PCB radio with improved RF amp

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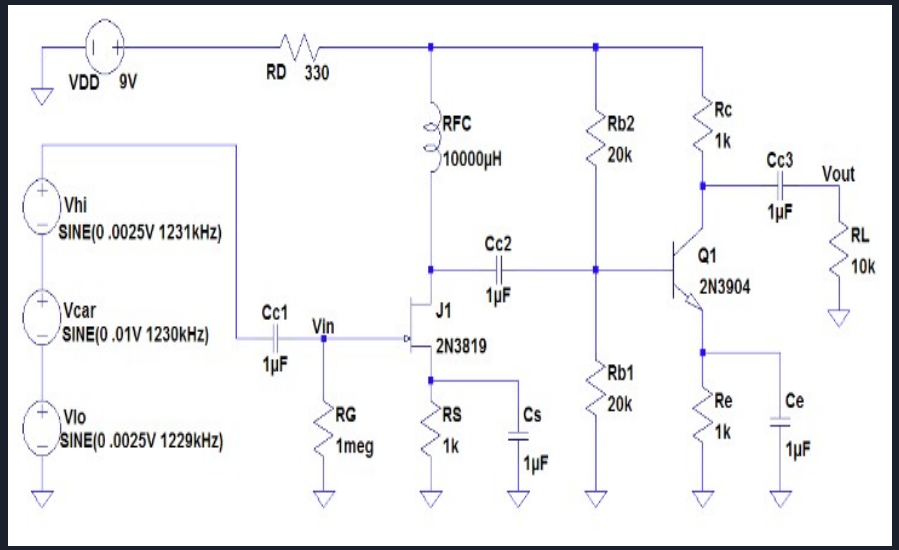
Tanner Veasey

Typical RF Amplifier



Why do you need an RF amp?

Boosts the weak AM signal received by the antenna

Advantages of CS+CE?

High input impedance leads to the weak signal appearing across the input terminals of the CS stage, followed by the CE stage increasing the overall gain

Typical RF Amplifier

Disadvantage?

Overall Gain ≈ 40 dB

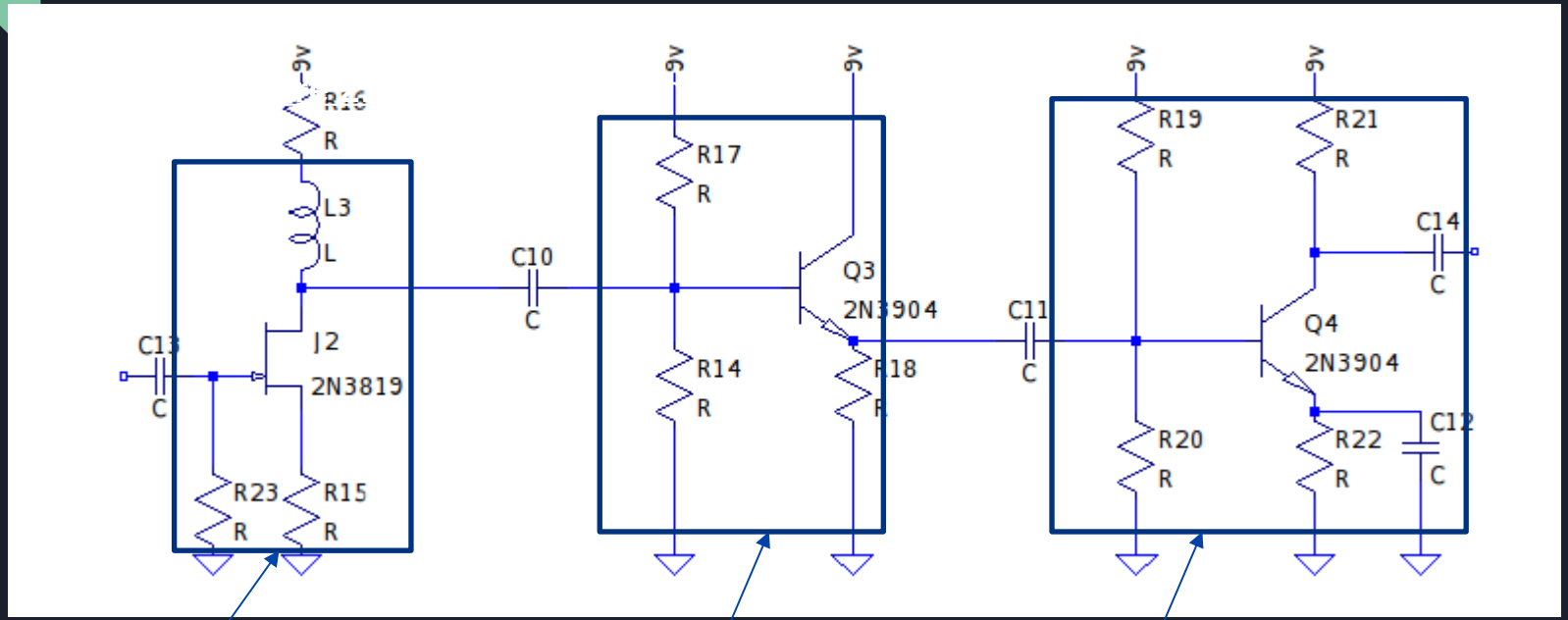
But we want MORE!

