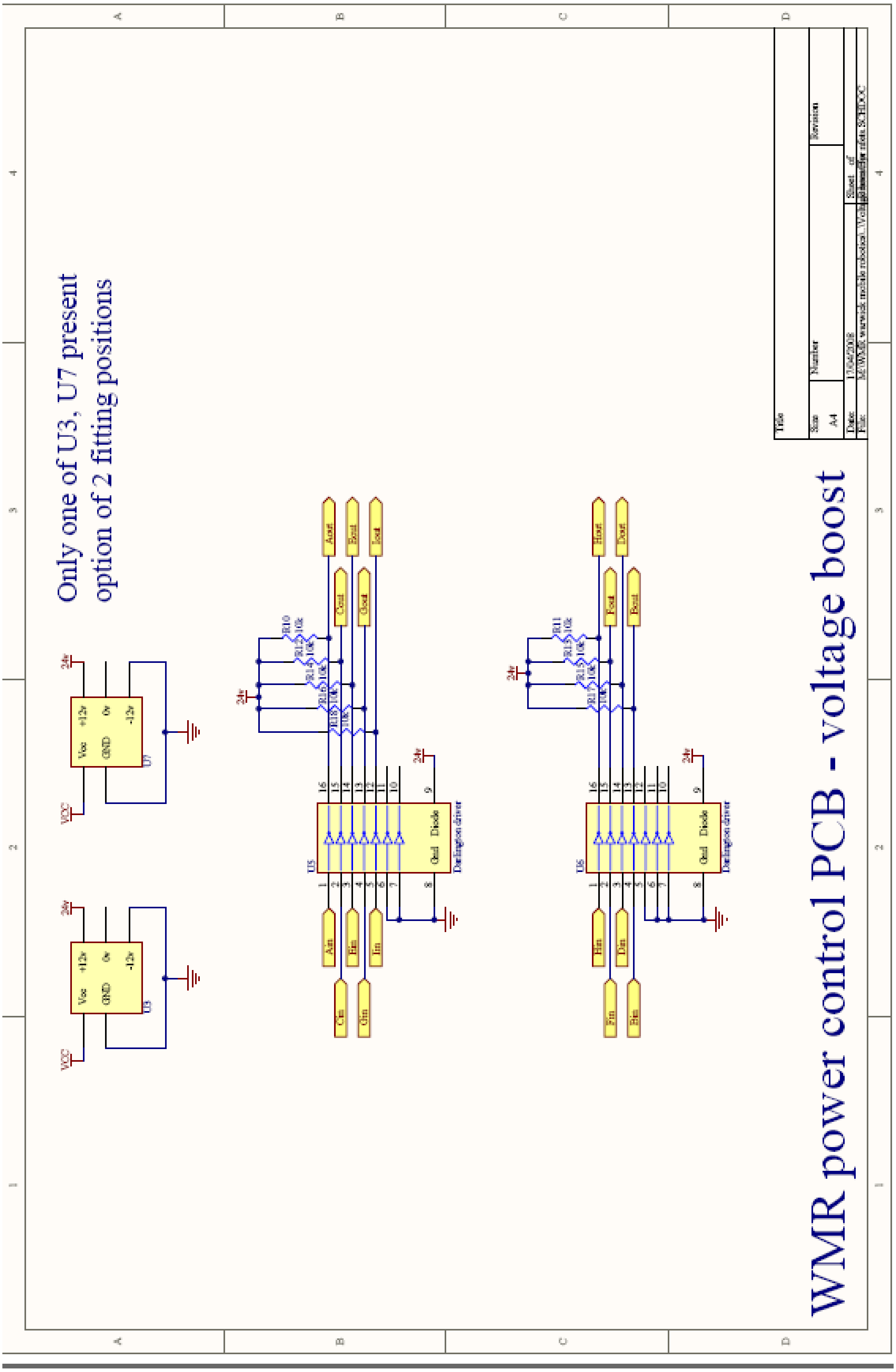
15.7.14 APPENDIX E14: POWER CONTROL PCB LAYOUT

