

High Performance Software Defined Radio

Open Source Hardware and Software Project Project Description: <u>http://openhpsdr.org</u>

Hardware Project #5 **METIS Board** Part #2

The Making of METIS



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METIS is a high speed PC interface board intended for use with the openHPSDR range of circuit boards. Metis is designed to plug into the openHSDR Atlas bus and is a drop in replacement for an Ozy or Magister USB2 interface board. Metis provides either a 100T or Gigabit (1000T) interface to the host PC. The board uses a large Altera FPGA (providing some 40,000 logic elements) which provides plenty of room for future code updates and new facilities. The user input and outputs (e.g. PTT, CW key, relay driver) that are currently available on the Ozy and Magister boards are provided. However, control of the SDR1000 is no longer supported. All the Ethernet protocol processing is undertaken by the FPGA. Protocols supported include: UDP/IP, DHCP, APR and ping. A unique MAC address is used by each board and either a static or automatically assigned IP address can be used. Future Metis code updates can be done via the Ethernet connection eliminating the need for special programming adapters.

This manual provides detailed step-by-step building instructions for the METIS card for those who are ambitious enough to build their own instead of buying a ready-made card.

73 Horst DL6KBF

1.1 Physical and mental preparation

Before you start building anything please check yourself regarding your personal physical and mental condition. You should ask yourself if you are physically so well that you could start such a project. If you are hyperactive or have problems with tremor in your hands I would recommend that you find another day to start or even stay away from this and buy a finished board.

If you just had a fight with your wife or your boss and you are still very angry or frustrated inside please don't start soldering. You definitely will throw all the tiny parts on the floor and can't find them anymore.

How you should be:

- in a good health condition
- in a goooooood mood
- calm and cool inside
- have self-confidence

You should be knowing what you are doing!

You also should be familiar with the basic SMT soldering techniques!

1.2 Workbench preparation

1.2.1 Table

The work table should be totally cleaned up and emptied before starting any work on METIS. This makes it easier to find any part which possibly jumps off the tweezers.

1.2.2 ESD (ElectroStatic Discharge) prevention

Since most of the ICs on METIS are very sensitive to ESD it is recommended that you use an ESD matt. This should be connected at least to the solder station ESD connector.

Before touching any IC you should place both hands flat on the matt in order to discharge yourself. Alternatively wear an ESD strap around your wrist which is connected either to the matt or to the same potential as the matt.

I use an ESD matt of about 60x50 cm² which is fairly cheap (approx. 15 EUR). It is made from PVC which has the advantage of also having an anti-slip surface. I am usually placing the PCB directly on the matt without using any vise. This makes the PCB handling very easy and convenient.



1.3 Soldering tools

For this type of project a good quality soldering tool is very essential. Preferably a soldering station with electronic temperature control and a wattage of around 50W to 80W should be used.

- forget about cheap irons. They are too hot. forget about so-called SMD soldering needles. They usually have around 8 watts which after my experience is useless.

Most important:

Buy the finest solder tip for your iron which you can get. Mine has a tip diameter of 0.2 mm (around .01 inch). This is suitable for soldering even the fine pitch CPLD.

Alternative methods include various kinds of reflow or hot air soldering techniques. You can find many details about reflowing or hot air soldering on the internet in the various microcontroller forums or on some HAM websites.

But be warned:

I tried to reflow OZY with my temperature controlled pizza oven and I had a very bad experience with the board delaminating despite the correct temperature profile.



That's what I am using

1.3.1 Solder wire

With solder wire you have the choice of using wire containing lead or the new lead-free (RoHS compliant) solder wire. Leaded solder wire is still available and you do not need to change your soldering habbits which you most probably have developed over the years.

Lead-free solder wire has the disadvantage of a higher melting temperature which you have to get used to. So, if you decide to use leadfree solder wire please do some test soldering before getting on METIS.

