DL0TI, Club Radio Texas Instruments

Emergency HAM System

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DARC, Ortsverband Ulm P14 & Freising C04

Level of Presentation: Beginner

Topic: Emergency HAM System for Radio Amateurs

author: Bernd Geck

Career
- a decade at the army,
  followed by the University of Ulm
- at TI / PDS since 2006 to 2023,
  after 15 years in TWT TX design at
  Telefunken and BTS design at Siemens

Expertise
- power electronics and RF electronics

Fun facts:
- radio amateur DB3GF & DL0TI,
  homebrewing RF LDMOS amplifiers
- freediving instructor, just a single breath…

Part A – RF System, Components

12V / 13.8V Components

Considerations:

- reuse of existing RF components
- all RF components powered out of 12Vdc
- “portable”, weight <20kg:
  (build with or without RF amplifier ?)
- tuner for undefined multiband antenna
  (“end fed” long wire is easy to use)
- isolated interface to PC adds digital modes
  (VARA)

findings at the attic:

TRX: IC-706MKIIG, *PA: RM HLA 300 plus,* *Tuner MFJ-994B (600W PEP)*
PSU: SPS 9600 (60A) *I/F: microHAM USB 3,* *tiny ACER Aspire NetBook 9”*

Part A – RF System, Open Frame Case

Console 49cm x 45cm x 27cm

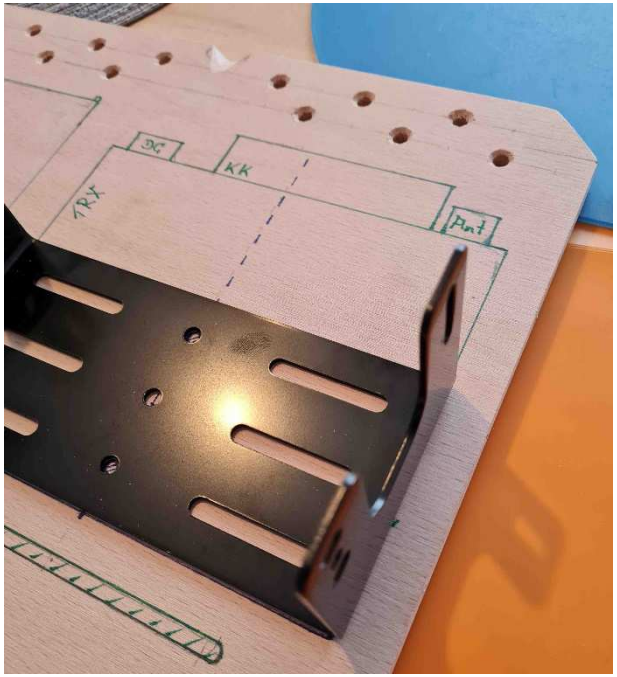
first orientating placement

Considerations:

- leave some space for convection
- place components for proper RF path
- use sturdy wood 12mm (“multiplex”), here: used beech, heavy but solid
- place handles barycentric
- case is varnished for outdoor use (field day)
- rubber pads prevent from slipping
-

Part A – RF System, Mounting Components

Example TRX



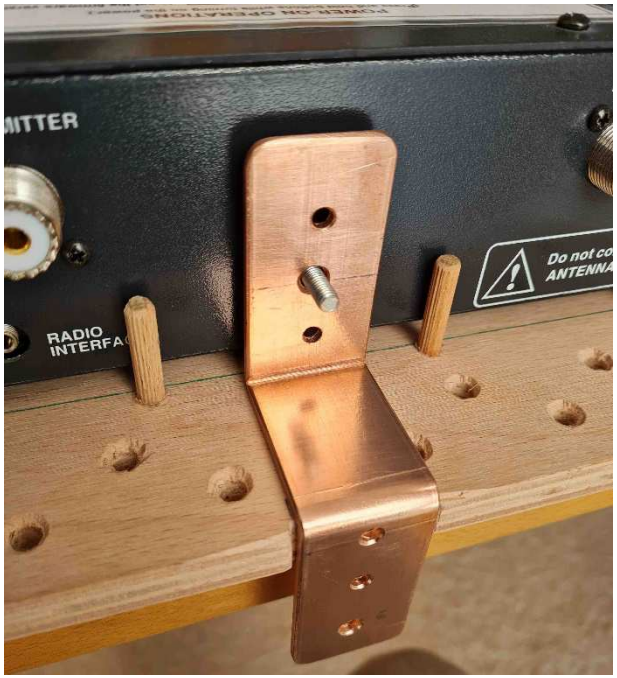
a sketch always helps…

Considerations:

- use drive-in nuts (!)
- bolted connections are best connections (shock & vibration during transportation)
- think about service and dismantling, too
-

Part A – RF System, Grounding Components

Common Ground



central ground at RF out

Considerations:

- ground all components of RF path
- use central ground at RF output,
  here at auto tuner MFJ-994B
- short connection to earth via 10mm^2
- ground any generator as well (!)
-

Part A – RF System, Final Layout

Ready to Run:

Bill of Materials:

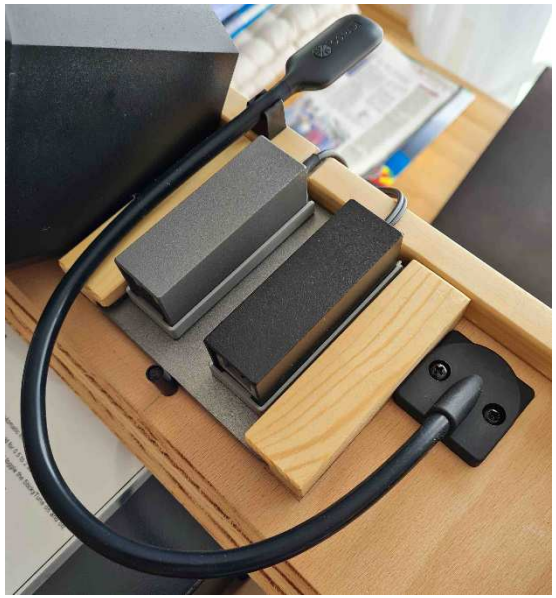
- 5” coaxial loudspeaker
- 12V/24V LED Osram ONYX, part B
- combo key, part C
- microHAM USB 3 interface

