
BOSEM Fieldbox

Circuit Board Documentation

Sean Leavey (*Max-Planck-Institut für Gravitationsphysik*)

Abstract

This circuit (BOSEM-1) provides an interface to control BOSEMs with the following features:

- Control for up to 4 BOSEMs
- Ultra low noise LED constant current drivers with ability to drive 50 mA nominally and up to 450 mA with modification of component values
- Photodiode readout with whitening and differential sending
- Coil drivers with dewhitening and differential receiving and ability to drive 50 mA nominally and up to 500 mA with modification of component values
- Digital inputs for disabling LEDs and whitening/dewhitening
- Digital outputs for LED and coil error detector circuits
- Diagnostics port

The LED error monitor checks the voltage drop across each LED. If the voltage drop is outside the 1.1..1.8 V range (configurable with resistors), an error is triggered.

The coil error monitor checks for open and short coils. When the coil is open, the coil driver rails at +/-15 V. When the coil is shorted, the coil voltage drop is close to 0. The coil error monitor therefore compares the coil voltage set point to the voltage drop across coil. Under normal operation, these are approximately equal, but when the difference drifts outside of the range -1.0..+1.0 V (configurable with resistors), an error is triggered. Note that this circuit is incapable of detecting shorts when the set point is within the range above (i.e. -1.0..+1.0 V).

All logic is active low. In normal operation, the error outputs are HIGH, and go LOW when an error is present. The !LED Disable input is nominally floating and should be brought LOW to disable the LEDs.

Proper heat sinking must be used when significant LED and coil currents are expected. Note that the voltage regulators cannot source or sink more than about 1 A total, so all four channels cannot be used at their maximum output current ratings simultaneously without using higher rated regulators.

Key words: coil led driver photodiode readout digital error switch

Safety Instructions

In order to operate the circuit properly and safely, review the following guidelines before installing and using the unit. Failure to do so may result in equipment damage or bodily injury:



This circuit warms up due to its power consumption. To enable proper cooling, observe the following rules:

- Do not block available air vents.
- Give the unit free access to the room ambient air for convection.



This circuit was designed as a laboratory equipment to be operated only by trained and qualified technicians in research institutes or development departments. For safety reasons, usage by other persons or in other environments is *not* recommended.



- This circuit uses extra-low voltage ($< 50 \text{ V}_{\text{AC}}$ and $< 75 \text{ V}_{\text{DC}}$) and is therefore exempt from the regulations of the *Low Voltage Directive* (2006/95/EC).
- The unit does not contain any mechanical drive system. Therefore, the regulations of the *Machinery Directive* (2006/42/EC) do not apply.

Sicherheitshinweise

Nehmen Sie vor Aufbau und Inbetriebnahme des Geräts folgende Empfehlungen zur Kenntnis, um die Schaltung korrekt und sicher zu betreiben sowie Schäden und Verletzungen zu vermeiden:



Diese Schaltung erwärmt sich aufgrund ihrer Verlustleistung. Zur Gewährleistung einer sinnvollen Kühlung sind folgende Punkte zu beachten:

- Vorhandene Lüftungsöffnungen nicht versperren.
- Gerät zur Konvektion freien Zugang zur Raumluft ermöglichen.



Diese Schaltung wurde als Laborausstattung entworfen, die nur von qualifizierten und eingewiesenen Technikern in Forschungsinstituten oder Entwicklungsabteilungen benutzt wird. Aus Sicherheitsgründen wird die Verwendung durch andere Personen oder in anderer Umgebung *nicht* empfohlen.

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- Diese Schaltung verwendet Kleinspannung ($< 50 \text{ V}_{\text{AC}}$ und $< 75 \text{ V}_{\text{DC}}$) und unterliegt daher nicht den Bestimmungen der *Niederspannungsrichtlinie* (2006/95/EC).
 - Das Gerät enthält kein mechanisches Antriebssystem – die Bestimmungen der *Maschinenrichtlinie* (2006/42/EC) sind daher nicht anwendbar.
-

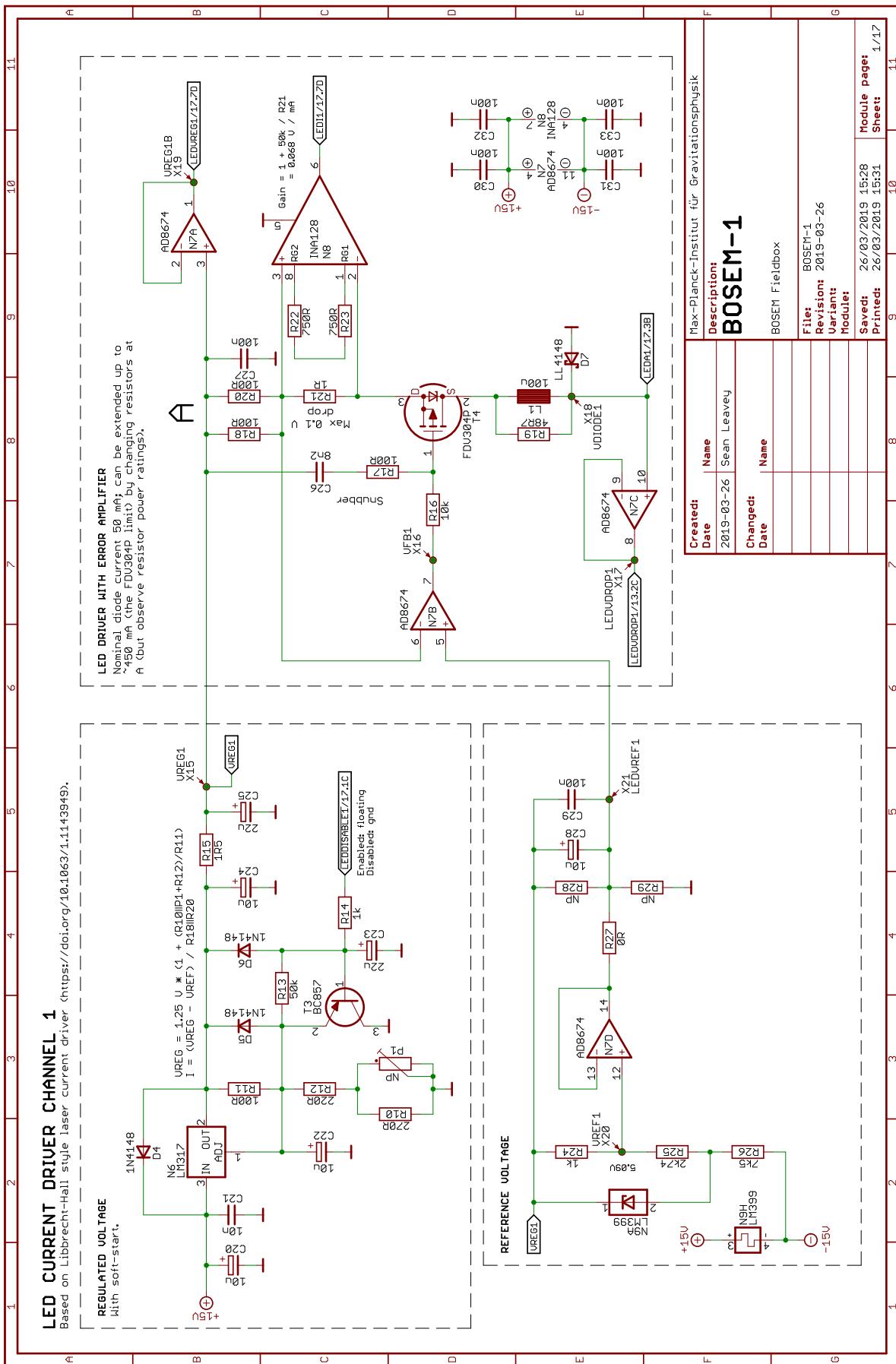


Figure 1: Project schematics (sheet 1)

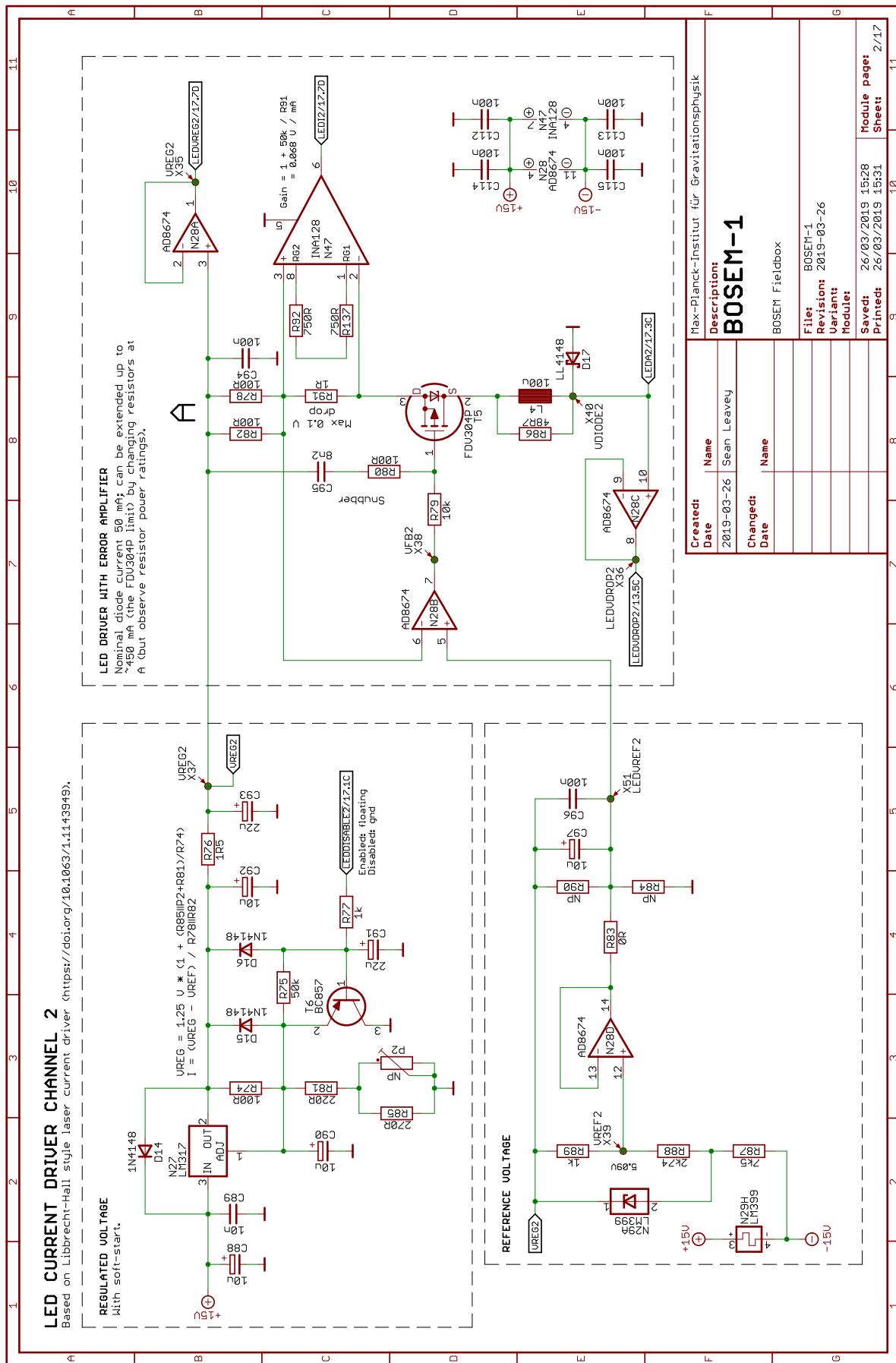


Figure 2: Project schematics (sheet 2)

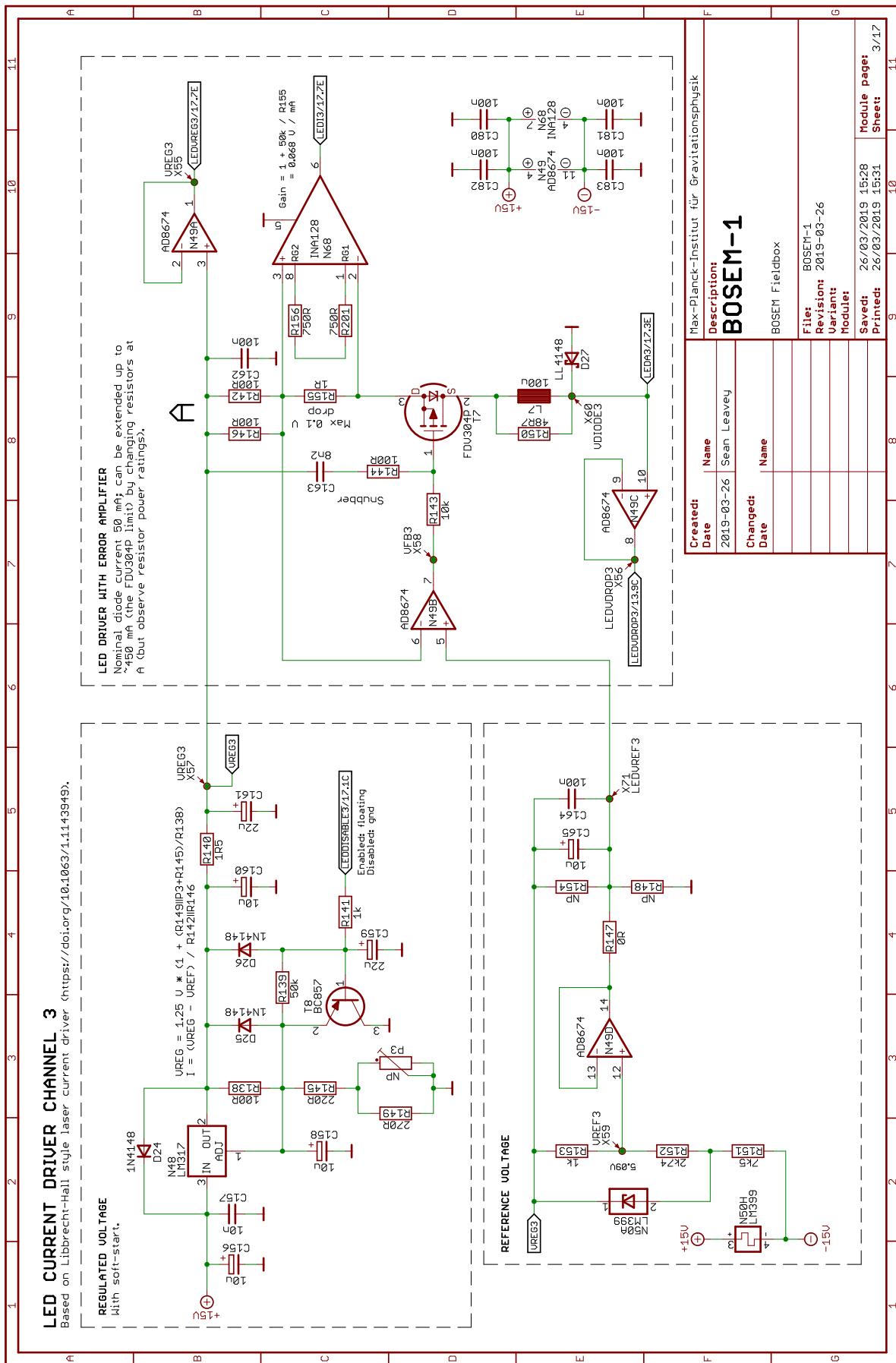


Figure 3: Project schematics (sheet 3)

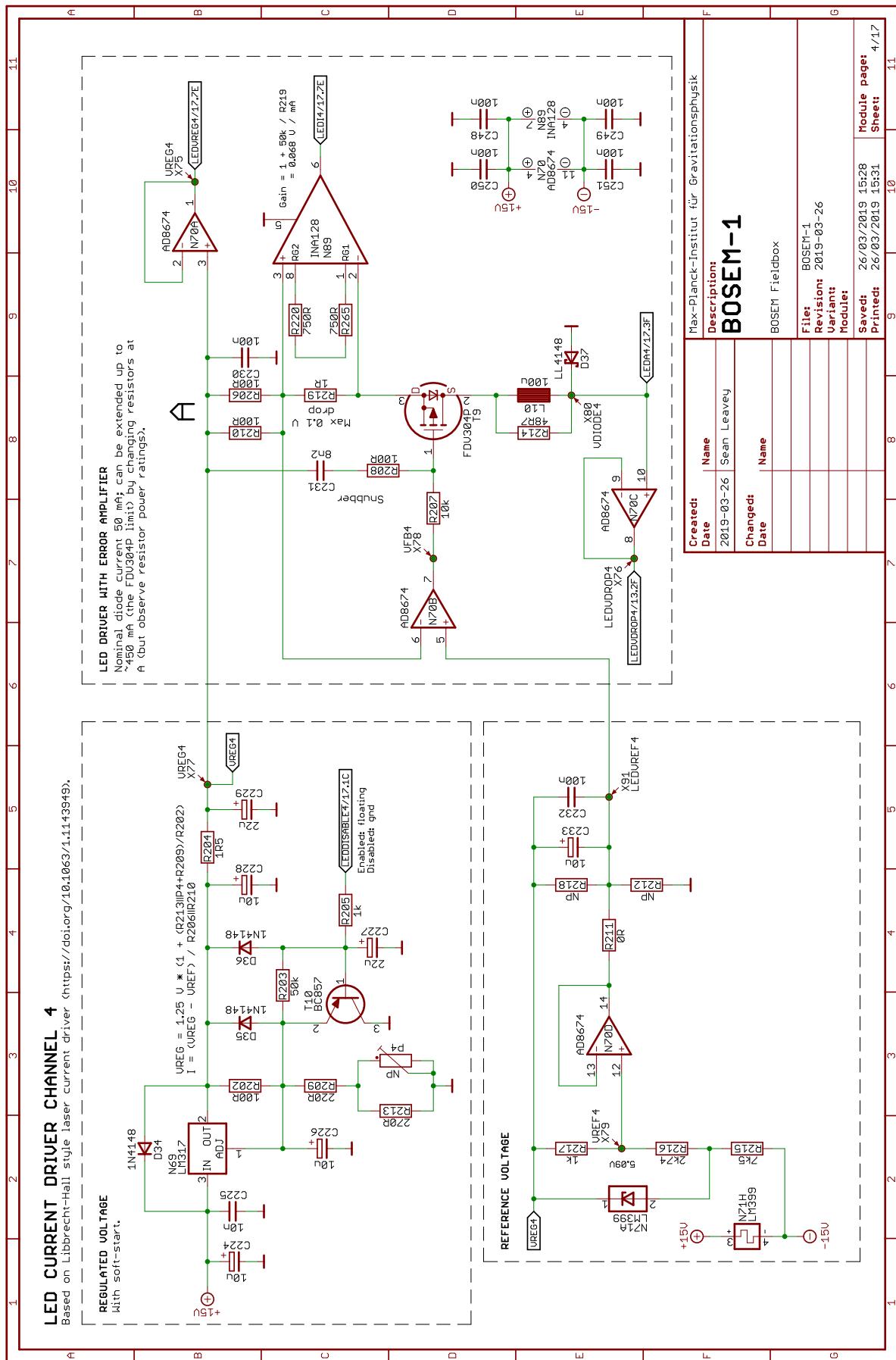


Figure 4: Project schematics (sheet 4)