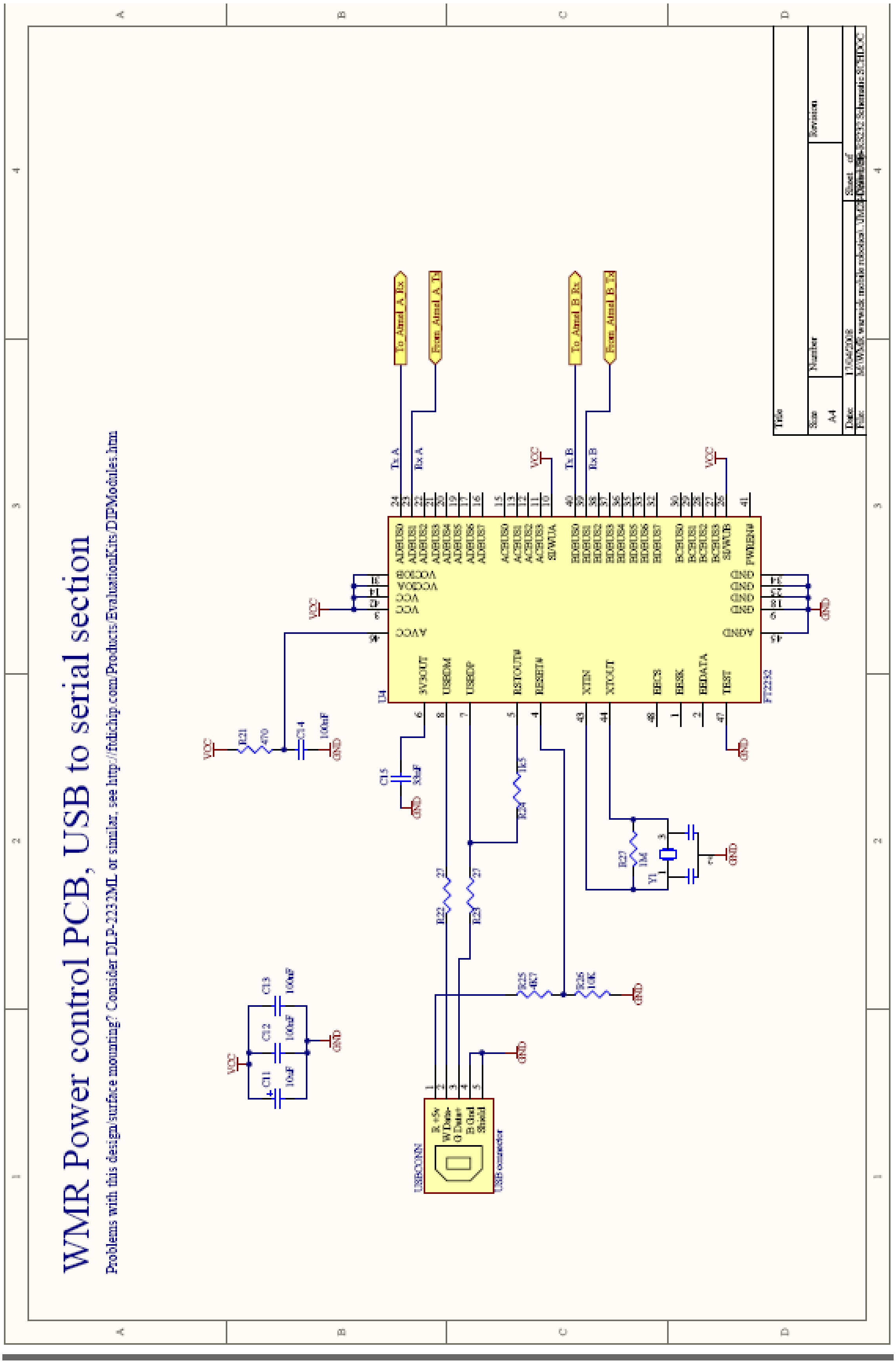


Note: Above footprint drawn by Mr Jonathan Meadows

15.7.15 APPENDIX E15: MICROCONTROLLER NEW SCHEMATIC



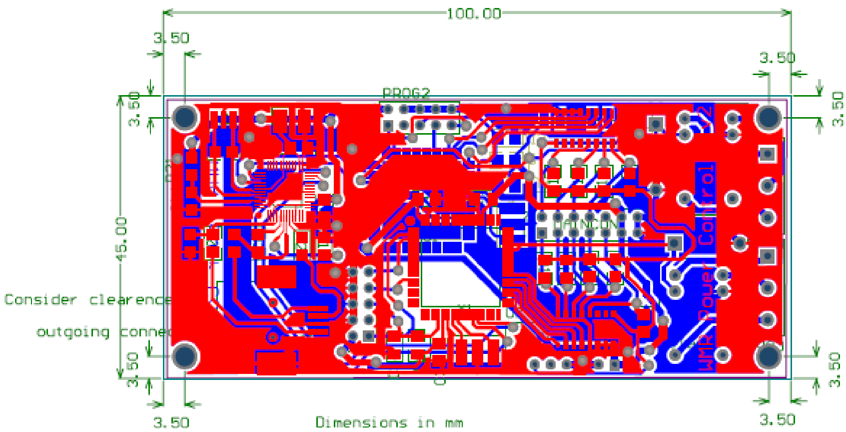

Only one of U3, U7 present
option of 2 fitting positions
WMR power control PCB - voltage boost
VCC
24v
Vcc
+12v
GND
0v
-12v
U3
U7
U5
U6
Darlington driver
Gnd
Diode
Ain
Bin
Cin
Din
Ein
Fin
Gin
Hin
Iin
Aout
Bout
Cout
Dout
Eout
Fout
Gout
Hout
Iout
R10
R11
R12
R13
R14
R15
R16
R17
R18
10k
Title
Size
A4
Number
Revision
Date:
17/04/2008
Sheet of
File:



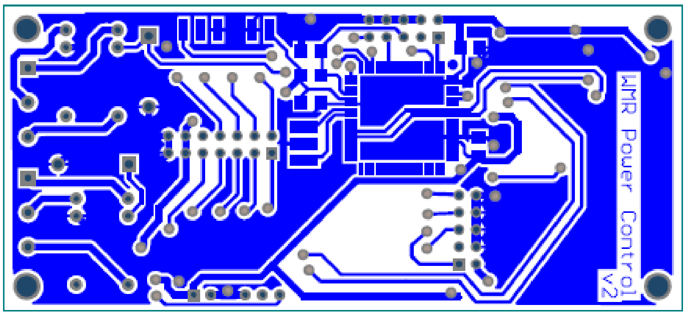
Note: Above schematics drawn by Mr Michael Tandy

