HV channel polarity switcher

Circuit Board Documentation

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Abstract

This circuit is designed to flip the polarity of its input, controlled via a signal between $\pm 10\,V_{DC}$. The input can have up to $\pm 1000\,V_{DC}$ per conductor. When the control signal goes LOW, the first output pair is engaged and the input polarity is maintained. When the control signal goes HIGH (rising above $5\,V_{DC}$), the second output pair is engaged and the input polarity is flipped at the output. The control signal can be generated by a CDS AA filter (using only the positive channel), or alternatively by a CMOS compatible digital output.

Circuit

Two pairs of reed relays map the input to output with opposing polarities. One pair of relays activates when the control signal is LOW (pair 1, polarity *maintaining*), and the other activates when it's HIGH (pair 2, polarity *switching*). During switch-over, the circuit uses a delay circuit to "break before make", to avoid momentarily shorting the output terminals together.

Components C17, C18, R8 and R9 are used to match the impedance and capacitance of any transmission lines connected at the outputs. Size C18 and C18 to match the transmission lines' capacitance, and set R8 and R9 to their characteristic impedance. Components D3 and D4 are used to snub any residual transients due to impedance mismatch to ground.

Truth table

Control input	Pair 1 (polarity maintaining)	Pair 2 (polarity switching)
LOW	**ON**	OFF
LOW to HIGH	OFF	OFF
HIGH	OFF	**ON**
HIGH to LOW	OFF	OFF

Switching delay

The time constant of the RC filter determines the time it takes for the capacitor to discharge to 37% (1/e) of its peak voltage. As the logic gates are CMOS type, the threshold where a logic output of HIGH flips to LOW occurs at 40%, so the time constant essentially sets the switch delay. The delay must be longer than the switching time of the reed relays, which is around 1 ms. The suggested $3\,k\Omega$ resistor and $1\,\mu F$ capacitor give a time constant of 3 ms.

Assembly

Use 0.6 W resistors.

Key words: HV, high voltage, relay, ESD, polarity, switch

Contents

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 contains hazardous voltages (50–1000 V_{AC} or 75–1500 V_{DC})[1]. To avoid the possibility of electrical shock, the following policies should be strictly observed:

- Operate the board only in an either isolated or properly earthed case, ensuring that live contacts and wires cannot be touched.
- Use only connectors and cables meeting the required specifications and with protection against direct contact.
- Before connecting or disconnecting cables, ensure that the power is disconnected and all internal capacitors are discharged.
- Check the circuit safety at regular intervals, label the unit accordingly, and immediately dispose of defective equipment.

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.

The unit does not contain any mechanical drive system. Therefore, the regulations of the *Machinery Directive* (2006/42/EC) do not apply.

[1] The regulations of the *Low Voltage Directive* (2006/95/EC) 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 enthält gefährliche Spannungen (50–1000 V_{AC} oder 75–1500 V_{DC})[2]. Zur Vermeidung von Stromschlägen sind folgende Regeln strikt einzuhalten:

- Platine nur in einem isolierten oder korrekt geerdeten Gehäuse betreiben, damit spannungsführende Kontakte und Drähte nicht berührt werden können.
- Nur Steckverbinder und Kabel verwenden, welche die nötigen Spezifikationen einhalten und berührungsgeschützt sind.
- Vor dem Ein- und Ausstecken von Kabeln sicherstellen, daß die Betriebsspannung ausgeschaltet ist und alle internen Kondensatoren entladen sind.
- Gerät in regelmäßigen Abständen auf Sicherheit prüfen, entsprechend beschriften und bei Defekten sofort aus dem Verkehr ziehen.

Diese Schaltung wurde als Laborausrüstung 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.

Das Gerät enthält kein mechanisches Antriebssystem – die Bestimmungen der *Maschinenrichtlinie* (2006/42/EC) sind daher nicht anwendbar.

[2]Es gelten die Bestimmungen der *Niederspannungsrichtlinie* (2006/95/EC).

