MPC5643L Dual Motor Controller Board User Guide

Devices Supported:
MPC5643L

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About This Book

This document describes the MPC5643L Controller Board design targeted for rapid development of motor control applications.

To locate any published updates for this document, refer to the Freescale website at: http://www.freescale.com/.

Revision History

Table i. Revision history table

Date	Revision level	Description	Page number(s)
08/08/2012	0	Initial release	N/A

Documentation

The MPC5643L documentation is available on the Freescale web site, http://www.freescale.com:

- Reference manuals — MPC5643L modules in detail
- Data sheets — Information mainly on the device's AC, DC, thermal characteristics, and packages pin-out
- Product briefs — Device overview
- Application notes — Addresses specific design issues

Chapter 1 Introduction

Chapter 2 Interface Description

Chapter 3 Design Consideration

Chapter 4 Electrical Characteristics

Chapter 5 Board Setup Guide

Chapter 6 MPC5643L Dual Motor Controller Board Schematics

Chapter 1 Introduction

The Freescale MPC5643L Dual Motor Controller Board is a controller board integrated into the Freescale embedded motion-control series of development tools. It is supplied with a universal interface interconnecting with one of the embedded motion-power stages or evaluation boards, providing a ready-made software-development platform for various electrical motors, and DC/DC converters.

The MPC5643L Dual Motor Controller Board is an evaluation-module type of board that includes an MPC5643L device, various position sensing interfaces, communication options, digital and analog power supplies, and peripheral expansion connectors. The expansion connectors are intended for signal monitoring and user expandability. Test pads are provided for monitoring critical signals and voltage levels.

The MPC5643L Dual Motor Controller Board facilitates the evaluation of various features in the MPC5643L. It can be used to develop real-time software and hardware products based on the MPC5643L in MAPBGA257 package. It provides the features necessary for you to write and debug software, demonstrate software function, and to interface with customer application specific devices. The MPC5643L Dual Motor Controller Board is flexible and allows you to fully exploit the MPC5643L features and optimize product performance. See Figure 1-1.

1.1 Features

The MPC5643L Dual Motor Controller Board evaluates various features in the MPC5643L. The following are board features:

- MPC5643L microcontroller, MAPBGA257 package
- JTAG/NEXUS interfaces for MCU code download and debugging
- System-basis chip MCZ33905D
- Motor control interface:
  - Two UNI-3
  - Two MC33937A predriver
  - Two Resolver
  - Two Encoder/Hall sensors
- Connectivity interface:
  - LIN
  - CAN
  - FlexRay
  - USB interface
- LEDs:
  - Power-supply indicators
  - PWM control signals
  - Faults monitoring
  - SBC safe mode
  - User application

- Two push buttons and switch for application control
- MCU pins accessible via pin headers
- Power plug 2.1 mm connector

1.2 MPC5643L Dual Motor Controller Board architecture

The MPC5643L Dual Motor Controller Board is flexible enough to allow to fully exploit the MPC5643L features and optimize performance of their product. Its basic building blocks are shown in (see Figure 1-1). The block colors differentiate a block function:

- Blue — MCU and application software download and the debug interface
- Green — Motor control related hardware
- Red — Board power supply and connectivity
- Violet — Application control

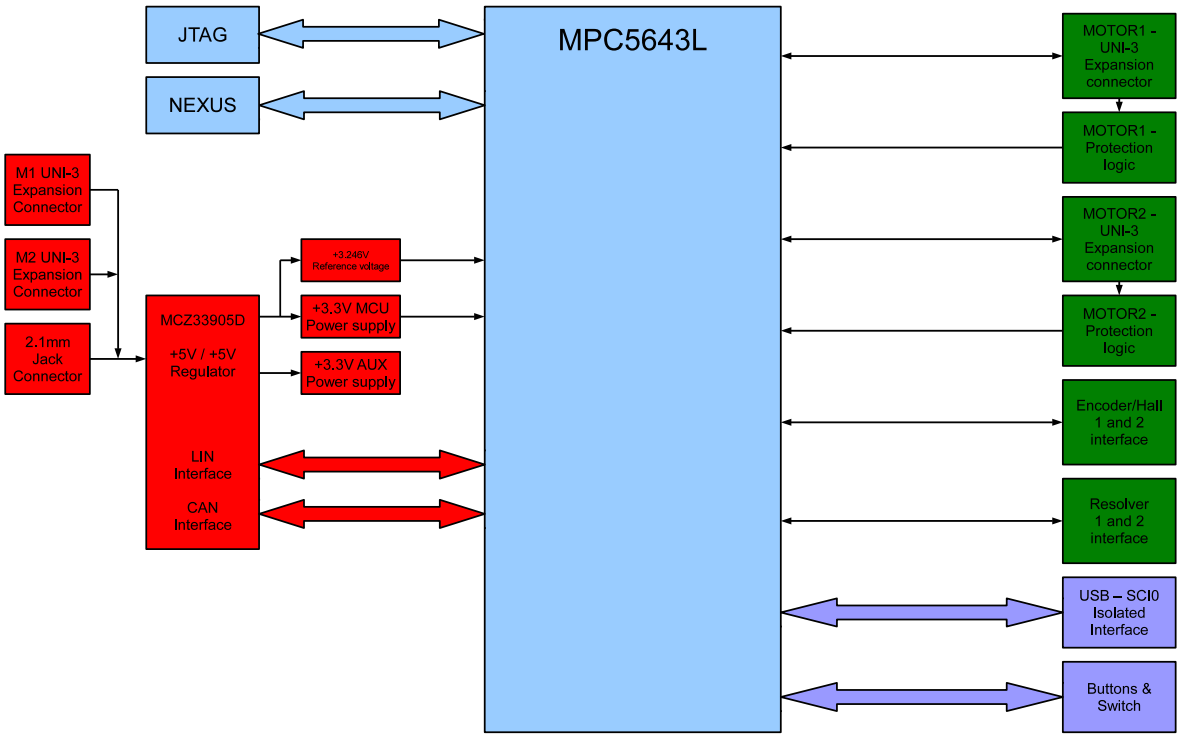


Figure 1-1. MPC5643L controller board block diagram

The board can be supplied by VBAT voltage in the range of 8 V to 18 V. The MC33905 provides two independent voltage sources, the first for supplying the MCU and the second for auxiliary logic. Both sources provide either 3.3 V or 5 V, depending on the assembled SBC version.

The UNI-3 expansion interface enables the MCU to direct control of the electrical motor or DC/DC converters.

The Fault logic triggers several important system faults as described. The circuitry behavior depends on the selected configuration. For more information see Chapter 3.3, “UNI3 interfaces and external fault management".

The application can be controlled using the switches USB interface (RS232), CAN, and LIN buses.

The JTAG/NEXUS interfaces are present on-board to enable download and debug MCU code.

For the on-board block location, see Figure 1-1.

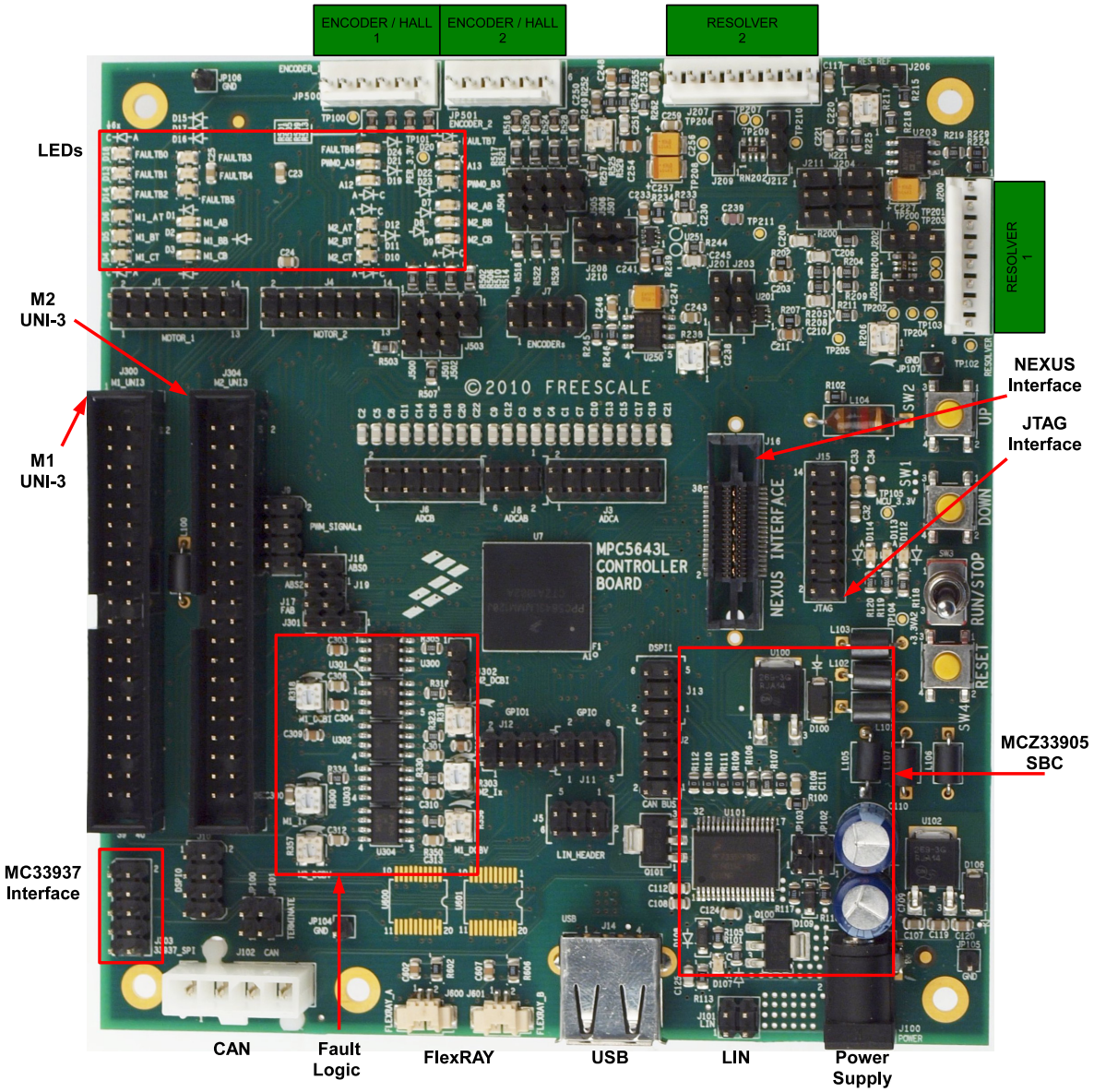


Figure 1-2. MPC5643L Dual Motor Controller Board block location

1.3 Board jumper configuration

See Table 1-1 and Figure 1-3 for proper jumper configuration.

Table 1-1. MPC5643L board configuration

Jumper	Selector	Function	Connections
JP100 JP101	CAN Termination	Terminate CAN bus node	Closed
JP102	MC33905 debug mode	Enter SBC driver MC33905 to debug mode	Closed
JP103	MC33905 save mode	Enter SBC driver MC33905 to safe mode	Closed
JP206	Resolver Enable	Resolver reference input signal from SWG module	1–2
		Resolver reference input signal from eTimer1-channel5	2–3
J202 J209	Resolver SIN input	Positive input for SIN OPAM is DC offset voltage set up by trimmer R208, R258	1–2
		Positive input for SIN OPAM is REFSIN input of resolver	2–3
J205 J212	Resolver COS input	Positive input for COS OPAM is DC offset voltage set up by trimmer R208, R258	1–2
		Positive input for COS OPAM is REFCOS input of resolver	2–3
J201 J208	Phase A digital signal	Resolver_X Phase A signals is connected to eTimer0-channel[0] resp. eTimer1-channel[1]	Closed
		Resolver_X Phase A signals is not connected to eTimer0-channel[0] resp. eTimer1-channel[1].	Closed
J203 J210	Phase B digital signal	Resolver_X Phase B signals is connected to eTimer0-channel[1] resp. eTimer1-channel[1].	Closed
		Resolver_X Phase B signals is not connected to eTimer0-channel[1] resp. eTimer1-channel[1].	Closed
J301	FAULT1 selection	UNI-3 M1 Phase A over-current signal is connected to FAULT1 input G[9].	1–2
		UNI-3 M1 DC-bus over-current signal is connected to FAULT1 input G[9].	2–3
J302	FAULT5 selection	UNI-3 M2 Phase A over-current signal is connected to FAULT5 input I[1].	1–2
		UNI-3 M2 DC-bus over-current signal is connected to FAULT5 input I[1].	2–3
J17 J18 J19	BOOT selection	FAB — MPC5643L boot from internal Flash. ABS0 — See MPC5643L documentation ABS1 — See MPC5643L documentation	Closed

Table 1-1. MPC5643L board configuration (continued)

Jumper	Selector	Function	Connections
J500	Encoder 1 Phase A	Encoder1 JP500 pin three “PHASE A” is connected to eTimer0-channel[0].	1–2
		UNI-3 “M1_BEMFZCA” is connected to eTimer0-channel[0].	2–3
J501	Encoder 1 Phase B	Encoder1 JP500 pin four “PHASE B” is connected to eTimer0-channel[1].	1–2
		UNI-3 “M1_BEMFZCB” input signal is connected to eTimer0-channel[1].	2–3
J502	Encoder 1 Index	Encoder1 JP500 pin five “INDEX” is connected to eTimer0-channel[4].	1–2
		UNI-3 “M1_BEMFZCC” input signal is connected to eTimer0-channel[4].	2–3
J503	Encoder 1 Home	Encoder1 JP500 pin six “HOME” is connected to eTimer0-channel[5].	Closed
J504	Encoder 2 Phase A	Encoder2 JP501 pin three “PHASE A” is connected to eTimer1-channel[1].	1–2
		UNI-3 “M2_BEMFZCA” input signal is connected to eTimer1-channel[1].	2–3
J505	Encoder 2 Phase B	Encoder2 JP501 pin four “PHASE B” is connected to eTimer1-channel[2].	1–2
		UNI-3 “M2_BEMFZCB” input signal is connected to eTimer1-channel[2].	2–3
J506	Encoder 2 Index	Encoder2 JP501 pin five “INDEX” is connected to eTimer1-channel[3].	1–2
		UNI-3 “M2_BEMFZCC” input signal is connected to eTimer1-channel[3].	2–3
J507	Encoder 2 Home	Encoder2 JP501 pin six “HOME” is connected to eTimer1-channel[4].	closed
	M1 DC BUS Voltage	M1 DC BUS Voltage signal from UNI-3 is connected to GPIO B[8], ADC0 channel1.	R336 populated
	M1 DC BUS Current	M1 DC BUS Current signal from UNI-3 is connected to GPIO B[14], ADC1 channel1.	R338 populated
	M2 DC BUS Voltage	M2 DC BUS Voltage signal from UNI-3 is connected to GPIO C[0], ADC0 channel3.	R337 populated
	M2 DC BUS Current	M2 DC BUS Current signal from UNI-3 is connected to GPIO C[2], ADC1 channel3.	R339 populated

Table 1-1. MPC5643L board configuration (continued)

Jumper	Selector	Function	Connections
	Analog input 11	UNI-3 M1 Phase A current is connected to GPIO B[9], ADC 0/1 input 11.	R343 populated
		UNI-3 M1 Phase A Back-EMF Voltage is connected to GPIO B[9], ADC 0/1 input 11.	R348 populated
	Analog input 12	UNI-3 M1 Phase B current is connected to GPIO B[10], ADC 0/1 input 12.	R352 populated
		UNI-3 M1 Phase B Back-EMF Voltage is connected to GPIO B[10]m ADC 0/1 input 12.	R354 populated
	ADC0 Analog input 2	UNI-3 M1 Phase C current is connected to GPIO C[1], ADC 0 input 2.	R358 populated
		UNI-3 M1 Phase C Back-EMF Voltage is connected to GPIO C[1]m ADC 0 input 2.	R360 populated
	Analog input 13	UNI-3 M2 Phase A current is connected to GPIO B[11], ADC 0/1 input 13.	R344 populated
		UNI-3 M2 Phase A Back-EMF Voltage is connected to GPIO B[11], ADC 0/1 input 13.	R349 populated
	Analog input 14	UNI-3 M2 Phase B current is connected to GPIO B[12], ADC 0/1 input 14.	R353 populated
		UNI-3 M2 Phase B Back-EMF Voltage is connected to GPIO B[12]m ADC 0/1 input 14.	R355 populated
	ADC1 Analog input 2	UNI-3 M2 Phase C current is connected to GPIO B[15], ADC 1 input 2.	R359 populated
		UNI-3 M2 Phase C Back-EMF Voltage is connected to GPIO B[15]m ADC 1 input 2.	R361 populated
	M1 TEMP	UNI-3 Temperature signal is connected to ADC0 input four.	R370 populated
	M2 TEMP	UNI-3 Temperature signal is connected to ADC1 input four.	R371 populated
	M1 BRAKE	UNI-3 M1 Brake output signal is connected to GPIO G[6] (PWM0-A3).	R362 populated
	M2 BRAKE	UNI-3 M2 Brake output signal is connected to GPIO H[14] (PWM1-A3).	R363 populated
	M1 PFC	UNI-3 M1 PFC output signal is connected to GPIO G[7] (PWM0-B3).	R364 populated
	M2 PFC	UNI-3 M2 PFC output signal is connected to GPIO H[15] (PWM1-B3).	R365 populated

