Introducing TULIP4041

The

ULtimate

Intelligent

Peripheral

for the ‘41

Contents

Credits due ...

The TULIP4041 project started with a post from Andrew Menahue (UK) in the MoHPC forum in May 2023. This was picked up by Thomas Fänge (Sweden). Both were a tremendous help in getting the project where it is today.

Support and inspiration came from visitors of the various HP websites, forums and various ad-hoc meetings.

Some vital parts of the firmware lean heavily on work from others: Christoph Giesselink (V41, HP-IL and printer simulators), Jean-Francois Garnier (EMU41, HP-IL emulation, PILBox) and Mike (NutEM/PC)

Thanks to Sylvain for the firsts tests and doing this presentation

TULIP4041, what is it?

Short version, it is (almost) all HP41 peripherals in one:

- *ROM emulator (including Bankswitching)*
- *QROM emulator (MLDL, HEPAX)*
- *User memory emulator (User/Extended/Expanded)*
- *Peripheral emulator (Printer/Blinky, HP-IL, Wand, TIME)*
  - No ‘real’ HP-IL or barcodes, in/output only through USB or IR
- *HP41 bus tracer and HP-IL scope*
- *And more …*

Many of the above functions have been tested but not fully implemented

From bulb to flower

In the spring of 2023 Andrew Menahue published his work based on the RP2040. This triggered me to start on what is now the TULIP4041. I had two main objectives to expand his work:

- *Use the RP2040's PIO for the HP41 bus interfacing. Andrew and Thomas use bit banging for this, but this has limitations (performance, overclocking needed)*
- *Implement (virtual) HP-IL, many HP41 peripherals have been emulated in hardware, but not HP-IL and for me that was a missing link*

Collateral

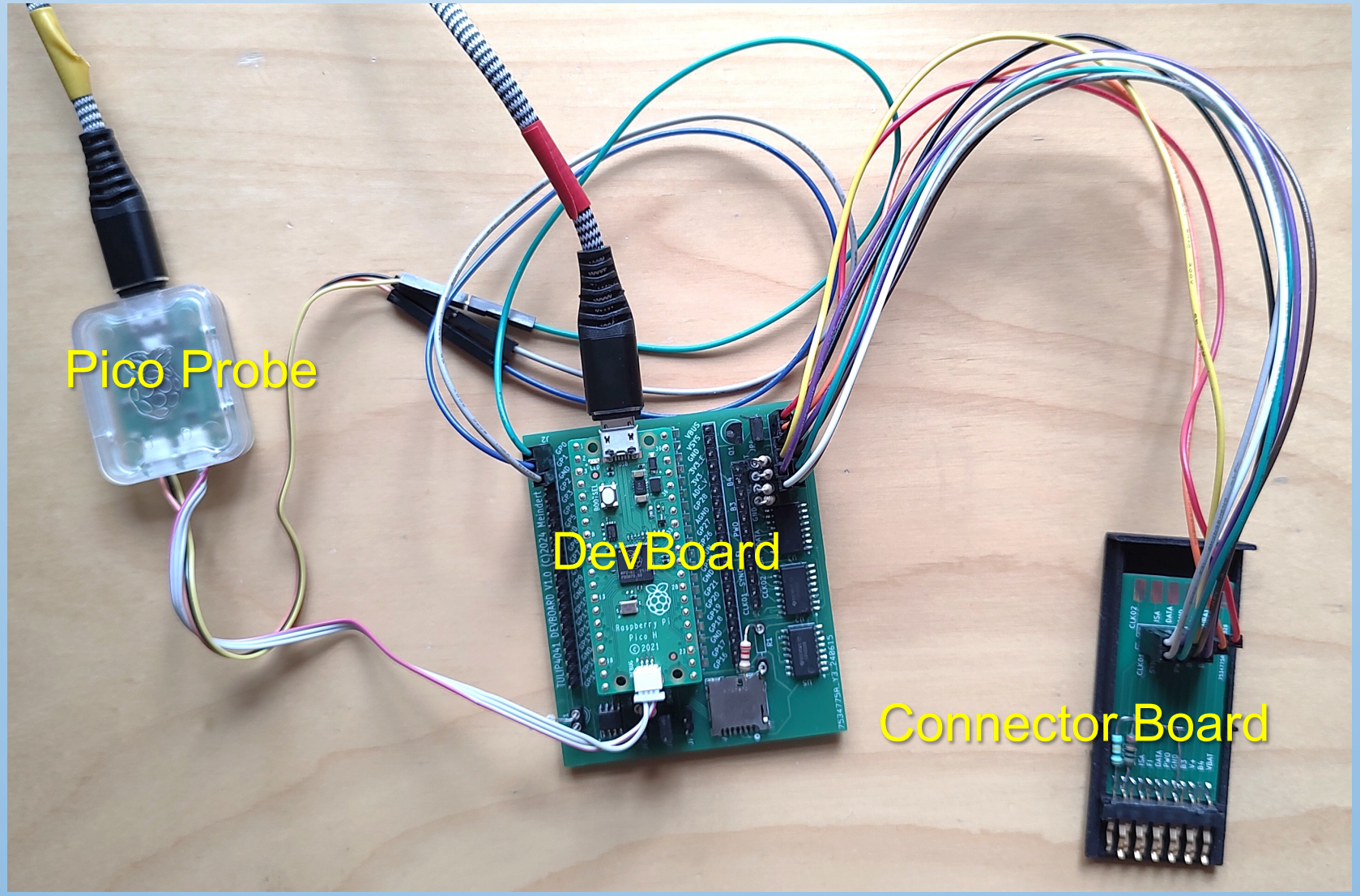
With the main peripheral tools working (driving FI, catching peripheral instructions, bus tracer) an interesting side project happened:

- *With an HP41 bus tracer at hand Thomas decided to dive into the last white spot in the HP41 world: the Blinky infrared printing module. I could borrow a real Blinky module and made my own traces available. Together with Thomas, Christoph and Mike we managed to understand the inner workings, and Blinky is now available on the DM41X thanks to these activities.*
- *Thomas has a full working Blinky emulation in his Tiny project (also RP2040 based)*

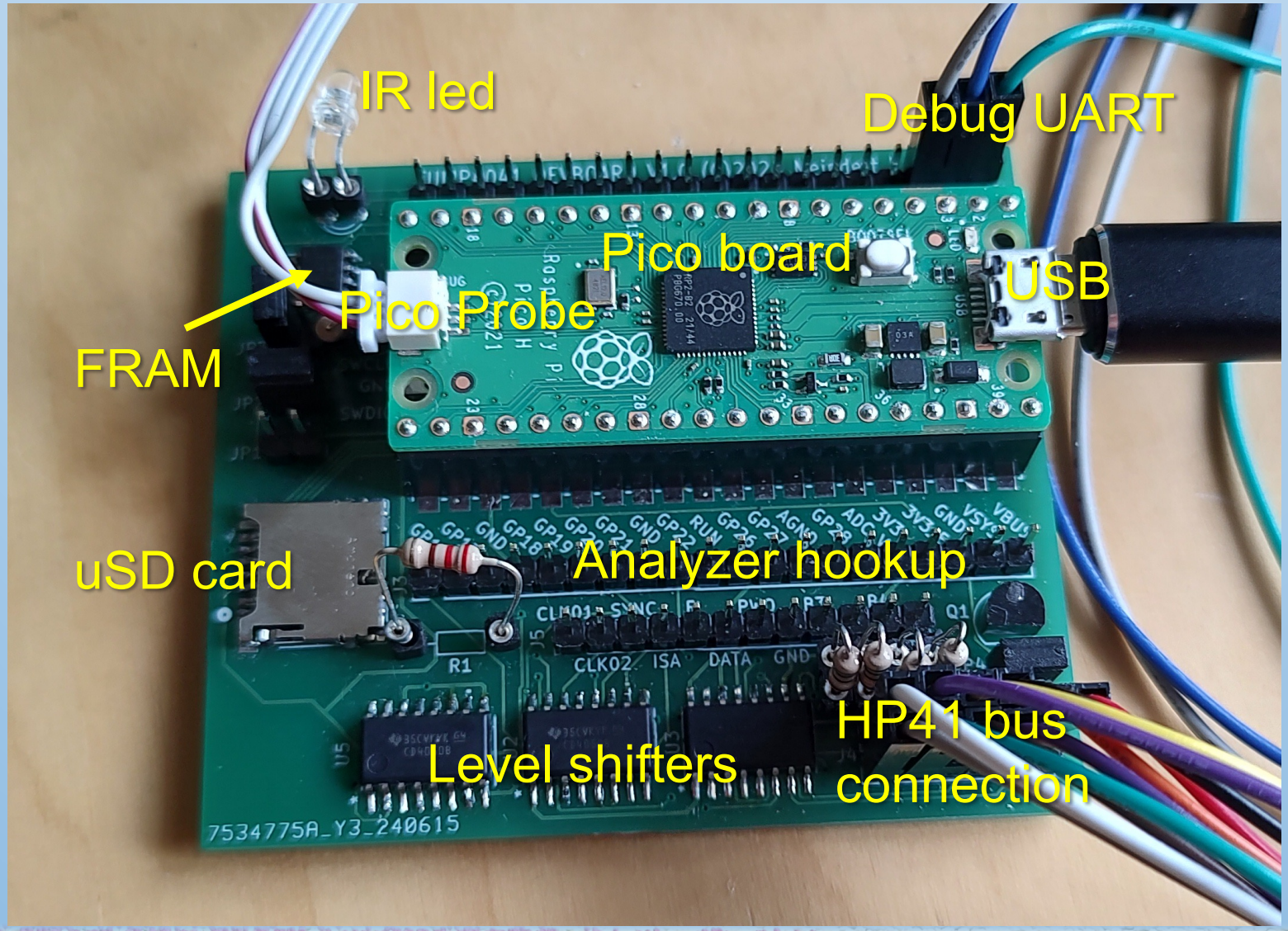
TULIP4041 Development board

- *Exists, comes with a module connector board*
  - HP41 bus tracer / HP IL Scope
  - HP-IL and PILBox emulation
  - HP82143A printer emulation, IR printing
  - Extended Memory emulation
  - CLI to control ROMs, emulation and tracer
  - More functions to come with ongoing firmware development
- *The DevBoard is on pre-sale, volume will be ordered and shipped after evaluation of the Pico2 with the latest RP2350 processor*
- *User will receive only the PCB's*
  - Component BOM published, bring your own module connector
  - Some soldering required

