Design specifications

Revision 299

Table of Contents

1 Document history

This document has been written by Resologis, Canada for OpenTekhnia, France.

2 Introduction

This document contains all the specifications of the Tio systems.

3 General specifications

3.1 Supply

The Tio rack is supplied via the CPU board.

The following table indicate the supply specifications of the Tio system.

	Nominal	Min	Max
V_{DC} (V)	24	12	30
I (A)	-	1	6*

* Depend on the number of Expansion card installed

3.2 Stacking

The Tio rack may have up to 16 expansion card.

3.3 Dimensions

Each board of the Tio system is 10cm x 15cm. All the connectors are located on only one of the two 15cm side of the card. This is the front side of the card.

4 IO Overview

- GPI (General Purpose Input)
- GPO (General Purpose Output)
- AI (Analog Input)
- AO (Analog Output)
- DDS Output (FSK, BPSK, PSK, chirp, AM operation)
- COMPORTS (Serial port RS232 ou RS485)

5 IO Specifications

5.1 Analog IO

5.1.1 DDS Output (FSK, BPSK, PSK, chirp, AM operation) (I & Q outputs)

- 80 dB SFDR at 100 MHz (±1 MHz)
- 200MSPS
- Resolution : 12 bits
- Impedance : 50ohms
- Power out : 10dBm
- Connector type : SMA
- High speed comparator output (VINN,VINP,VOUT)
- DDS IC: AD9850
- Output amplifier IC : LM7171

5.1.2 Analog Input

- Input voltage (+/- 10V or +/-5V) soft configurable2
- Resolution : 16 bits → (0.0015% resolution)
- 1KHz sampling rate with CPU card
- Up to 200 kSPS on all channel internally within FPGA

5.1.3 Analog Output

- Output voltage (+/-10V or +/-5V or 0-10V or 0-5V) soft configurable
- Current output (0-20mA, 4-20mA) soft configurable
- Resolution : 16 bits → (0.0015% resolution)
- 1KHz sampling rate with CPU card
- Up to 200KHz update rate internally within FPGA

5.2 Digital IO

5.2.1 General Purpose Output (GPO)

- Output signal voltage from 10VDC to 30 VDC (Vss to Vdd)
- Output type : Push-pull
- Current out : 400mA
- Logic low : < Vss + 0.7V
- Logic high : Vdd - 0.7V
- Isolated from control circuit, up to 1000V
- Need external supply : Vss, Vdd
- Max frequency : 25kHz

5.2.2 Genera Purpose Input (GPI)

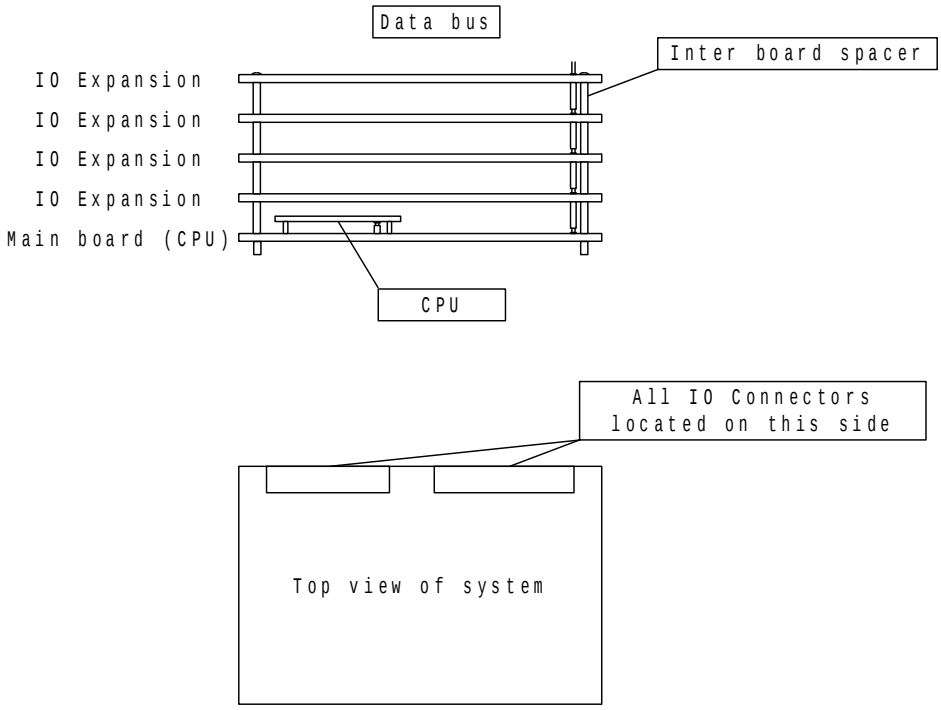
- Logic low : < Vss + 0.7 VDC
- Logic high : > Vdd + 3 VDC
- Input current : 0.5mA
- Maximum input voltage : 24V
- Isolated from control circuit up to 1000V
- Internal pull-up resistor
- Need external supply : Vss, Vdd

