LGP-21 Replica

Preliminary Building Instructions
Draft 0.1, 31. December 2019
For board revision 11-2019

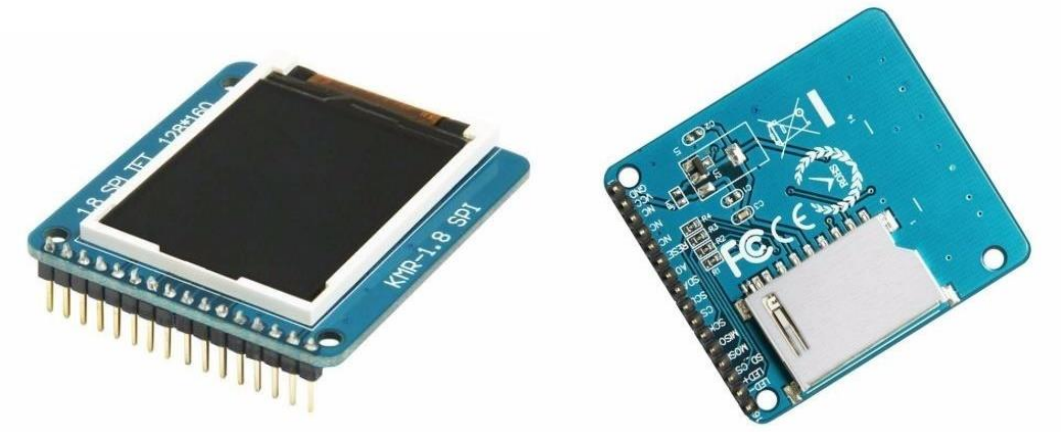
Jürgen Müller, juergen@e-basteln.de

Contents

Building Notes

Parts

- All required components are listed in the BOM (appendix of this document), except for mechanical mounting parts. See the "Mounting" section below for comments on mounting hardware.
- All parts are available from standard distributors like Mouser, except for the FPGA and display modules and the HDMI jack.
- The Numato Mimas (Spartan 6) FPGA module is available directly from the manufacturer, Numato.com. Shipment from India via DHL has worked smoothly for me several times. I have not tried the resellers on Amazon and ebay.
- The display KMR-1.8 SPI, 128*160 pixels, comes in slightly different versions. Be sure to get the version with SPI interface and a single row of pins, as pictured here.



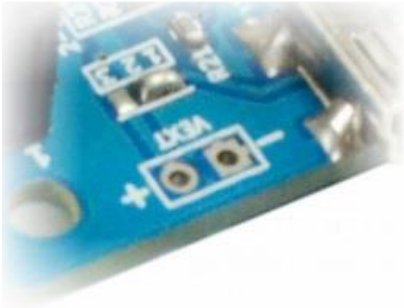
- The HDMI jack has three rows of through-hole pins, arranged as 6+6+7 pins. This is the same version which is used in the Playstation PS3 ("fat" version, model number 2000/2500). These are available on ebay and AliExpress, often advertised with reference to the PS3.

Mimas board: Power supply connection

The Mimas board and front-end PCB require a +5V regulated supply, with a current rating of 500 mA or more. (Up to 350 mA current consumption with an HDMI monitor connected, depending on the number of LEDs that are on.) Any regular USB port or small USB-style power supply should be adequate.

To provide a 5V connection between the Mimas board and the front end, populate the "VEXT" connector on the Numato Mimas board with a 2-pin female header. This will mate with the two-pin header P4 on the LGP-21 board.