15.7.16 APPENDIX E16:MICROCONTROLLER PCB LAYOUT

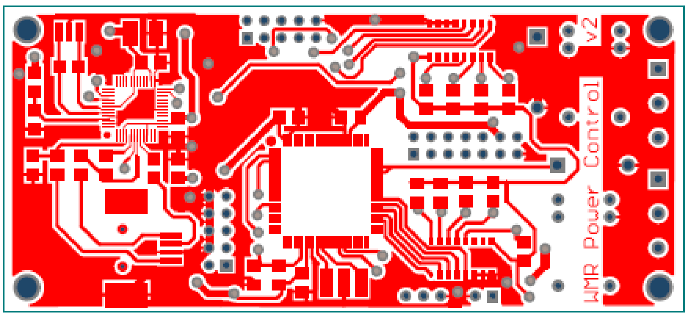
VIEW FROM TOP SIDE



VIEW FROM BOTTOM SIDE



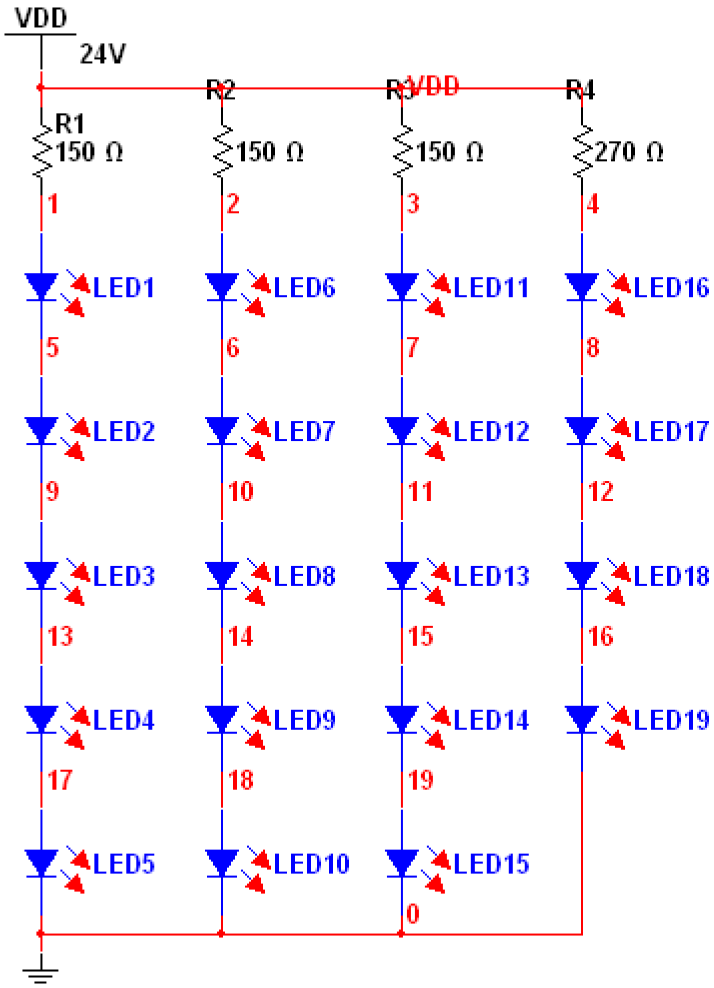
VIEW FROM TOP SIDE



Note: Above footprints drawn by Mr Michael Tandy

15.7.17 APPENDIX E17: LED DESIGNS AND CALCULATIONS

The front headlights of the robot consist of 19 LEDs, which are arranged as shown in the circuit diagram below.



These LEDs have a forward voltage of 4.0 V and a forward current of 30 mA. The resistor values are calculated as follows:

