A

Appendix A

Overview of NIRS-systems from research

Type	**Lock-In**	**TDM**	**# CH**	λ **[nm]**	**LS Type**	**DET Type**	**d [cm]**	**Portable**	**Wireless**	**Attachment**	**ADC**	**Ref.**
CW	No	Yes	32	735 850	32 LED	1 APD	4	Yes	No	neoprene hood	20 Hz 16 Bit	Lareau 2011 [38]
CW	Yes	No	22	754 830	8 LD	8 APD	3	Yes	No	600g headset		Kiguchi 2012 [48]
CW	Yes	Yes		760 850	8 LED	8 PD	..3..	Yes	No	EEG-Cap	6.25 Hz	Piper 2013 [49]
CW	No	Yes	32+	760 850	32 LED	4 PD	2/4	No	Yes	EEG-NIRS-plastic chain	8 Hz 16 Bit	Safaie 2013 [15]
CW	No		16	730 805 850	4 LED	10 PD	2.5	No	No	Flex. PCB with cushioning	2 Hz	Bunce 2006 [14]
CW	Yes		1	670 890	1 LED	1 APD	3	No	No	Flex. Strap	250 Hz	Bauernfeind 2008 [50]
CW	Yes		288	780 830	18 LD	16 PD	4-8	No	No		0.25 Hz 16 Bit	Siegel 1999 [44]
CW	No	Yes	3	780 810 830	3 LD	1 PD						Benni 1995 [32]

Table A.1: NIRS-Systems overview (I): CW = Continuous Wave, TD = Time Domain, FD = Frequency Domain, TDM = Time-Division Multiplex, # CH = Number of Channels, LS Type = Light Source Type: LED = Laser Emitting Diode, LD = Laser Diode, VCEL = Vertical-cavity surface-emitting laser, DET Type = Detector Type: APD = Avalanche Photodiode, PD = Silicium Photodiode, PMT = Photo Multiplier Tube, PIN = Positive intrinsic negative photodiode, d = source - detector distance: ..x.. variable, ADC = Sampling rate and quantization depth.

Type	**Lock-In**	**TDM**	**# CH**	**λ [nm]**	**LS Type**	**DET Type**	**d [cm]**	**Portable**	**Wireless**	**Attachment**	**ADC**	**Ref.**
FD	Yes		3	775 810 850 905	1 LD	3 PMT	5	No	No			Rolfe 2000 [30]
FD	Yes		2	780 850	2 LD	1 PIN		No	No			Rolfe 2001 [51]
CW			56	780 880	48 LED	14 PD	..1..	No	No	Flex. PCB with cushioning	3 Hz	Vaithianathan 2004 [58]
CW	Yes	Yes	22	790 850	16 VCEL	8 PD	3	Yes	No			Atsumori 2007 [52]
CW	Yes			700 880	LED	APD	3-4	No	No		100 Hz 16 Bit	Coyle 2004 [18]
CW				735 850	LED	8 PD	3	Yes	Yes			Chang 2011 [56]
CW	No	Yes	2	730 850	1 LED	2 PD	2	Yes	No	Flexible PCB with sticky tape	10 Hz 12 Bit	Bozkurt 2005 [53]
CW	Yes			760 880	LED	APD	3-4	No	No	Seat fixation	100 Hz 16 Bit	Coyle 2007 [20]
CW	No			778 813 867 904	LD	PMT		No	No			Cope 1988, 1991[3], [21]
CW	No	Yes	1	730 804 850	LED	PD	3,5	Yes	No	Velco straps	23 Hz 18 Bit	Chenier 2007 [54]
CW			16		8 LED	2 PD	1 + 0.5x	Yes	No	embedded silicon patch	2 Hz 16 Bit	Rajkumar 2012 [59]
CW	Yes	Yes	32+	785 830	32 LD	32 APD		No	No			Boas 2001 [45]
CW	Yes		12	760 880	24 LED	3 APD	3	No	No		10 Hz 24 Bit	Soraghan 2008 [19]
CW		Yes		760 850	LED	PD		Yes	No		40 Hz	Zhang 2009 [55]

Table A.2: NIRS-Systems overview (II): CW = Continuous Wave, TD = Time Domain, FD = Frequency Domain, TDM = Time-Division Multiplex, # CH = Number of Channels, LS Type = Light Source Type: LED = Laser Emitting Diode, LD = Laser Diode, VCEL = Vertical-cavity surface-emitting laser, DET Type = Detector Type: APD = Avalanche Photodiode, PD = Silicium Photodiode, PMT = Photo Multiplier Tube, PIN = Positive intrinsic negative photodiode, d = source - detector distance: ..x.. variable, ADC = Sampling rate and quantization depth.

	Device	(Manufacturer), country	Time-res. [Hz]	#Emitter	#Detector	MUX	SDS [mm]	E-tech	Wavelengths [nm]	D-tech	Data	Wear	CE
D1	OXYMON MkIII[a]	(Artinis), Netherlands	250	32	16	t	a	Laser	760, 850*	APD	Raw	n	y
D2	PortaLite	(Artinis), Netherlands	50	3	1	t	20 + 25 / 30 + 35 + 40	LED	760, 850*	PD	Raw	y	y
D3	fNIR1100	(fNIR Devices), USA	2	1/1/4	2/4/10	t	20/25/25	LED	730, 850		Hb	n	n
D4	fNIR1100w	(fNIR Devices), USA	2	1	2/4	t	20/25	LED	730, 850		Hb	y	n
D5	ETG-4000	(Hitachi), Japan	10	18	8	f	20/30	Laser	695, 830	APD	Raw	n	y
D6	ETG-7100	(Hitachi), Japan	10	40	40	f	20/30	Laser	695, 830	APD	Raw	n	y
D7	WOT[b]	(Hitachi), Japan	5	8	8	t + f	30	Laser	705, 830	PD	Raw	y	n*
D8	Genie	(MRRA), USA	5.02	4 to16	8 to 32	c	a	LED	700, 830	PD	Raw	y	n
D9	NIRScout	(NIRx), USA	6.25 to 62.5	8 or 16	4 to 24	t + f	a	LED	760, 850	PD	Raw	n	y
D10	NIRScoutX	(NIRx), USA	6.25 to 62.5	48	32	t + f	a	LED	760, 850	PD	Raw	n	y
D11	NIRSport	(NIRx), USA	6.25 to 62.5	8	8	t + f	a	LED	760, 850	PD	Raw	y	y
D12	Brainsight NIRS	(Rogue Research), Canada	100	4 to16	8 to 32	f	a	Laser	685, 830, (808)*	APD	Raw	n	n*
D13	FOIRE-3000	(Shimadzu), Japan	7.5 to 40	4 to 16	4 to 16	t	a	Laser	780, 805, 830	PMT	OD	n	n
D14	OEG-SpO2	(Spectratech), Japan	1.52/12.2	6	6	c	30/25/15–40	LED	770, 840	PD	Raw	y*	n*
D15	CW6	(TechEn), USA	10 to 50	4 to 48	8 to 32	f	a	Laser	690, 830*	APD	Raw	n	y
D16	UCL Optical Topography System[c]	(University College London), UK	10 to 160	16	16	f	a	Laser	780, 850	APD	Raw	n	n
D17	Imagent	(ISS), USA	16 to 60	16 or 32	4 or 8	t	a	Laser	690, 830	PMT	Raw	n	y

[a] van der Sluijs et al. (1998).
[b] Atsumori et al. (2009).
[c] Everdell et al. (2005).

