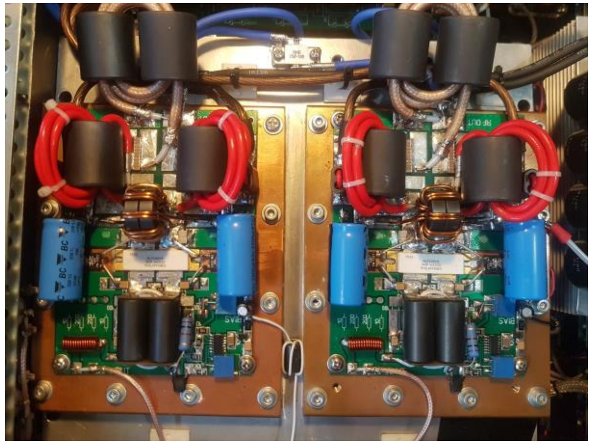
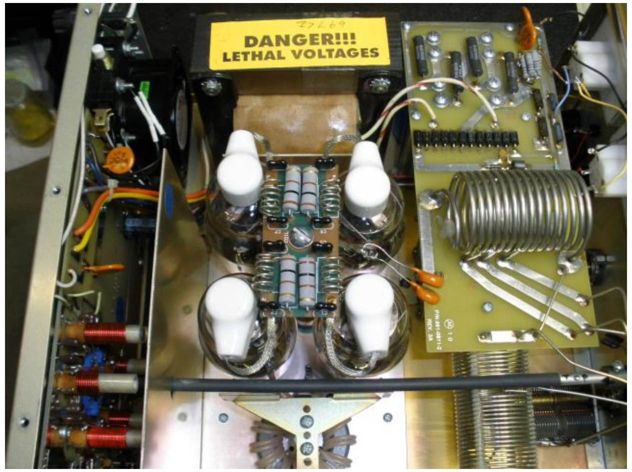
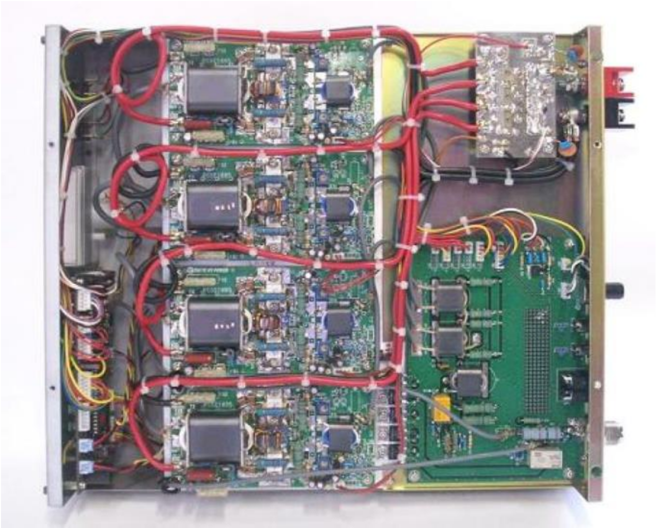
Building your own SS Amplifier (Part 2)

Tino Zottola, VE2GCE

November 16, 2020







Agenda

- Review of Part 1 presentation
- Building your own SS Amplifier
- Amplifier Protection
- Sequencing & Monitor Circuits
- Automatic Band Selection
- Conclusion

Review

Why are tube amplifiers still dominating the Amateur Radio landscape ?

1) Commercial solid state amps are <u>very expensive, costing between $3000 to $6000 USD.</u>

2) Quality used tube amplifiers from 1970-80's are available for anywhere between $300-600 USD.

- 1970's and 80's brand names like Heathkit, Dentron, Amp Supply are the best deals
- Most post-1980 amplifiers support WARC bands (30, 17 and 12 meters)
- Modern tube amplifiers to be avoided unless they are "Cadillac" brands like Alpha

3) Why even consider solid state amplifiers when tube amplifiers are so cheap ?

- Ease of operation especially during contesting
- Tube supply might not be around forever
- During current COVID-19 crisis, current tube quality has dropped considerably

4) Building an SS Amplifier

- Homebrew SS amp by integrating pre-built modules ('Lego approach') as opposed to 'ground up' build.
- Can be made for under $1000 USD
- Reliability and functionality of commercial amplifiers can be had.

Homebrew options

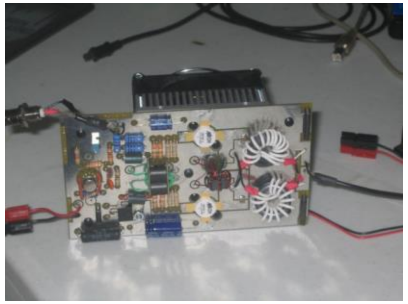
1) AN758 Bipolar Amplifier: <u>RF parts $990 USD</u>
- 4 x 300 watt modules ➔ 4 x $150 USD each
- Splitter x combiner kit ➔$150 USD
- Low Pass Filter ➔ $240 USD

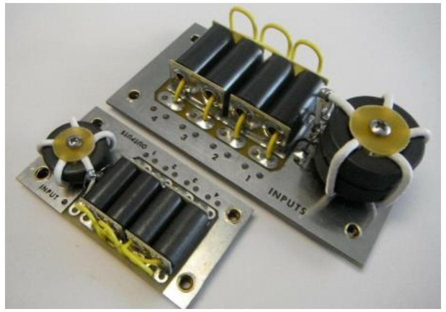
2) AR347 MOSFET Amplifier: <u>RF parts $1390 USD</u>
- 1200 watt module ➔ $1100 USD
- Input attenuator ➔ $50 USD
- Low Pass Filter ➔ $240 USD

3) LDMOS Amplifier: <u>RF parts $540 USD</u>
- 1200 watt LDMOS device ➔ $125 USD
- Input / output kit ➔ $125 USD
- Input attenuator ➔ $50 USD
- Low Pass Filter ➔ $240 USD

In terms of RF core components:
- Bipolar amplifier ➔ 1.21 watts / USD
- MOSFET amplifier ➔ 0.86 watts / USD
- LDMOS amplifier ➔ 2.22 watts / USD

