SCOMS TACNPR project

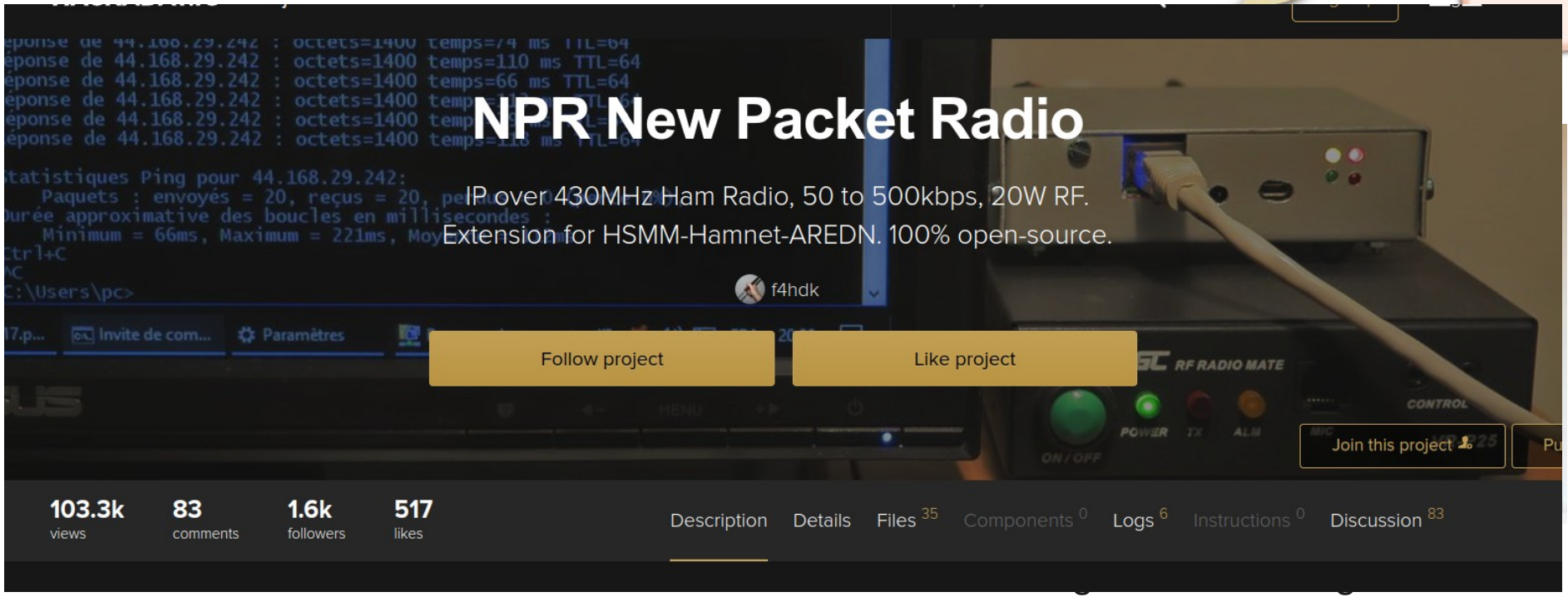
Binary-compatible New Packet Radio HW w/ integrated SRAM, USB serial & 20W RF PA

OH3HZB & OH2EAT & OH2FLO et al.
2021-2022

Presentation at VUSHF2022 27.5.2022
Lasse OH3HZB

At first some background;
the original NPR project by F4HDK

What is NPR?



https://hackaday.io/project/164092-npr-new-packet-radio

What is NPR?

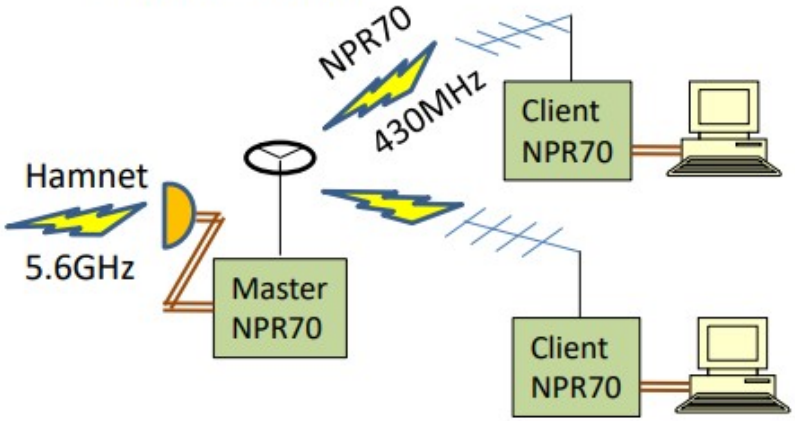
- NPR = **New Packet Radio**
- Bidirectional protocol by F4HDK, **optimized for point-to-multipoint** (managed TDMA)
- 110 kbps to 1 Mbps (raw),
  50-500 kbps (net) on 70cm HAM band
- Original design was based on ISM radio module (SI4463) and STM32 eval board, intended to be easy & cheap to build
- **Ethernet** connection,
  no special software on PC
- **Open-source**: open HW, open SW,
  open protocol specification

Original NPR design

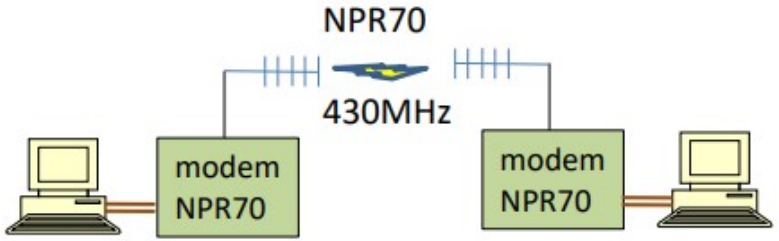
https://hackaday.io/project/164092-npr-new-packet-radio

Optimised for “Point To Multipoint” configurations

- 1 central repeater, called MASTER
- Several CLIENTS



Possibility to use “Point to Point” configuration



Source: https://cdn.hackaday.io/files/1640927020512128/NPR70_introduction_EN_v3.6.pdf

What is NPR?

