Chapter 7 Evaluation Board

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1. Abstract

This evaluation board is designed only for Fuji M653 IGBT module.
The board can control the module safely by monitoring two on-chip sensors, which are junction temperature sensor and emitter current sensor.
Gate driver IC ADuM4138 of Analog Devices, Inc. is used in this evaluation board.

*1) This evaluation board was developed only for evaluation purpose of our IGBT module and it is not a regular product. In addition, the part constants described in this document are intended to assist design, and they do not fully consider variations in parts and conditions of use. In actual design, please consider these parts dispersion and use conditions carefully.

2. Features

- Six channel driver
- 26 pin connector
- Isolated DC/DC converters
- Interface for 5V logic levels
- Active Clamping
- High voltage DC link monitoring
- Short-circuit (SC) protect and alarm
- Over temperature protection and alarm
  +15V/0V gate drive voltage (To be applied)

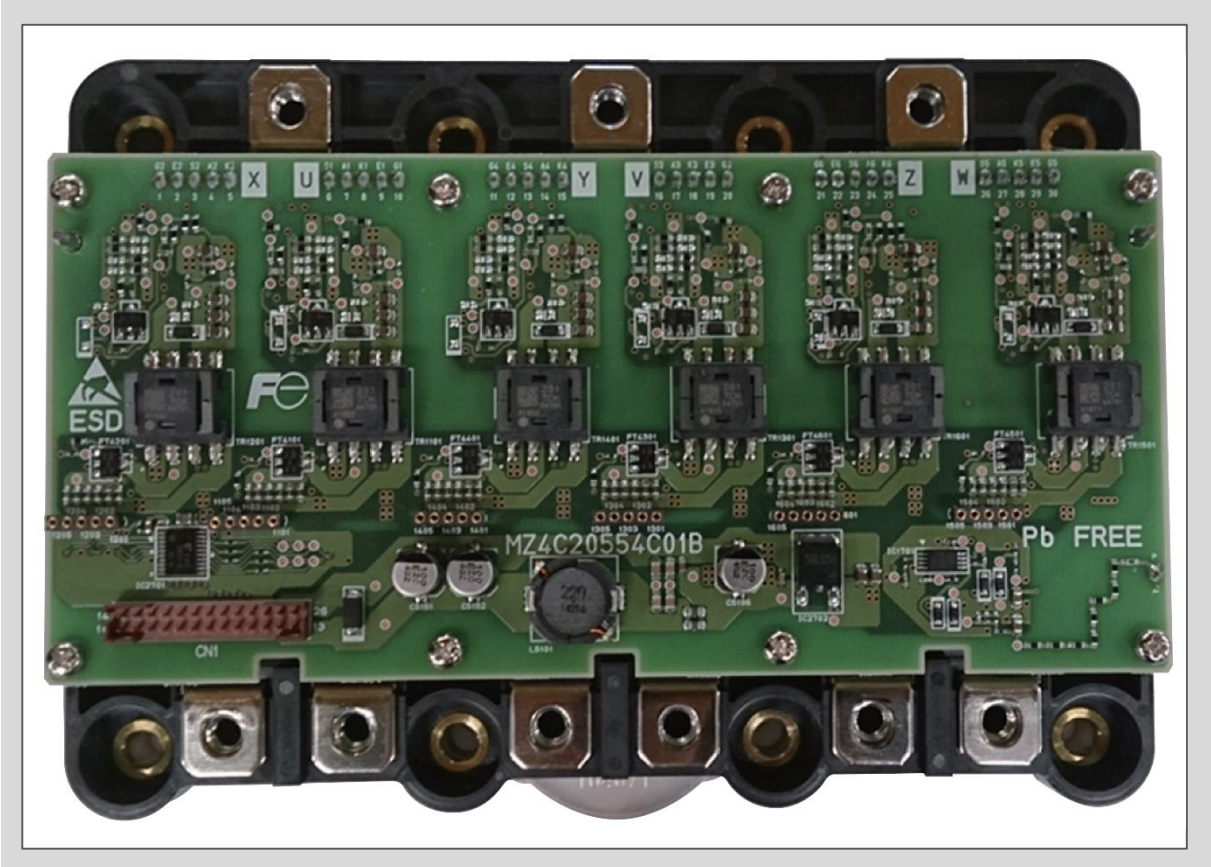

Fig. 7-1 M653 IGBT module evaluation board

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3. System Outline

The basic topology of the driver is shown in Fig. 7-2.

Fuji sets the values for gate resistors and other key components based on our evaluation results by using M653 IGBT module.

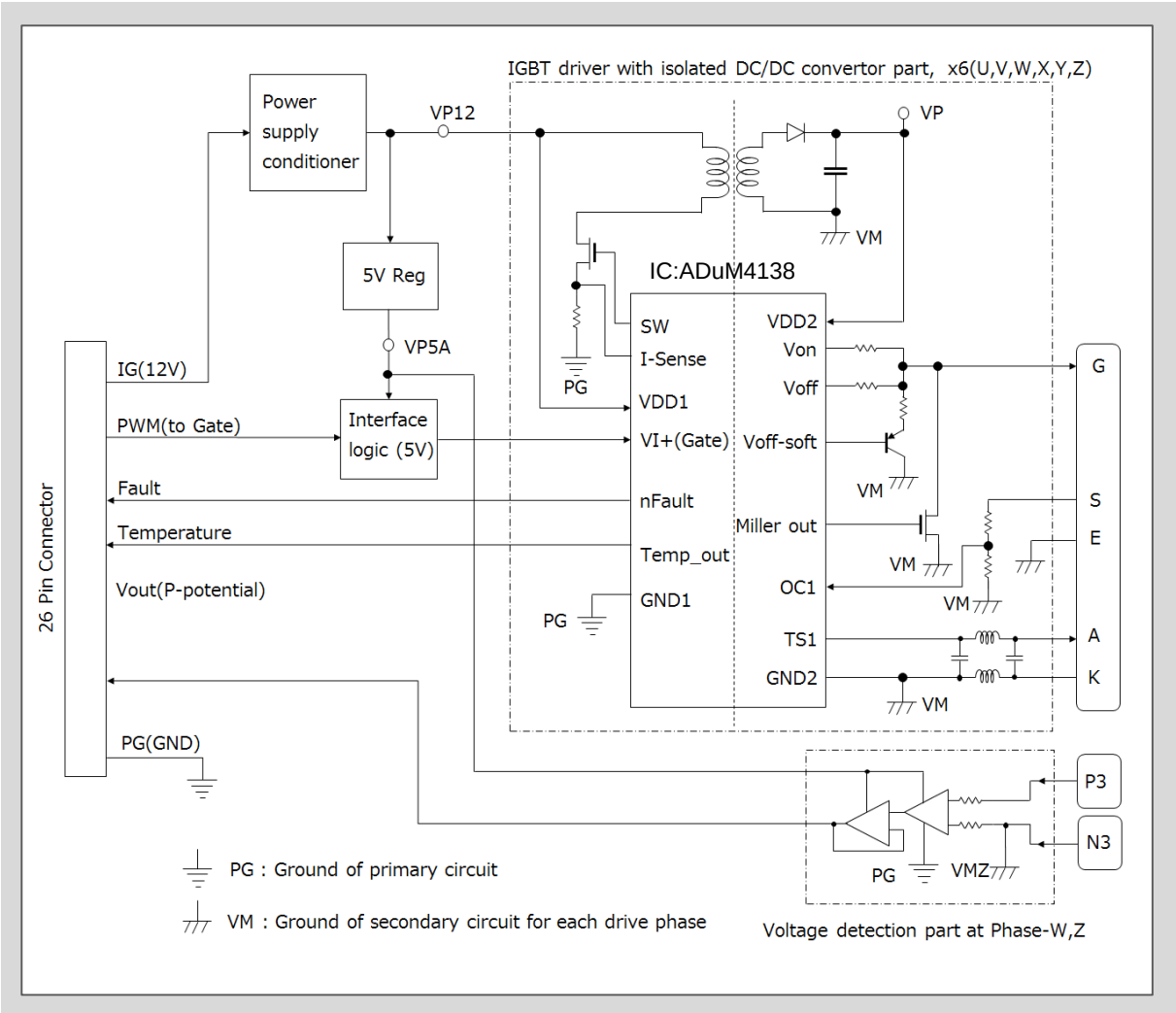

Fig. 7-2 Basic schematic of the M653 IGBT module evaluation board

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4. Absolute Maximum Ratings

Table 7-1 Absolute maximum ratings

Parameter	Description	Min	Max	Unit
Supply Voltage	IG Input	-0.3	25	V
Peak Gate Current		-6	6	A
Input Logic Levels	To GND	-0.3	5.3	V
Switching Frequency			20	kHz
Isolation Voltage	Primary to Secondary		2500	Vrms
Operating Temperature		-40	+105	°C
Storage Temperature		-40	+105	°C

* measured under ambient temperature 25°C. unless otherwise specified.

5. Electrical Characteristics

Table 7-2 Electrical characteristics

Power Supply	Description	Min	Typ	Max	Unit
Supply Voltage	IG input	6	12	16	V
Supply Current	Without Load		200		mA
Rush Current	Start up Current		16		A
Average Supply Current	Switching Frequency: 10KHz		600		mA
UVLO Level (Primary Side)	Primary Side low voltage detect fault level		4.13		V
UVLO Level (Secondary Side)	Secondary Side low voltage detect fault level		11.2		V
Secondary Output Voltage	Fly-Back Output Voltage	14	15	16	V

Logic Signal	Description	Min	Typ	Max	Unit
Input Current			1.0		mA
V5 Regulated Voltage		4.85	5.00	5.15	V
Logic High Input Voltage		2.0			V
Logic Low Input Voltage				0.8	V
PWM Pulse On Delay Time	PWM Input to IGBT Gate		0.5		μs
PWM Pulse Off Delay Time	PWM Input to IGBT Gate		0.45		μs
Gate Output Voltage Low				0.1	V
Gate Output Voltage High		14	15	16	V
Alarm Output Impedance	Fault pull down		10	30	Ω
Alarm Fault Hold Time			26.4		ms

* measured under ambient temperature 25°C. unless otherwise specified.

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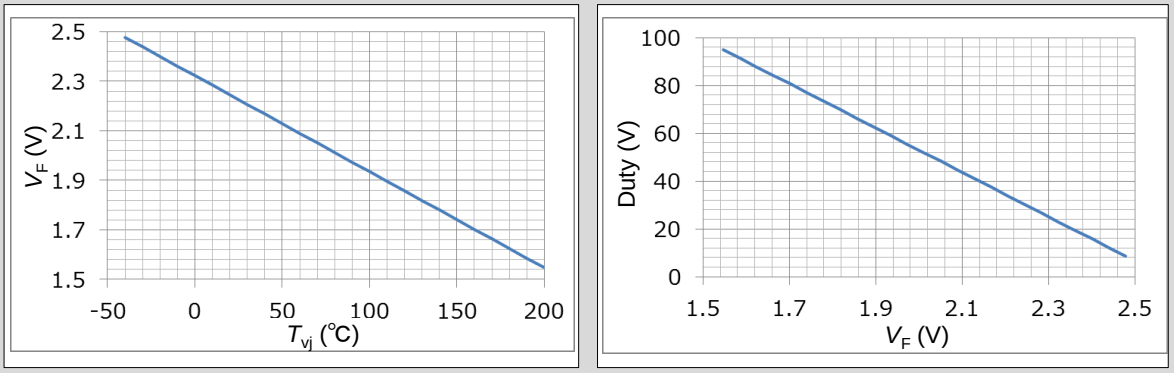
6. Junction Temperature Monitoring Function

Table 7-3 Junction temperature monitoring

IGBT temperature communication	Description	Min	Typ	Max	Unit
Output high voltage		4.85	5.00	5.15	V
Output low voltage				0.1	V
Output frequency			50		kHz
PWM duty	Temp V_F = 2.23V		30		%
PWM duty	Temp V_F = 1.65V		82		%

* measured under ambient temperature 25°C. unless otherwise specified.



(a) V_F vs. T_{vj} (b) Duty vs. V_F

Fig. 7-3 Relation among T_{vj}, V_F and Duty

* Note:
I_F current specification on ADuM4138: ±5 %@ I_F = 1(mA) .
→ V_F shift of Temperature Diode under ±5% of I_F (1mA) : ±11 mV.

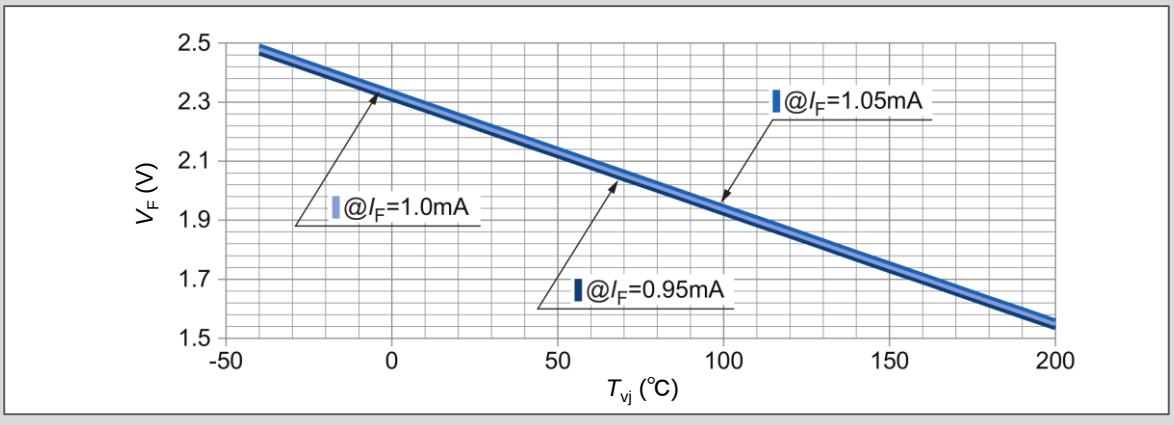


Fig. 7-4 V_F - T_{vj} shift according to I_F@±0.05(mA)

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7. PN Voltage Monitoring Function

Table 7-4 PN voltage monitoring

PN Voltage Communication	Description	Min	Typ	Max	Unit
Output Voltage	PN = 100V		0.79		V
Output Voltage	PN = 250V		1.94		V
Output Voltage	PN = 400V		3.09		V

* measured under ambient temperature 25°C. unless otherwise specified.