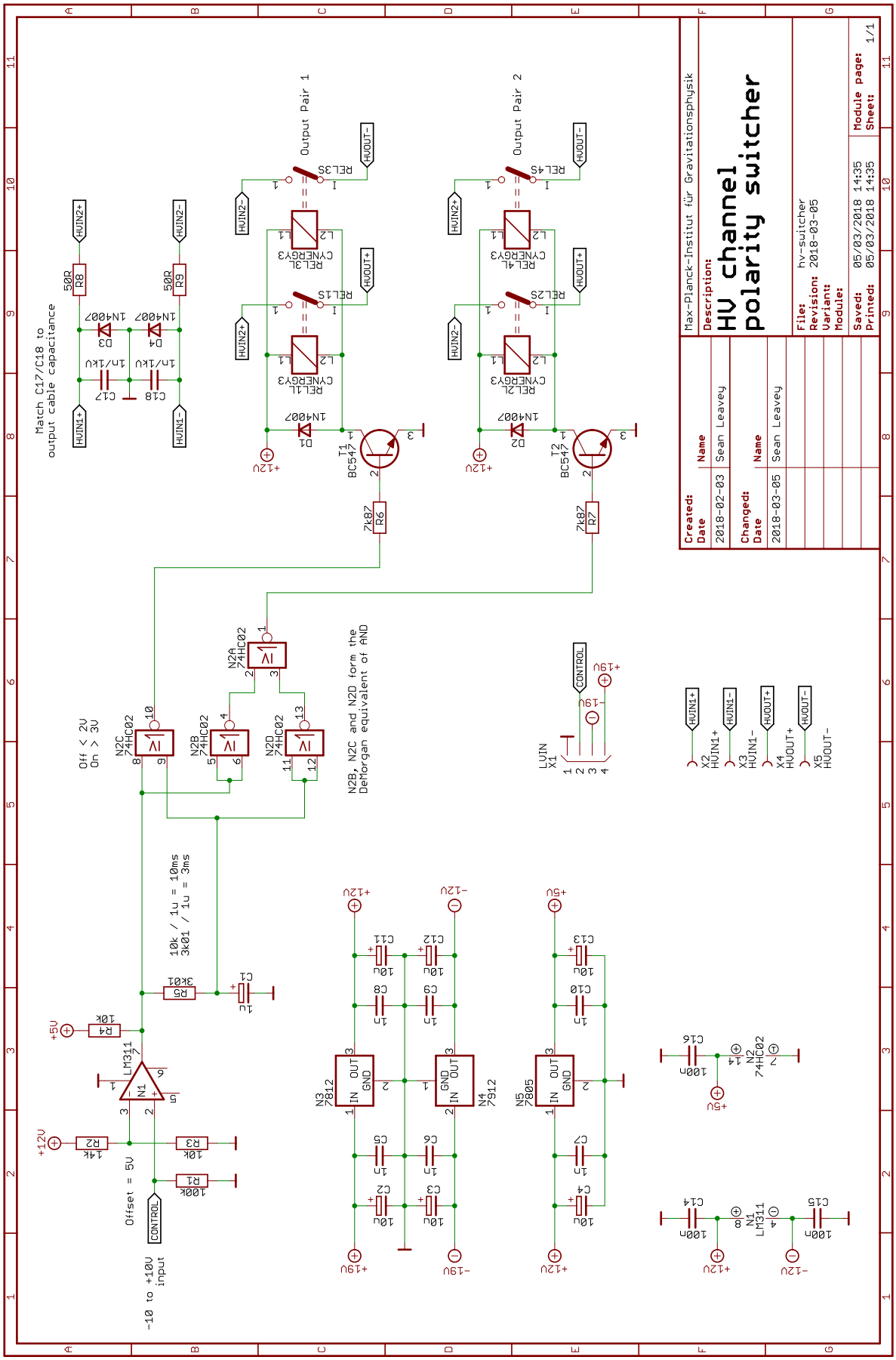

Figure 1: *Project schematics*

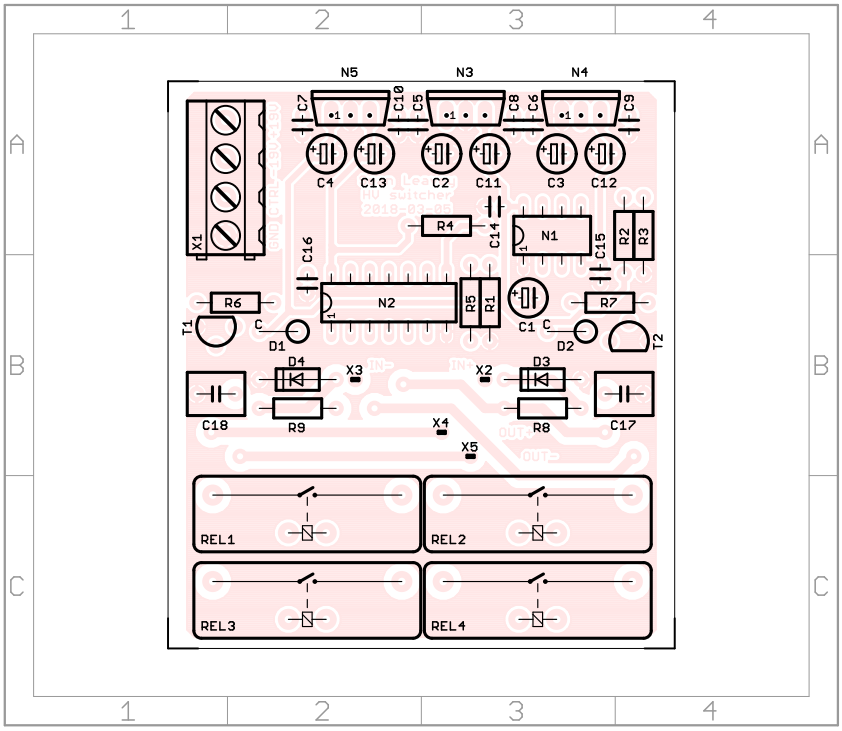

Figure 2: *Board top view showing placeplan with component names*

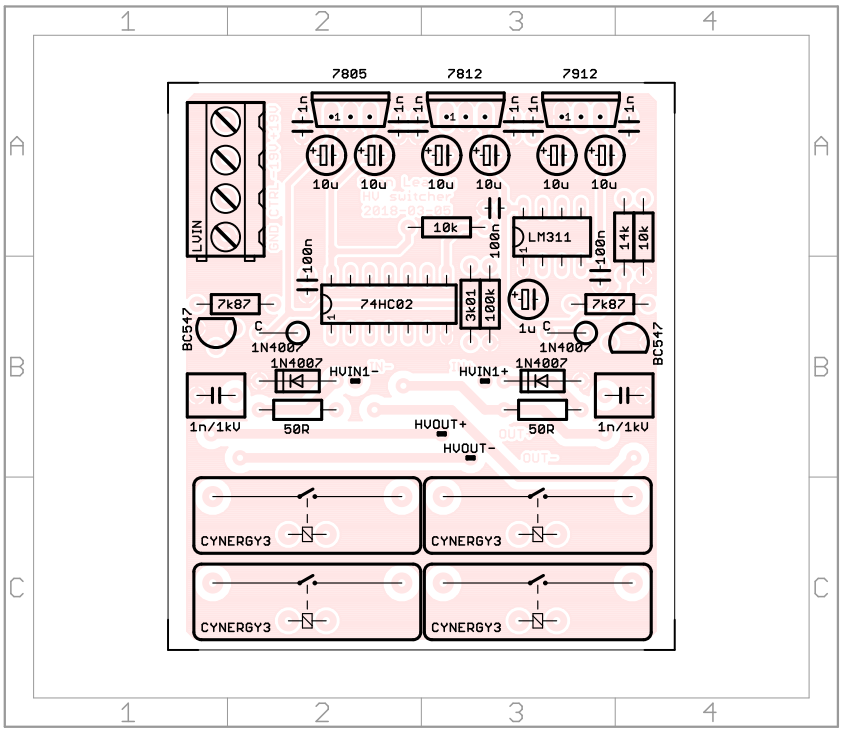

Figure 3: *Board top view showing placeplan with component values*