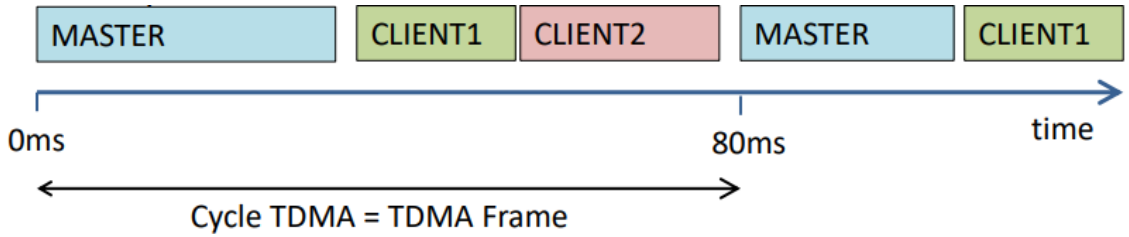
- **Compatible with HAM radio rules**
  - Periodic transmission of callsigns
  - No encryption
  - The Master node transmits only when solicited (at least by one “client”)
- **Limitations:**
  - Currently max 7 simultaneous clients (planned to be extended to 15)
  - 300 km max range (due to protocol)
  - Modulation not intended for “mobile use”

Source: https://cdn.hackaday.io/files/1640927020512128/NPR70_introduction_EN_v3.6.pdf

What is NPR?

- Protocol designed by Guillaume F4HDK
  - Modulations: 2GFSK, 4GFSK
  - Simple (non-tuneable) FEC (Forward Error Correction)
  - TDD: time division duplex. All stations transmit on the same frequency, one at a time
    - Fast TX/RX cycles : 80ms to 200ms (like in DMR).
- Managed TDMA : The Master (central station) allocates transmission times to each station (master and clients), according to the needs, in real time.

  => No collisions
- Timing Advance management (max distance)



Source: https://cdn.hackaday.io/files/1640927020512128/NPR70_introduction_EN_v3.6.pdf

Two digits: Modulation + Symbol rate

	Modulation name 2nd digit	x0	x1	x2	x3	x4	
	Symbol Rate	50	100	180	300	500	kS/s
	Radio bandwidth	100	200	360	600	1000	kHz
2GFSK (1st digit of name : 1x)	**Modulation name**		**11** (*)	**12** (*)	**13**	**14**	
	Raw data rate		100	180	300	500	kbps
	Usable data rate		71	120	190	300	kbps
4GFSK (1st digit of name : 2x)	**Modulation name**	**20** (*)	**21** (*)	**22**	**23**	**24**	
	Raw data rate	100	200	360	600	1000	kbps
	Usable data rate	68	130	220	330	470	kbps

(*) Available for firmware ≥ 2019_06_08

Source: https://cdn.hackaday.io/files/1640927020512128/NPR70_introduction_EN_v3.6.pdf

Motivation

- We wanted more integrated hardware than the original (+integrated PA)
- Finnish Scouts organization was seeking a reliable telemetry solution for a big scout camp
- Scoms* team (Scout Monitoring System) had some ideas and synergy with their earlier projects
- Personally, I wanted to learn KiCAD (switched from EAGLE)