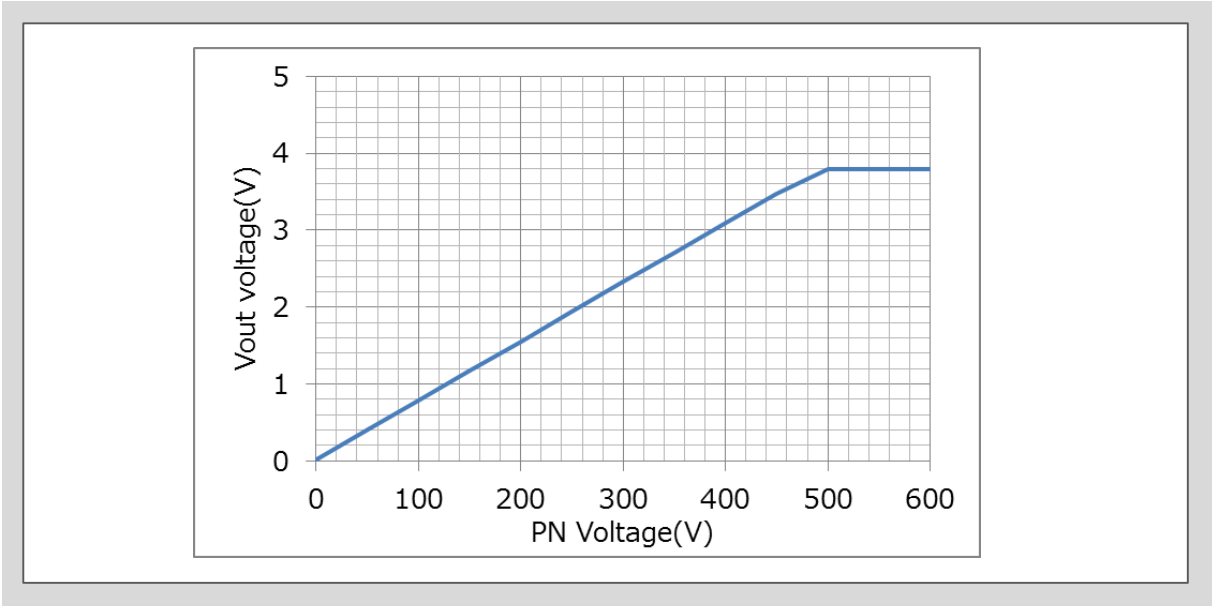

Fig. 7-5 Output voltage vs. PN voltage

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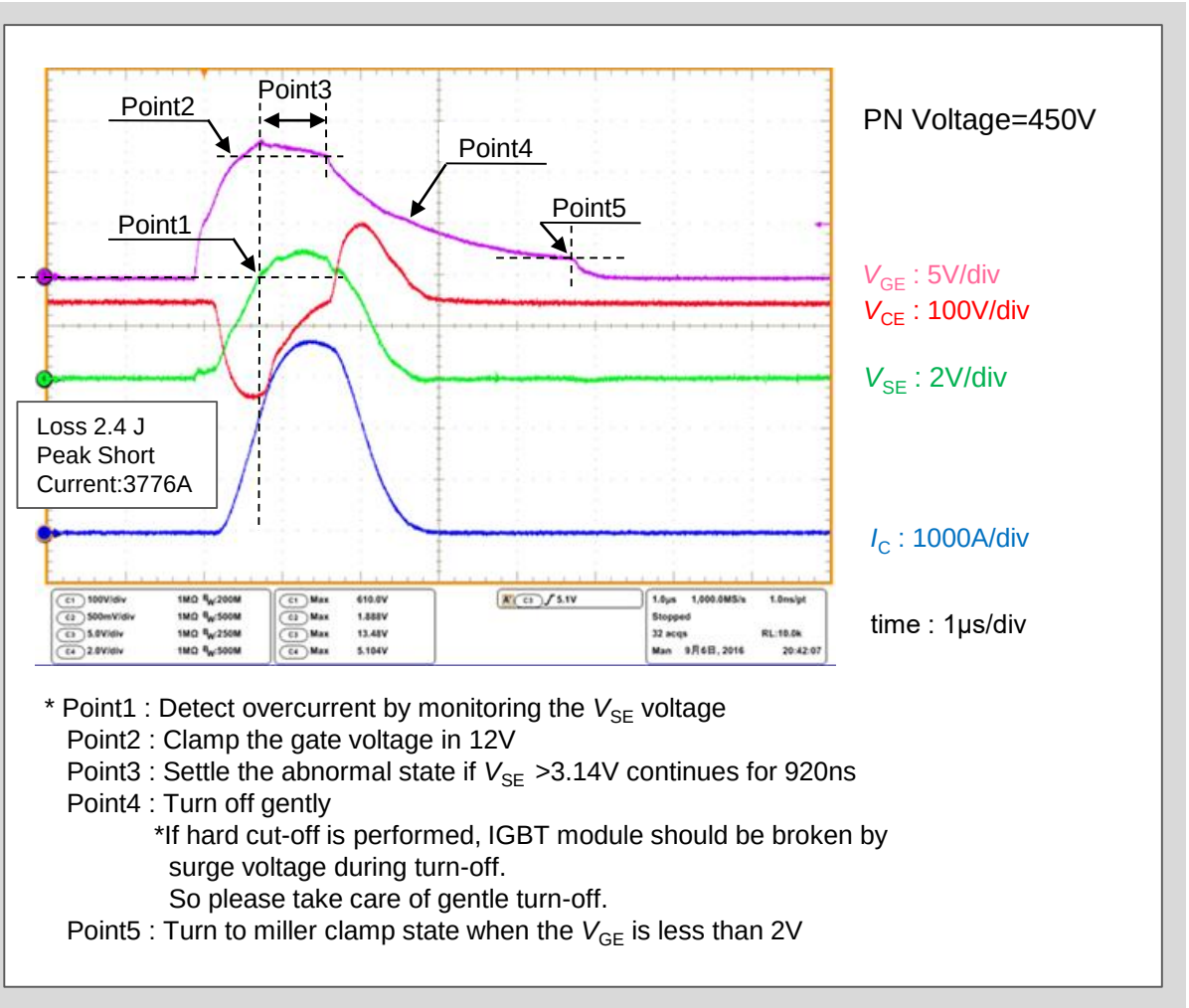
8. Short-Circuit (SC) Protection Function

Table 7-5 Short-circuit protection conditions

IGBT Short Protection	Description	Min	Typ	Max	Unit
Short-Current Detect Voltage	Point 1		3.14		V
Gate Clamp Voltage	Point 2		11.9		V
Detect Delay Time	Point 3		920		ns
Soft Shutdown Impedance	Point 4		30		Ω
Miller Clamp Gate Voltage Threshold	Point 5	1.9	2.00	2.1	V

* measured under ambient temperature 25°C. unless otherwise specified.



* Point1 : Detect overcurrent by monitoring the V_{SE} voltage
  Point2 : Clamp the gate voltage in 12V
  Point3 : Settle the abnormal state if V_{SE} >3.14V continues for 920ns
  Point4 : Turn off gently
  *If hard cut-off is performed, IGBT module should be broken by surge voltage during turn-off.
  So please take care of gentle turn-off.
  Point5 : Turn to miller clamp state when the V_{GE} is less than 2V

Fig. 7-6 Short-circuit protection function

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9. Timing Diagrams

Input Waveform to PWM-U, V, W, X, Y, Z (to Gate)

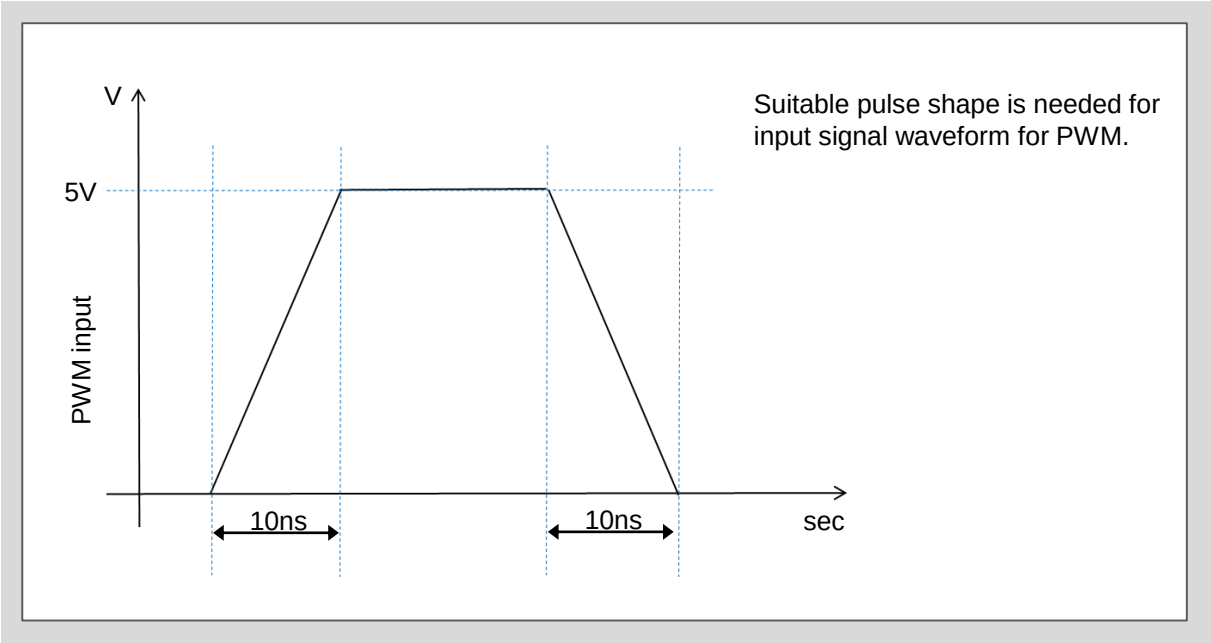

Fig. 7-7 Input signal waveform for PWM input

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10. Generic Sample Factory Settings

The default gate resistor and dividing resistor for current sense function are shown in below Table 7-6.

R_G setting are set by taking account of Short circuit protection and surge voltage which does not exceed 700V at -40℃.

Table 7-6 Default value of the circuit board parameters

	R_{Gon} (Ω) / R_{Goff} (Ω)	C_{GE} (μF)	R_{SENSE} (divider: Ω/Ω)
Upper arm	2.8 / 2.8	0.047	47 / 82
Lower arm	2.8 / 2.8	0.068	47 / 82

11. Recommended Start-Up Testing

Caution: Handling devices with high voltage involves risk to life. It is imperative to comply with all respective precautions and safety regulations.

1. Connect the driver through the 26 pin post header to test board and supply +12V through pins 12 and 13.

2. Although there is no fault reset pin, fault function is automatically reset by power-off and power-on sequence.

3. Check the gate voltage according to followings:
   a) For the off-state, the nominal gate voltage should be 0V.
   b) For the on-state, it is +14 to +16V
   c) Check the current consumption of the driver without the clock signals and the desired switching frequency driving a capacitive load equivalent to the Gate Capacitance of the IGBT.
   In the case of M653 module, 0.22μF of the capacitance is recommended.
   And its consumption is around 600mA as typical value.
   On the other hand, it is less than 200mA without any load.
   d) Above test should be performed before board installation.

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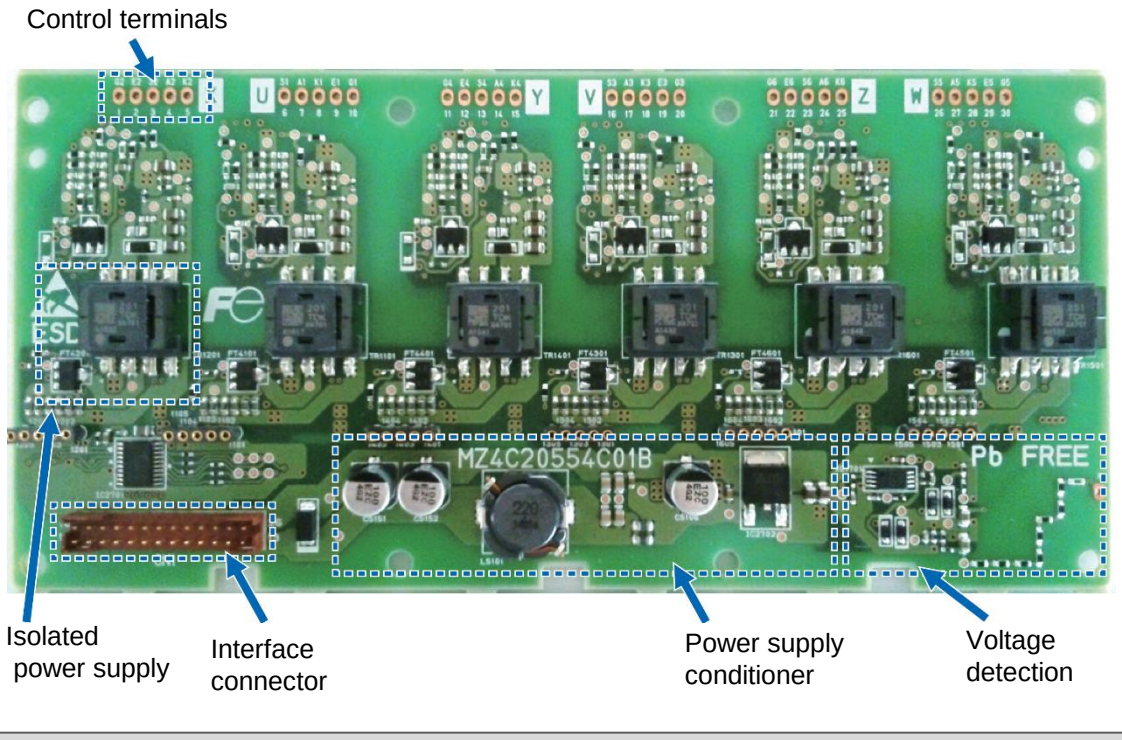
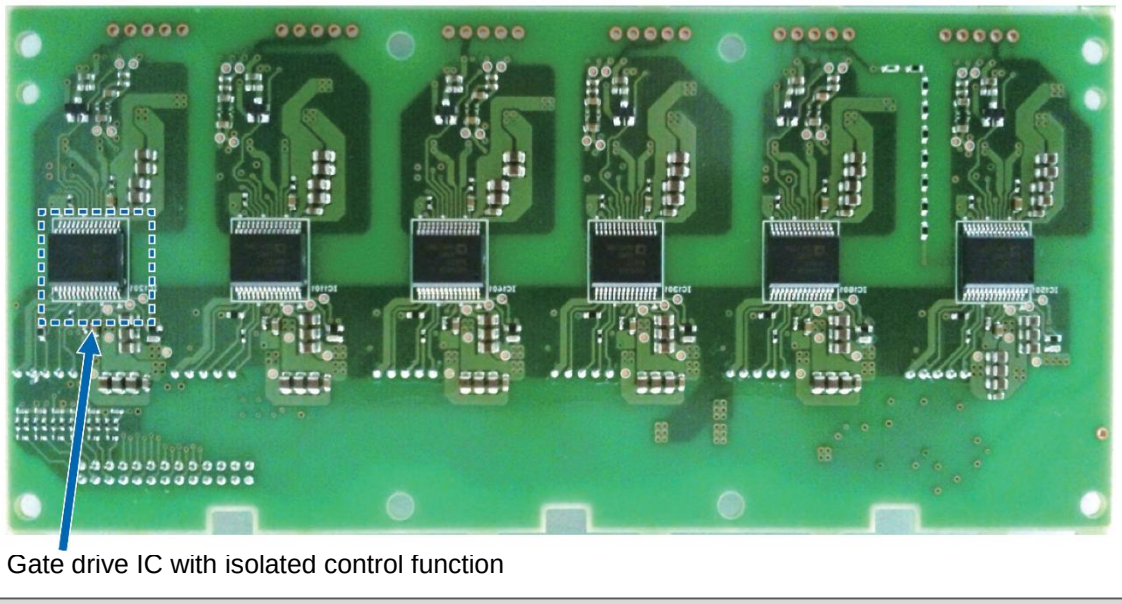
12. Evaluation Board Appearance

IGBT driving part for each phase, which are U, V, W, X, Y and Z, has an isolated power supply. The driver IC has an isolated Input-Output.