Table 1-1. MPC5643L board configuration (continued)

Jumper	Selector	Function	Connections
	M1 PFC_EN	UNI-3 M1 PFC Enable signal is connected to GPIO C[10].	R366 populated
	M2 PFC_EN	UNI-3 M2 PFC Enable signal is connected to GPIO E[13].	R367 populated

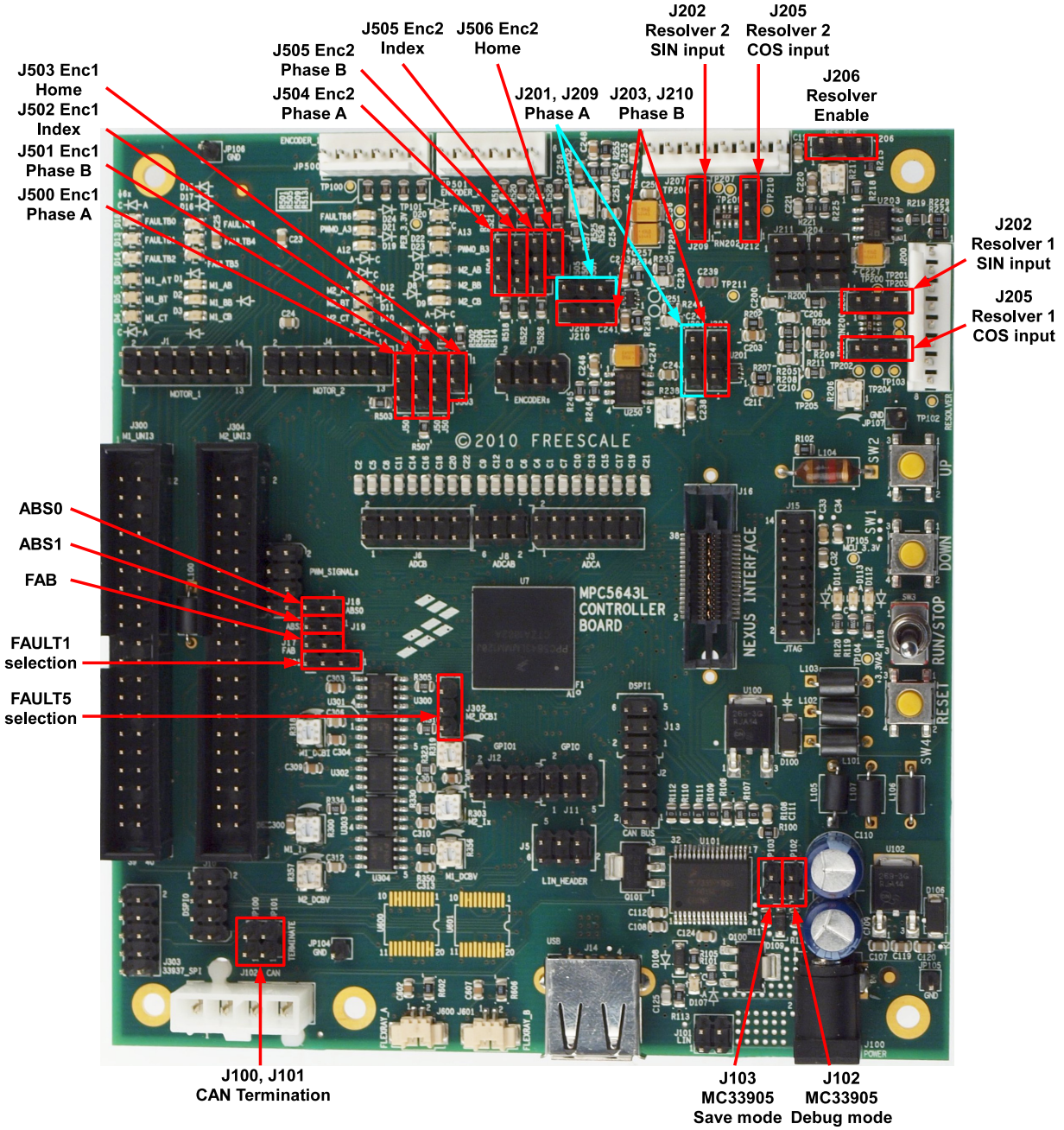


Figure 1-3. MPC5643L board jumper position

1.4 Board LEDs

The Table 1-2 displays the on-board LEDs. For on-board LED locations, see Figure 1-2.

Table 1-2. On-board LEDs

LED	Signal Name	Description
D112	+12 V	+12 V power supply input
D107	/SAFE	MCZ33905 safe pin state (ON - SBC in safe mode)
D113	MCU_3.3V	+ 3.3 V MCU power supply
D114	PER_3.3V	+ 3.3 V AUX power supply
D1	PWM0 B0	Motor 1 Phase A bottom switch signal
D2	PWM0 B1	Motor 1 Phase B bottom switch signal
D3	PWM0 B2	Motor 1 Phase C bottom switch signal
D4	PWM0 A2	Motor 1 Phase C top switch signal
D5	PWM0 A1	Motor 1 Phase B top switch signal
D6	PWM0 A0	Motor 1 Phase A top switch signal
D7	PWM1 B0	Motor 2 Phase A bottom switch signal
D8	PWM1 B1	Motor 2 Phase B bottom switch signal
D9	PWM1 B2	Motor 2 Phase C bottom switch signal
D10	PWM1 A2	Motor 2 Phase C top switch signal
D11	PWM1 A1	Motor 2 Phase B top switch signal
D12	PWM1 A0	Motor 2 Phase A top switch signal
D13	FAULTB1	Motor 1 FAULTB1 signal
D14	FAULTB2	Motor 1 FAULTB2 signal
D15	FAULTB3	Motor 1 FAULTB3 signal
D16	FAULTB5	Motor 2 FAULTB5 signal
D17	FAULTB4	Motor 2 FAULTB4 signal
D18	FAULTB0	Motor 1 FAULTB0 signal
D19	A12	User LED 1
D20	FAULTB7	Motor 2 FAULTB7 signal
D21	PWM0 A3	PWM module 0, A3 output
D22	A13	User LED 1
D23	PWM0 B3	PWM module 0, B3 output
D24	FAULTB6	Motor 2 FAULTB6 signal

Chapter 2 Interface Description

The following chapters summarize the on-board connectors and headers pin-outs, signal meanings, and MCU pin assignments.

2.1 Power supply J100

The MPC5643L Dual Motor Controller Board can be supplied either by using the 2.1 mm DC power plug, J100, or the UNI-3 connectors (J300, J304, pin 19).

The controller board is powered by two independent voltage regulators that provide 5 V for auxiliary logic and 5 V for MCU and debugger logic. Both voltages are generated by the MC33905 SBC integrated circuit. Proper operation is monitored by LEDs D113 for the MCU 3.3 V line and D114 for the AUX 3.3 V line (see Table 1-2).

The board is designed to operate in the voltage range from 8 V to 18 V. The board is protected against a reverse battery.

2.2 UNI3 Interface J300, and J304

The UNI-3 interface (connector J300, J304) defines the interface between the MPC5643L Dual Motor Controller Board and a 3 phase electrical motor power stages.

The list of UNI-3 signals:

- Control signals:
  - PWM phase A, B, C top and bottom switches control
  - Brake signal control
  - Power Factor Correction (PFC)
- Monitor signals
  - DC-bus voltage
  - DC-bus current
  - Phase A, B, C current
  - Zero-cross signals
  - Back-EMF phase A, B, C
  - Temperature monitoring
- Power Supply 12 V
- Serial line — A bidirectional communication line between the controller board and power stage

Table 2-1 defines the UNI-3 pin-out and pin assignment to the MCU.

Table 2-1. Motor 1 — UNI-3 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	PWM_AT	PWM0_A0	Phase A top switch control (H -> Turn OFF)	Digital output
3	PWM_AB	PWM0_B0	Phase A bottom switch control (H -> Turn ON)	Digital output
5	PWM_BT	PWM0_A1	Phase B top switch control (H -> Turn OFF)	Digital output
7	PWM_BB	PWM0_B1	Phase B bottom switch control (H -> Turn ON)	Digital output
9	PWM_CT	PWM0_A2	Phase C top switch control (H -> Turn OFF)	Digital output
11	PWM_CB	PWM0_B2	Phase C bottom switch control (H -> Turn ON)	Digital output
2, 4, 6, 8, 10	Shield	–	PWM signals shield (grounded on the power stage side only)	–
12,13	GND_D	–	Digital power supply ground	–
14, 15	+5 V DC	–	+5 V digital power supply	–
17, 18	AGND	–	Analog power supply ground	–
19	+12/+15 V DC	–	Analog power supply	–
16,20, 27, 28,37	NC	–	Not connected	–
21	V_{DCBUS}	B[8]	DC-bus voltage sensing, 0 V – 3.3 V, ADC0 channel 1	Analog input
22	I_{DCBUS}	B[14]	DC-bus current sensing, 0 V – 3.3 V, ADC1 channel 1	Analog input
23	I_A	B[9]	Phase A current sensing, 0 V – 3.3 V, ADCx channel 11	Analog input
24	I_B	B[10]	Phase B current sensing, 0 V – 3.3 V, ADCx channel 12	Analog input
25	I_C	C[1]	Phase C current sensing, 0 V – 3.3 V, ADC0 channel 2	Analog input
26	TEMP	E[6]	Analog temperature 0 V – 3.3 V, ADC0 channel 4	Analog input
29	BRAKE_CONT	PWM0_A3	DC-bus brake control	Digital output
30	SERIAL	–	Serial interface	Digital bidirectional
31	PFC	–	Power factor correction PWM	Digital output
32	PFCEN	–	Power factor correction enable	Digital output
33	PFCZC	–	Power factor correction Zero-cross	Digital input
34	ZCA	D[9] or A[0]	Phase A Back-EMF zero crossing	Digital input
35	ZCB	D[12] or A[1]	Phase B Back-EMF zero crossing	Digital input
36	ZCC	G[2] or C[11]	Phase C Back-EMF zero crossing	Digital input
38	Back-EMF_A	B[9]	Phase A Back-EMF voltage sensing	Analog input

Table 2-1. Motor 1 — UNI-3 signal description (continued)

Interface Pin	Signal Name	MCU Signal	Description	Direction
39	Back-EMF_B	B[10]	Phase B Back-EMF voltage sensing	Analog input
40	Back-EMF_C	C[1]	Phase C Back-EMF voltage sensing	Analog input

Table 2-2. Motor 2 — UNI-3 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	PWM_AT	PWM1_A0	Phase A top switch control (H -> Turn OFF)	Digital output
3	PWM_AB	PWM1_B0	Phase A bottom switch control (H -> Turn ON)	Digital output
5	PWM_BT	PWM1_A1	Phase B top switch control (H -> Turn OFF)	Digital output
7	PWM_BB	PWM1_B1	Phase B bottom switch control (H -> Turn ON)	Digital output
9	PWM_CT	PWM1_A2	Phase C top switch control (H -> Turn OFF)	Digital output
11	PWM_CB	PWM1_B2	Phase C bottom switch control (H -> Turn ON)	Digital output
2, 4, 6, 8, 10	Shield	–	PWM signals shield (grounded on the power stage side only)	–
12,13	GND_D	–	Digital power supply ground	–
14, 15	+5V DC	–	+5 V digital power supply	–
17, 18	AGND	–	Analog power supply ground	–
19	+12/+15V DC	–	Analog power supply	–
16,20, 27, 28,37	NC	–	Not connected	–
21	V_{DCBUS}	C[2]	DC-bus voltage sensing, 0 V – 3.3 V, ADC0 channel 3	Analog input
22	I_{DCBUS}	C[0]	DC-bus current sensing, 0 V – 3.3 V, ADC1 channel 3	Analog input
23	I_A	B[11]	Phase A current sensing, 0 V – 3.3 V, ADCx channel 13	Analog input
24	I_B	B[12]	Phase B current sensing, 0 V – 3.3 V, ADCx channel 14	Analog input
25	I_C	B[15]	Phase C current sensing, 0 V – 3.3 V, ADC1 channel 2	Analog input
26	TEMP	E[6]	Analog temperature 0 V – 3.3 V, ADC0 channel 4	Analog input
29	BRAKE_CONT	PWM1_A3	DC-bus brake control	Digital output
30	SERIAL	–	Serial interface	Dig. bidirectional
31	PFC	PWM1_B3	Power factor correction PWM	Digital output
32	PFCEN	E[13]	Power factor correction enable	Digital output
33	PFCZC	–	Power factor correction Zero-cross	Digital input
34	ZCA	H[4] or C[13]	Phase A Back-EMF zero crossing	Digital input

Table 2-2. Motor 2 — UNI-3 signal description (continued)

Interface Pin	Signal Name	MCU Signal	Description	Direction
35	ZCB	H[7] or C[14]	Phase B Back-EMF zero crossing	Digital input
36	ZCC	H[10] or F[12]	Phase C Back-EMF zero crossing	Digital input
38	Back-EMF_A	B[11]	Phase A Back-EMF voltage sensing	Analog input
39	Back-EMF_B	B[12]	Phase B Back-EMF voltage sensing	Analog input
40	Back-EMF_C	B[15]	Phase C Back-EMF voltage sensing	Analog input

2.3 MC33937A interface J303 and J305

While using Freescale 3-phase power stages, the electrical inverter switches are controlled by the MC33937A pre-driver. The device behavior is configured by this interface, see Table 2-3.

Table 2-3. Motor 1 — MC33937A signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	NC	–	Not connected	–
2	NC	–	Not connected	–
3	MC33937_EN	A[11]	Motor 1 device-enable output	Digital output
4	MC33937_OC	D[6]	Over-current input	Digital input
5	MC33937_/RST	A[10]	Reset output. Active in low	Digital output
6	MC33937_INT	D[5]	Interrupt pin	Digital input
7	MC33937_SOUT	DSPI0_SIN	Input data from MC33937 SPI port. Tri-state until $\overline{CS}$ becomes low.	Digital input
8	MC33937_SCK	DSPI0_SCK	Clock for SPI port. Output.	Digital output
9	MC33937_CS	DSPI0_/CS0	Chip-select 0 output. It frames SPI command and enables SPI port.	Digital output
10	MC33937_SIN	DSPI0_SOUT	Output data for MC33937 SPI port. Clocked on the falling edge of SCLK, MSB first.	Digital output

Table 2-4. Motor 2 — MC33937A signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	NC	–	Not connected	–
2	NC	–	Not connected	–
3	MC33937_EN	A[9]	Motor 2 device-enable output	Digital output
4	MC33937_OC	D[6]	Over-current input	Digital input
5	MC33937_/RST	A[10]	Reset output. Active in low	Digital output
6	MC33937_INT	D[5]	Interrupt pin	Digital input

Table 2-4. Motor 2 — MC33937A signal description (continued)

Interface Pin	Signal Name	MCU Signal	Description	Direction
7	MC33937_SOUT	DSPI0_SIN	Input data from MC33937 SPI port. Tri-state until $\overline{CS}$ becomes low.	Digital input
8	MC33937_SCK	DSPI0_SCK	Clock for SPI port. Output	Digital output
9	MC33937_CS	DSPI0_/CS1	Chip-select 1 output. It frames SPI command and enables SPI port.	Digital output
10	MC33937_SIN	DSPI0_SOUT	Output data for MC33937 SPI port. Clocked on the falling edge of SCLK, MSB first.	Digital output

2.4 Resolver connector J200 and J207

The controller board calculates motor rotor position from two resolver or SIN/COS sensors. They are connected to the board through connectors J200 resp. J207. Table 2-5 and Table 2-6 shows the pin description for resolver 1 and for resolver 2.

Table 2-5. Resolver 1 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	RES1_E_R1	–	Positive sinusoidal reference signal for resolver Signal output range from 0 V up to +12 V	Output
2	RES1_E_R2	–	Negative sinusoidal reference signal for resolver Signal output range from 0 V up to +12 V	Output
3	RES1_E_S2	–	SIN input signal	Differential analog input
4	RES1_E_S4	–	SIN reference input signal	Differential analog input
5	RES1_E_S1	–	COS input signal	Differential analog input
6	RES1_E_S3	–	COS reference input signal	Differential analog input
7	GNDA	–	Analog ground	–
8	GNDA	–	Analog ground	–

Table 2-6. Resolver 2 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	RES2_E_R1	–	Positive sinusoidal reference signal for resolver Signal output range from 0 V up to +12 V	Output
2	RES2_E_R2	–	Negative sinusoidal reference signal for resolver Signal output range from 0 V up to +12 V	Output
3	RES2_E_S2	–	SIN input signal	Differential analog input

Table 2-6. Resolver 2 signal description (continued)

Interface Pin	Signal Name	MCU Signal	Description	Direction
4	RES2_E_S4	–	SIN reference input signal	Differential analog input
5	RES2_E_S1	–	COS input signal	Differential analog input
6	RES2_E_S3	–	COS reference input signal	Differential analog input
7	GNDA	–	Analog ground	–
8	GNDA	–	Analog ground	–

2.5 Encoder/Hall connector J500 and J501

The motor rotor position can be transformed from encoder or Hall rotor position sensor. They can be connected to the board through connector J500 and J501. For proper signal connections, see Table 2-7.