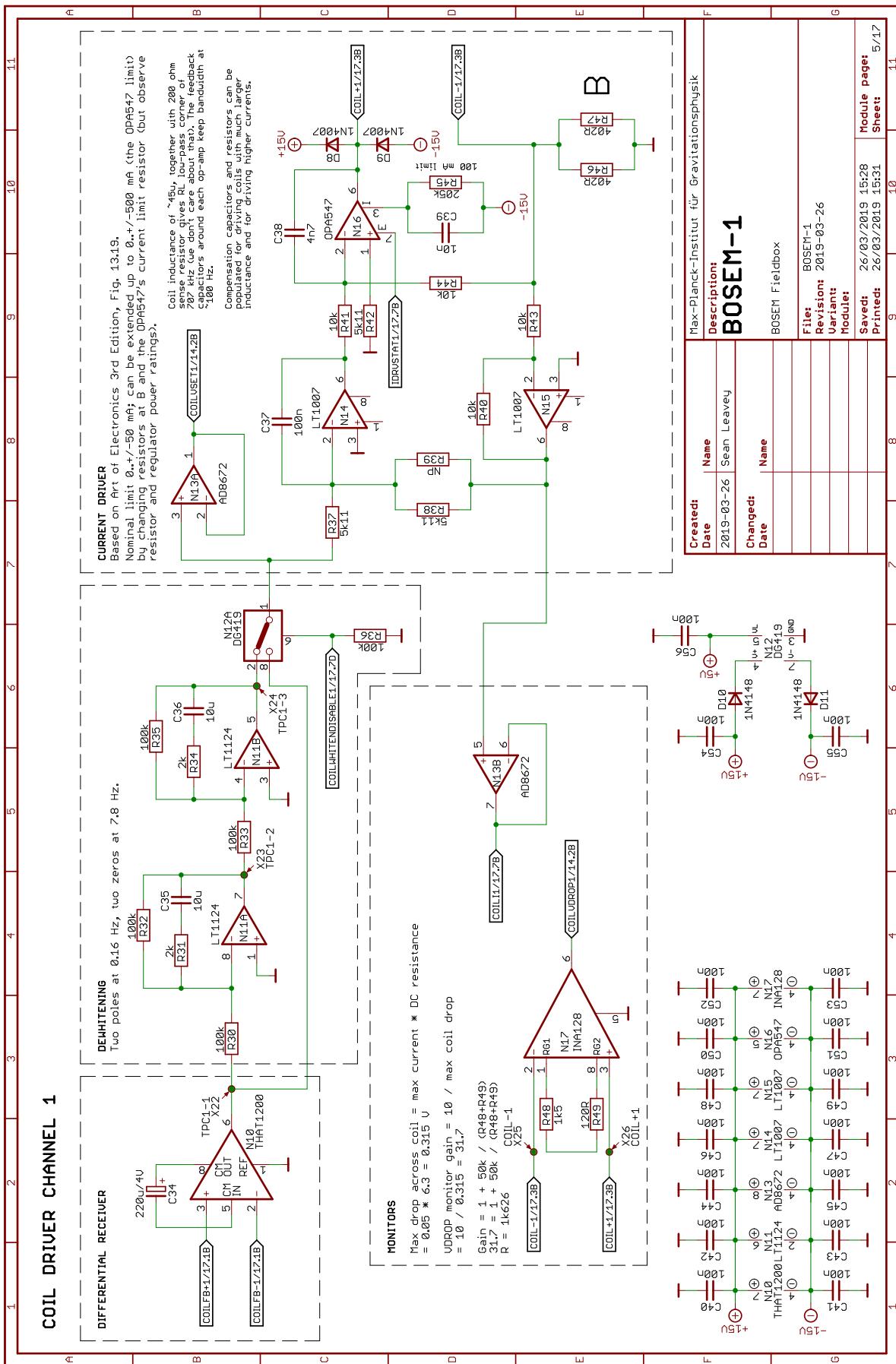


Figure 5: Project schematics (sheet 5)

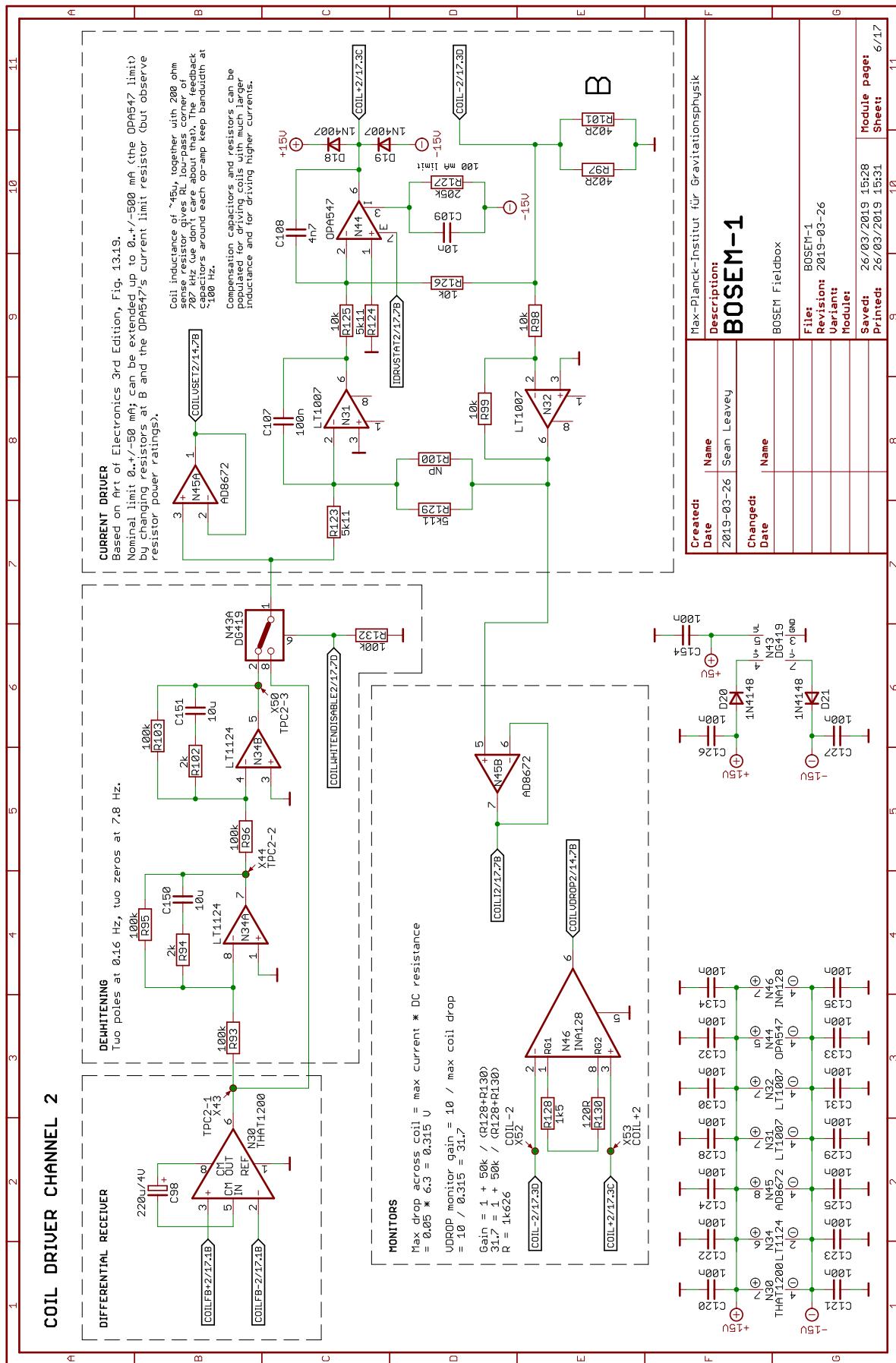


Figure 6: Project schematics (sheet 6)

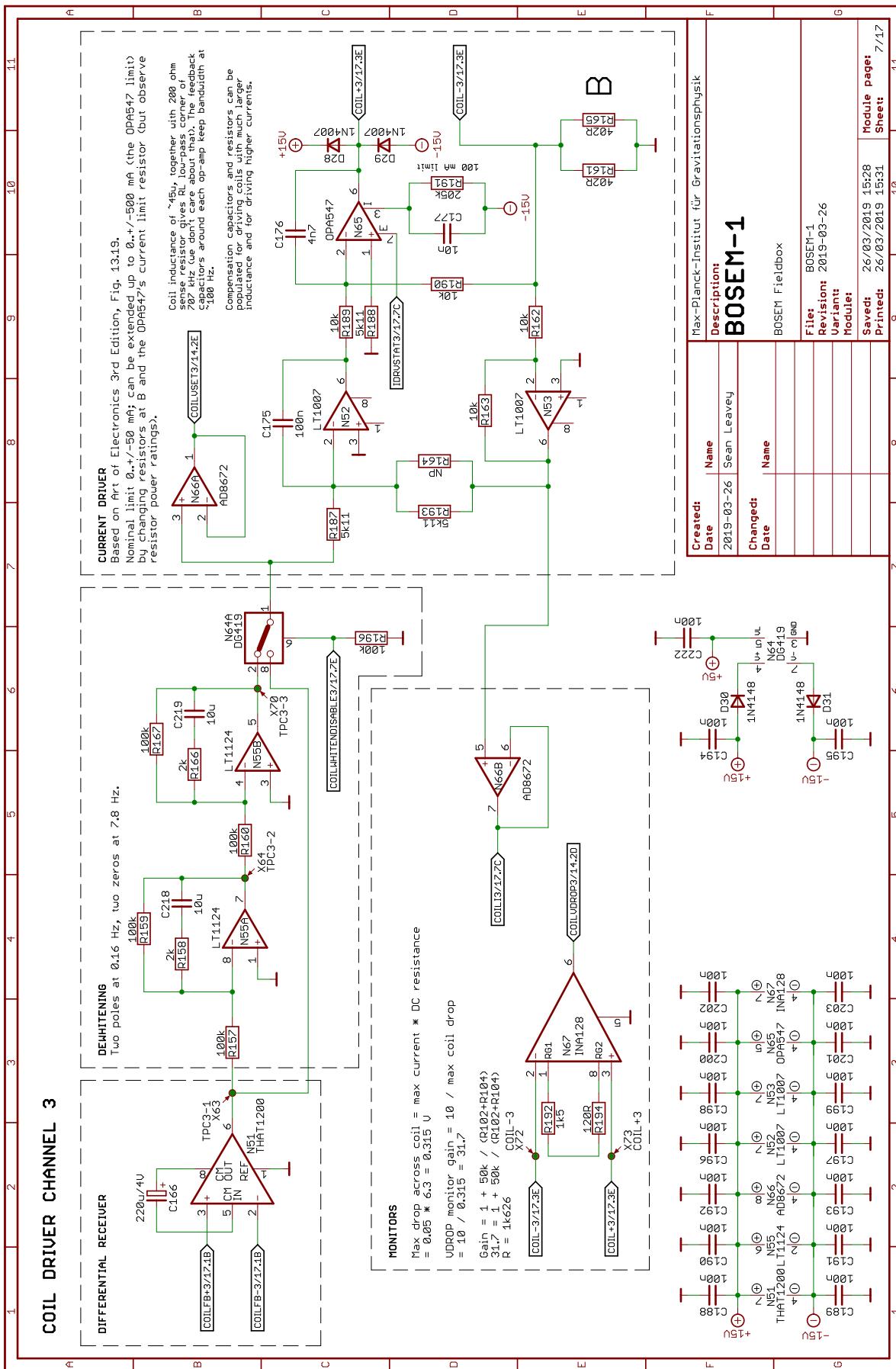


Figure 7: Project schematics (sheet 7)

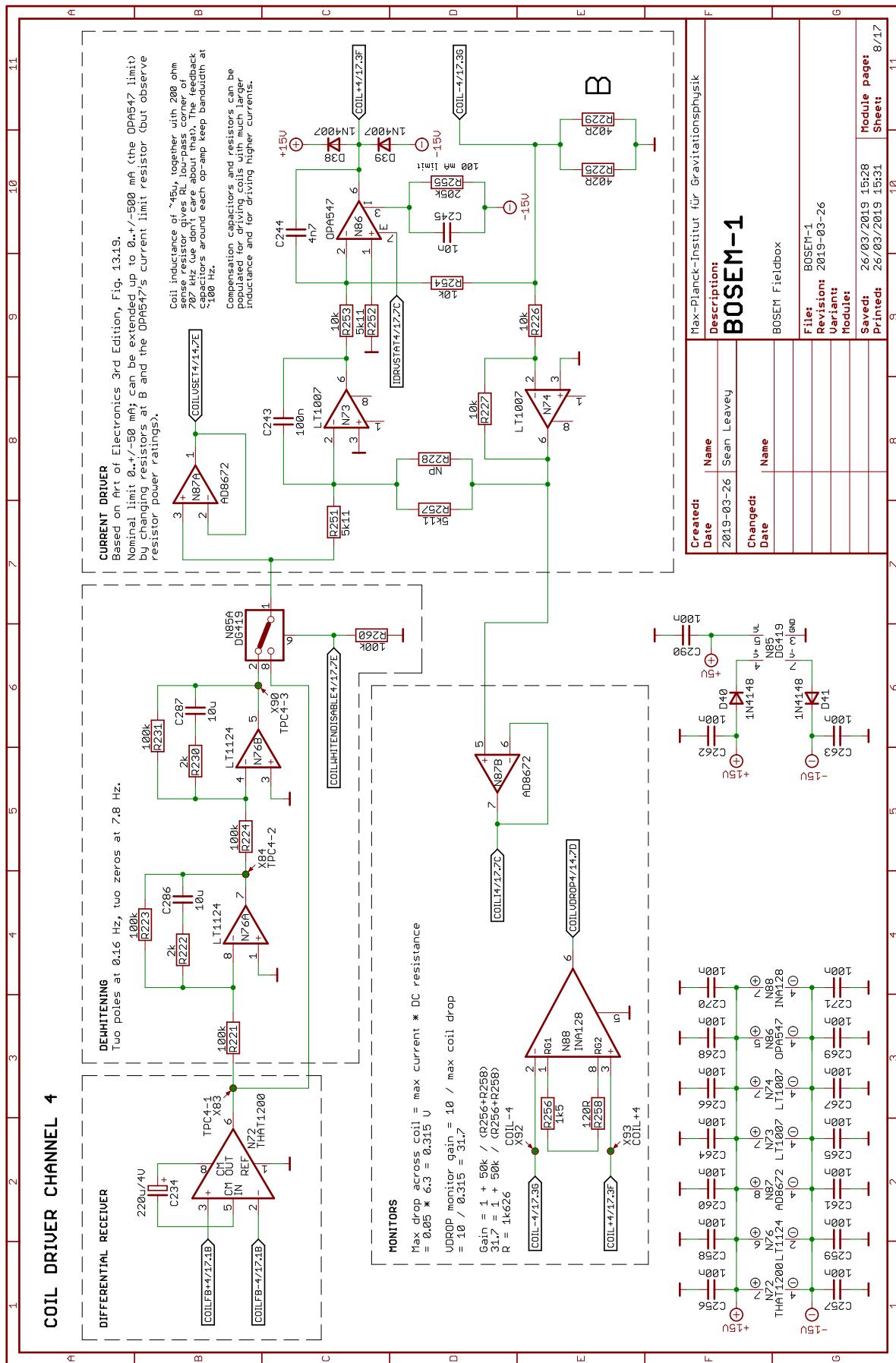


Figure 8: Project schematics (sheet 8)