- auto tuner MFJ-994B
- IC-706MKIIG

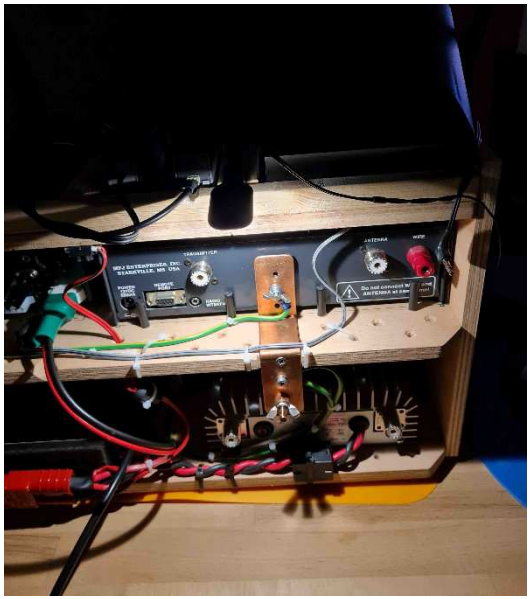
- solid state PA RM HLA 300 plus
- power supply SPS 9600, 13V8 / 60A

Part B – 500mW LED

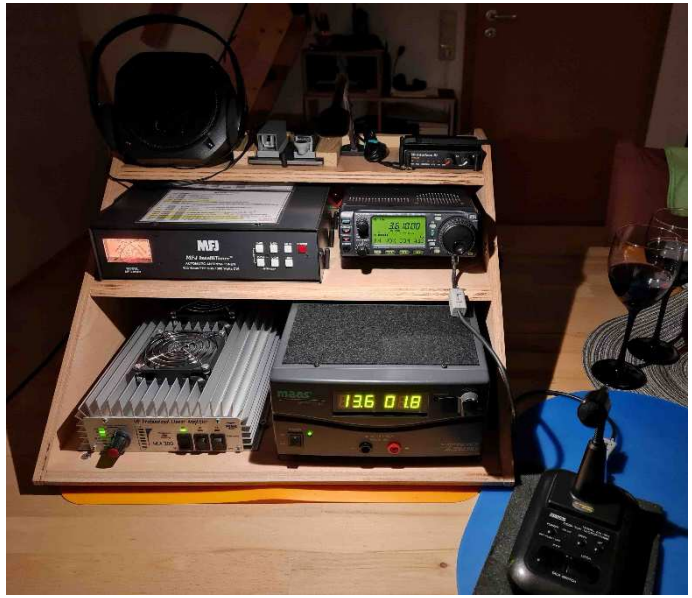
Brightness 500mW LED, Load Current <50mA:



LED in service position,



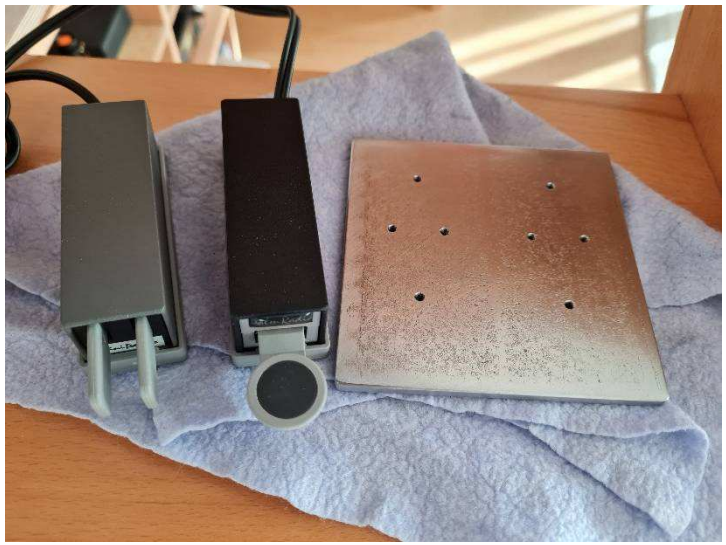
lighting the back,

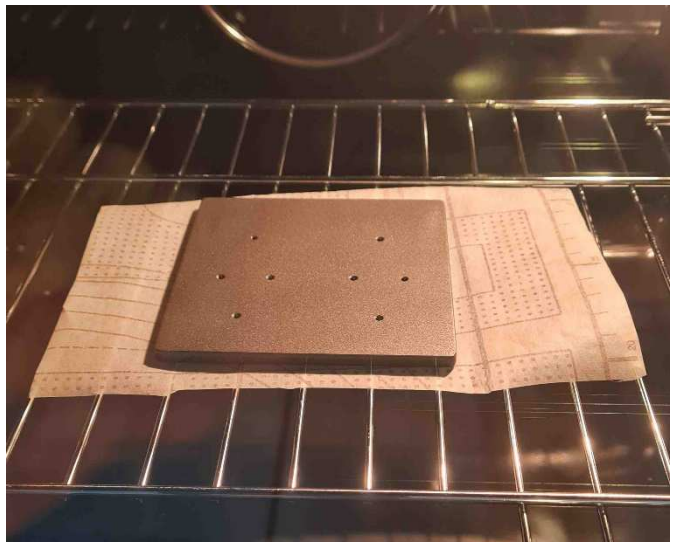


or illuminating at night

Part C – Tiny Combo Key using Palm Radio

Another Finding at the Attic:

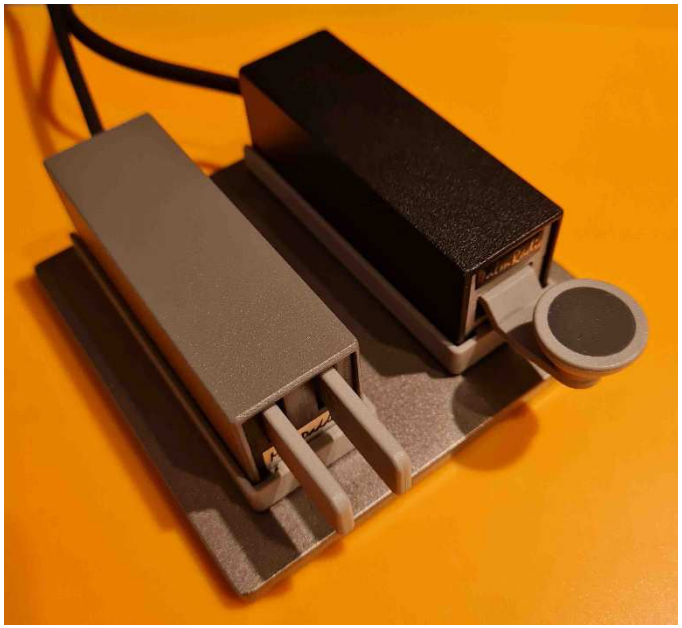




some basic steel ST37 (100mm x 100mm x 5mm = 400g),
the shower gets a paint shop,
and stove enameling 75c at the baking oven makes every housewife very happy…