Table 2-7. Encoder/Hall signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	+5 Vdc	–	+5 V sensor supply voltage	–
2	GND	–	Ground	–
3	ENC1_PhaseA / HALL0 ENC2_PhaseA / HALL0	A[0] C[13]	Digital input signal phase A or Hall 0 input signal	Digital input
4	ENC1_PhaseB / HALL1 ENC2_PhaseB / HALL1	A[1] C[14]	Digital input signals phase B or Hall 1 input signal	Digital input
5	ENC1_INDEX / HALL2 ENC2_INDEX / HALL2	C[11] F[12]	Digital input signals INDEX or Hall 2 input signal	Digital input
6	ENC1_HOME ENC2_HOME	C[12] F[13]	Digital input signals HOME	Digital input

Table 2-8. J7 Header signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	ENC1_PHA	A[0]	Encoder 1 digital input signal phase A.	Digital input
2	ENC2_PHA	C[13]	Encoder 2 digital input signal phase A.	Digital input
3	ENC1_PHB	A[1]	Encoder 1 digital input signal phase B.	Digital input
4	ENC2_PHB	C[14]	Encoder 2 digital input signal phase B.	Digital input
5	ENC1_INDEX	C[11]	Encoder 1 digital input signal INDEX.	Digital input

Table 2-8. J7 Header signal description (continued)

Interface Pin	Signal Name	MCU Port	Description	Direction
6	ENC2_INDEX	F[12]	Encoder 2 digital input signal INDEX.	Digital input
7	ENC1_HOME	C[12]	Encoder 1 digital input signal HOME.	Digital input
8	ENC2_HOME	F[13]	Encoder 2 digital input signal HOME.	Digital input

2.6 LIN connector J101

The MC33905 LIN transceiver is used as an on-board LIN hardware interface. The LIN node can be configured to either the Master or Slave mode, see Table 1-1.

A Table 2-9 shows the LIN connector pin-out and pin assignment to the MCU

Table 2-9. LIN signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	GND	–	Ground	–
2	VSUP	–	Power Supply	–
3	GND	–	Ground	–
4	LIN	LIN1_RXD / LIN1_TXD	LIN bus	Digital bidirectional

Table 2-10. Header J5 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	LIN0_RXD	B[3]	LIN module 0 receive input	Digital input
2	LIN0_TXD	B[2]	LIN module 0 transmit output	Digital output
3	GND	–	Ground	–
4	GND	–	Ground	–
5	LIN1_RXD	F[15]	LIN module 1 receive input	Digital input
6	LIN1_TXD	F[14]	LIN module 1 transmit output	Digital output

2.7 CAN connector J102

The system basis chip MC33905 CAN transceiver is used as the CAN hardware interface. On-board jumpers JP101, JP102 enable node termination, impedance of 120R, see Table 1-1.

Table 2-11 shows the CAN connector pin-out and pin assignment to the MCU.

Table 2-11. CAN signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	CANH	CAN0_RXD / CAN0_TXD	CAN bus H	Diff. bidirectional
2	CANL	CAN0_RXD / CAN0_TXD	CAN bus L	Diff. bidirectional
3	GND	–	Ground	–
4	NC	–	Not connected	–

Table 2-12. Header J2 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	CAN0_RX_PHY	–	–	–
2	CAN0_TX_PHY	–	–	–
3	CAN0_RXD	B[1]	CAN module 0 receive input	Digital input
4	CAN0_TXD	B[0]	CAN module 0 receive output	Digital output
5	CAN1_RX_PHY	–	–	–
6	CAN1_TX_PHY	–	–	–
7	CAN1_RXD	A[15]	CAN module 1 receive input	Digital input
8	CAN1_TXD	A[14]	CAN module 1 receive output	Digital output

2.8 USB Connector J14

The USB line is used for board communication with the PC, when using for example Freescale FreeMASTER tool to control and visualize the user application.

The interface uses an A type connector which is isolated from the board environment. See Table 2-13 for the pin description and pin assignment to the MCU.

Table 2-13. USB signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	VBUS	–	USB Power Supply	–
2	D-	LIN0_RXD / LIN0_TXD	Data –	Dig. bidirectional
3	D+	LIN0_RXD / LIN0_TXD	Data +	Dig. bidirectional
4	GNDB	–	USB Ground	–

2.9 Header J1 and J4

Monitoring the PWM signal is possible using J1 or J4. The Table 2-14 summarizes the header pin-out.

Table 2-14. J1 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	PWM0_A0	D[10]	Motor 1 — Phase A top switch control	Digital output
2	PWM0_B0	D[11]	Motor 1 — Phase A bottom switch control	Digital output
3	PWM0_A1	F[0]	Motor 1 — Phase B top switch control	Digital output
4	PWM0_B1	D[14]	Motor 1 — Phase B bottom switch control	Digital output
5	PWM0_A2	G[3]	Motor 1 — Phase C top switch control	Digital output
6	PWM0_B2	G[4]	Motor 1 — Phase C bottom switch control	Digital output
7	FAULTB0	G[8]	PWM module 0 fault input 0	Digital input
8	FAULTB1	G[9]	PWM module 0 fault input 1	Digital input
9	FAULTB2	G[10]	PWM module 0 fault input 2	Digital input
10	FAULTB3	G[11]	PWM module 0 fault input 3	Digital input
11	PWM0_X0	D[9]	PWM module 0 auxiliary PWM signal 0	Digital input/output
12	PWM0_X1	D[12]	PWM module 0 auxiliary PWM signal 1	Digital input/output
13	PWM0_X2	G[2]	PWM module 0 auxiliary PWM signal 2	Digital input/output
14	GND	-	Ground	

Table 2-15. J4 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	PWM1_A0	H[5]	Motor 2 — Phase A top switch control	Digital output
2	PWM1_B0	H[6]	Motor 2 — Phase A bottom switch control	Digital output
3	PWM1_A1	H[8]	Motor 2 — Phase B top switch control	Digital output
4	PWM1_B1	H[9]	Motor 2 — Phase B bottom switch control	Digital output
5	PWM1_A2	H[11]	Motor 2 — Phase C top switch control	Digital output
6	PWM1_B2	H[12]	Motor 2 — Phase C bottom switch control	Digital output
7	FAULTB4	I[0]	PWM module 1 fault input 0	Digital input
8	FAULTB5	I[1]	PWM module 1 fault input 1	Digital input
9	FAULTB6	I[2]	PWM module 1 fault input 2	Digital input
10	FAULTB7	I[3	PWM module 1 fault input 3	Digital input
11	PWM1_X0	H[4]	PWM module 1 auxiliary PWM signal 0	Digital input/output
12	PWM1_X1	H[7]	PWM module 1 auxiliary PWM signal 1	Digital input/output

Table 2-15. J4 signal description (continued)

Interface Pin	Signal Name	MCU Port	Description	Direction
13	PWM1_X2	H[10	PWM module 1 auxiliary PWM signal 2	Digital input/output
14	GND	–	Ground	–

2.10 Header J3, J6, and J8

Headers J3, J6, and J8 allow monitoring the analog-to-digital converter signals, see Table 2-16.

Table 2-16. Header J3 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	ADC0_AN0	B[7]	ADC module 0 channel 0 input	Analog input
2	ADC0_AN1	B[8]	ADC module 0 channel 1 input	Analog input
3	ADC0_AN2	C[1]	ADC module 0 channel 2 input	Analog input
4	ADC0_AN3	C[2]	ADC module 0 channel 3 input	Analog input
5	ADC0_AN4	E[6]	ADC module 0 channel 4 input	Analog input
6	ADC0_AN5	E[2]	ADC module 0 channel 5 input	Analog input
7	ADC0_AN6	E[7]	ADC module 0 channel 6 input	Analog input
8	ADC0_AN7	E[4]	ADC module 0 channel 7 input	Analog input
9	SWG_OUT	D[7]	Sinewave generator output1	Analog output
10	ADC0_AN8	E[8]	ADC module 0 channel 8 input	Analog input
11	+3.3 VA2	–	+3.3 V analogue voltage	–
12	GNDA	–	Analogue ground	–

Table 2-17. Header J6 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	ADC1_AN0	B[13]	ADC module 1 channel 0 input	Analog input
2	ADC1_AN1	B[14]	ADC module 1 channel 1 input	Analog input
3	ADC1_AN2	B[15]	ADC module 1 channel 2 input	Analog input
4	ADC1_AN3	C[0]	ADC module 1 channel 3 input	Analog input
5	ADC1_AN4	E[11]	ADC module 1 channel 4 input	Analog input
6	ADC1_AN5	E[0]	ADC module 1 channel 5 input	Analog input
7	ADC1_AN6	E[12]	ADC module 1 channel 6 input	Analog input
8	ADC1_AN7	E[9]	ADC module 1 channel 7 input	Analog input
9	NC	–	–	–
10	ADC1_AN8	E[10]	ADC module 1 channel 8 input	Analog input

Table 2-17. Header J6 signal description (continued)

Interface Pin	Signal Name	MCU Signal	Description	Direction
11	+3.3 VA2	–	+3.3 V analogue voltage	–
12	GNDA	–	Analogue ground	–

Table 2-18. Header J8 signal description

Interface Pin	Signal Name	MCU Signal	Description	Direction
1	ADC0/1_AN11	B[9]	ADC module 0/1 channel 11 input	Analog input
2	ADC0/1_AN12	B[10]	ADC module 0/1 channel 12 input	Analog input
3	ADC0/1_AN13	B[11]	ADC module 0/1 channel 13 input	Analog input
4	ADC0/1_AN14	B[12]	ADC module 0/1 channel 14 input	Analog input
5	+3.3 VA2	–	+3.3 V analogue voltage	–
6	GNDA	–	Analogue ground	–

2.11 Header J11 and J12

Headers J11, and J12 allow monitoring the miscellaneous digital signals. See Table 2-19 and Table 2-20.

Table 2-19. Header J11 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	A12	A[12]	Digital input / output	Digital I/O
2	A13	A[13]	Digital input / output	Digital I/O
3	FCCU_F0	G[0]	FCCU output F[0]	Digital output
4	FCCU_F1	G[1]	FCCU output F[1]	Digital output
5	+3.3 Vdc	–	+3.3 V voltage	–
6	GND	–	Ground	–

Table 2-20. Header J12 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	F3	F[3]	Digital input / output	Digital I/O
2	A10	A[10]	Digital input / output	Digital I/O
3	E13	E[13]	Digital input / output	Digital I/O
4	A11	A[11]	Digital input / output	Digital I/O
5	C10	C[10]	Digital input / output	Digital I/O
6	eTimer1_CH5	E[14]	Digital input / output	Digital I/O
7	GND	–	Ground	–
8	NC	–	–	–

2.12 Header J13

Headers J13 allow monitoring the DSPI module 1 digital signals. See Table 2-21.

Table 2-21. Header J13 signal description

Interface Pin	Signal Name	MCU Port	Description	Direction
1	DSPI1_SOUT	A[7]	DSPI module 1 serial data output	Digital output
2	DSPI1_SIN	A[8]	DSPI module 1 serial data input	Digital input
3	DSPI1_SCK	A[6]	DSPI module 1 clock	Digital output
4	DSPI1_/CS0	A[5]	DSPI module 1 chip select 0	Digital output
5	DSPI1_/CS2	D[8]	DSPI module 1 chip select 2	Digital output
6	GND	–	Ground	–

Chapter 3 Design Consideration

The MPC5643L Dual Motor Controller Board demonstrates the ability of the Freescale MPC5643L device to control various electrical motors and easier development of the motor-control applications. In addition to the hardware needed to run a motor, a variety of feedback signals that facilitate control-algorithm development are provided. A set of schematics for the controller board appears in the following section.

3.1 MPC5643L features

The MPC5643L is a member of the family of microcontrollers based on Power Architecture™. It targets electric power steering, chassis and safety market segment, and safety applications that require a high safety integrity level. The MPC5643L devices are built around a dual-core safety platform with an innovative safety concept targeting ISO26262 ASILD and IEC61508 SIL3 integrity levels. To minimize additional software and module level features to reach this target; on-chip redundancy is provided for the critical components of the microcontroller:

- CPU core
- DMA controller
- Interrupt controller
- Crossbar bus system
- Memory protection unit
- Flash-memory controller and RAM controllers
- Peripheral bus bridge
- System timers
- Watchdog timer

Lock step Redundancy Checking Units are implemented at each output of this Sphere of Replication (SoR). ECC is available for on-chip RAM and flash memories. A programmable fault collection and control unit monitors the integrity status of the device and provides flexible safe state control.

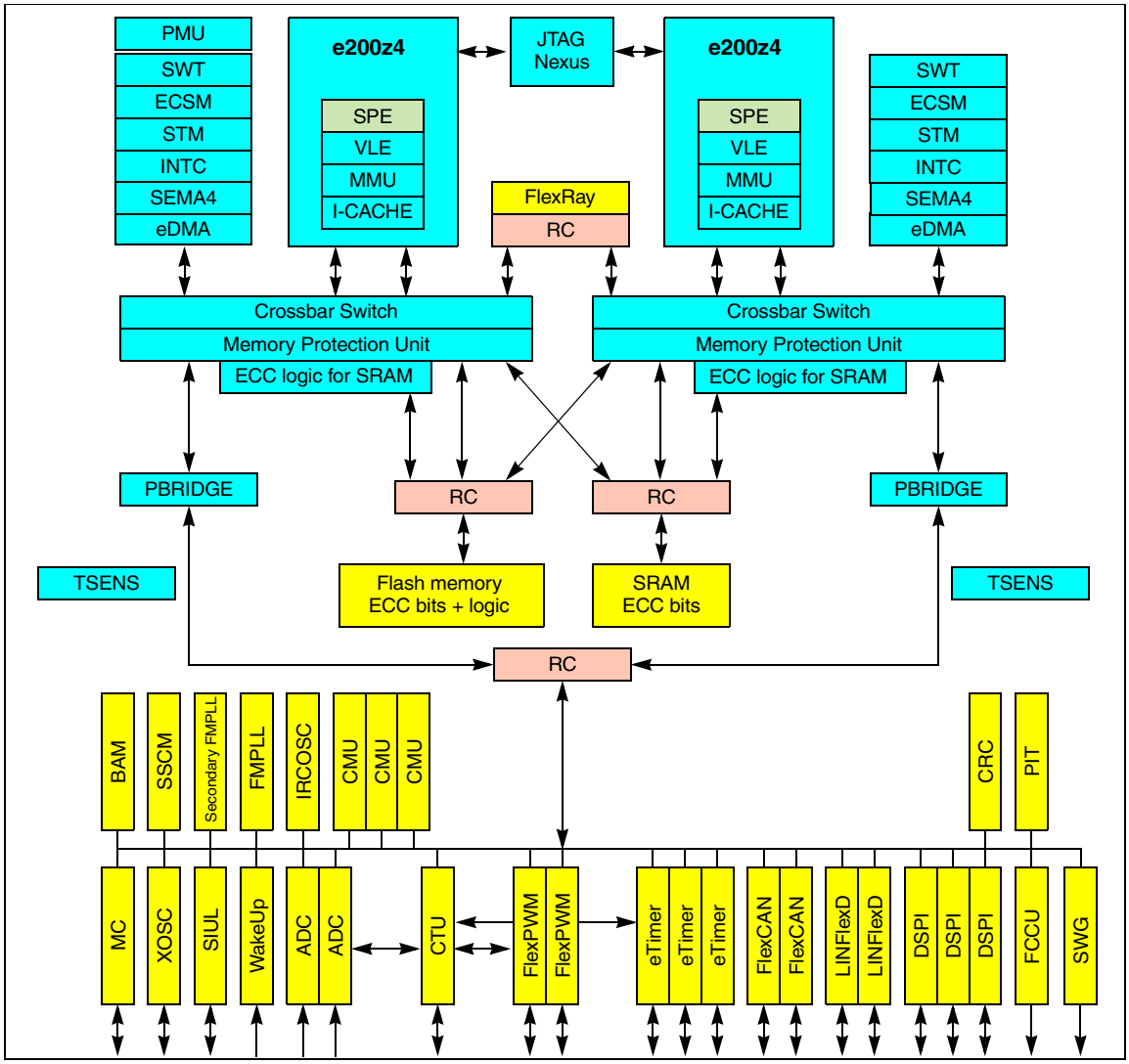
The MPC5643L has included two e200z4 cores that can be used in lock-step mode (LSM) or decoupled parallel mode (DPM). The maximal execution speed is 120 MHz.

The peripheral set is compatible with the MPC5604P device family and provides high-end electrical motor control capability with very low CPU load. This is due to special motor control peripherals like cross-triggering unit, flexPWM, eTimer, and ADC modules. The timer functions of MPC5643L are performed by the eTimer — Modular Timer System and FlexPWM. The three eTimer modules implement enhanced timer features (six channels each for a total of 18) including dedicated motor-control quadrature-decode function and DMA support. Two FlexPWM modules provides capability to independent control two 3-phase PMSM/BLDC motors. Each consist of four submodules controlling a pair of PWM channels. Three submodules may be used to control the three phases of a motor and the additional pair to support the DC-DC converter width modulation control. The SWG Sine Wave Generator module generates high-quality sinusoidal voltage in output frequency range 1 – 50 kHz.