https://www.pinterest.com/pin/685321268273514239/

Comforting Alex

Why do we want more?
We can use worse antennas or operate in worse environments

Improved RF Amplifier Design



Common Source

Common Collector

Common Emitter

Including the CC stage

Why?

- Commonly used where a high impedance input source needs to be connected to a low impedance output load.

- The overall gain of our RF amplifier is increased because of the high current gain (Beta) of the CC amplifier.

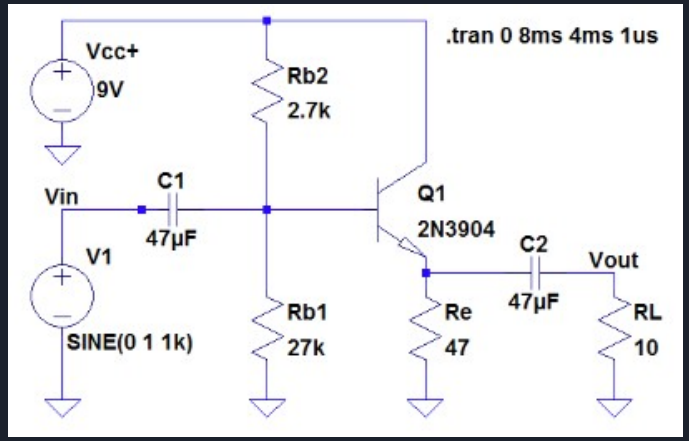


Figure 3: Typical common-collector amplifier

Improved RF Amplifier

Simulation Results?