Part C – Tiny Combo Key using Palm Radio

Talk with Your Fingers:



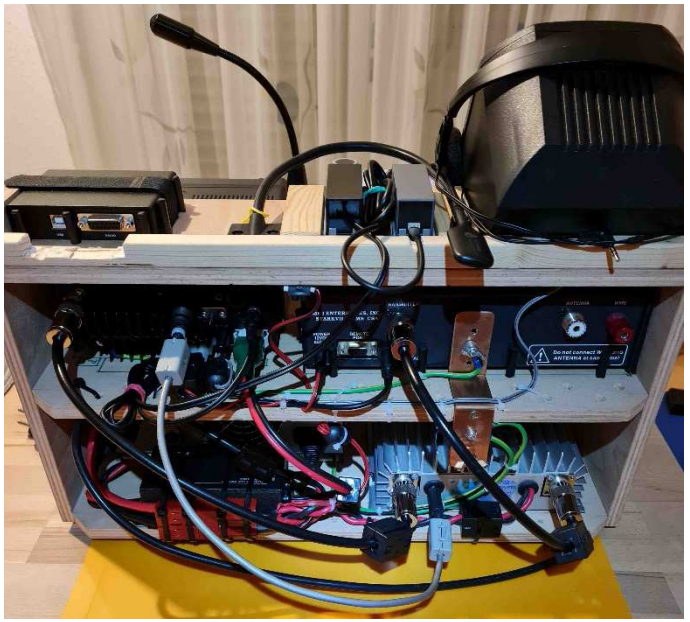
keyer and paddle,

protected and parked…

RF System On Air

Mains Operations 230Vac:

70W CW in Digi Mode, 300W PEP in SSB



and the back…

Part D – an Universal Power Concept 800W+

Electrical Specifications for Maximum Output Power:

- 300W RF peak power results in 50Apk (!);
  expect 30% to 40% continuous power in SSB using a compressor, so 20A cont
  for 50% TX/RX in contest expect 11A average current (13.8V x 11A = 152W !!!)

- 70W RF power in digi mode results in 23A cont;
  for 50% TX/RX expect 12A average current, NetBook adds another 2A worst case;
  average power consumption in digi mode up to **13.8V x 14A = 193W !!!**

- battery operations for ten hours at maximum output needs an energy of 2kWh

- if conditions are fine switch off PA to stretch life time of battery = QRP
if conditions are even better use IC-706 at 5W output power – or less…

Part D – an Universal Power Concept 800W+

Various Power Sources:

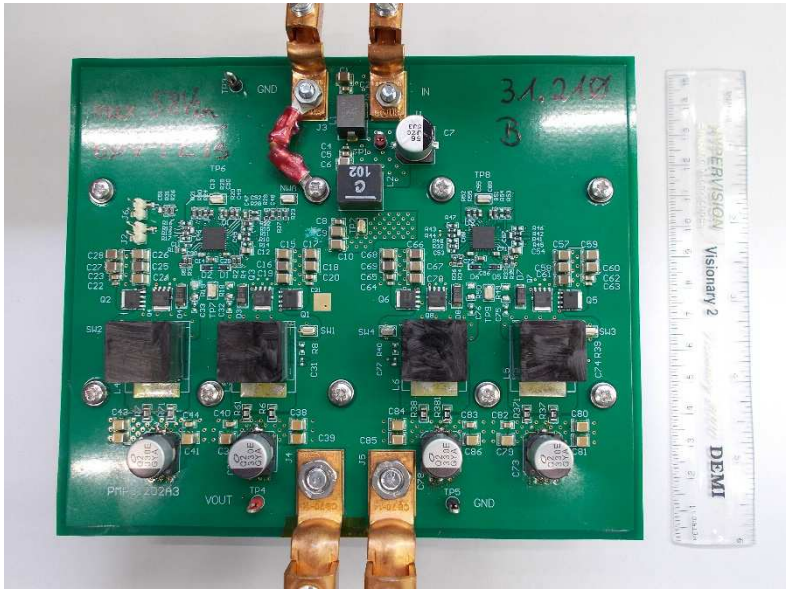
- mains operations is covered by switched mode power supply SPS 9600:
  this power supply uses power factor correction PFC and the pre boost allows wideband input range 170Vac to 264Vac supporting an electrical generator

- “portable” generator MXR3500 (3.1kWpk/2.8kWcont) is in house:
  weight 22kg, needs less than one liter ROZ91/95 per hour in economy mode;
  upper PFC allows economy mode (transient response vs. load transient RX/TX)

- any battery power, i.e. “portable” around 20kg = **LiFePO4 24V / 100Ah**;
  allows 10hrs+ operation, **needs DC/DC converter** for constant output voltage 13.8V,
  such a step down solution could be solar buffered as well

Part D - DC/DC Converter 800W+, PMP31210 RevB

Built on PCB 31202 Rev A3



four layers, single side assembly,
152.6mm x 130.8mm x 16mm

Specifications:

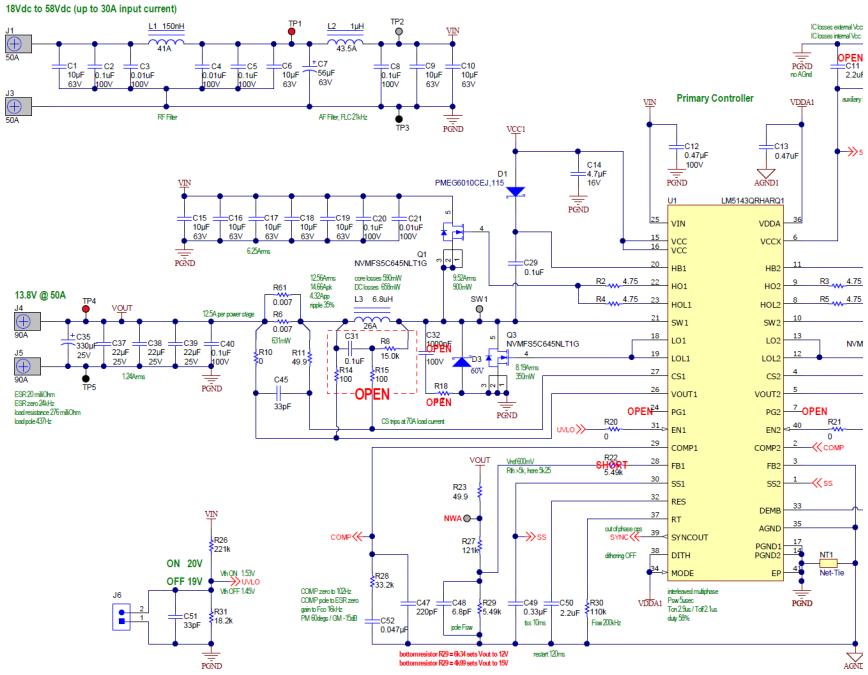
- synchronous four phase buck converter
- interleaved operation provides lowest ripple
- full thermal solution, shielded metal case