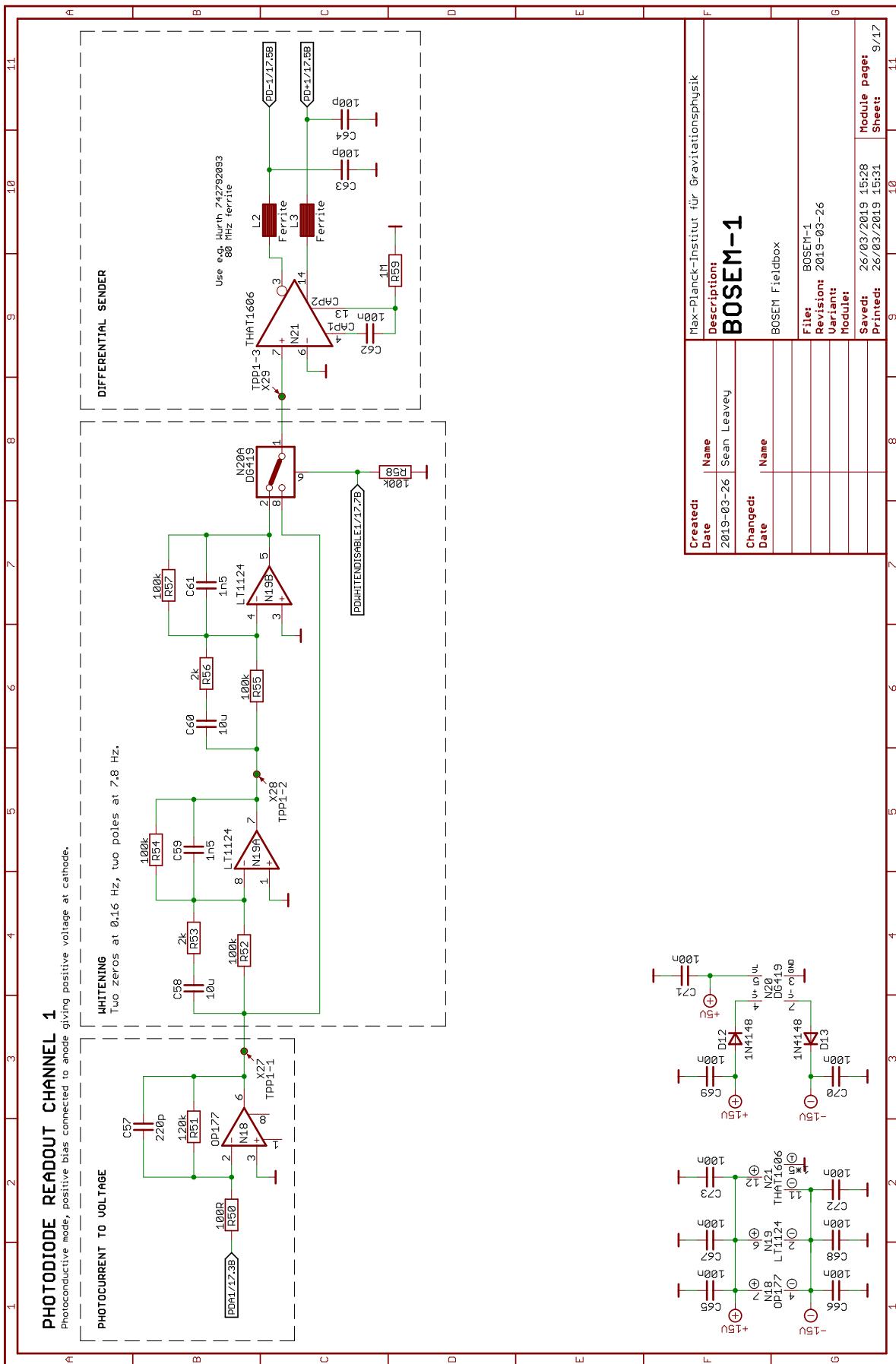


Figure 9: Project schematics (sheet 9)

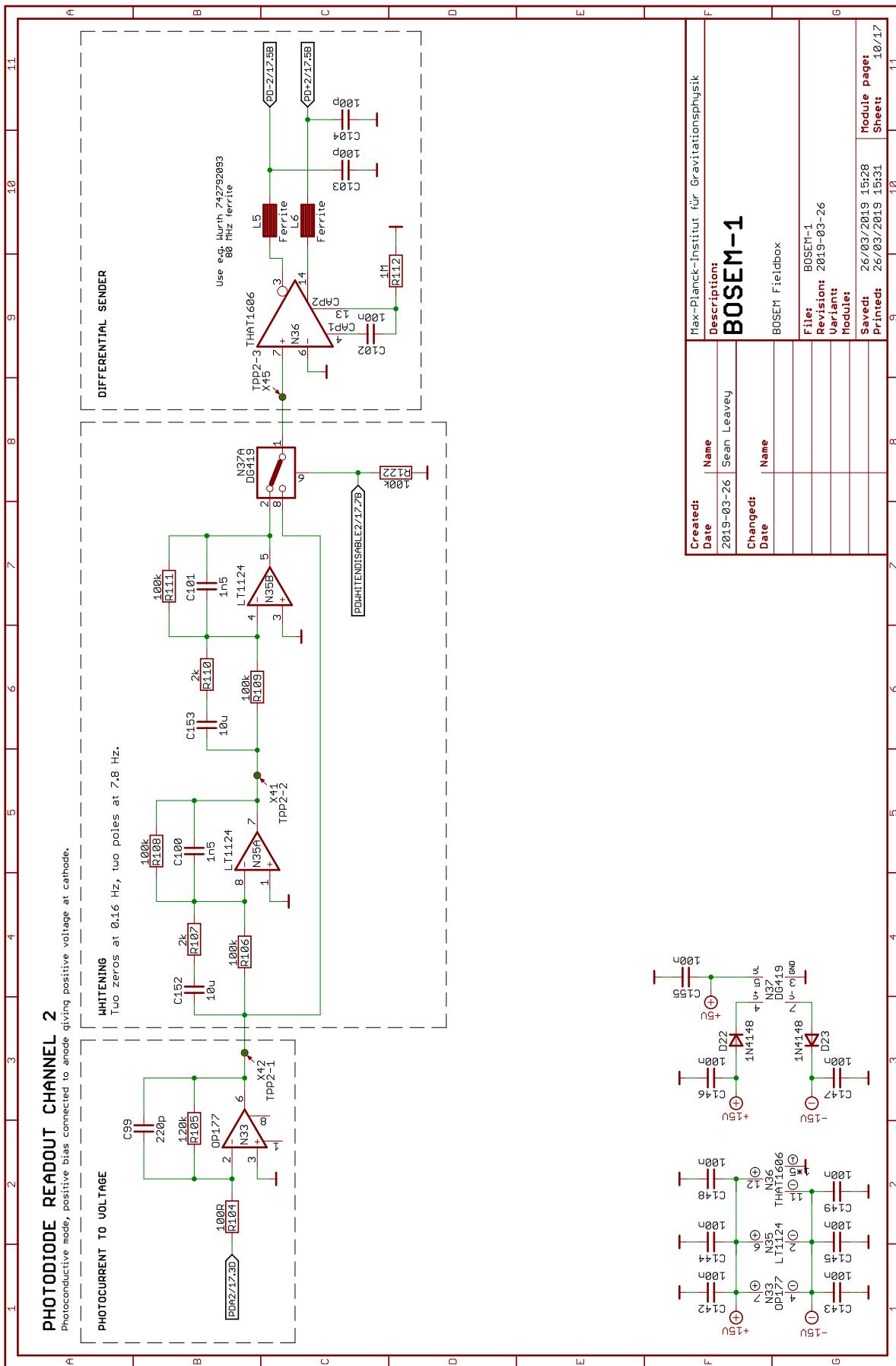


Figure 10: Project schematics (sheet 10)

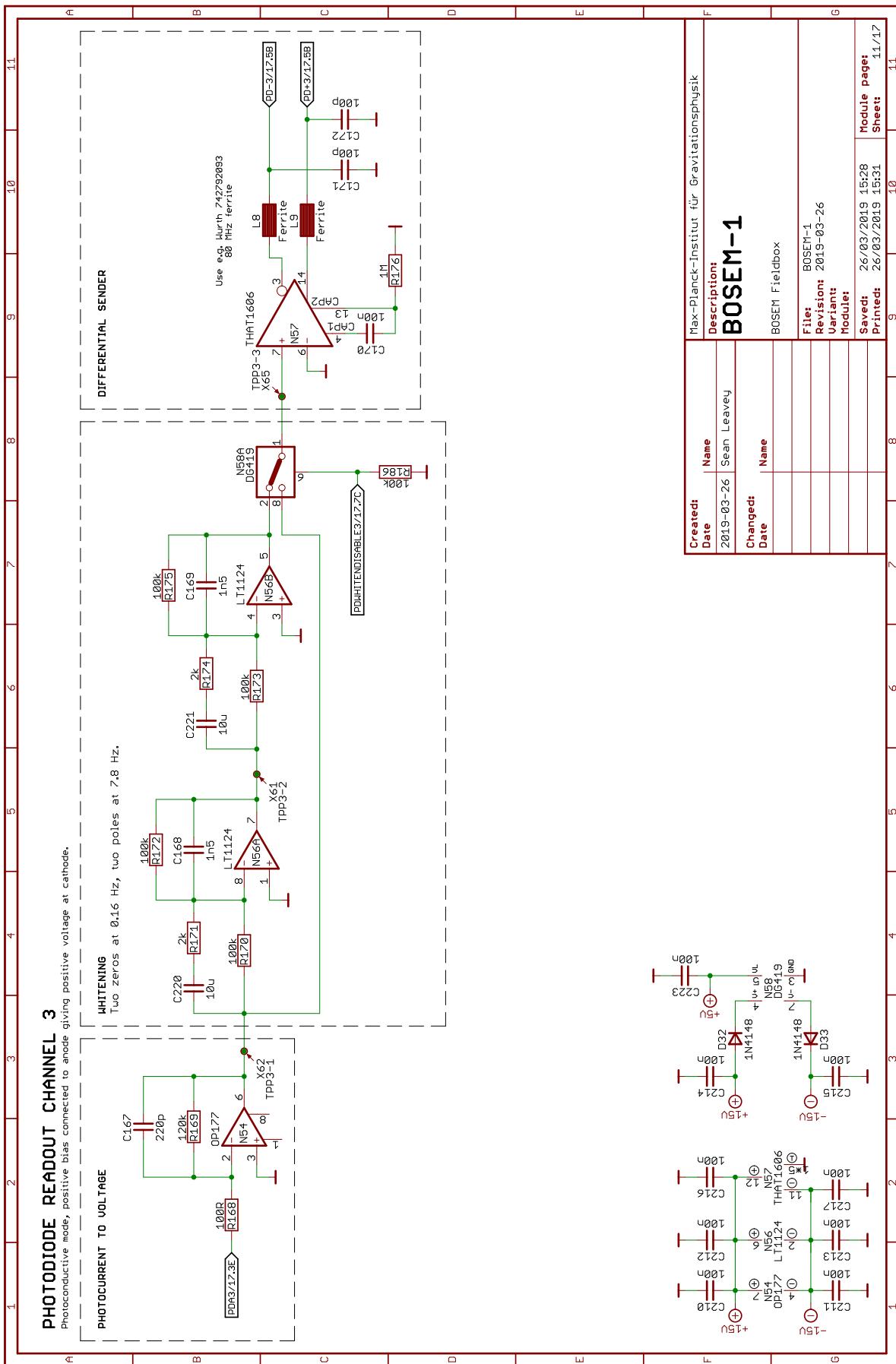


Figure 11: Project schematics (sheet 11)

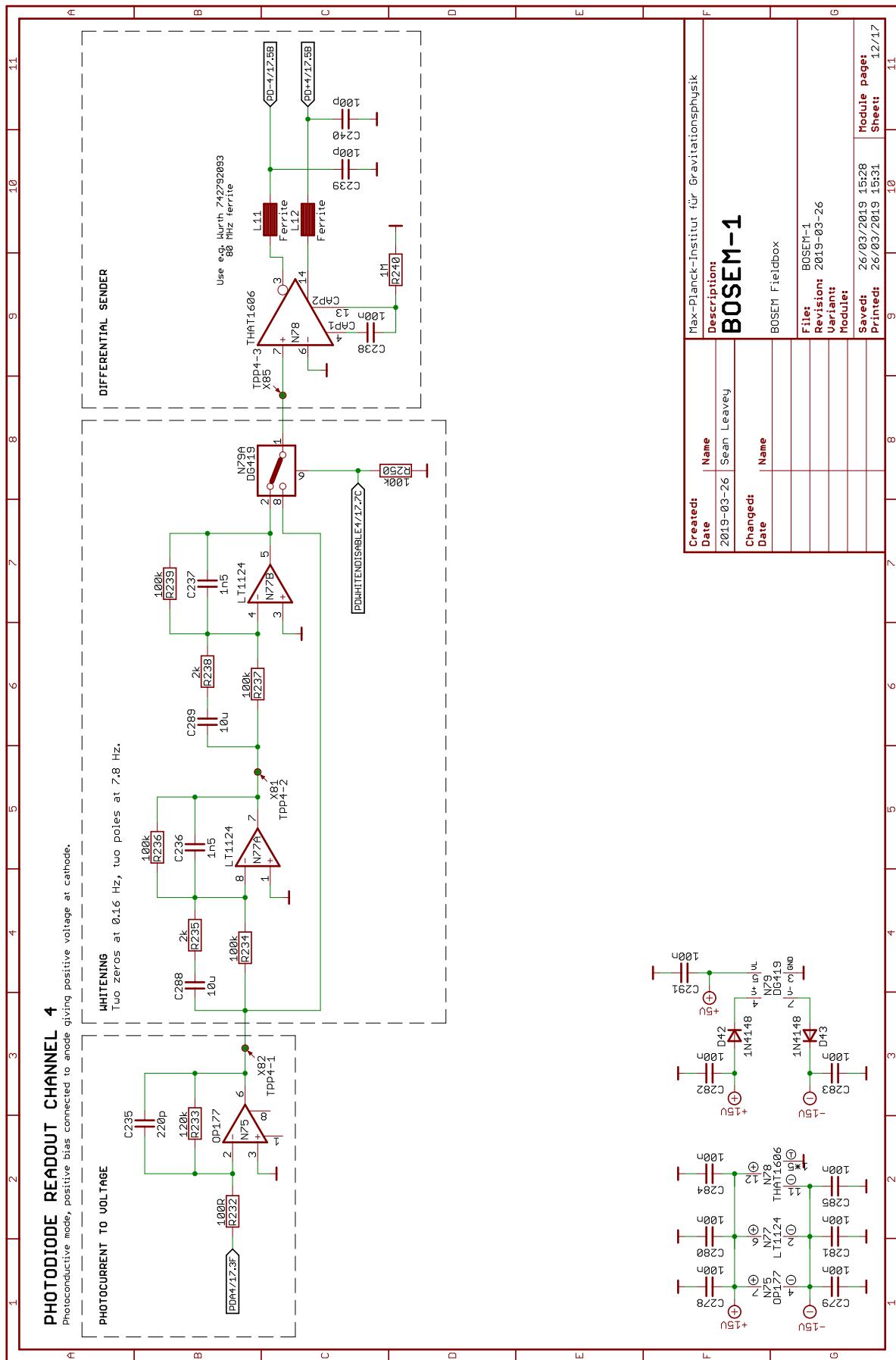


Figure 12: Project schematics (sheet 12)

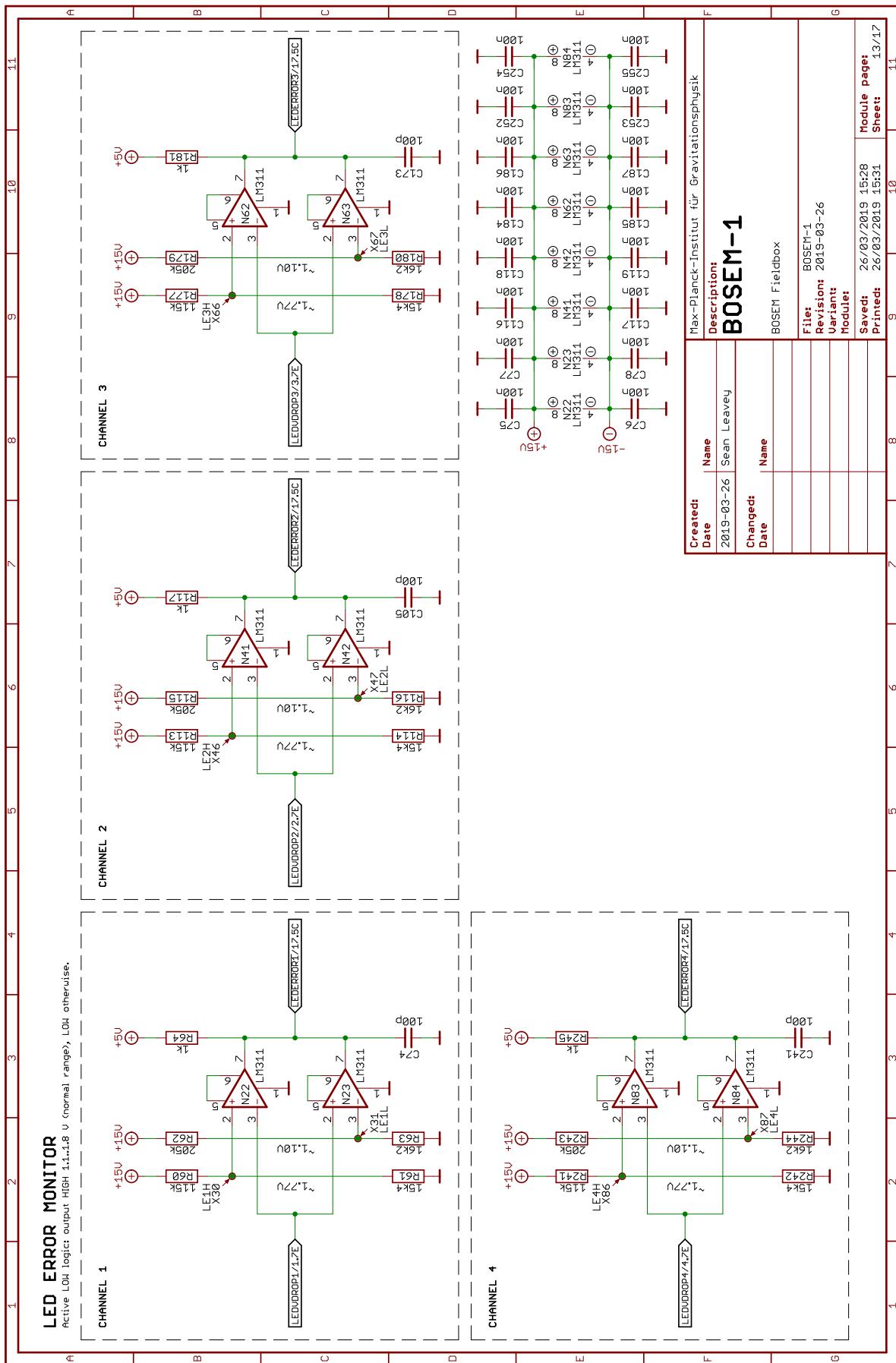


Figure 13: Project schematics (sheet 13)