For 5 LEDs in series:

$$R = \frac{V}{I}$$

$$R = \frac{24 - (5 \times 4)}{0.03}$$

$$R = 133\ \Omega$$

The nearest standard value above 133 Ω is selected; 150 Ω.

This gives a power rating across the resistor of:

$$P = IV$$

$$P = 0.03 \times (24 - (5 \times 4))$$

$$P = 0.12\ W$$

For 4 LEDs in series:

$$R = \frac{V}{I}$$

$$R = \frac{24 - (4 \times 4)}{0.03}$$

$$R = 266\ \Omega$$

The nearest standard value above 266 Ω is selected; 270 Ω.

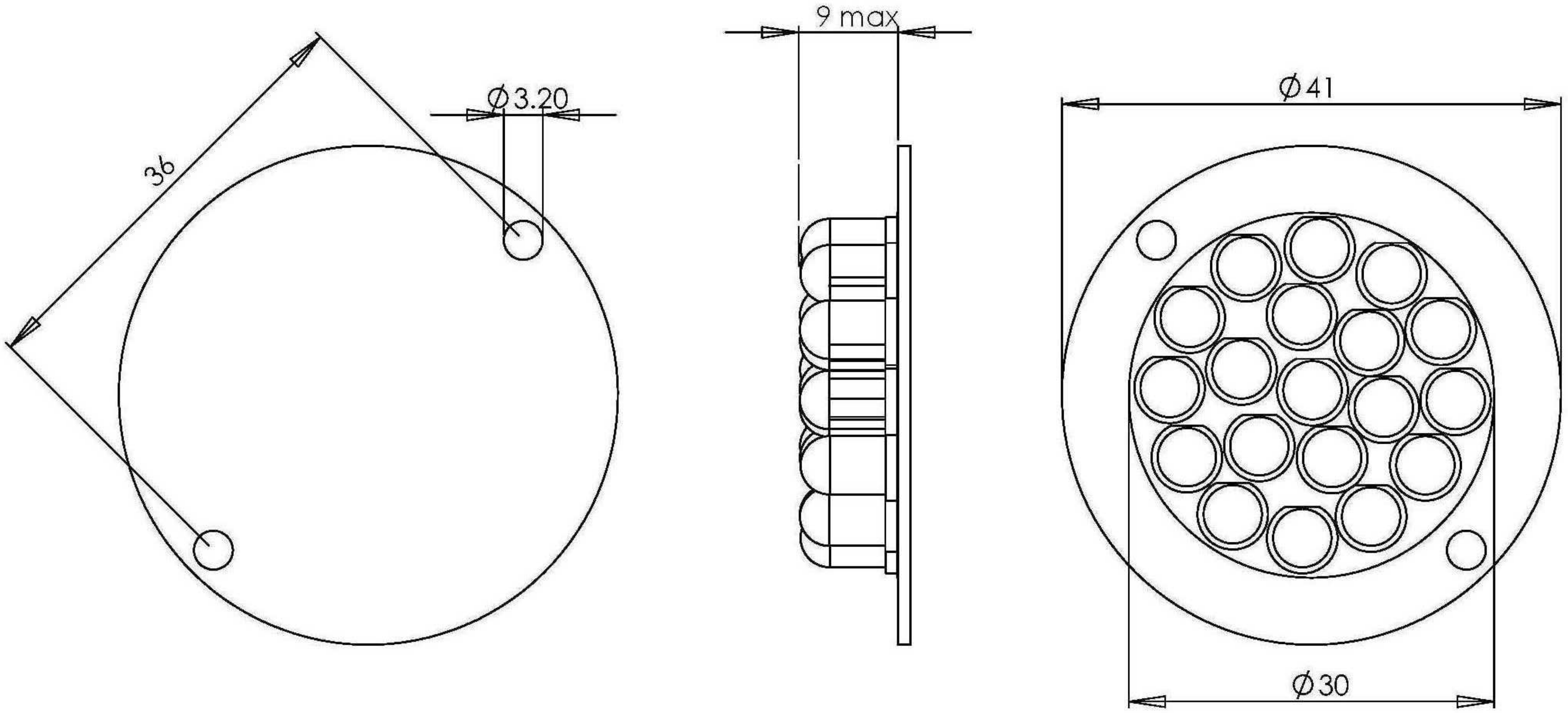
This gives a power rating across the resistor of:

$$P = IV$$

$$P = 0.03 \times (24 - (4 \times 4))$$

$$P = 0.24\ W$$

The drawing on the following page shows the arrangement of the array in each of the headlights.



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

Warwick Mobile Robotics

	NAME	SIGNATURE	DATE
DRAWN	A. J. Smith		11.03.08
CHK'D	R.J. Sanders		
APPV'D			
MFG			
Q.A			

MATERIAL:

WEIGHT:

TITLE:

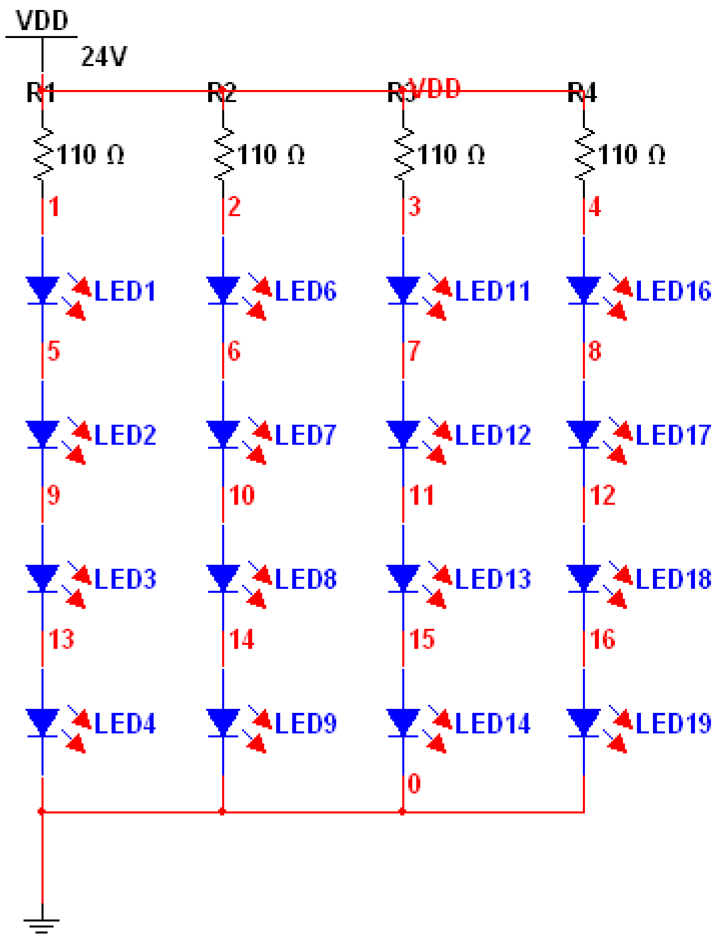
DWG NO. **LED Array**

A4

SCALE:2:1

SHEET 1 OF 1

The robot arm array consists of 16 LEDs in the following arrangement:



It can be found from the datasheet that the forward voltage is 5.2 V and the forward current is 50 mA. This results in the following resistor and power calculations:

$$R = \frac{V}{I}$$

$$R = \frac{24 - (4 \times 5.2)}{0.03}$$

$$R = 107\,\Omega$$

The nearest standard value above 107 Ω is selected; 110 Ω.