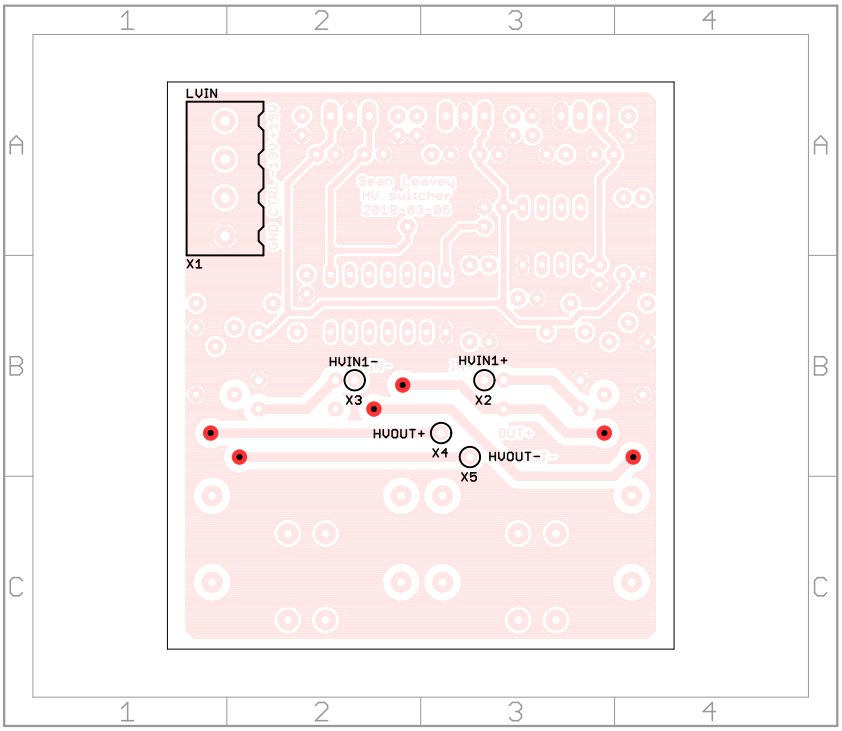

Figure 4: *Board top view showing connectors, test points, vias and wired components*

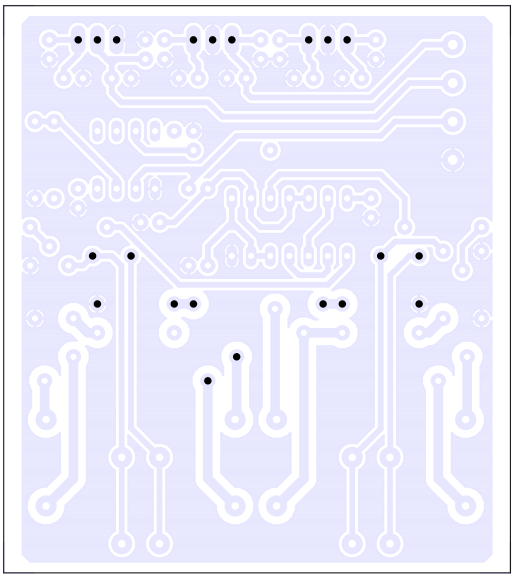

Figure 5: *Board bottom view showing drills with 1.0 mm (0.039 in) diameter*