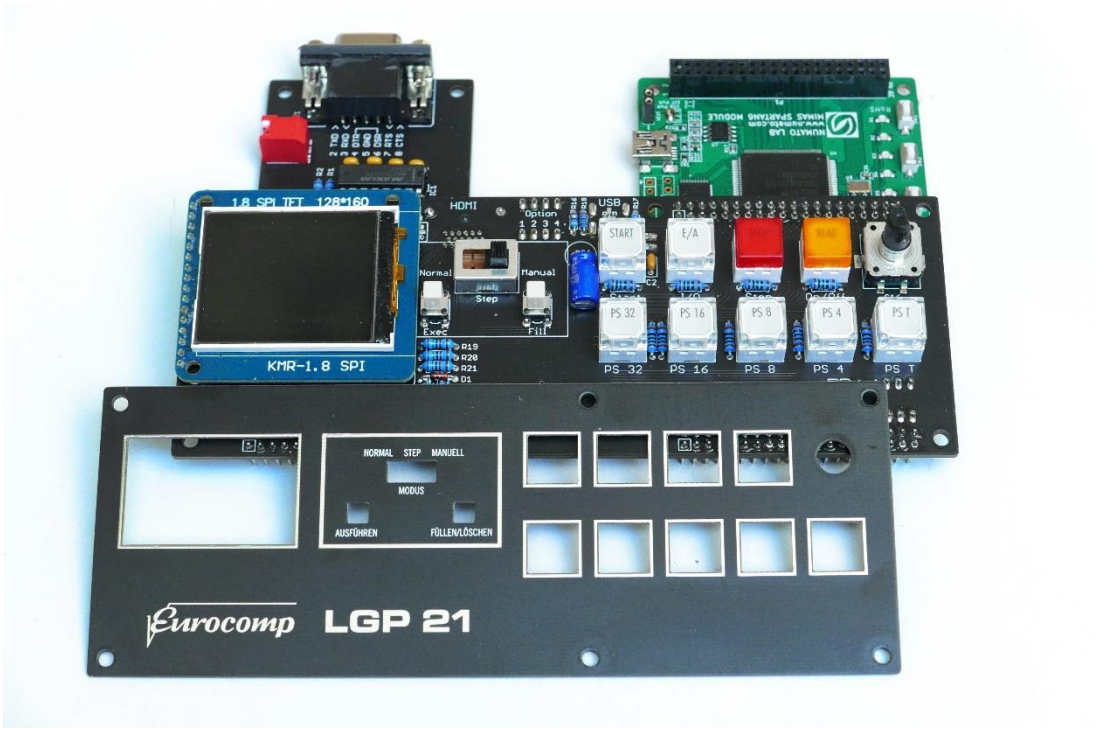
- On the power selection solder jumper, located right behind the VEXT connector, connect all three pins with a fat solder bridge. Power can now be supplied either via the Mimas USB port (for testing and FPGA programming) or via the USB port on the LGP-21 PCB (when using the LGP-21 replica).