Off-chip communication is performed by a suite of serial protocols including FlexRay, CANs, enhanced SPIs (DSPI), and SCIs (LinFlex).

The System Integration Unit Lite (SIUL) performs several chip-wide configuration functions. Pad configuration and General-Purpose Input and Output (GPIO) are controlled from SIUL. External interrupts and reset control are also found in the SIUL. The internal Multiplexer sub-block (IOMUX) provides multiplexing of daisy chaining the DSPIs and external interrupt signal.

You can find a detailed description of the MCU in the data sheet or reference manual.



ADC – Analog-to-Digital Converter
BAM – Boot Assist Module
CMU – Clock Monitoring Unit
CRC – Cyclic Redundancy Check unit
CTU – Cross Triggering Unit
DSPI – Serial Peripherals Interface
ECC – Error Correction Code
ECSM – Error Correction Status Module
eDMA – Enhanced Direct Memory Access controller
FCCU – Fault Collection and Control Unit
FlexCAN – Controller Area Network controller
FMPLL – Frequency Modulated Phase Locked Loop
INTC – Interrupt Controller
IRCOSC – Internal RC Oscillator
JTAG – Joint Test Action Group interface
LINFlexD – LIN controller with DMA support
MC – Mode Entry, Clock, Reset, & Power
PBRIDGE – Peripheral bridge
PIT – Periodic Interrupt Timer
PMU – Power Management Unit
RC – Redundancy Checker
RTC – Real Time Clock
SEMA4 – Semaphore Unit
SIUL – System Integration Unit Lite
SSCM – System Status and Configuration Module
STM – System Timer Module
SWG – Sine Wave Generator
SWT – Software Watchdog Timer
TSENS – Temperature Sensor
XOSC – Crystal Oscillator

Figure 3-1. MCPC5643L block diagram

3.2 Clock source

The MPC5643L uses an external 8.00 MHz crystal oscillator mounted on the board and internal PLL0 to multiply the input frequency and achieve its 80 MHz maximum operating frequency. The second PLL1 is used to achieve suitable frequency for internal Motor control, SWG, and communication modules. The MPC5643L can also use internal 16 MHz RC oscillator as a clock source. In this mode FlexRAY protocol clock does not support IRCOSC as a clock source.

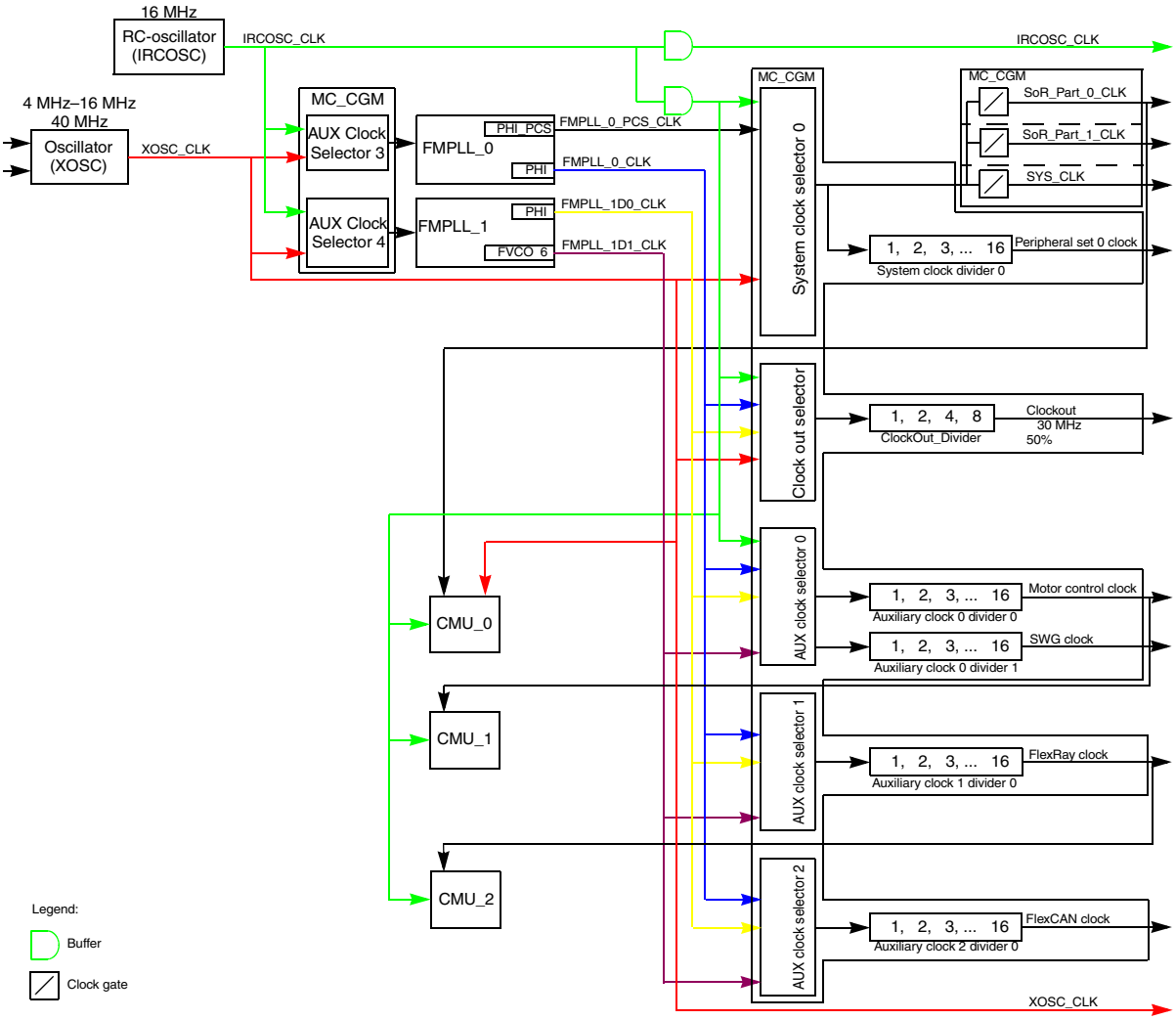


Figure 3-2. MCPC5643L clock block diagram

3.3 UNI3 interfaces and external fault management

The motor power stages are controlled by microcontroller boards through two UNI3 and MC33937 connectors. The connector pin description was mentioned in Chapter 2.2, “UNI3 Interface J300, and J304". Analog or digital signals from the power stages M1 and M2 can be processed by the hardware to maintain fault management. The MPC5643L has eight fault inputs, the first four are routed into PWM module 0, the second four into PWM module 1. Switch off PWM output signals for each module.

The FAULT0, resp. FAULT4 signal can be set up as under- or over-voltage. Whether the output signals from Phase A or DCBUS over-current comparator can be asserted to the input FAULT1, resp. FAULT5, depends on jumper position J301, and J302. The FAULT2 and FAULT3, resp. FAULT6 and FAULT7 MCU inputs can be used as over-current signals from phase B and C. The phase OC level is setup by trimmer R300 resp. R301. See Figure 3-3.

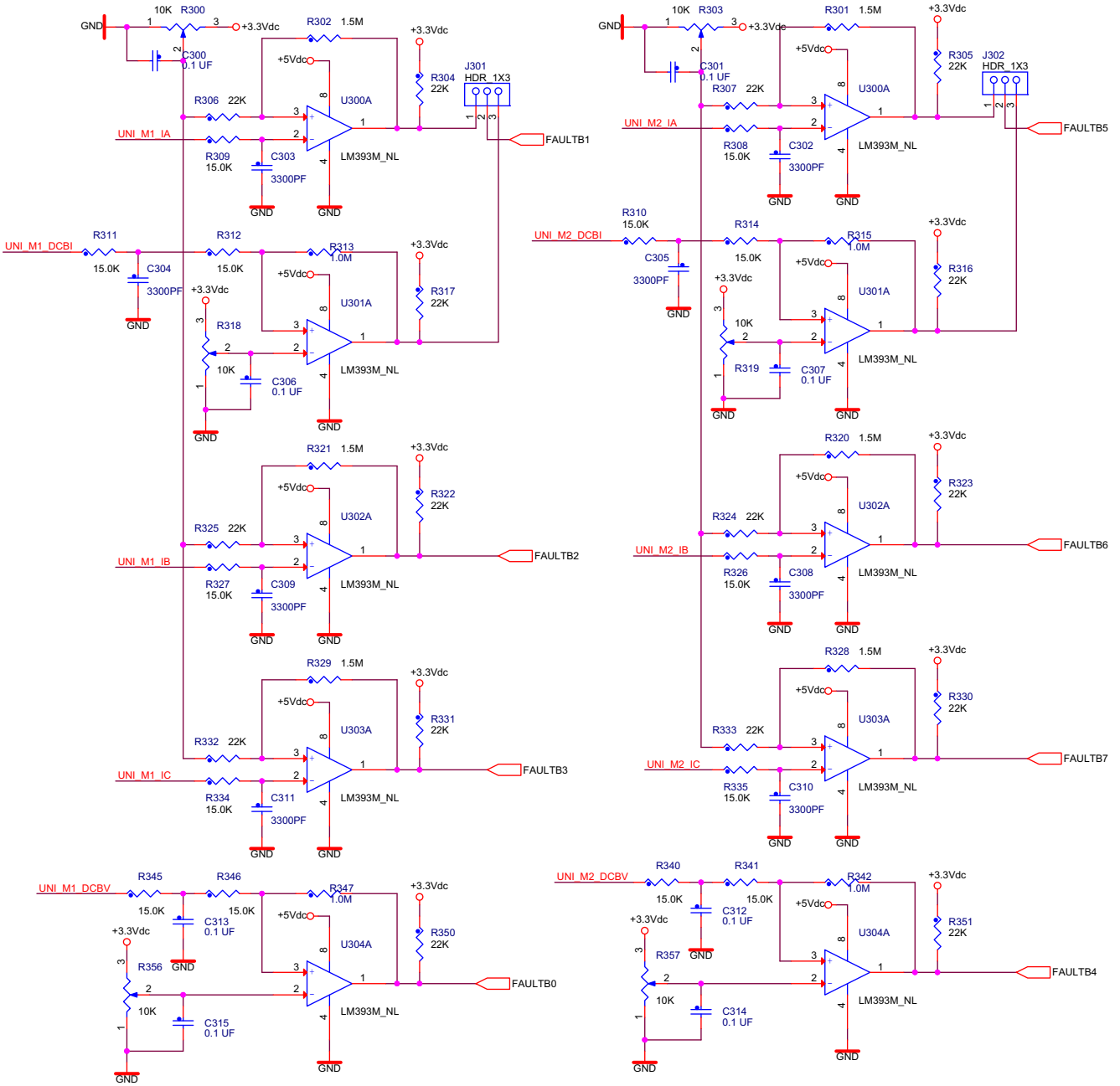


Figure 3-3. FAULT management

Table 3-1. Header J301, J302 — FAULT1, FAULT5 signal assignment

Jumper position	Description
1–2	Phase A over-current
2–3	DC-bus over-current

3.4 Encoder/Hall sensor interface

The motor control application can read position or speed from up to two independent encoders or HALL sensors. The on-board interfaces provide the 5 V power supply voltage to supply the sensors. The Hall interface inputs are designed to support an open collector as well as push-pull Hall sensor outputs (see Figure 3-4). A single pole RC low pass filter is present to reduce a signal noise.

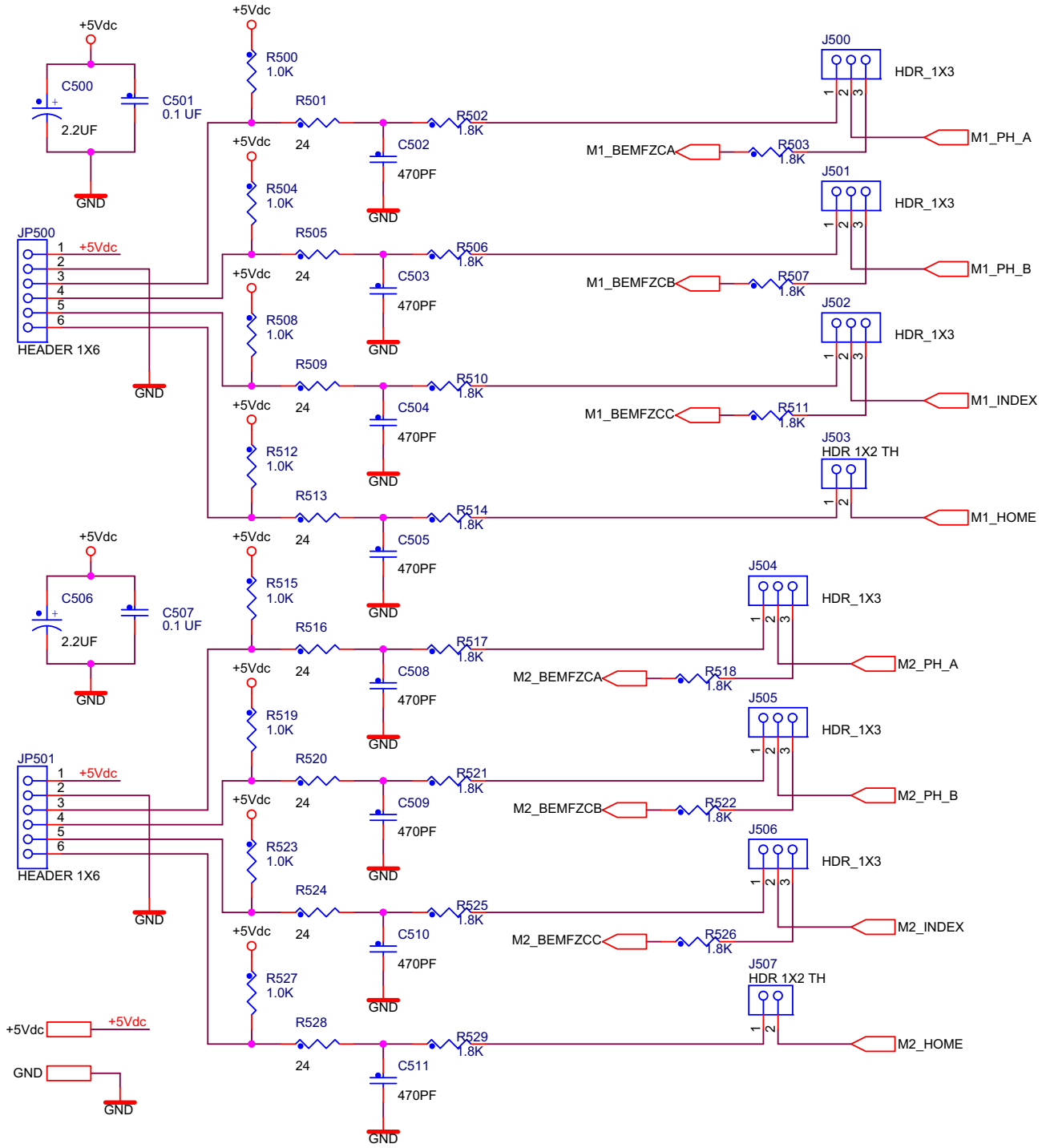


Figure 3-4. Encoder/Hall sensor interface circuit

3.5 Resolver and SinCos sensor interface

The resolver or SinCos interfaces on the board observe actual motor rotor position. The board is populated with two independent HW interfaces that allow the independent measurement of two motor rotor positions and speed. Figure 3-5. shows hardware circuitry for one sensor, the second hardware is similar. The

resolver sensor can be connected through J200 and J207 connector. The jumpers J202 and J205. J209 and J212 provide selection of the positive input signal for differential amplifiers. In case a resolver sensor is used, pins two and three must be shortened. The excitation signal output level (terminals RESx_E_R1 and RESx_E_R2) is setup by trimmer R217 and R249. The resolver excitation signal for the first resolver circuitry can be selected by J206. The source signals are outputs from the SWG module and eTimer0, channel5. The resolver excitation signal for the second resolver circuitry is routed to the eTimer1, channel4 output. It is also connected to the M2_HOME signal from encoder2.

For a detailed J200 connector signal description, see Table 2-5 and Table 2-6.