Very important:

The diameter of the solder wire should be

as small as possible. I am using a wire diameter of 0.5 mm. If you can get a smaller wire diameter this should be even better. In Europe the readily availabe minimum diameter is 0.5 mm.



Solder containing lead



Lead-free solder





1.3.2 Solder Flux

Actually my personal experience with solder flux is twofold:

- it is a fantastic aid for soldering

- depending on the kind of flux it bears some danger of getting bad solder joints and it makes the board look ugly

My experience:

In the beginning I had been using a flux with kind of a jelly texture. It is very sticky and the ICs could be positioned very easily and stayed at their position. But after soldering you could not clearly see the pads anymore in order to check the soldering quality. It also did not disolve with isopropyl alcohol so that the board looked ugly.

My recommendation:

For the METIS board with its pre-tinned pads you should better use a water-clear no-clean flux and you will only need it to solder the two fine-pitch ICs. The other ICs and components can be soldered fine without using any flux at all.

I am using a solder flux stick as shown in the next picture.



No-clean water-clear solder flux

1.3.3 Solder Wick

This is what you actually need in a good quality and probably a good quantity of it.

It should be of a fine diameter (0.8 mm) for IC pins and about 1.5 mm diameter for other solder joints.



Solder Wick

1.4 Essential tools

Besides the soldering iron this project requires some other specialized tools. You may get along without them but they make life much easier and they are not too ex-pensive. Some of them look like dentist tools and they actually are. So all the HAM dentists out there have an advantage: they can bring home their tools from work. But don't use them for your patients anymore afterwards!

1.4.1 Tweezers

This will be your main tool besides the soldering iron and it should be of excellent quality. The tweezers should be specialized for SMD work and should be stainless steel.



This is what I am using

This model for me is the most convenient one because it has this 30 degree angle and the two little pads at the tips. Others may have other preferences.

Additionally you should have at least one





extra pair of tweezers with acute tips, either straight or angled.



They may look like this

1.4.2 Dentist tools

As mentioned before these tools are very helpful for manipulating parts (especially ICs), cleaning the PCB and probing the quality of solder joints on IC pins. You can get a set of these in acceptable quality for a good price.



1.4.3 What else?

What I am also using are sewing machine needles. You can also use hand sewing needles but household sewing machine needles are more readily available.

So, during your next stop at the convenience store get yourself a pack of sewing machine needles. Microtex needles are to be preferred because they have a sharp tip.

What do I do with them?

The needles have a nice nickel plated surface. So you can solder some wire on them and use them as fantastic probes.

Connected to your multimeter in audible continuity test you are able to touch every single pin of a fine-pitch IC right where they come out of the case and use the second needle probe to touch the pad below the pin or even penetrate through the solder mask lacquer and touch the copper traces in order to verify continuity.

They are a nice and inexpensive tool and I love them (because my company makes them, hi).

Once the tip is worn off just take another set.





1.5 Last and most important

Vision

Personally I am nearsighted (-6 diopters). So what I am doing is take out my contact lenses, put on **safety glasses** and stick my nose very close to the PCB. Then I have a beautiful and clear view on all the soldering pads.

For the fine-pitch ICs this is still not enough. You should definitely have some kind of magnifying glass with at least a 5x magnification.



A higher magnification is not useful because then you do not have any working distance under the magnifying glass anymore. The best tool to use is a microscope with 10x and 20x magnification or even a zoom lens. This is what I am using:



I got a very good bargain on a second-hand one on the internet and this is the best tool I ever bought. It has 10x, 20x and 35x magnification and a work distance of 160 mm with 10x magnification.

The technical data can be viewed at http://www.euromex.nl.

I also have got a USB microscope camera but the disadvantage with this camera is that even with 10x magnification the camera is too close to the board. There is no real workspace under it anymore.