(a) Top view



(b) Bottom view (mirror)

Fig. 7-8 Evaluation board appearance

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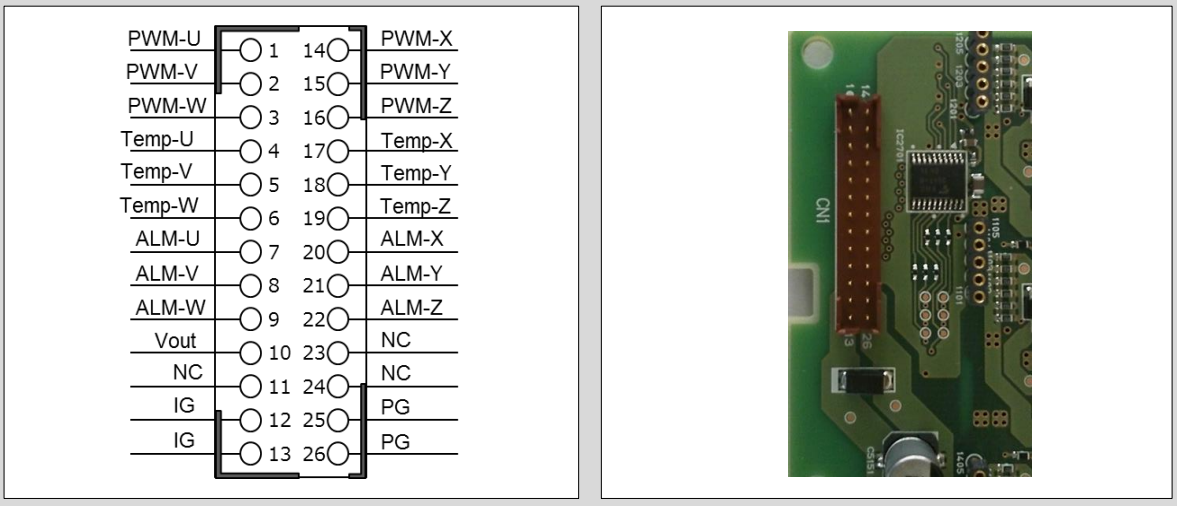
Table 7-7 External connector pin assignment

Pin Number	Pin Name	Type	Description
1	PWM-U	Input	Gate drive PWM signal for phase U
2	PWM-V	Input	Gate drive PWM signal for phase V
3	PWM-W	Input	Gate drive PWM signal for phase W
4	Temp-U	Output	Temperature data output of phase U
5	Temp-V	Output	Temperature data output of phase V
6	Temp-W	Output	Temperature data output of phase W
7	ALM-U	Output	Alarm signal output when any fault is occurred on phase U
8	ALM-V	Output	Alarm signal output when any fault is occurred on phase V
9	ALM-W	Output	Alarm signal output when any fault is occurred on phase W
10	Vout	Output	Potential monitor at P3 which shows Battery voltage
11	NC	NC	Not connected
12	IG	Supply	+12.0V Power Supply
13	IG	Supply	+12.0V Power Supply
14	PWM-X	Input	Gate drive PWM signal for phase X
15	PWM-Y	Input	Gate drive PWM signal for phase Y
16	PWM-Z	Input	Gate drive PWM signal for phase Z
17	Temp-X	Output	Temperature data output of phase X
18	Temp-Y	Output	Temperature data output of phase Y
19	Temp-Z	Output	Temperature data output of phase Z
20	ALM-X	Output	Alarm signal output when any fault is occurred on phase X
21	ALM-Y	Output	Alarm signal output when any fault is occurred on phase Y
22	ALM-Z	Output	Alarm signal output when any fault is occurred on phase Z
23	NC	NC	Not connected
24	NC	NC	Not connected
25	PG	Supply	Ground
26	PG	Supply	Ground



(a) External connector pin assignment

(b) Top view of external connector

Fig. 7-9 Pin assignment and top view of external connector

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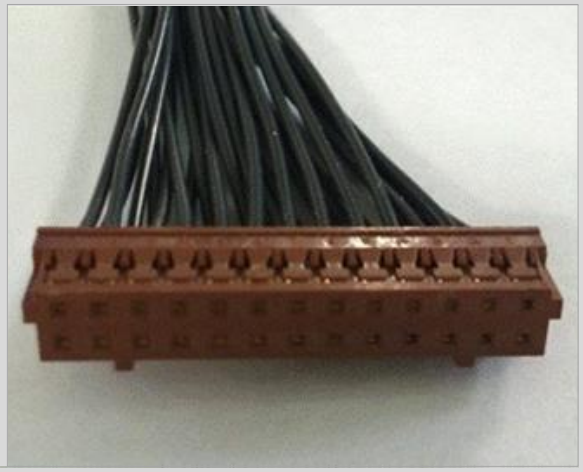
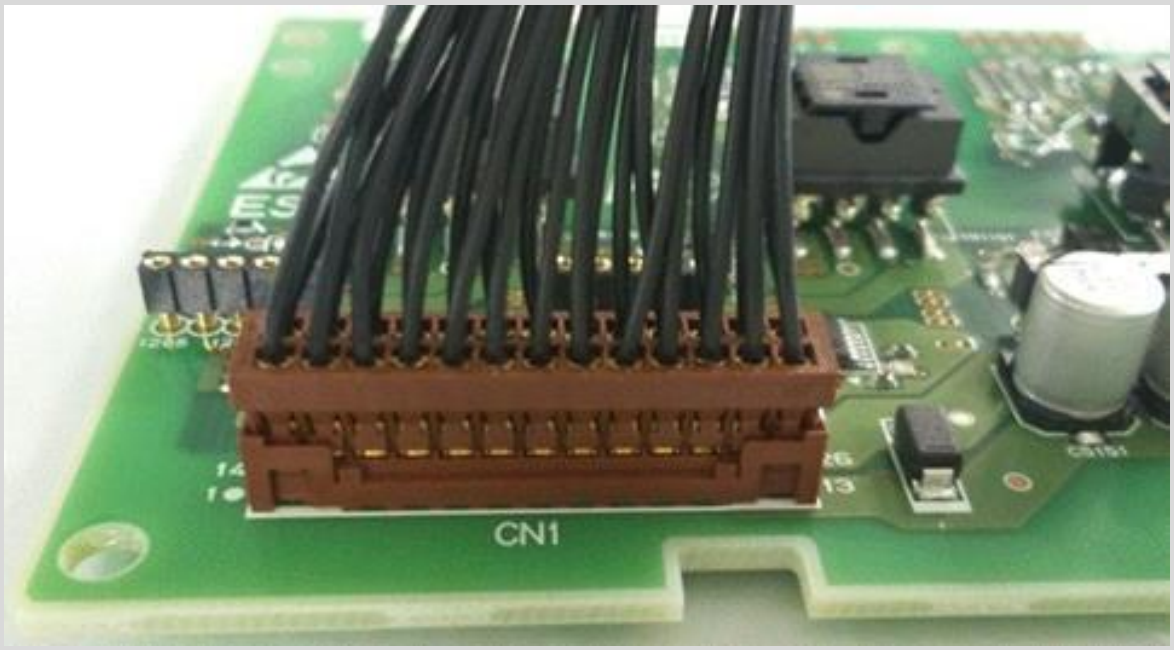
13. Interface Connector and Harness

Connection to the evaluation board is performed by an optional interface cable.
As shown in Fig. 7-10(a), the optional interface cable has 2 socket housings in both ends respectively. So any other interface board preparation might be useful for testing.

(a) Harness for board interface



(b) Socket housing



(c) Connecting the cable to the board

Fig. 7-10 Interface harness and its application

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14. Evaluation Board Installation to the Module

Caution: An IGBT module is an electric device and weak against ESD, so please take it with enough countermeasure against electro static prior to board installation.

Board installation procedure:

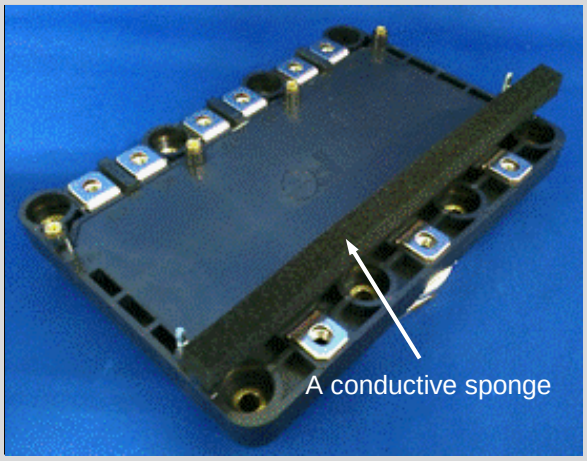
(a) Remove the sponge with take care.
A conductive sponge is attached to protect the module from ESD prior to factory shipment.

(b) Confirm whether there is any vended control pin or not.
There are 30 pcs of control pin and one voltage detection pin, so call P-terminal, all terminals should be confirmed.

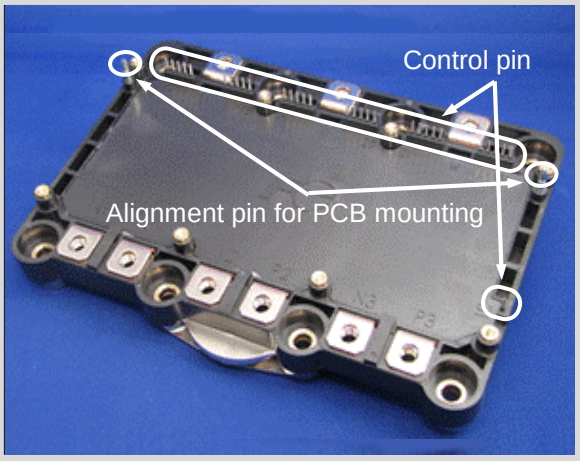
(c) Mount the board along the alignment pin at the both side of the module.

(d) Tighten the screws within specific torque.

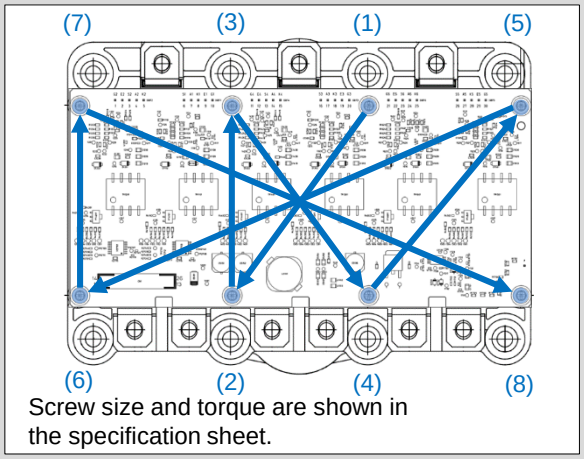
(e) Soldering the control pins. Soldering condition is shown in the specification sheet.



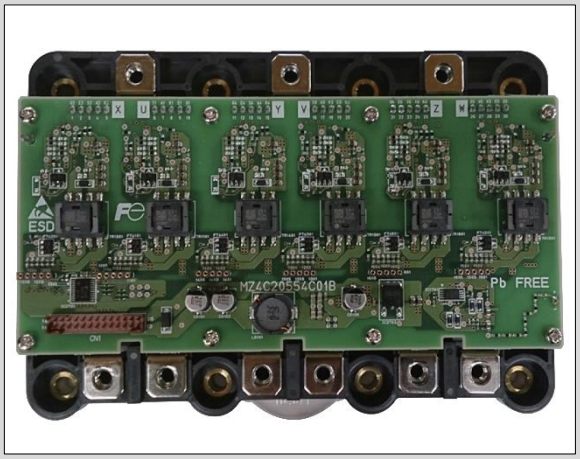
(a) Protection the module from ESD



(b) Alignment pin for the board installation



(c) Sequence of tightening screw



(d) The installed board on the module

Fig. 7-11 The board installation

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15. Evaluation Board Circuit Diagram