DevBoard setup



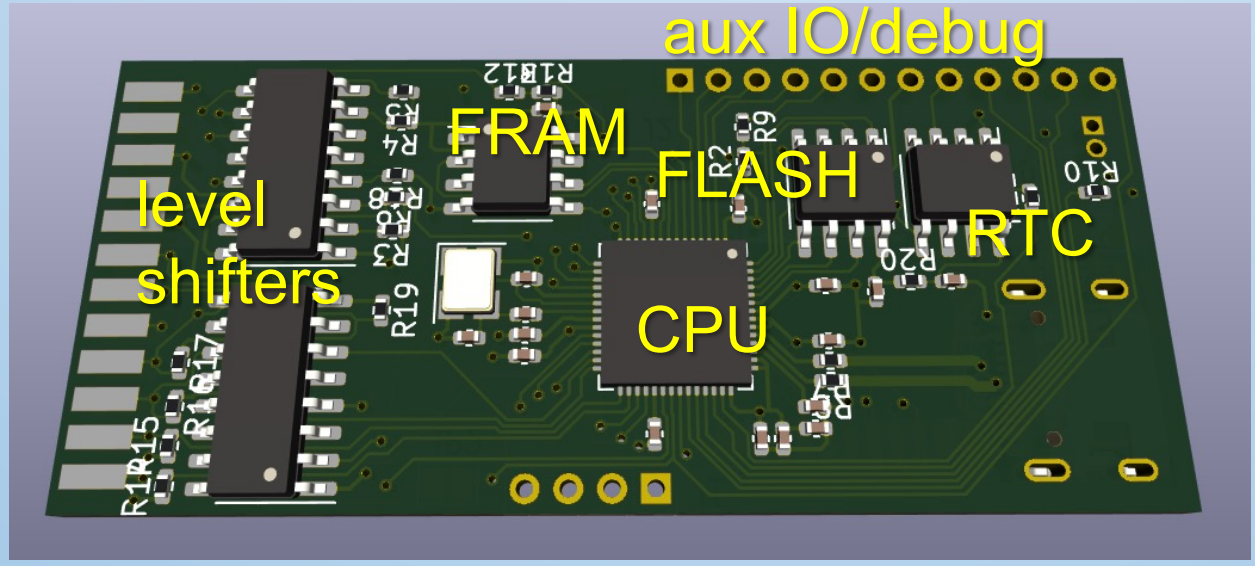
DevBoard setup

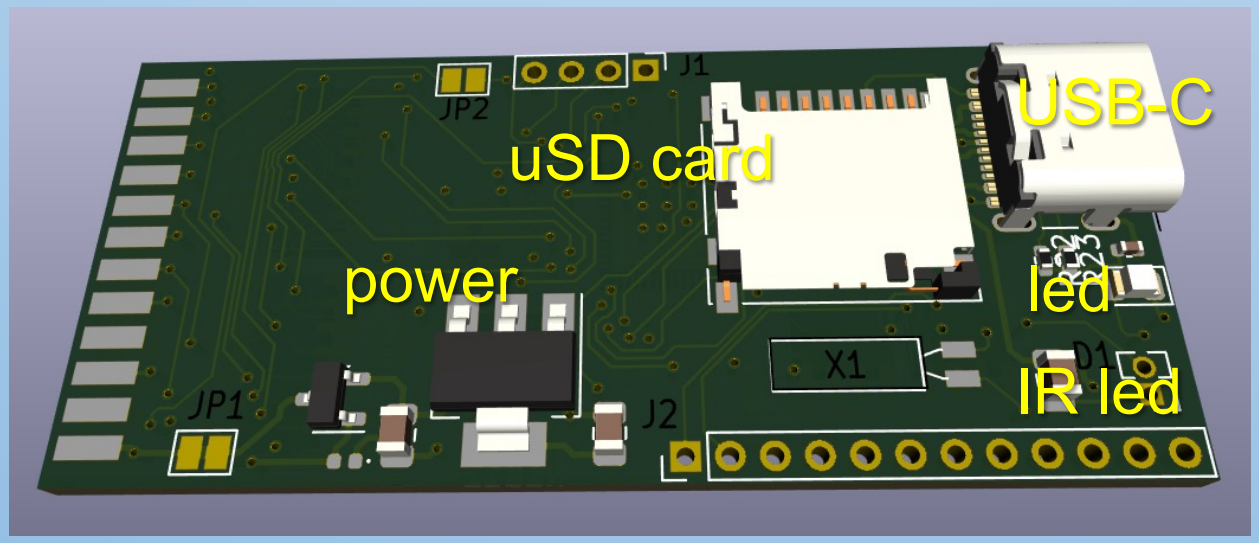


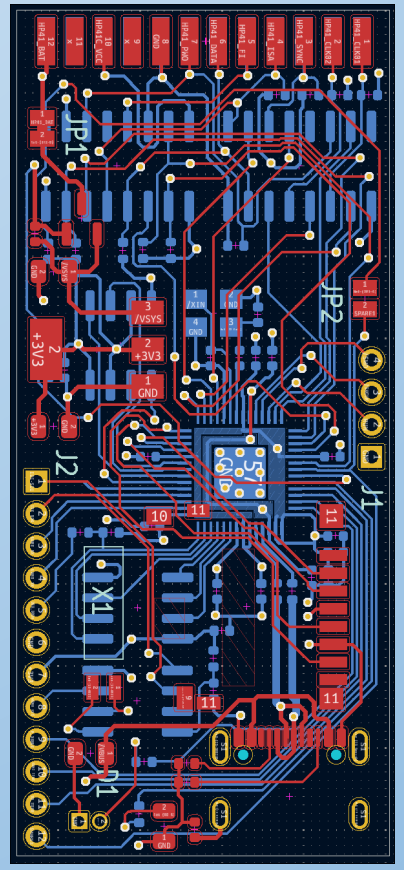
TULIP4041 module version

- *Hardware design ongoing*
  - All functions of the DevBoard except FI tracing
  - Extra RTC for TIME emulation (needs external backup battery)
  - More flash memory (up to 16 MByte)
  - 3D printed module housing
  - More functions to come with ongoing firmware development
- *The TULIP Module hardware design now paused pending a decision to migrate to the RP2350 CPU*
  - Recently introduced by Raspberry Pi
  - Presumable lower power consumption, we need this
  - More RAM (trace buffer !)
  - More powerful CPU (M33 vs. M0+), but overkill
  - More PIO state machines (HP41 bus tricks, HP-IL?)