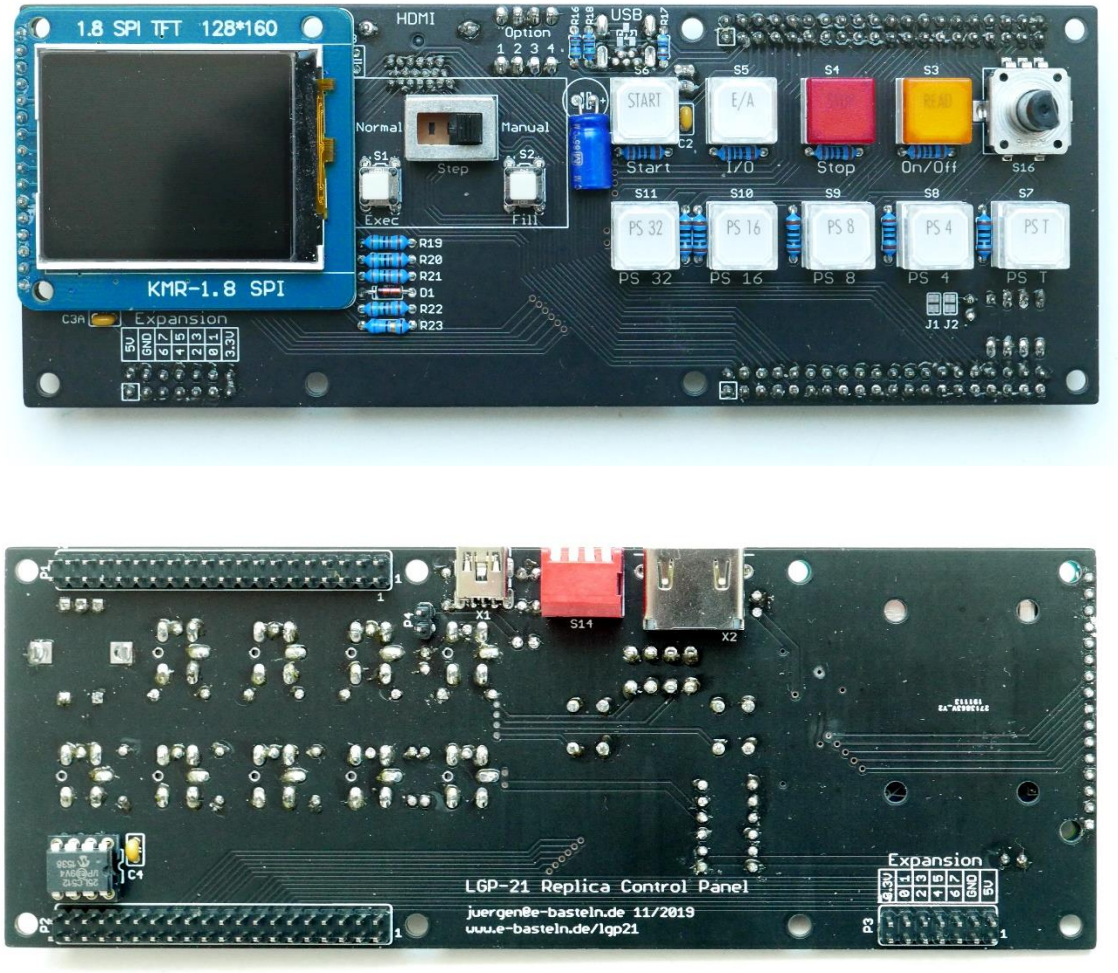


Configuring the FPGA

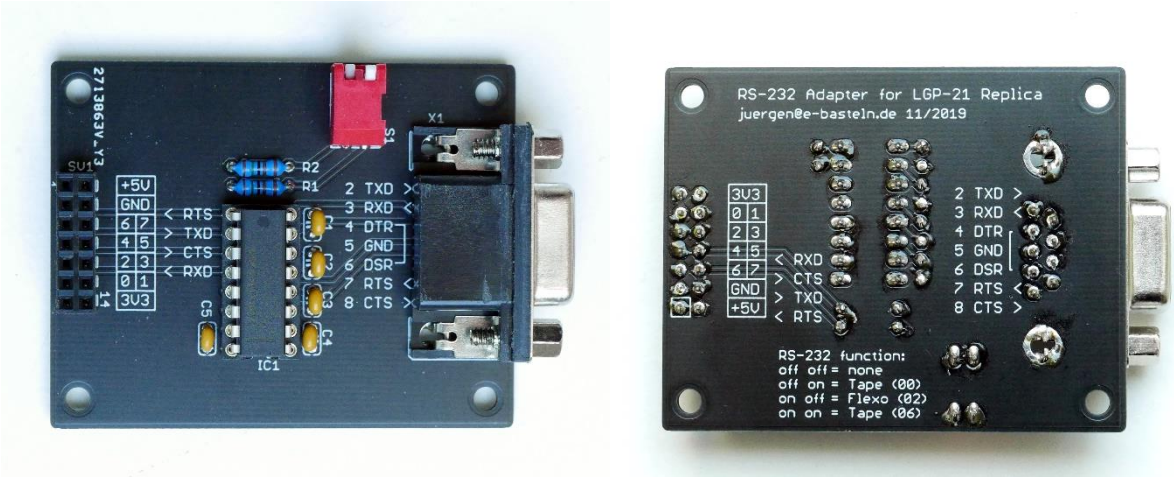
To configure the FPGA with an available .BIN binary file, it is *not* necessary to install the Xilinx development environment. A simple downloading tool from Numato, the supplier of the FPGA board, is required. This tool is only available as a Windows program. You only need to perform these steps once; the FPGA will then store its configuration in flash memory:

- Obtain the .BIN file for this project from www.e-basteln.de/lgp21.
- Download the FPGA Configuration Tool, mimasConfig.exe, from Numato: http://productdata.numato.com/assets/downloads/fpga/mimas/mimasConfig.exe
- Download the USB Driver from Numato. Unpack the ZIP file, but don't install it yet: http://productdata.numato.com/assets/downloads/common/numato_lab_usb_cdc_driver.zip
- Connect the Numato board to the PC via a USB cable.
- When prompted on the PC, install the USB driver.
- Run mimasConfig.exe, which does not require installation. Select the correct COM port (check in the device manager if unsure) and .BIN binary file, and click "Program".
- Further documentation from Numato can be found at https://docs.numato.com/doc/mimas-spartan-6-fpga-development-board/





Populated main PCB, top and bottom view. All connectors, the DIP switch, and the EEPROM and its decoupling capacitor are mounted on the bottom side.



The RS-232 expansion board. All components are mounted on the top. The Sub-D jack's plastic body can be filed down by 0.5mm to 12mm height.

PCB Assembly

Assembly of the LGP-21 PCB is mostly straightforward. Only through-hole components are used (except for optional transient suppression diode D2). Most components are mounted on top of the PCB, but all connectors, the DIP switch, and the EEPROM are installed on the bottom. The silkscreen print indicates the correct positions. No components are mounted on top of each other, and there are no constraints to the order of installing components.

Just a few notes:

- Prepare the LCD display. It will be powered by 5V, so its on-board 3.3V regulator needs to be active. Jumper JP1, near the GND and VCC terminals on the pin header, needs to be **open**.

- Prepare the mode slide switch. The mounting tabs need to be clipped off before installing it; the switch will be held securely by its eight pins. (This is the factory configuration for various other models of the CPT slide switch.)