- input voltage range 18Vdc to 58Vdc
- 50A+ continuous load current
- 70A peak current
- efficiency up to 98%
- output ripple <10mVpp
- transient response <3% for 90% transient
- gate drive control to attenuate RF noise

- link: https://www.ti.com/tool/PMP31210

PMP31210 Design Review – Solution by LM5143

Schematics PMP31210 Rev B, two controllers / four power stages

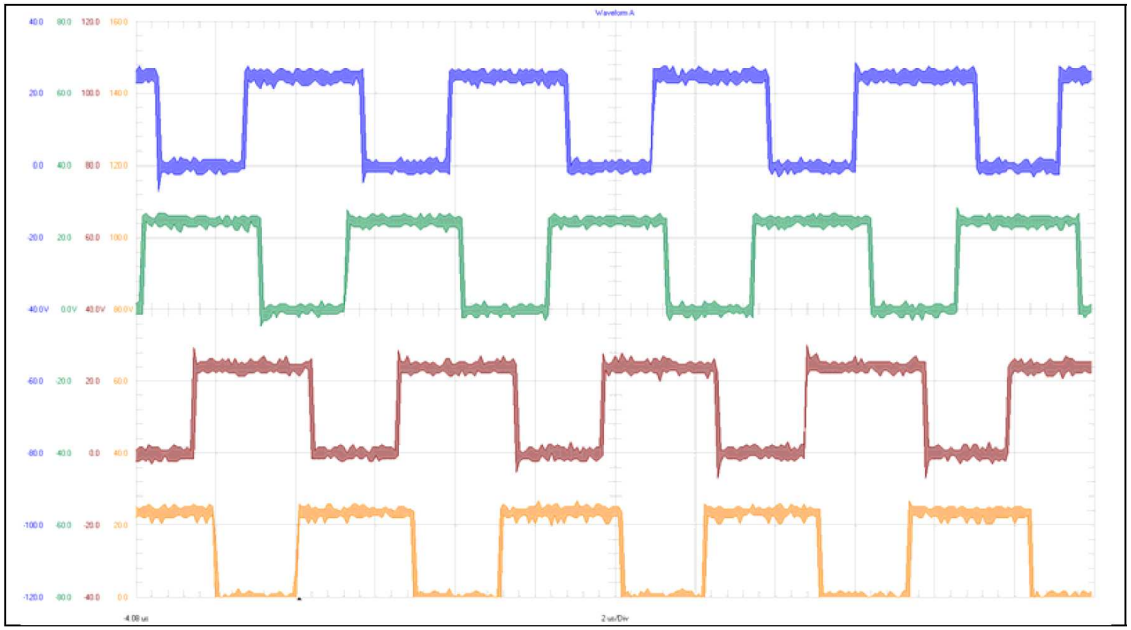


single power stage (x4)

- stacked 2x LM5143 to 4-phase design, IC allows adjustment of rise and fall times !
- full ripple rejection at 24V / 48V input, here duty cycle is around 25% / 50%
- high dynamic performance, transient response 400mVpk, so <3% for **90%** load step 5A / 50A (RX/TX)
- 800W continuous output power, 1kW peak

PMP31210 Design Review – Interleaved Operation

Switch Nodes PMP31210 Rev B



four phase interleaved operation, 200W per phase

Four Phase Design:

- power distribution
- losses distribution
- heat distribution

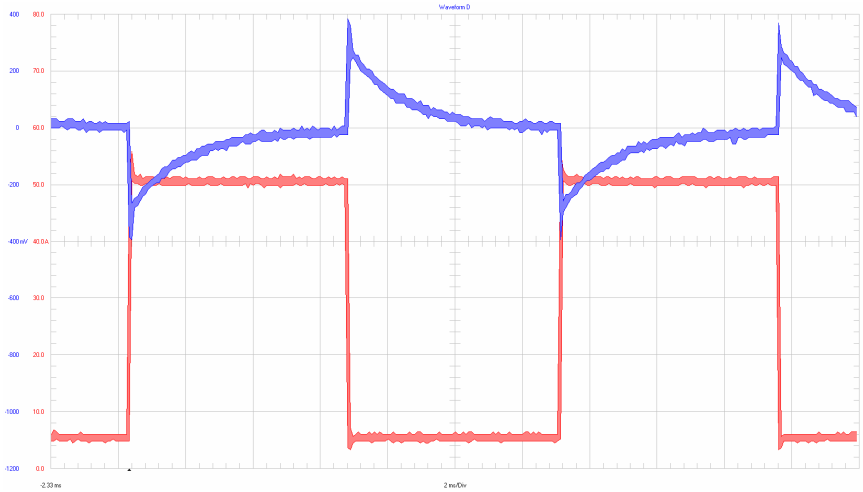
- maximum ripple rejection
  (at 25% and 50% duty cycle)

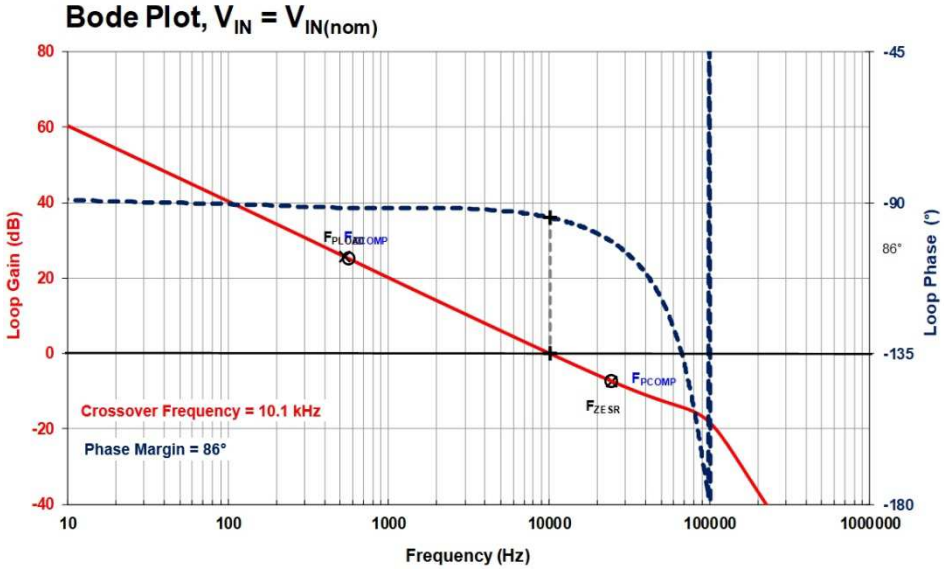
- RMS stress reduction,
  especially at input capacitors