Figure A.1: Overview of commercial NIRS-Devices, taken from [11].

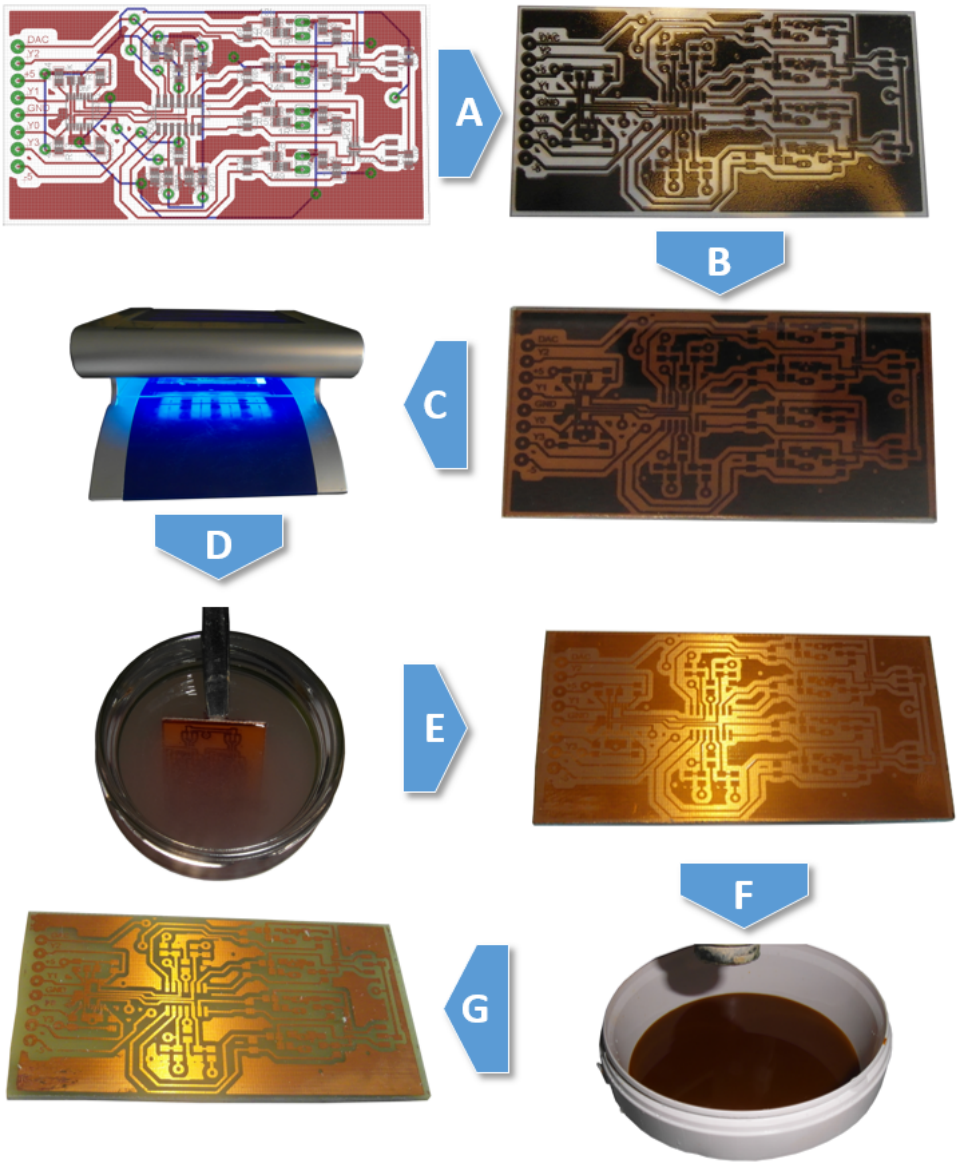

Figure A.2: PCB prototyping process. A: printing layout on plastic film, B: covering copper PCB, C: UV-light exposure, D: etching in diluted sodium hydroxide, E: exposed UV-lacquer is removed, F: etching in iron (III) chloride solution, G: removing lacquer with ethanol and drilling vias.