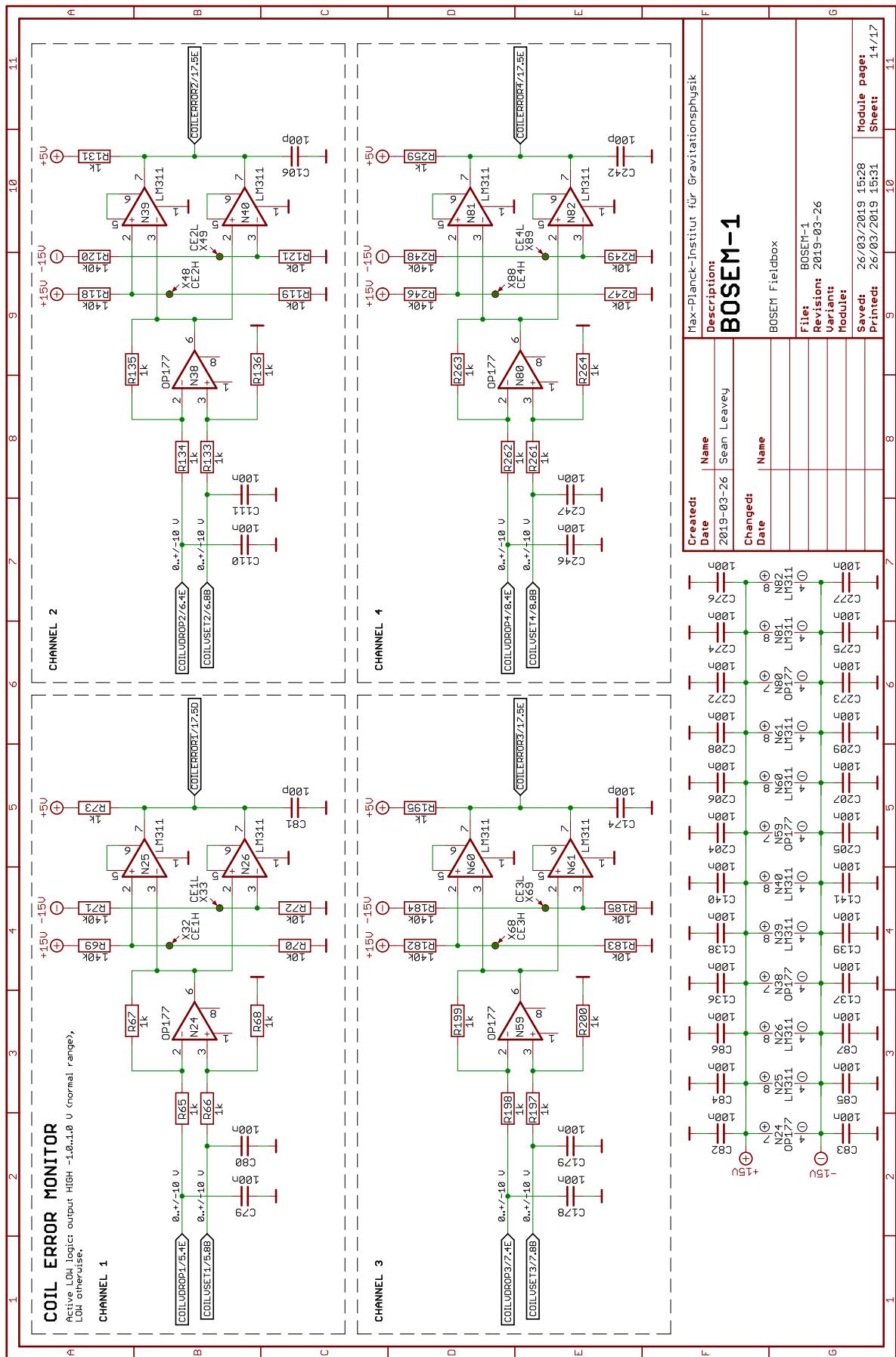


Figure 14: Project schematics (sheet 14)

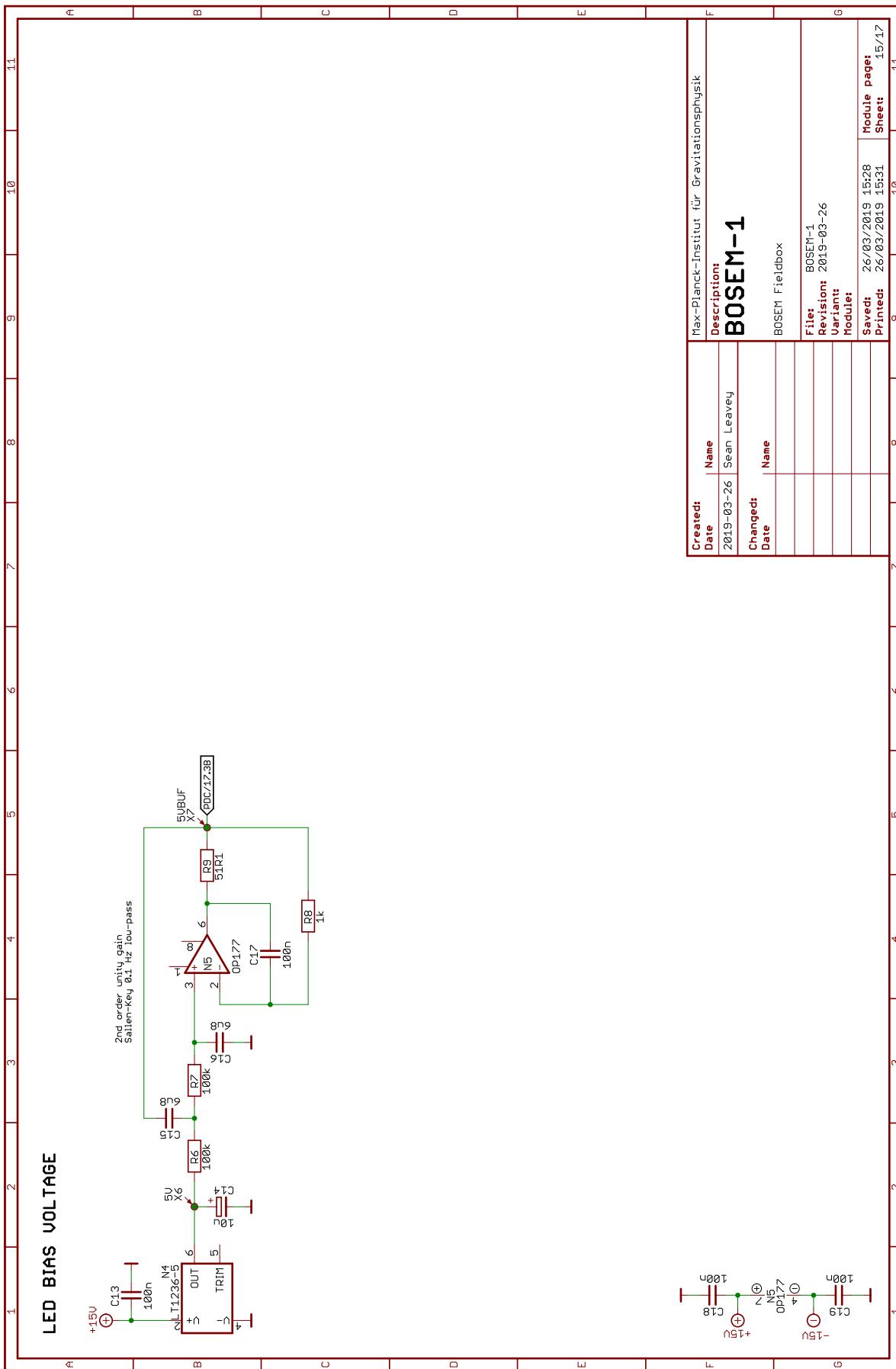


Figure 15: Project schematics (sheet 15)

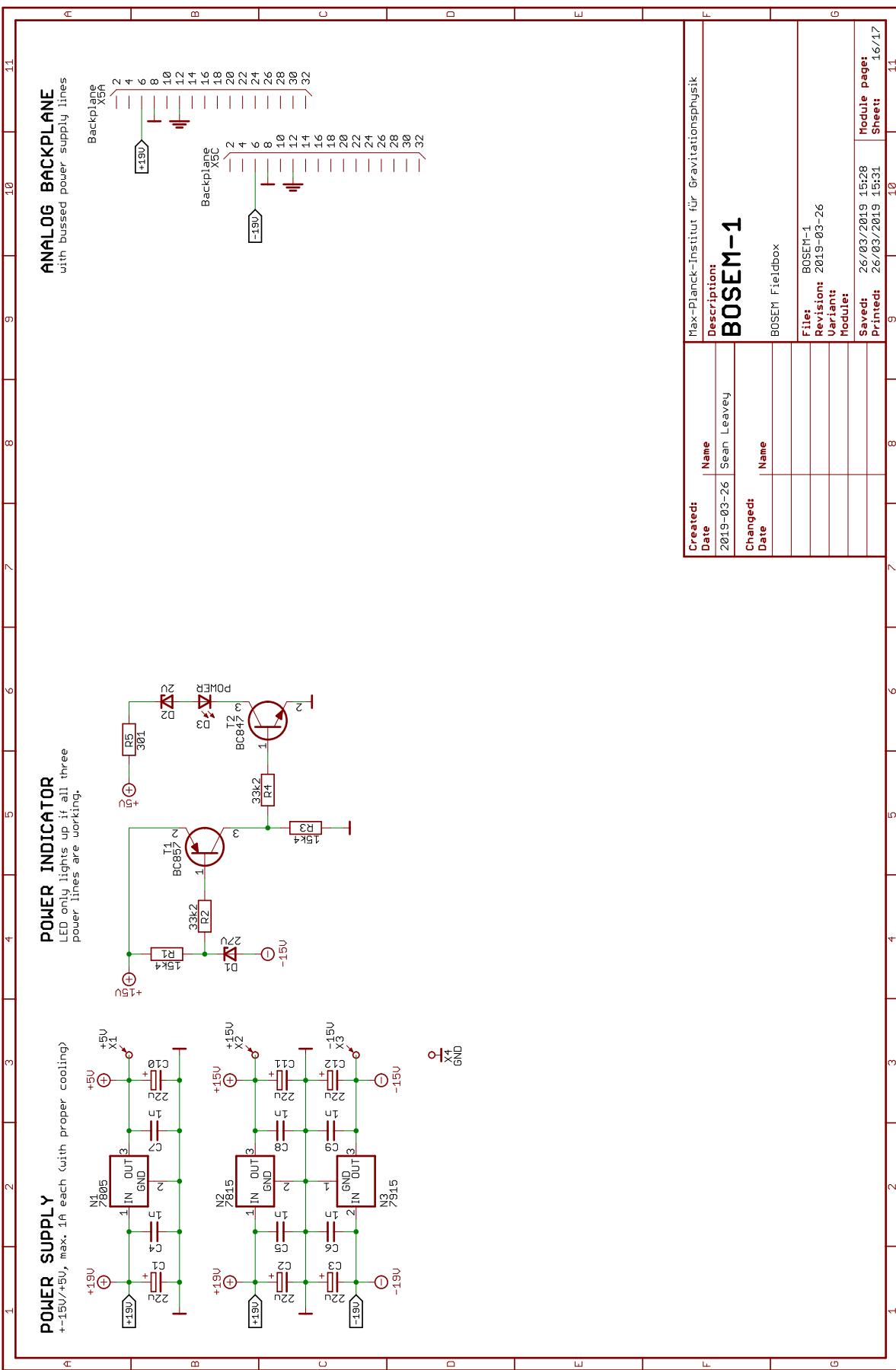


Figure 16: Project schematics (sheet 16)

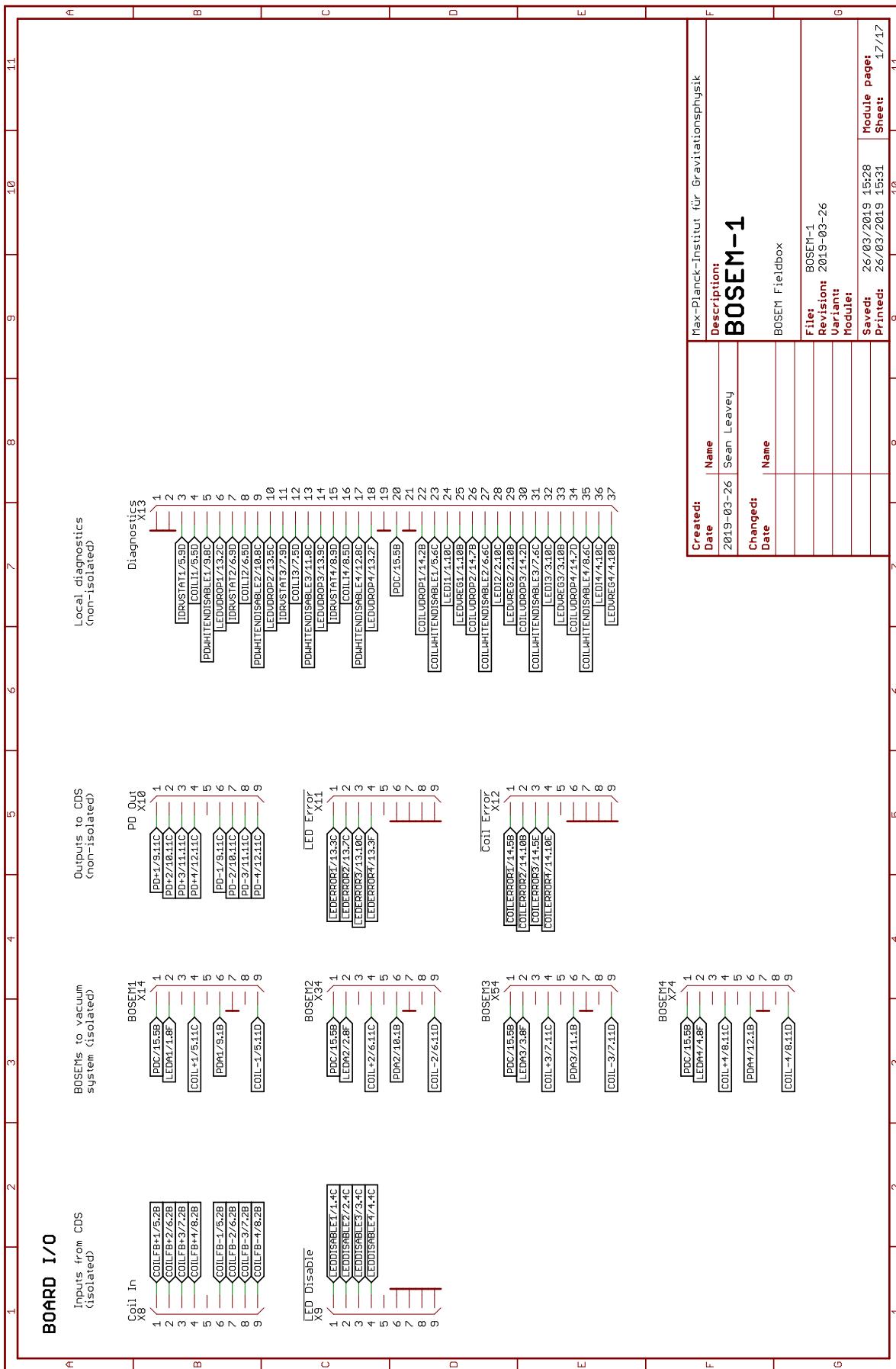


Figure 17: Project schematics (sheet 17)