- less EMI

PMP31210 Design Review – Dynamics

Dynamic performance PMP31210 Rev B



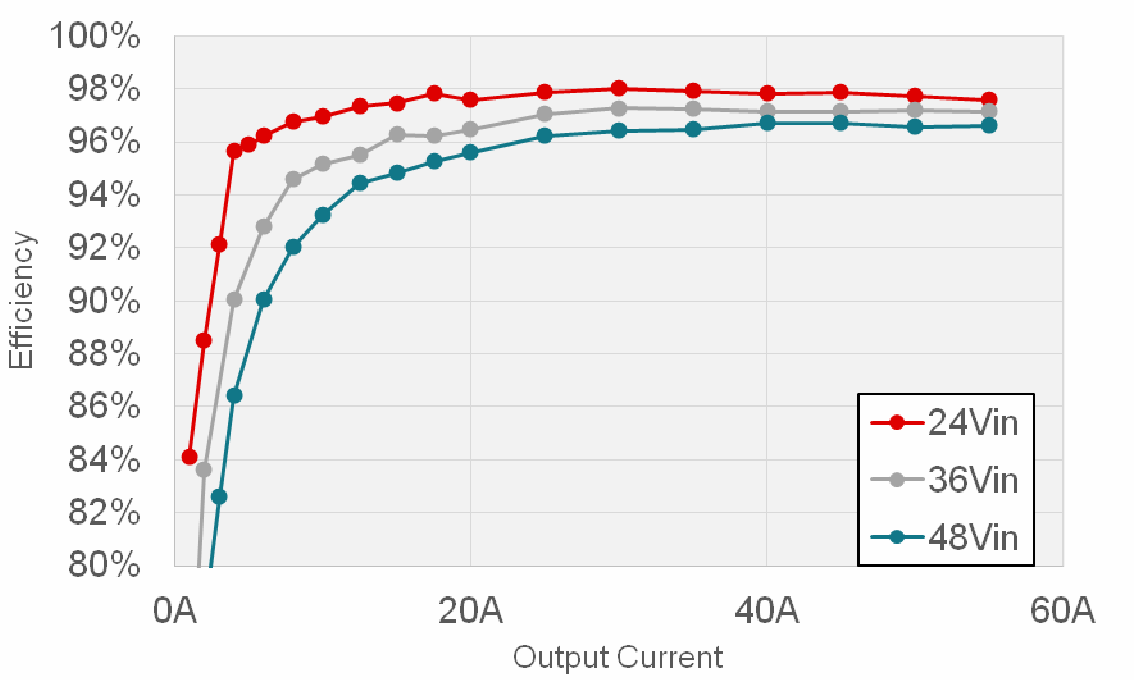


load transient 90%, 5A to 50A
transient response <400mV, less than 3% (!)

Loop in frequency domain,
PM > 80degs / GM < -15dB

PMP31210 Design Review – Efficiency & Losses

Efficiency PMP31210 Rev B (60V-FETs)



efficiency 98% at nominal truck input 24V

Efficiency 98% sounds good, BUT:

output power 13.8V x 60A =
828W

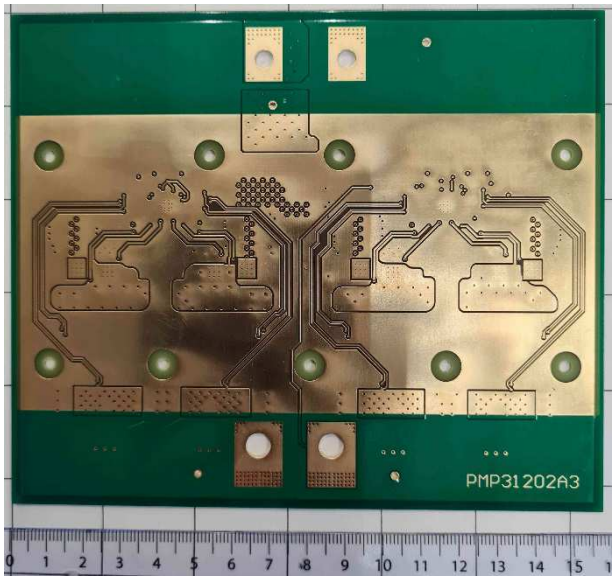
input power 828W / 0.98 =
845W

power losses 845W – 828W =
17W (!!!)

- how to sink the heat ?
- how to get rid of the heat ?