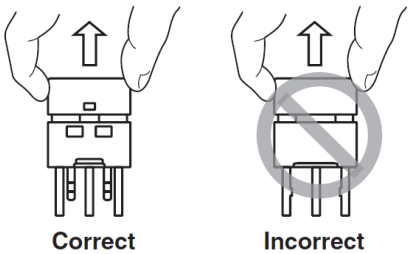
- The PCB is prepared for an alternative display module, which is connected directly via a flex cable rather than an SIL through-hole adapter. This connection is not used when you install the LCD with SIL adapter as pictured above. The four mounting holes beneath the LCD remain unused as well. Install capacitor C3 in location C3A and leave C3B unpopulated.

- The LCD, mode slide switch, encoder, and capacitor C1 are mounted on top of the PCB and will jointly determine the minimum height of the front panel. C1 should be mounted on the top side, lying flat. A test fit of these components, the OMRON switches, and the spacers you intend to use between the PCB and the front panel, is highly recommended! 7 mm spacers are recommended.

- Solder the LCD onto the main PCB with a pin header but *without* a socket, to keep its profile low. Depending on the spacer height between the PCB and the front panel, you may want to slightly elevate the LCD, to make it sit flush behind the front panel.

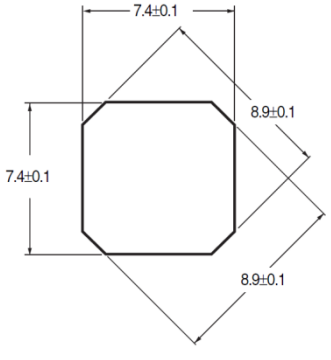
- For the serial EEPROM and the MAX3232 on the expansion board, there is room for sockets if desired.

- Before installing the OMRON switches, remove their key-caps. OMRON advises against pulling off the caps once the switches have been soldered, to avoid putting stress on the pins. Grab the caps on the side away from their mating latches, as illustrated.



- Be sure to install the red-illuminated OMRON switch in position S4 (Stop light). It is labelled “0-R1” on the side.

- Before putting the key caps back on, print and insert labels. These look best when printed on clear transparent film; plain paper absorbs and scatters light unevenly and gives a “cloudy”

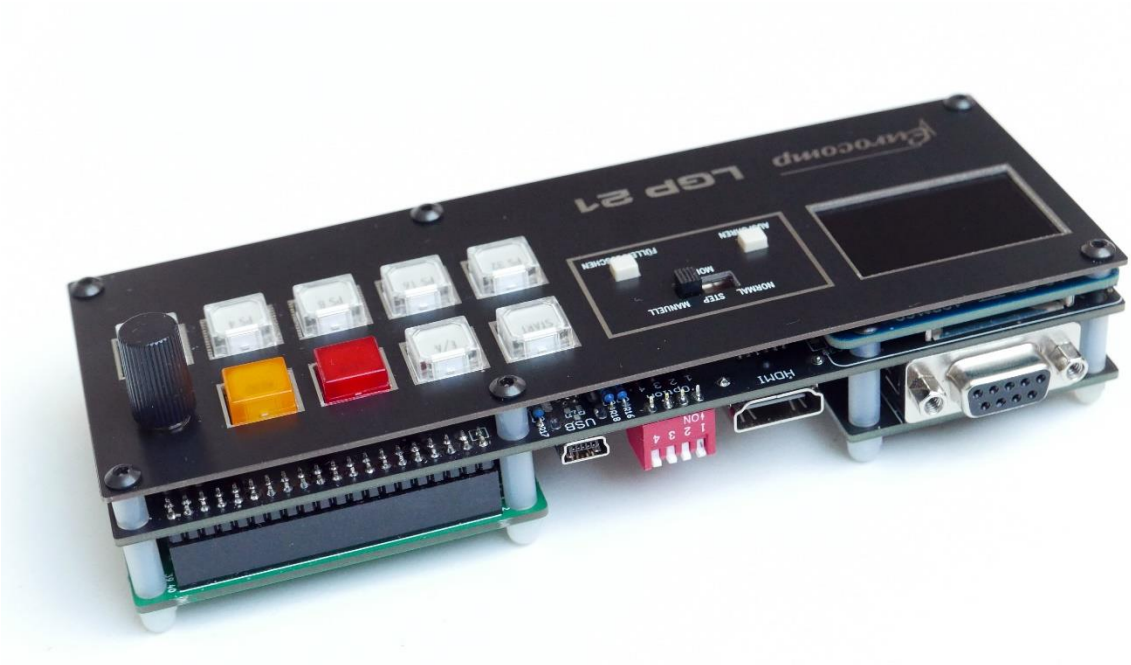


look when back-illuminated. OMRON's official dimension drawing is shown on the right; these labels fit into a recessed area inside the key caps. I have found that, unless they are printed on very thick film, the small labels can move around inside the caps. Larger labels which fill the full width of the caps stay in place better. A Powerpoint template with labels in both sizes is available on the LGP-21 page.

- If you get a label wrong, it is feasible to carefully pry the key caps back off (violating OMRON's advice).