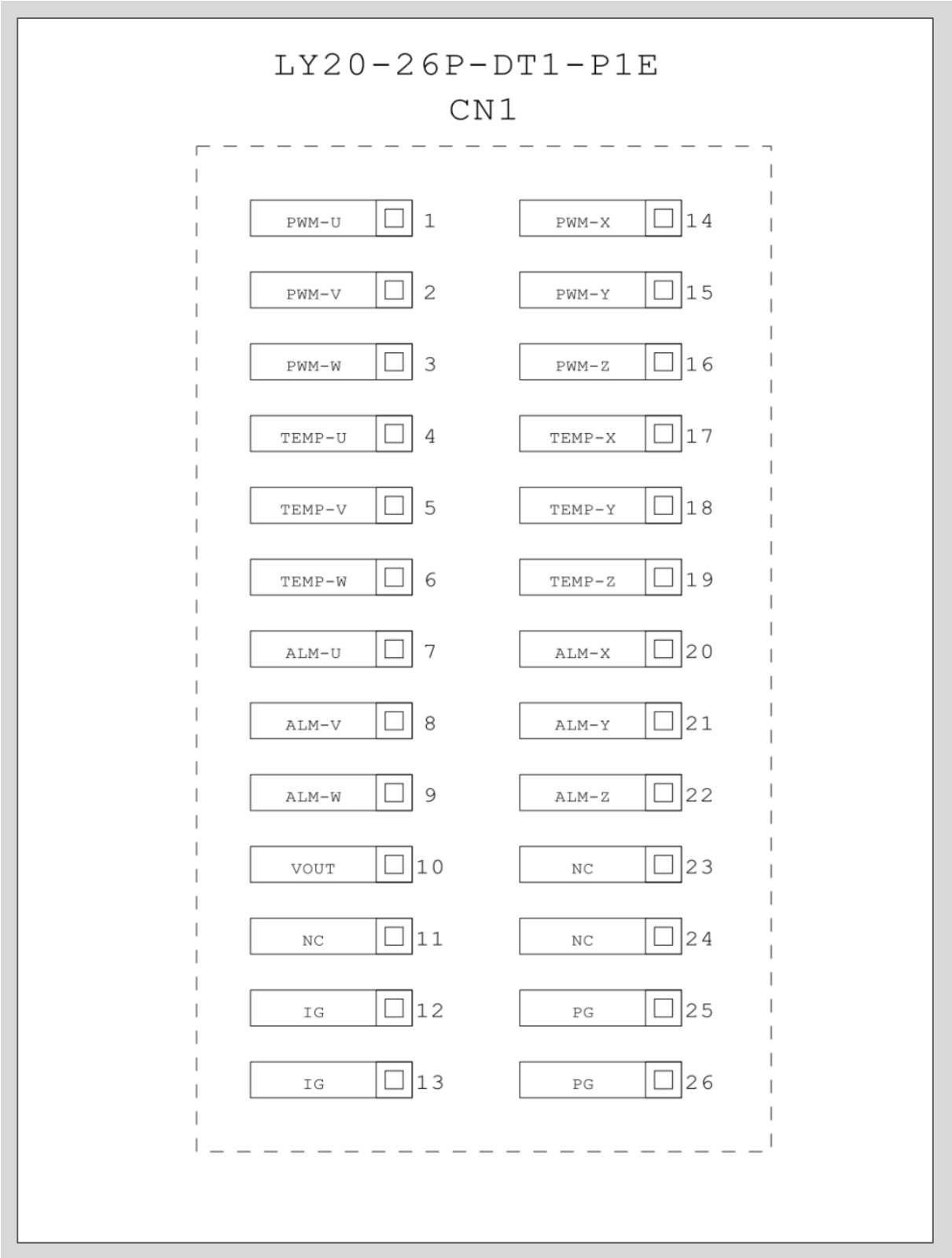

Fig. 7-12 External connector pin assignment

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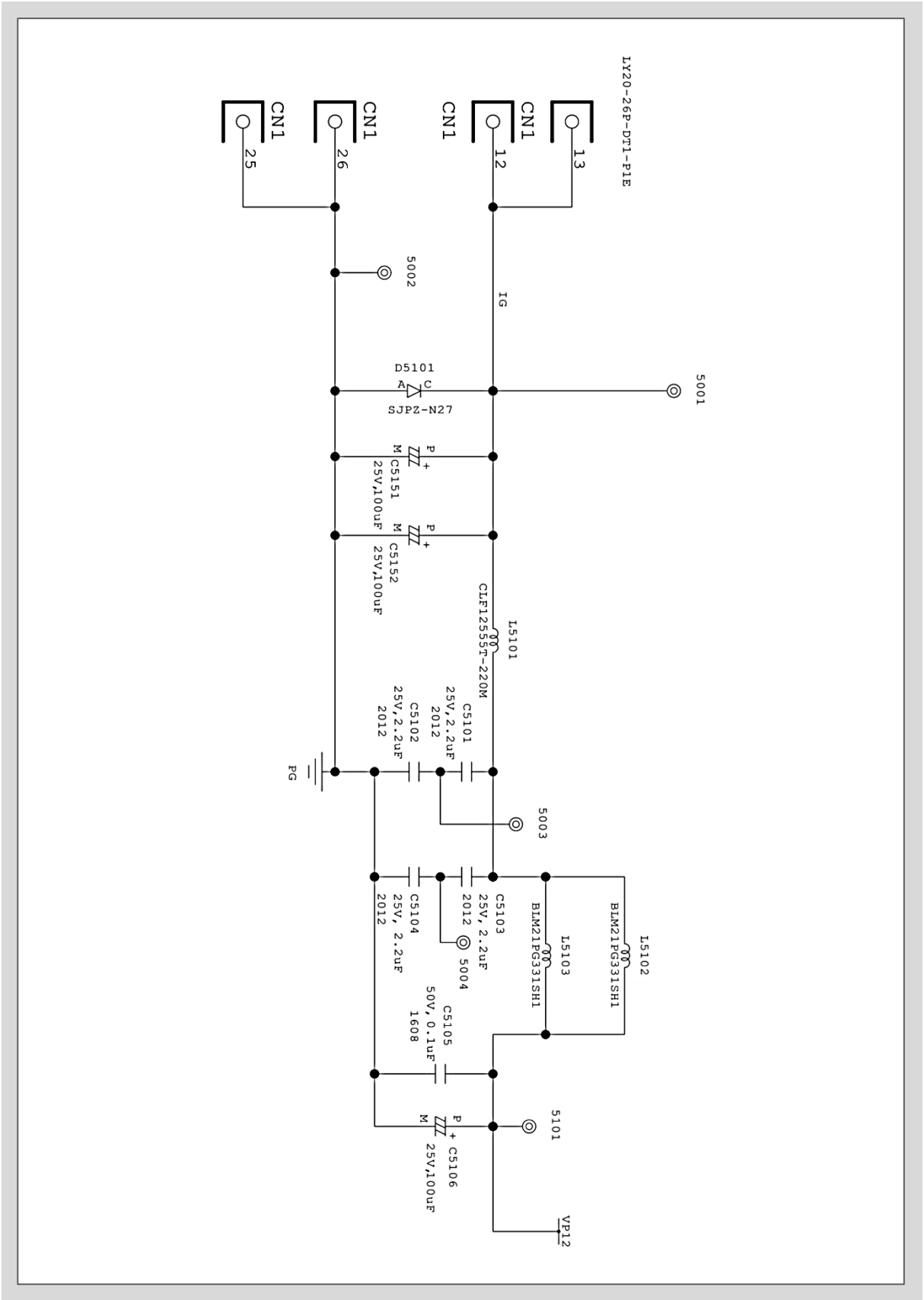

Fig. 7-13 Power supply conditioner

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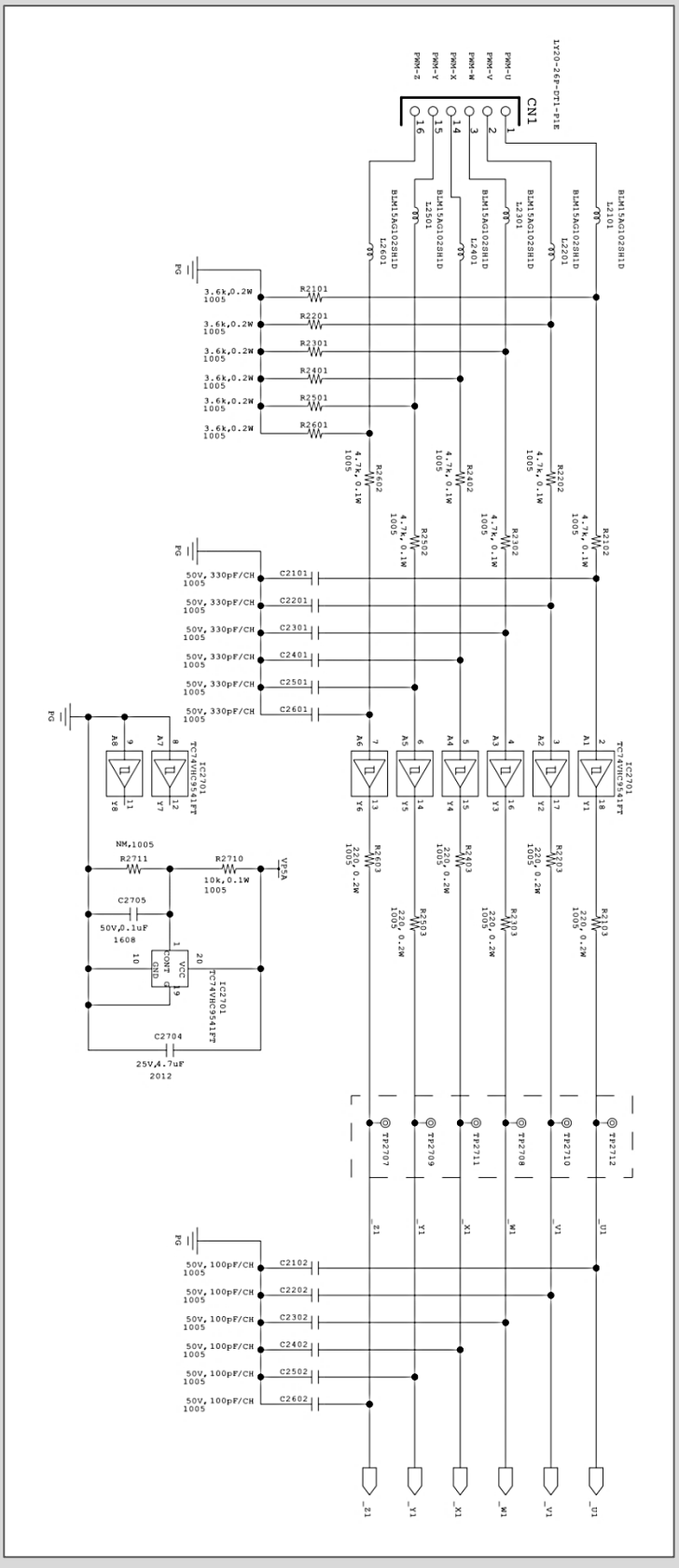

Fig. 7-14 Interface logic

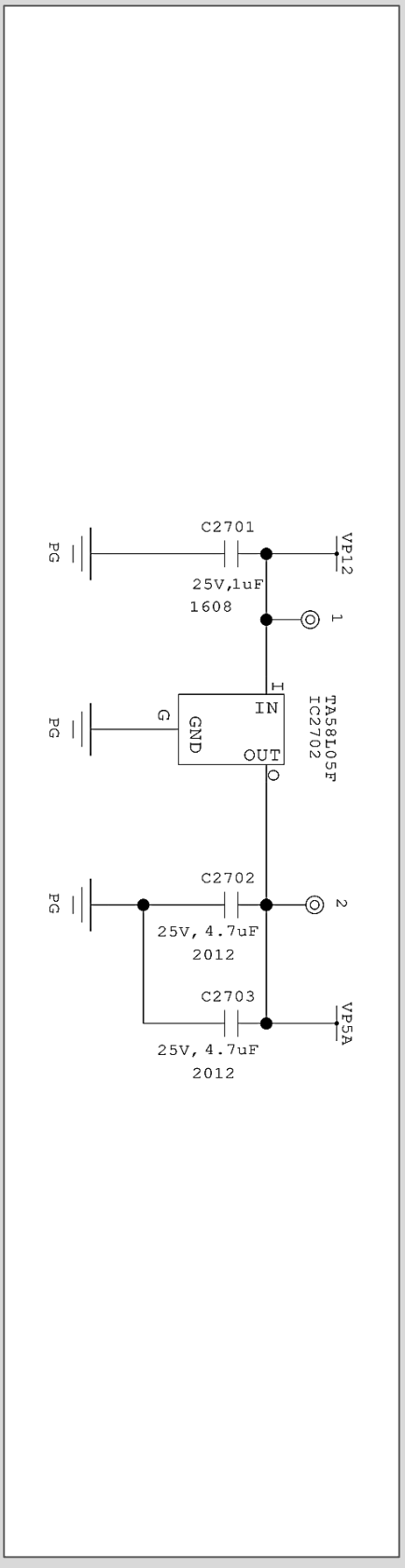

Fig. 7-15 5V power supply

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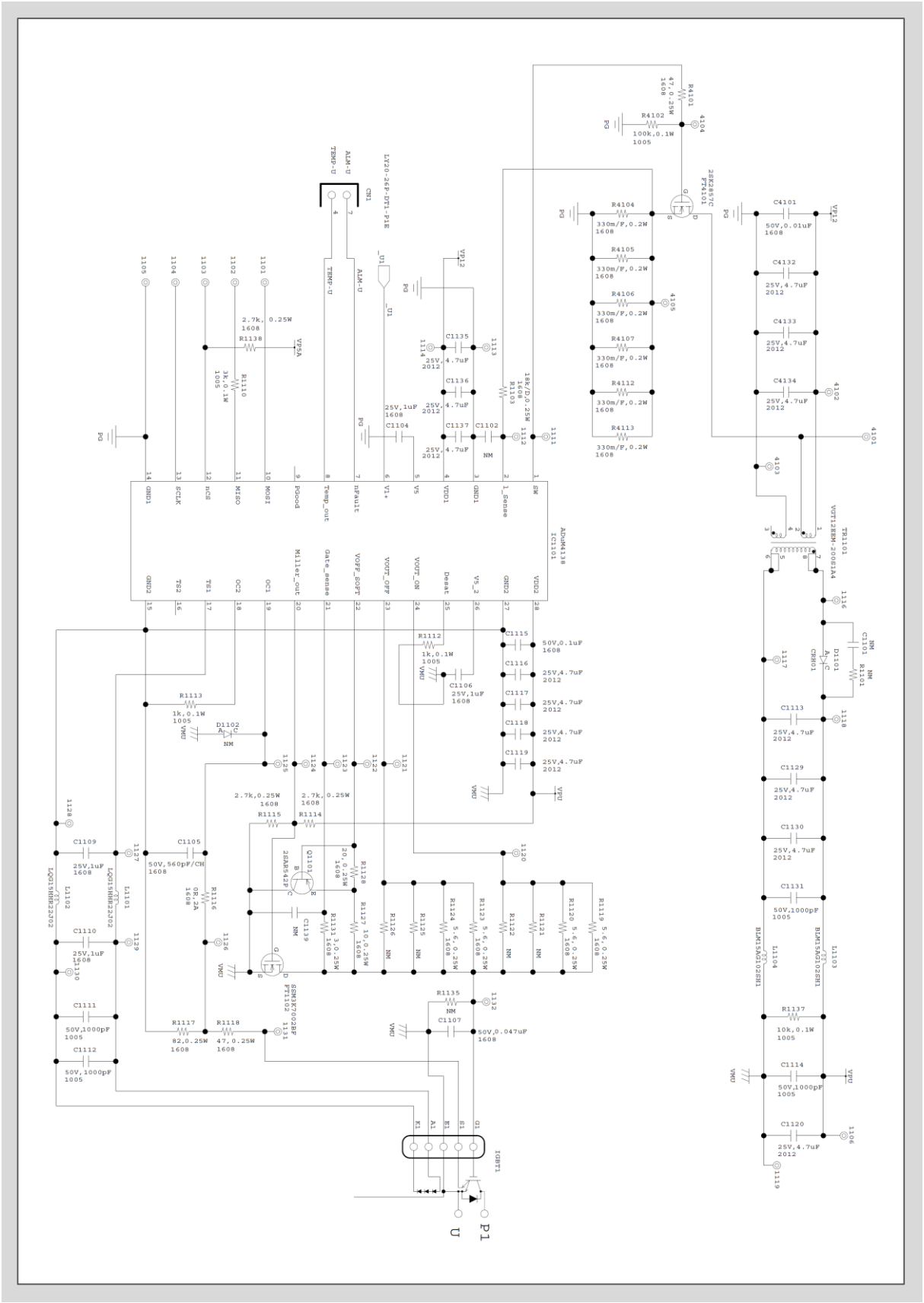

Fig. 7-16 Gate driver for Phase U

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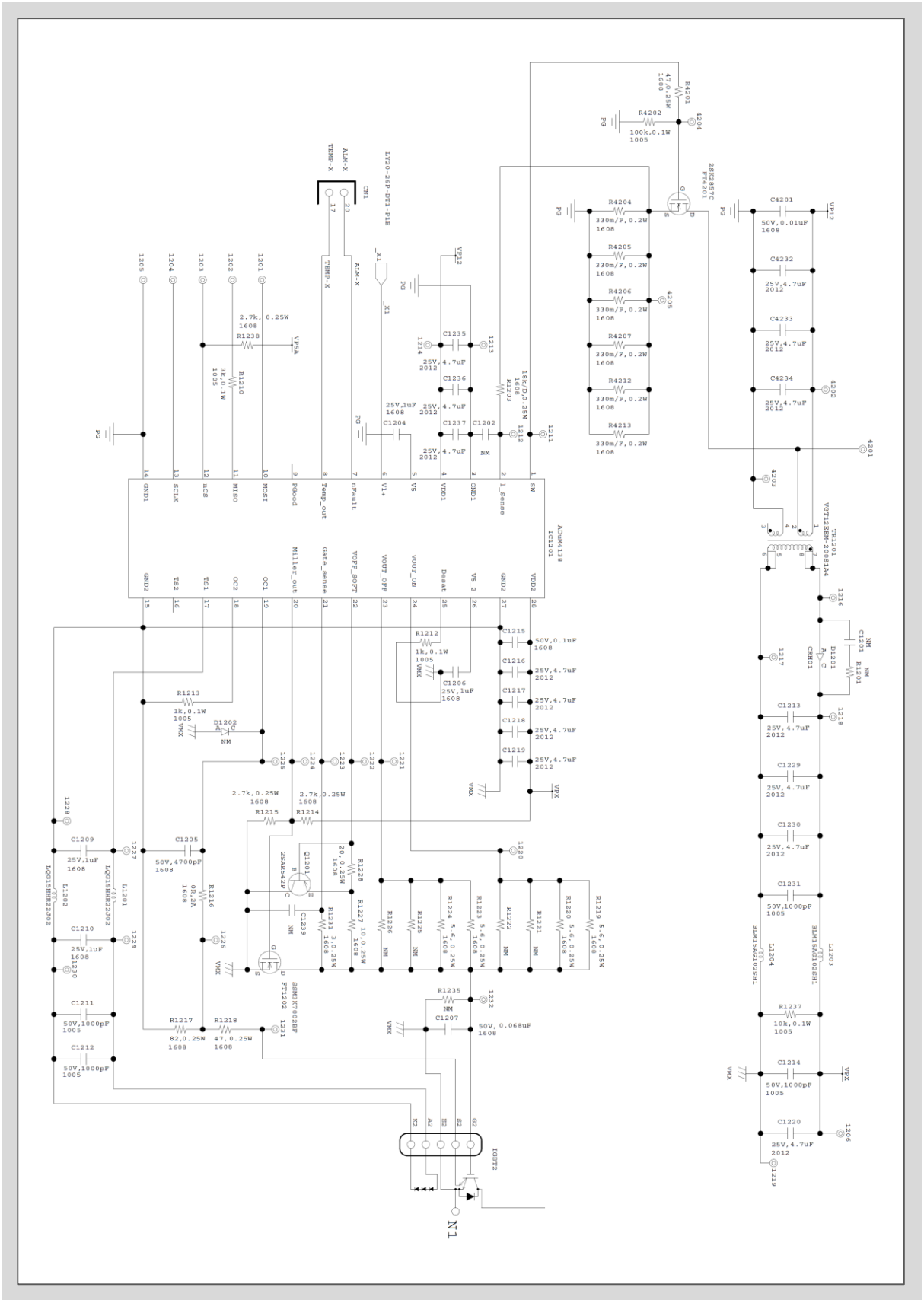