4 x





Core Components

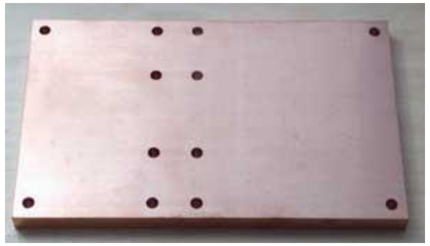
All amplifier require the following support components
Total cost of support components: $390 USD

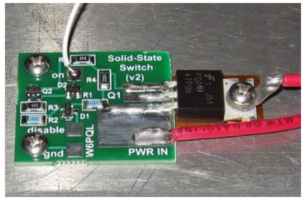
Power Supply
- Power Supply ➔ $75 USD
- 48 to 12 volt supply ➔ $5 USD

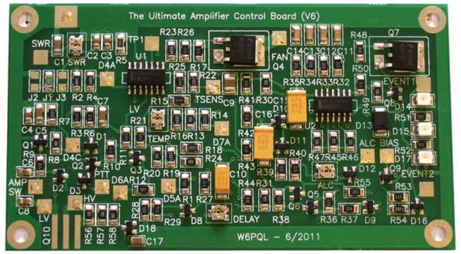
Thermal Management
- Copper plate ➔ $100 USD
- Aluminum Heatsink ➔ $50 USD
- Fans ➔ $25 USD

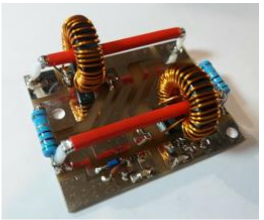
Control, Protection and Monitoring
- TR relay ➔ $25 USD
- Amp power SS switch ➔ $20 USD
- (*) Protection and sequencing circuit ➔ $50 USD
- SWR sensor ➔ $25 USD
- Temp sensor ➔ $5 USD
- (*) Automatic Band Select ➔ $15 USD
- Arduino Controller ➔ $10 USD
- LCD Screen ➔$10 USD

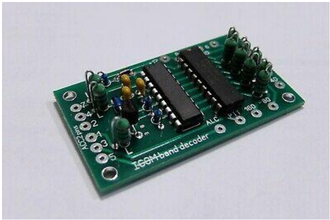
* Can be done in software via Arduino

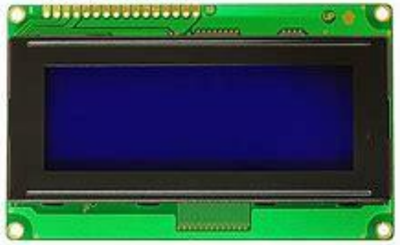












Building a Basic SS HF Amplifier

It is not necessary to build an amplifier from the ground up.

Basic amplifier can be built from modules (i.e. Lego approach):

1) LDMOS device (e.g. BLF188XR)

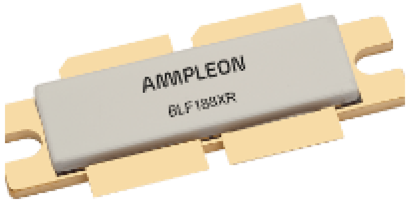
2) RF input and output board kit

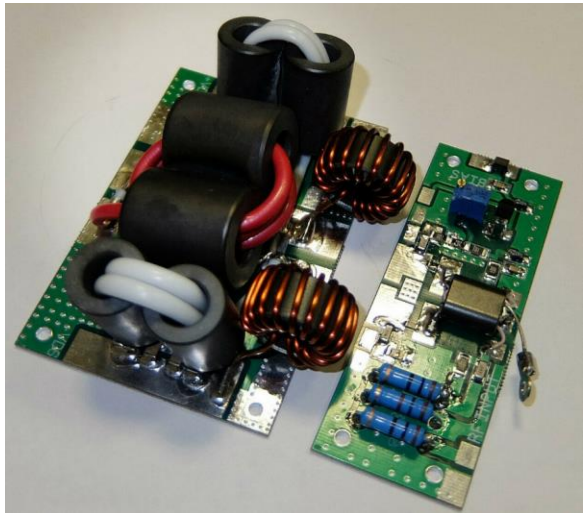
3) Low Pass Filter

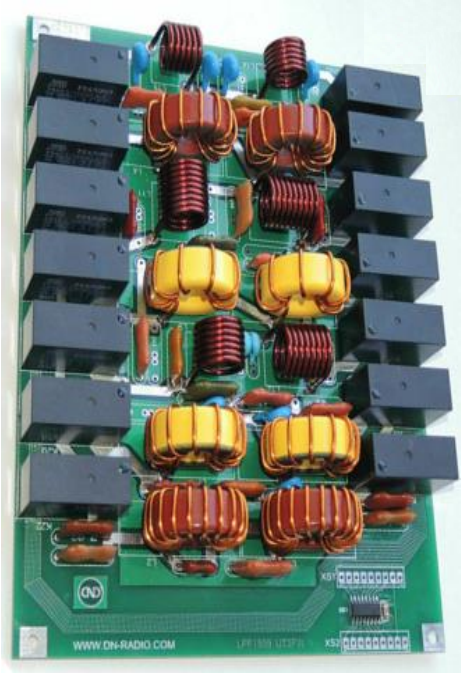
4) TR Relay

5) 50 volt 50 amp power supply

6) Copper plate + Heatsink + Fan







Powering Solid State Amplifiers

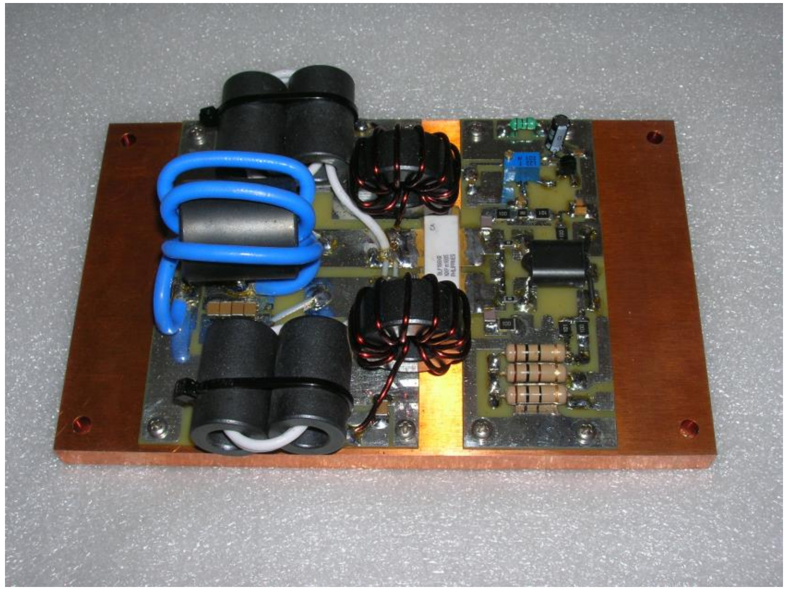
Solid State amplifier can be powered by surplus 48 volt telecom power supply ($100 or less)