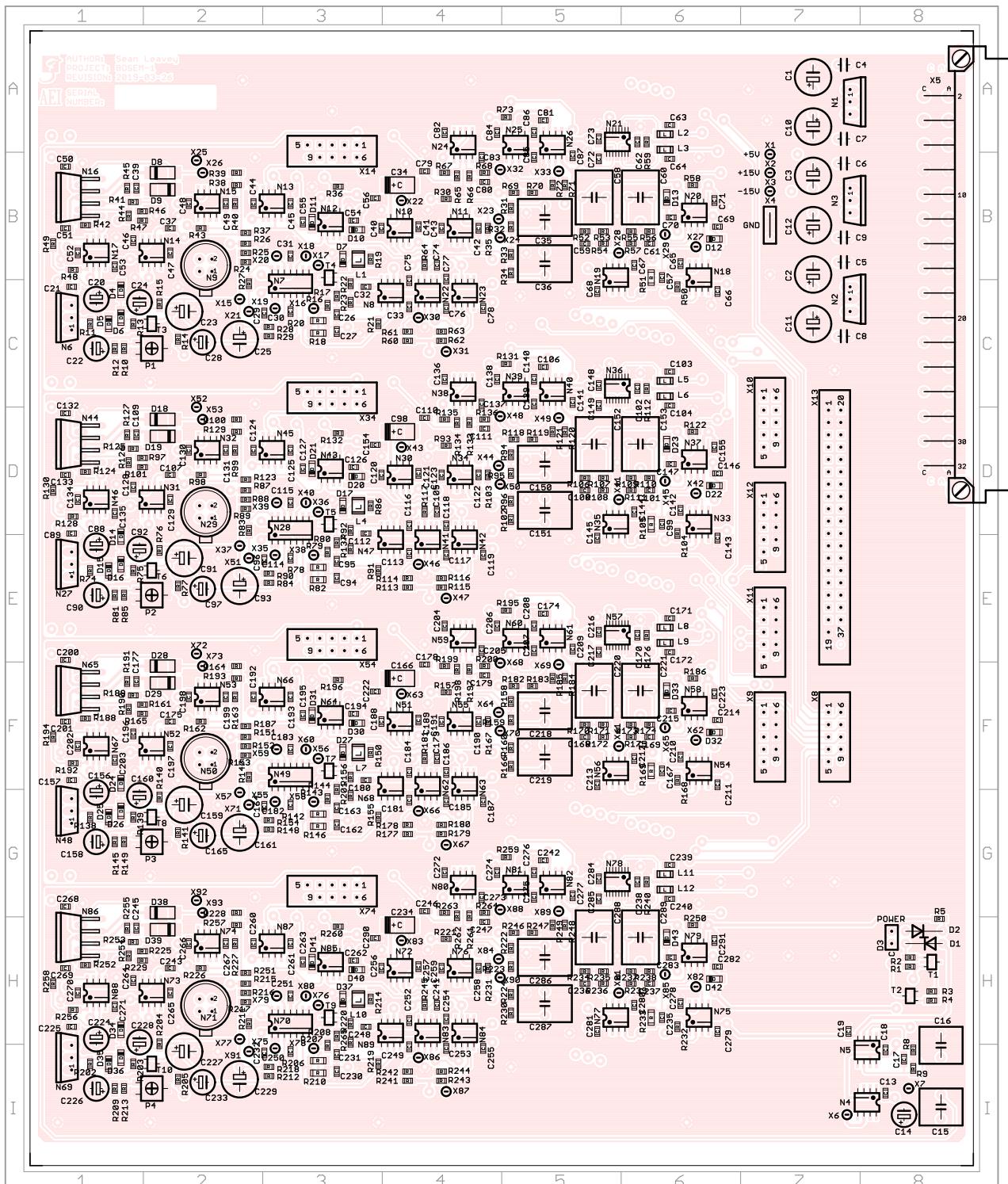


Figure 18: Board top view showing placeplan with component names

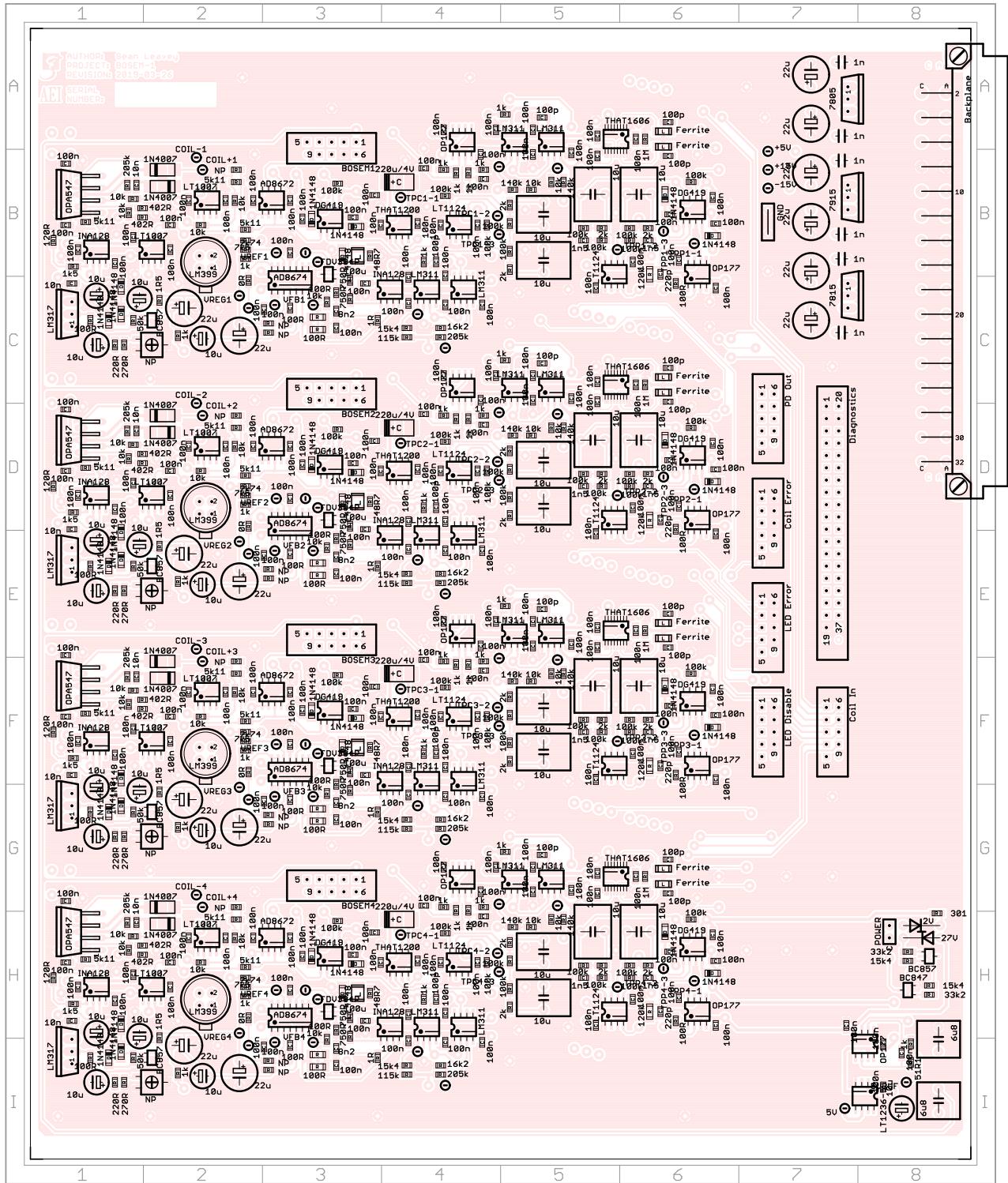


Figure 19: Board top view showing placeplan with component values

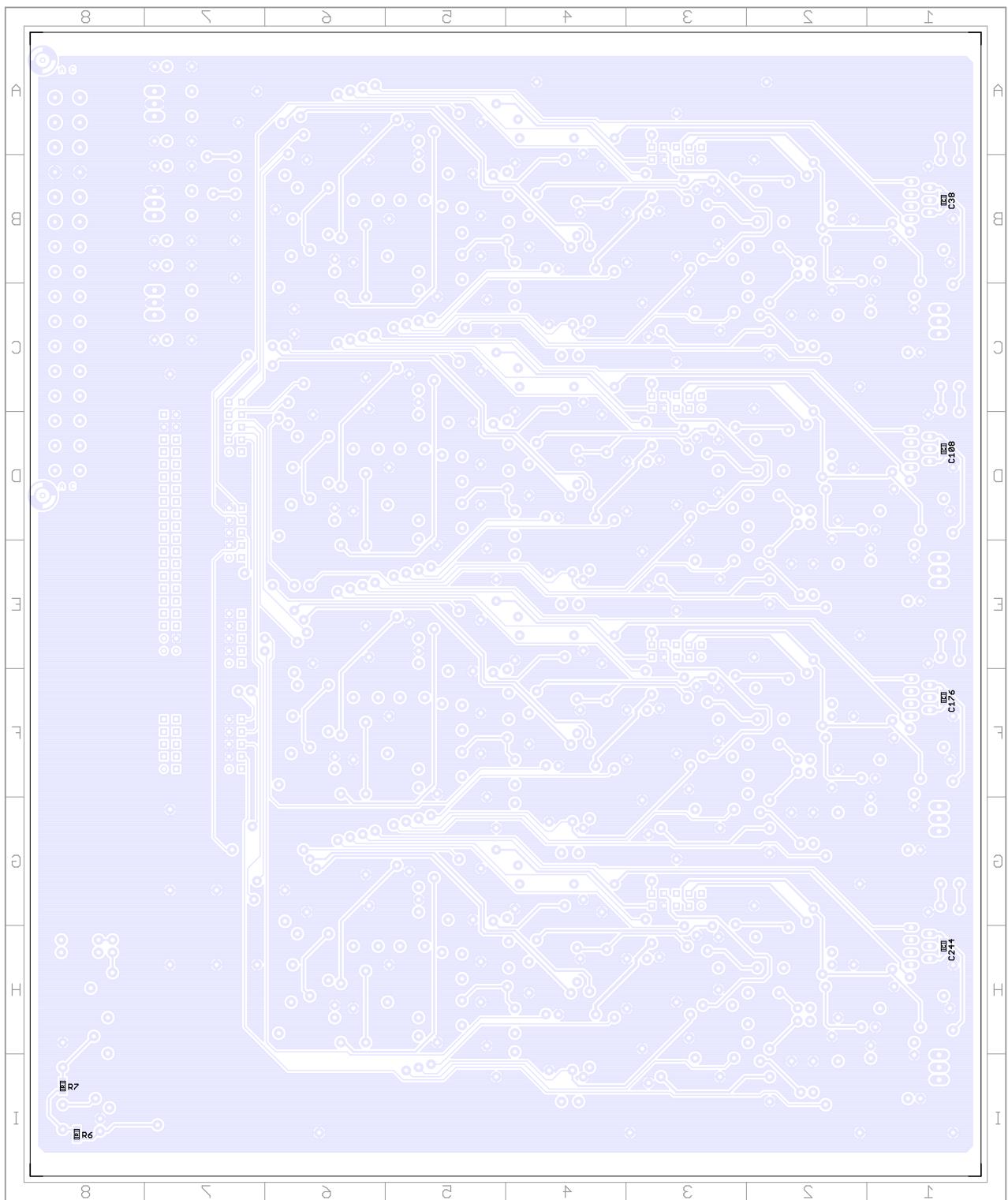


Figure 20: Board bottom view showing placeplan with component names

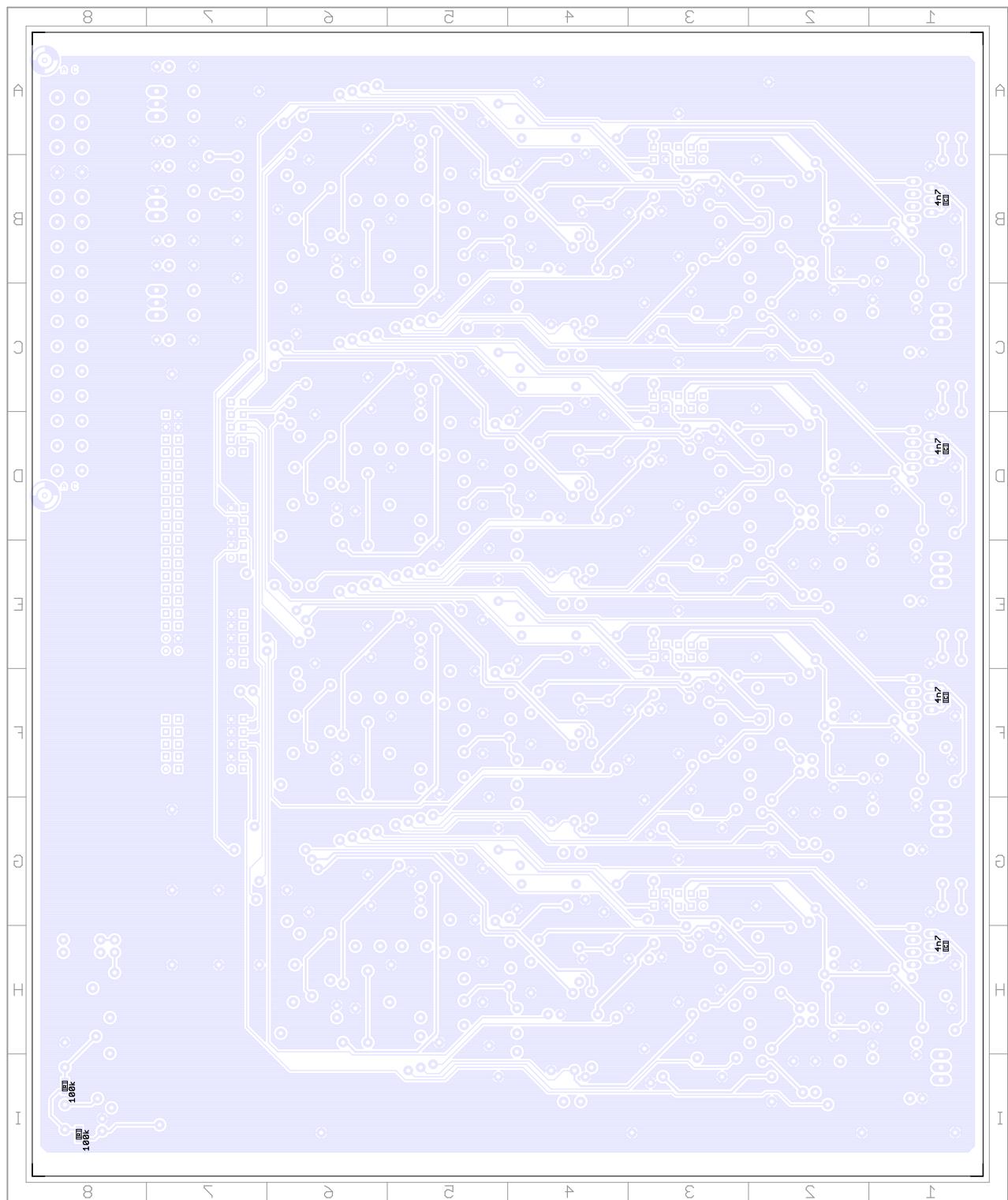


Figure 21: Board bottom view showing placeplan with component values



Figure 22: Board top view showing connectors, test points, vias and wired components

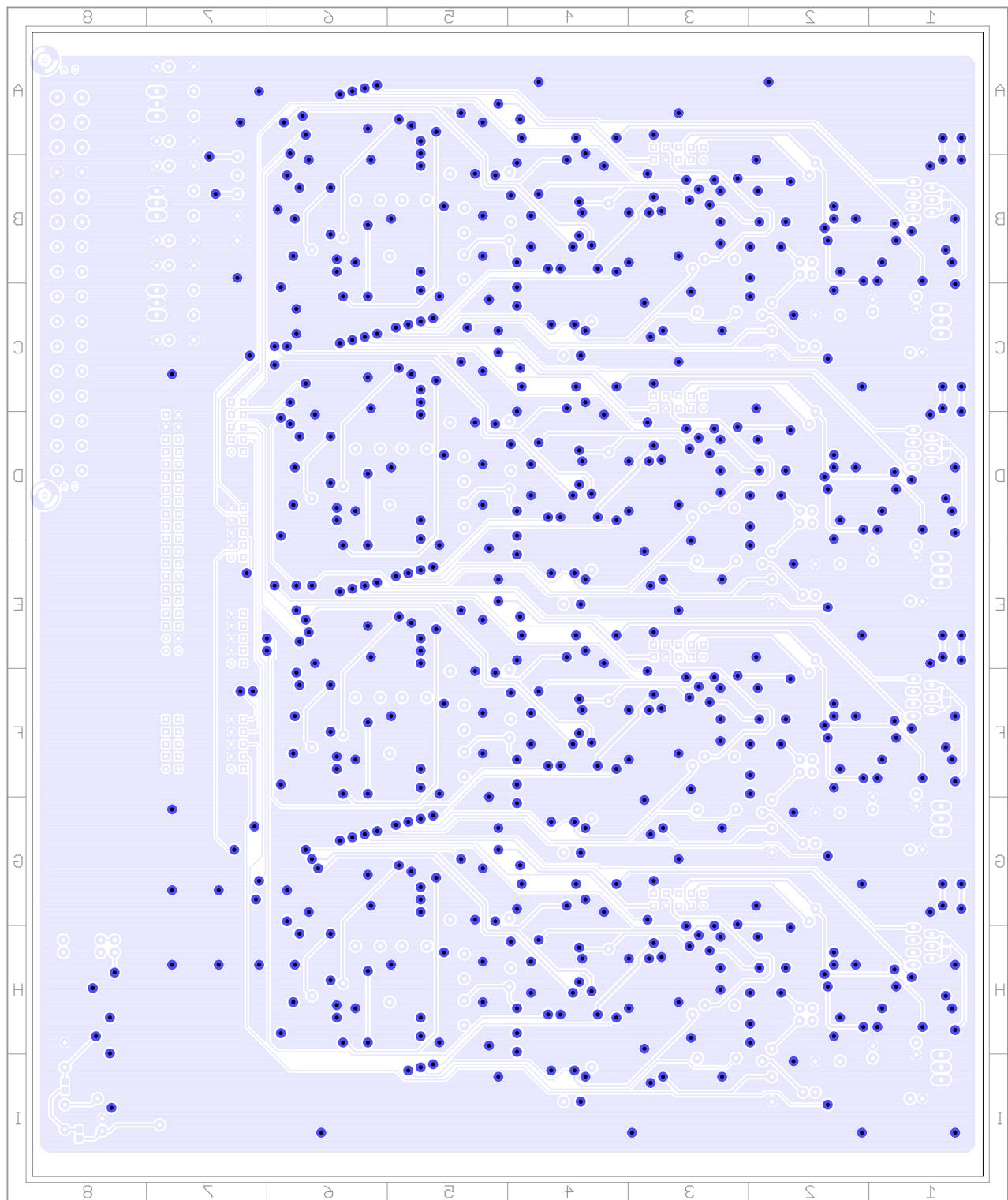


Figure 23: Board bottom view showing connectors, test points, vias and wired components