Fig. 7-17 Gate driver for Phase X

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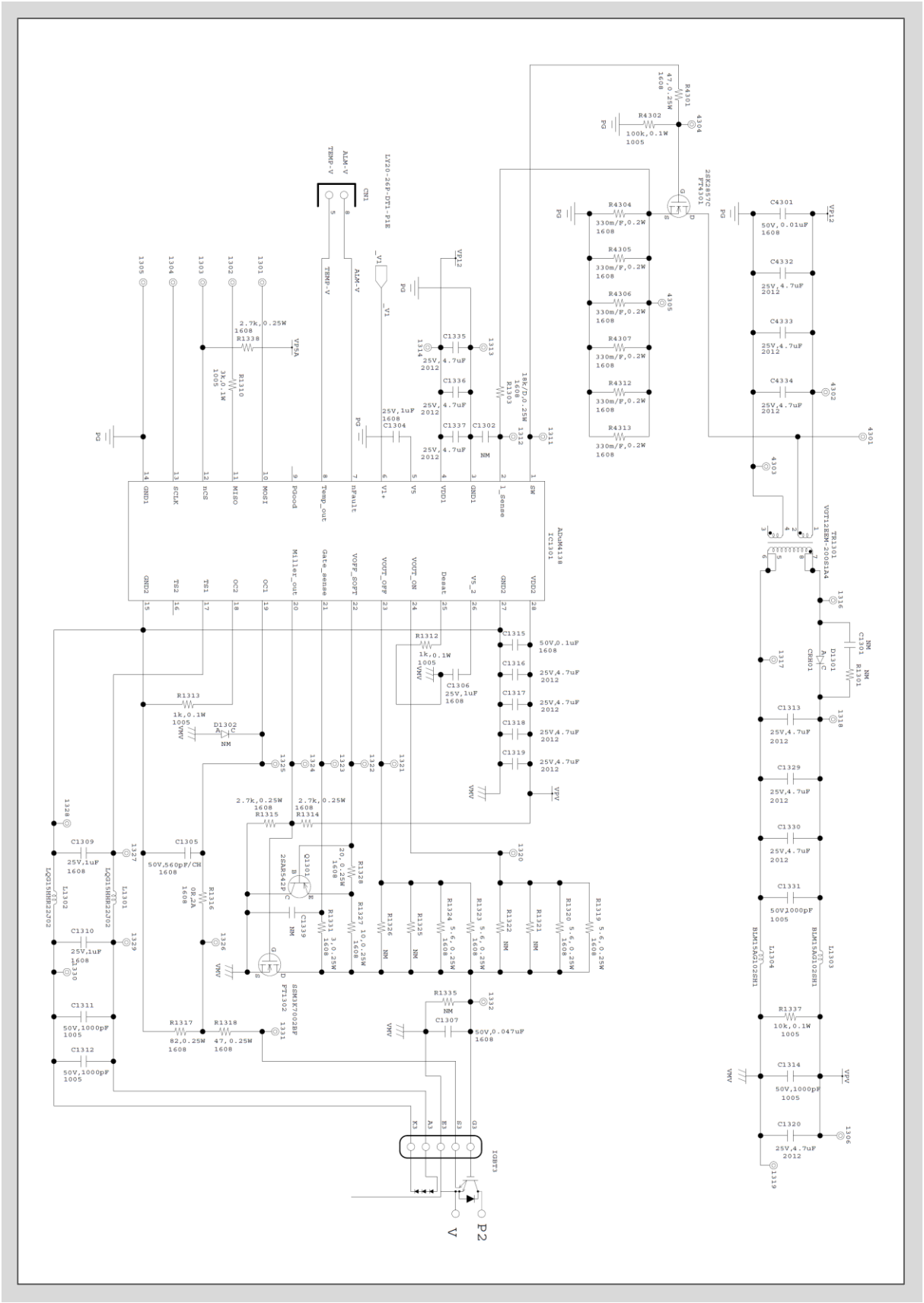

Fig. 7-18 Gate driver for Phase V

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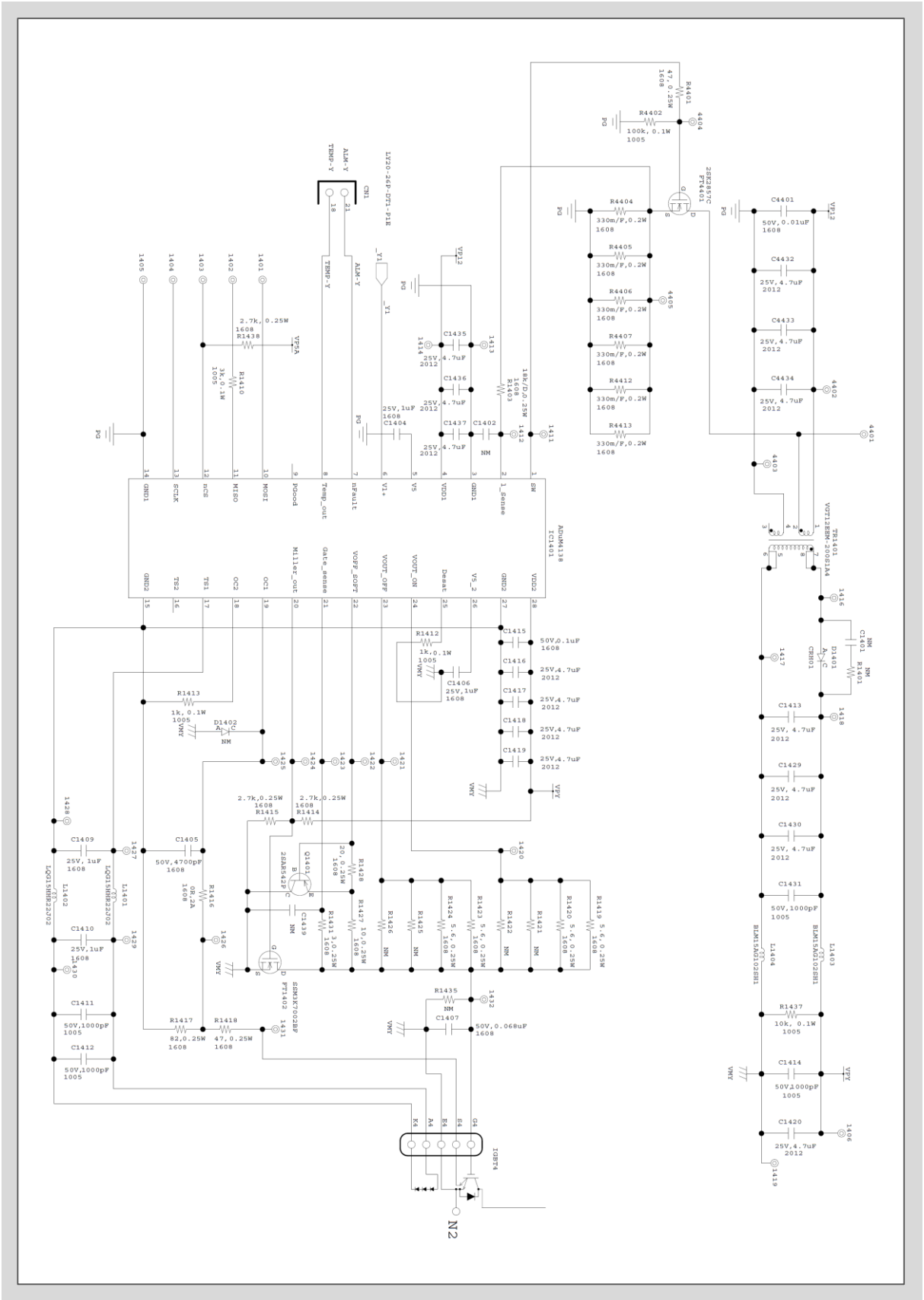

Fig. 7-19 Gate driver for Phase Y

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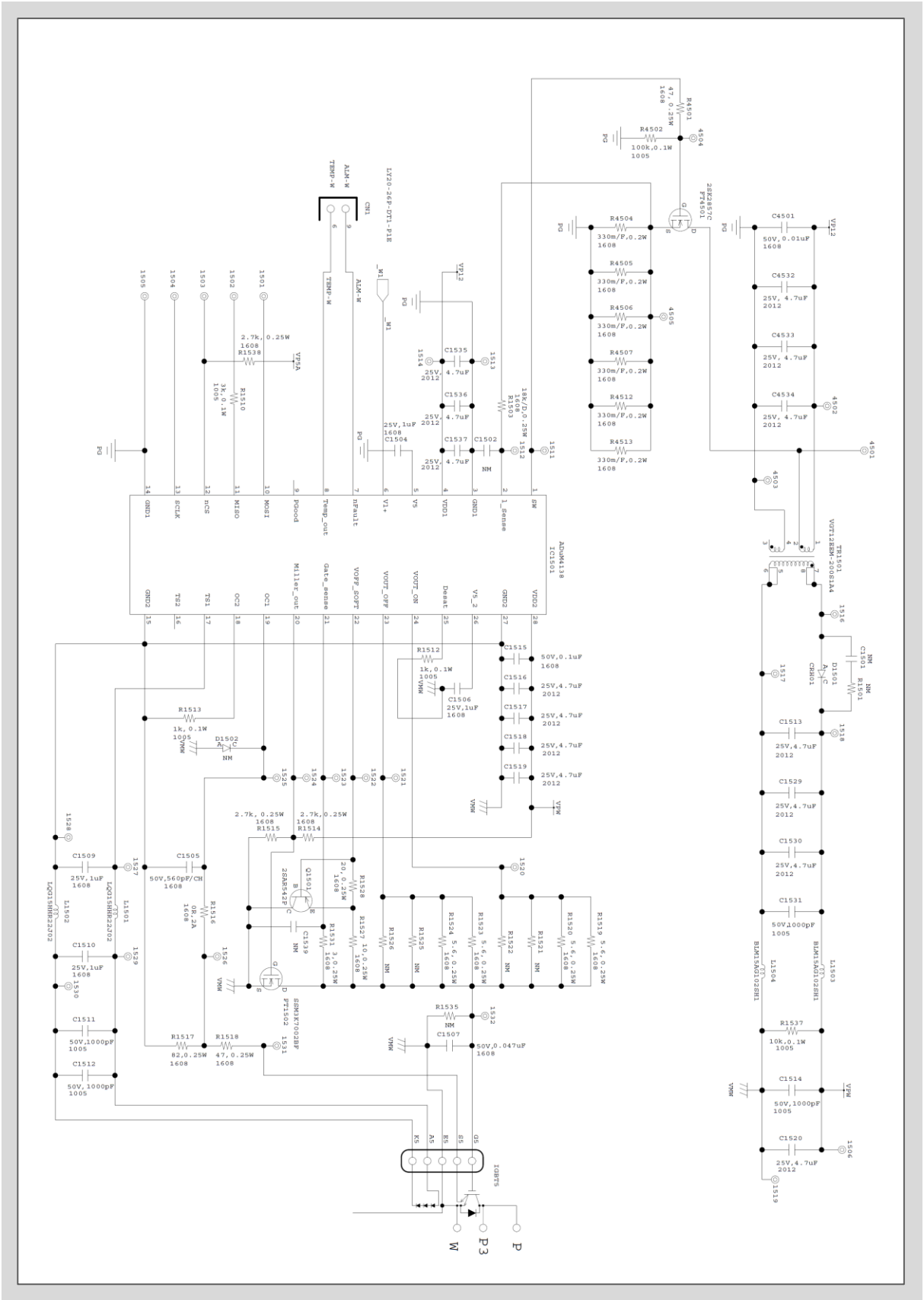

Fig. 7-20 Gate driver for Phase W

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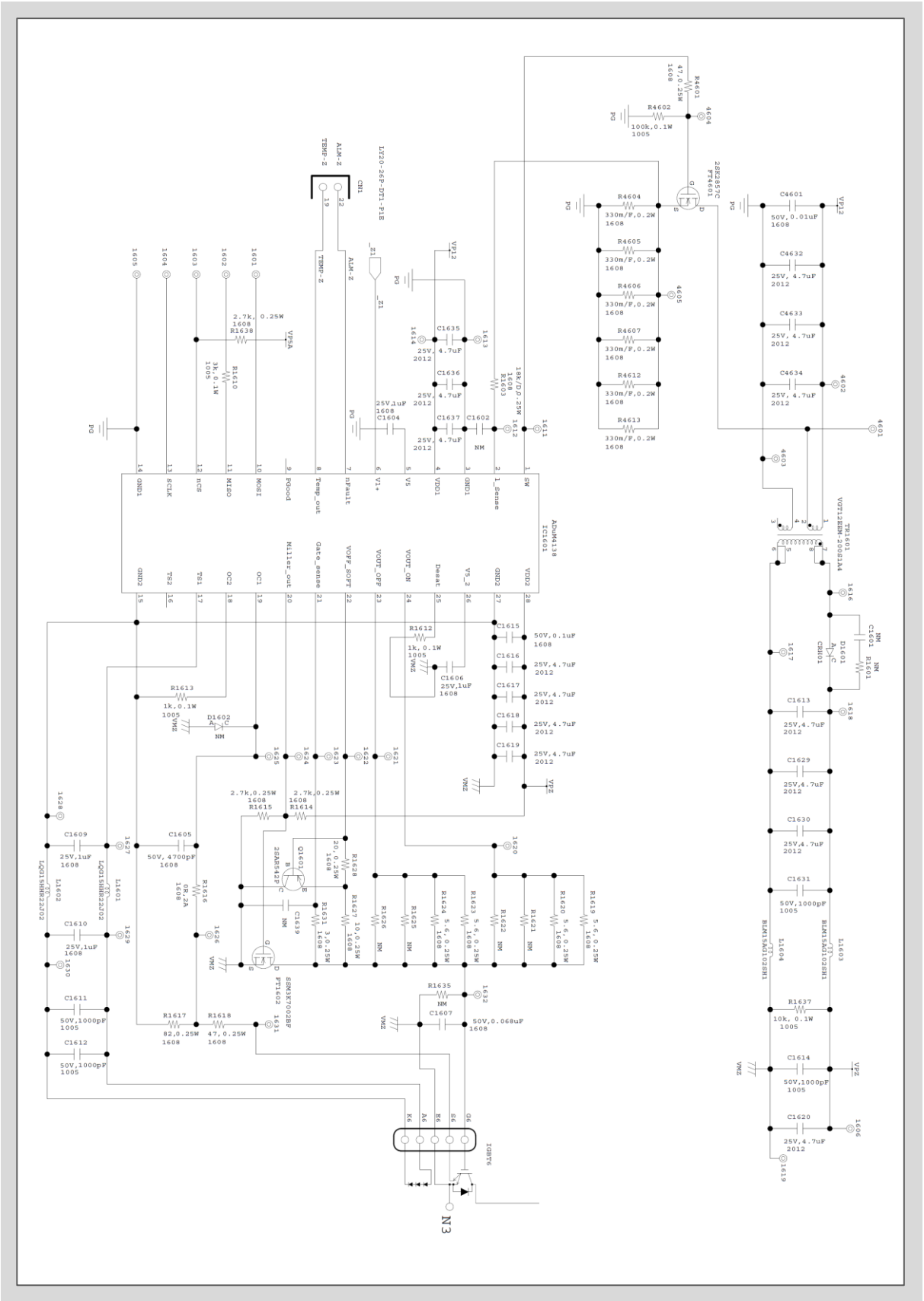