- Hewlett Packard ESP120: 50 volts, 57 amps, 2950 watts
- Emerson R48-2900: 50 volts, 50 amps, 2900 watts
- Huawei R4850G: 50 volts, 56 amps, 3000 watts

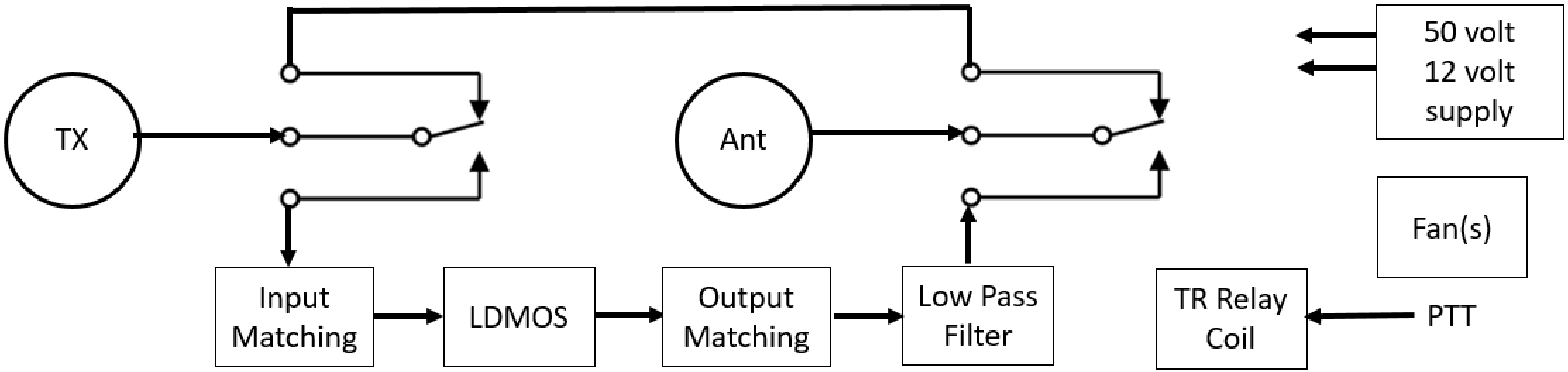
- Secondary power supply 48 volts to 12 volts is also required

Thermal Management

- Large amount of heat generated in small concentrated area
- Device mounted (soldered) to a large copper plate (4” by 6” by ½”)
- High conductivity of copper serves as heat spreader for semiconductors
- Copper plate is mounted to aluminum heatsink (6” by 10.080” extrusion)
- 3 x fans (> 100 CFM) to keep temperature under 40 C



Basic LDMOS Amplifier



1) RF input / output boards match LDMOS to transmitter and antenna

2) Low Pass Filter (switchable with band) supresses harmonics

3) TR Switch

4) 50 volt 50 amp PS ➔ LDMOS device

5) 12 volt 3 amps PS ➔ Amplifier bias, fans and TR relay

*** This implementation is not recommended, <u>do not build a SS amp like this</u>

Architecture is OK, if we were building a tube amplifier

Amplifier Protection

1) TR Switching:

Short period when TR relay switches from receive to transmit, the amplifier operates without a load.

➔ Transistors can be damaged.

Solution: Use sequencing circuit to turn-on (or off) amplifier gradually

2) SWR Mismatch:

A no load or bad SWR condition

➔ Transistors can be damaged.

Solution: Use SWR monitor circuit to disable amplifier when fault condition exists

3) Overdrive Protection:

Tube amplifiers work with 50-100 watts input and many solid state amplifier requires only 2-6 watts

➔Overdrive can destroy transistors instantly

Solution: Input power attenuator

4) ***Temperature Protection:***

➔Temperature in excess of 40-50 C can destroy transistors

Solution: Speed up fans when temp increases and shuts down amplifier when threshold exceeded

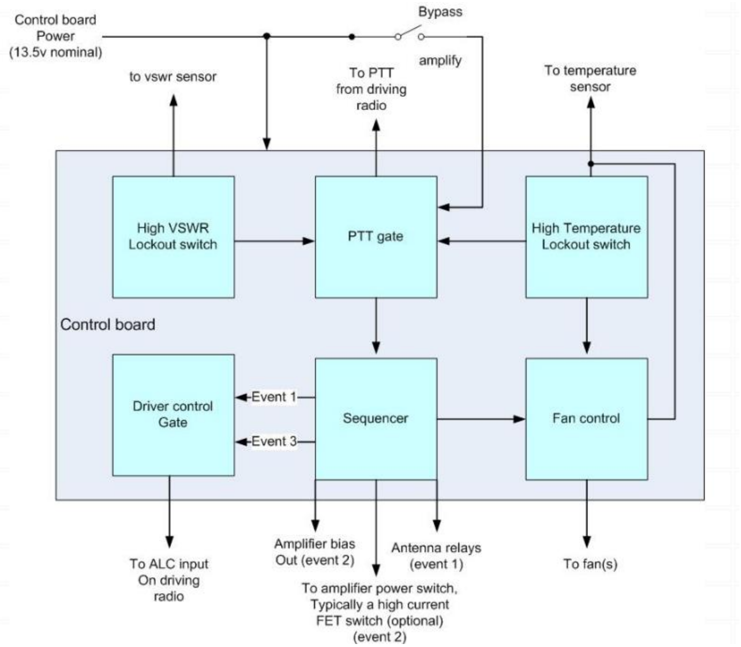
Amplifier Protection & Sequencer

Control hardware by W6PQL does the following:

1) Amp circuit sequencer
   a) Sequences activation of amplifier circuits after PTT signal is raised
   b) Sequences de-activation of amplifier circuits after PTT signal is dropped

2) Lockouts amplifier during excessive SWR or temperature events
   - During fault condition, same event sequence as PTT drop scenario.