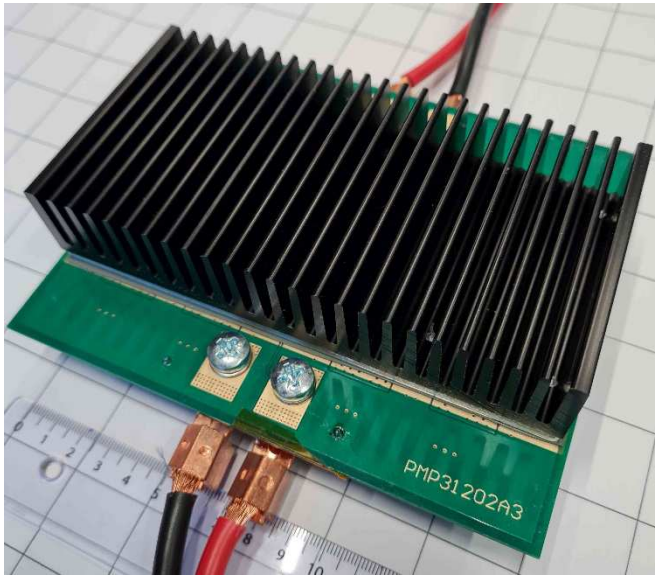
PMP31210 Design Review – Heat Sink

Thermal Interface PCB 31202 Rev A3, at the end the mechanics solution



power polygons at bottom

a) PCB
b) thermal pad
c) heat sink



first prototype with standard heat sink 150mm x 75mm

PMP31210 Design Review – Thermal Results

PMP31210 Rev B, prototype under test at ambient temperature +23c

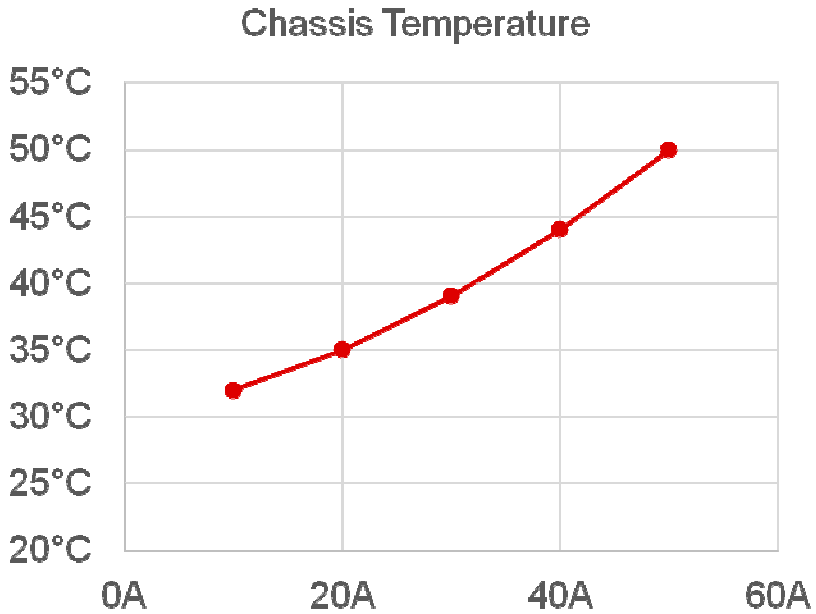
Output Current	Hottest Spot HS FET Q6 NVMFS5C456, pure PCB	Hottest Spot with Airflow 0.5m/s..1m/s, pure PCB	Hottest Spot, just mounted Aluminum Adapter, 150mm x 75mm x 5mm	added Heatsink to adapter, FISCHER, SK 58 75 SA
10 A	35.3°C	n/a	n/a	n/a
20 A	42.8°C	n/a	n/a	n/a
30 A	**52.4°C**	n/a	49.8°C	47.7°C
40 A	**65.4°C**	n/a	60.4°C	56.1°C
50 A	**81.4°C**	45.4°C	73.5°C	**66.4°C**
60 A	n/a	**52.5°C**	**89.6°C**	**77.6°C**

Remember: even a small air flow helps more than a big heat sink !

PMP31210 Design Review – Thermal Results

PMP31210 Rev B inside shielded metal case at 23c ambient

test set up – equipment at it's limits…



ten hours continuous operation...

Part D – Low Noise NetBook Supply

DC/DC Adapter Input 13.8V to Output 17V/19V:

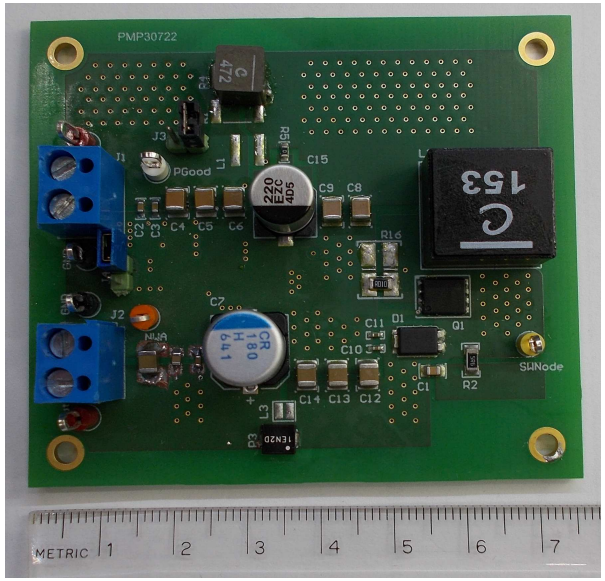
- an old NetBook ACER Aspire is reused to support various digital modes; beneficial is the low power consumption **< 30W** of such a 9” portable PC

- despite it’s 3s battery (12.6Vmax / 11.1Vtyp) the DC voltage of 13.8V is NOT sufficient to drive the PC ! The internal watchdog sets the threshold to 16V+, the AC adapter itself provides 19V

- next task is a cost effective but efficient DC/DC boost converter to provide 17Vdc to the PC; worst case current consumption while charging battery and executing a test software has been measured around 1.4A; targeting an efficiency 95% for a non synchronous topology this PC adds up to 1.95A to the 13.8V bus

Part D - DC/DC Converter 30W+, PMP31242 RevA

Built on PCB 30722



four layers, double side assembly,

x 15mm

Specifications:

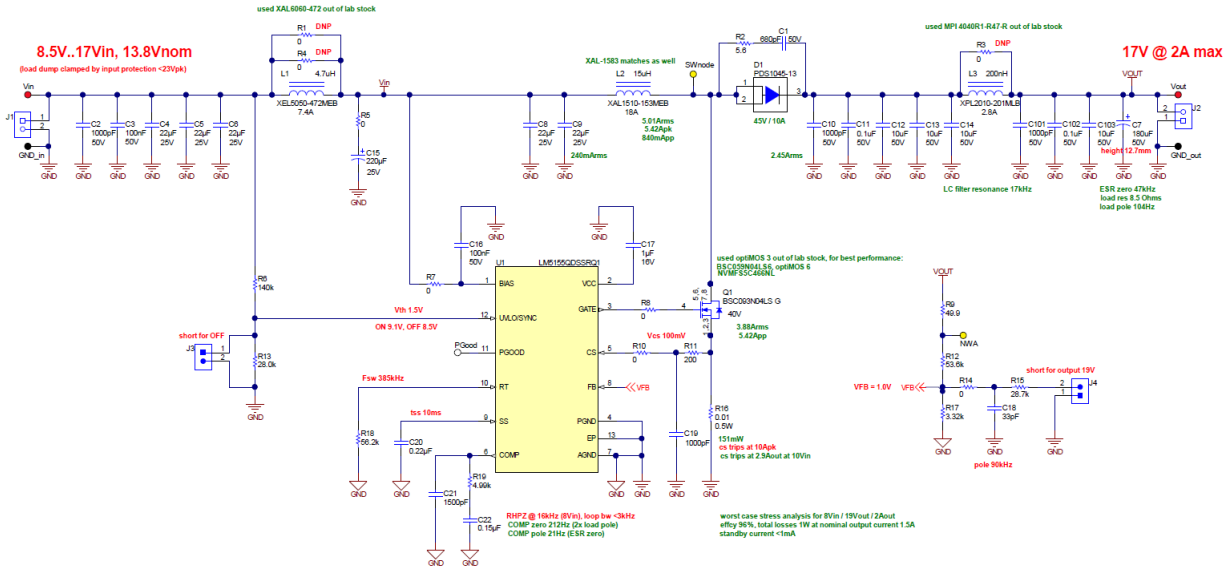
- non synchronous step up (= boost) converter
- high and flat efficiency
- shielded metal case, low EMI needed