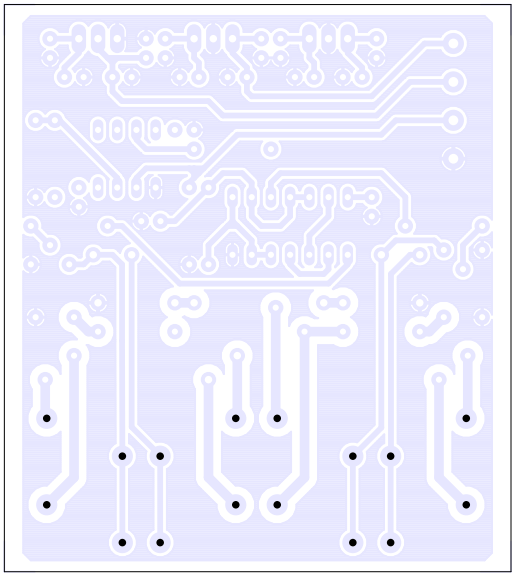

Figure 6: *Board bottom view showing drills with 1.0 mm (0.039 in) diameter*

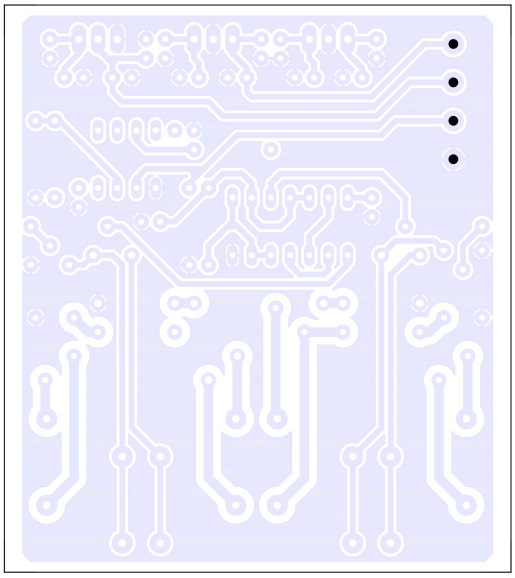

Figure 7: *Board bottom view showing drills with 1.3 mm (0.051 in) diameter*

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.