5.2.3 RS232/RS485 Com Port

- RS232 / RS485 (jumper selectable)
- Full duplex
- 120 Ohms impedance for RS485
- Up to 1Mbit/s
- Male DB9 connector

6 Board description

6.1 Physical stacking



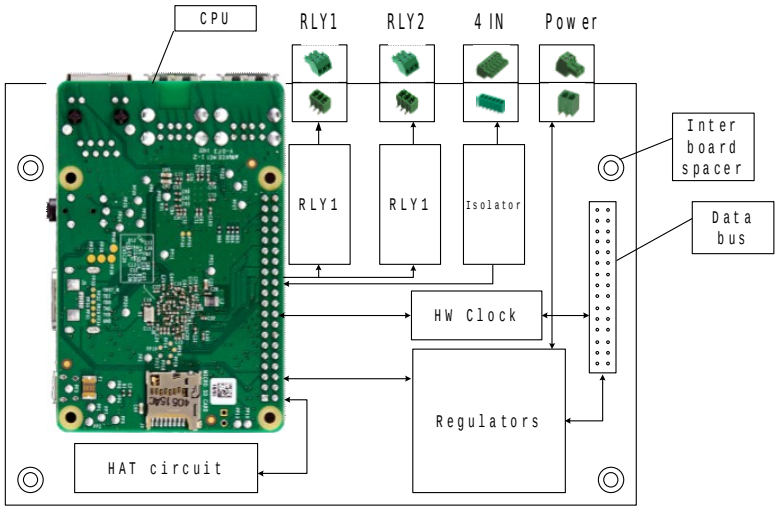
7 Board lists

The Tio system is designed to be expansible and may contains up to 16 expansion cards.

Here is the list of the boards actually designed/supported by the Tio system.