TULIP4041 module (current design state)

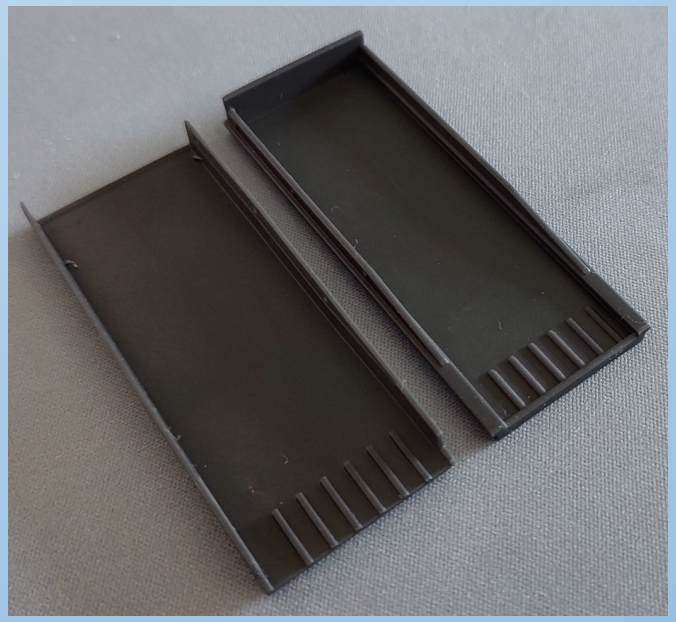






TULIP4041 module

- *3D printed housing in development*
  - I/O cutouts to be defined
  - First trials
  - By Andrew Menahue



Challenges

- *HP41 Module connector is not supplied*
  - Always bring your own module connector
  - There may be a possible solution coming, stay tuned …
- *RP2040 or RP2350*
  - Evaluation pending, Pico 2 boards in backorder
- *Documentation*
  - Always a challenge
- *Feature creep*
  - With the TULIP4041 almost every possible peripheral is possible
  - Many ideas, but must stay focused on roadmap

How does it work?

The TULIP4041 is based on the RP2040 microcontroller, by Raspberry Pi. It has some unique features that makes it an almost perfect fit for HP41 interfacing:

- *Dual core ARM Cortex M0+ @133 MHz*
- *Up to 16 MByte External QSPI FLASH for code and data (ROM images)*
- *Many peripheral interfaces*
- *PIO, Programmable IO controllers (!)*
- *Very low cost (around EUR 1)*
- *Multi platform open development toolchain*

How does it work?

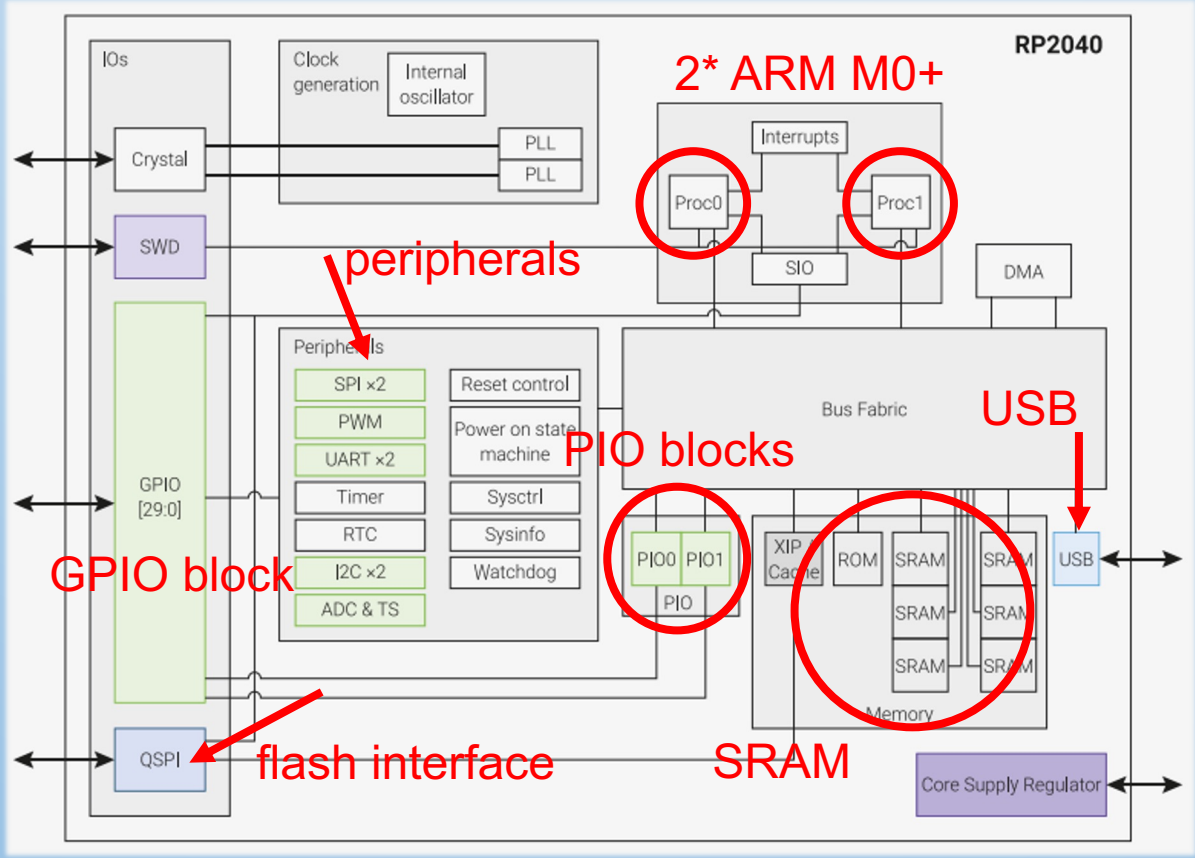
The RP2040 has a few disadvantages as well:

- *No internal FLASH, always external FLASH needed: more costs and slower but large capacities up to 16 MByte*
- *High power consumption (TULIP firmware runs at about 25-30 mA) and no real low power modes, lowest power mode in TULIP is stil 2.5-3 mA*
- *Some time needed for boot after power-up*

A new RP2350 processor is now available. It may be overkill but could offer better power management. Evaluation pending.

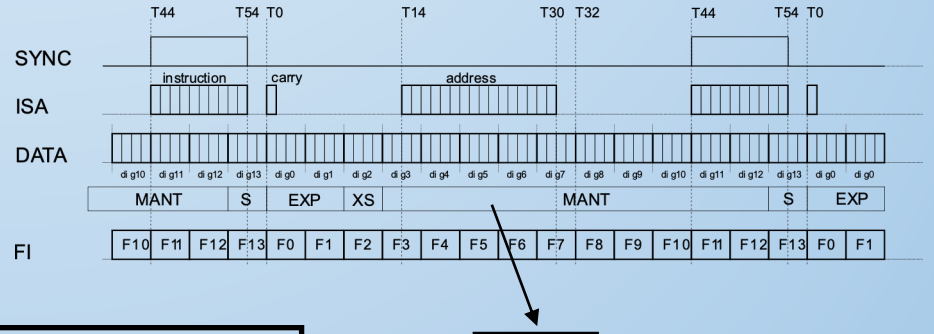
How does it work?