- input voltage range 8.5Vdc to 17Vdc
- 1.5A continuous load current
- 2.5A peak current
- efficiency up to 96% at load current 1A to 2.5A
- output ripple <10mVpp
- reflected input ripple <10mVpp
- standby current <1mA, here 600uA

- link: https://www.ti.com/tool/PMP31242

PMP31242 Design Review – Solution by LM5155

Schematics PMP31242 Rev A

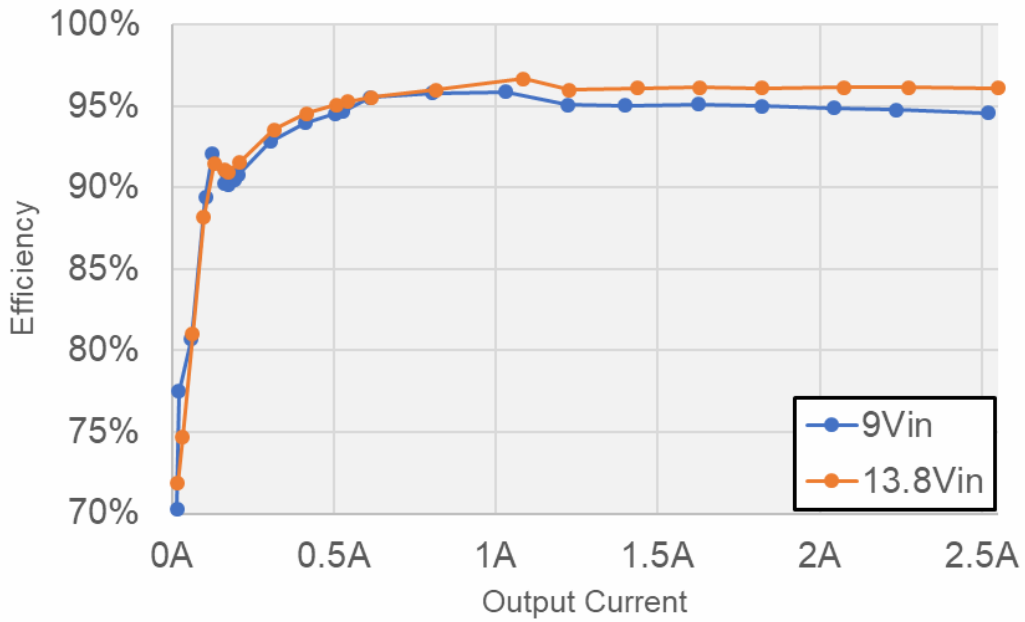


30W+ boost converter

- used LM5155/56
- added RF input filter
- added RF output filter
- RC damping at rectifier
- Fsw 385kHz,
  harmonics out of band
  i.e. f(8) 3465kHz
  f(9) 3850kHz

PMP31242 Design Review – Efficiency & Losses

Efficiency PMP31242 Rev A (40V-FET)



input voltage range 8.5V to 17V

output voltage selectable 17V / 19V

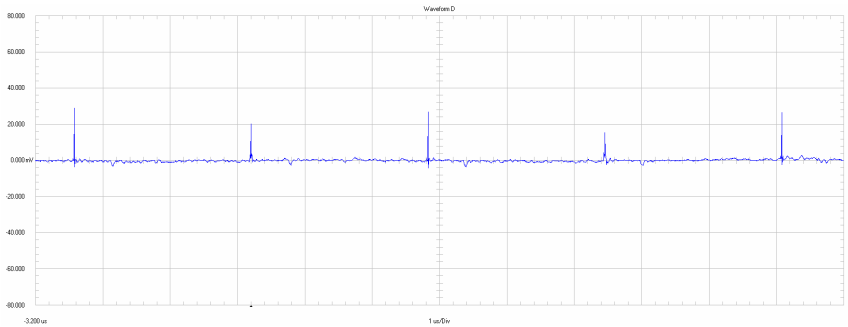
allows peak currents up to 2.5A

losses <1W at max. current 1.5A

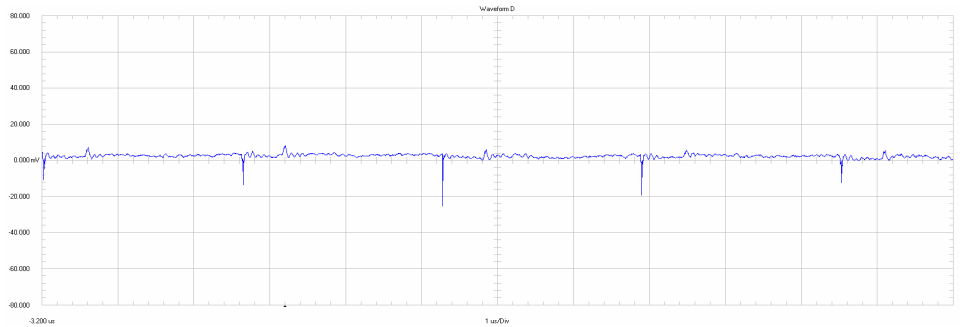
flat efficiency 95%+ 500mA to 2.5A load current