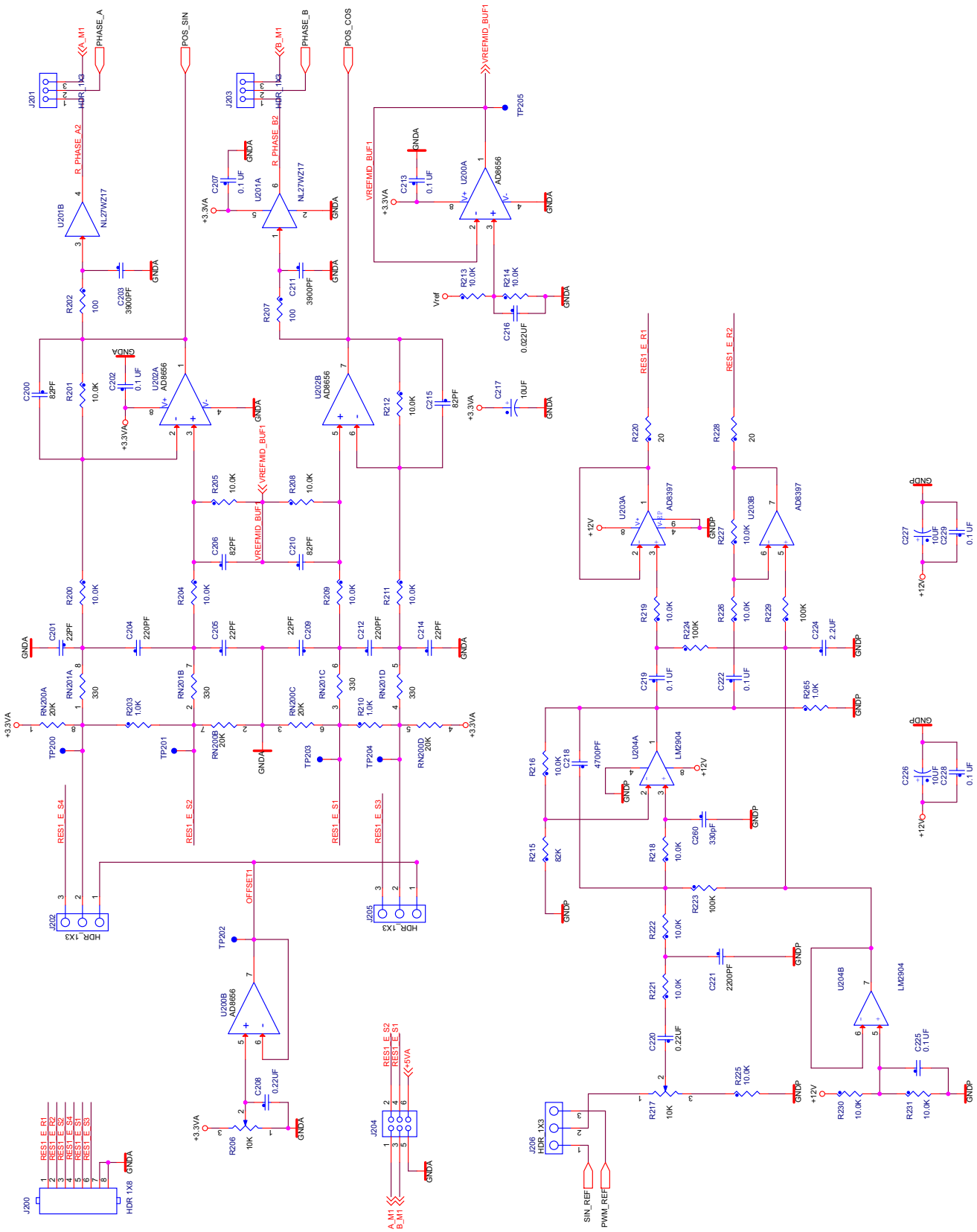


Figure 3-5. Resolver 1 interface schematic

The resolver is an electro-mechanical transformer whose analog output voltages are a function of the shaft angle. It is therefore, an absolute position transducer, providing true angular information at any time. The reference winding (R1 and R2 terminals) is supplied by an alternating signal Vref. Output is taken from the two stator windings, shown in Figure 3-6. The two stator windings fixed at right (90°) angles to each other on the stator produce sine and co-sine feedback voltages Vsin, and Vcos. However, their amplitudes are modulated by sine and cosine as the shaft rotates (see Figure 3-7). That is, the voltages induced into the stator winding will be Vsin=K*sin(?)*sin(ωt) and Vsin=K*cos(?)*sin(ωt), where K is the transformation ratio, ? is the shaft rotation from the reference zero-degree position, and ω =2πf carrier frequency.

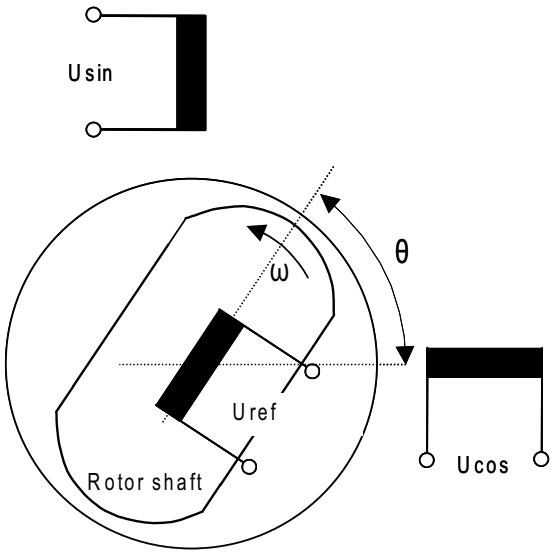


Figure 3-6. Resolver basics

These outputs are modified by differential amplifiers and fed to an analog-to-digital converter. The rotor angle ? can be extracted from these voltages using a digital approach. For a detailed description, see the application note titled *56F80x Resolver Driver and Hardware Interface* (document number AN1942).

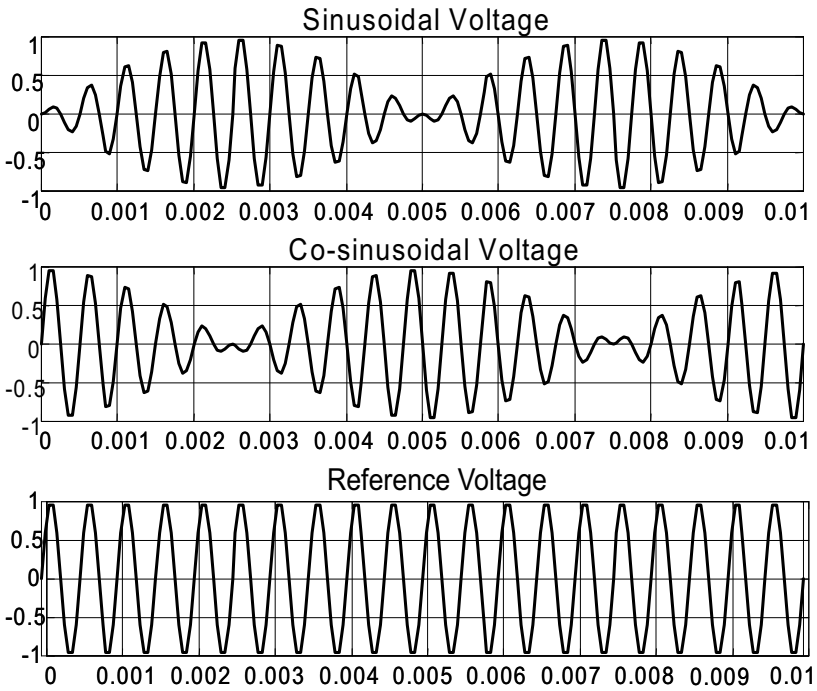


Figure 3-7. Resolver excitation signals

3.6 Analog signal sensing

The MPC5643L can sample up to 2 × 16 analog signals. External 2 × 9 channels are connected through RC filters directly to ADC converters zero and one. The next four channels are common and can be internally switched between both converters. They can be used to sample phase motor currents. The ADC0 channel 15 is dedicated to temperature sensor 0, ADC1 channel 15 for temperature sensor 1, and ADC0/1 channel 10 for measure Vreg 1.2 V.

The time constant of the RC filter must be set according to system requirements. The default time constant was set to approximately 1.2 µs on the inputs zero to ten, and inputs that sample motor currents are set to approximately 50 ns.

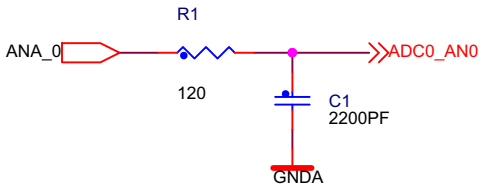


Figure 3-8. Analog sensing circuit

3.7 Power supplies and voltage reference

The MPC5643L Dual Motor Controller Board can be supplied from three main power supply inputs. The first one uses a 2.1 mm coaxial power jack and the others use UNI-3 connectors. The more suitable one depends on the application type. The controller board provides a +5 V DC-voltage regulation for the resolver, encoder, FlexRAY driver, a +3.3 V DC-voltage regulation for MCU and supporting logic, and

provides a reference voltage for the ADC module. Power applied to the MPC5643L Dual Motor Controller Board is indicated by a power-on LED D112. +3.3 V for the MCU and peripherals are signalized by LEDs D113 and D114. The block diagram is shown in Figure 3-9.

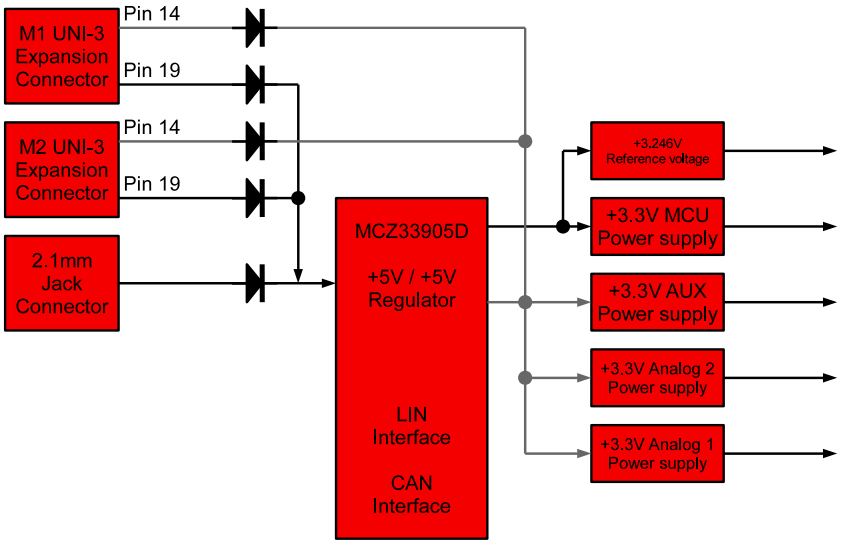


Figure 3-9. Power supply

3.8 UNI-3 PFC-PWM signal (power factor correction)

The PFC-PWM signal is used to additionally control the power stage circuit like PFC or power DC-DC converter. These signals are connected to the MPC5643L controller pins GPIO G[7], and H[15].

3.9 UNI-3 brake signals

The brake signals are used to control the DC-bus resistor switches on each connected power stage. It is accessible via the GPIO G[6] for motor M1, and H[14] for motor M2.

3.10 CAN Bus

The FlexCAN module is a communication controller that implements the CAN protocol according to the CAN 2.0B protocol specification, which supports both standard and extended message frames. A number of Message Buffers (32) are also supported. For a detailed description refer to the reference manual titled *Qorivva MPC5643L Microcontroller Reference Manual* (document number MPC5643LRM). Freescale system basis chip MC33905S with one CAN and one LIN interface is used as the hardware interface for flexCAN module 0. Jumpers JP100 and JP101 define the middle or end node. The flexCAN module 1 does not have a physical interface populated on the board, but the signals are accessible via header J2.

3.11 FlexRAY interface

The FlexRAY module implements the FlexRay Communications System Protocol Specification, Version 2.1 Rev A. The hardware interface consists of two TJA1080 ICs, see Figure 6-9.

Chapter 4 Electrical Characteristics

The electrical characteristics in Table 4-1 apply to an operation at 25 °C.

Table 4-1. Electrical characteristics

Characteristic	Symbol	Min	Typ	Max	Units
Power supply Voltage	V_{DC}	8	12	18	V
Current consumption(1)	I_{CC}		TBD		mA
Minimum Logic one Input Voltage	V_{IH}				mA
Maximum Logic zero Input Voltage	V_{IL}				mA
Input Logic Resistance	R_{IN}	–	4.7	–	kΩ
Analog Input Range	V_{IN}	0	–	3.3	V

1—12 V power supply, MCU without software

Chapter 5 Board Setup Guide

The board uses either the UNI-3 interface or the on-board J1 connector with a power supply voltage from 8 to 18 V. While using the board as a standalone EVB, connect the power supply to J1. In the case of board operation with the power stage it is recommended to use on the board the UNI-3 interface.

The MPC5643L controller board (blue board) is designed for operation with the FSL MC33937A based 3-Phase low voltage power stage (green board), see Figure 5-1. The complete 3-phase BLDC/PMSM Sensor/Sensorless Development Kit can be ordered at http://www.freescale.com.