- Overall gain = 70.6 dB
- 3400 V/V vs 100 V/V

Antenna attempt

- Ferrite Rod
- ~100 Turns

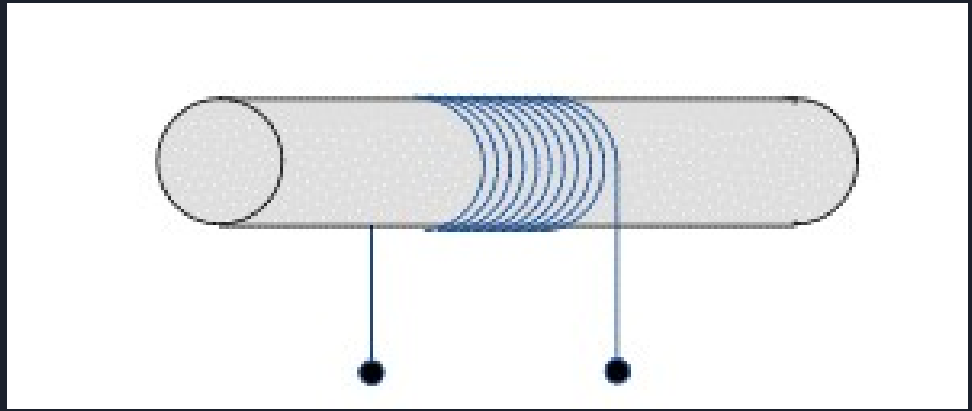


Figure 4: Simple ferrite antenna

Source:
https://www.st-andrews.ac.uk/~www_pa/Scots_Guide/RadCom/part7/page5.html

Compared to Pizza Box Antenna

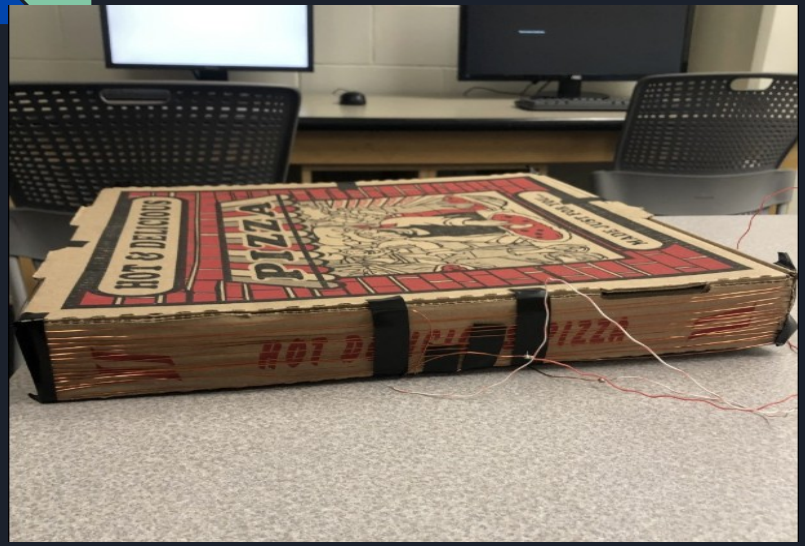


Figure 5: Square Antenna
Inductance = 87µH

Figure 6: Ferrite rod antenna
Inductance = 226µH

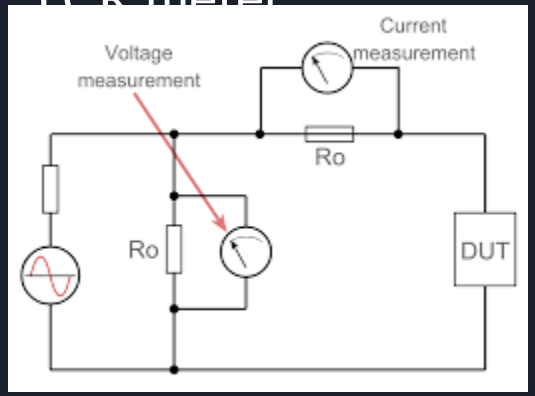
https://www.ebay.com/itm/MW-AM-Radio-60mm-X-10mm-FERRITE-ROD-ANTENNA-approx-350uH-also-for-Crystal-Radio-/152458024513

Issues While Tuning Our Radio

- Calculating antenna inductance
- Added capacitance while trimming resistors

Issues While Tuning Our Radio

- Calculating antenna inductance
  - Fgen + Oscope
  - LCR meter



https://www.electronics-notes.com/articles/test-methods/lcr-meter-bridge/primer-basics.php

- Tools interfering with resonance

A new and innovative capacitor shape!

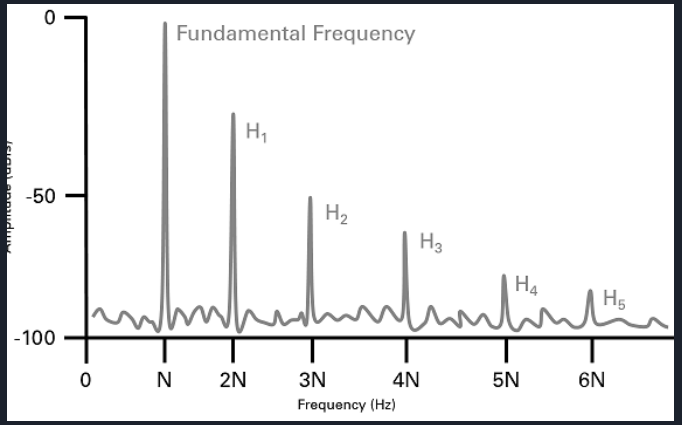
https://www.amazon.com/iFixit-Phillips-000-Screwdriver/dp/B07C4M424V