PMP31242 Design Review – Ripple Voltages

Ripple and Noise PMP31242 Rev A



Input Voltage Ripple



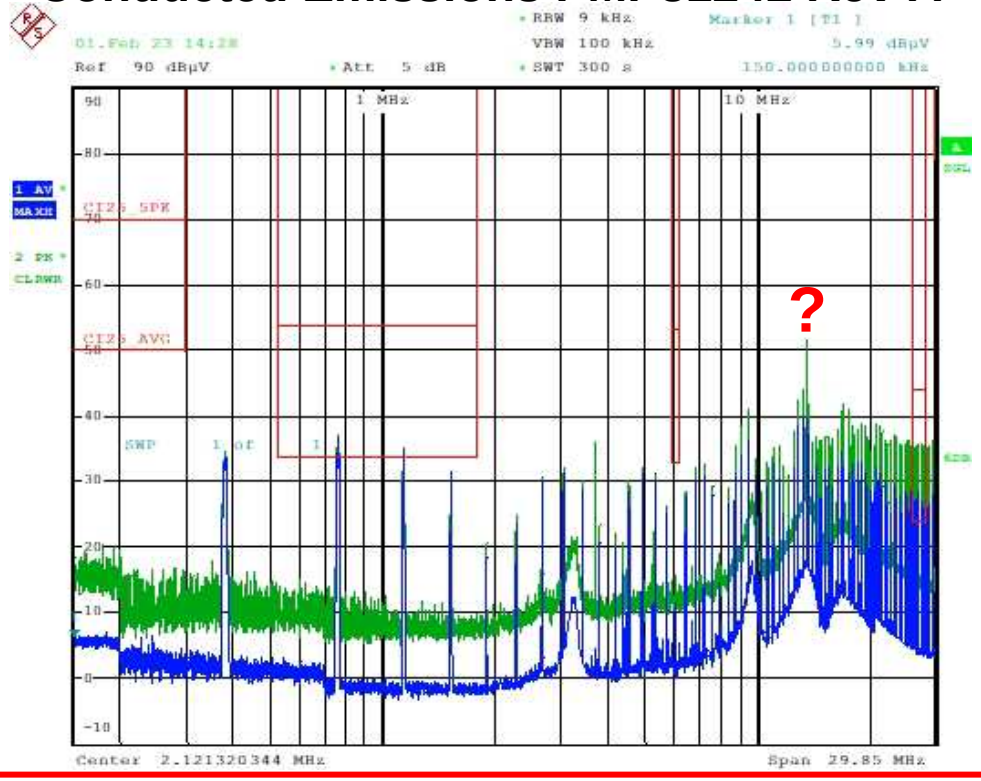
Output Voltage Ripple

Reflected ripple and output voltage ripple at 20mV / division, **20MHz bandwidth**; ripple <5mVpp and noise <30mVpk - in time domain looks promising,

but what about frequency domain ?

PMP31242 Design Review – CISPR 25 class 5

Conducted Emissions PMP31242 Rev A



Positive Line 150kHz to 30MHz,

- **PEAK LEVEL**
- **AVERAGE LEVEL**

limits at

- LW band, 150kHz to 300kHz
- MW band, 530kHz to 1.8MHz
- 49m band, 5.9MHz to 6.2MHz
- CB band, 26MHz to 28MHz

fails at

- f(1) 764kHz / f(2) 1146kHz, < 5db AVG
- 11m band, < 5dB AVG

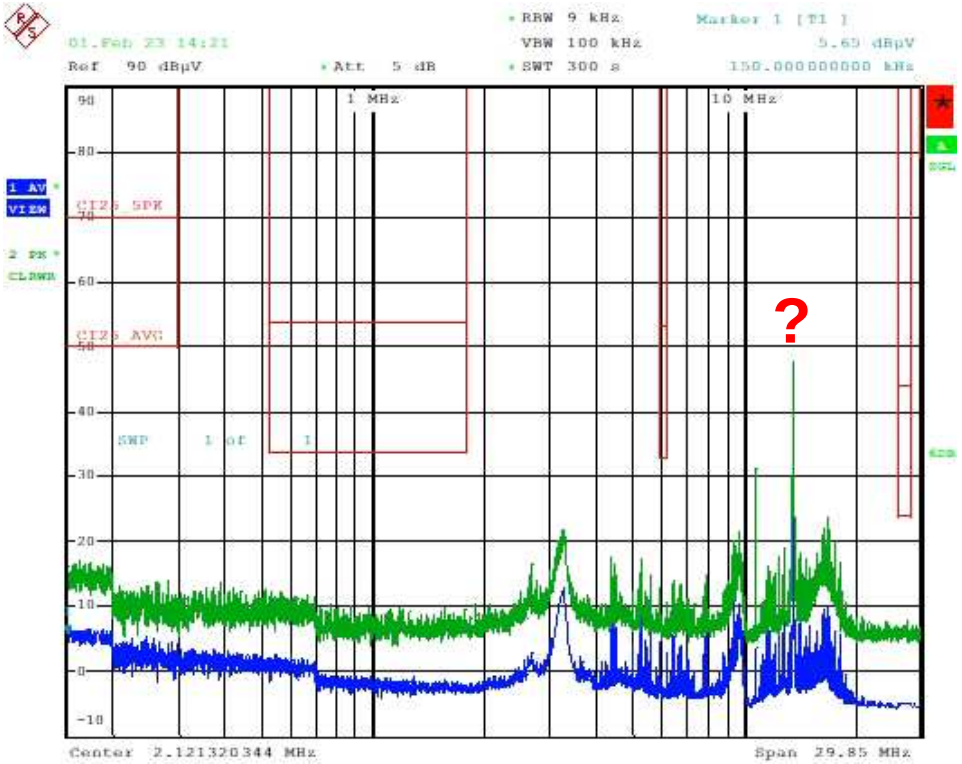
(solution: gate resistor R8 10 Ohms)

DARC OV P14

but peak at 14 MHz, 20m band 2

PMP31242 Design Review – CISPR 25 class 5

DUT PMP31242 Rev A switched OFF



Noise Floor 150kHz to 30MHz,

- **PEAK LEVEL**
- **AVERAGE LEVEL**

- *peak at 14 MHz still there…*

btw. limits at

- LW band, 150kHz to 300kHz
- MW band, 530kHz to 1.8MHz
- 49m band, 5.9MHz to 6.2MHz
- CB band, 26MHz to 28MHz

no limits for HAM bands 160m to 10m

Agenda

- Funkstation
- Versorgungskonzept PMP31210 (+ PMP31242)
- End Fed Antenne
- Felderprobung

Nachteile, IC-706 (20 Jahre alt !)

- hohe Stromaufnahme RX, >1A
- keine Wasserfallanzeige, kein Display-Ausgang
- kein integrierter Tuner
- kein isoliertes i/f
- mangelhafte Grossignalfestigkeit an langen Antennen
  (jedoch klein, und deckt HF/50m/2m/70cm ab)

> IC-7300 (int. Tuner / int. I/F, 4.2kg) + Alinco DM-330 (2.5kg)