METIS

Jason, N8INJ, has reported of having used a cheap webcam:

"...One other idea you may want to share with others is that if a microscope is out of their price range there are some other ways to get more magnification. Possibly the simplest is to use a "webcam" on your computer - most of them are capable of very close focusing out of the box (though some may require minor adjustments to the lens) and can give a good deal of effective magnification cheaply. It's usually also possible to tape a loupe over the lens to get even more magnification. ..."





1.5 Soldering techniques

On the internet you can find numerous pages with information on soldering fine-pitch ICs

A good information source is

http://www.solder.net

where they have some training videos from time to time which you can download.

Training on old computer boards is also helpful in getting some soldering skills for fine-pitch ICs.

But I am sure that everybody who has ordered the bare METIS board has understood as well that this is not one of the easiest hobby projects.

And now let's start.

Enough preliminaries.

Let's heat up the soldering station and

DO IT.

METIS



Chapter 2: How to start



2.1 Don't panic at hundred pins and more

After roughly aligning the chip on the pads (don't be afraid of touching the IC with your fingers if working on an ESD matt) put a pair of tweezers or a similar tool on the chip as a load. Another method which I use very often is to put a thin layer of solder honey on the pads. This makes the pads sticky and the IC can't barely move anymore. In this way it can be aligned properly.

Using the tweezer method I take the soldering iron in one hand, press one finger on the tweezers and with the soldering iron I touch a corner pin of the IC. The tin on the pad (with pre-tinned pads) mostly is enough to tack down that pin on the pad.

Again you should check the correct placement of the chip on the pads and then tack down the corner pin diagonally across the first soldered pin.

If everything fits well I usually solder pin by pin around the IC.

If by accident you use too much solder and make a short between two pins just use the solder wick to remove the excess solder.

Don't be too anxious. In a reflow oven the chip withstands temperatures of 240 °C for minutes.







Chapter 3: Parts Placement









Itom 1				
CAP CER .1U	CAP CER .1UF 50V Y5V 0805			
Pos	Reel/Tick			
C63	38			
C64	39			
C71	40			
C73	41			
C75	42			
C76	43			
C77	44			
C83	45			
C90	46			
C102	47			

Item 2				
CAP 10nF 50	CAP 10nF 50V X7R 0805			
Pos	Reel/Tick			
C58	2			
C59	3			
C60	4			
C67	5			
C68	6			
C69	7			
C70	8			
C72	9			
C86	10			
C89	11			
C91	12			
C92	13			
C93	14			
C94	15			
C95	16			
C96	17			
C97	18			
C98	19			
C99	20			
C100	21			
C101	22			





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	1 4 1 6V 2216 CMD
AP TANT TUP	10V 3210 SMD
Pos	Reel/Tick
C3	1
C6	2
C9	3
C13	4
C65	5

Item 5			
CAP TANT 10UF	16V 3216 SMD		
Pos	Reel/Tick		
C4	1		
C7	2		
C10	3		
C14	4		
C15	5		
C17	6		
C61	7		
C66	8		
C84	9		

Item 6			
CAP TANT 47UF 16V 6032 SMD			
Pos Reel/Tick			
C1	1		
C11	2		
C62	3		
C81	4		
C82	5		
5	•		





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Item 7			
Pana RP-Bus 8x100k EXB- A10P104J			
Position	Reel		
RP1			
RP2			
RP3			
RP4			
RP5			
RP6			

Item 8		
Pana RP-Bus 8x10k EXB- A10P103J		
Position	Reel	
RP7		

Item 10		
FERRITE CHIP 600 OHM 500MA 0805		
Reel/Tick		





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Item 11

Item 15		
RES 120 OHM 1/8W 5% 0805 SMD		
Pos	Reel/Tick	
R2		

Item 16		
RES 220 OHM 1/8W 5% 0805 SMD		
Pos	Reel/Tick	
R16		
R17		

Item 17			
RES 1k 1/8W 5% 0805 SMD			
Pos	Reel/Tick		
R6			
R11			
R12			
R13			



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Item 19		
RES 4k7 1/8W 5% 0805 SMD		
Pos	Reel/Tick	
R28		

Item 21			
RES 10k 1/8W 5% 0805 SMD			
Pos	Reel/Tick		
R15	1		
R31	2		
R32	3		
R33	4		
R52	6		

Item 22		
RES 100k 1/8W 5% 0805 SMD		
Reel/Tick		



Backside ready



The Making of ...