Original NPR design

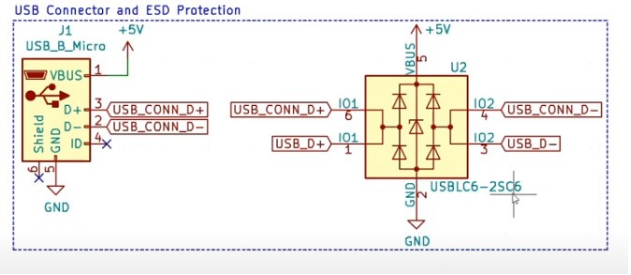
*) see www.scoms.fi

https://hackaday.io/project/164092-npr-new-packet-radio

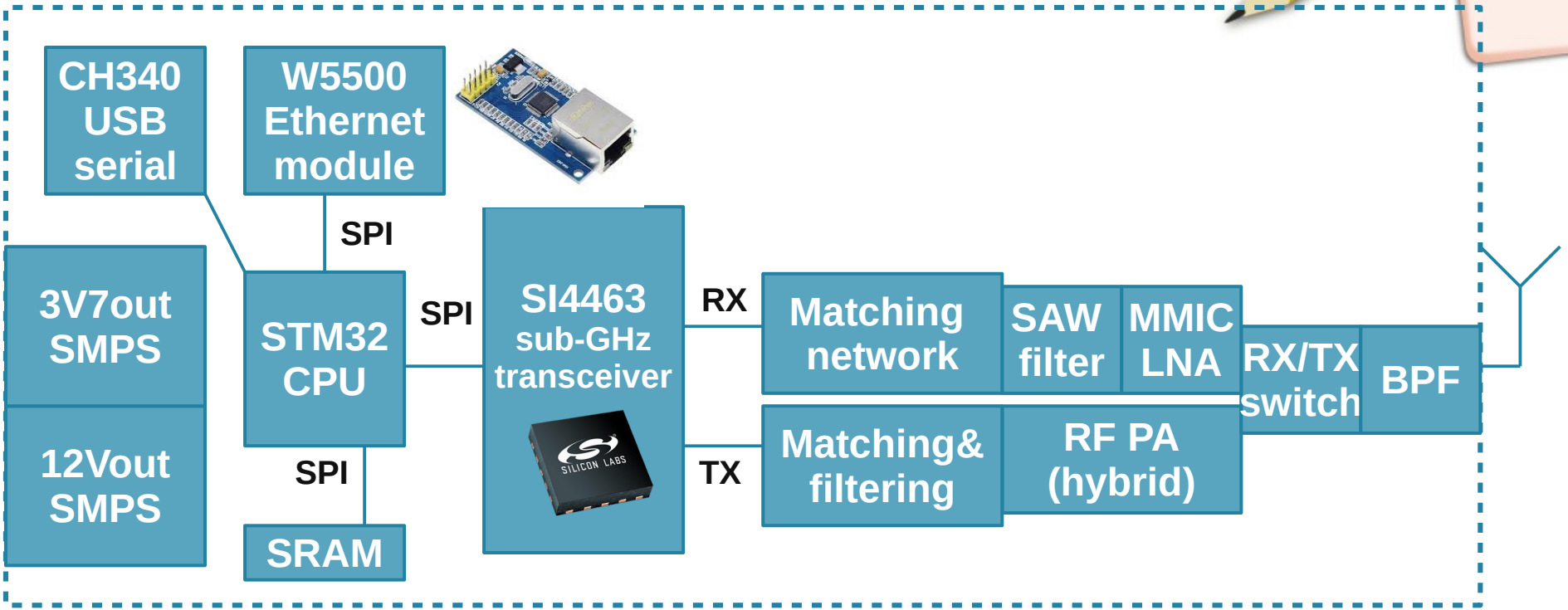
Technical guidelines

- **Must:** Binary compatibility with the original design (exactly the same CPU)
- W5500 (SPI ethernet) and RJ45 jack integrated
  (this decision was changed later on: module, to save space on board)
- RF PA would be Motorola MHW720A hybrid (20W out) [well-known from RD5* Mobiras]
- PSU: Buck converter design from an earlier Scoms project
  - 2 converters in parallel to generate enough amps at 12V, third one to step down 12→3V8 for logic
- KiCAD will be used, prototypes using JLCPCB PCBA (assembly) service
- targetting 100mm x 100mm board size
- SRAM option included, but no support for FDD mode
- SMD LEDs where they happen to be
- same license as the original work (TAPR OHL)

https://hackaday.io/project/164092-npr-new-packet-radio



Simplified block diagram



TACBUCK https://scoms.fi/teknologia/tacbuck-a-muuttajat/
STM32L432KC https://www.st.com/en/evaluation-tools/nucleo-l432kc.html
W5500 Ethernet PHY https://www.wiznet.io/product-item/w5500/
SI4463 https://www.silabs.com/wireless/proprietary/ezradiopro-sub-ghz-ics/device.si4463

https://www.st.com/en/microcontrollers-microprocessors/stm32l432kc.html

life.augmented

STM32L432KB STM32L432KC

Ultra-low-power Arm® Cortex®-M4 32-bit MCU+FPU, 100DMIPS, up to 256KB Flash, 64KB SRAM, USB FS, analog, audio

Datasheet - production data

KC: 256kB

Features

- Ultra-low-power with FlexPowerControl
  - 1.71 V to 3.6 V power supply
  - -40 °C to 85/105/125 °C temperature range
  - 8 nA Shutdown mode (2 wakeup pins)
  - 28 nA Standby mode (2 wakeup pins)
  - 280 nA Standby mode with RTC
  - 1.0 µA Stop 2 mode, 1.28 µA with RTC
  - 84 µA/MHz run mode
  - Batch acquisition mode (BAM)
  - 4 µs wakeup from Stop mode
  - Brown out reset (BOR)
  - Interconnect matrix
- Core: Arm® 32-bit Cortex®-M4 CPU with FPU, Adaptive real-time accelerator (ART Accelerator™) allowing 0-wait-state execution

UFQFPN32 (5x5)

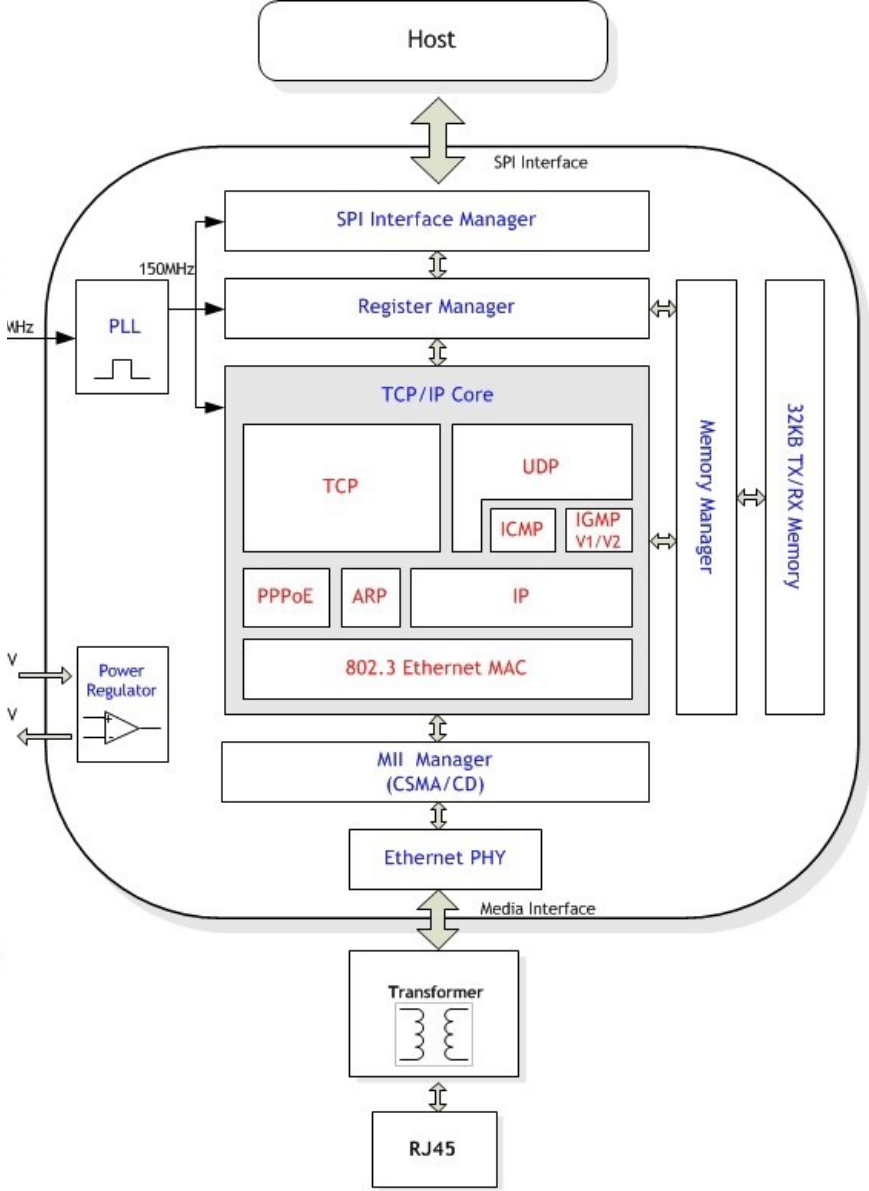
- Up to 26 fast I/Os, most 5 V-tolerant
- RTC with HW calendar, alarms and calibration
- Up to 3 capacitive sensing channels
- 11x timers: 1x 16-bit advanced motor-control, 1x 32-bit and 2x 16-bit general purpose, 2x 16-bit basic, 2x low-power 16-bit timers (available in Stop mode), 2x watchdogs, SysTick timer
- Memories
  - Up to 256 KB single bank Flash, proprietary code readout protection
  - 64 KB of SRAM including 16 KB with hardware parity check
  - Quad SPI memory interface