Simulation based redesign

Amplifiers

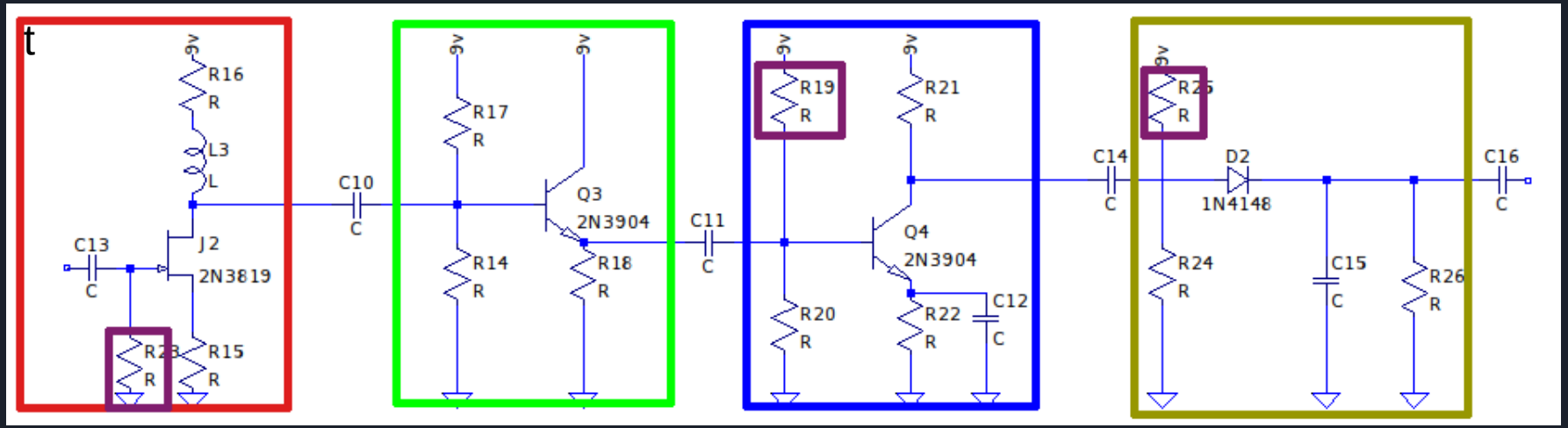
Criterion of performance:

- Gain - handled
- Distortion - horrible
- ~~Efficiency~~
- ~~Quiescent Power~~



Source: http://www.ni.com/product-documentation/3359/en/

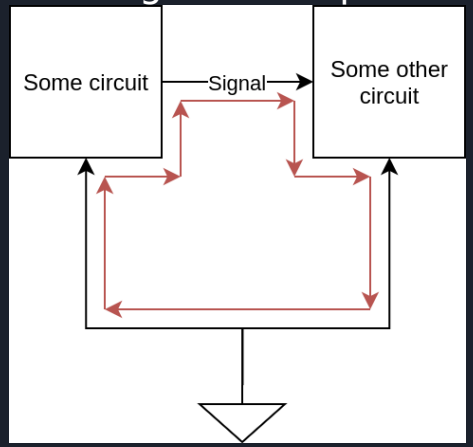
LTSpice optimization



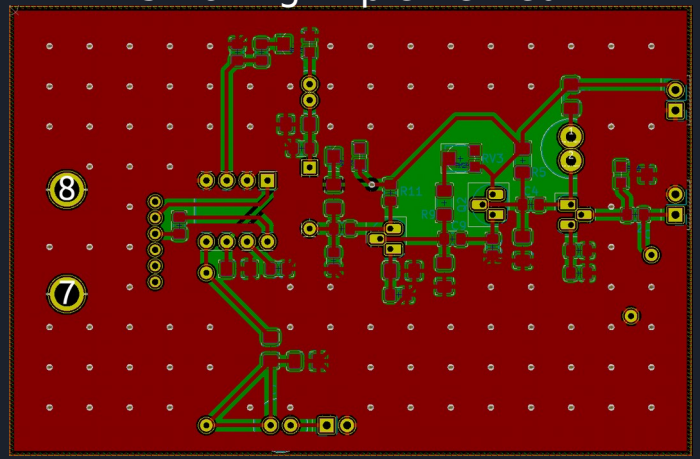
Advantages of a PCB

Ground loops

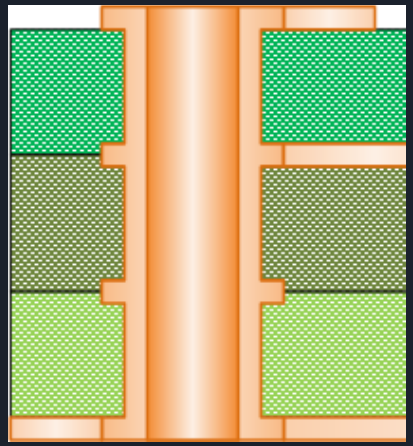
Generic illustration of ground loops



Our circuit board with via stitching implemented



What a via is



Source: https://www.eevblog.com/forum/manufacture/buried-vias-and-their-effect-on-pcb-cost/

Ground loops reduced in PCB’s by via stitching ground planes together

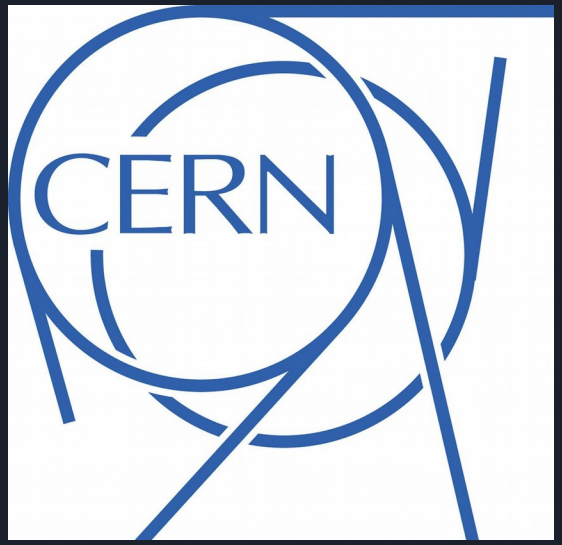
Aside from ground loops

- Mechanical rigidity
- Smaller size
- Increased complexity
- Cheaper components - sometimes
- More aesthetically pleasing

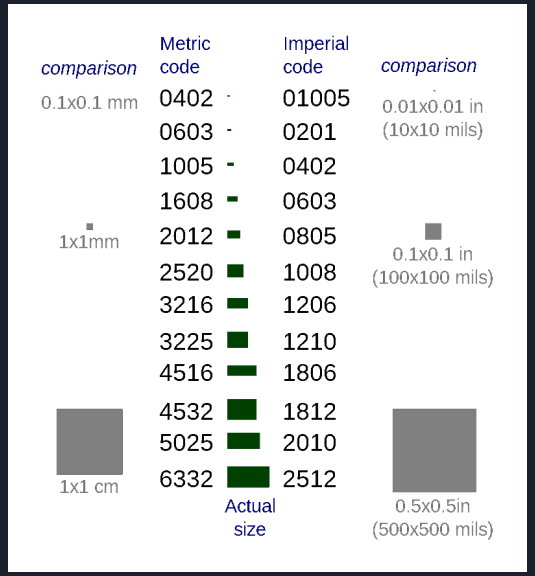
Source: http://www.spazztech.net/resistors.html