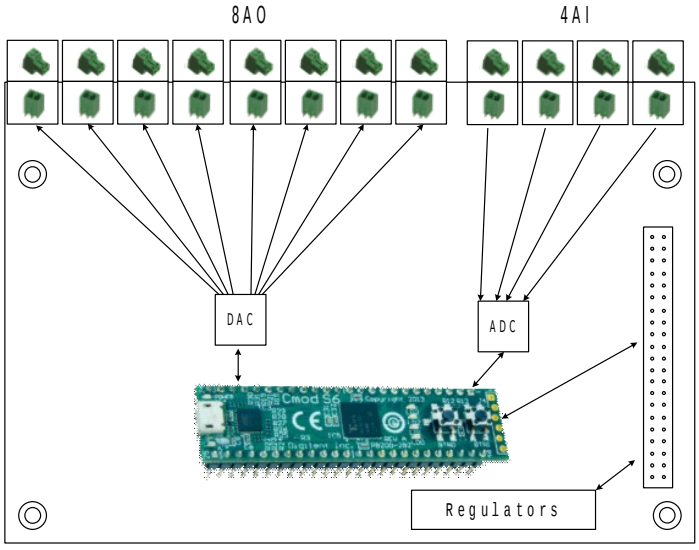
7.1 CPU

- 2 Relay out
- 4 Isolated inputs
- Main supply input
- Est price = 100$



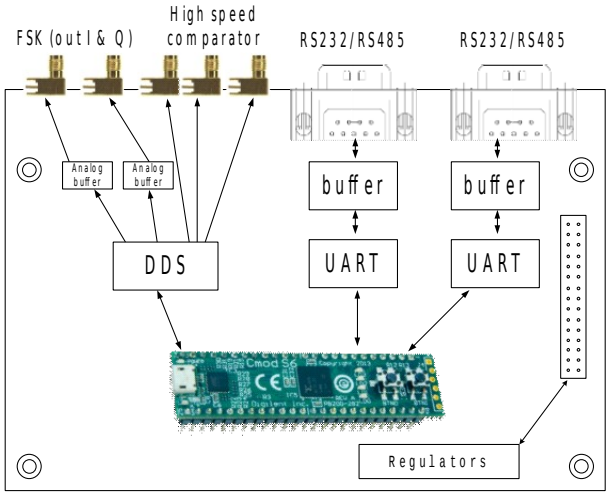
7.2 AIO

- 4 AI
- 8 AO
- FPGA control
- EST Price = 233$



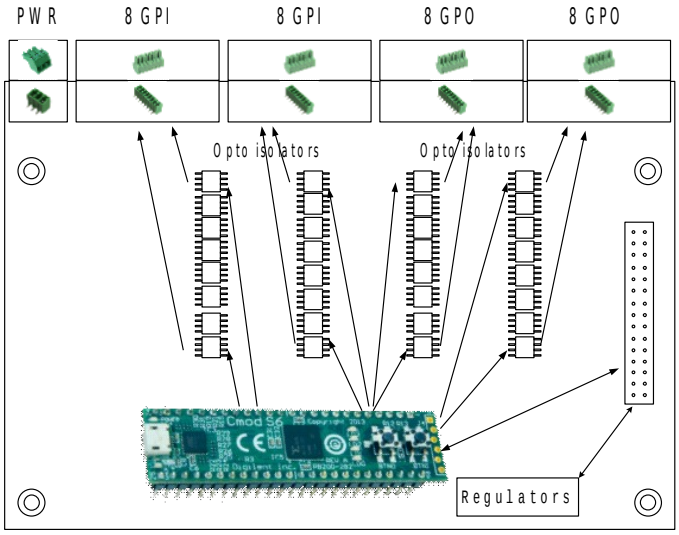
7.3 FSK - COM

- 2 Comport
- 2 FSK Out (I & Q)
- High speed comparator (2IN, 1OUT)
- FPGA control
- EST cost price = 182$



7.4 32 GPIO Expansion

- 16 GPI
- 16 GPO
- FPGA control
- Est cost price : 166$



8 Card interconnect

8.1 Specifications

The databus is not compatible to any bus on the market, and is intended to be used only with compatible Tio cards.

The communication are over a SPI bus. Each board have it's own chip_select line, which goes to the CPU board.

Each board type may have it's own protocol implementation. The protocol implementation is defined for each board in it's section.