Wiznet 5500 Ethernet chip

- Supports Hardwired TCP/IP Protocols : TCP, UDP, ICMP, IPv4, ARP, IGMP, PPPoE
- Supports 8 independent sockets simultaneously
- Supports Power down mode
- Supports Wake on LAN over UDP
- Supports High Speed Serial Peripheral Interface(SPI MODE 0, 3)
- Internal 32Kbytes Memory for TX/RX Buffers
- 10BaseT/100BaseTX Ethernet PHY embedded
- Supports Auto Negotiation (Full and half duplex, 10 and 100-based)
- Not supports IP Fragmentation
- 3.3V operation with 5V I/O signal tolerance
- LED outputs (Full/Half duplex, Link, Speed, Active)
- 48 Pin LQFP Lead-Free Package (7x7mm, 0.5mm pitch)

SPI bus

https://www.wiznet.io/product-item/w5500/



SILICON LABS

Si4464/63/61/60

HIGH-PERFORMANCE, LOW-CURRENT TRANSCEIVER

Features

- Frequency range = 119–1050 MHz
- Receive sensitivity = –126 dBm
- Modulation
  - (G)FSK, 4(G)FSK, (G)MSK
  - OOK
- Max output power
  - +20 dBm (Si4464/63)
  - +16 dBm (Si4461)
  - +13 dBm (Si4460)
- PA support for +27 or +30 dBm
- Low active power consumption
  - 10/13 mA RX
  - 18 mA TX at +10 dBm (Si4460)
- Ultra low current powerdown modes
  - 30 nA shutdown, 50 nA standby
- Data rate = 100 bps to 1 Mbps
- Fast wake and hop times
- Power supply = 1.8 to 3.6 V
- Excellent selectivity performance
  - 60 dB adjacent channel
  - 75 dB blocking at 1 MHz
- Antenna diversity and T/R switch control
- Highly configurable packet handler
- TX and RX 64 byte FIFOs
- Auto frequency control (AFC)
- Automatic gain control (AGC)
- Low BOM
- Low battery detector
- Temperature sensor
- 20-Pin QFN package
- IEEE 802.15.4g compliant
- FCC Part 90 Mask D, FCC part 15.247, 15,231, 15,249, ARIB T-108, T-96, T-67, RCR STD-30, China regulatory
- ETSI Class-I Operation with SAW

Pin Assignments

https://www.silabs.com/wireless/proprietary/ezradiopro-sub-ghz-ics/device.si4463

MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by MHW720A1/D

The RF Line

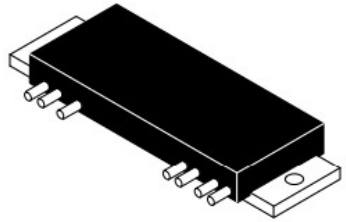
UHF Power Amplifiers

Capable of wide power range control as encountered in UHF cellular telephone applications.

- MHW720A1 400–440 MHz
- MHW720A2 440–470 MHz
- Specified 12.5 Volt, UHF Characteristics —
  Output Power = 20 Watts
  Minimum Gain = 21 dB
  Harmonics = –40 dB (Max)
- 50 Ω Input/Output Impedance
- Guaranteed Stability and Ruggedness
- Epoxy Glass PCB Construction Gives Consistent Performance and Reliability
- Circuit board photomaster available upon request by contacting RF Tactical Marketing in Phoenix, AZ.

MHW720A1
MHW720A2

20 W, 400 to 470 MHz
RF POWER
AMPLIFIERS



CASE 700–04, STYLE 2

Low Noise, High IP3

Monolithic Amplifier

PSA4-5043+

50Ω 0.05 to 4 GHz

The Big Deal

- Ultra Low Noise Figure, 0.75 dB
- High IP3 and Po at low DC power consumption
- May be used as a replacement for SPF5043Z[a,b]
- Class 1B HBM ESD rating (500V)

CASE STYLE: MMM1362

NF 0.66dB typical at 500 MHz
Gain 21.2 dB at 500 MHz

Product Overview

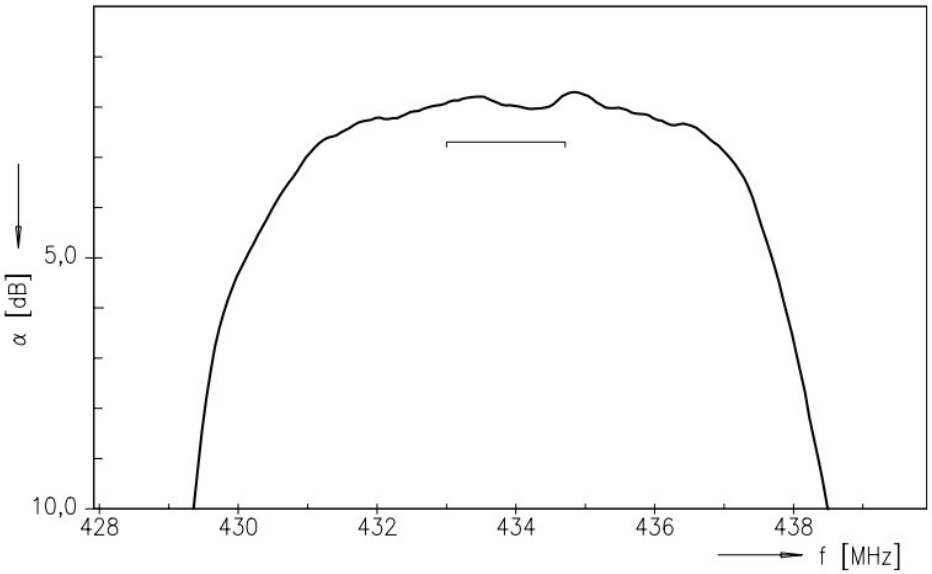
Mini-Circuits PSA4-5043+ is a E-PHEMT based Ultra-Low Noise MMIC Amplifier operating from 50 MHz to 4 GHz with a unique combination of low noise and high IP3 making this amplifier ideal for sensitive high dynamic range receiver applications. This design operates on +3 to +5V supply at only 33 mA at 3V and 56mA at +5V, is internally matched to 50 ohms and is supplied in a super small SC-70 (SOT-343) MSL 1 package.