∅ [µm]	∅ [mm]	∅ [in]	Count
813	0.8	0.032	88
991	1.0	0.039	21
1000	1.0	0.039	16
1295	1.3	0.051	4
		Total	129

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 *(library)*
	— C —			
1	1n	C-0.1"	6	C5-C10 *(miscs)*
2	1n/1kV	C-WIMA:MKS2	2	C17,C18 *(miscs)*
3	100n	C-0.1"	3	C14-C16 *(miscs)*
4	1u	CE-TANTAL:0.1"	1	C1 *(miscs)*
5	10u	CE-TANTAL:0.1"	6	C2-C4,C11-C13 *(miscs)*
	— D —			
6	1N4007	D02N-DO41	2	D1,D2 *(diodes)*
7	1N4007	D04N-DO41	2	D3,D4 *(diodes)*
	— N —			
8	74HC02	DIP-14	1	N2 *(digitals)*
9	7805	TO-220	1	N5 *(ics)*
10	7812	TO-220	1	N3 *(ics)*
11	7912	TO-220	1	N4 *(ics)*
12	LM311	DIP-8	1	N1 *(opamps)*
	— R —			
13	50R	R-wired:0.6W	2	R8,R9 *(miscs)*
14	3k01	R-wired:0.6W	1	R5 *(miscs)*
15	7k87	R-wired:0.6W	2	R6,R7 *(miscs)*
16	10k	R-wired:0.6W	2	R3,R4 *(miscs)*
17	14k	R-wired:0.6W	1	R2 *(miscs)*
18	100k	R-wired:0.6W	1	R1 *(miscs)*
	— REL —			
19	CYNERGY3	REL-CYNERGY	4	REL1-REL4 *(miscs)*
	— T —			
20	BC547	TO-92	2	T1,T2 *(transistors)*

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Table 2: *Value list — continued*

	Value	Package	Count	Component names *(library)*
	— X —			
21	*[ignored]*	ScrewTerminal:4-pin/vert.	1	X1 *(connectors)*
22	*[ignored]*	XT-1.0METAL-N	4	X2-X5 *(connectors)*

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	1-B3	T
2	C2	1-C2	T
3	C3	1-D2	T
4	C4	1-E2	T
5	C5	1-C2	T
6	C6	1-D2	T
7	C7	1-E2	T
8	C8	1-C3	T
9	C9	1-D3	T
10	C10	1-E3	T
11	C11	1-C4	T
12	C12	1-D4	T
13	C13	1-E4	T
14	C14	1-F2	T
15	C15	1-G2	T
16	C16	1-F3	T
17	C17	1-A8	T
18	C18	1-B8	T
	— D —		
19	D1	1-C8	T
20	D2	1-E8	T
21	D3	1-A9	T
22	D4	1-B9	T
	— N —		
23	N1	A: 1-B3	T
		P: 1-F2	
24	N2	A: 1-C6	T
		B: 1-B5	
		C: 1-B5	
		D: 1-C5	
		P: 1-F3	
25	N3	1-C3	T

— continued on next column —

Table 2: *Part list — continued*

	Name	Sheets	Board
26	N4	1-D3	T
27	N5	1-E3	T
	— R —		
28	R1	1-B2	T
29	R2	1-A2	T
30	R3	1-B2	T
31	R4	1-A3	T
32	R5	1-B3	T
33	R6	1-C7	T
34	R7	1-E7	T
35	R8	1-A9	T
36	R9	1-B9	T
	— REL —		
37	REL1	L: 1-C9	T
		S: 1-C9	
38	REL2	L: 1-E9	T
		S: 1-E9	
39	REL3	L: 1-C10	T
		S: 1-C10	
40	REL4	L: 1-E10	T
		S: 1-E10	
	— T —		
41	T1	1-C8	T
42	T2	1-E8	T
	— X —		
43	X1	1-E5	T
44	X2	1-F5	T
45	X3	1-F5	T
46	X4	1-G5	T
47	X5	1-G5	T