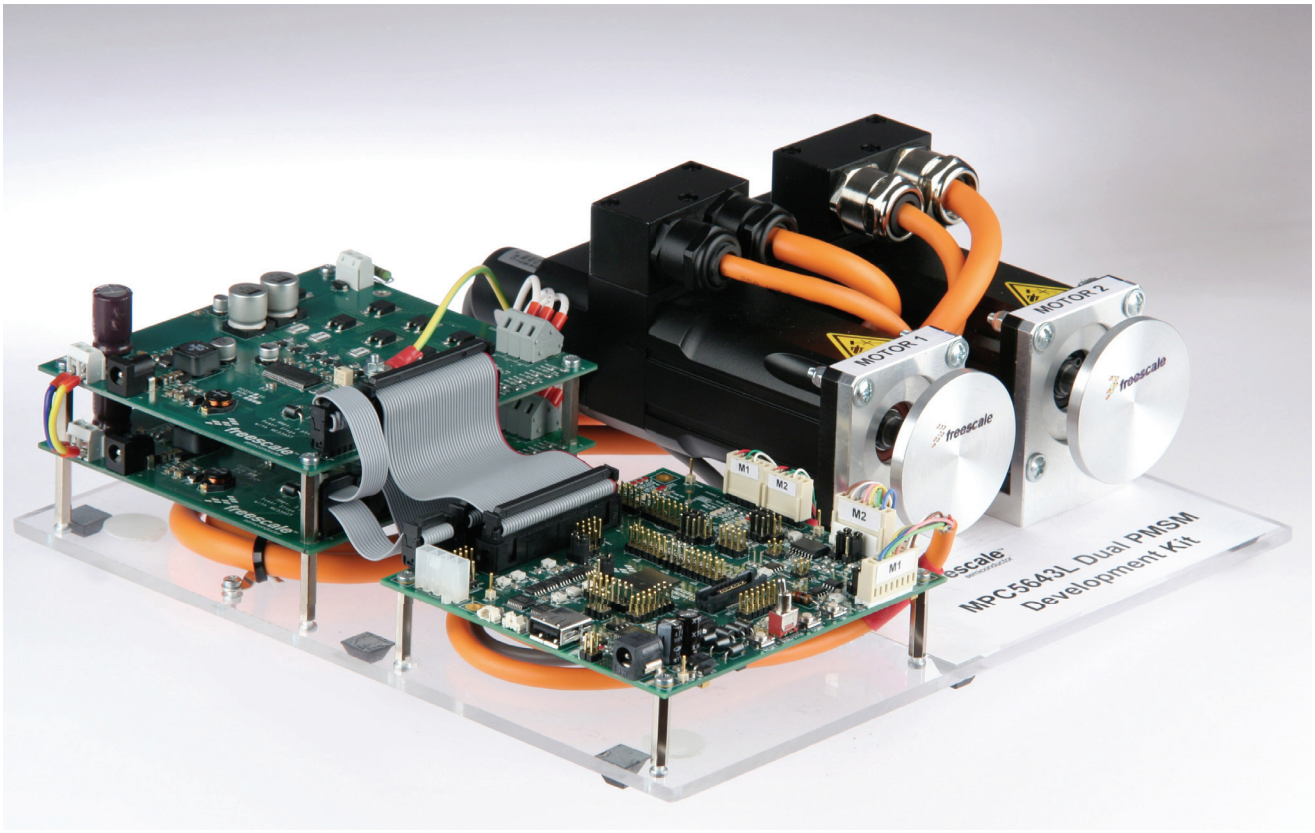


Figure 5-1. 3-Phase dual PMSM development kit

Chapter 6 MPC5643L Dual Motor Controller Board Schematics

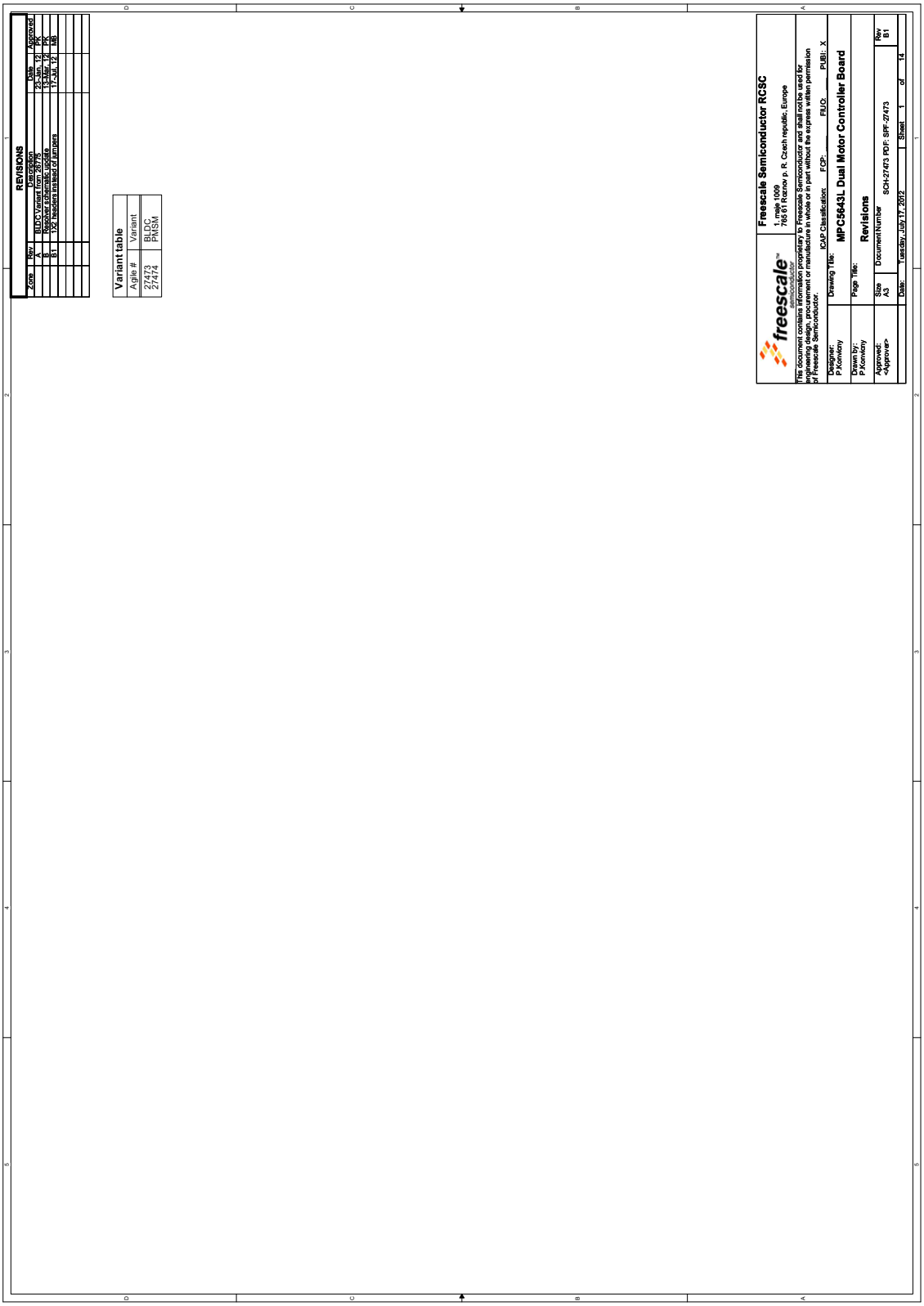


Figure 6-1. Revisions page

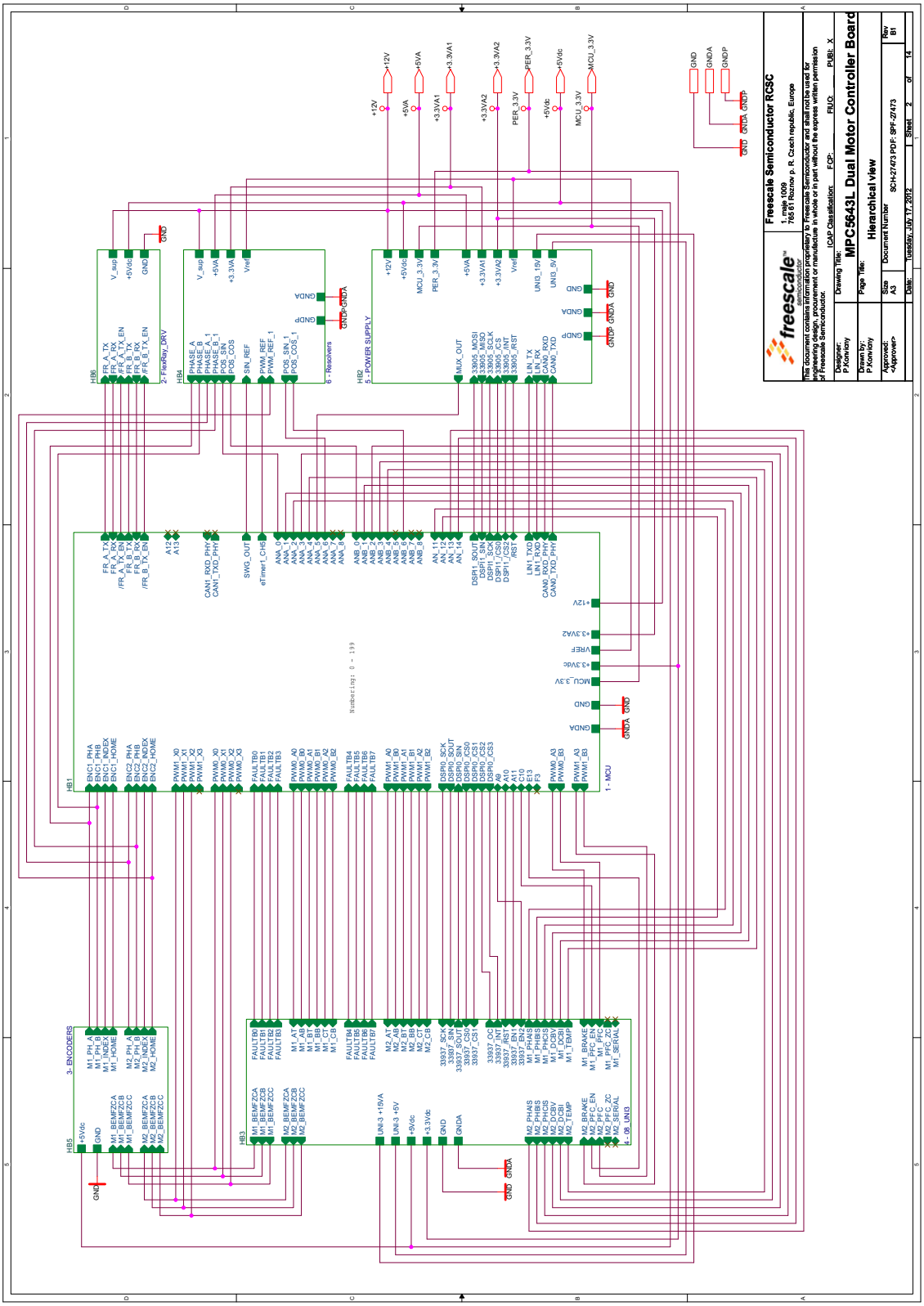


Figure 6-2. Hierarchical view

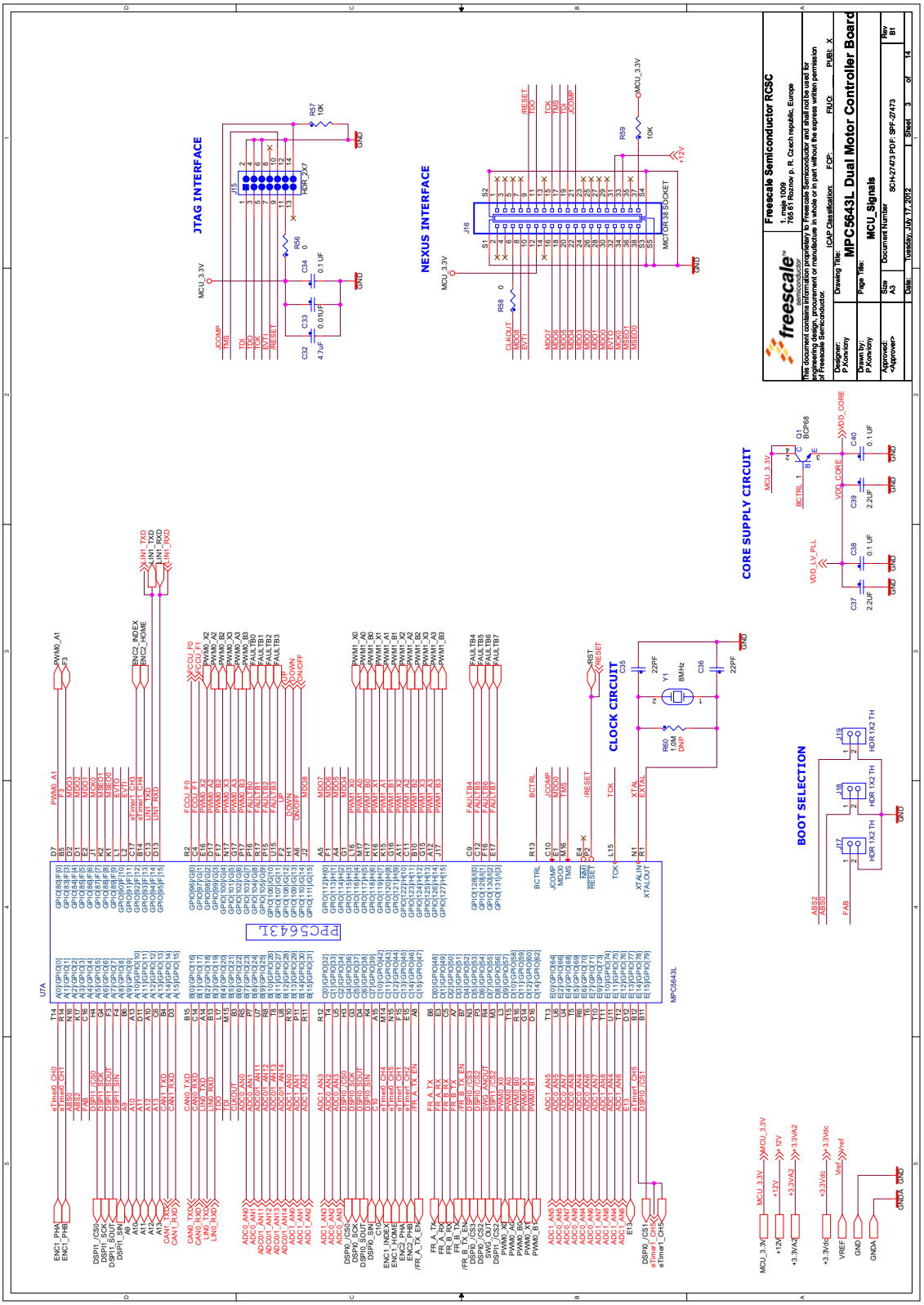


Figure 6-3. MPC5643L signals

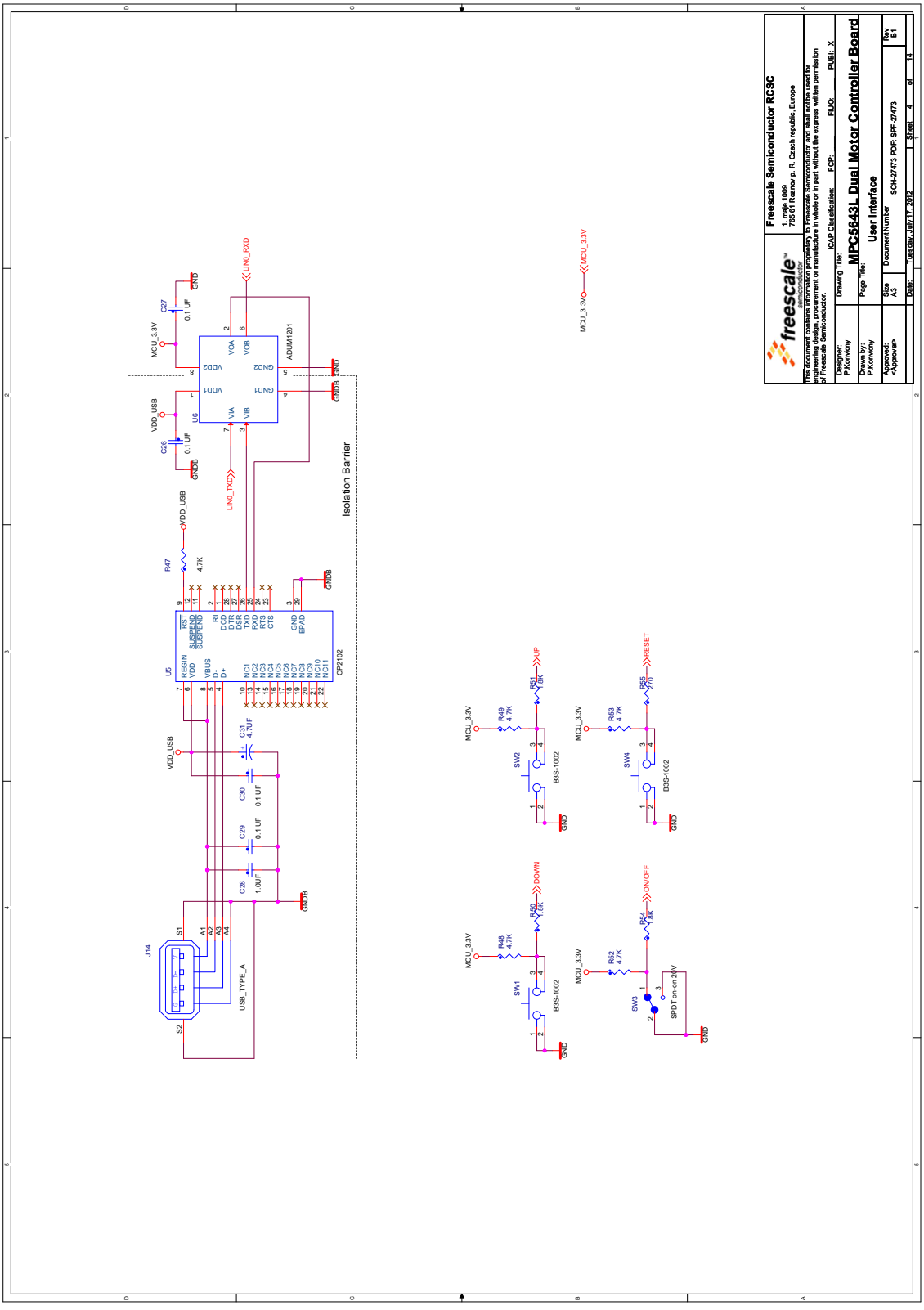