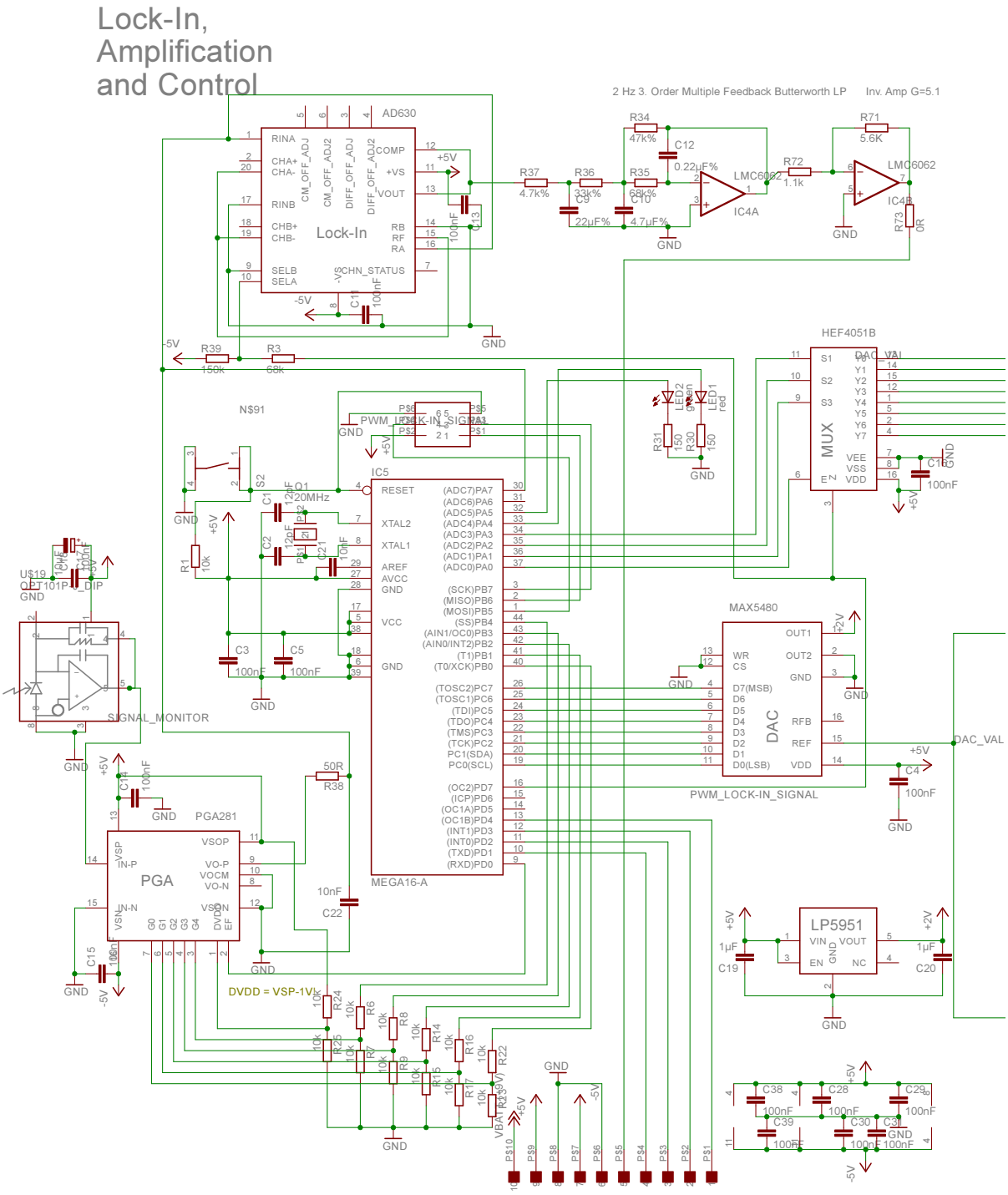

Figure A.3: fNIRS module full schematics part a.

Author	**>650**	**>675**	**>700**	**>725**	**>750**	**>775**	**>800**	**>825**	**>850**	**>875**	**>900**
Piper2013 [49]					760				850		
Safaie2013 [15]					760				850		
Kiguchi2012 [48]					754			830			
Chang2011 [56]				735					850		
Lareau2011 [38]				735					850		
Kanoh2009 [62]						780		830			
Zhang2009 [55]					760				850		
Bauernfeind2008 [50]	670									890	
Soraghan2008 [19]					760					880	
Kawaguchi2008		680						830			
Atsumori2007 [52]						790			850		
Coyle2007 [20]						760				880	
Chenier2007 [54]				730					850		
Bunce2006 [14]				730					850		
Bozkurt2005 [53]				730					850		
Vaithianathan2004 [58]						780				880	
Coyle2004 [18]			700							880	
Sato2004 [69]		680						830			
Strangman2003 [66]					760			830			
Rolfe2001 [51]						780			850		
Boas2001 [45]						785		830			
Yamashita2001 [68]	660							830			
Rolfe2000 [30]					775				850		
Siegel1999 [44]						780		830			
Benni1995 [32]						780		830			
Cope1991 [21]						778			867		
Okui2005 [70]		690	...	...	750			830			
Funane2009		690	...	...	..775			825..	...	...	900
Correia2010 [72]			704							887	
Yamashita2001 [68]	...	...	...	...	...	780		830			
OXYMON Mk III, Artinis					760				850		
PortaLite, Artinis					760				850		
fNIR1100, fNIR Devices				730					850		
ETG-4000, Hitachi		695							850		
ETG-7100, Hitachi		695							850		
WOT, Hitachi			705					830			
Genie, MRRA			700					830			
NIRScout(X), NIRx					760				850		
Brainsight NIRS, R. Research		685						830			
FOIRE-3000, Shimadzu						780		830			
OEG-SpO2, Spectratech					770			840			
CW6, TechEn		690						830			
UCL Optical Topography, UCL						780			850		
Imagent, ISS		690						830			
	>650	**>675**	**>700**	**>725**	**>750**	**>775**	**>800**	**>825**	**>850**	**>875**	**>900**

Table A.3: Overview of wavelength pairs and selection optimization in fNIRS systems.