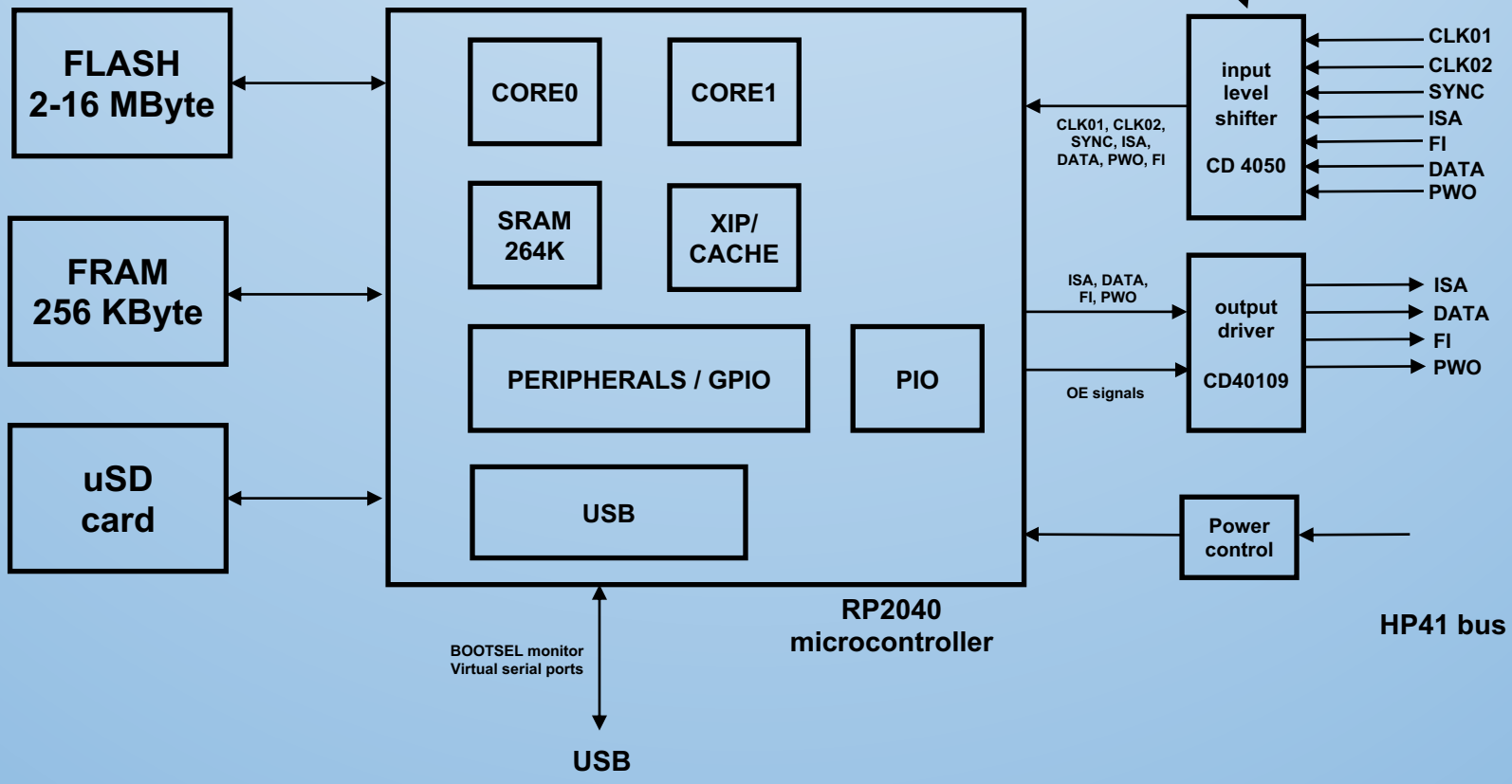
RP2040 processor block diagram



How does it work?

TULIP4041 block diagram

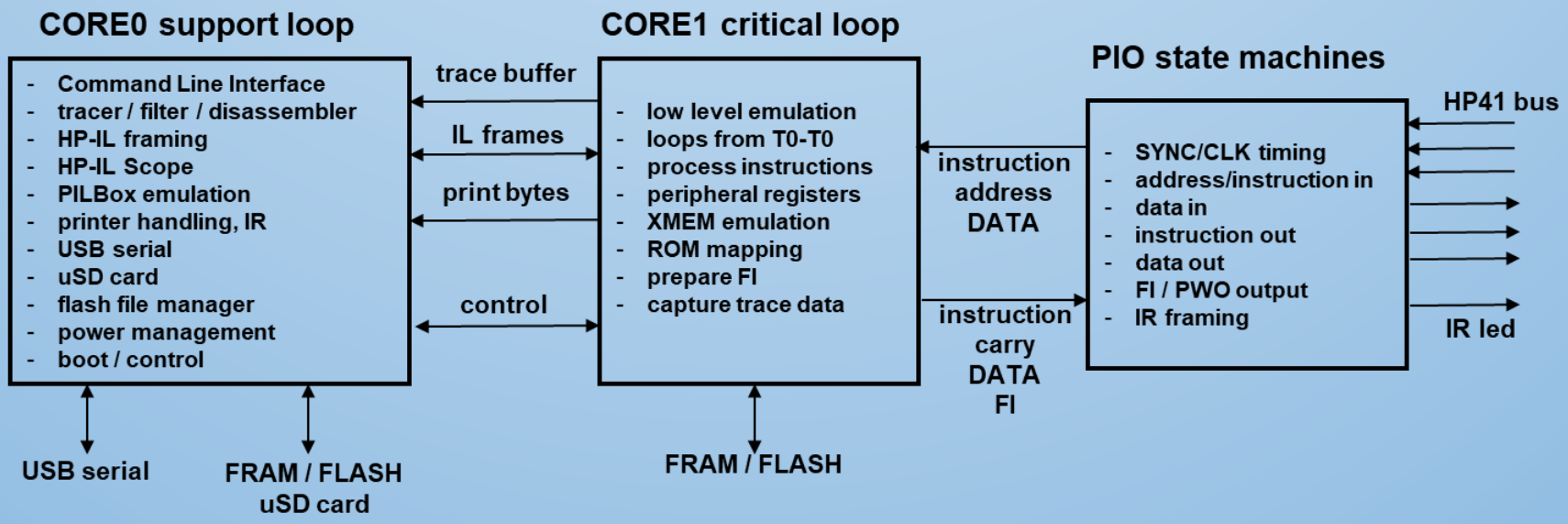




How does it work?

TULIP Firmware architecture

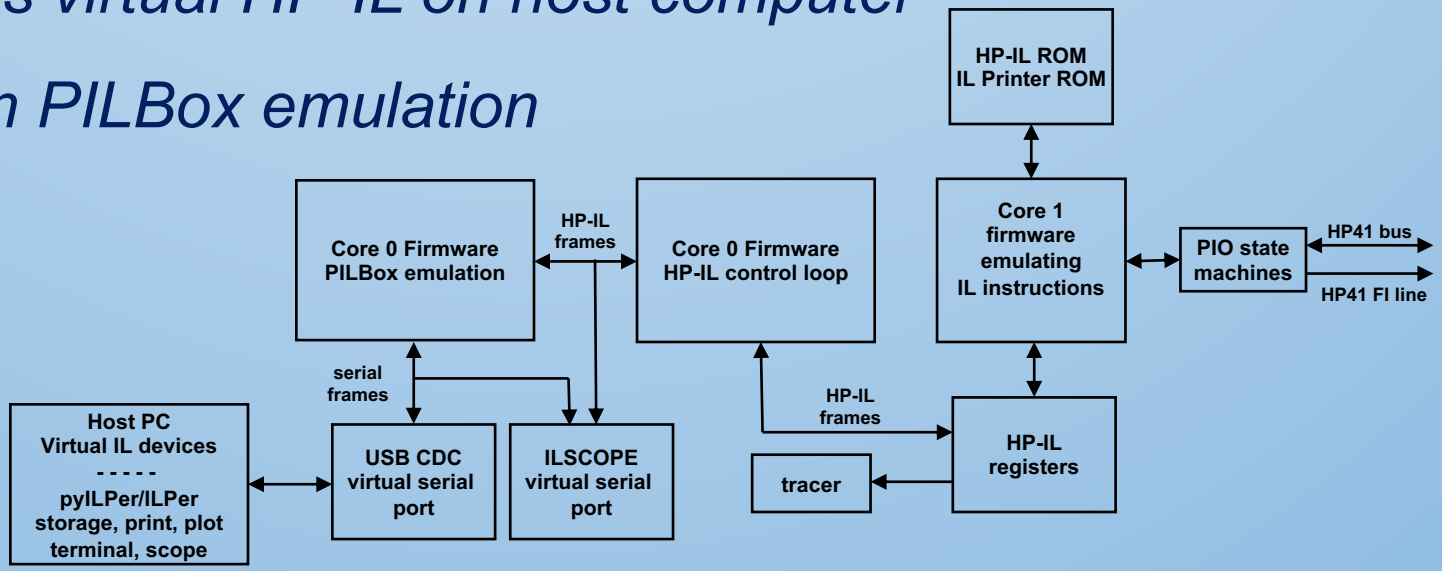
- *Uses both M0 cores @ 125 MHz*
- *Almost all PIO capacity is used*
- *Almost all GPIO's are used*