8.2 Connector pinout

Supply+	1	2	Supply+
GND	3	4	GND
+5V	5	6	+5V
GND	7	8	GND
Reset	9	10	Fault (open-collector)
Sync Reset	11	12	Sync clock (1kHz)
GND	13	14	GND
GND	15	16	CLK
MOSI	17	18	GND
MISO	19	20	SCK
CS1	21	22	CS2
CS3	23	24	CS4
CS5	25	26	CS6
CS7	27	28	CS8
CSMUX0	29	30	CSMUX1
CSMUX2	31	32	SPARE1
SPARE2	33	34	SPARE3
SPARE4	35	36	SPARE5
SPARE6	37	38	SPARE7
SPARE8	39	40	SPARE9
SPARE10	41	42	SPARE11
SPARE12	43	44	SPARE13
GND	45	46	GND
SPARE14	47	48	SPARE15
GND	49	50	GND

8.3 Pins description

9 API (communication protocol)

9.1 General specifications

SPI mode = 0 (CPOL = 0, CPHA = 0)

SPI max frquency : 8Mhz

9.2 Packet structure

The first byte sent of each packet determine the command.

The first byte received correspond to the status register of the card.

9.3 Status register

The status register show the state of the card, and is also useful to valid the SPI communication.

Bit number	Description
Bit [0:3]	Constant ID
Bit [4]	Reset indicator
Bit [5]	Alive indicator
Bit [6]	Last command invalid
Bit [7]	Last command incomplete

9.3.1 Constant ID

The constant ID may be used to check if the communication with the TIO card is correct. The value of the ID is always “0x05”, which means that bits 0 and 2 are high and bit 1 and 4 are low.

9.3.2 Reset indicator

This bit indicate if the card have been reset correctly since the power up of the system.

Bit value	Description
0	Card need to be reset
1	Card have been reset and ready to run

9.3.3 Alive indicator

The alive indicator is used to determine if the card is alive. The value of this bit toggle at each time a valid command is received.

9.3.4 Last command invalid

This bit is set when an invalid command for the card is received. (This include the common command and the specifics commands).

The bit clear itself when a valid command is received.

9.3.5 Last command incomplete

This bit is set when an incomplete command is received. (Insufficient number of byte sent).

The bit clear itself when a valid command is received.

9.4 Card ID

Each card type have a specific ID. Here is the list of the ID of the currently supported card by the TIO system

ID	Card
0	Invalid value
1	AIO

9.5 Common commands to all cards

9.5.1 Read card ID (0x00)

Purpose :

Read the card ID and version of the card

Description :

- Command value : 0x00
- Data size : 3 bytes

Command TX : [0x00] [0x00] [0x00] [0x00]

Command RX : [Status register] [ID] [Version major] [Version minor]

Status register : Refer to the status register section for the details

ID : ID of the card, refer to the Card ID section

Version major :Number before the dot of the firmware version ex : 1.2 will give 1

Version minor : Number after the dot of the firmware version ex 1.2 will give 2

9.5.2 Write config register (0x01)

Not implemented. Do not use.

9.5.3 LED control (0x02)

Purpose :

Control the led state on the FPGA module

Description :

- Command value : 0x02
- Data size : 1 byte

Command TX : [0x02] [Led values]

Command RX : [Status register] [0x00]

Status register : Refer to the status register section for the details

Led values : Bit mapping of the accessible user led on the card.

- LED1 correspond to bit 0
- LED2 correspond to bit 1
- LED3 correspond to bit 2

9.5.4 Read sync register (0x03)

Purpose :

Read the time sync counter in the FPGA

Description :

- Command value : 0x03
- Data size : 4 bytes

Command TX : [0x03] [0x00] [0x00][0x00][0x00]

Command RX :

[Status register]

[counter(31:24)]

[counter(23:16)]

[counter(15:8)]

[counter(7:0)]

Status register : Refer to the status register section for the details

Counter : The number of cycle of (1/1024) ms since sync reset occur

9.6 AIO Card specific commands

9.6.1 Write DAC at time (0x04)

Purpose :

Program a DAC write at a specific time

Description :

- Command value : 0x04
- Data size : 7 bytes

Command TX :

[0x04]
[time(31:24)] [time(23:16)] [time(15:8)] [time(7:0)]
[channel][Voltage MSB][Voltage LSB]

Command RX : [Status register] [0x00][0x00][0x00][0x00][0x00][0x00][0x00]

Status register : Refer to the status register section for the details

Time : 32 bits unsigned value, that correspond to the desired time to send the command.