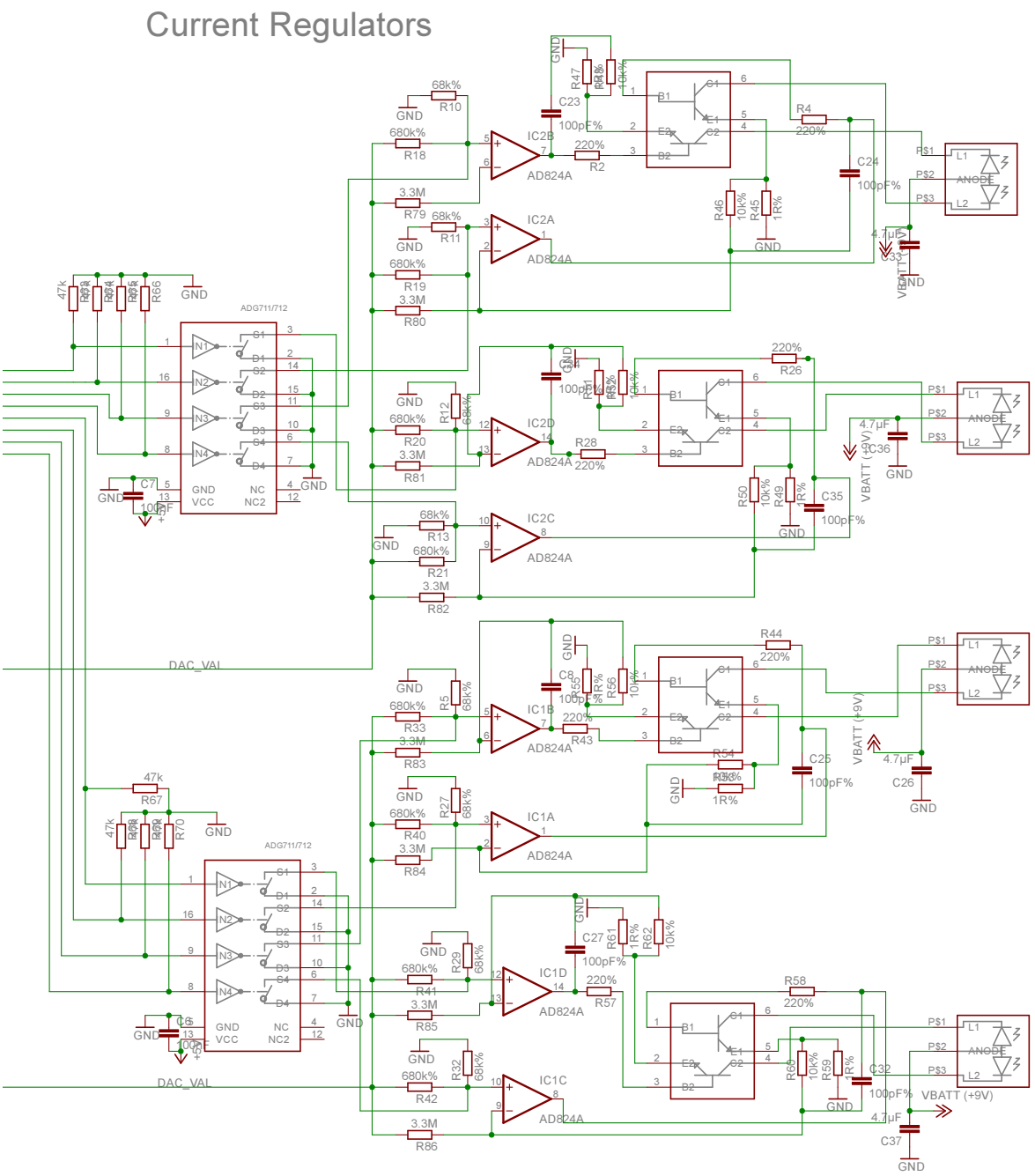

Figure A.4: fNIRS module full schematics part b.

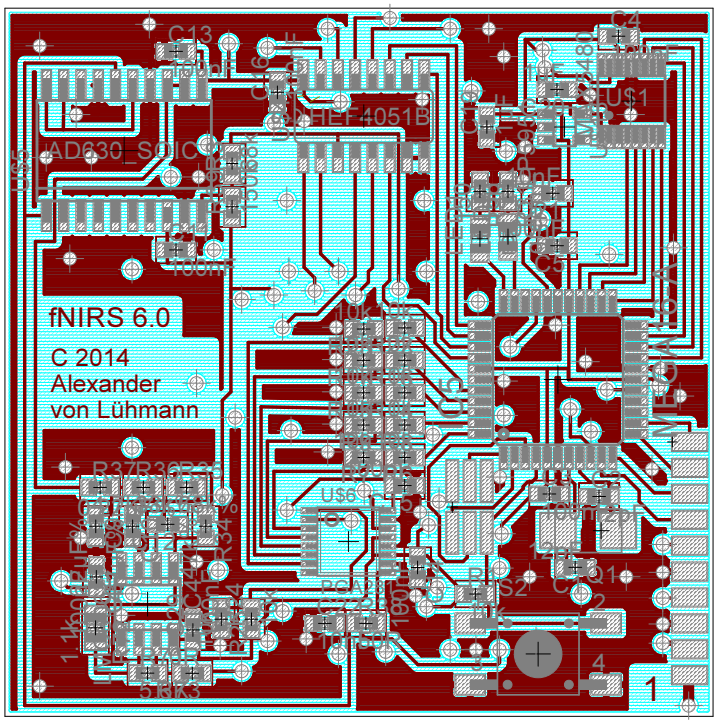

Figure A.5: fNIRS module layout, layers 1 & 2 (top).

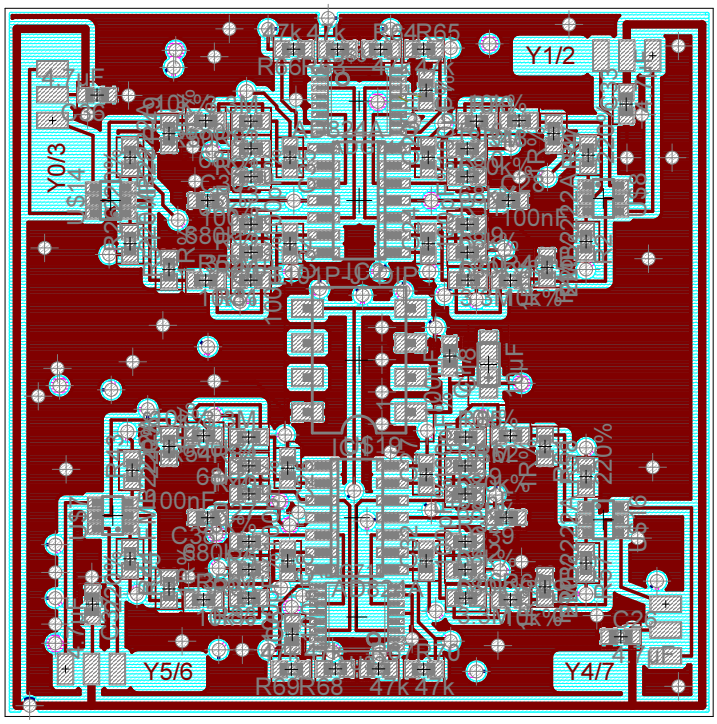

Figure A.6: fNIRS module layout, layers 3 & 4 (bottom).