METIS



Item 1 CAP CER .1UF 50V Y5V 0805 **Reel/Tick** Pos C56 TOP 1 C78 TOP 2 C79 TOP 3 C80 TOP 4 C87 TOP 5 6 C88 TOP

Item 2		
CAP 10nF 50V X7R 0805		
Pos	Reel/Tick	
C57 TOP	1	

Item 3		
0805 SMD Ceramic Chips		
10pF 50volts COG 1%		
Pos	Reel/Tick	
C18	1	
C19	2	
C20	3	
C21	4	

Item 5		
CAP TANT 10UF 16V 3216 SMD		
Pos	Reel/Tick	
C74 TOP	9	
C85 TOP	11	



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R49

3 3 014

12 8

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JP4

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JP3

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E324425 FA 94V-0

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C78

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R36

C79 🗾 💓

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0

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C80 R420

R41

J9

71-7

D9

R43 D8

Metis - A GigaBit Ethernet Controller

•C85

J7

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R21

R20

R19

U9 R34

02

R5

07

Q1

R50

C1 🗶 B1

A1

R35

R14 C56

De

R51

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0

R18

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0.0

Item 11			
RES 0.0 OHM 1/8W 5% 0805 SMD			
Pos	Reel/Tick		
R23 TOP	1		
R46 TOP	3		
R53 TOP	4		
R55 TOP	6		
R56 TOP	7		

Item 12		
RES 22 OHM 1/8W 5% 0805 SMD		
Pos	Reel/Tick	
R8 TOP		
R9 TOP		
101		

Item 13	
RES 100 OHM 1/8W 5% 0805 SMI	
Reel/Tick	

Item 15	
RES 120 OHM 1/8W 5% 0805 SMD	
Pos	Reel/Tick
R43 TOP	

Item 17	
RES 1k 1/8W 5% 0805 SMD	
Reel/Tick	



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 Item 18

 RES 1k5 1/8W 5% 0805 SMD

 Pos
 Reel/Tick

 R1 TOP
 R4 TOP

 R48 TOP
 R48 TOP

Item 19	
RES 4k7 1/8W 5% 0805 SMD	
Reel/Tick	

Item 20	
RES 4k99 1/8W 1% 0805 SMD	
Pos	Reel/Tick
R14 TOP	

Item 21	
RES 10k 1/8W	5% 0805 SMD
Pos	Reel/Tick
R5 TOP	1
R10 TOP	2
R18 TOP	3
R19 TOP	4
R20 TOP	5
R21 TOP	6
R22 TOP	7
R30 TOP	8
R34 TOP	9
R35 TOP	10
R36 TOP	11
R39 TOP	12
R40 TOP	13
R50 TOP	14
R51 TOP	15
R59 TOP	16





Special Instructions: Placing the LEDs

How to determine the polarity of the 0805 LEDs?

It can be difficult to find out the polarity of the tiny 0805 LEDs if you don't know what to look for.

The Lite-ON[®] LEDs used in the METIS BOM are easy to determine the polarity. Looking on them under a magnifying glass you can see that the LED dice (photo) is visible and off-center from the body. This is the anode (+) side which has to match with + on the PCB.