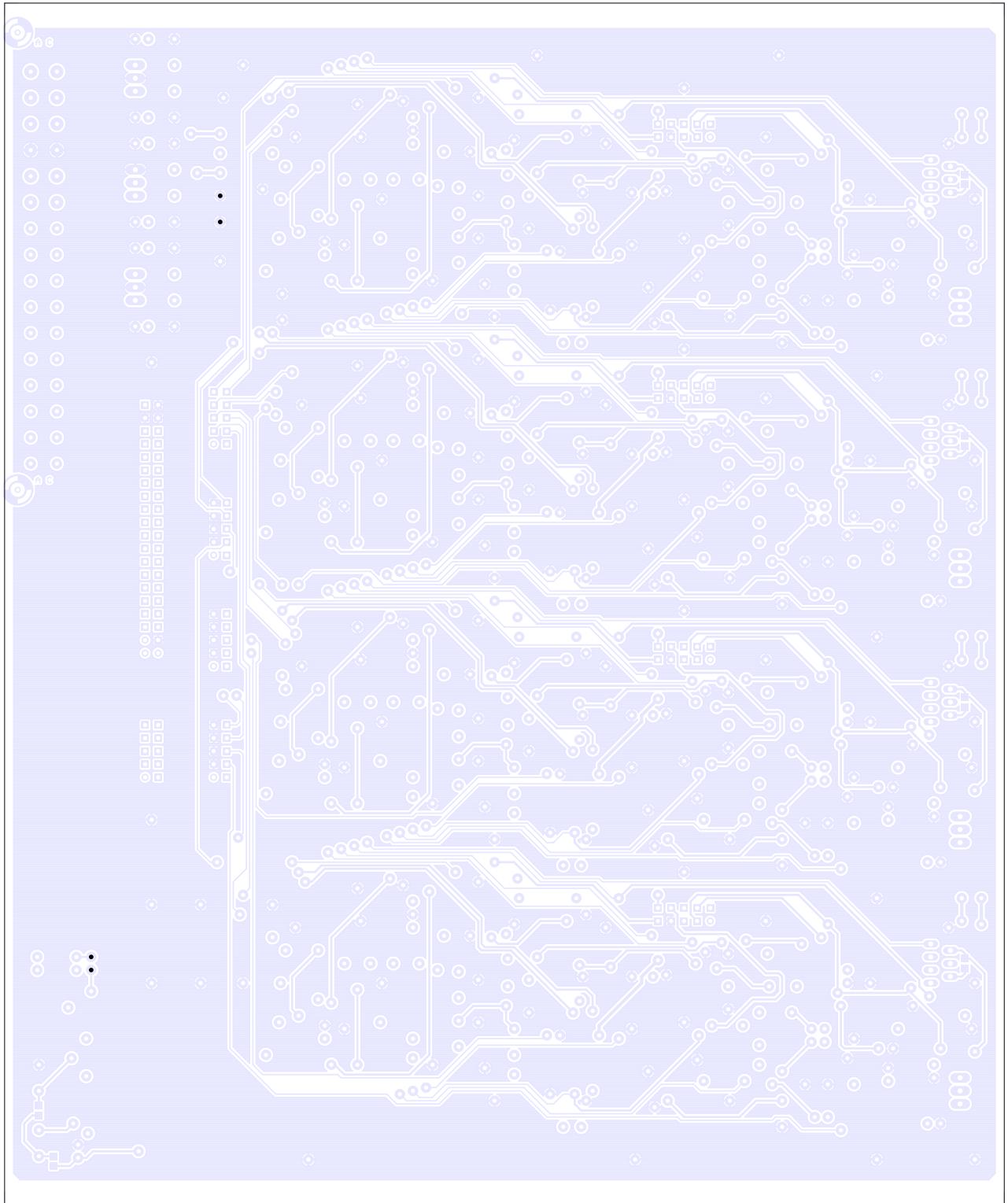


Figure 24: Board bottom view showing drills with 0.9 mm (0.035 in) diameter

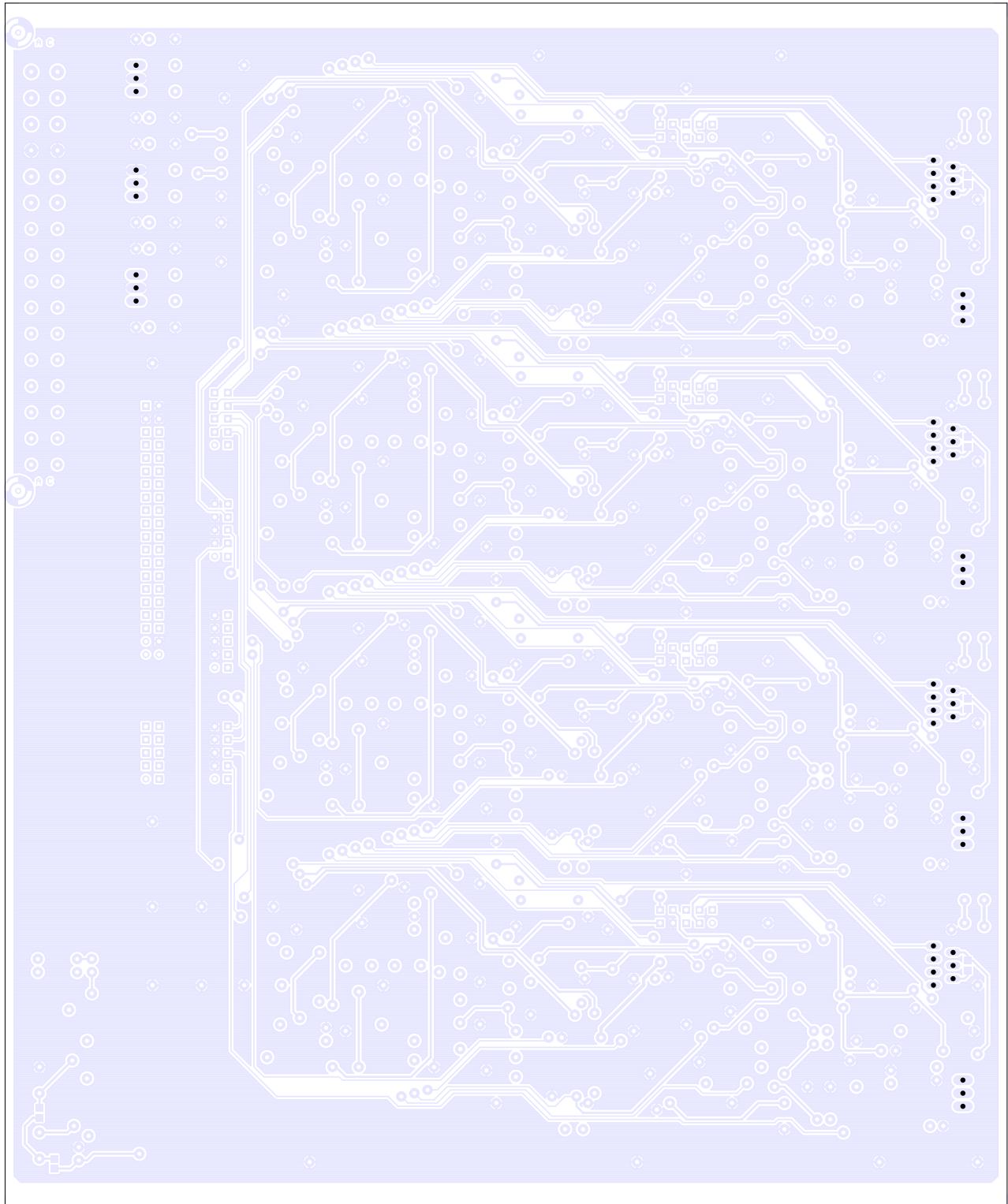


Figure 25: Board bottom view showing drills with 1.0 mm (0.039 in) diameter

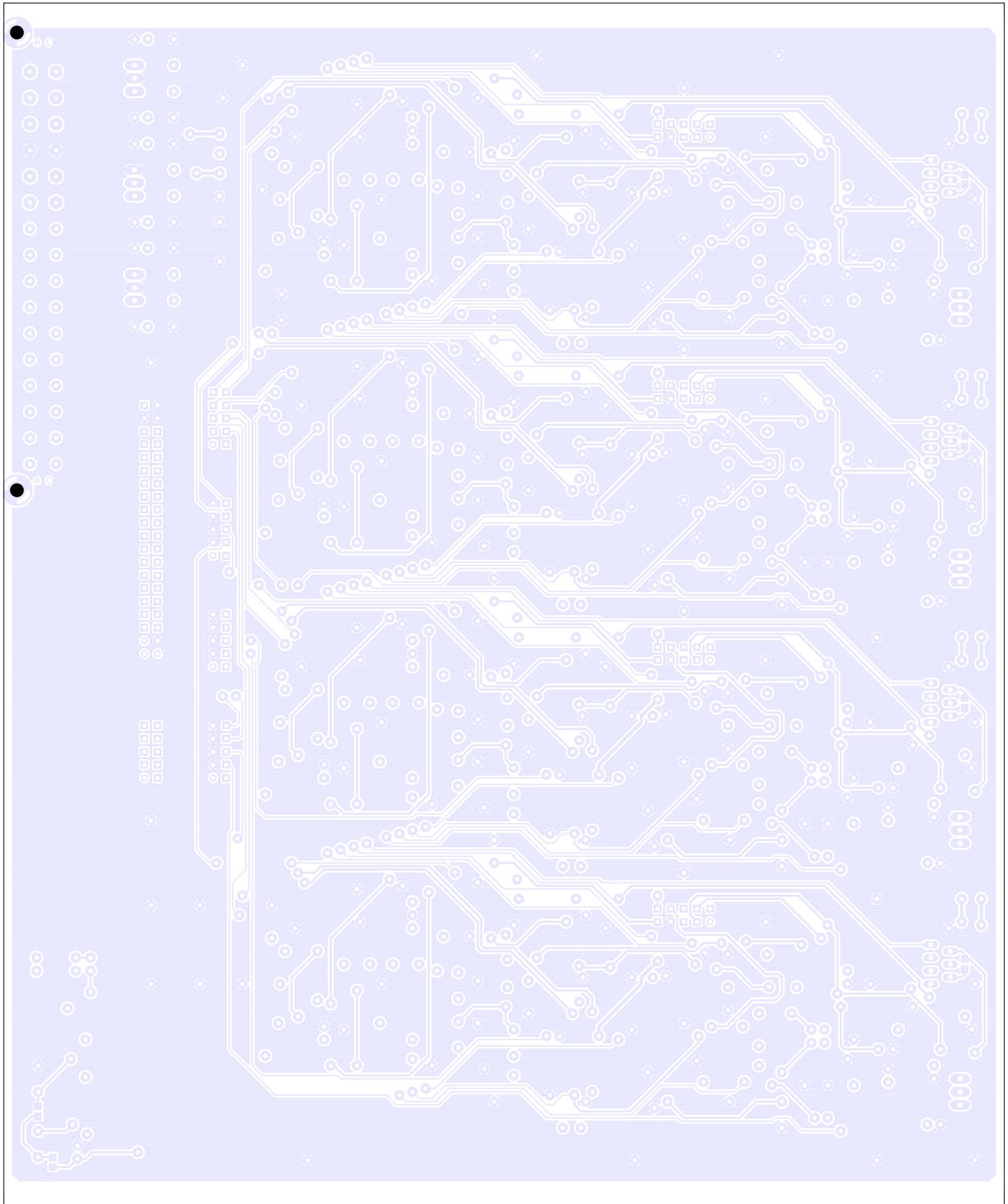


Figure 26: Board bottom view showing drills with 2.7 mm (0.106 in) diameter

Circuit Lists

Drill list: The following table shows all *final* drill diameters used in the board. When manually drilling the clearance holes, round up to the nearest available drill bit diameter, ensuring that all components fit well. When manufacturing *through-plated* boards, adjust for the additional copper coating by increasing the diameter accordingly.

\varnothing [μm]	\varnothing [mm]	\varnothing [in]	Count
813	0.8	0.032	950
889	0.9	0.035	4
991	1.0	0.039	49
2692	2.7	0.106	2
	Total		1005

Table 1: Drill diameters used in the board

Standard properties: If not explicitly stated otherwise in the schematics or value and part lists, the circuit components have the following standard properties. Parts with ‘better’ properties can be easily substituted, but care should be taken if the specifications are *not* met.

- Wired resistors: Metal film 0.6 W, 1%, 200 V, TK 100
- SMD resistors: 1%, 150 V, TK 50, MiniMELF in thin film, other packages in thick film technology

Value list: The following list shows all components available on the board (sorted by part *values*) and can be used to quickly gather components. Additional information can possibly be found directly on the board (or in the schematics).

Value	Package	Count	Component names (<i>library</i>)
— C —			
1 100p	C-SMD:0805	16	C63,C64,C74,C81,C103-C106,C171-C174,C239-C242 (<i>misscs</i>)
2 220p	C-SMD:0805	4	C57,C99,C167,C235 (<i>misscs</i>)
3 1n	C-CERAMIC:0.1"	6	C4-C9 (<i>misscs</i>)
4 1n5	C-SMD:0805	8	C59,C61,C100,C101,C168,C169,C236,C237 (<i>misscs</i>)
5 4n7	C-SMD:0805	4	C38,C108,C176,C244 (<i>misscs</i>)
6 8n2	C-SMD:0805	4	C26,C95,C163,C231 (<i>misscs</i>)
7 10n	C-SMD:0805	8	C21,C39,C89,C109,C157,C177,C225,C245 (<i>misscs</i>)
8 100n	C-SMD:0805	188	C13,C17-C19,C27,C29-C33,C37,C40-C56,C62,C65-C73, C75-C80,C82-C87,C94,C96,C102,C107,C110-C149,C154, C155,C162,C164,C170,C175,C178-C217,C222,C223,C230, C232,C238,C243,C246-C285,C290,C291 (<i>misscs</i>)
9 6u8	C-WIMA:MKS2	2	C15,C16 (<i>misscs</i>)
10 10u	C02-MKS2-11.0-N	16	C35,C36,C58,C60,C150-C153,C218-C221,C286-C289 (<i>misscs</i>)
11 10u	CE-TANTAL:0.1"	17	C14,C20,C22,C24,C28,C88,C90,C92,C97,C156,C158, C160,C165,C224,C226,C228,C233 (<i>misscs</i>)
12 22u	CE-TANTAL:0.2"	14	C1-C3,C10-C12,C23,C25,C91,C93,C159,C161,C227,C229 (<i>misscs</i>)
13 220u/4V	CE-SMD:C	4	C34,C98,C166,C234 (<i>misscs</i>)
— D —			
14 2V	DZ-0.3"	1	D2 (<i>diodes</i>)
15 27V	DZ-0.3"	1	D1 (<i>diodes</i>)
16 1N4007	D-SMD:MELF	8	D8,D9,D18,D19,D28,D29,D38,D39 (<i>diodes</i>)
17 1N4148	D-SMD:MiniMELF	28	D4-D6,D10-D16,D20-D26,D30-D36,D40-D43 (<i>diodes</i>)
18 LL4148	D-SMD:MiniMELF	4	D7,D17,D27,D37 (<i>diodes</i>)
19 [ignored]	DL-CABLE-UNCODED-N	1	D3 (<i>optos</i>)
— L —			

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Table 2: Value list — continued