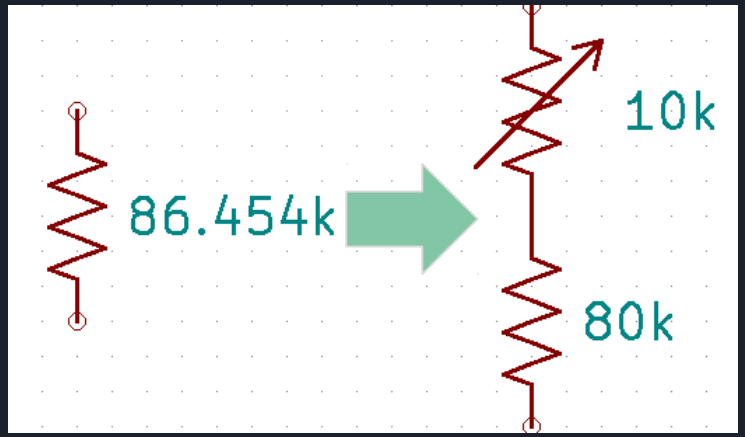
Designing a PCB

Tools



Component selection

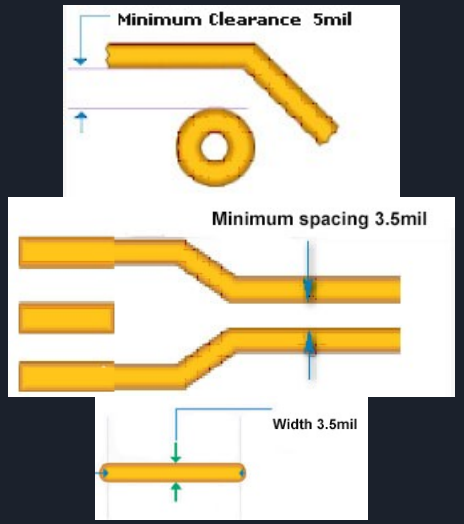




Source: https://en.wikipedia.org/wiki/Surface-mount_technology

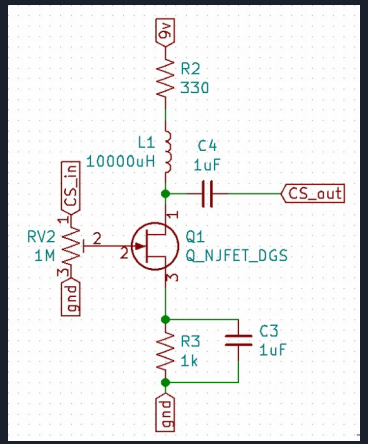
Layout

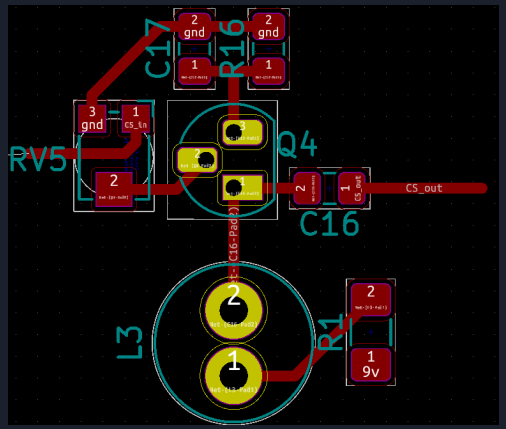
Design rules

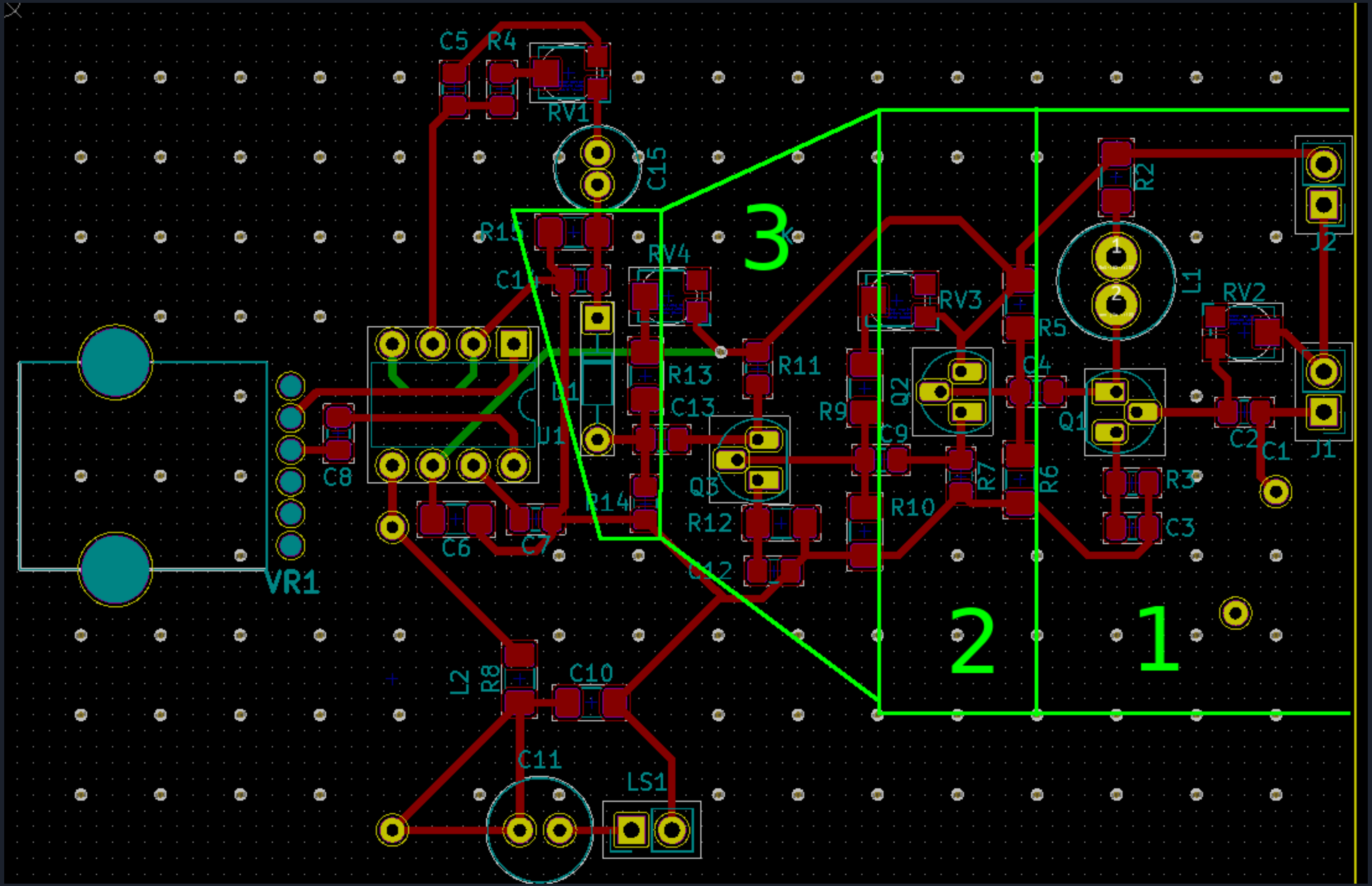


Source:https://jlcpcb.com/capabilities/Capabilities

1. Separate design into distinct blocks
2. Layout individual blocks
3. Layout blocks relative to one another
4. Finish interconnects
5. Flood fill ground planes
6. Via stitch







C5
R4
RV1
C15
R15
C14
RV4
R11
R13
C13
D1
U1
C8
VR1
C6
C7
R14
Q3
R12
C12
RV3
R9
C9
R10
Q2
R7
R5
R6
Q4
L1
Q1
R2
J2
RV2
C2
C1
J1
R3
C3
L2
R8
C10
C11
LS1
3
2
1

Cost

Parts - Mouser

- 27 distinct components
- 51 components in total
- Component cost of $7.43/radio

Manufacturing

- PCBshopper
- JLCpcb - $0.40 per board
  - 2 days plus shipping lead time

Assembly

- Totally possible with hand tools

Source: https://www.aliexpress.com/item/1926979484.html

Did it work?

Improved gain

- Works faintly all the way down to -95 dBm
- Tends to amplify a huge amount of noise due to no input or intermediary filtering

Decreased distortion

- Measured THD of 14% down from 25% of original amp given the same input.
- THD measurement is not well standardized.

What would we change?

Improved gain

- Input filtering
- AGC to prevent saturation

PCB Design

- Better connectors
- More modular layout
- Test points
- Silk screen art
- Use both sides of the board