LED Dice

The ones which I am using have a little mark printed on the bottom:





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Item 8		
Pana RP-Bus 8x2.2k EXB-A10P222J		
Position	Reel	
RP26		
RP49		

Item 23	
LED-RED 0805 SMD	
Pos	Reel/Tick
D1	1
D2	2
D3	3
D10	4
D11	5
D12	6
D13	7
D14	8
D15	9
D16	10
D17	11
D18	12
D19	13
D20	14
D21	15
D22	16
D23	17





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METIS



Item 10	
FERRITE CHIP 600 OHM 500MA 0805	
Pos	Reel/Tick
L1 TOP	
L4 TOP	
L5 TOP	

Item 24 2N7002K SOT23 SMD	
Q1	
Q2	
Q3	

Iten	n 25
BAT54A S	OT23 SMD
Pos	Reel/Tick
D6	
D9	

Item 26				
BAT54C SOT23 SMD				
Pos	Reel/Tick			
D4				
D5				
D7				
D8				





X1

Item 28 ICs Pos Reel/Tick LD1117-3.3 U1 U2 LD1117-1.2 LD1117-2.5 U3 LD1117-3.3 U4 EP3C40Q240 U6 M25P16VMW6G U7 U8 KSZ9021RL_A U9 74LCX541MTC U10 SN65LVDM050D MCP130T-300ITT U11 25AA02E48T-I/OT U12 U14 LT1529-3.3 MIC94052 U15

25Mhz clock





METIS Bill of Materials

Item 1 CAP CER .1UF 50V Y5V 0805		Item 1 CAP CER .1UF 50V Y5V 0805		Item 2 CAP 10nF 50V X7R 0805		Item 6 CAP TANT 47UF 16V 6032 SMD	
C2	1	C63	38	C98	19	C1	1
C5	2	064	39	C99	20	C11	2
C8	3	071	40	C100	21	C62	3
C12	4	073	41	C101	22	C81	4
C16	5	075	42	C57 TOP	1	C82	5
C22	6	076	43	· · · · · · · · · · · · · · · · · · ·			
C23	7	077	44				
C24	8	C83	45			Iter	m 7
C25	9	C90	46			Pana RP-Bus 8x10	Ok EXB-A10P104J
C26	10	C102	47		Item 3	Position	Reel
C27	11			0805 SMD	Ceramic Chips	RP1	
C28	12		Item 1	10pF 50	volts COG 1%	RP2	
C29	13	CAP CER .1	UF 50V Y5V 0805	Pos	Reel/Tick	RP3	
C30	14	Pos	Reel/Tick	C18	1	RP4	1
C31	15	C56 TOP	38	C19	2	RP5	
C32	16	C78 TOP	46	C20	3	RP6	
C34	17	C79 TOP	47	C21	4		and.
C35	18	C80 TOP	48			Iter	m 8
C36	19	C87 TOP	50		Item 4	Pana RP-Bus 8x2.	2k EXB-A10P222J
C37	20	C88 TOP	51	CAP TANT 1	UF 16V 3216 SMD	Position	Reel
C38	21			Pos	Reel/Tick	RP26	
C39	22		Item 2	C3	1	RP49	
C41	23	CAP 10n	F 50V X7R 0805	C6	2		
C42	24	Pos	Reel/Tick	C9	3	Item 9	
C43	25	C58	2	C13	C13 4 EMI FILTER 1000PF 50V SM		00PF 50V SMD
C44	26	C59	3	C65	5	EXC-CE	T102U
C45	27	C60	4			Pos	Reel/Tick
C46	28	C67	5		item 5	L8	
C47	29	C68	6	CAP TANT 10UF 16V 3216 SMD		L9	
C48	30	C69	7	Pos	Reel/Tick	L10	
C49	31	C70	8	C74 TOP	9		
C50	32	C72	9	C85 TOP	11	Item	10
C51	33	C86	10	C4	1	FERRITE CHIP 600	OHM 500MA 0805
C52	34	C89	11	C7	2	Pos	Reel/Tick
C53	35	C91	12	C10	3	L1 TOP	
C54	36	C92	13	C14	4	L4 TOP	
C55	37	C93	14	C15	5	L5 TOP	
		C94	15	C17	6	L2	
		C95	16	C61	7	L3	
		C96	17	C66	8	L6	100 B
-		C97	18	C84	9	L7	