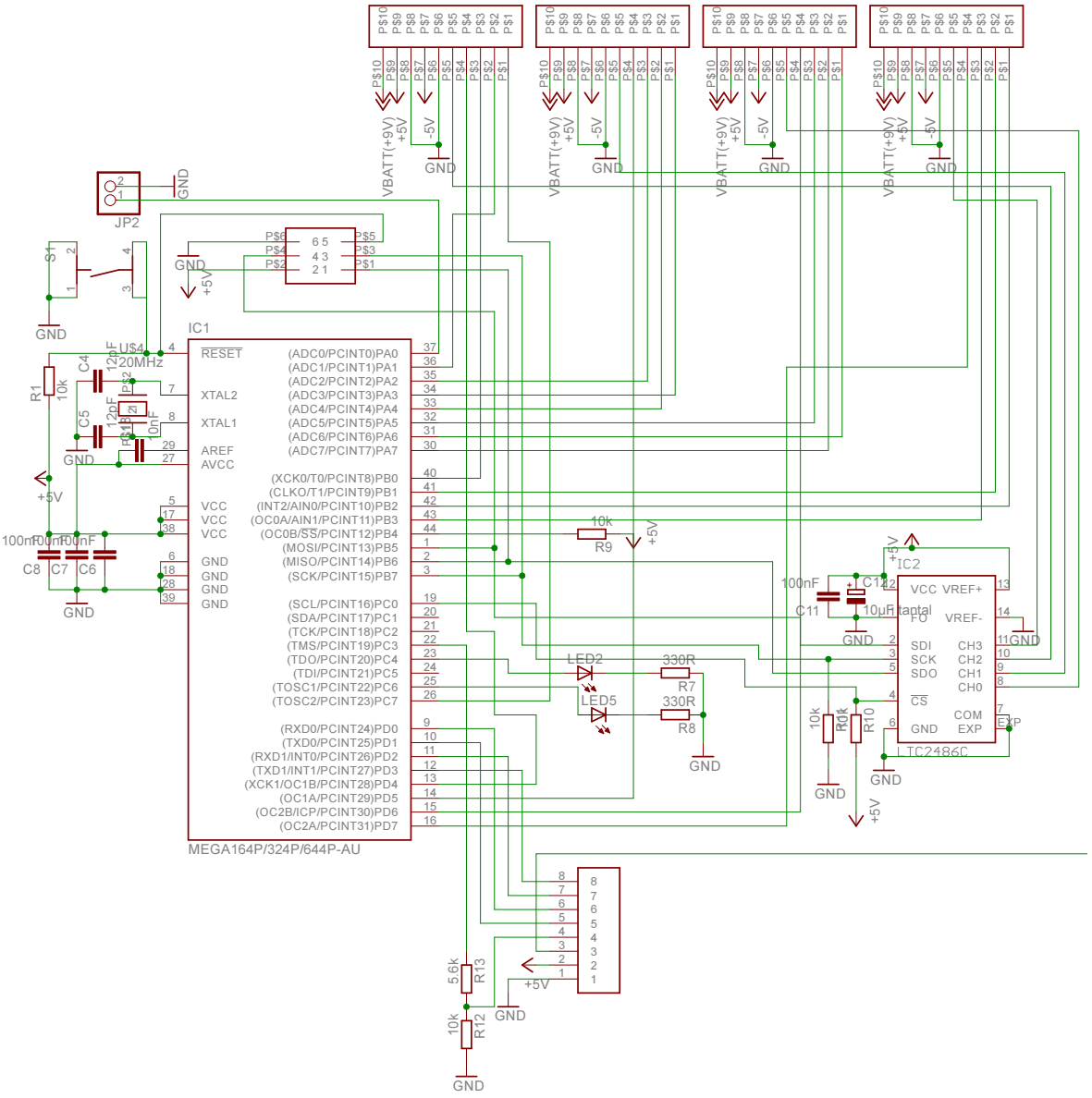

Figure A.7: fNIRS mainboard full schematics part a.

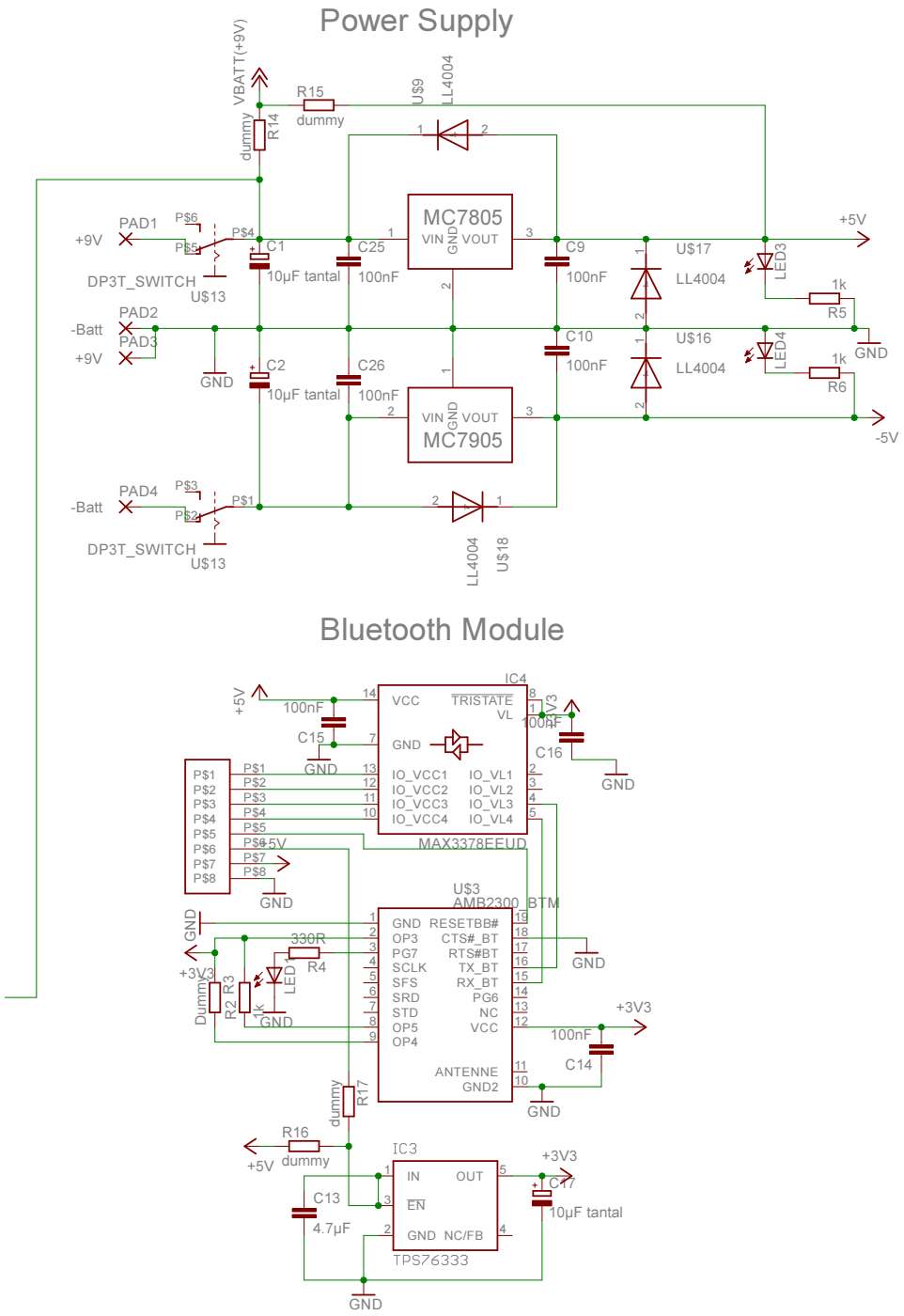

Figure A.8: fNIRS mainboard full schematics part b.