This gives a power rating across the resistor of:

$$P = IV$$

$$P = 0.03 \times (24 - (4 \times 5.2))$$

$$P = 0.096\,W$$

15.7.18 APPENDIX E18: ROTARY ENCODER TEST RESULTS

The following table shows the results obtained when testing various angles of the rotary encoder. This test was performed on two separate occasions.

	Test 1	**Test 2**
0	0.234	0.233
1	0.245	-
2	0.258	-
3	0.271	-
4	0.284	-
5	0.296	-
6	0.309	-
7	0.322	-
8	0.334	-
9	0.346	-
10	0.359	0.365
11	0.37	-
12	0.382	-
13	0.394	-
14	0.405	-
15	0.416	-
16	0.428	-
17	0.44	-
18	0.45	-
19	0.461	-
20	0.472	0.492
21	0.485	-
22	0.495	-
23	0.506	-
24	0.517	-
25	0.527	-
26	0.538	-
27	0.55	-
28	0.56	-
29	0.571	-
30	0.581	0.62
31	-	-
32	-	-
33	-	-
34	-	-
35	-	-
36	-	-
37	-	-

38	-	-
39	-	-
40	-	0.746
41	-	-
42	-	-
43	-	-
44	-	-
45	-	-
46	-	-
47	-	-
48	-	-
49	-	-
50	-	0.87
51	-	-
52	-	-
53	-	-
54	-	-
55	-	-
56	-	-
57	-	-
58	-	-
59	-	-
60	-	0.989
61	-	-
62	-	-
63	-	-
64	-	-
65	-	-
66	-	-
67	-	-
68	-	-
69	-	-
70	-	1.104
71	-	-
72	-	-
73	-	-
74	-	-
75	-	-
76	-	-
77	-	-
78	-	-
79	-	-
80	-	1.215
81	-	-

82	-	-
83	-	-
84	-	-
85	-	-
86	-	-
87	-	-
88	-	-
89	-	-
90	1.x2	1.332
91	1.21	-
92	1.221	-
93	1.232	-
94	1.243	-
95	1.255	-
96	1.265	-
97	1.275	-
98	1.289	-
99	1.299	-
100	1.311	1.444
101	1.322	-
102	1.334	-
103	1.343	-
104	1.355	-
105	1.366	-
106	1.379	-
107	1.39	-
108	1.4	-
109	1.411	-
110	1.426	1.557
111	1.436	-
112	1.449	-
113	1.46	-
114	1.471	-
115	1.483	-
116	1.495	-
117	1.508	-
118	1.521	-
119	1.533	-
120	1.547	1.678
121	-	-
122	-	-
123	-	-
124	-	-
125	-	-

126	-	-
127	-	-
128	-	-
129	-	-
130	-	1.796
131	-	-
132	-	-
133	-	-
134	-	-
135	-	-
136	-	-
137	-	-
138	-	-
139	-	-
140	-	1.917
141	-	-
142	-	-
143	-	-
144	-	-
145	-	-
146	-	-
147	-	-
148	-	-
149	-	-
150	-	2.04
151	-	-
152	-	-
153	-	-
154	-	-
155	-	-
156	-	-
157	-	-
158	-	-
159	-	-
160	-	2.16
161	-	-
162	-	-
163	-	-
164	-	-
165	-	-
166	-	-
167	-	-
168	-	-
169	-	-