How does it work?

Fully functional HP-IL emulation with ILScope function

- *Based on V41/EMU41 implementation of HP82160A*
- *HP-IL Printer ROM can be disabled (and will NOT go to Page 4)*
- *Targets virtual HP-IL on host computer*
- *Built-in PILBox emulation*



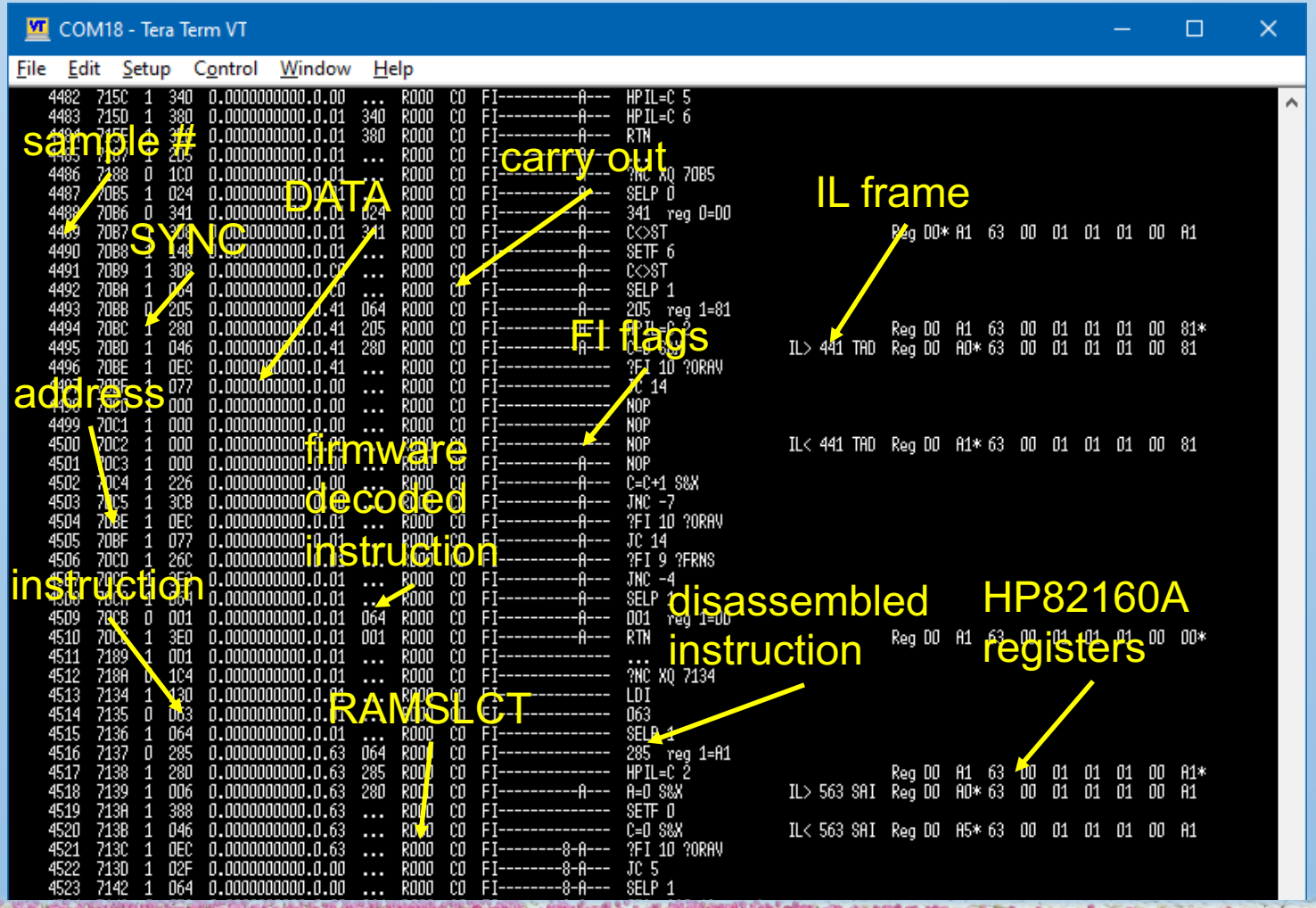
How does it work?