3) Standby switch: bypass / amplify states
   - Bypass state, same event sequence as PTT drop scenario.
     (except transmitter is enabled, example: ALC = 0 volts instead of -4 volts)



W6PQL sequencer is cleverly done in analog circuitry.

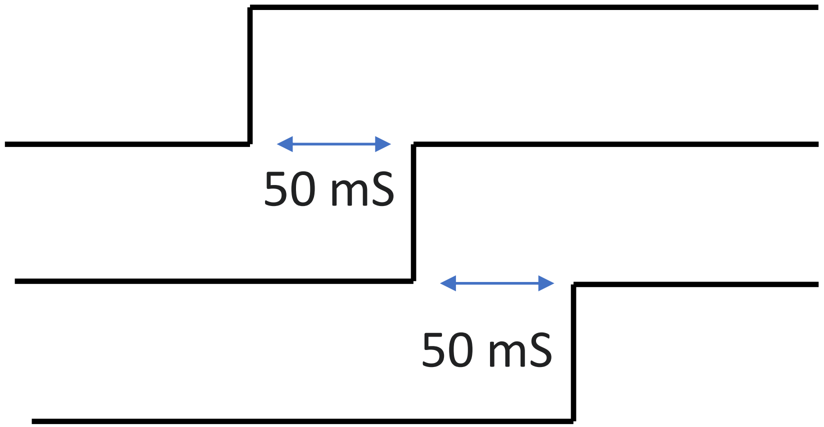
- PTT up/down event ramps up/down RC circuit and
  events determined by 3 x comparators following points on RC curve

<u>Sequencing alternatives:</u>

- Discrete logic using flip-flops and 20 Hz clock
- Software based using Arduino controller

Amplifier Sequencing

Sequencing after PTT activated

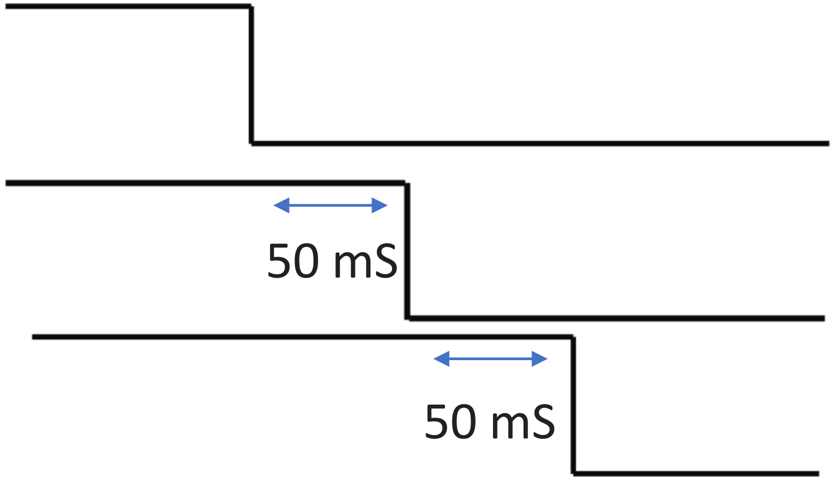


Turn off Tx (ALC = -4v), turn on fans and TR relay

Wait 50 mS, turn on amplifier

Wait 50 mS, turn on transmitter (ALC = 0)

Sequencing after PTT dropped (or fault condition)

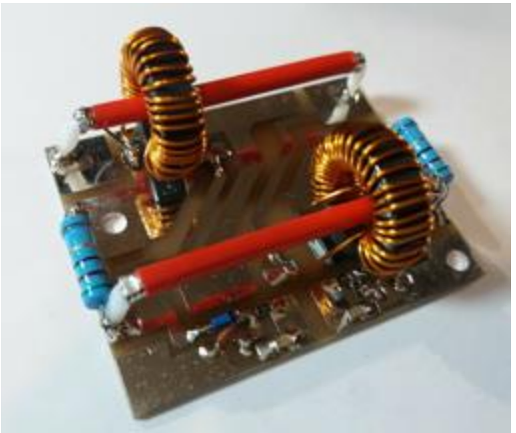


Turn off Tx (ALC = -4v)