Channel : Channel to control (0 to 3)

Voltage : 16 bits voltage value in 2 complement. The output range if -10V to +10V.

9.6.2 Read ADC at time (0x05)

Purpose :

Program a ADC conversion at a specific time

Description :

- Command value : 0x05
- Data size : 4 bytes

Command TX :

[0x05]

[time(31:24)] [time(23:16)] [time(15:8)] [time(7:0)]

Command RX : [Status register] [0x00][0x00][0x00][0x00]

Status register : Refer to the status register section for the details

Time : 32 bits unsigned value, that correspond to the desired time to send the command.

Channel : Channel to control (0 to 3)

Voltage : 16 bits voltage value in 2 complement. The output range is -10V to +10V.

9.6.3 Read ADC results (0x06)

Purpose :

Read the last Adc conversion result

Description :

- Command value : 0x06
- Data size : 17 bytes

Command TX : [0x06] [0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00]

Command RX : [Status register] [conversion status][CH1 MSB][CH1 LSB].....[CH8 MSB][CH8 LSB]

Status register : Refer to the status register section for the details

Conversion status : Bit 0 tell if the conversion is completed or not. Logic high indicate that the last conversion is done. The bit is cleared when readed.

CH1 to 8 : 16 bits voltage value in 2 complement. The input range is -10V to +10V.

9.6.4 Read ADC NOWs (0x07)

Purpose :

Read the Adc now and output conversion result

Description :

- Command value : 0x07
- Data size : 33 bytes

Command TX : [0x07] [0x00]

Command RX : [Status register] [cmd_status][busy_status] [0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00][0x00]

[conversion_status]

[CH1 MSB][CH1 LSB].....[CH8 MSB][CH8 LSB]

Status register : Refer to the status register section for the details

Cmd_status : Bit 0 tell if the command will be processed correctly or not (fifo flag)

Busy_status : Bit 0 tell if the ADC is busy right now (the result will no be valid if so)

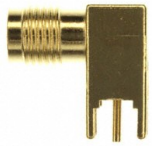
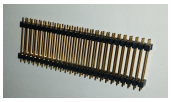
Conversion status : Bit 0 tell if the conversion is completed or not. Logic high indicate that the conversion is done. The bit is cleared when readed.

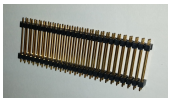
CH1 to 8 : 16 bits voltage value in 2 complement. The input range is -10V to +10V.

10 Part lists

This part list is not definitive, and is here to help for the design of the Tio cards.

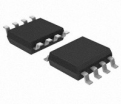
10.1 Connector

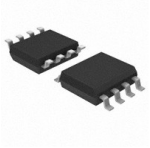
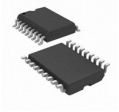
Use	Description	Part No	Supplier	Price	Datasheet name	Image
Comm port	DSUB9 Male Right Angle	S9575-ND	www.digikey.ca	$1,08	345_11773,_SDS107-PR___-_____-SN___-___.pdf	
FSK output	CONN SMA JACK R/A 50 OHM PCB	A97593-ND	www.digikey.ca	$3,44	ENG_CD_1814400_D_base Filename.pdf	
Power & RLY	TERM BLOCK HDR 3POS R/A 3.81MM	609-3820-ND	www.digikey.ca	$0,50	20020110.pdf	
Power & RLY	TERM BLOCK PLUG 3POS STR 3.81MM	609-3798-ND	www.digikey.ca	$1,21	20020004.pdf	
GPIO	TERM BLOCK HDR 8POS R/A 3.81MM	609-3825-ND	www.digikey.ca	$0,94	20020110.pdf	
GPIO	TERM BLOCK PLUG 8POS STR 3.81MM	609-3803-ND	www.digikey.ca	$2,68	20020004.pdf	
Backplane connector		CLT-125-02-F-D	Www.samtec.com	$4,15	CLT-1XX-XX-XX-D-XX-FOOTPRINT.pdf CLT-1XX-XX-XX-D-MKT.pdf	
Backplane spacing 2cm		TW-25-07-G-D-605-073	Www.samtec.com	$6,93	TW-XX-XX-X-X-XXX-XXX-XXX-XX-MKT1.pdf TW-XX-XX-X-X-XXX-XXX-XXX-XX	