Fig. 7-21 Gate driver for Phase Z

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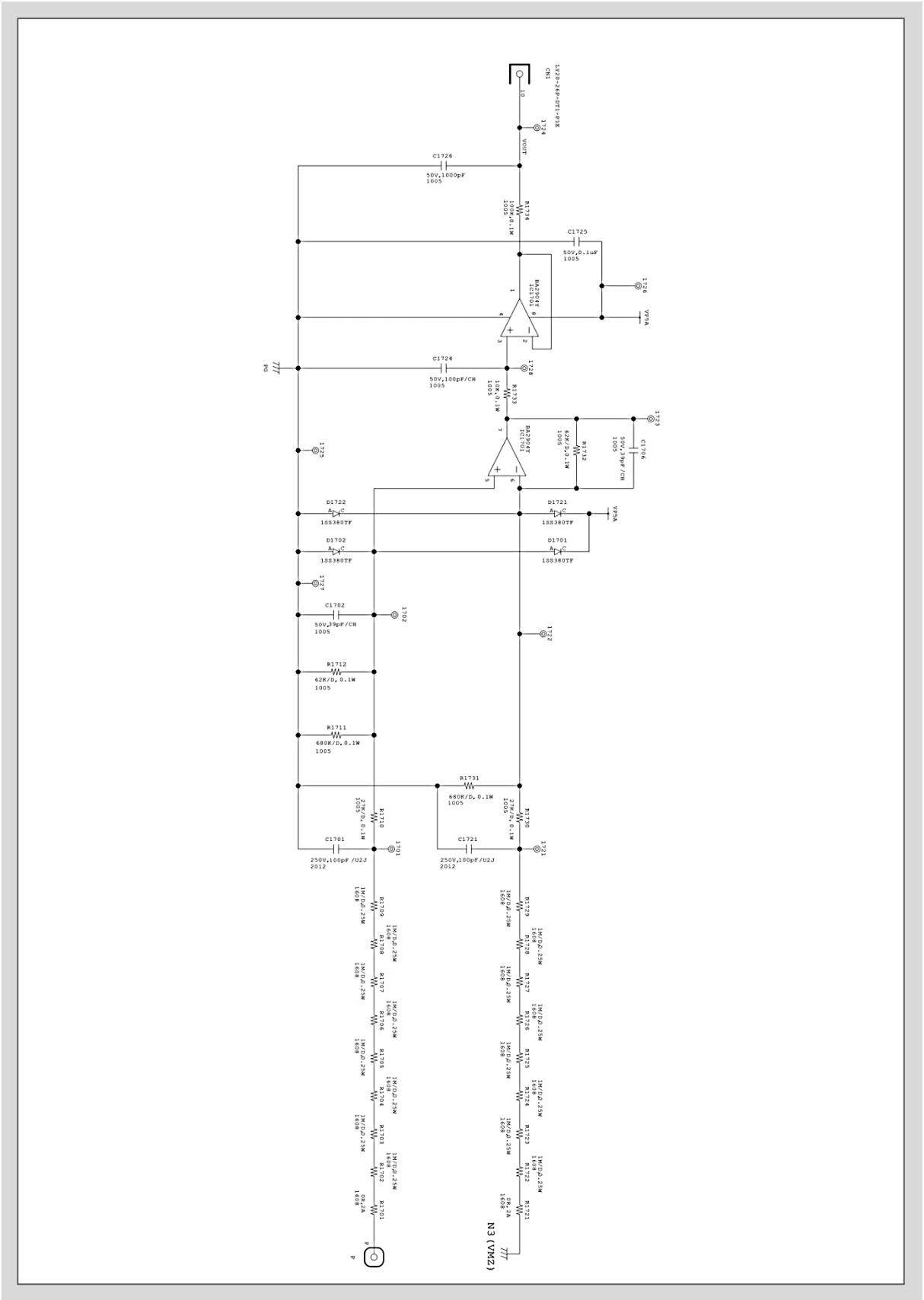

Fig. 7-22 Voltage detection part at Phase W, Z

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16. Evaluation Board Dimensions

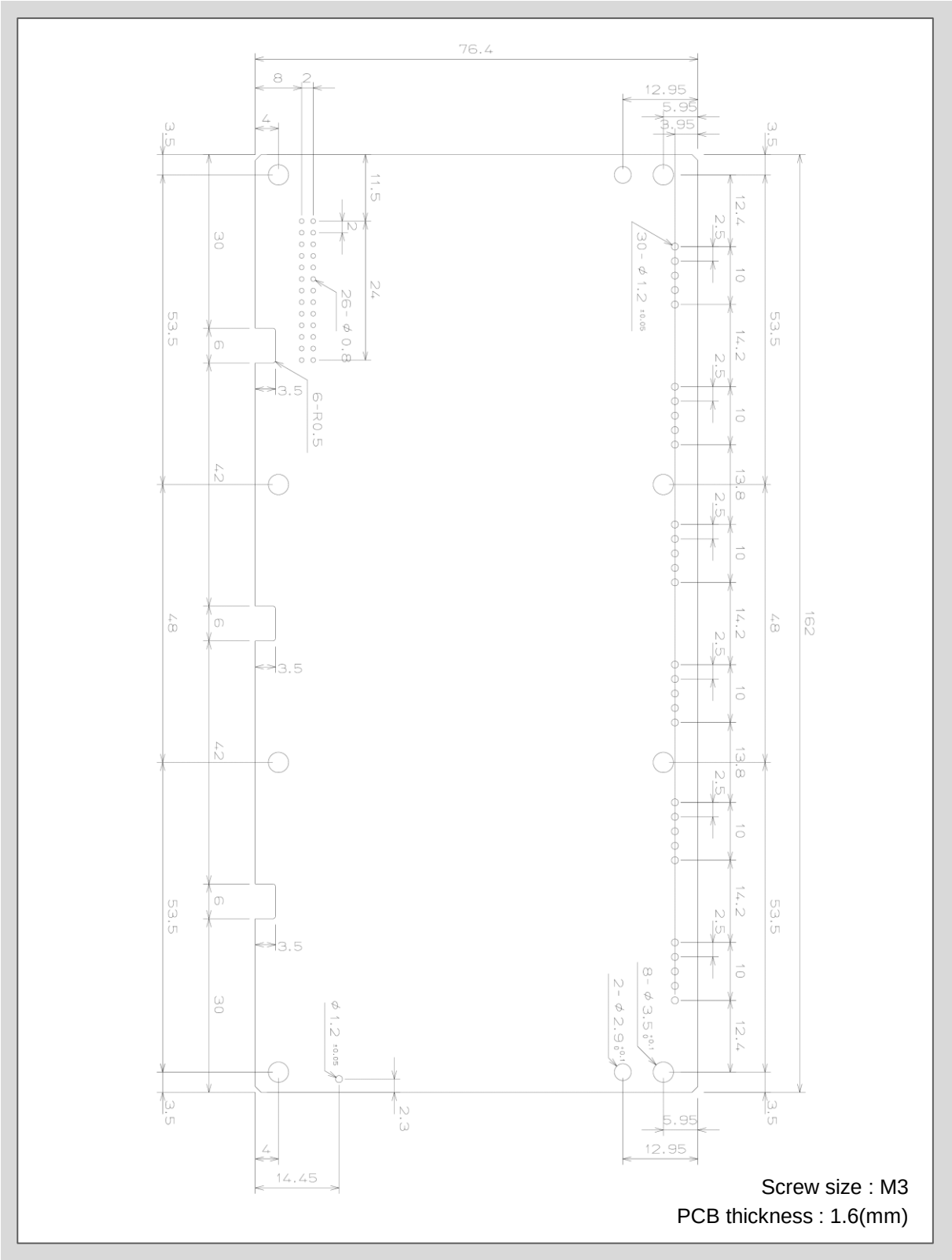

Fig. 7-23 Assembly drawing of the driver board (Top)

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17. Assembly Drawing

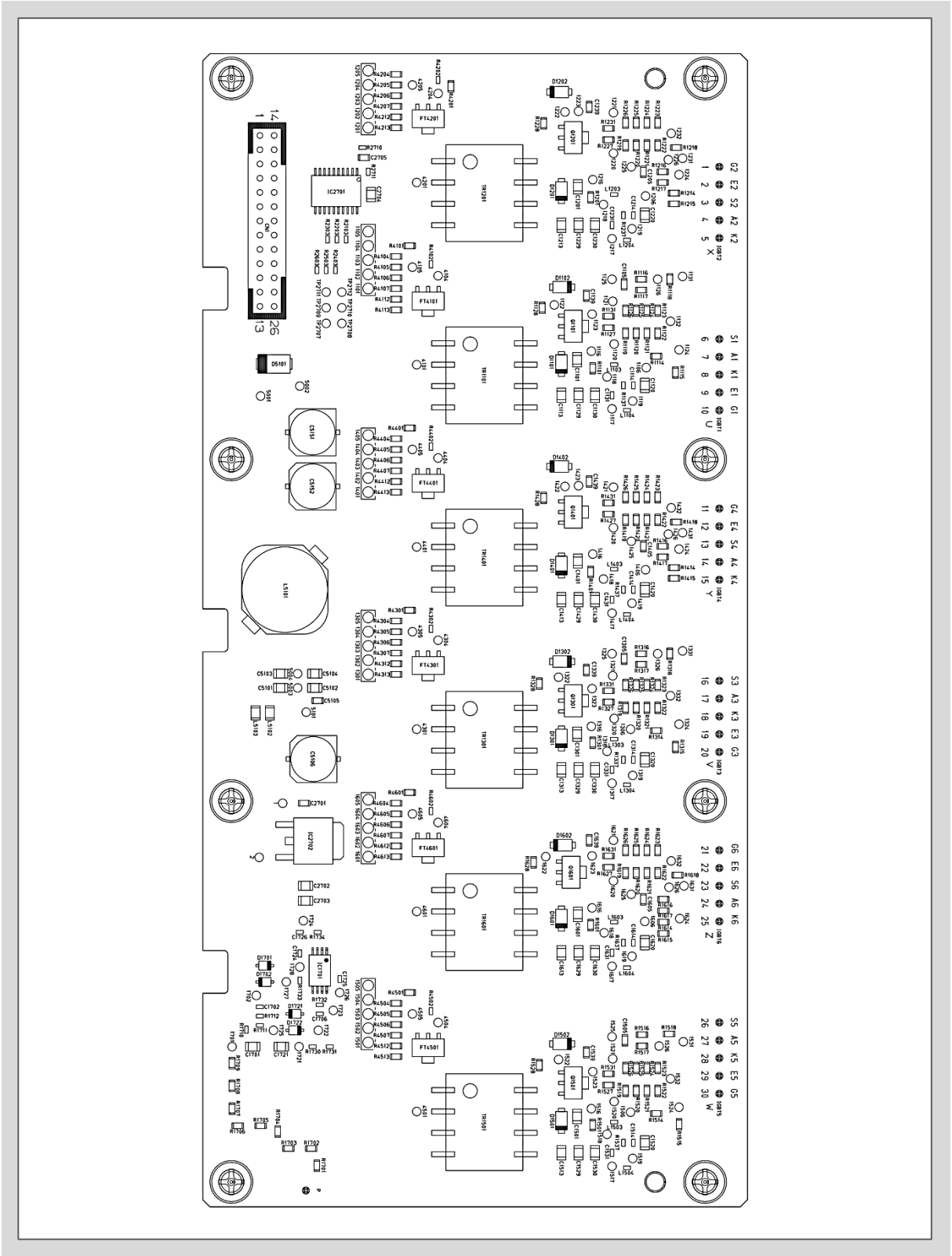

Fig. 7-24 Assembly drawing of the driver board (Top)

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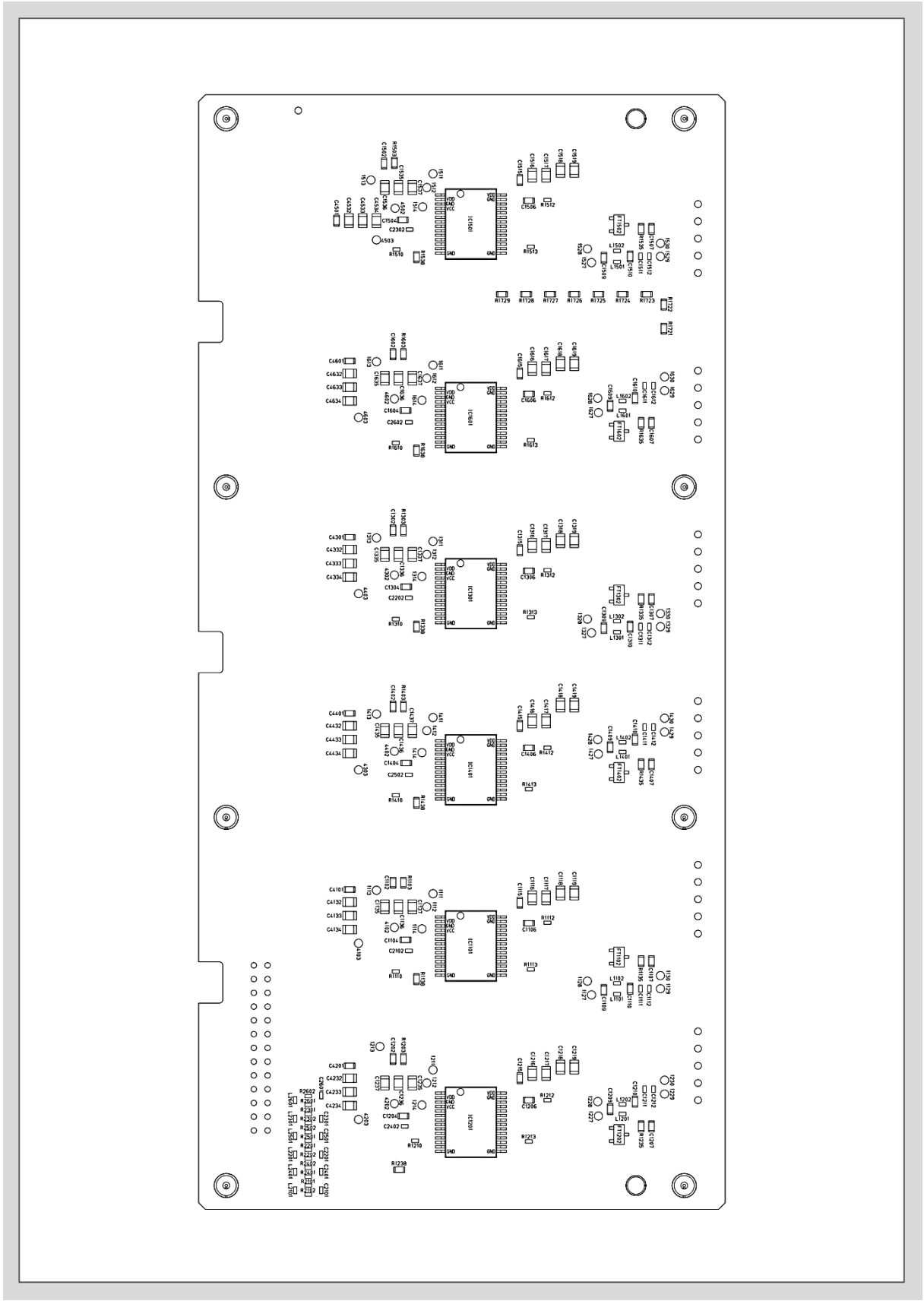

Fig. 7-25 Assembly drawing of the driver board (Bottom)