HP41 bus tracer with disassembler

- *Passive catching all HP41 bus cycles*
- *Optional trace of HP-IL registers and IL frames*
- *Disassembly of HP-IL peripheral instructions*
- *Optional filter for some known system loops, system ROMs*
- *Currently buffer of 3000 samples*
- *One of the next versions will have user defined filters (block or pass address range) and triggers*
- *Near real-time bus tracing*

How does it work?

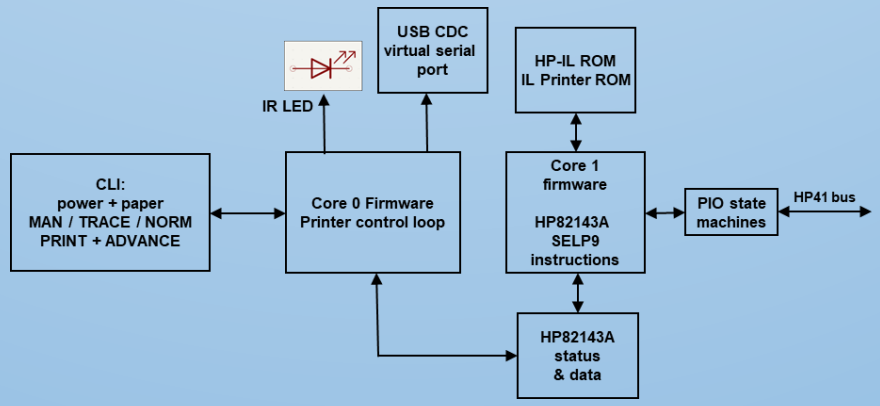
HP41 bus tracer with disassembler



How does it work?

HP82143A printer emulator

- *Original HP82143A ROM*
- *Prints to HP82143A simulator on host*
- *Data via USB serial or IR (to external IR receiver)*
- *Use CLI to push PRINT / ADV buttons, power, load paper and MAN / TRACE / NORM slider*



How does it work?

Command Line Interface (CLI)

- *Status and control of the TULIP4041*
- *Enter firmware upgrade mode*
- *Plug/unplug ROMs*
- *Control HP82143A printer (buttons/slider/power/paper)*
- *Plug/unplug XMEM modules*
- *Control tracer (filters)*

```
  CDC Port 2 [tracer] connected
TULIP>
TULIP>
TULIP> system
type help for more info

*************************************************************************
*
*   Welcome to TULIP4041 - The ULtimate Intelligent Peripheral for the HP41
*
*   VERSION 00.01.01 BETA
*
*   Running at :  125.00 MHz
*   Total heap :  218.00 KBytes
*   Free heap  :   77.00 KBytes
*   Tracebuffer:  140.00 KBytes, 3000 samples = 48 bytes/traceline
*
*************************************************************************
TULIP>
```

TULIP4041, current status (September 2024)

- *TULIP DevBoard design ready*
- *Hardware tested on the HP41CX, C, and CL*
- *First unit outside my lab is tested by Sylvain and some bugs were already fixed with his input*
- *First BETA sources published on GitHub*
- *Awaiting backorder of Pico-2 boards*
- *Evaluate RP2350 (Pico-2), focus on power management, verify if this works on the current DevBoard design*
- *Decide RP2040 or RP2350*
- *Order DevBoards for BETA users plus some extra stock*

TULIP4041, current status (September 2024)

- *The first public BETA firmware is published with the following functionality:*
  - Command Line Interface (CLI) with system functions
  - Micro SD card interface working but not actively used
  - plug and unplug (status and selected modules)
  - HP-IL/HP-IL Printer and PILbox emulation to virtual HP-IL devices on a host computer
  - HP82143A emulation to printer simulator on PC (IR and virtual USB serial port)
  - Extended Memory emulation with FRAM testing
  - HP41 bus tracer with disassembler
- *Some minor issues identified and to be fixed*

TULIP4041, next steps

- *Collect experience from BETA users*
- *Finalized hardware design of module version*
- *Prepare BETA2 firmware version*
  - Fix bugs
  - Add basic FLASH file system for ROM/MOD images, import/export using micro SD card
  - Enable full plug/unplug of ROM images in FLASH/FRAM
  - Add support for HEPAX and bank switching
  - Add support for QROM (MLDL RAM)
  - Add Power Management
  - Enhance Tracer functionality
  - Extended Functions and Quad User memory

TULIP4041, next steps after BETA2

- *Verify hardware design of module version, first prototypes (December 2024 ??)*
  - Availability of RP2350 (if I do the switch) may be critical
- *Prepare V1.0 firmware version (November 2024??)*
  - Add support for MOD files, plugging/unplugging
  - Complete HP-IL emulation (device mode)
- *Pre-sales of module version*
- *Module version redesign (if needed) and prototypes*
- *Production order (February/March 2024)*
- *Shipment of module version*

TULIP4041, Roadmap / ideas

- *Serial interface to real (new) PILBox*
- *Blinky emulation*
- *Wand emulation, paper keyboard in CLI*
- *HP-IL Mass Storage emulation on micro SD card*
- *TULIP ROM*
  - Expanded Memory functions / MAXX emulation
  - custom peripheral functions
  - direct RAW file import/export from/to uSD card
  - HP41 interface to CLI functions
    - plug/unplug ROMs
    - co-processor function access (PNG, math accelerator)

Wrap up

TULIP4041 is for me a very exciting project, its functionality goes beyond what I ever thought possible

All sources, documentation and schematics will be open source.

The HP41 is truly a system that will keep on running

Thanks to Sylvain for doing the presentation

Time for demo and Q&A