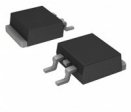
					FOOTPRINT.pdf	
Backplane spacing 1.5cm		TW-25-04-G-D-410-072	Www.samtec.com	$6,31	TW-XX-XX-X-X-XXX-XXX-XXX-XX-MKT1.pdf TW-XX-XX-X-X-XXX-XXX-XXX-XX FOOTPRINT.pdf	
Backplane spacing 2.5cm		TW-25-12-G-D-965-055	Www.samtec.com			
		RASP-STACK-HEAD40	http://shop.mchobby.be/raspberry-pi-b-plus/485-stacking-header-2x20-pour-raspberry-pi-b.html	$6,00		
CMOS S6 socket	CONN SOCKET IC 48-PIN T/H	ED3034-ND	www.digikey.ca	$2,32	SAXXX0X0.pdf	
RTC Battery holder	HOLDER BATTERY SONY CR2032 SMD	BC2032-F1-ND	www.digikey.ca	$1,00	BC2032-F1-datasheet.pdf	
6 pins connector receptacle	TERM BLOCK HDR 6POS R/A 3.81MM	609-3823-ND	www.digikey.ca	$1,35	20020110.pdf	
6 pins connector block	TERM BLOCK PLUG 6POS STR 3.81MM	609-3801-ND	www.digikey.ca	$3,03	20020004.pdf	
2 pins connector receptacle	TERM BLOCK HDR 2POS R/A 3.81MM	609-3819-ND	www.digikey.ca	$0,63	20020110.pdf	
2 pins connector block	TERM BLOCK PLUG 2POS STR 3.81MM	609-3797-ND	www.digikey.ca	$1,18	20020004.pdf	

Coding key for connector	CODING KEY SKT 3.50/3.81MM	609-4060-ND	www.digikey.ca	$0,36	20020802.pdf	

10.2 IC

Use	Description	Part No	Supplier	Price	Datasheet	Image
FPGA	CMOD S6	410-282P-KIT	http://www.digilentinc.com	$60,00	Cmod S6_sch.pdf	
Input opto	OPTOISO 3.75KV DARL W/BASE 8SOIC	516-1488-1-ND	www.digikey.ca	$2,98	AV02-1359EN+DS+6N139_HCNW138+27Jul2012.pdf	
Push-pull out (10-30V)	IC DGTL ISO 1CH PUSH PULL 8SOIC	336-2420-5-ND	www.digikey.ca	$1,69	Si826x_Rev0.9.pdf	
UART	IC UART SPI/I2C 128 FIFO 24SSOP	MAX3107EAG+-ND	www.digikey.ca	$7,49	MAX3107.pdf	
ADC (AD)	IC DAS W/ADC 16BIT 64LQFP	AD7606BSTZ-4RLCT-ND	www.digikey.ca	$25,16	AD7606_7606-6_7606-4.pdf	
DDS (AD)	IC DDS QUADRATURE CMOS 80-LQFP	AD9854ASTZ-ND	www.digikey.ca	$40,13	AD9854.pdf	
DAC (AD)	IC DAC 16BIT QUAD VOUT 32-TQFP	AD5764RBSUZ-ND	www.digikey.ca	$61,90	AD5764R.pdf	
Out amplifier for DDS	IC OPAMP VFB 200MHZ 8SOIC	LM7171BIMX/NOPBCT-ND	www.digikey.ca	$3,57	lm7171.pdf	