Value	Package	Count	Component names (<i>library</i>)
20 100u	L-SMD:1210	4	L1,L4,L7,L10 (<i>misscs</i>)
21 Ferrite	L-SMD:1206	8	L2,L3,L5,L6,L8,L9,L11,L12 (<i>misscs</i>)
— N —			
22 7805	T0-220	1	N1 (<i>ics</i>)
23 7815	T0-220	1	N2 (<i>ics</i>)
24 7915	T0-220	1	N3 (<i>ics</i>)
25 AD8672	S0-8	4	N13,N45,N66,N87 (<i>opamps</i>)
26 AD8674	S0-14	4	N7,N28,N49,N70 (<i>opamps</i>)
27 DG419	S0-8	8	N12,N20,N37,N43,N58,N64,N79,N85 (<i>ics</i>)
28 INA128	S0-8	8	N8,N17,N46,N47,N67,N68,N88,N89 (<i>opamps</i>)
29 LM311	S0-8	16	N22,N23,N25,N26,N39-N42,N60-N63,N81-N84 (<i>opamps</i>)
30 LM317	T0-220	4	N6,N27,N48,N69 (<i>ics</i>)
31 LM399	T0-46	4	N9,N29,N50,N71 (<i>ics</i>)
32 LT1007	S0-8	8	N14,N15,N31,N32,N52,N53,N73,N74 (<i>opamps</i>)
33 LT1124	S0-8	8	N11,N19,N34,N35,N55,N56,N76,N77 (<i>opamps</i>)
34 LT1236-5	S0-8	1	N4 (<i>ics</i>)
35 OP177	S0-8	9	N5,N18,N24,N33,N38,N54,N59,N75,N80 (<i>opamps</i>)
36 OPA547	T0-220	4	N16,N44,N65,N86 (<i>opamps</i>)
37 THAT1200	S0-8	4	N10,N30,N51,N72 (<i>opamps</i>)
38 THAT1606	QSOP-16	4	N21,N36,N57,N78 (<i>opamps</i>)
— R —			
39 0R	R-SMD:0805	4	R27,R83,R147,R211 (<i>misscs</i>)
40 1R	R-SMD:0805	4	R21,R91,R155,R219 (<i>misscs</i>)
41 1R5	R-SMD:0805	4	R15,R76,R140,R204 (<i>misscs</i>)
42 48R7	R-SMD:0805	4	R19,R86,R150,R214 (<i>misscs</i>)
43 51R1	R-SMD:0805	1	R9 (<i>misscs</i>)
44 100R	R-SMD:0805	12	R11,R17,R50,R74,R80,R104,R138,R144,R168,R202,R208,R232 (<i>misscs</i>)
45 100R	R-SMD:MiniMELF	8	R18,R20,R78,R82,R142,R146,R206,R210 (<i>misscs</i>)
46 120R	R-SMD:0805	4	R49,R130,R194,R258 (<i>misscs</i>)
47 220R	R-SMD:0805	4	R12,R81,R145,R209 (<i>misscs</i>)
48 270R	R-SMD:0805	4	R10,R85,R149,R213 (<i>misscs</i>)
49 301	R-SMD:0805	1	R5 (<i>misscs</i>)
50 402R	R-SMD:0805	8	R46,R47,R97,R101,R161,R165,R225,R229 (<i>misscs</i>)
51 750R	R-SMD:0805	8	R22,R23,R92,R137,R156,R201,R220,R265 (<i>misscs</i>)
52 1k	R-SMD:0805	33	R8,R14,R24,R64-R68,R73,R77,R89,R117,R131,R133-R136,R141,R153,R181,R195,R197-R200,R205,R217,R245,R259,R261-R264 (<i>misscs</i>)
53 1k5	R-SMD:0805	4	R48,R128,R192,R256 (<i>misscs</i>)
54 2k	R-SMD:0805	16	R31,R34,R53,R56,R94,R102,R107,R110,R158,R166,R171,R174,R222,R230,R235,R238 (<i>misscs</i>)
55 2k74	R-SMD:0805	4	R25,R88,R152,R216 (<i>misscs</i>)
56 5k11	R-SMD:0805	12	R37,R38,R42,R123,R124,R129,R187,R188,R193,R251,R252,R257 (<i>misscs</i>)
57 7k5	R-SMD:0805	4	R26,R87,R151,R215 (<i>misscs</i>)
58 10k	R-SMD:0805	28	R16,R40,R41,R43,R44,R70,R72,R79,R98,R99,R119,R121,R125,R126,R143,R162,R163,R183,R185,R189,R190,R207,R226,R227,R247,R249,R253,R254 (<i>misscs</i>)
59 15k4	R-SMD:0805	6	R1,R3,R61,R114,R178,R242 (<i>misscs</i>)
60 16k2	R-SMD:0805	4	R63,R116,R180,R244 (<i>misscs</i>)
61 33k2	R-SMD:0805	2	R2,R4 (<i>misscs</i>)
62 50k	R-SMD:0805	4	R13,R75,R139,R203 (<i>misscs</i>)
63 100k	R-SMD:0805	42	R6,R7,R30,R32,R33,R35,R36,R52,R54,R55,R57,R58,R93,R95,R96,R103,R106,R108,R109,R111,R122,R132,R157,R159,R160,R167,R170,R172,R173,R175,R186,R196,R221,R223,R224,R231,R234,R236,R237,R239,R250,R260 (<i>misscs</i>)

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Table 2: Value list — continued

Value	Package	Count	Component names (<i>library</i>)
64 115k	R-SMD:0805	4	R60,R113,R177,R241 (<i>miscs</i>)
65 120k	R-SMD:MiniMELF	4	R51,R105,R169,R233 (<i>miscs</i>)
66 140k	R-SMD:0805	8	R69,R71,R118,R120,R182,R184,R246,R248 (<i>miscs</i>)
67 205k	R-SMD:0805	8	R45,R62,R115,R127,R179,R191,R243,R255 (<i>miscs</i>)
68 1M	R-SMD:0805	4	R59,R112,R176,R240 (<i>miscs</i>)
— T —			
69 BC847	SOT-23	1	T2 (<i>transistors</i>)
70 BC857	SOT-23	5	T1,T3,T6,T8,T10 (<i>transistors</i>)
71 FDV304P	SOT-23	4	T4,T5,T7,T9 (<i>transistors</i>)
— X —			
72 [ignored]	Backplane:32-pin/AC	1	X5 (<i>connectors</i>)
73 [ignored]	GND-0.2"	1	X4 (<i>connectors</i>)
74 [ignored]	IDC:10-pin/ribbon	9	X8-X12,X14,X34,X54,X74 (<i>connectors</i>)
75 [ignored]	Testpin:0.8mm/ceramic	81	X1-X3,X6,X7,X15-X33,X35-X53,X55-X73,X75-X93 (<i>connectors</i>)
76 [ignored]	X37-DSUBRIBBON	1	X13 (<i>connectors</i>)
— [unpopulated] —			
77 [undefined]		16	P1-P4,R28,R29,R39,R84,R90,R100,R148,R154,R164, R212,R218,R228 (<i>miscs</i>)

Part list: The following list shows all components available in the schematics (sorted by part *names*) and can be used to quickly locate components. The column *Sheets* shows the position of *all* the part's gates in the schematics: Gate name followed by sheet number followed by the cell of the surrounding frame (if available). The column *Board* shows the position of the part on the board: *T* for top side and *B* for bottom side, followed by the cell of the surrounding frame (if available). Additional information can possibly be found directly in the schematics.

Name	Sheets	Board
— C —		
1 C1	16-B1	T
2 C2	16-C1	T
3 C3	16-C1	T
4 C4	16-B2	T
5 C5	16-C2	T
6 C6	16-C2	T
7 C7	16-B2	T
8 C8	16-C2	T
9 C9	16-C2	T
10 C10	16-B3	T
11 C11	16-C3	T
12 C12	16-C3	T
13 C13	15-A1	T
14 C14	15-B2	T
15 C15	15-B3	T
16 C16	15-B3	T
17 C17	15-C4	T
18 C18	15-F1	T
— continued on next column —		

Table 2: Part list — continued

Name	Sheets	Board
19 C19	15-G1	T
20 C20	1-B1	T
21 C21	1-B2	T
22 C22	1-C2	T
23 C23	1-C4	T
24 C24	1-B4	T
25 C25	1-B5	T
26 C26	1-C8	T
27 C27	1-B9	T
28 C28	1-E5	T
29 C29	1-E5	T
30 C30	1-D10	T
31 C31	1-E10	T
32 C32	1-D11	T
33 C33	1-E11	T
34 C34	5-B2	T
35 C35	5-B4	T
36 C36	5-B6	T
37 C37	5-C8	T
38 C38	5-C10	B
— continued on next column —		

Table 2: Part list — continued

Name	Sheets	Board
39 C39	5-D10	T
40 C40	5-F1	T
41 C41	5-G1	T
42 C42	5-F2	T
43 C43	5-G2	T
44 C44	5-F2	T
45 C45	5-G2	T
46 C46	5-F2	T
47 C47	5-G2	T
48 C48	5-F3	T
49 C49	5-G3	T
50 C50	5-F3	T
51 C51	5-G3	T
52 C52	5-F4	T
53 C53	5-G4	T
54 C54	5-F6	T
55 C55	5-G6	T
56 C56	5-F6	T
57 C57	9-B2	T
58 C58	9-B4	T
— continued on next column —		

Table 2: Part list — continued

	Name	Sheets	Board
59	C59	9-B5	T
60	C60	9-B6	T
61	C61	9-B7	T
62	C62	9-C9	T
63	C63	9-C10	T
64	C64	9-C11	T
65	C65	9-F1	T
66	C66	9-G1	T
67	C67	9-F2	T
68	C68	9-G2	T
69	C69	9-F3	T
70	C70	9-G3	T
71	C71	9-F4	T
72	C72	9-G2	T
73	C73	9-F2	T
74	C74	13-D3	T
75	C75	13-D8	T
76	C76	13-E8	T
77	C77	13-D9	T
78	C78	13-E9	T

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Table 2: Part list — continued

	Name	Sheets	Board
79	C79	14-B2	T
80	C80	14-B2	T
81	C81	14-C5	T
82	C82	14-F2	T
83	C83	14-G2	T
84	C84	14-F3	T
85	C85	14-G3	T
86	C86	14-F3	T
87	C87	14-G3	T
88	C88	2-B1	T
89	C89	2-B2	T
90	C90	2-C2	T
91	C91	2-C4	T
92	C92	2-B4	T
93	C93	2-B5	T
94	C94	2-B9	T
95	C95	2-C8	T
96	C96	2-E5	T
97	C97	2-E5	T
98	C98	6-B2	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
99	C99	10-B2	T
100	C100	10-B5	T
101	C101	10-B7	T
102	C102	10-C9	T
103	C103	10-C10	T
104	C104	10-C11	T
105	C105	13-D7	T
106	C106	14-C10	T
107	C107	6-C8	T
108	C108	6-C10	B
109	C109	6-D10	T
110	C110	14-B7	T
111	C111	14-B8	T
112	C112	2-D11	T
113	C113	2-E11	T
114	C114	2-D10	T
115	C115	2-E10	T
116	C116	13-D9	T
117	C117	13-E9	T
118	C118	13-D9	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
119	C119	13-E9	T
120	C120	6-F1	T
121	C121	6-G1	T
122	C122	6-F2	T
123	C123	6-G2	T
124	C124	6-F2	T
125	C125	6-G2	T
126	C126	6-F6	T
127	C127	6-G6	T
128	C128	6-F2	T
129	C129	6-G2	T
130	C130	6-F3	T
131	C131	6-G3	T
132	C132	6-F3	T
133	C133	6-G3	T
134	C134	6-F4	T
135	C135	6-G4	T
136	C136	14-F4	T
137	C137	14-G4	T
138	C138	14-F4	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
139	C139	14-G4	T
140	C140	14-F4	T
141	C141	14-G4	T
142	C142	10-F1	T
143	C143	10-G1	T
144	C144	10-F2	T
145	C145	10-G2	T
146	C146	10-F3	T
147	C147	10-G3	T
148	C148	10-F2	T
149	C149	10-G2	T
150	C150	6-B4	T
151	C151	6-B6	T
152	C152	10-B4	T
153	C153	10-B6	T
154	C154	6-F6	T
155	C155	10-F4	T
156	C156	3-B1	T
157	C157	3-B2	T
158	C158	3-C2	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
159	C159	3-C4	T
160	C160	3-B4	T
161	C161	3-B5	T
162	C162	3-B9	T
163	C163	3-C8	T
164	C164	3-E5	T
165	C165	3-E5	T
166	C166	7-B2	T
167	C167	11-B2	T
168	C168	11-B5	T
169	C169	11-B7	T
170	C170	11-C9	T
171	C171	11-C10	T
172	C172	11-C11	T
173	C173	13-D10	T
174	C174	14-E5	T
175	C175	7-C8	T
176	C176	7-C10	B
177	C177	7-D10	T
178	C178	14-E2	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
179	C179	14-E2	T
180	C180	3-D11	T
181	C181	3-E11	T
182	C182	3-D10	T
183	C183	3-E10	T
184	C184	13-D10	T
185	C185	13-E10	T
186	C186	13-D10	T
187	C187	13-E10	T
188	C188	7-F1	T
189	C189	7-G1	T
190	C190	7-F2	T
191	C191	7-G2	T
192	C192	7-F2	T
193	C193	7-G2	T
194	C194	7-F6	T
195	C195	7-G6	T
196	C196	7-F2	T
197	C197	7-G2	T
198	C198	7-F3	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
199	C199	7-G3	T
200	C200	7-F3	T
201	C201	7-G3	T
202	C202	7-F4	T
203	C203	7-G4	T
204	C204	14-F5	T
205	C205	14-G5	T
206	C206	14-F5	T
207	C207	14-G5	T
208	C208	14-F6	T
209	C209	14-G6	T
210	C210	11-F1	T
211	C211	11-G1	T
212	C212	11-F2	T
213	C213	11-G2	T
214	C214	11-F3	T
215	C215	11-G3	T
216	C216	11-F2	T
217	C217	11-G2	T
218	C218	7-B4	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
219	C219	7-B6	T
220	C220	11-B4	T
221	C221	11-B6	T
222	C222	7-F6	T
223	C223	11-F4	T
224	C224	4-B1	T
225	C225	4-B2	T
226	C226	4-C2	T
227	C227	4-C4	T
228	C228	4-B4	T
229	C229	4-B5	T
230	C230	4-B9	T
231	C231	4-C8	T
232	C232	4-E5	T
233	C233	4-E5	T
234	C234	8-B2	T
235	C235	12-B2	T
236	C236	12-B5	T
237	C237	12-B7	T
238	C238	12-C9	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
239	C239	12-C10	T
240	C240	12-C11	T
241	C241	13-G3	T
242	C242	14-E10	T
243	C243	8-C8	T
244	C244	8-C10	B
245	C245	8-D10	T
246	C246	14-E7	T
247	C247	14-E8	T
248	C248	4-D11	T
249	C249	4-E11	T
250	C250	4-D10	T
251	C251	4-E10	T
252	C252	13-D11	T
253	C253	13-E11	T
254	C254	13-D11	T
255	C255	13-E11	T
256	C256	8-F1	T
257	C257	8-G1	T
258	C258	8-F2	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
259	C259	8-G2	T
260	C260	8-F2	T
261	C261	8-G2	T
262	C262	8-F6	T
263	C263	8-G6	T
264	C264	8-F2	T
265	C265	8-G2	T
266	C266	8-F3	T
267	C267	8-G3	T
268	C268	8-F3	T
269	C269	8-G3	T
270	C270	8-F4	T
271	C271	8-G4	T
272	C272	14-F6	T
273	C273	14-G6	T
274	C274	14-F6	T
275	C275	14-G6	T
276	C276	14-F7	T
277	C277	14-G7	T
278	C278	12-F1	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
279	C279	12-G1	T
280	C280	12-F2	T
281	C281	12-G2	T
282	C282	12-F3	T
283	C283	12-G3	T
284	C284	12-F2	T
285	C285	12-G2	T
286	C286	8-B4	T
287	C287	8-B6	T
288	C288	12-B4	T
289	C289	12-B6	T
290	C290	8-F6	T
291	C291	12-F4	T
	— D —		
292	D1	16-B4	T
293	D2	16-B6	T
294	D3	16-B6	T
295	D4	1-B2	T
296	D5	1-B3	T
297	D6	1-B4	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
298	D7	1-E9	T
299	D8	5-C10	T
300	D9	5-C10	T
301	D10	5-F6	T
302	D11	5-G6	T
303	D12	9-F3	T
304	D13	9-G3	T
305	D14	2-B2	T
306	D15	2-B3	T
307	D16	2-B4	T
308	D17	2-E9	T
309	D18	6-C10	T
310	D19	6-C10	T
311	D20	6-F6	T
312	D21	6-G6	T
313	D22	10-F3	T
314	D23	10-G3	T
315	D24	3-B2	T
316	D25	3-B3	T
317	D26	3-B4	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
318	D27	3-E9	T
319	D28	7-C10	T
320	D29	7-C10	T
321	D30	7-F6	T
322	D31	7-G6	T
323	D32	11-F3	T
324	D33	11-G3	T
325	D34	4-B2	T
326	D35	4-B3	T
327	D36	4-B4	T
328	D37	4-E9	T
329	D38	8-C10	T
330	D39	8-C10	T
331	D40	8-F6	T
332	D41	8-G6	T
333	D42	12-F3	T
334	D43	12-G3	T
335	L1	1-E8	T
336	L2	9-C10	T

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Table 2: Part list — continued