Mounting

- The Mimas board and expansion board should be mounted below the PCB with four PCB spacers each. 12mm spacers work well.
- The plastic body of the RS-232 connector on the expansion board is 12.5mm tall and can be filed down slightly. The connector's metal front plate sits in front of the PCBs and can keep its full height.
- The front panel should be mounted to the PCB with six PCB spacers.
  7mm spacers work well for all mounting points except the upper left (LCD display position).
- The two upper mounting holes through the LCD should be used. You will need to cut custom spacer lengths or use washers for these.
- The encoder knob suggested on the parts list is cheap and unobtrusive, but needs to be drilled out with a 7mm drill if you don't want it to sit very high. The required depth of drilling depends on the height at which the front panel is installed – please check and drill after final assembly. Do not drill too deep; the knob should sit at least 0.5mm above the front panel to allow the pushbutton to be actuated! Before clamping the knob in a vise for drilling, wrap it with a few turns of masking tape – the plastic is quite soft.



One possible mounting scheme: 7mm spacers between the PCB and front panel, 12mm spacers between the PCB and Mimas and expansion boards below. For the two screws which are guided through the LCD board, trim spacers to the required length. Nylon cap nuts are used as feet. Screws have 25mm thread length, except for one 20mm screw which connects the PCB and expansion board only.

- The LCDs come mounted to their adapter PCBs with some tolerance. If your LCD is tilted or off-center vs. the cutout in the front panel, you can carefully lift it off with a knife and reposition the LCD – it is simply attached with double-sided adhesive tape. Be careful not to damage the flat cable and the white reflective foil behind the LCD.

Usage Notes

- The USB port provides power supply and the main terminal connection.
    - The USB device will appear on your computer as a composite device with *two* serial CDC devices. Since the LGP-21 can address its Flexowriter and paper tape punch/reader independently, two terminal connections via USB are used to simulate these devices.
    - This should work without further driver installation under Windows 10 and Linux. Earlier Windows versions will require an INF file which is not available so far.

- Like on the LittleGP-30, the rotary encoder has multiple functions:
    - Pushing and releasing the knob will alternate between clock rate selection and horizontal scrolling of HDMI drum display.
    - Rotating the encoder while holding the knob down adjusts the LED brightness for the control panel buttons (but not the LCD screen).

- The buttons on the control panel mostly serve the same function as on the original LGP-21. The yellow “power” button is re-purposed and replaces the “Start read”/”Stop read” levers on the Flexowriter.

- The LCD mainly shows the original LGP-21’s oscilloscope traces (in green) and the printed scale overlay (in white). In addition, the top line shows the current clock rate, inverted when controlled by the encoder.

- RS-232 interface
    - The RS-232 expansion board either provides a third peripheral device (high-speed paper tape punch & reader) or can operate in parallel with one of the USB devices in order to connect a real, physical terminal. This is controlled via the two DIP switches on the expansion board:
    - "00" UART not used. Tally Reader and Read/Punch both via USB (2nd channel).
      "01" UART duplicates Tally Reader device

"10" UART duplicates Flexowriter device
"11" UART serves as Tally Punch/Reader device
- The UART currently operates at a fixed speed or 19200 baud.

- Option switches:
  The four DIP switches enable or disable the replication of hardware options which were available for the LGP-21.
  - 1 – Doubled disk capacity (64 tracks).
    - Switches the HDMI display, disk simulation and logic equations to support a large disk with 64 tracks. XModem and EEPROM storage also support the larger disk size.
    - Changes are documented in the "Einbauanleitung für Speicher mit doppelter Kapazität, Zeichnung Nr. MiEK 69097-14 (1) A", file "Doppelter Speicher.pdf" from the Stuttgart server.
    - In instruction words, bit 31 (second-most significant bit) is chosen to store the 6th track address bit. This is a guess, based on the fact that this bit is shown in the C register display on the oscilloscope. To be confirmed by original documentation or programs, or by measuring the S2 and S3 signals in an original large-disk LGP-21.
  - 2 – Fast memory and index register, *not implemented yet,*
  - 3 – Model 81 “sequence tag mode”, *not implemented yet,*
  - 4 – reserved for future use.

- Hardware configuration jumpers – *not implemented yet.*
  Jumpers J1 and J2 are meant to inform the FPGA about different hardware configurations (e.g. display types); these are not currently used.

- XModem storage of disk contents:
  To support experiments with different programs, complete disk contents can be transferred between the FPGA and the computer used for terminal emulation via XModem transfers.