Wait 50 mS, turn off amplifier

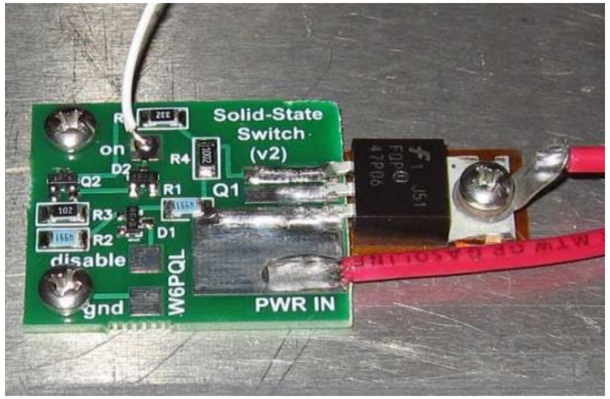
Wait 50 mS, disactivate TR relay

Amplifier Protection

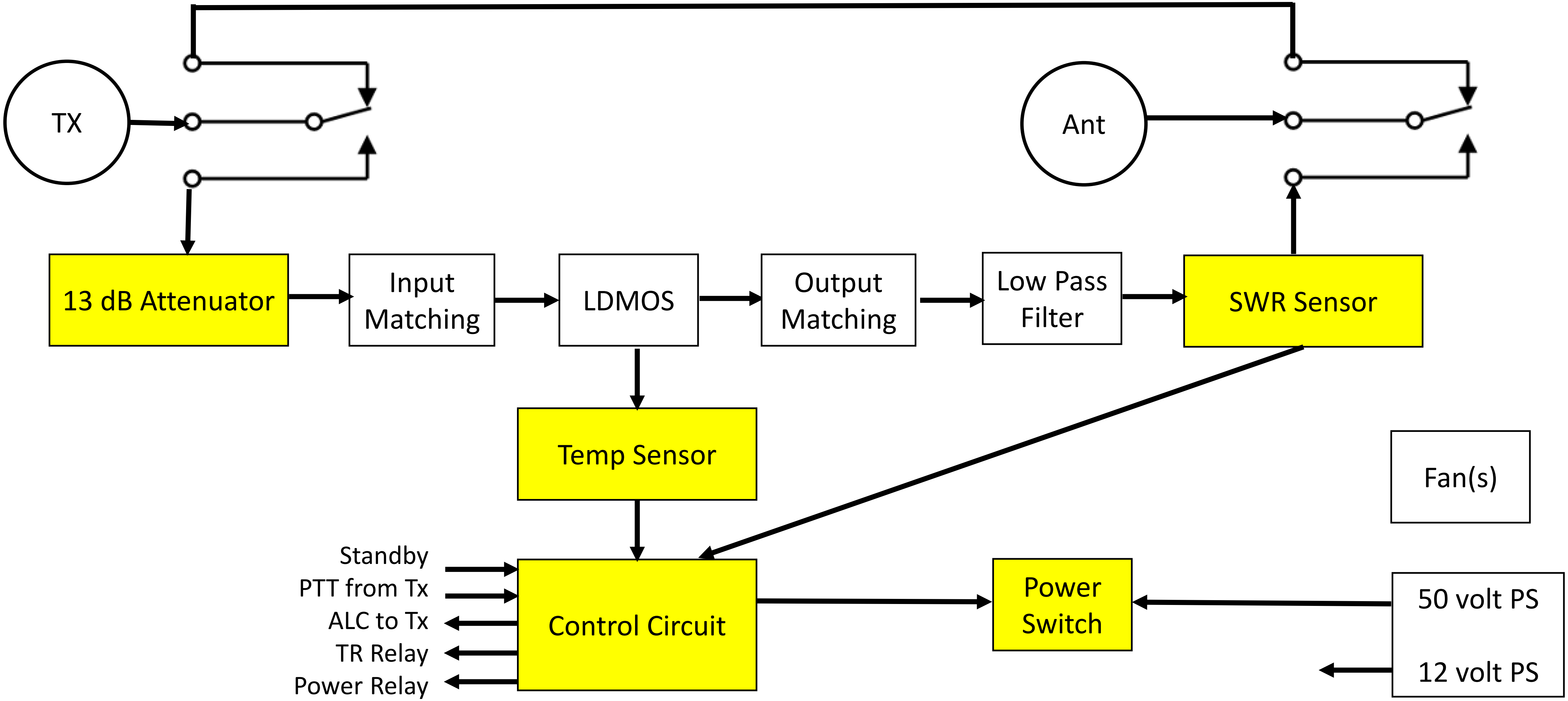


The following additional components are needed to protect amplifier

- Attenuator (e.g. Tx =100 watts out and LDMOS=2 watts in) use 16 dB
- SWR sensor (forward and reverse power) at output
- Control board for fault detect + PTT sequencing
- 48 volt power switch
- Temperature sensor on heatsink (e.g. Dallas DS18B20)



LDMOS Amplifier with Protection Circuit



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Monitor and Control Panel

1) W6PQL Homebrew:

- Classis Analog: Voltmeter and Ammeter
- SWR LED bar display
- Conventional switches / band selector

2) ON7EQ Homebrew:

- Alpha-numeric LCD
- Switches with status lamps

3) *Commercial RF-Kit RF2K-S

- Color LCD touch screen dashboard
- Conventional power switch

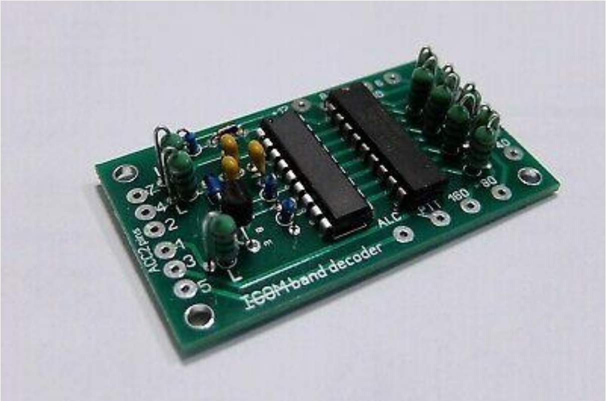
- ON7EQ Arduino + alphanumeric LCD link in references
- YO4HFU homebrew color TFT link in references

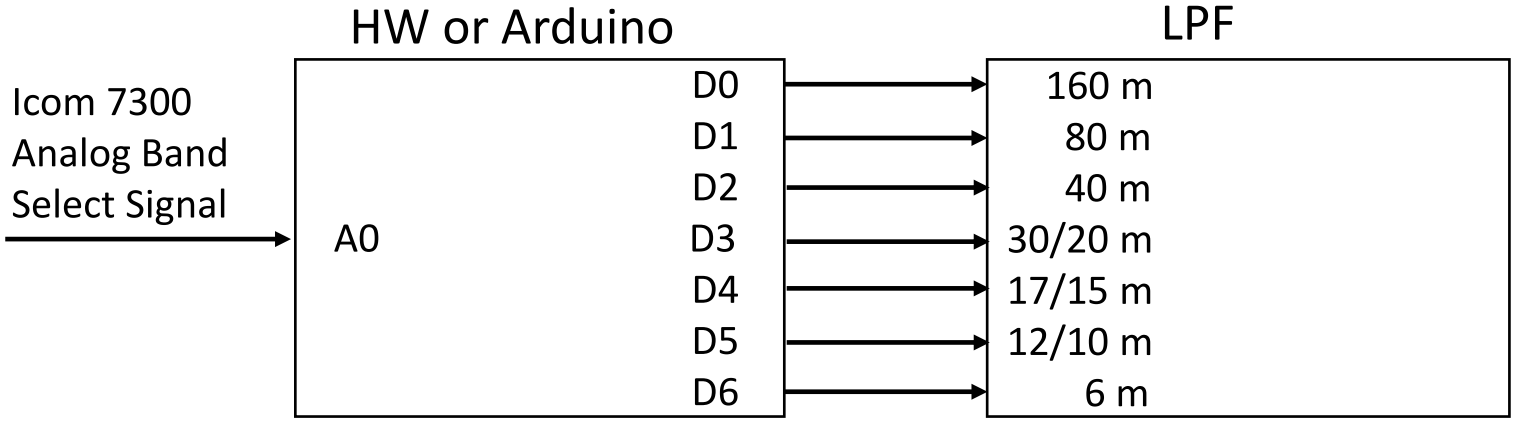
Automatic Band Selection

Traditional band selection is done with a rotary switch.