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18. Layout

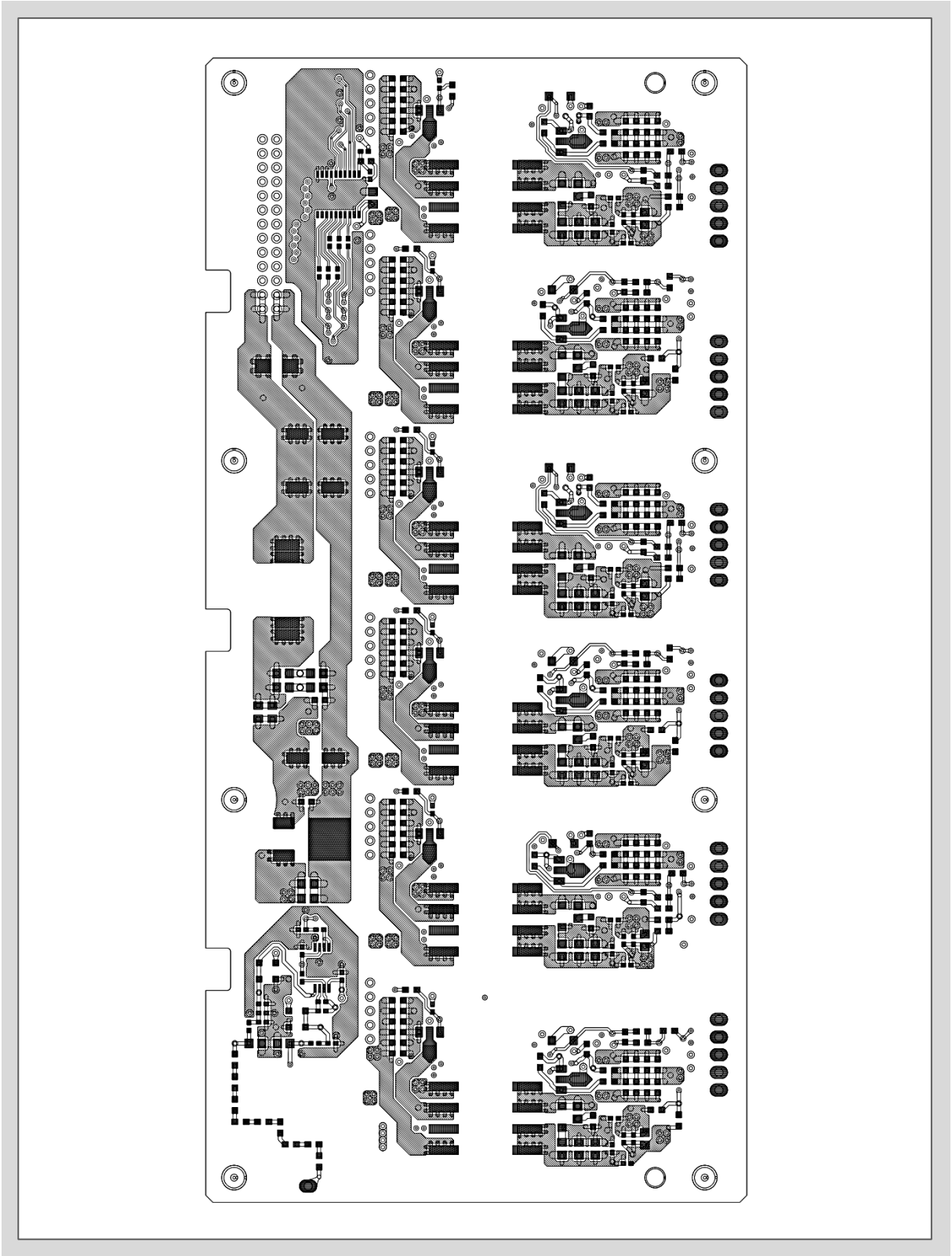

Fig. 7-26 Driver board – Top layer

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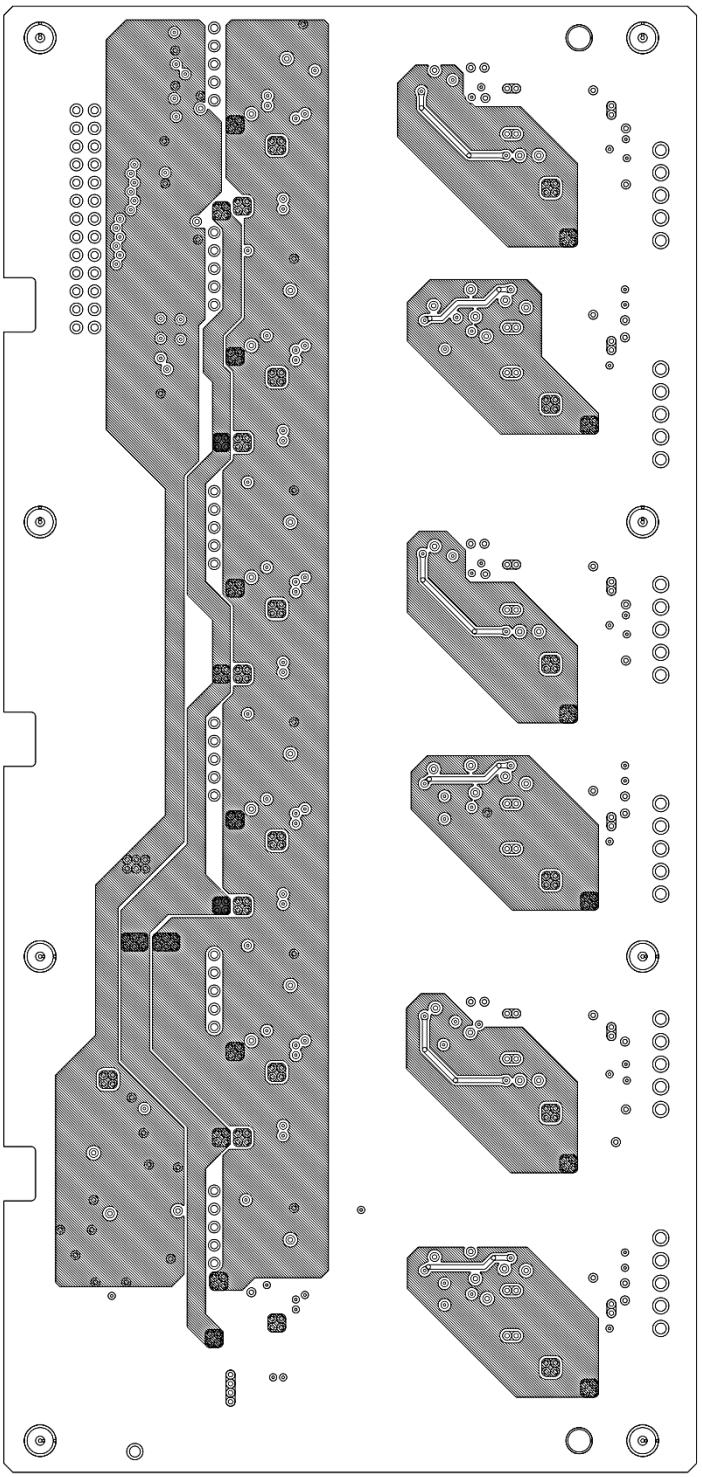

Fig. 7-27 Driver board – Layer 2

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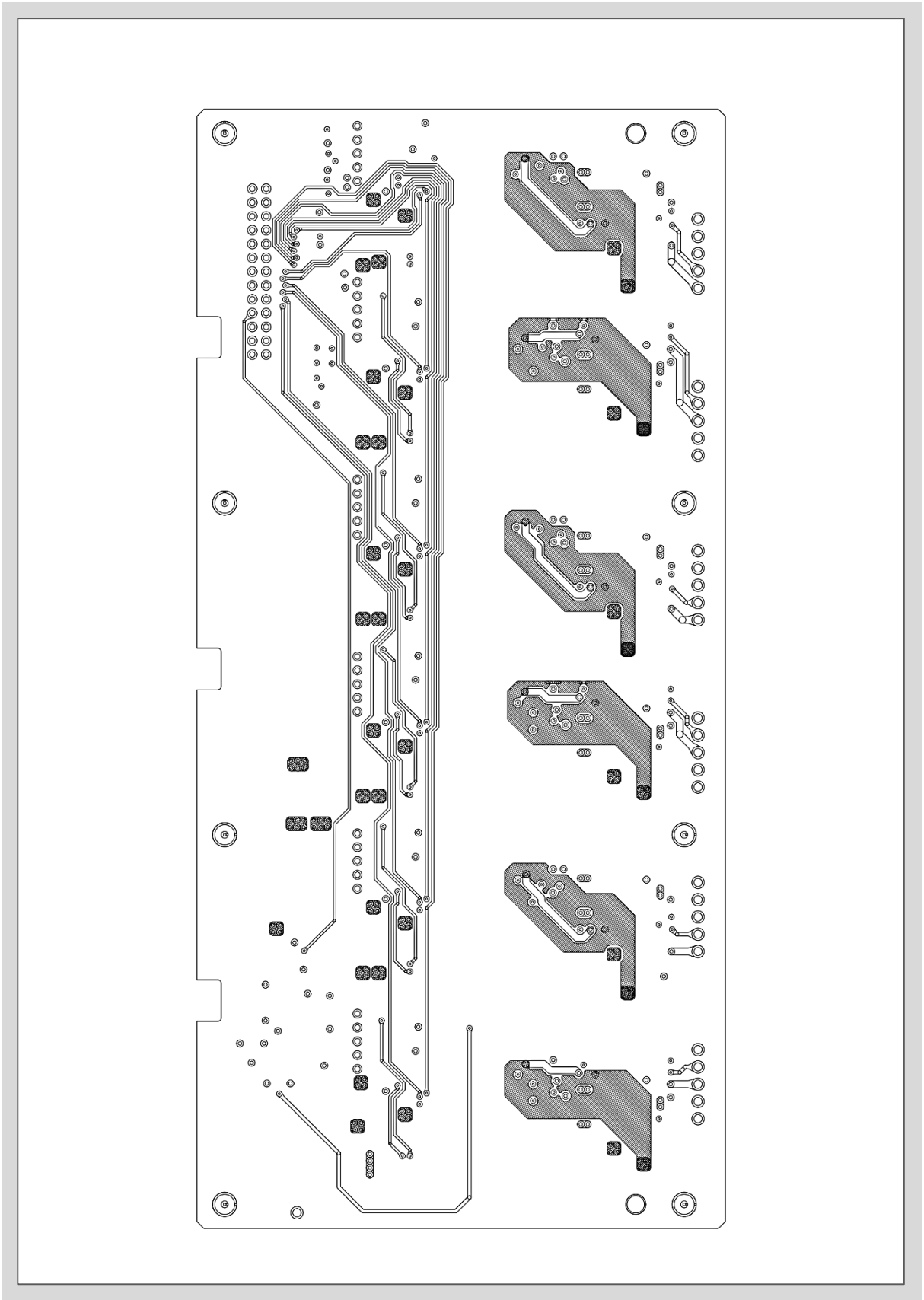

Fig. 7-28 Driver board – Layer 3

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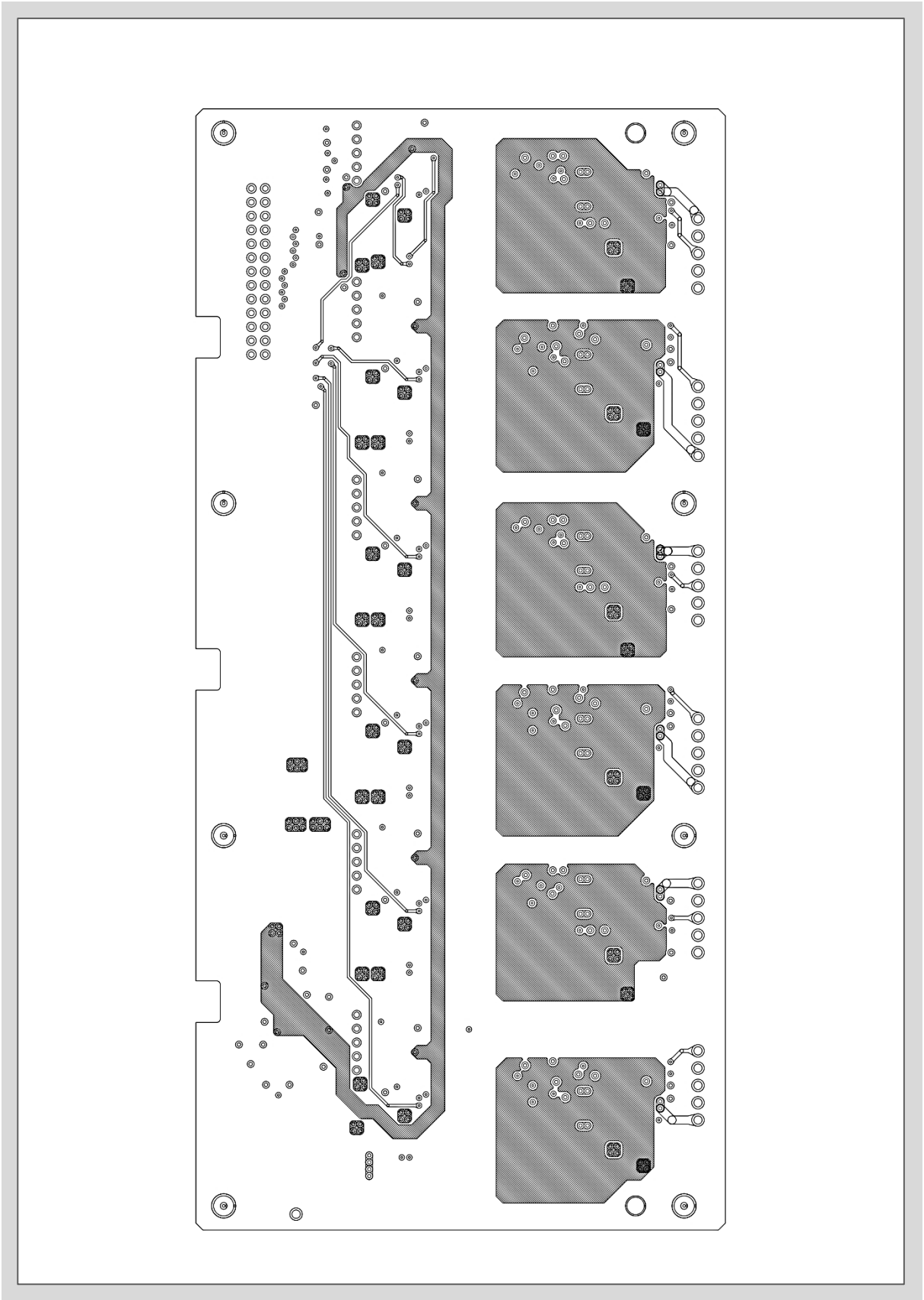

Fig. 7-29 Driver board – Layer 4

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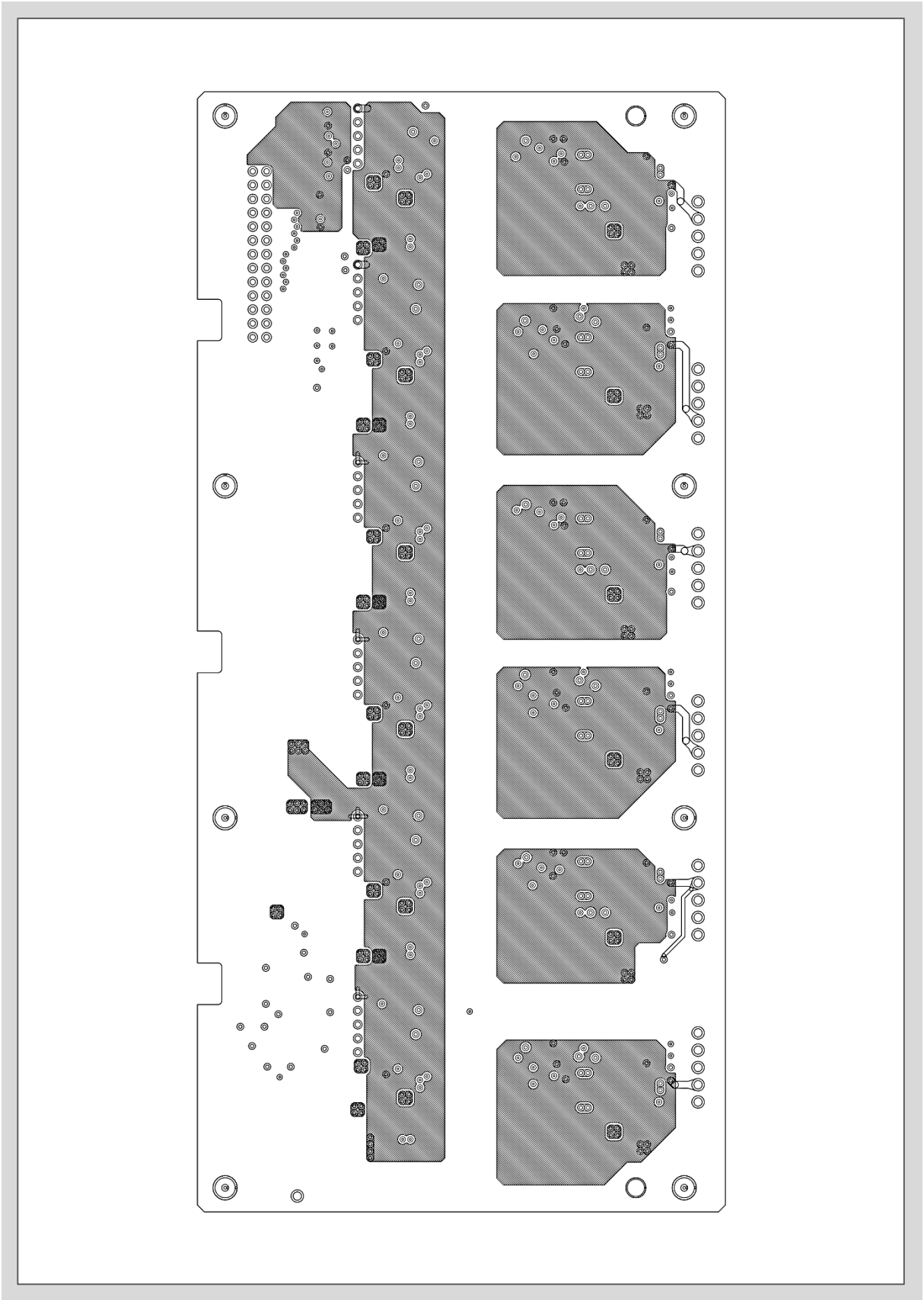