170	-	2.29
171	-	-
172	-	-
173	-	-
174	-	-
175	-	-
176	-	-
177	-	-
178	-	-
179	-	-
180	2.36	2.41
181	2.37	-
182	2.38	-
183	2.39	-
184	2.4	-
185	2.42	-
186	2.43	-
187	2.44	-
188	2.46	-
189	2.47	-
190	2.48	2.54
191	2.5	-
192	2.51	-
193	2.52	-
194	2.53	-
195	2.55	-
196	2.56	-
197	2.57	-
198	2.58	-
199	2.59	-
200	2.6	2.67
201	2.61	-
202	2.63	-
203	2.64	-
204	2.65	-
205	2.66	-
206	2.67	-
207	2.69	-
208	2.7	-
209	2.71	-
210	2.72	2.79
211	-	-
212	-	-
213	-	-

214	-	-
215	-	-
216	-	-
217	-	-
218	-	-
219	-	-
220	-	2.91
221	-	-
222	-	-
223	-	-
224	-	-
225	-	-
226	-	-
227	-	-
228	-	-
229	-	-
230	-	3.03
231	-	-
232	-	-
233	-	-
234	-	-
235	-	-
236	-	-
237	-	-
238	-	-
239	-	-
240	-	3.15
241	-	-
242	-	-
243	-	-
244	-	-
245	-	-
246	-	-
247	-	-
248	-	-
249	-	-
250	-	3.27
251	-	-
252	-	-
253	-	-
254	-	-
255	-	-
256	-	-
257	-	-

258	-	-
259	-	-
260	-	3.38
261	-	-
262	-	-
263	-	-
264	-	-
265	-	-
266	-	-
267	-	-
268	-	-
269	-	-
270	3.38	3.49
271	3.39	-
272	3.4	-
273	3.41	-
274	3.42	-
275	3.43	-
276	3.45	-
277	3.46	-
278	3.47	-
279	3.48	-
280	3.49	3.6
281	3.51	-
282	3.52	-
283	3.53	-
284	3.54	-
285	3.55	-
286	3.57	-
287	3.58	-
288	3.59	-
289	3.6	-
290	3.61	3.72
291	3.63	-
292	3.64	-
293	3.66	-
294	3.67	-
295	3.68	-
296	3.69	-
297	3.71	-
298	3.72	-
299	3.73	-
300	3.75	3.83
301	-	-

302	-	-
303	-	-
304	-	-
305	-	-
306	-	-
307	-	-
308	-	-
309	-	-
310	-	3.95
311	-	-
312	-	-
313	-	-
314	-	-
315	-	-
316	-	-
317	-	-
318	-	-
319	-	-
320	-	4.07
321	-	-
322	-	-
323	-	-
324	-	-
325	-	-
326	-	-
327	-	-
328	-	-
329	-	-
330	-	4.2
331	-	-
332	-	-
333	-	-
334	-	-
335	-	-
336	-	-
337	-	-
338	-	-
339	-	-
340	-	4.32
341	-	-
342	-	-
343	-	-
344	-	-
345	-	-

346	-	-
347	-	-
348	-	-
349	-	-
350	4.44	-
351	4.45	-
352	4.46	4.45
353	4.48	-
354	4.49	-
355	4.5	-
356	4.52	-
357	4.53	-
358	4.54	-
359	4.55	4.55
360	4.55	-

15.7.19 APPENDIX E19: ANALYSIS OF COMMUNICATIONS TECHNIQUES

Condition	None	Wired	Wireless	Both
Ease of communication	No communication until end of mission; 0	Easy to transfer data over LAN; 4	Easy to set up a router and wireless network; 4	Requires integration of wireless and wired setup; 1
Bandwidth	Bandwidth not an issue; 5	100Mbps; 4	83.5MHz; 3	up to 100Mbps; 4
Resilience to Interference	Interference not an issue; 5	Interference is if cable gets caught; 3	Susceptible to RF interference; 3	Very resilient; backup present if one fails; 4
Distance	Distance the robot can travel using half its battery life, as this method relies on it returning to the start; 2	Depends on length of cable. However, Long cables have weight issues and are impractical; 2	approx 30m before significant reduction in bandwidth; 4	Either 30 m or the length of cable that can be carried by the robot (whichever is greater); 4
Reliability	Highly unreliable, as state and condition of robot is unknown until it reappears; 0	Cable will get caught going round corners, etc; 1	signal could be blocked by walls / interference; 2	Backup present so most reliable method; 3
Cost	Very cheap; 5	Cheap; 4	Moderate; 3	Most expensive option; 1
Total Score	17	18	19	17