Figure 6-4. User interface

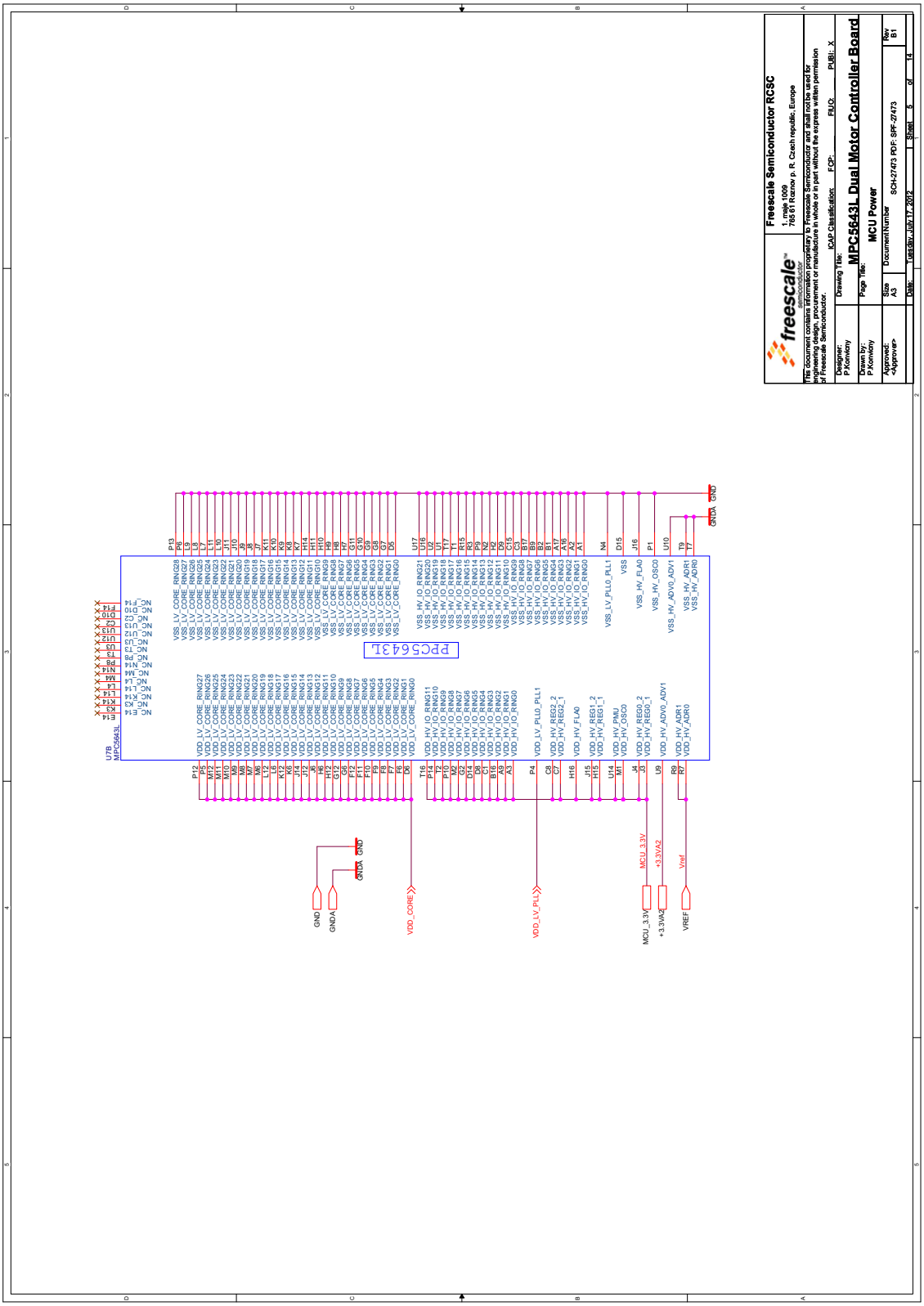


Figure 6-5. MPC5643L power

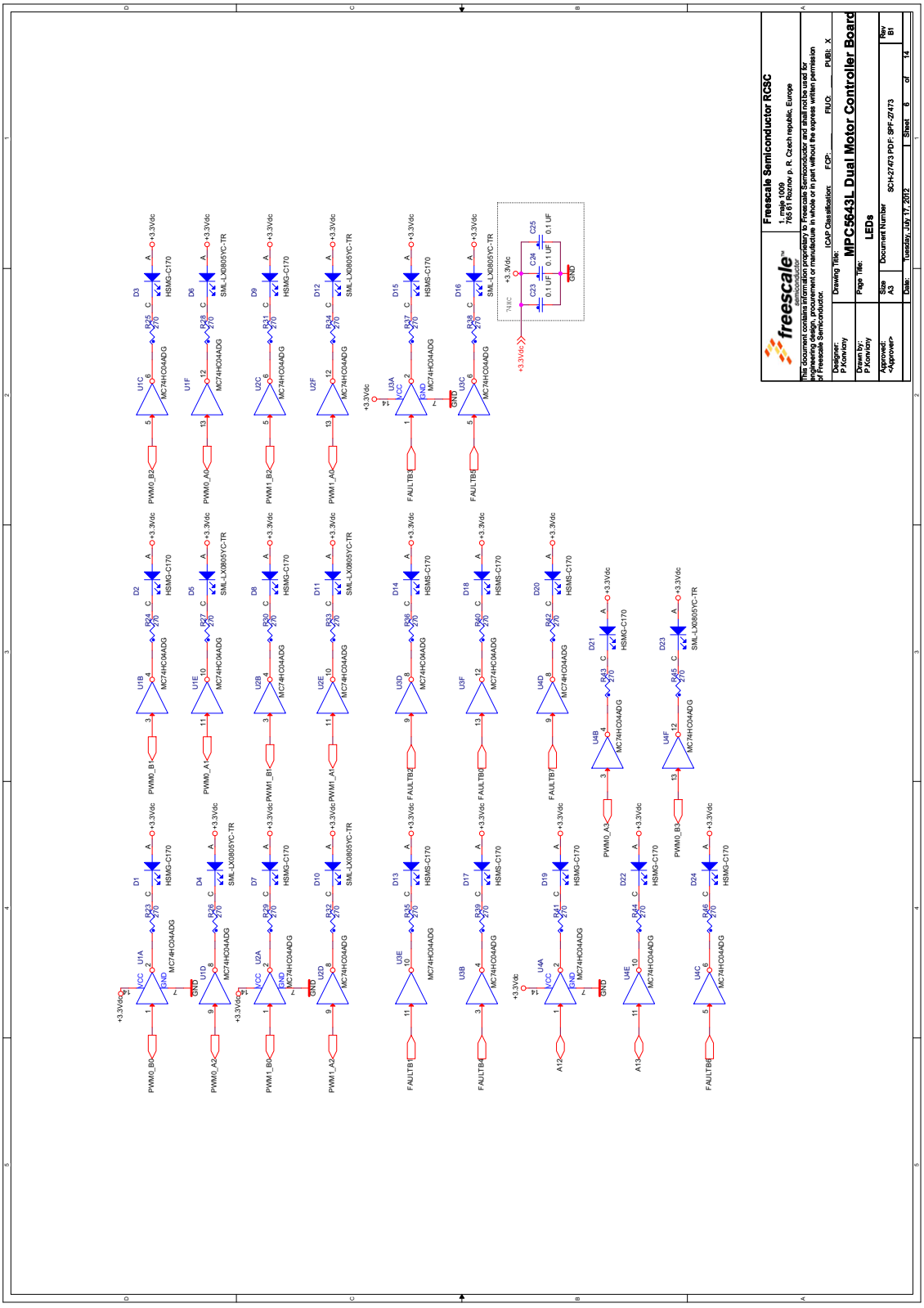


Figure 6-6. LEDs

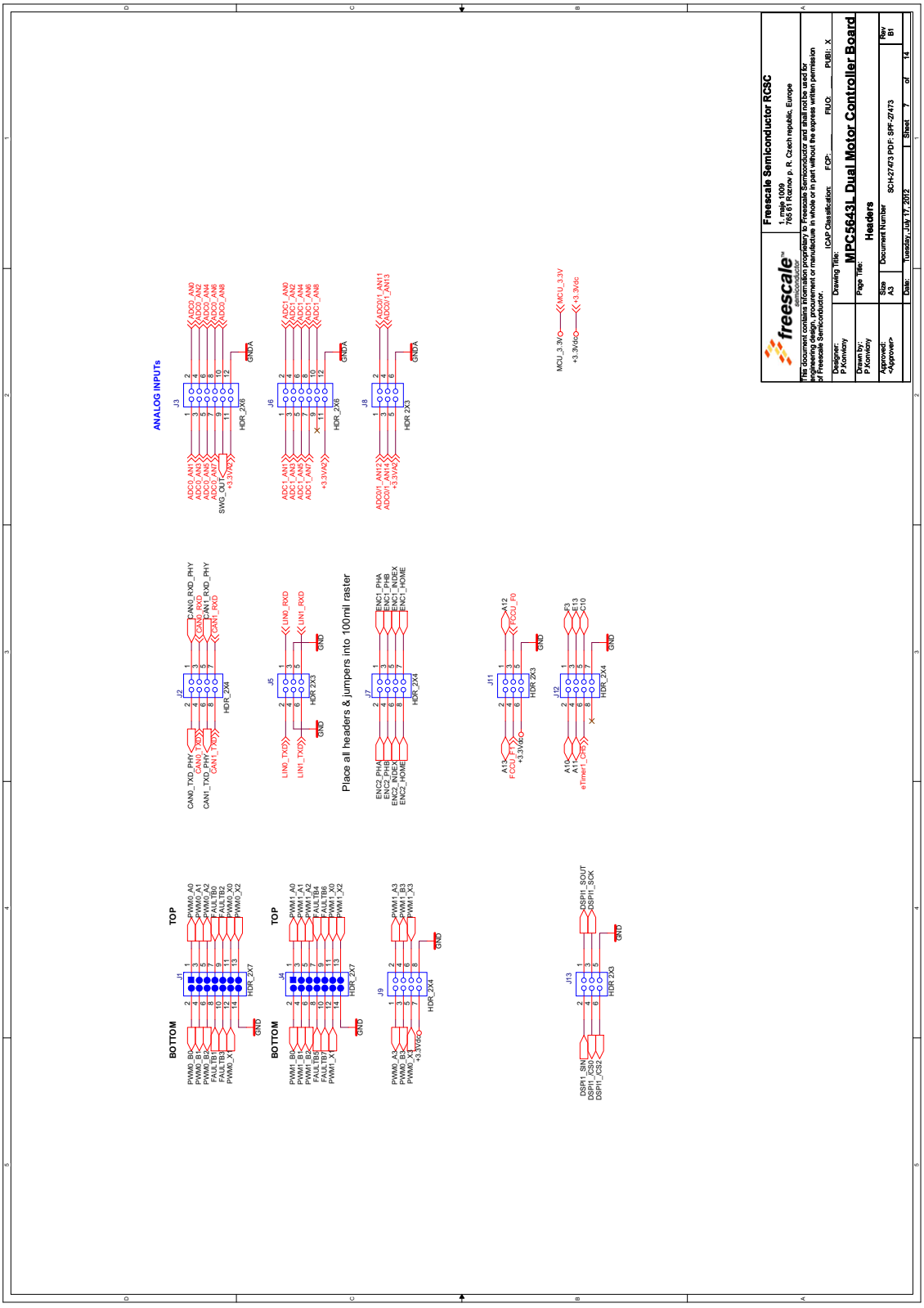


Figure 6-7. Headers

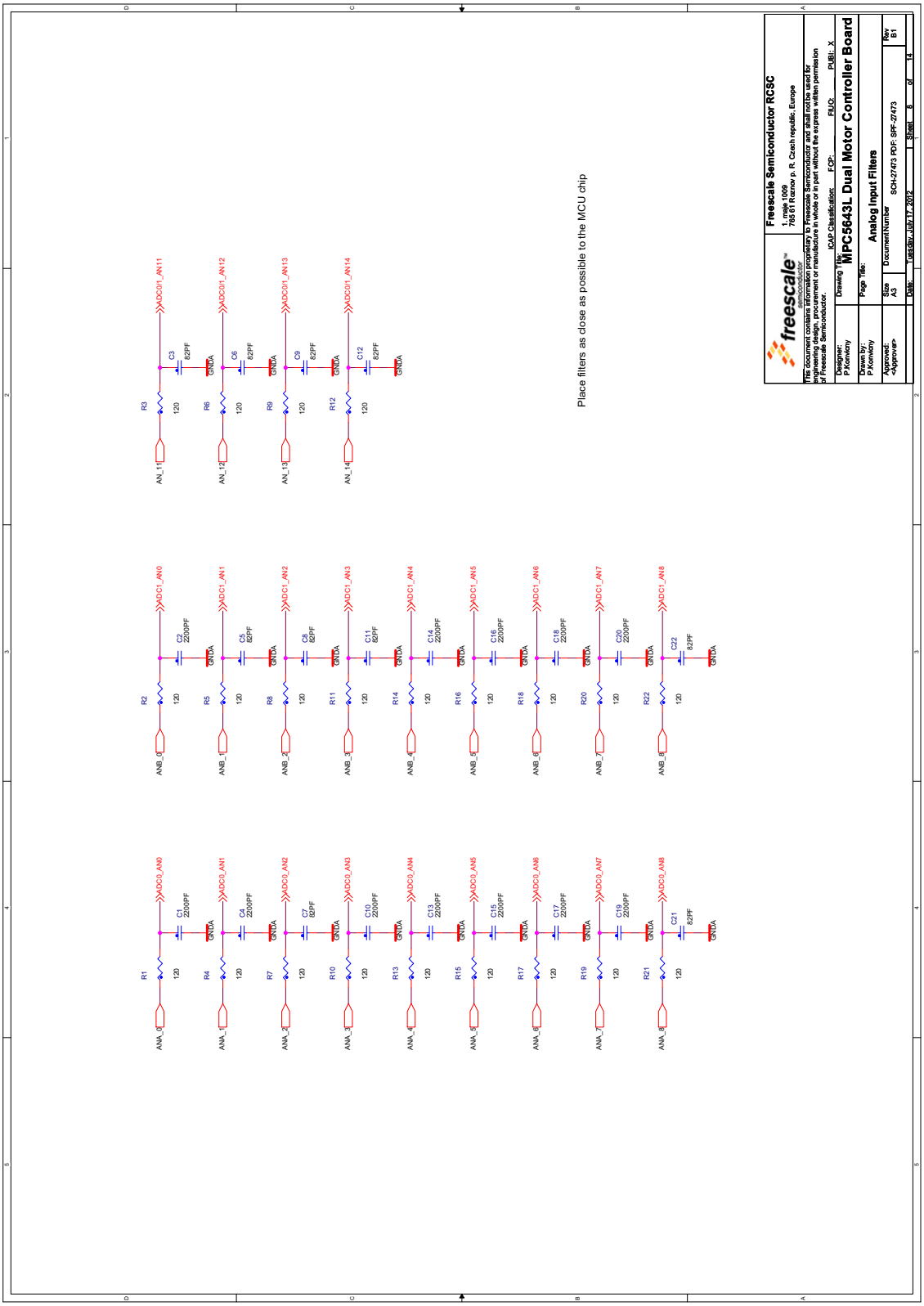


Figure 6-8. Analog input filters

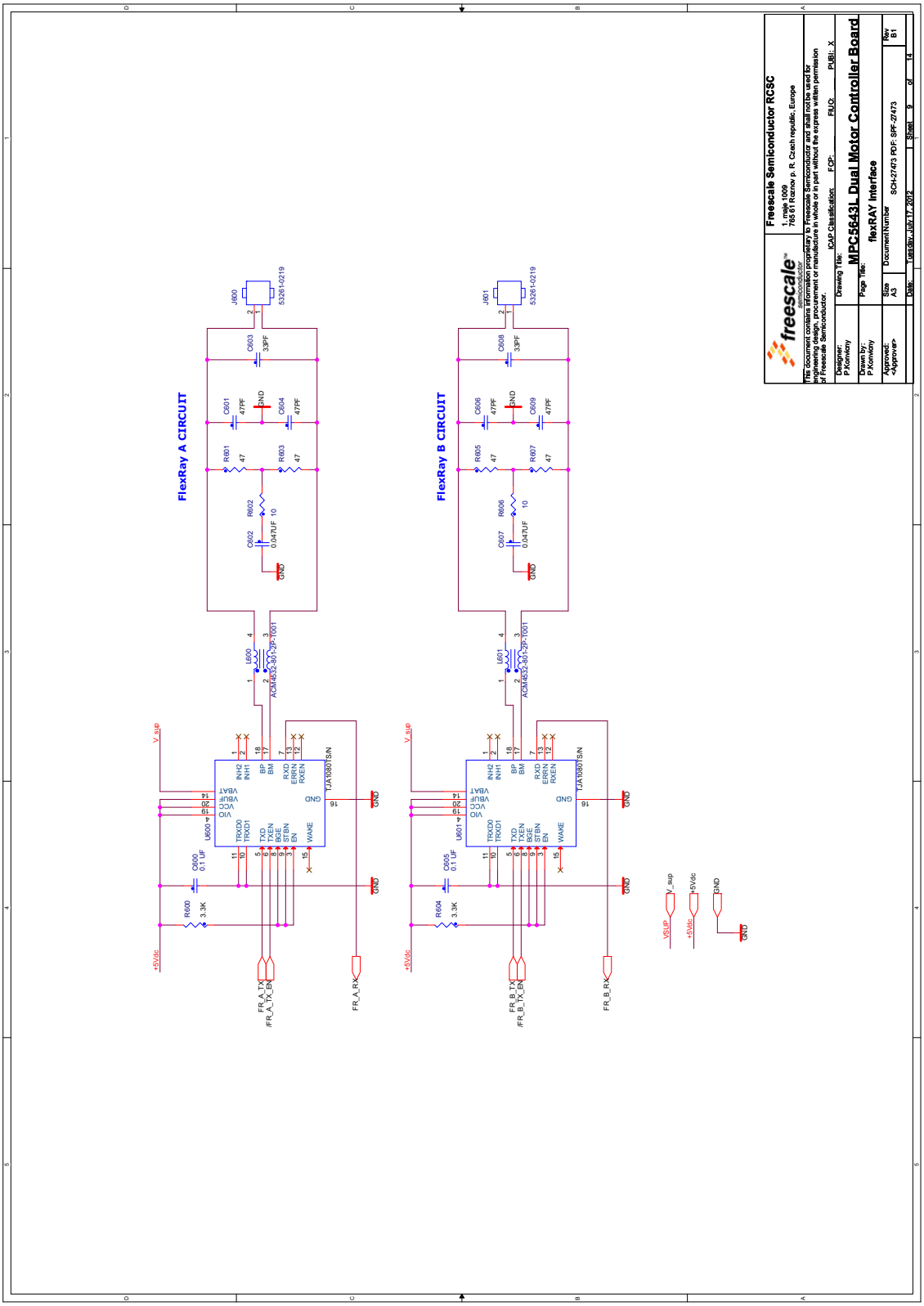


Figure 6-9. FlexRAY interface

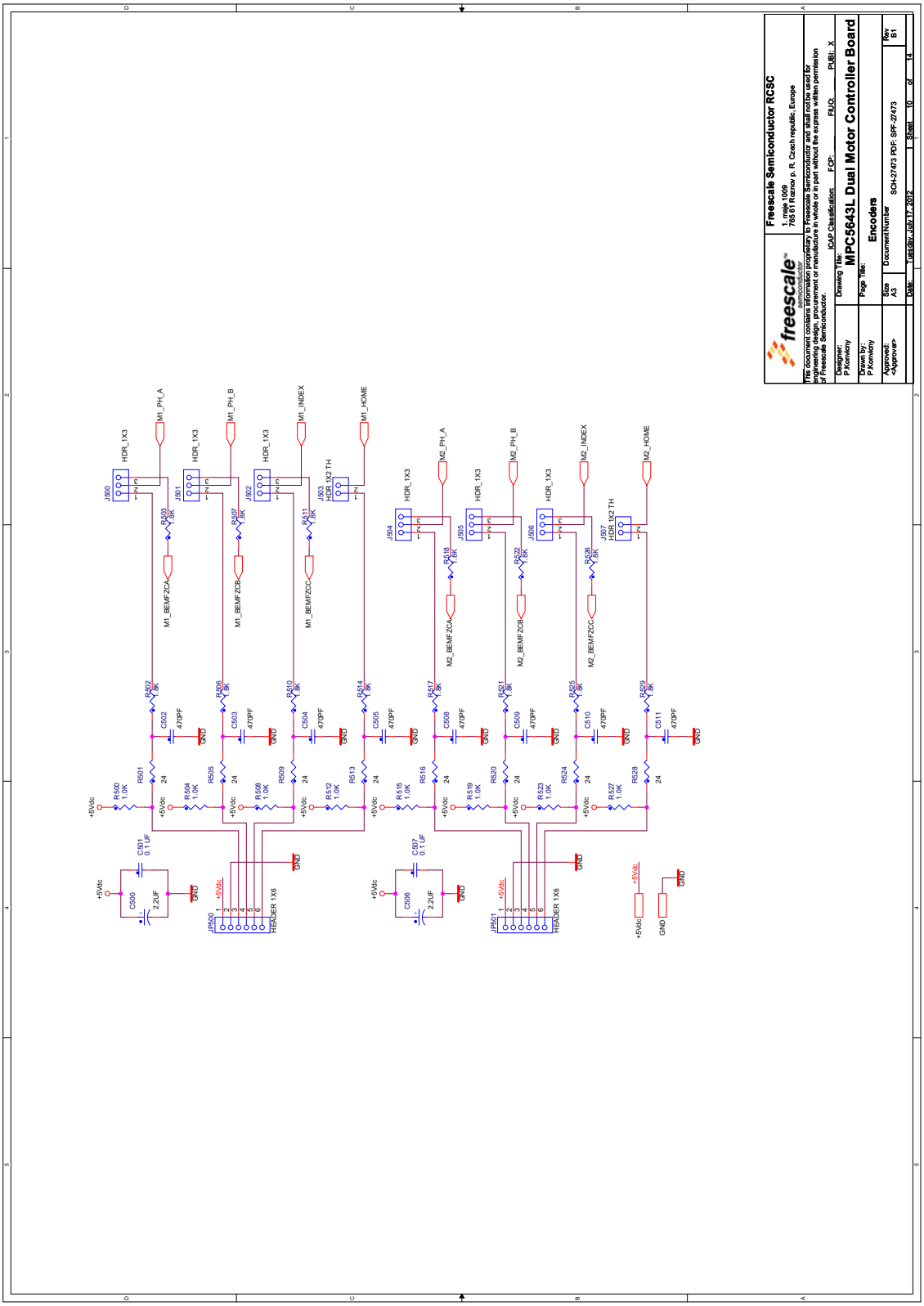