  - The classic XModem protocol is used, with 128 Byte blocks and 1-byte checksums (not CRC).
  - Main memory and register tracks (A, R, C) are stored. The size of main memory images *downloaded* from the FPGA depends on the current setting of option switch 1 (replication of small or large disk, i.e. 32 or 64 tracks of 128 words each). Small or large disk images can be *uploaded* at any time.
  - The binary format of disk images differs from the LittleGP-30 replica format: Register tracks A, R, C are transferred first, followed by either 32 or 64 tracks of main memory data. Word order within the tracks follows the physical order on the disk; logical sectors are interleaved as documented in the original LGP-21 manuals. Byte order within each word is low-byte first.
  - For XModem transfers, set the LGP-21 replica to “Manual” mode and use the Flexowriter terminal.

- Download of the disk contents from the FPGA is started via the terminal program. The simulator will recognize the NACK control character sent by the terminal program and will automatically start the transfer. This is part of the standard XModem protocol and should work for all terminal programs that implement XModem.
- Upload of drum contents to the FPGA is also started from the terminal program. It requires sending the reserved "\" character to signal a transfer to the replica, which will then enter reception mode and send a NACK. This function of the "\" character is *not* an XModem standard feature, but a convention adopted for the LGP-21 replica only.
- The "\" can either be sent manually from the terminal program; in this case the upload must be started max. 100 seconds afterwards. Alternatively, some terminal programs are configurable to send an XModem upload command automatically.

- EEPROM storage of disk contents:
  A serial EEPROM is provided on the replica PCB for permanent storage of disk data. Its contents are automatically read on power-up to initialize the disk data and registers. Disk content is not written back to the EEPROM automatically, but only on demand: Press the red "Stop" button to initiate writing.