https://www.minicircuits.com/pdfs/PSA4-5043+.pdf

SAW: B39431B3710U410

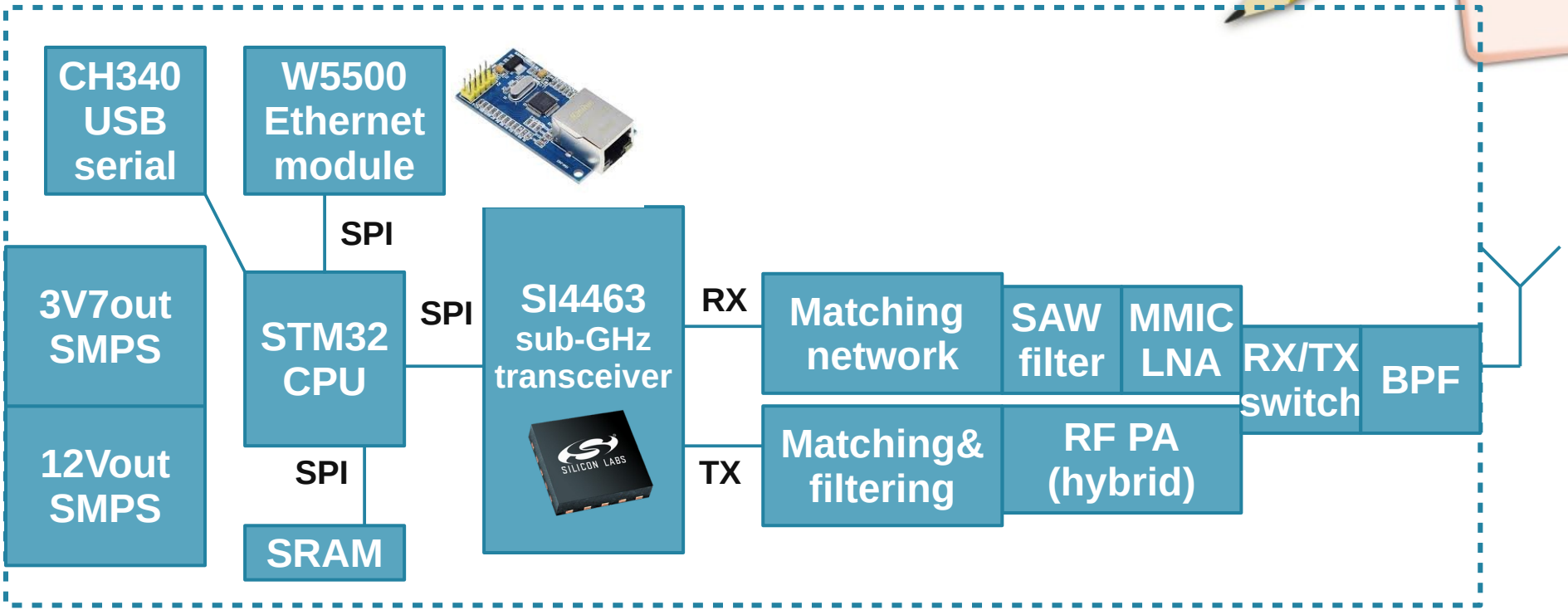
Frequency - Center	433.92MHz
Bandwidth	1.7MHz
Insertion Loss	2dB

Low-loss RF filter for remote control receivers
No matching network required for operation at 50ohm