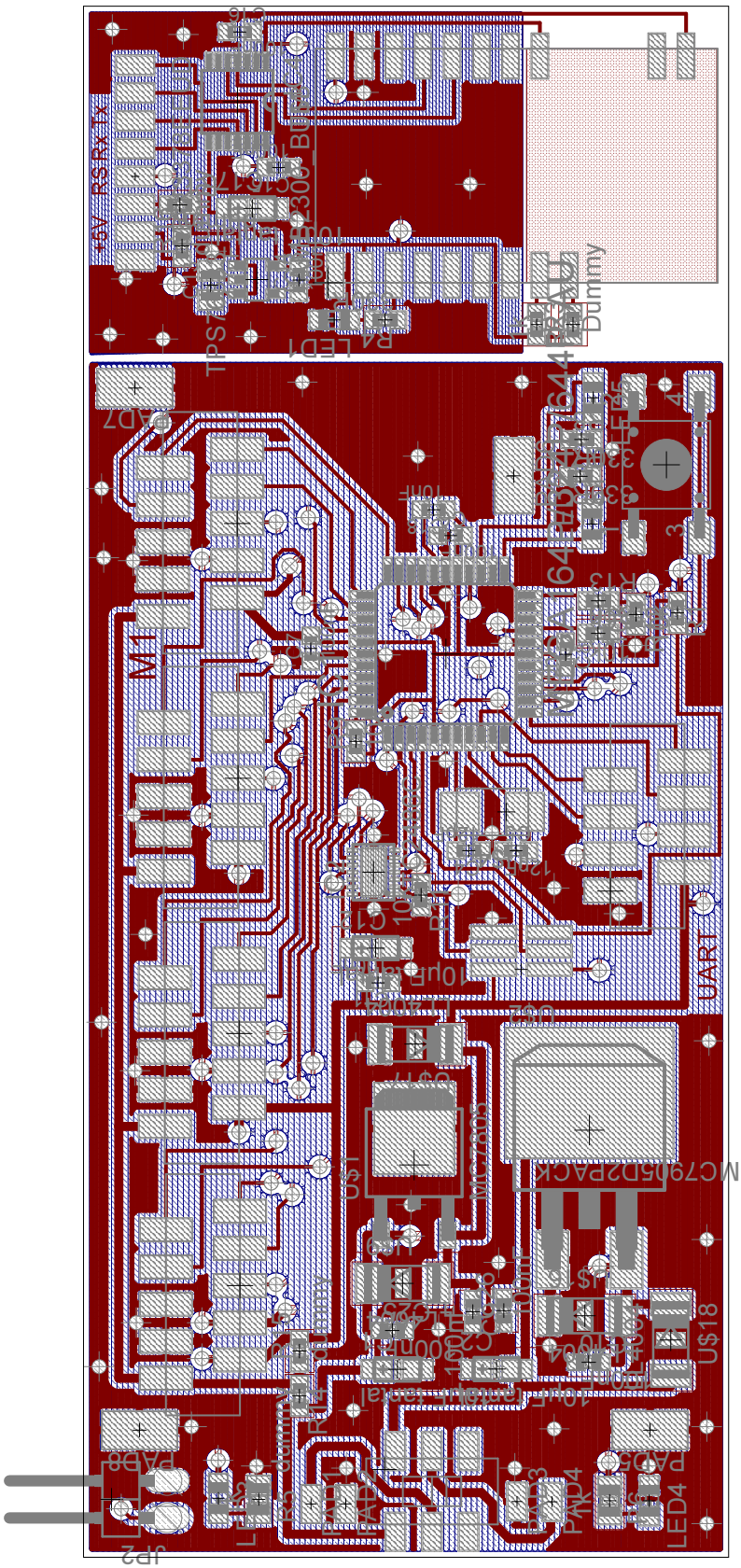

Figure A.9: fNIRS mainboard layout.

Model	Wave-lengths λ1	λ2	Max I_F [mA]		Max pulse I_p [mA]		Typ. Total rad. Power [mW]		Half width Δλ [nm]		View. Half angle [deg]	Type [mm]
L760/850-04A	760	850	100	100			15	18	30	35	+-20	5 Mold
L760/850-38	760	850	75	75			16	18	30	35	+-40	3 Mold
L770/840-40D59	770	840	100	100	500	500	12	9	28	32	+-55	4.65 Stem
SMT735/850	735	850	75	75	300	300	10	18	20	35	+-55	2.7 SMD
L750/850-04A	750	850	100	100			15	18	30	35	+-20	5 Mold
L760/840-05A	760	840	100	100			15	18	30	35	+-40	5.4 Stem
L760/850-05A	760	850	100	100			15	18	30	35	+-40	5.4 Mold

Figure A.10: Comparison of available LED alternatives.