Bill of Materials

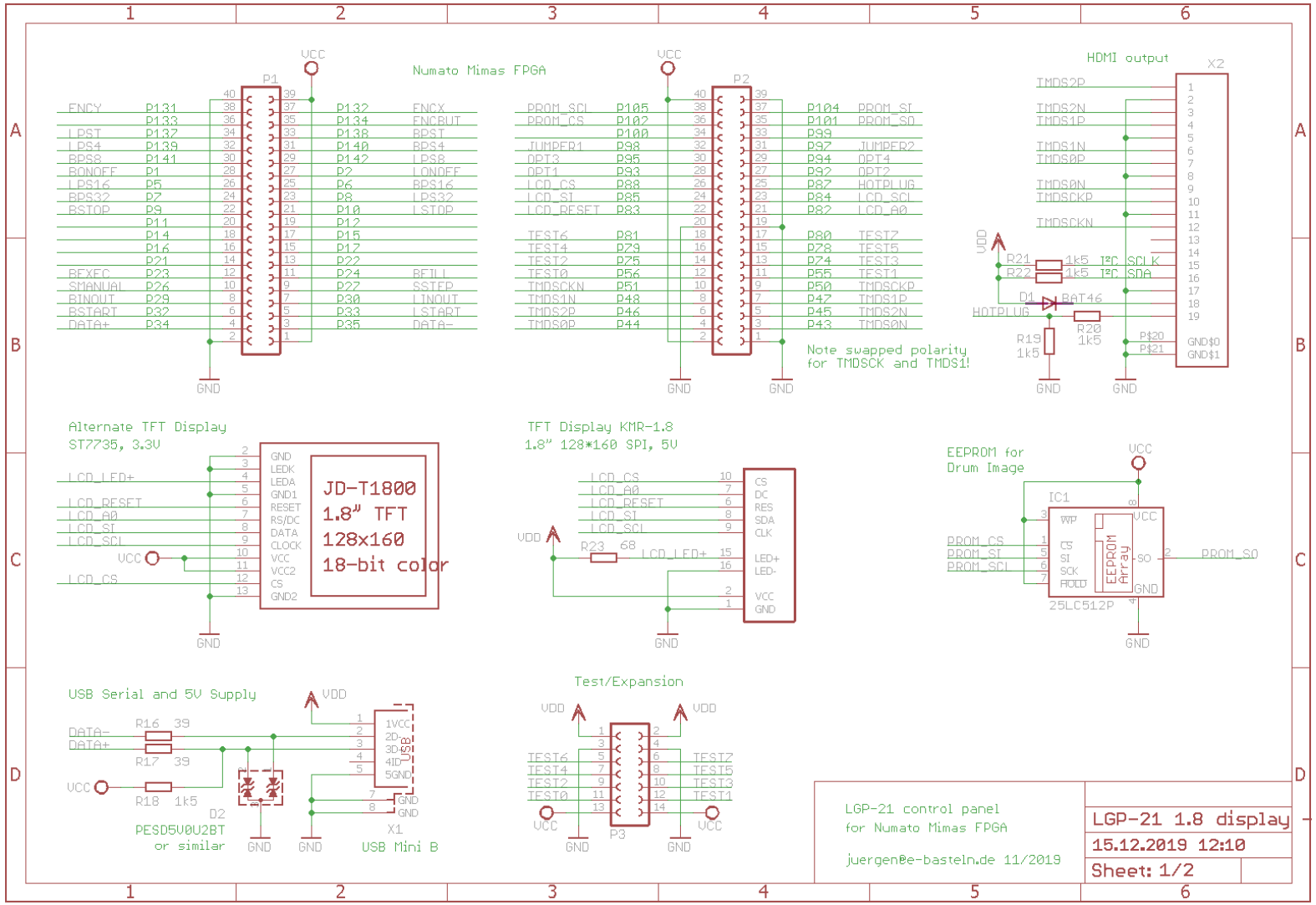
Front Panel

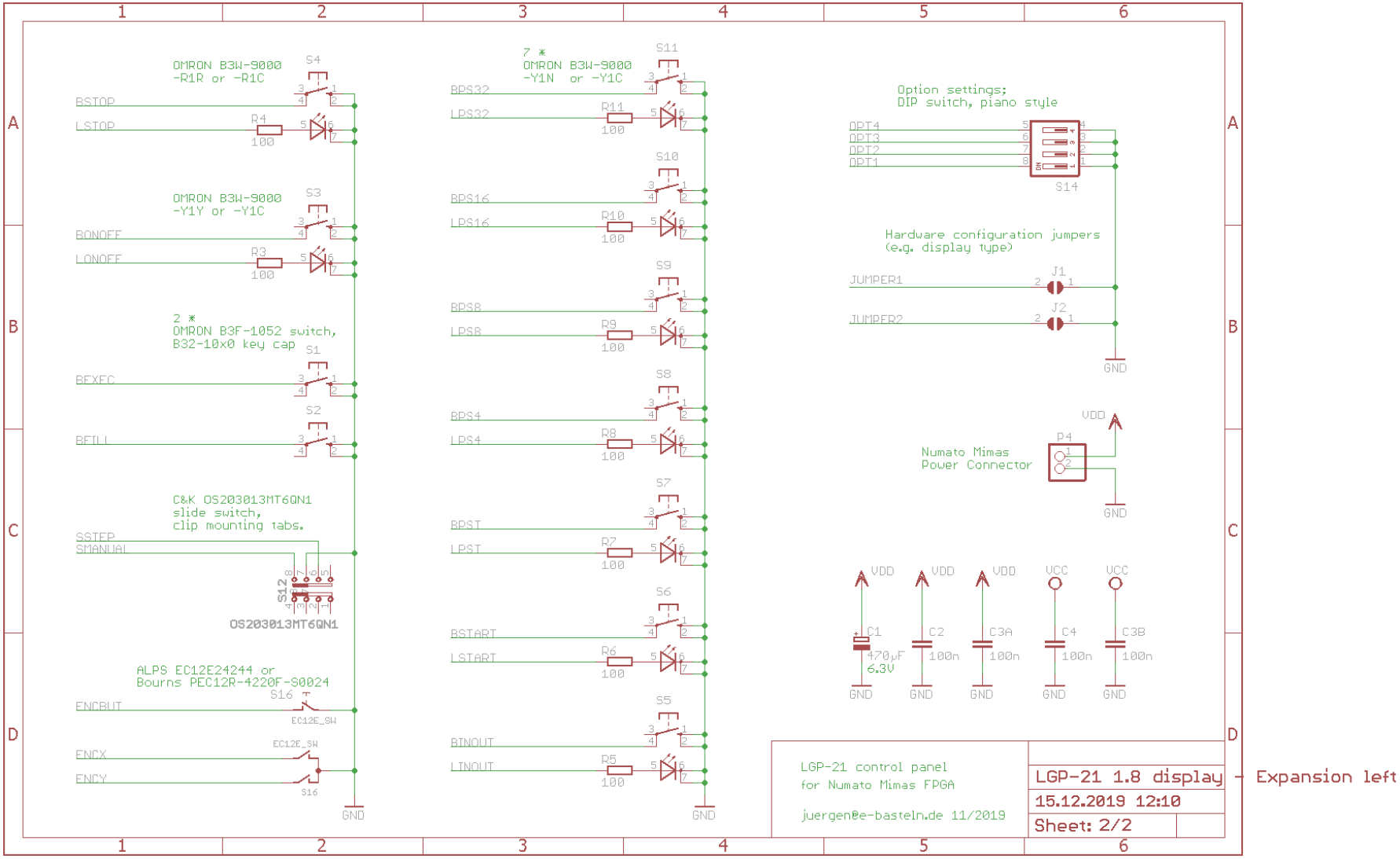
Part	Quant	Item	Value	Package	Comment
C1	1	electrolytic capacitor	470µF, 6V	2.54 mm pitch, 6mm diameter	
C2 - C4	3	ceramic capacitor	100nF	2.54 mm pitch	
D1	1	Schottky diode	BAT46	DO35-7	
D2	1	dual TVS diodes	PESD5V0U2BT	SOT23	optional
IC1	1	serial EEPROM	25LC512P	DIL8	
P1, P2	2	pin header	2*20 pins	2.54 mm pitch	male, straight
P3	1	pin header	2*7 pins	2.54 mm pitch	male, straight
P4	1	pin header	1*2 pins	2.54 mm pitch	male, straight
R3 - R11	9	resistor 0.6W	100	0204/7	
R16, R17	2	resistor 0.125W	39	0204/5	small package!
R18	1	resistor 0.125W	1k5	0204/5	small package!
R19 - R22	4	resistor 0.6W	1k5	0204/7	
R23	1	resistor 0.6W	68	0204/7	
S1, S2	2	tactile switch	OMRON B3F-1052	jm-switch-CK	
S3	1	tactile switch	OMRON B3W-9000 Y1Y		yellow LED, yellow cap
S4	1	tactile switch	OMRON B3W-9000 R1R		red LED, red cap
S5 - S11	7	tactile switch	OMRON B3W-9000 Y1C		yellow LED, clear cap
S12	1	slide switch	C&K OS203013MT6QN1	OS203013MT6QN1_NOTABS	clip mounting tabs
S14	1	DIP switch	4 positions	switch-dil	
S16	1	encoder with switch	ALPS EC12E24244	or Bourns PEC12R-4220F-S0024	24 steps/rev with detents
X1	1	USB jack mini B		through hole	
X2	1	HDMI jack	HDMI-THROUGH-3X	through hole, 6+6+7 pins	as used in Playstation PS3 model 2000/2500
LCD1	1	TFT display	KMR-1.8 SPI	SIL 16 pins	128*160 pixel
(none)	2	switch cap	OMRON B32-10x0		-1000 ivory, -1060 white