Figure 6-10. Encoders

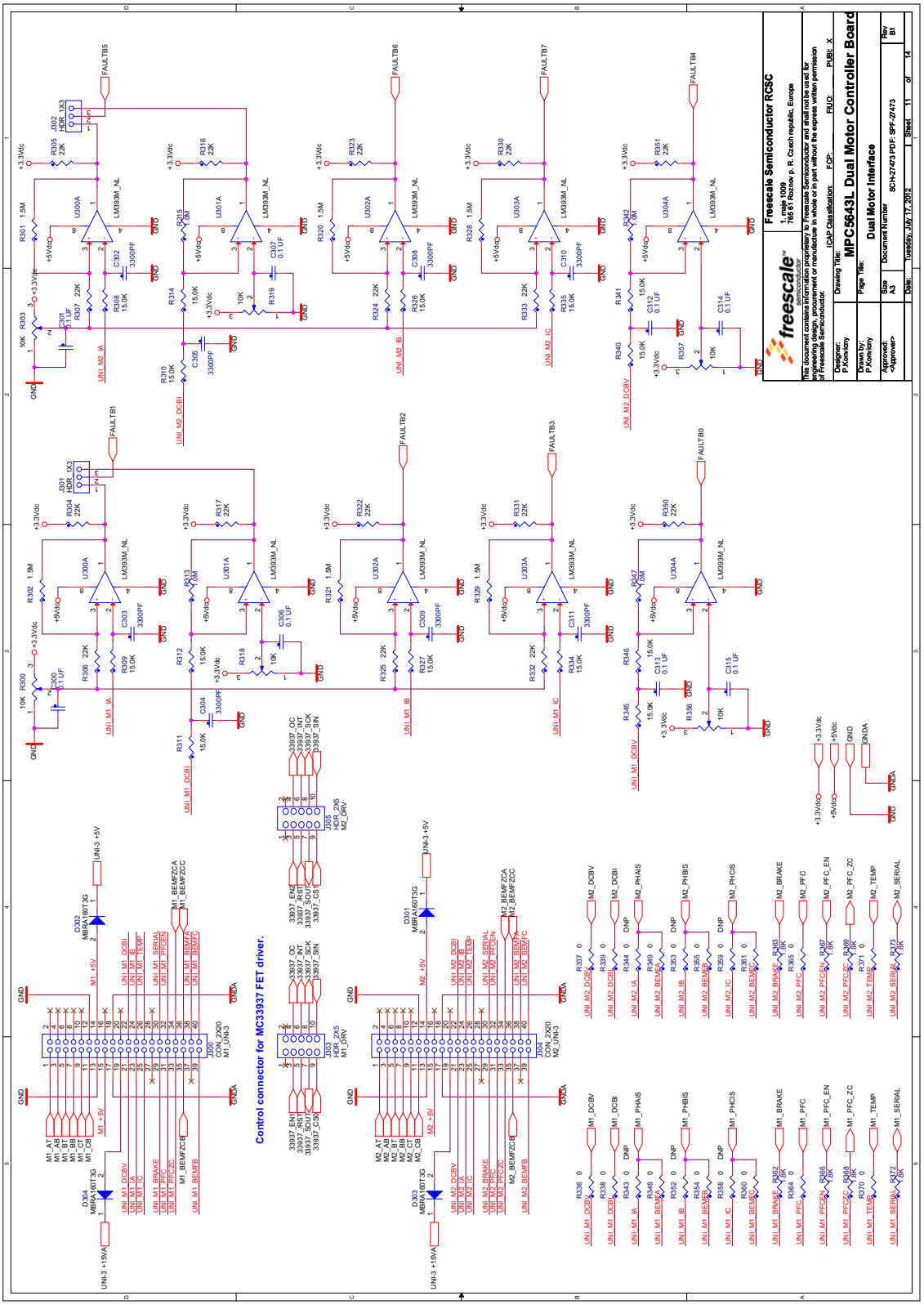


Figure 6-11. Dual motor interfaces

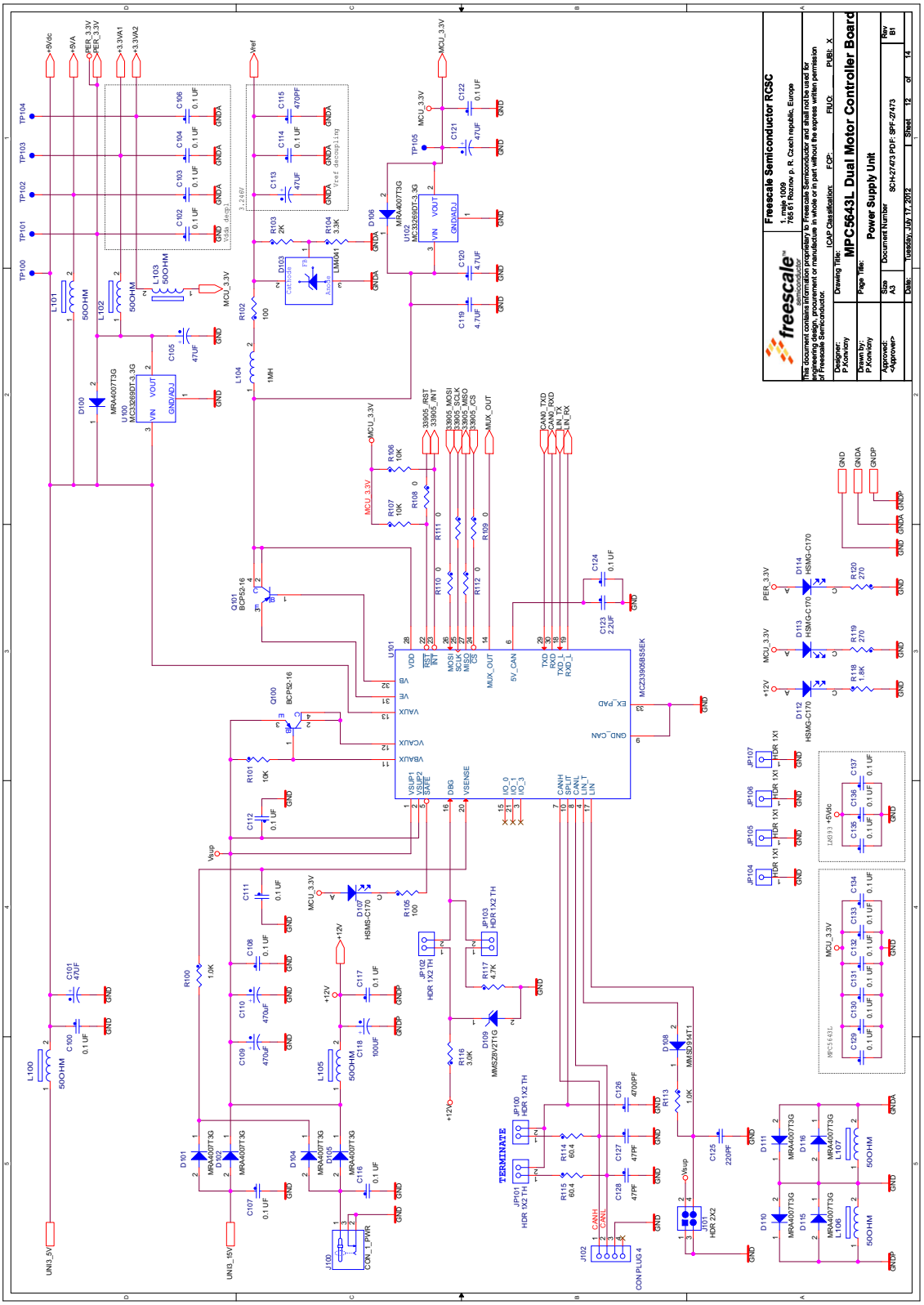


Figure 6-12. Power supply unit

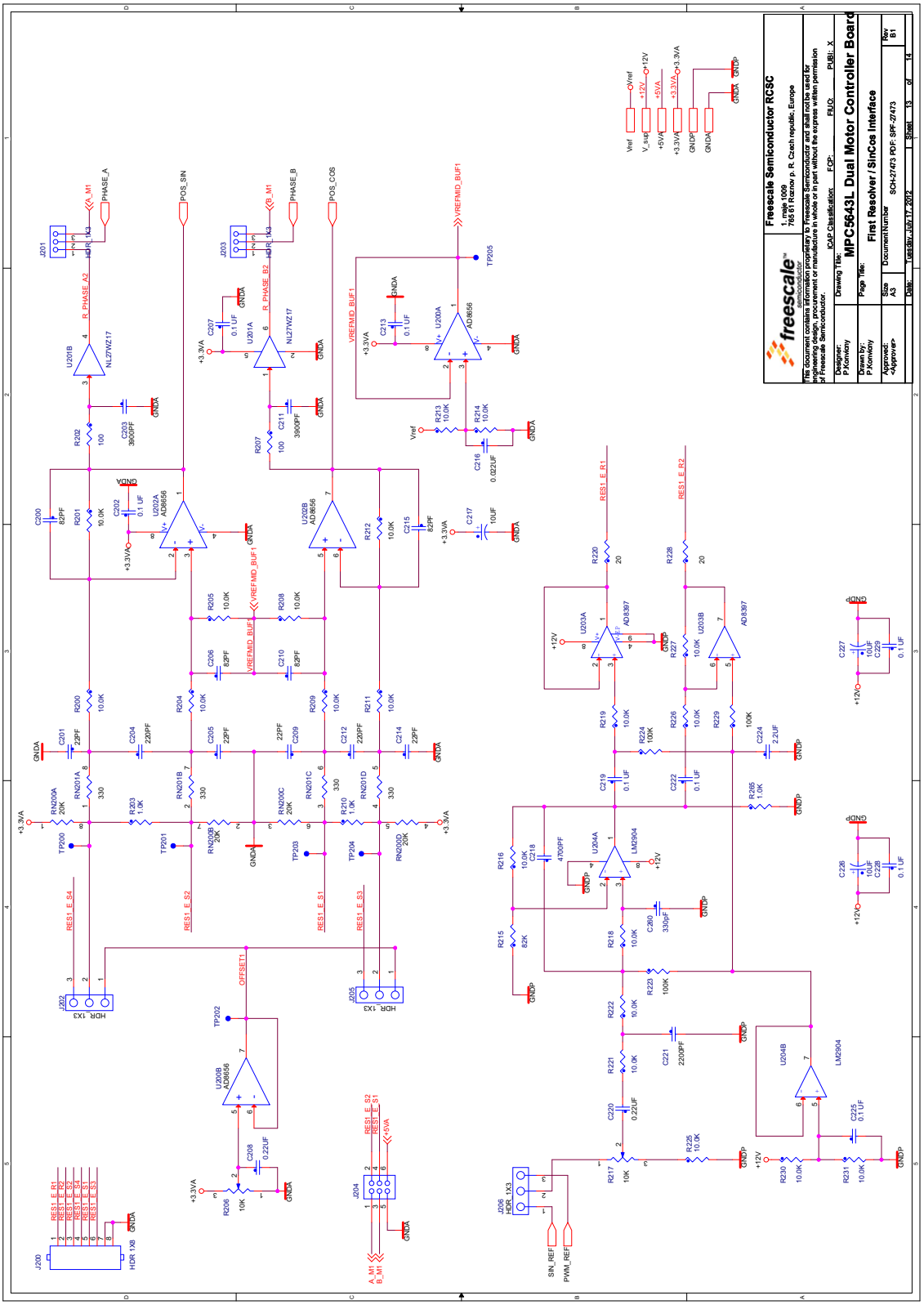


Figure 6-13. First resolver / SinCos interface

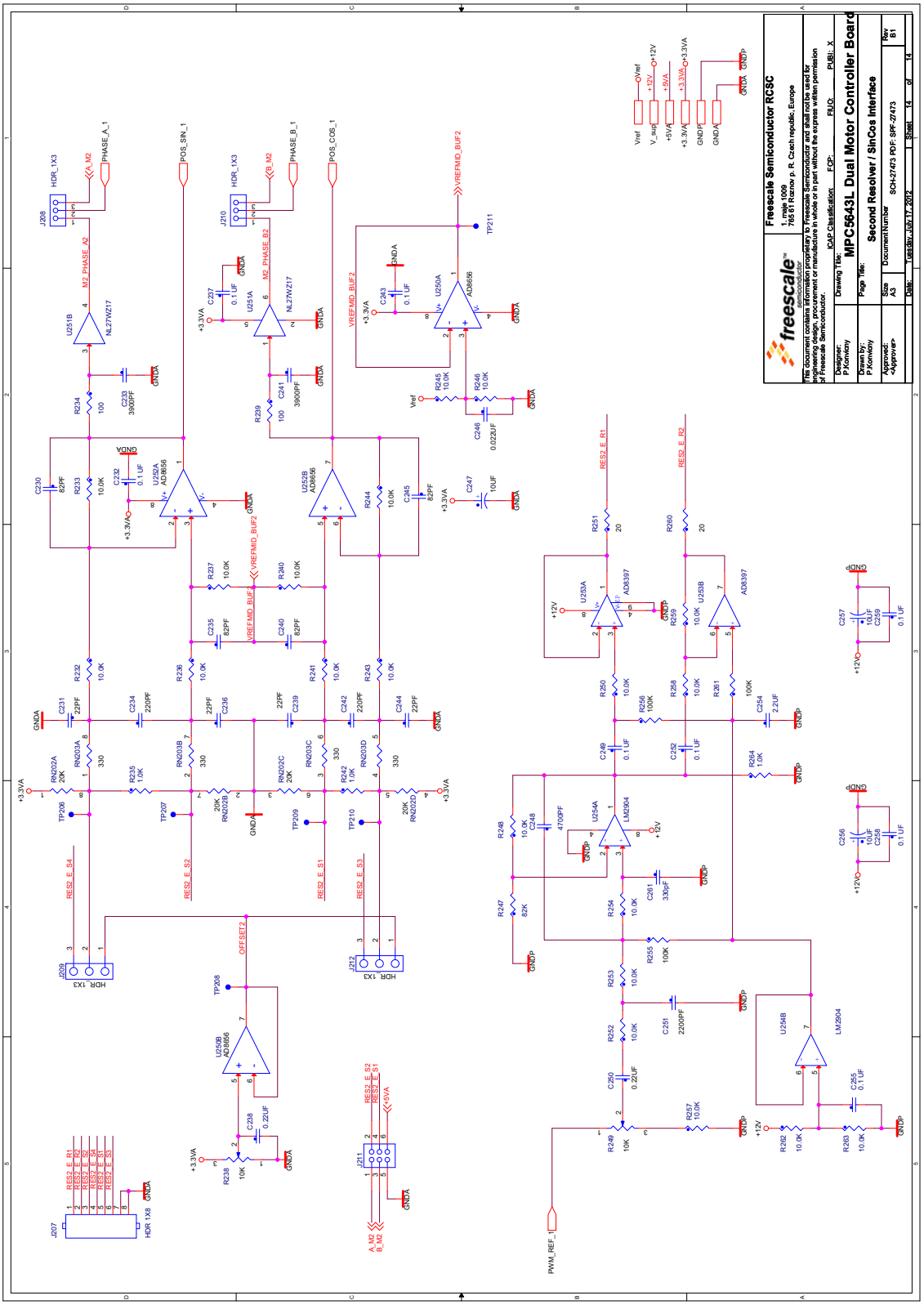


Figure 6-14. Second resolver / SinCos interface

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