Regulateur 3.3V	IC REG LDO 3.3V 1A SOT223-3	ADP3338AKCZ-3.3RL7CT-ND	www.digikey.ca	$3,22	ADP3338.pdf	
Relay out	RELAY GEN PURPOSE SPDT 12A 5V	G2RL-1DC5-ND	www.digikey.ca	$3,29	G2RL_0911.pdf	
DC-DC	IC REG BUCK ADJ 3A 20TSSOP	LM5576MHX/NOPBCT-ND	www.digikey.ca	$8,07	lm5576.pdf	
HAT eeprom	IC EEPROM 32KBIT 400KHZ 8SOIC	CAT24C32WI-GT3CT-ND	www.digikey.ca	$0,69	CAT24C32-D.PDF	
RTC	IC RTC CLK/CAL I2C/SPI 20-SOIC	568-10212-1-ND	www.digikey.ca	$4,58	PCF2127AT.pdf	
Opto out for CPU board	OPTOISOLATOR 5KV DARL 4SMD	PS2533L-1-F3-ACT-ND	www.digikey.ca	$2,25	ps2533.pdf	
General purpose 8A diode	DIODE GEN PURPOSE 1000V 8A SMC	S8MCDICT-ND	www.digikey.ca	$0,87	ds31117.pdf	
Inductive load free-wheel diode	DIODE FAST RECOVERY 1KV 1A SMA	RS1M-FDICT-ND	www.digikey.ca	$0,48	ds15002.pdf	
Output driver (non-isolated)	ULN2803AFWG	ULN2803AFWGCELCT-ND	www.digikey.ca	$0,75	ULN2803APG_datasheet_en_20121126.pdf	

Input opto to use	OPTOISO 5KV TRANS W/BASE 8SMD	160-1801-ND	www.digikey.ca	$2,52	6N139S.pdf	
Part for switching supply	IC REG BUCK ADJ 3A 20TSSOP	LM5576MHX/NOPBCT-ND	www.digikey.ca	$8,13	lm5576.pdf	
Part for switching supply	INDUCTOR SHIELD PWR 33UH SMD	513-1047-1-ND	www.digikey.ca	$1,98	Bus_Elx_DS_4315_DR_Series.pdf	
Part for switching supply	RES 10 OHM 1W 1% 2512 SMD	PT10AECT-ND	www.digikey.ca	$1,23	ERJ1TYFyyyU, ERJ1TY0R00U.pdf	
Part for switching supply	DIODE SCHOTTKY 100V 7.5A DPAK	497-3208-1-ND	www.digikey.ca	$1,53	CD00002831.pdf	
Part for switching supply	CAP TANT 150UF 6.3V 20% 2917	399-4033-1-ND	www.digikey.ca	$2,93	KEM_T2015_T520.pdf	
Part for switching supply	CAP CER 22UF 16V 20% X7R 1210	445-3955-1-ND	www.digikey.ca	$1,01	mlcc_commercial_general_en.pdf	
Part for switching supply	CAP CER 0.47UF 25V 10% X7R 0805	445-1353-1-ND	www.digikey.ca	$0,25	mlcc_commercial_general_en.pdf	
Part for switching supply	CAP CER 0.022UF 100V X7R 0805	490-1658-1-ND	www.digikey.ca	$0,22	GRM21BR72A223KA01.pdf	
Part for switching supply	CAP CER 10000PF 100V X7R 0805	399-1159-1-ND	www.digikey.ca	$0,12	KEM_C1002_X7R_SMD.pdf	
Part for switching supply	CAP CER 330PF 100V 5% NP0 0805	399-1131-1-ND	www.digikey.ca	$0,19	KEM_C1002_X7R_SMD.pdf	
LED for general purpose	LED SMARTLED 630NM RED 0603 SMD	475-2506-1-ND	www.digikey.ca	$0,20	00077099_0.pdf	