	Name	Sheets	Board
337	L3	9-C10	T
338	L4	2-E8	T
339	L5	10-C10	T
340	L6	10-C10	T
341	L7	3-E8	T
342	L8	11-C10	T
343	L9	11-C10	T
344	L10	4-E8	T
345	L11	12-C10	T
346	L12	12-C10	T
	— N —		
347	N1	16-A2	T
348	N2	16-B2	T
349	N3	16-C2	T
350	N4	15-B1	T
351	N5	A: 15-B4 P: 15-G1	T
352	N6	1-B2	T
353	N7	A: 1-B10 B: 1-D7	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
		C: 1-E7	
		D: 1-E3	
		P: 1-E10	
354	N8	A: 1-C10	T
		P: 1-E11	
355	N9	A: 1-E2	T
		H: 1-F2	
356	N10	A: 5-B2	T
		P: 5-G1	
357	N11	A: 5-B4	T
		B: 5-B5	
		P: 5-G2	
358	N12	A: 5-C6	T
		P: 5-G6	
359	N13	A: 5-B8	T
		B: 5-D5	
		P: 5-G2	
360	N14	A: 5-C8	T
		P: 5-G2	
361	N15	A: 5-E8	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
		P: 5-G3	
362	N16	A: 5-C10	T
		P: 5-G3	
363	N17	A: 5-E3	T
		P: 5-G4	
364	N18	A: 9-B2	T
		P: 9-G1	
365	N19	A: 9-B5	T
		B: 9-C7	
		P: 9-G2	
366	N20	A: 9-C8	T
		P: 9-G4	
367	N21	A: 9-C9	T
		P: 9-G2	
368	N22	A: 13-B3	T
		P: 13-E8	
369	N23	A: 13-C3	T
		P: 13-E9	
370	N24	A: 14-B3	T
		P: 14-G2	

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
371	N25	A: 14-B5	T
		P: 14-G3	
372	N26	A: 14-B5	T
		P: 14-G3	
373	N27	2-B2	T
374	N28	A: 2-B10	T
		B: 2-D7	
		C: 2-E7	
		D: 2-E3	
		P: 2-E10	
375	N29	A: 2-E2	T
		H: 2-F2	
376	N30	A: 6-B2	T
		P: 6-G1	
377	N31	A: 6-C8	T
		P: 6-G2	
378	N32	A: 6-E8	T
		P: 6-G3	
379	N33	A: 10-B2	T
		P: 10-G1	

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
380	N34	A: 6-B4 B: 6-B5 P: 6-G2	T
381	N35	A: 10-B5 B: 10-C7 P: 10-G2	T
382	N36	A: 10-C9 P: 10-G2	T
383	N37	A: 10-C8 P: 10-G4	T
384	N38	A: 14-B9 P: 14-G4	T
385	N39	A: 14-B10 P: 14-G4	T
386	N40	A: 14-B10 P: 14-G4	T
387	N41	A: 13-B6 P: 13-E9	T
388	N42	A: 13-C6 P: 13-E9	T

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Table 2: Part list — continued

	Name	Sheets	Board
389	N43	A: 6-C6 P: 6-G6	T
390	N44	A: 6-C10 P: 6-G3	T
391	N45	A: 6-B8 B: 6-D5 P: 6-G2	T
392	N46	A: 6-E3 P: 6-G4	T
393	N47	A: 2-C10 P: 2-E11	T
394	N48	3-B2	T
395	N49	A: 3-B10 B: 3-D7 C: 3-E7 D: 3-E3 P: 3-E10	T
396	N50	A: 3-E2 H: 3-F2	T
397	N51	A: 7-B2	T

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Table 2: Part list — continued

	Name	Sheets	Board
398	N52	P: 7-G1 A: 7-C8	T
399	N53	P: 7-G2 A: 7-E8	T
400	N54	P: 7-G3 A: 11-B2	T
401	N55	P: 11-G1 A: 7-B4	T
402	N56	B: 7-B5 P: 7-G2 A: 11-B5	T
403	N57	P: 7-G2 A: 11-C7	T
404	N58	P: 11-G4 A: 11-C8	T
405	N59	P: 14-G5 A: 14-E3	T
406	N60	P: 14-G5 A: 14-D5	T

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Table 2: Part list — continued

	Name	Sheets	Board
		P: 14-G5	
407	N61	A: 14-E5	T
		P: 14-G6	
408	N62	A: 13-B10	T
		P: 13-E10	
409	N63	A: 13-C10	T
		P: 13-E10	
410	N64	A: 7-C6	T
		P: 7-G6	
411	N65	A: 7-C10	T
		P: 7-G3	
412	N66	A: 7-B8	T
		B: 7-D5	
		P: 7-G2	
413	N67	A: 7-E3	T
		P: 7-G4	
414	N68	A: 3-C10	T
		P: 3-E11	
415	N69	4-B2	T
416	N70	A: 4-B10	T

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Table 2: Part list — continued

	Name	Sheets	Board
		B: 4-D7	
		C: 4-E7	
		D: 4-E3	
		P: 4-E10	
417	N71	A: 4-E2	T
		H: 4-F2	
418	N72	A: 8-B2	T
		P: 8-G1	
419	N73	A: 8-C8	T
		P: 8-G2	
420	N74	A: 8-E8	T
		P: 8-G3	
421	N75	A: 12-B2	T
		P: 12-G1	
422	N76	A: 8-B4	T
		B: 8-B5	
		P: 8-G2	
423	N77	A: 12-B5	T
		B: 12-C7	
		P: 12-G2	

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Table 2: Part list — continued

	Name	Sheets	Board
424	N78	A: 12-C9	T
		P: 12-G2	
425	N79	A: 12-C8	T
		P: 12-G4	
426	N80	A: 14-E9	T
		P: 14-G6	
427	N81	A: 14-D10	T
		P: 14-G6	
428	N82	A: 14-E10	T
		P: 14-G7	
429	N83	A: 13-E3	T
		P: 13-E11	
430	N84	A: 13-F3	T
		P: 13-E11	
431	N85	A: 8-C6	T
		P: 8-G6	
432	N86	A: 8-C10	T
		P: 8-G3	
433	N87	A: 8-B8	T
		B: 8-D5	

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Table 2: Part list — continued

	Name	Sheets	Board
		P: 8-G2	
434	N88	A: 8-E3	T
		P: 8-G4	
435	N89	A: 4-C10	T
		P: 4-E11	
	— P —		
436	P1	1-D3	T
437	P2	2-D3	T
438	P3	3-D3	T
439	P4	4-D3	T
	— R —		
440	R1	16-B4	T
441	R2	16-B4	T
442	R3	16-C5	T
443	R4	16-C5	T
444	R5	16-A6	T
445	R6	15-B2	B
446	R7	15-B3	B
447	R8	15-C4	T
448	R9	15-B5	T

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Table 2: Part list — continued

	Name	Sheets	Board
449	R10	1-D3	T
450	R11	1-B3	T
451	R12	1-C3	T
452	R13	1-C4	T
453	R14	1-C4	T
454	R15	1-B5	T
455	R16	1-D7	T
456	R17	1-C8	T
457	R18	1-B8	T
458	R19	1-E8	T
459	R20	1-B8	T
460	R21	1-C8	T
461	R22	1-C9	T
462	R23	1-C9	T
463	R24	1-E2	T
464	R25	1-F2	T
465	R26	1-F2	T
466	R27	1-E4	T
467	R28	1-E4	T
468	R29	1-F4	T

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Table 2: Part list — continued

	Name	Sheets	Board
469	R30	5-B3	T
470	R31	5-B4	T
471	R32	5-B4	T
472	R33	5-B5	T
473	R34	5-B5	T
474	R35	5-B6	T
475	R36	5-C6	T
476	R37	5-C7	T
477	R38	5-D7	T
478	R39	5-D8	T
479	R40	5-D8	T
480	R41	5-C9	T
481	R42	5-C9	T
482	R43	5-E9	T
483	R44	5-D9	T
484	R45	5-D10	T
485	R46	5-E10	T
486	R47	5-E11	T
487	R48	5-E3	T
488	R49	5-E3	T

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Table 2: Part list — continued

	Name	Sheets	Board
489	R50	9-B2	T
490	R51	9-B2	T
491	R52	9-B4	T
492	R53	9-B4	T
493	R54	9-B5	T
494	R55	9-B6	T
495	R56	9-B6	T
496	R57	9-B7	T
497	R58	9-D8	T
498	R59	9-D9	T
499	R60	13-B2	T
500	R61	13-D2	T
501	R62	13-B2	T
502	R63	13-D2	T
503	R64	13-B3	T
504	R65	14-B3	T
505	R66	14-B3	T
506	R67	14-A3	T
507	R68	14-B3	T
508	R69	14-A4	T

— continued on next column —

Table 2: Part list — continued

	Name	Sheets	Board
509	R70	14-C4	T
510	R71	14-A4	T
511	R72	14-C4	T
512	R73	14-A5	T
513	R74	2-B3	T
514	R75	2-C4	T
515	R76	2-B5	T
516	R77	2-C4	T
517	R78	2-B8	T
518	R79	2-D7	T
519	R80	2-C8	T
520	R81	2-C3	T
521	R82	2-B8	T
522	R83	2-E4	T
523	R84	2-F4	T
524	R85	2-D3	T
525	R86	2-E8	T
526	R87	2-F2	T
527	R88	2-F2	T
528	R89	2-E2	T

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Table 2: Part list — continued

	Name	Sheets	Board
529	R90	2-E4	T
530	R91	2-C8	T
531	R92	2-C9	T
532	R93	6-B3	T
533	R94	6-B4	T
534	R95	6-B4	T
535	R96	6-B5	T
536	R97	6-E10	T
537	R98	6-E9	T
538	R99	6-D8	T
539	R100	6-D8	T
540	R101	6-E11	T
541	R102	6-B5	T
542	R103	6-B6	T
543	R104	10-B2	T
544	R105	10-B2	T
545	R106	10-B4	T
546	R107	10-B4	T
547	R108	10-B5	T
548	R109	10-B6	T

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Table 2: Part list — continued

	Name	Sheets	Board
549	R110	10-B6	T
550	R111	10-B7	T
551	R112	10-D9	T
552	R113	13-B6	T
553	R114	13-D6	T
554	R115	13-B6	T
555	R116	13-D6	T
556	R117	13-B7	T
557	R118	14-A9	T
558	R119	14-C9	T
559	R120	14-A9	T
560	R121	14-C9	T
561	R122	10-D8	T
562	R123	6-C7	T
563	R124	6-C9	T
564	R125	6-C9	T
565	R126	6-D9	T
566	R127	6-D10	T
567	R128	6-E3	T
568	R129	6-D7	T

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Table 2: Part list — continued

	Name	Sheets	Board
569	R130	6-E3	T
570	R131	14-A10	T
571	R132	6-C6	T
572	R133	14-B8	T
573	R134	14-B8	T
574	R135	14-A9	T
575	R136	14-B9	T
576	R137	2-C9	T
577	R138	3-B3	T
578	R139	3-C4	T
579	R140	3-B5	T
580	R141	3-C4	T
581	R142	3-B8	T
582	R143	3-D7	T
583	R144	3-C8	T
584	R145	3-C3	T
585	R146	3-B8	T
586	R147	3-E4	T
587	R148	3-F4	T
588	R149	3-D3	T

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Table 2: Part list — continued

	Name	Sheets	Board
589	R150	3-E8	T
590	R151	3-F2	T
591	R152	3-F2	T
592	R153	3-E2	T
593	R154	3-E4	T
594	R155	3-C8	T
595	R156	3-C9	T
596	R157	7-B3	T
597	R158	7-B4	T
598	R159	7-B4	T
599	R160	7-B5	T
600	R161	7-E10	T
601	R162	7-E9	T
602	R163	7-D8	T
603	R164	7-D8	T
604	R165	7-E11	T
605	R166	7-B5	T
606	R167	7-B6	T
607	R168	11-B2	T
608	R169	11-B2	T

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Table 2: Part list — continued

	Name	Sheets	Board
609	R170	11-B4	T
610	R171	11-B4	T
611	R172	11-B5	T
612	R173	11-B6	T
613	R174	11-B6	T
614	R175	11-B7	T
615	R176	11-D9	T
616	R177	13-B9	T
617	R178	13-D9	T
618	R179	13-B9	T
619	R180	13-D9	T
620	R181	13-B10	T
621	R182	14-D4	T
622	R183	14-E4	T
623	R184	14-D4	T
624	R185	14-E4	T
625	R186	11-D8	T
626	R187	7-C7	T
627	R188	7-C9	T
628	R189	7-C9	T

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Table 2: Part list — continued

	Name	Sheets	Board
629	R190	7-D9	T
630	R191	7-D10	T
631	R192	7-E3	T
632	R193	7-D7	T
633	R194	7-E3	T
634	R195	14-D5	T
635	R196	7-C6	T
636	R197	14-E3	T
637	R198	14-D3	T
638	R199	14-D3	T
639	R200	14-E3	T
640	R201	3-C9	T
641	R202	4-B3	T
642	R203	4-C4	T
643	R204	4-B5	T
644	R205	4-C4	T
645	R206	4-B8	T
646	R207	4-D7	T
647	R208	4-C8	T
648	R209	4-C3	T

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Table 2: Part list — continued

	Name	Sheets	Board
649	R210	4-B8	T
650	R211	4-E4	T
651	R212	4-F4	T
652	R213	4-D3	T
653	R214	4-E8	T
654	R215	4-F2	T
655	R216	4-F2	T
656	R217	4-E2	T
657	R218	4-E4	T
658	R219	4-C8	T
659	R220	4-C9	T
660	R221	8-B3	T
661	R222	8-B4	T
662	R223	8-B4	T
663	R224	8-B5	T
664	R225	8-E10	T
665	R226	8-E9	T
666	R227	8-D8	T
667	R228	8-D8	T
668	R229	8-E11	T

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Table 2: Part list — continued

	Name	Sheets	Board
669	R230	8-B5	T
670	R231	8-B6	T
671	R232	12-B2	T
672	R233	12-B2	T
673	R234	12-B4	T
674	R235	12-B4	T
675	R236	12-B5	T
676	R237	12-B6	T
677	R238	12-B6	T
678	R239	12-B7	T
679	R240	12-D9	T
680	R241	13-E2	T
681	R242	13-G2	T
682	R243	13-E2	T
683	R244	13-G2	T
684	R245	13-E3	T
685	R246	14-D9	T
686	R247	14-E9	T
687	R248	14-D9	T
688	R249	14-E9	T

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Table 2: Part list — continued

	Name	Sheets	Board
689	R250	12-D8	T
690	R251	8-C7	T
691	R252	8-C9	T
692	R253	8-C9	T
693	R254	8-D9	T
694	R255	8-D10	T
695	R256	8-E3	T
696	R257	8-D7	T
697	R258	8-E3	T
698	R259	14-D10	T
699	R260	8-C6	T
700	R261	14-E8	T
701	R262	14-D8	T
702	R263	14-D9	T
703	R264	14-E9	T
704	R265	4-C9	T

— T —

705	T1	16-B5	T
706	T2	16-C6	T
707	T3	1-C3	T

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Table 2: Part list — continued

	Name	Sheets	Board
708	T4	1-D8	T
709	T5	2-D8	T
710	T6	2-C3	T
711	T7	3-D8	T
712	T8	3-C3	T
713	T9	4-D8	T
714	T10	4-C3	T

— X —

715	X1	16-A3	T
716	X2	16-B3	T
717	X3	16-C3	T
718	X4	16-D3	T
719	X5	A: 16-B11 C: 16-C10	T

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Table 2: Part list — continued

	Name	Sheets	Board
726	X12	17-E5	T
727	X13	17-C7	T
728	X14	17-B4	T
729	X15	1-B5	T
730	X16	1-D7	T
731	X17	1-E7	T
732	X18	1-E8	T
733	X19	1-B10	T
734	X20	1-E2	T
735	X21	1-E5	T
736	X22	5-B3	T
737	X23	5-B4	T
738	X24	5-B6	T
739	X25	5-E2	T
740	X26	5-E2	T
741	X27	9-B3	T
742	X28	9-B5	T
743	X29	9-C8	T
744	X30	13-B2	T
745	X31	13-C2	T

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Table 2: Part list — continued

	Name	Sheets	Board
746	X32	14-B4	T
747	X33	14-B4	T
748	X34	17-C4	T
749	X35	2-B10	T
750	X36	2-E7	T
751	X37	2-B5	T
752	X38	2-D7	T
753	X39	2-E2	T
754	X40	2-E8	T
755	X41	10-B5	T
756	X42	10-B3	T
757	X43	6-B3	T
758	X44	6-B4	T
759	X45	10-C8	T
760	X46	13-B6	T
761	X47	13-C6	T
762	X48	14-B9	T
763	X49	14-B9	T
764	X50	6-B6	T
765	X51	2-E5	T

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Table 2: Part list — continued

	Name	Sheets	Board
766	X52	6-E2	T
767	X53	6-E2	T
768	X54	17-E4	T
769	X55	3-B10	T
770	X56	3-E7	T
771	X57	3-B5	T
772	X58	3-D7	T
773	X59	3-E2	T
774	X60	3-E8	T
775	X61	11-B5	T
776	X62	11-B3	T
777	X63	7-B3	T
778	X64	7-B4	T
779	X65	11-C8	T
780	X66	13-B9	T
781	X67	13-C9	T
782	X68	14-D4	T
783	X69	14-E4	T
784	X70	7-B6	T
785	X71	3-E5	T

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Table 2: Part list — continued

	Name	Sheets	Board
786	X72	7-E2	T
787	X73	7-E2	T
788	X74	17-F4	T
789	X75	4-B10	T
790	X76	4-E7	T
791	X77	4-B5	T
792	X78	4-D7	T
793	X79	4-E2	T
794	X80	4-E8	T
795	X81	12-B5	T
796	X82	12-B3	T
797	X83	8-B3	T
798	X84	8-B4	T
799	X85	12-C8	T
800	X86	13-E2	T
801	X87	13-F2	T
802	X88	14-D9	T
803	X89	14-E9	T
804	X90	8-B6	T
805	X91	4-E5	T

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Table 2: Part list — continued

	Name	Sheets	Board
806	X92	8-E2	T
807	X93	8-E2	T