https://media.digikey.com/pdf/Data%20Sheets/TDK%20PDFs/B39431B3710U410.pdf

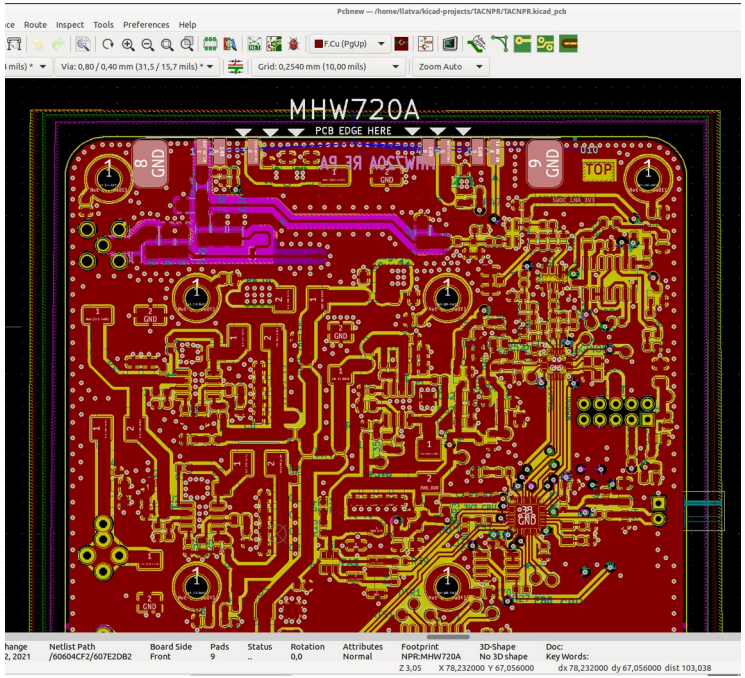
Simplified block diagram



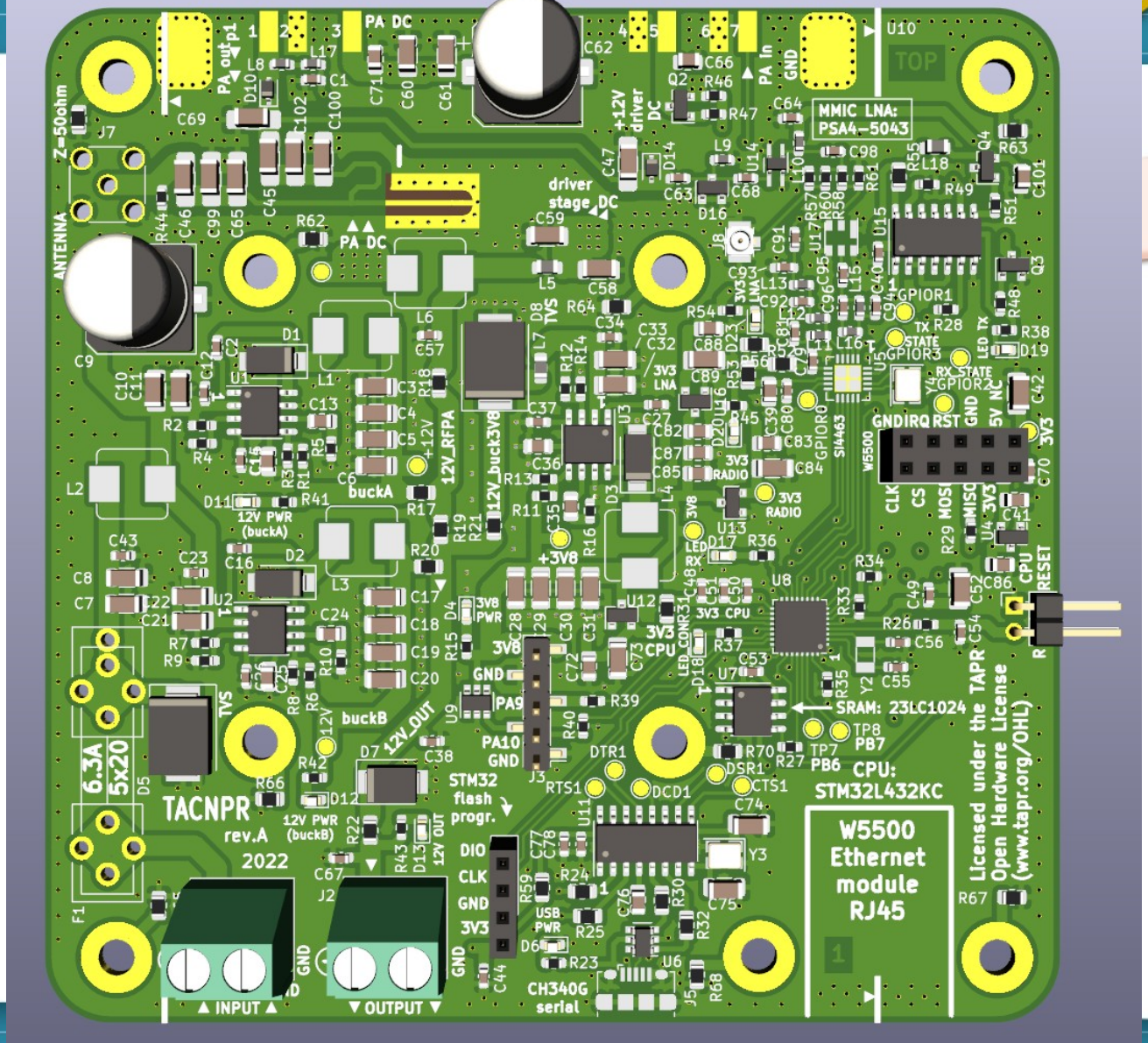
TACBUCK https://scoms.fi/teknologia/tacbuck-a-muuttajat/
STM32L432KC https://www.st.com/en/evaluation-tools/nucleo-l432kc.html
W5500 Ethernet PHY https://www.wiznet.io/product-item/w5500/
SI4463 https://www.silabs.com/wireless/proprietary/ezradiopro-sub-ghz-ics/device.si4463

Working methods

- Team of four persons:
  - Mikko OH2FLO, project lead
  - Tatu OH2EAT, focusing on RF design / schema
  - Lasse OH3HZB (me), focusing on PCB layout
  - Vili OH5GE, focusing on mechanics concept
  - (Buck converter design by Tommi OH1GJV)
- Regular telco meetings, reviewing design choices and PCB layout, following the progress
- Instant messaging channel
- Mostly remotely (COVID..), 1 face2face session
- Project started in 2021
  - 13 months calendar time to rev A assembly