Item 8 Pana RP-Bus 8x10k EXB-A10P103J		Item 17 RES 1k 1/8W 5% 0805 SMD		Item 21 RES 10k 1/8W 5% 0805 SMD		Item 24 2N7002K SOT23 SMD		
								Position
RP7		R3 TOP		R40 TOP	13	Q1		
		R47 TOP		R50 TOP	14	Q2		
		R6		R51 TOP	15	Q3		
		R11		R59 TOP	16		1	
	ltem 11	R12		R15	8			
RES 0.0 OHM :	1/8W 5% 0805 SMD	R13		R31	9	Item 25		
Pos	Reel/Tick			R32	10	BAT5	4A SOT23 SMD	
R23 TOP	1			R33	11	Pos	Reel/Tick	
R46 TOP	3	1	tem 18	R52	12	D6		
R53 TOP	4	RES 1k5 1/8	3W 5% 0805 SMD			D9		
R55 TOP	6	Pos	Reel/Tick					
R56 TOP	7	R1 TOP			Item 22			
R27	2	R4 TOP		RES 100k 1	RES 100k 1/8W 5% 0805 SMD		Item 26	
R54	5	R48 TOP		Pos	Reel/Tick	BATS	4C SOT23 SMD	
R57	8			R41 TOP		Pos	Reel/Tick	
R58	9			R42 TOP		D4	He city Helt	
1.50	-		tem 19	R24		D5		
	-	RES 447 1/8	SW 5% 0805 SMD	P25	-	07		
	from 12	RE3 4K/ 1/0	Peel/Tick	R25		07		
DES 22 OHM	1/8W 50% 0805 SMD	POS TOP	Reel/ IICK	D45	_	10		
RES 22 UNPL	Deel/Tick	R29 TOP		K45				
POS TOP	Keel/ IICK	820					Them 27	
RO TOP					floor 22	ID	Z11/420// 10	
R9 TOP				150.0	Etem 23	IDT/1V429/L10		
	_	DEC ALOO 1	20 20 20 CMD	LED-R	ED 0805 SMD	POS	IDTTIVA20// 10	
1.1		RES 4K99 1/	SW 1% USUS SMD	Pos	Reel/TICK	013	101/10429/110	
PEC 100 0111	Kem 13	POS	Reel/ IICK	D1				
RES 100 OHM	1/8W 5% 0805 SMD	RI4 TOP		02	2			
Pos	Reel/Tick			D3	3		Item 28	
R37 TOP				D10	4		ICs	
R38 TOP			tem 21	D11	5	Pos	Reel/Tick	
		RES 10k 1/8	3W 5% 0805 SMD	D12	6	01	LD1117-3.3	
-		Pos	Reel/Tick	D13	7	U2	LD1117-1.2	
	Item 15	R5 TOP	1	D14	8	U3	LD1117-2.5	
RES 120 OHM	1/8W 5% 0805 SMD	R10 TOP	2	D15	9	U4	LD1117-3.3	
Pos	Reel/Tick	R18 TOP	3	D16	10	U6	EP3C40Q240	
R43 TOP		R19 TOP	4	D17	11	U7	M25P16VMW6G	
R2		R20 TOP	5	D18	12	US	KSZ9021RL_A	
		R21 TOP	6	D19	13	U9	74LCX541MTC	
	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	R22 TOP	7	D20	14	U10	SN65LVDM050D	
	Item 16		8	D21	15	U11	MCP130T-300ITT	
RES 220 OHM	1/8W 5% 0805 SMD	R34 TOP	9	D22	16	U12	25AA02E48T-I/OT	
Pos	Reel/Tick	R35 TOP	10	D23	17	U14	LT1529-3.3	
R16		R36 TOP	11			U15	MIC94052	
017		R39 TOP	12			X1	25Mhz clock	