Fig. 7-30 Driver board – Layer 5

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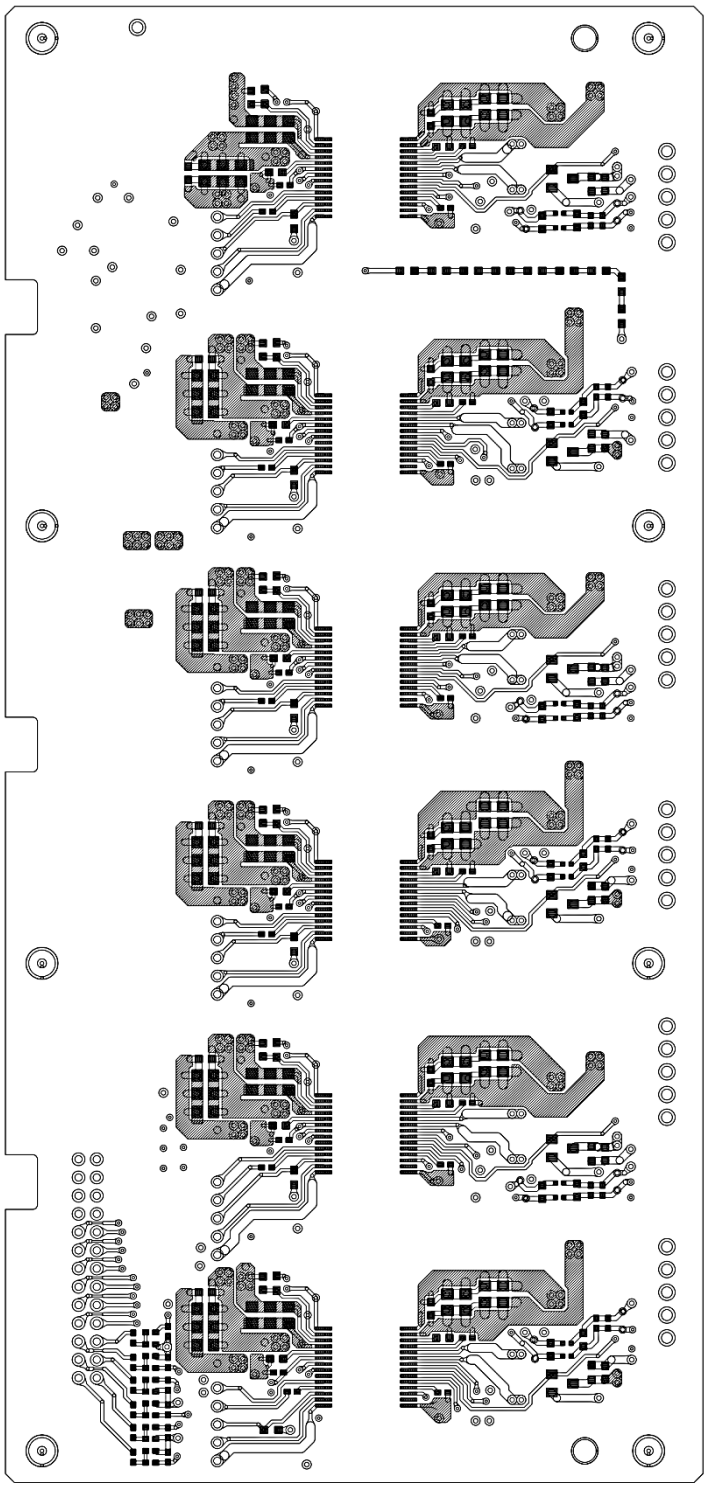

Fig. 7-31 Driver board – Bottom layer

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19. Parts List

Table 7-8 Bill of materials for the M653 IGBT module evaluation board

No	Value / Device	Package type (JEDEC)	Classification	Reference					
1	SJPZ-N27VR Sanken	No description	Diode	D5101					
2	CRH01 Toshiba	Toshiba:3-2A1A	Diode	D1101	D1201	D1301	D1401	D1501	D1601
3	1SS380TF Rohm	SOD-323	Diode	D1701	D1702	D1721	D1722		
4	2SAR542P Rohm	SOT89	PNP Middle Power Transistor	Q1101	Q1201	Q1301	Q1401	Q1501	Q1601
5	2SK2857C-T1-AZ/AY Renesas	SOT89	Nch MOS-FET	FT4101	FT4201	FT4301	FT4401	FT4501	FT4601
6	SSM3K7002BF Toshiba	TO-236MOD	Nch MOS-FET	FT1102	FT1202	FT1302	FT1402	FT1502	FT1602
7	ADuM4138 Analog Devices	ADI:28L SSOP	Driver IC Automotive	IC1101	IC1201	IC1301	IC1401	IC1501	IC1601
8	TA58L05F Toshiba	HSOP3-P2.30D	Low-dropout regulators	IC2702					
9	TC74VHC9541FT Toshiba	TSSOP14-004-0.65A	Logic IC	IC2701					
10	BA2904Y Rohm	SSOP-B8	OP-Amp Automotive	IC1701					
11	VGT12EEM-200S1A4 TDK	SMD	Transformers Automotive	TR1101	TR1201	TR1301	TR1401	TR1501	TR1601
12	CLF12555T-220M TDK	SMD	Power Inductor	L5101					
13	BLM15AG102SH1 Murata	SMD 1005(mm)	Chip ferrite bead Automotive	L1103 L1104 L2101	L1203 L1204 L2201	L1303 L1304 L2301	L1403 L1404 L2401	L1503 L1504 L2501	L1603 L1604 L2601
14	BLM21PG331SH1 Murata	SMD 2012(mm)	Chip ferrite bead Automotive	L5102	L5103				
15	LQG15HHR22J02 Murata	SMD 1005(mm)	Inductor Automotive	L1101 L1102	L1201 L1202	L1301 L1302	L1401 L1402	L1501 L1502	L1601 L1602

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Table 7-9 Bill of materials for the M653 IGBT module evaluation board (cont'd)

No	Value / Device	Package type (JEDEC)	Classification	Reference					
16	25V,100uF	φ6.3xH7.7	Capacitor	C5106	C5151	C5152			
17	50V,39pF,CH	SMD 1005(mm)	Capacitor	C1702	C1706				
18	50V,100pF,CH	SMD 1005(mm)	Capacitor	C1724 C2102	C2202	C2302	C2402	C2502	C2602
19	50V,330pF,CH	SMD 1005(mm)	Capacitor	C2101	C2201	C2301	C2401	C2501	C2601
20	50V,1000pF	SMD 1005(mm)	Capacitor	C1111 C1112 C1114 C1131 C1726	C1211 C1212 C1214 C1231	C1311 C1312 C1314 C1331	C1411 C1412 C1414 C1431	C1511 C1512 C1514 C1531	C1611 C1612 C1614 C1631
21	50V,0.1uF	SMD 1005(mm)	Capacitor	C1725					
22	50V,560pF,CH	SMD 1608(mm)	Capacitor	C1105		C1305		C1505	
23	50V,4700pF	SMD 1608(mm)	Capacitor		C1205		C1405		C1605
24	50V,0.01uF	SMD 1608(mm)	Capacitor	C4101	C4201	C4301	C4401	C4501	C4601
25	50V,0.047uF	SMD 1608(mm)	Capacitor	C1107		C1307		C1507	
26	50V,0.068uF	SMD 1608(mm)	Capacitor		C1207		C1407		C1607
27	50V,0.1uF	SMD 1608(mm)	Capacitor	C1115 C2705	C1215 C5105	C1315	C1415	C1515	C1615
28	25V,1uF	SMD 1608(mm)	Capacitor	C1104 C1106 C1109 C1110 C2701	C1204 C1206 C1209 C1210	C1304 C1306 C1309 C1310	C1404 C1406 C1409 C1410	C1504 C1506 C1509 C1510	C1604 C1606 C1609 C1610
29	250V,100pF	SMD 2012(mm)	Capacitor	C1701	C1721				
30	25V,2.2uF	SMD 2012(mm)	Capacitor	C5101	C5102	C5103	C5104		

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Table 7-10 Bill of materials for the M653 IGBT module evaluation board (cont'd)

No	Value / Device	Package type (JEDEC)	Classification	Reference					
31	25V,4.7uF	SMD 2012(mm)	Capacitor	C1113	C1213	C1313	C1413	C1513	C1613
				C1116	C1216	C1316	C1416	C1516	C1616
				C1117	C1217	C1317	C1417	C1517	C1617
				C1118	C1218	C1318	C1418	C1518	C1618
				C1119	C1219	C1319	C1419	C1519	C1619
				C1120	C1220	C1320	C1420	C1520	C1620
				C1129	C1229	C1329	C1429	C1529	C1629
				C1130	C1230	C1330	C1430	C1530	C1630
				C1135	C1235	C1335	C1435	C1535	C1635
				C1136	C1236	C1336	C1436	C1536	C1636
				C1137	C1237	C1337	C1437	C1537	C1637
				C4132	C4232	C4332	C4432	C4532	C4632
				C4133	C4233	C4333	C4433	C4533	C4633
				C4134	C4234	C4334	C4434	C4534	C4634
				C2702	C2703	C2704			
32	27k/D,0.1W	SMD 1005(mm)	Resistor	R1710	R1730				
33	62k/D,0.1W	SMD 1005(mm)	Resistor	R1712	R1732				
34	680k/D,0.1W	SMD 1005(mm)	Resistor	R1711	R1731				
35	1k,0.1W	SMD 1005(mm)	Resistor	R1112	R1212	R1312	R1412	R1512	R1612
				R1113	R1213	R1313	R1413	R1513	R1613
36	3k,0.1W	SMD 1005(mm)	Resistor	R1110	R1210	R1310	R1410	R1510	R1610
37	4.7k,0.1W	SMD 1005(mm)	Resistor	R2102	R2202	R2302	R2402	R2502	R2602
38	10k,0.1W	SMD 1005(mm)	Resistor	R1137	R1237	R1337	R1437	R1537	R1637
				R1733	R2710				
39	100k,0.1W	SMD 1005(mm)	Resistor	R4102	R4202	R4302	R4402	R4502	R4602
				R1734					
40	0R,2A	SMD 1608(mm)	Resistor	R1116	R1216	R1316	R1416	R1516	R1616
				R1701	R1721				
41	330m/F,0.2W	SMD 1608(mm)	Resistor	R4104	R4204	R4304	R4404	R4504	R4604
				R4105	R4205	R4305	R4405	R4505	R4605
				R4106	R4206	R4306	R4406	R4506	R4606
				R4107	R4207	R4307	R4407	R4507	R4607
				R4112	R4212	R4312	R4412	R4512	R4612
				R4113	R4213	R4313	R4413	R4513	R4613

Each tolerance of resistor are described on the part table like below example or ±5% unless otherwise specified.
Example: No. 32, 27k/D, 0.1W: Character "D" means ±0.5%, "F" means ±1.0%
Maker name of the resistors: TAIYOSHA ELECTRIC CO.,LTD.

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Table 7-11 Bill of materials for the M653 IGBT module evaluation board (cont'd)

No	Value / Device	Package type (JEDEC)	Classification	Reference					
42	3,0.25W	SMD 1608(mm)	Resistor	R1131	R1231	R1331	R1431	R1531	R1631
43	5.6/D,0.25W	SMD 1608(mm)	Resistor	R1119 R1120 R1123 R1124	R1219 R1220 R1223 R1224	R1319 R1320 R1323 R1324	R1419 R1420 R1423 R1424	R1519 R1520 R1523 R1524	R1619 R1620 R1623 R1624
44	10,0.25W	SMD 1608(mm)	Resistor	R1127	R1227	R1327	R1427	R1527	R1627
45	20,0.25W	SMD 1608(mm)	Resistor	R1128	R1228	R1328	R1428	R1528	R1628
46	47/D,0.25W	SMD 1608(mm)	Resistor	R1118 R4101	R1218 R4201	R1318 R4301	R1418 R4401	R1518 R4501	R1618 R4601
47	82/D,0.25W	SMD 1608(mm)	Resistor	R1117	R1217	R1317	R1417	R1517	R1617
48	2.7k,0.25W	SMD 1608(mm)	Resistor	R1114 R1115 R1138	R1214 R1215 R1238	R1314 R1315 R1338	R1414 R1415 R1438	R1514 R1515 R1538	R1614 R1615 R1638
49	18k/D,0.25W	SMD 1608(mm)	Resistor	R1103	R1203	R1303	R1403	R1503	R1603
50	1M/D,0.25W	SMD 1608(mm)	Resistor	R1702 R1708 R1726	R1703 R1709 R1727	R1704 R1722 R1728	R1705 R1723 R1729	R1706 R1724	R1707 R1725
51	220,0.2W	SMD 1005(mm)	Resistor	R2103	R2203	R2303	R2403	R2503	R2603
52	3.6k,0.2W	SMD 1005(mm)	Resistor	R2101	R2201	R2301	R2401	R2501	R2601
53	LY20-26P-DT1-P1E JAE	26pin	Connector for interface	CN1					
54	PM-80 Mac8	5pin	Socket pin	TP1101-5	TP1201-5	TP1301-5	TP1401-5	TP1501-5	TP1601-5

Table 7-12 Bill of not populated materials for the M653 IGBT module evaluation board

No	Value / Device	Package type (JEDEC)	Classification	Reference					
1		1005R		R2711					
2		1608R		R1101 R1121 R1122 R1125 R1126 R1135	R1201 R1221 R1222 R1225 R1226 R1235	R1301 R1321 R1322 R1325 R1326 R1335	R1401 R1421 R1422 R1425 R1426 R1435	R1501 R1521 R1522 R1525 R1526 R1535	R1601 R1621 R1622 R1625 R1626 R1635
3		1608C		C1139	C1239	C1339	C1439	C1539	C1639
4		2012C		C1101	C1201	C1301	C1401	C1501	C1601
5		CRH01		D1102	D1202	D1302	D1402	D1502	D1602
6	50V,100pF,CH	SMD 1608(mm)	Capacitor	C1102	C1202	C1302	C1402	C1502	C1602

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