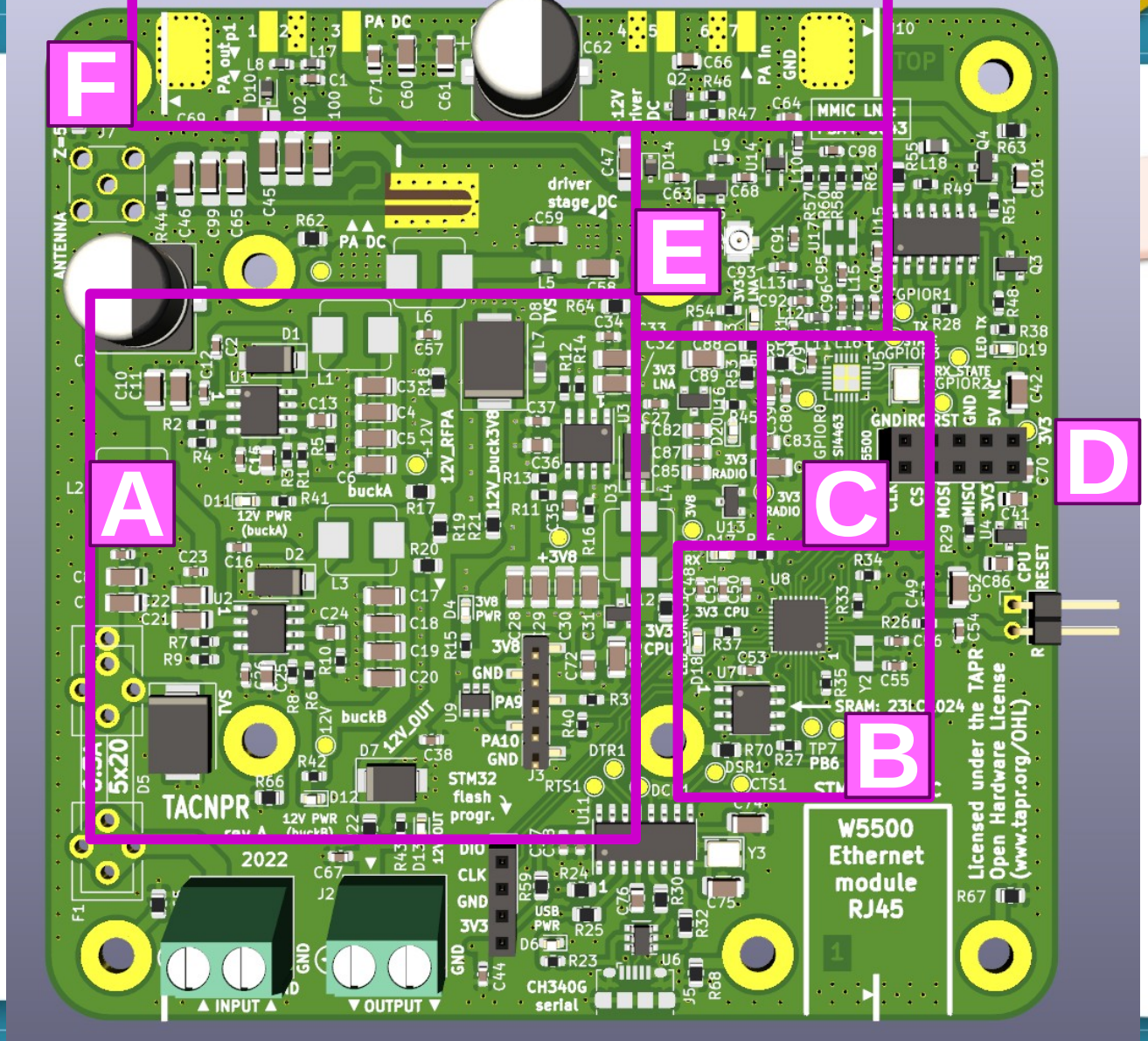


- 4-layer FR4 PCB
- 10 cm * 10 cm
- All soldered components on TOP
- Holes for heat spreader



- 4-layer FR4 PCB
- 10 cm * 10 cm
- All soldered components on TOP

A step-down PSU 12V, 3V8
B CPU & SRAM
C SI4463 transceiver
D Ethernet module
E LNA & RX filtering
F RF PA

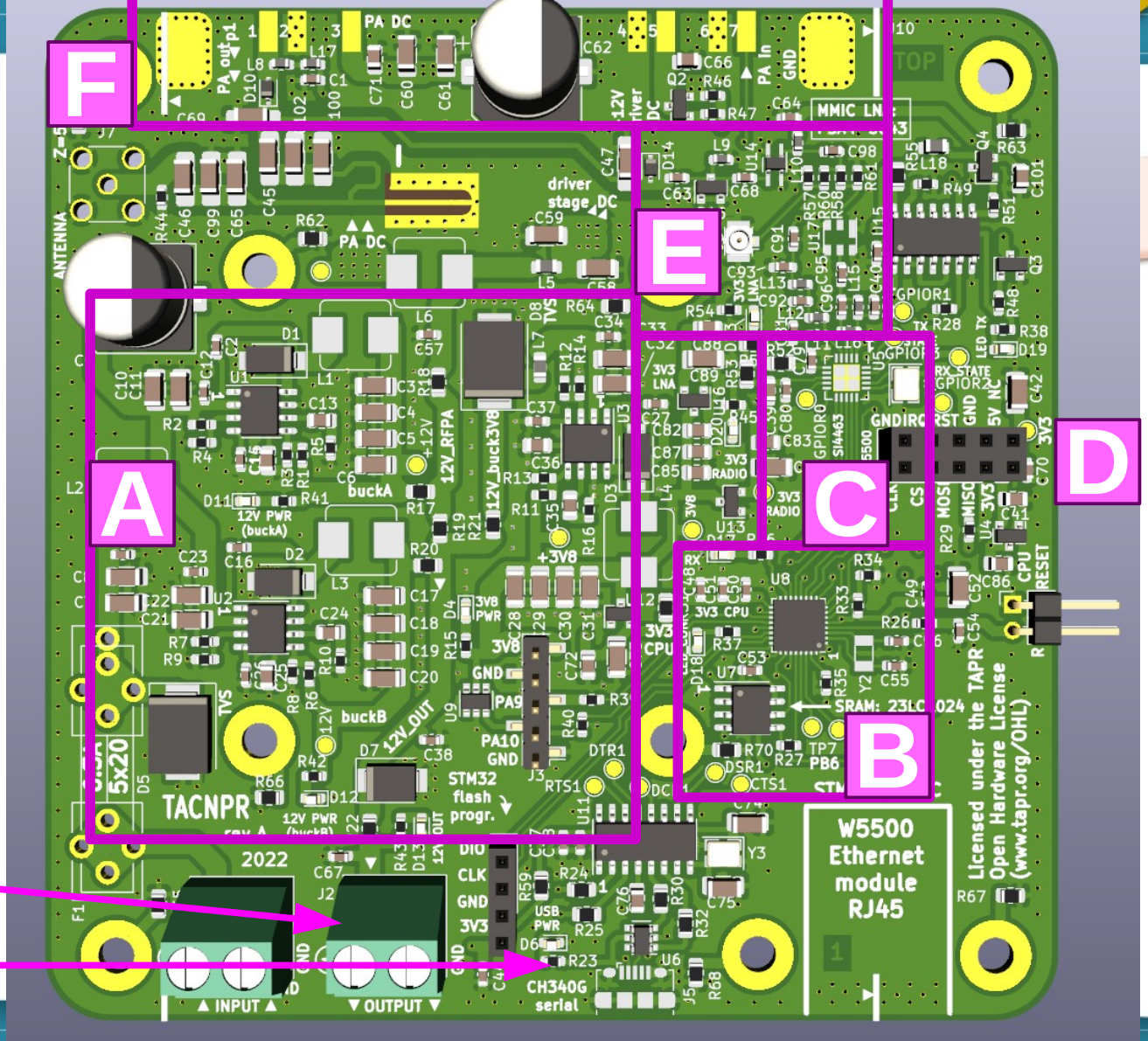


- 4-layer FR4 PCB
- 10 cm * 10 cm
- All soldered components on TOP

What else:

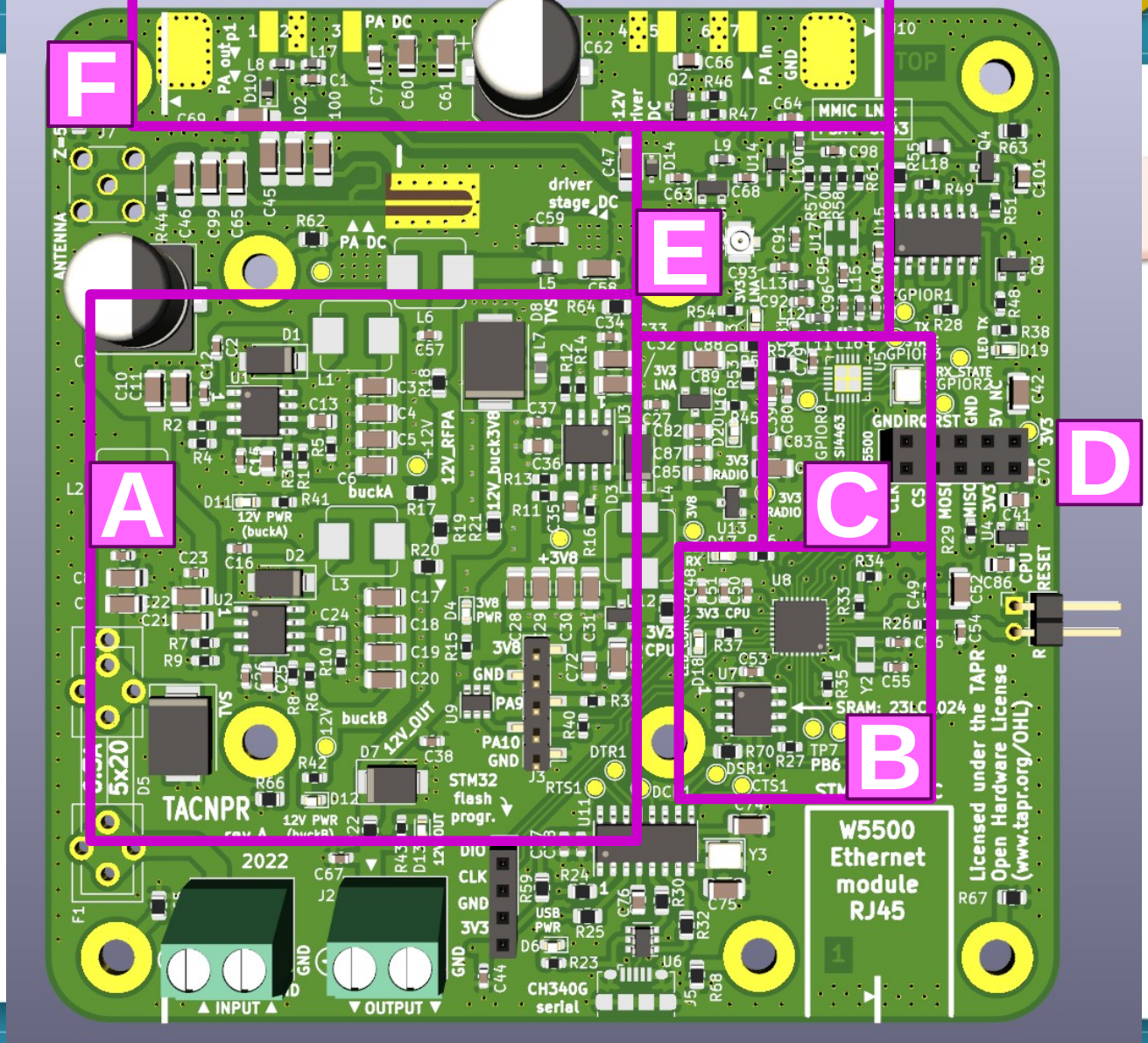
- 12V output for e.g. fiber optic converter

- USB serial (CH340)



- 4-layer FR4 PCB
- 10 cm * 10 cm
- All soldered components on TOP

Separate linear regulators (3V8 → 3V3):
-Ethernet
-STM32 CPU
-Si4463 transceiver
-LNA



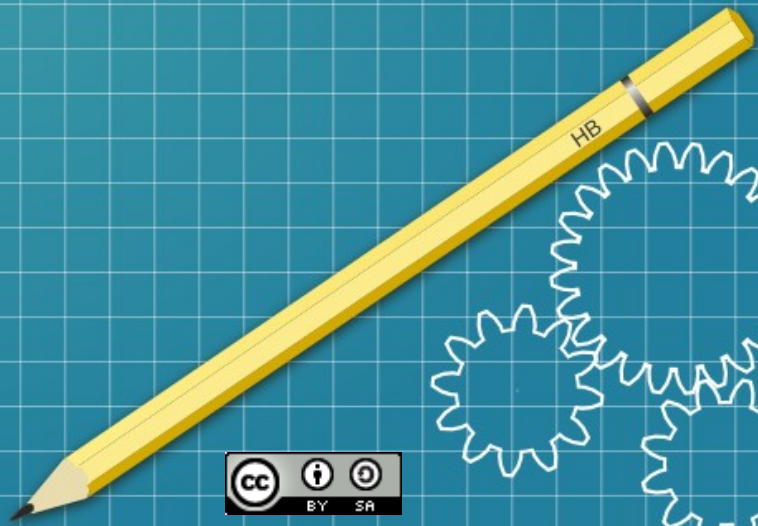
- 4-layer FR4 PCB
- 10 cm * 10 cm
- All soldered components on TOP
- Holes for heat spreader

Photo: Mikko OH2FLO

More information

- Original NPR project (firmware, docs etc):
  - https://hackaday.io/project/164092-npr-new-packet-radio
- **TACNPR @ Github:**
  - **https://github.com/partio-scout/scoms-tacnpr/**
  - (to be open soon)
- Scoms
  - https://scoms.fi/

Questions?



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