- Many modern transceiver provide an output that indicate band position.
- Example, Icom IC-7300 provides a DC voltage on pin #5 of the ACC connector

Band	Voltage
160	7.0 - 8.0
80	6.0 - 6.8
40	5.0 - 5.8
30	0
20	4.0 - 4.8
17 - 15	3.0 - 3.8
12 - 10	2.0 - 2.8
6 - 2	1.0 - 1.9





Automatic band selection can be done via HW or SW:

1) PCB for $4.00 from eBay seller R3KBO + $0.25 for LM3914 + misc parts $5.00 ➔ $10.00

2) With Arduino controller (and 10 lines of code)

Automated band selection guards against LPF in wrong position vs actual band in-use scenario.

Intelligent Controller

Intelligent control can be implemented with an Arduino for $15 Cdn.

Arduino features the following input/outputs:

- 6 x analog inputs (0 to 5 volts)
- 14 x digital input/outputs
- Simple 4 wire interface (I2C) to LCD display

Following functions can be implemented in software.

- System Monitor: SWR, power, temperature, voltage and current
- Fault detection and protection (i.e. SWR and temperature faults)
- Amplifier circuit sequencing: TR relay, amp power and ALC
- Automatic band selection

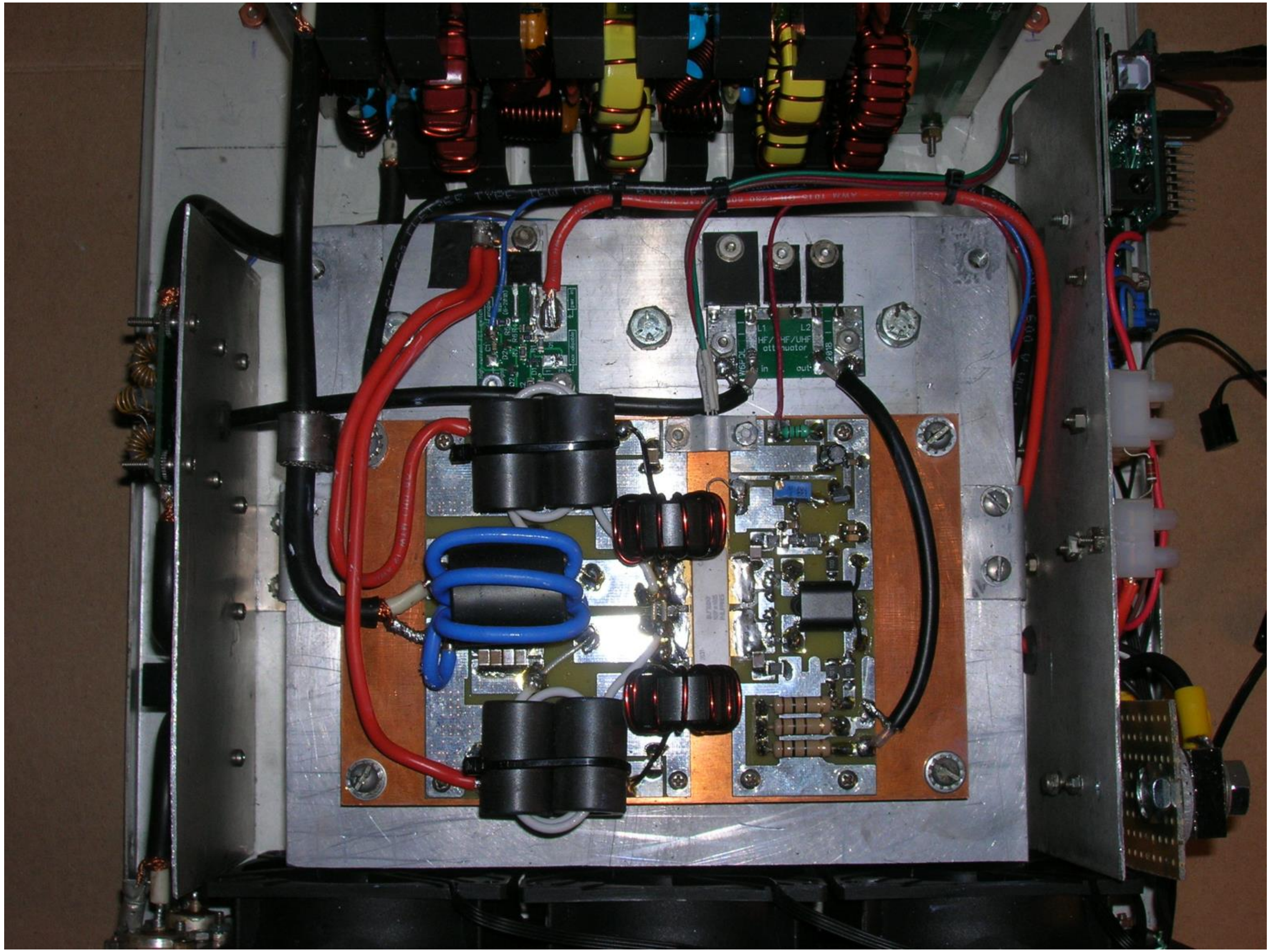
My Build

1) Setup to solder LDMOS to copper plate
Hotplate, IR temp gun and solder strip

2) LDMOS soldered to copper plate
with input / output boards installed

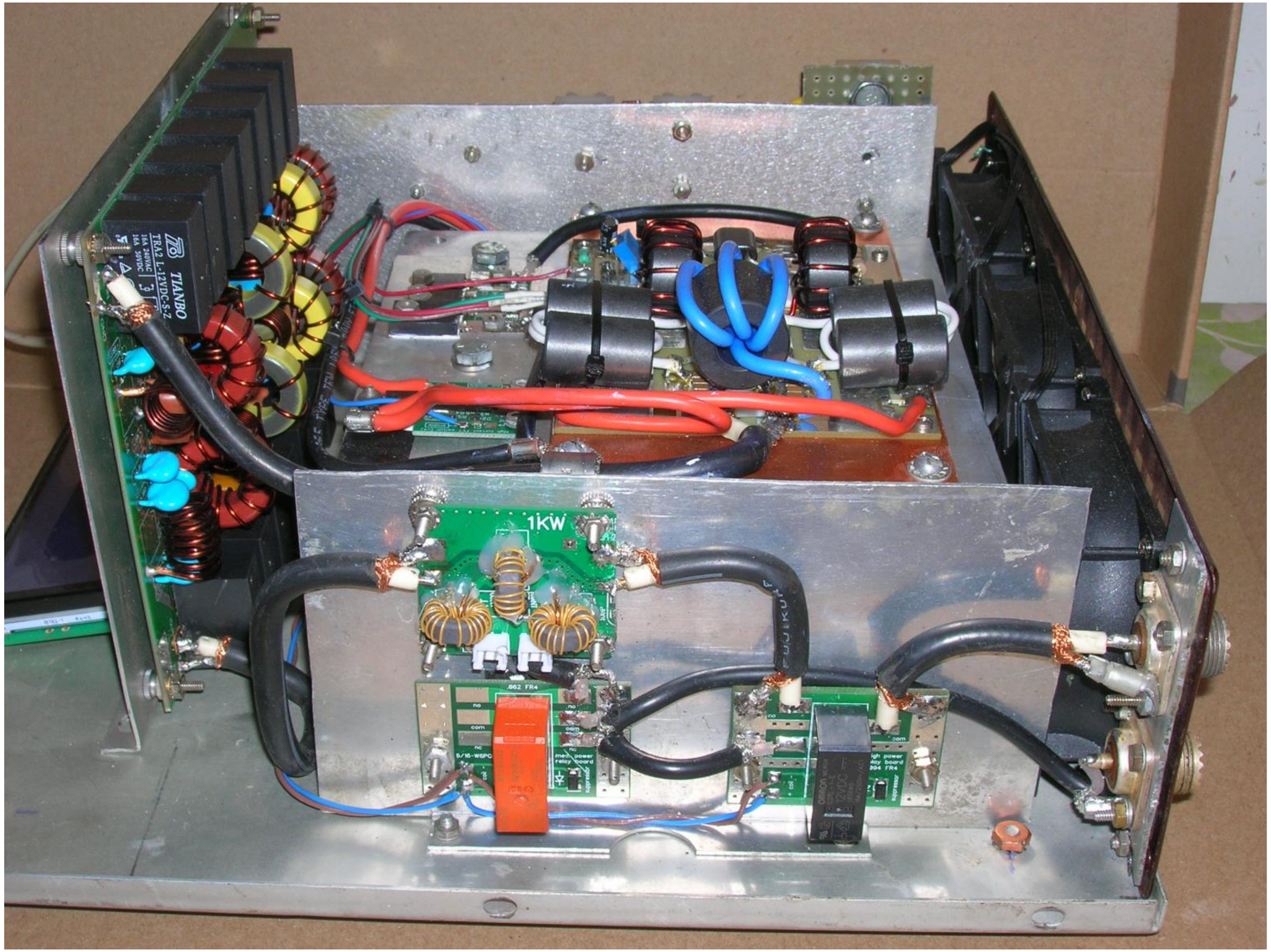
3) LDMOS sub-assembly on aluminum heatsink
with 100 watt attenuator and power switch