RS-232 Interface

Part	Quant	Item	Value	Package	Comment
C1 - C5	5	ceramic capacitor	100nF	2.54 mm pitch	
R1, R2	2	resistor 0.6W	1k5	0204/7	
IC1	1	RS-232 level shifter	MAX3232	DIL16	
S1	1	DIP switch	2 positions		
SV1	1	female header	2*7	2.54 mm pitch	
X1	1	Sub-D connector	9 pin female	angled, 9.4mm edge distance	

Schematics


Numato Mimas FPGA
P1
P2
HDMI output
X2
Note swapped polarity
for TMDSCK and TMDS1!
Alternate TFT Display
ST7735, 3.3V
JD-T1800
1.8" TFT
128x160
18-bit color
TFT Display KMR-1.8
1.8" 128*160 SPI, 5V
EEPROM for
Drum Image
25LC512P
USB Serial and 5V Supply
PESD5V0U2BT
or similar
USB Mini B
Test/Expansion
P3
LGP-21 control panel
for Numato Mimas FPGA
juergen@e-basteln.de 11/2019
LGP-21 1.8 display - Expansion left
15.12.2019 12:10
Sheet: 1/2


OMRON B3W-9000
-R1R or -R1C
S4
BSTOP
LSTOP
R4
100
OMRON B3W-9000
-Y1Y or -Y1C
S3
BONOFF
LONOFF
R3
100
2 *
OMRON B3F-1052 switch,
B32-10x0 key cap
S1
BEXEC
S2
BFILL
C&K OS203013MT6QN1
slide switch,
clip mounting tabs.
SSTEP
SMANUAL
S12
OS203013MT6QN1
ALPS EC12E24244 or
Bourns PEC12R-4220F-S0024
S16
ENCBUT
EC12E_SW
ENCX
ENCY
GND
7 *
OMRON B3W-9000
-Y1N or -Y1C
S11
BPS32
LPS32
R11
100
S10
BPS16
LPS16
R10
100
S9
BPS8
LPS8
R9
100
S8
BPS4
LPS4
R8
100
S7
BPST
LPST
R7
100
S6
BSTART
LSTART
R6
100
S5
BINOUT
LINOUT
R5
100
GND
Option settings;
DIP switch, piano style
OPT4
OPT3
OPT2
OPT1
S14
Hardware configuration jumpers
(e.g. display type)
JUMPER1
JUMPER2
J1
J2
GND
VDD
P4
Numato Mimas
Power Connector
GND
VDD
VDD
VDD
VCC
VCC
C1
470µF
6.3V
C2
100n
C3A
100n
C4
100n
C3B
100n
GND
GND
GND
GND
GND
LGP-21 control panel
for Numato Mimas FPGA
juergen@e-basteln.de 11/2019
LGP-21 1.8 display - Expansion left
15.12.2019 12:10
Sheet: 2/2

RS-232 Expansion Board