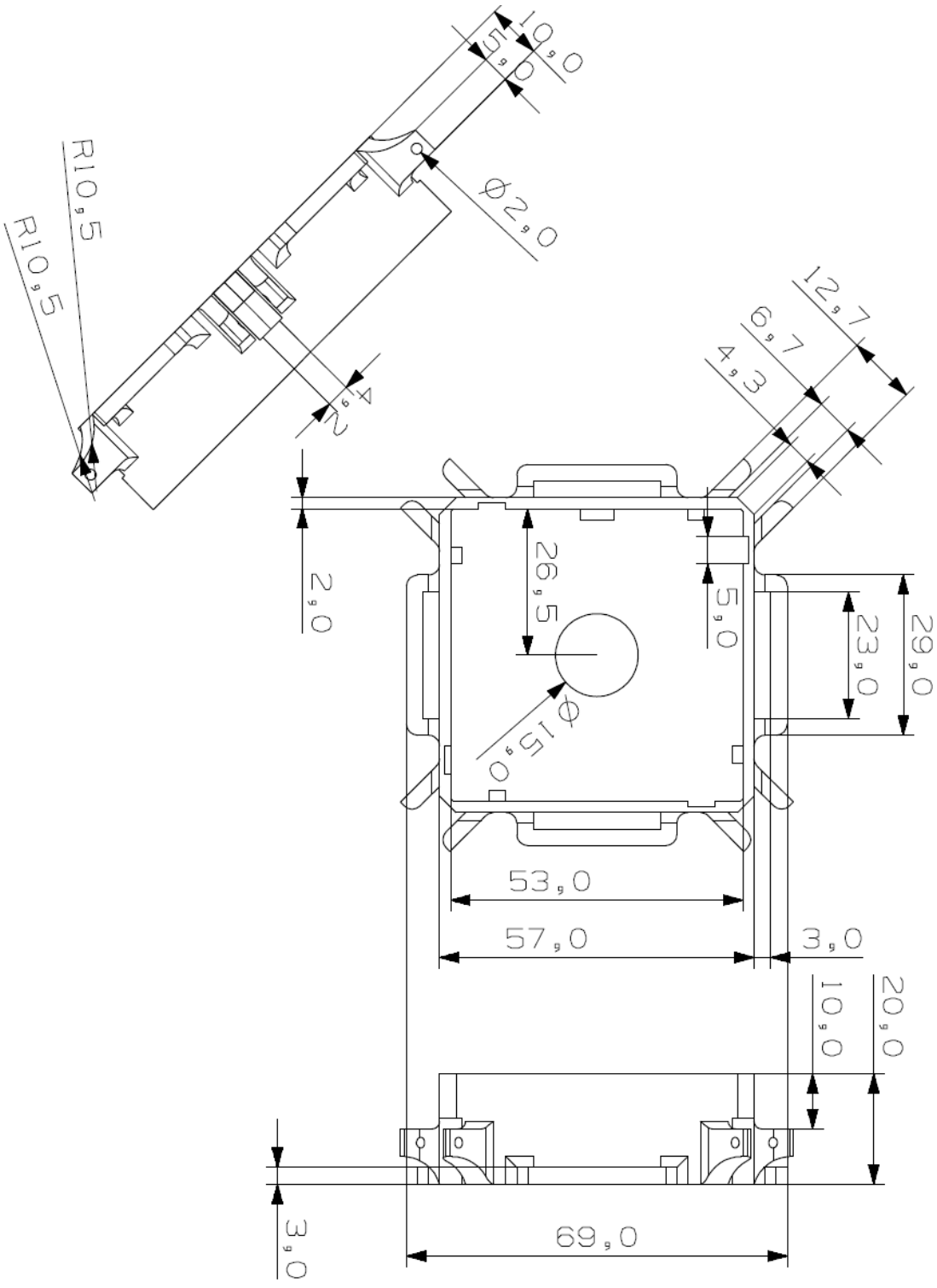

Figure A.11: Technical drawing NIRS module body housing. Units are [mm].

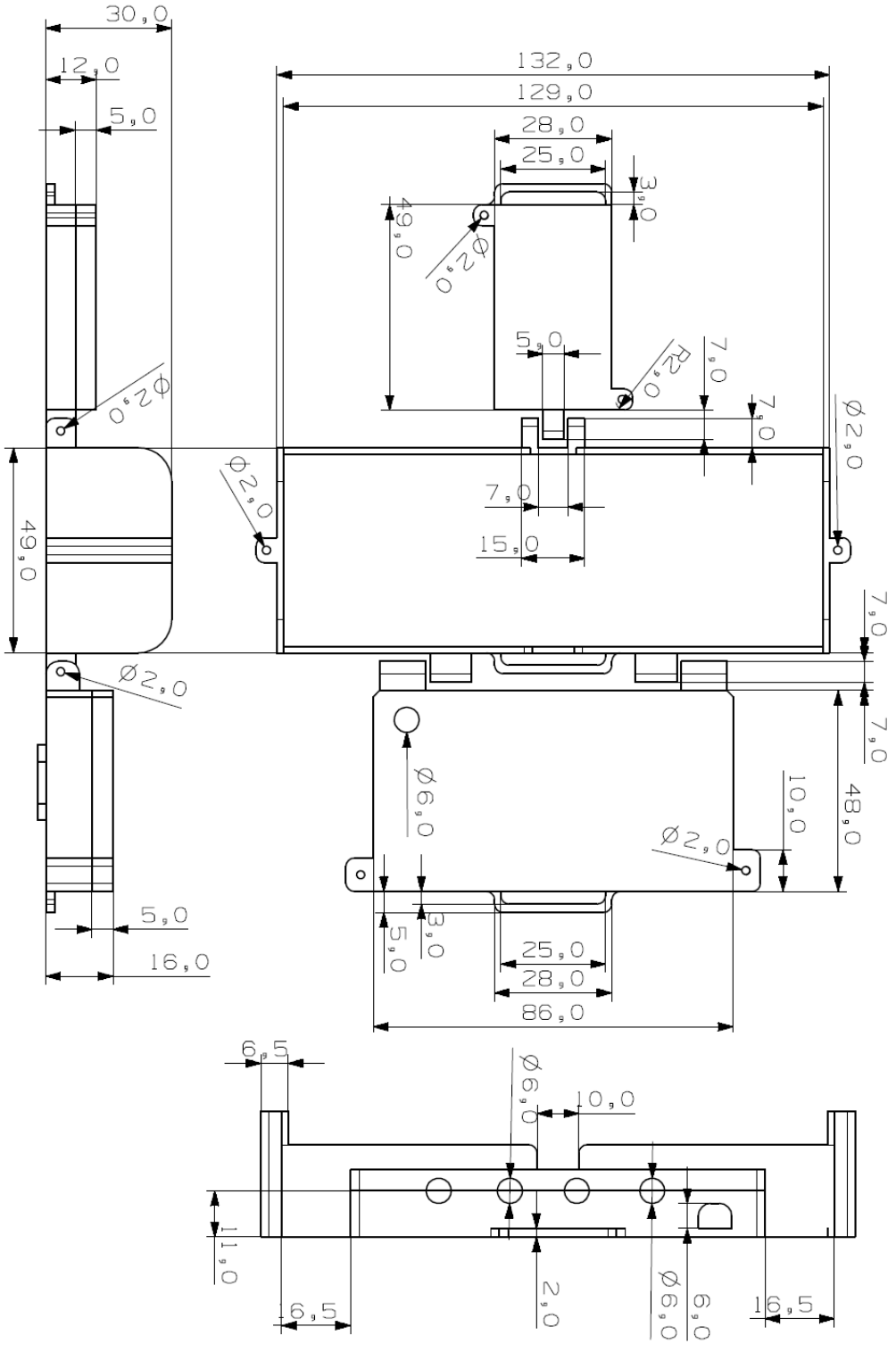

Figure A.12: Technical drawing NIRS mainboard body housings. Units are [mm].