RF Amplifier Core

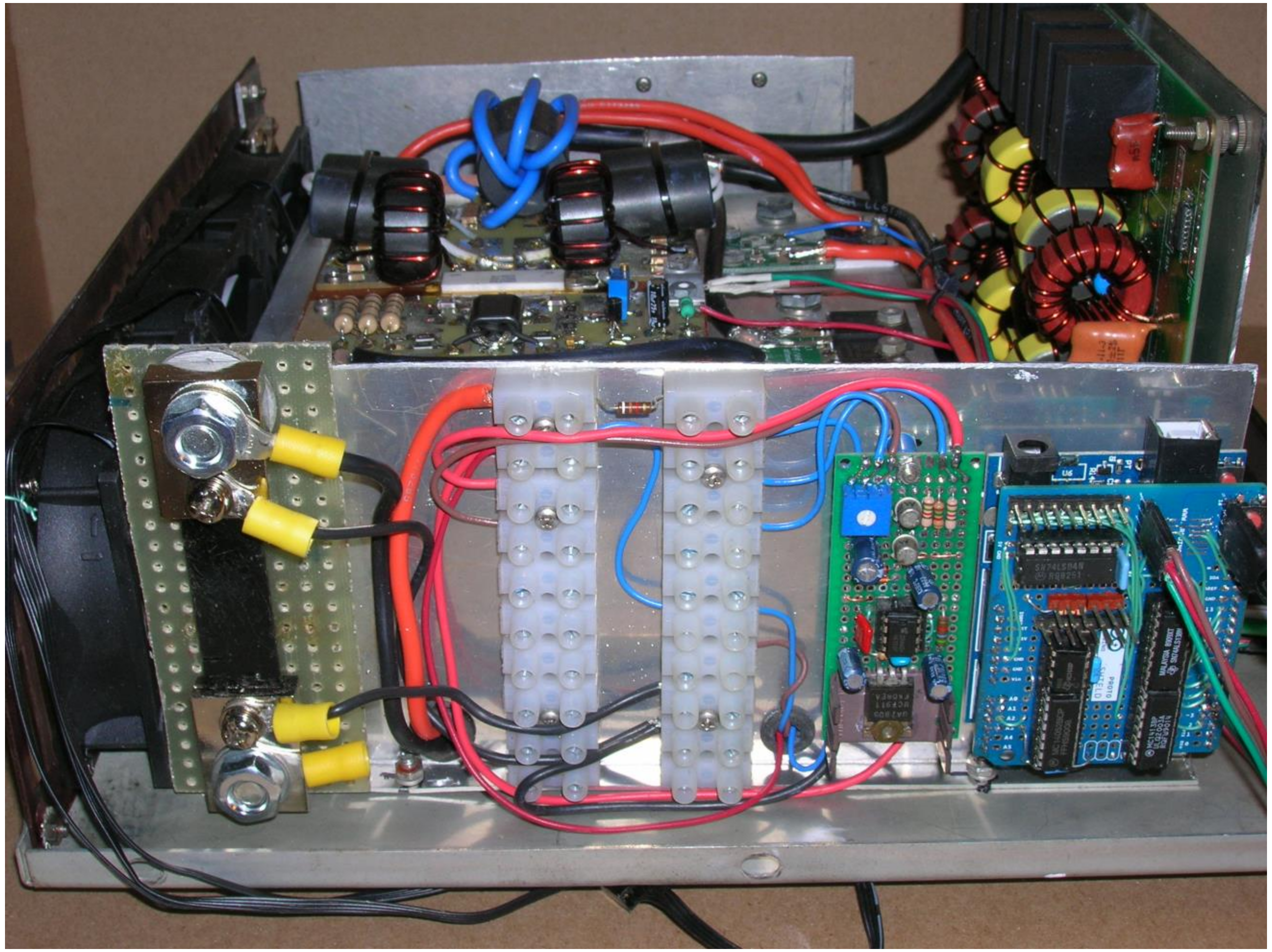


Cooling, RF Module and LPF

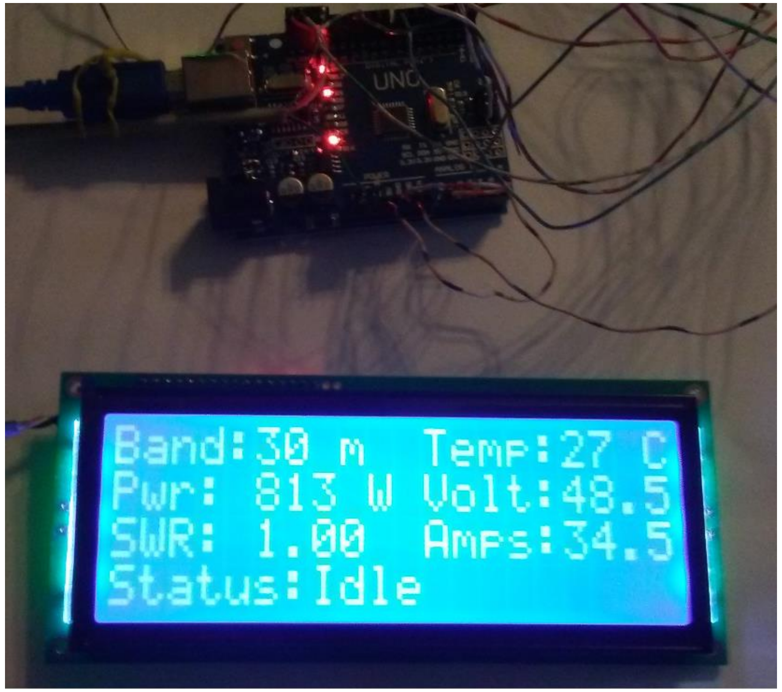
Relays and SWR Monitor

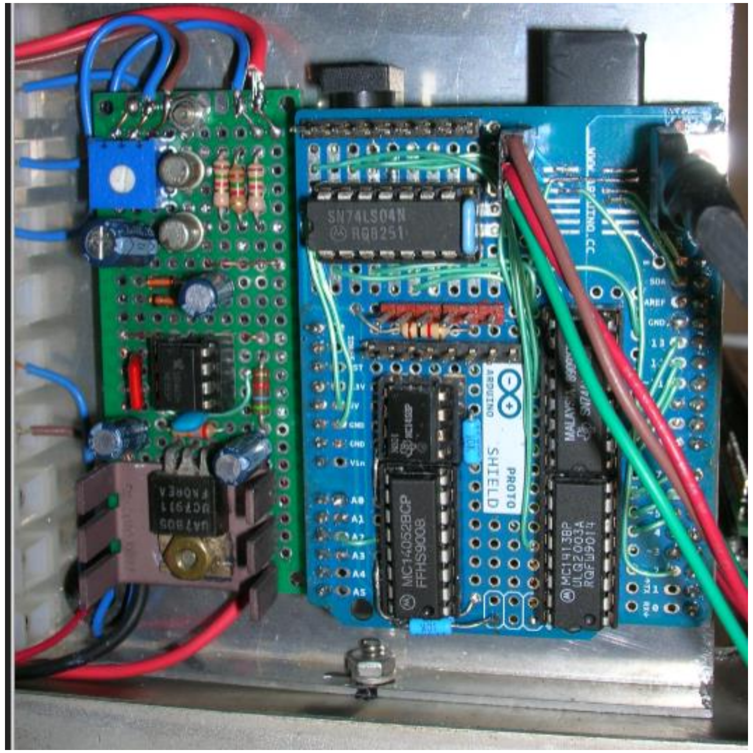


Control Wiring and Controller



Arduino Sequencer and Monitor





1) Arduino monitor Screen
- Band select, power, SWR & status monitor
- Temp, voltage and current monitor
- Status options:
    - Idle
    - On Air
    - Bypass (Standby)
    - SWR, Temp, VDS, IDS or Icom fault

Part 2: Conclusion

Homebrew solid state amplifier project is worth undertaking.

- Commercial units cost typically $4000 USD versus homebrew unit $1000 USD
- ‘Lego’ approach: Integrate prebuilt modules versus instead of ‘ground up’ build
- LDMOS amplifier most cost effective approach, best watts per dollar ratio

- Never build basic unit only (i.e. with no protection circuitry)
- Add all protection mechanisms (e.g. SWR, temp, overdrive, TR sequencing)
- Arduino + LCD display can provide cheap monitor of vital statistics:
  ➔Power out, SWR, temp, power supply and band position

- Automatic band selection offers:
  - Easy of use (i.e. no manual band selection on amp)
  - Protection against user error (i.e. amp band switch does not match Tx band switch)

Resources

Bipolar and MOSFET amplifier build descriptions:

AN758 Motorola Bipolar 1200 watt amplifier:

https://www.rf-microwave.com/app/resources/uploads/transistors/Motorola_AN758.pdf

EB104 Motorola FET 600 watt amplifier

https://www.ab4oj.com/dl/eb104.pdf

AR347 Motorola MOSFET 1200 watt amplifier

http://www.communication-concepts.com/content/AR347/AR347_Application_Note.pdf

Useful information with many details on LDMOS amplifier construction (1.8 to 1200 MHz)

https://w6pql.com/

➔SS amplifier builders users group

Facebook: RF SSPA Builders group

LDMOS amplifiers controlled by Arduino

https://www.qsl.net/on7eq/projects/arduino_sspa.htm

https://www.qsl.net/yo4hfu/LDMOS_2M.html

Resources

Amplifier component and kit supplier:

https://w6pql.com/

https://www.communication-concepts.com/

https://eb104.ru/

https://www.heatsinkusa.com/

https://www.rf-microwave.com/

Questions ?