LED for general purpose	LED YELLOW 587NM 0603 SMD	475-1196-1-ND	www.digikey.ca	$0,20	LY L29K - SMARTLED 0603.pdf	
LED for general purpose	LED SMARTLED 570NM GREEN 0603	475-3118-1-ND	www.digikey.ca	$0,20	00077107_0.pdf	
Resistor 2K 0805 for general purpose	RES 2K OHM 1/8W 1% 0805 SMD	P2.00KCCT-ND	www.digikey.ca	$0,13		
0.1uF general purpose	CAP CER 0.1UF 100V 10% X7R 0805	490-4789-1-ND	www.digikey.ca	$0,12	GCM21BR72A104KA37L.pdf	
10uF general purpose	CAP CER 10UF 35V 10% JB 0805	445-11516-1-ND	www.digikey.ca	$0,84	mlcc_commercial_general_en.pdf	
Resistor 10K 0805 for general purpose	RES 10K OHM 1/8W 1% 0805 SMD	P10.0KCCT-ND	www.digikey.ca	$0,13		
Resistor 100Ohms 0805 for general purpose	RES 100 OHM 1/8W 1% 0805 SMD	P100CCT-ND	www.digikey.ca	$0,13		
1uF genral purpose	CAP CER 1UF 35V 10% X7R 0805	490-5320-1-ND	www.digikey.ca	$0,42		
10ohms general purpose	RES 10 OHM 1/8W 1% 0805 SMD	P10.0CCT-ND	www.digikey.ca	$0,13		
649ohms general purpose	RES 649 OHM 1/10W 1% 0603 SMD	P649HCT-ND	www.digikey.ca	$0,13		
1.6k general purpose	RES 1.6K OHM 1/10W 1% 0603 SMD	P1.60KHCT-ND	www.digikey.ca	$0,13		

DC-DC to have +/-12V from 5V	CONV DC/DC 8.5W DUAL 5V +-12V SMD	445-3328-ND	www.digikey.ca	$31,00		
Isolation Bead	FERRITE BEAD 150 OHM 5A SMD 2220	732-3423-1-ND	www.digikey.ca	$1,58		
0.015uF General purpose	CAP CER 0.015UF 100V X7R 0805	445-4435-1-ND	www.digikey.ca	$0,18		
2.2uF General pupose	CAP CER 2.2UF 50V 10% X7R 0805	445-5968-1-ND	www.digikey.ca	$0,86		
RS232/485 Driver	IC TXRX RS232/485/422 20SSOP	MAX3160CAP+-ND	www.digikey.ca	$12,21	MAX3160-MAX3162.pdf	
120Ohms RS485 terminator	RES 120 OHM 1W 5% 2512	RMCF2512JT120RCT-ND	www.digikey.ca	$0,56		
XTAl for uart	CRYSTAL 14.7456MHZ 20PF SMD	XC1280CT-ND	www.digikey.ca	$0,68		
Clock buffer	IC RECEIVER ECL DIFF 3.3V 8SOIC	MC100LVEL16DGOS-ND	www.digikey.ca	$7,60		
Xtal for DDS	OSC XO 30.000MHZ CMOS SMD	SER2843CT-ND	www.digikey.ca	$3,41		

10.3 Hardware

Use	Description	Part No	Supplier	Price	Datasheet name	Image
Interboard spacer 2.5cm	HEX STANDOFF M3 BRASS 25MM	952-1512-ND	www.digikey.ca	$0,74	R30-300.pdf	
Interboard spacer 2cm	HEX STANDOFF M3 BRASS 20MM	952-1510-ND	www.digikey.ca	$0,69	R30-300.pdf	

Interboard spacer 1.5cm	HEX STANDOFF M3 BRASS 15MM	952-1506-ND	www.digikey.ca	$0,64	R30-300.pdf	
Interboard spacer End nut	HEX NUT 0.217" M3	H762-ND	www.digikey.ca	$0,05	NA