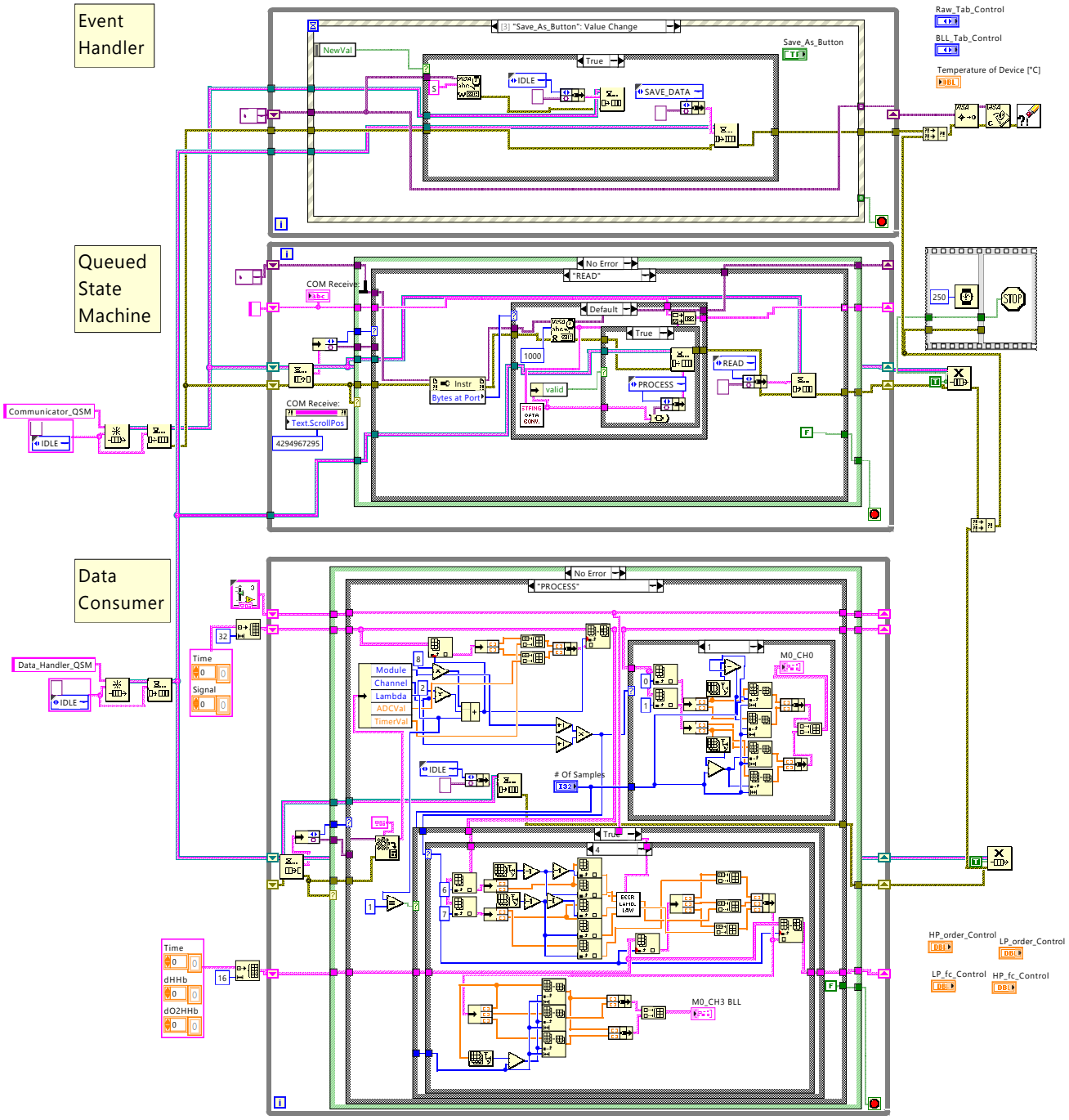

Figure A.13: LabView eQSM block diagram overview.

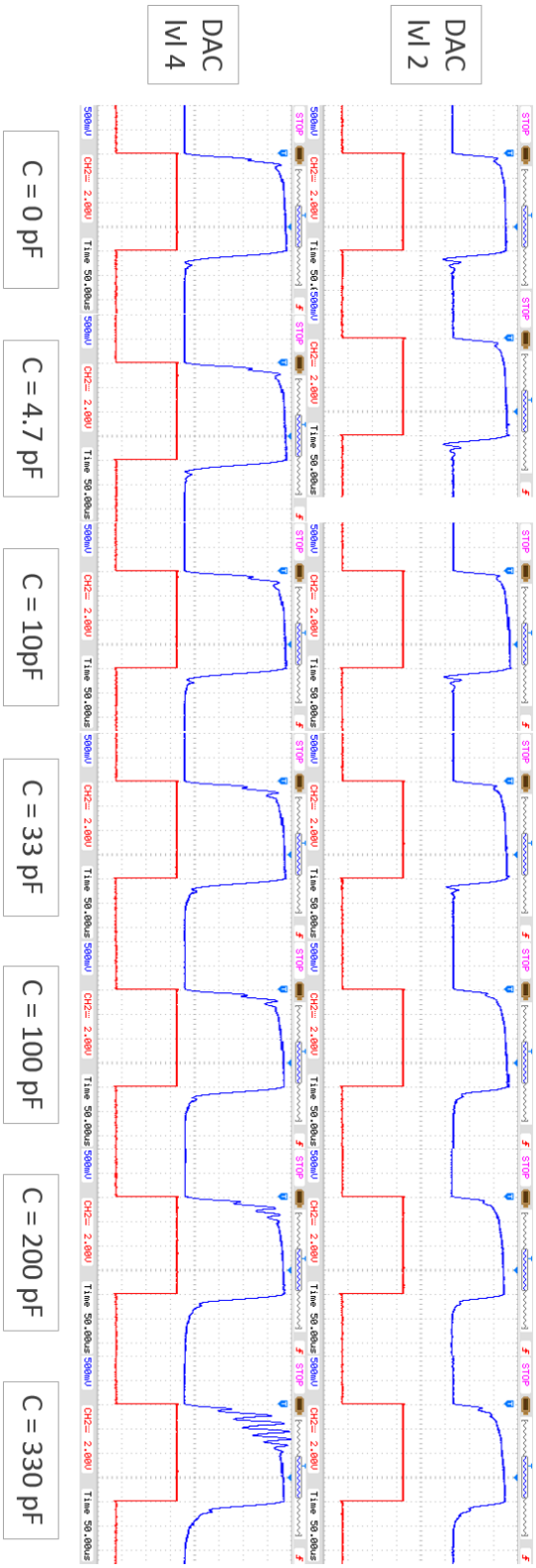

Figure A.14: Evaluation of optimal current regulator decoupling capacitor value.