Grounding and Layout for Audio

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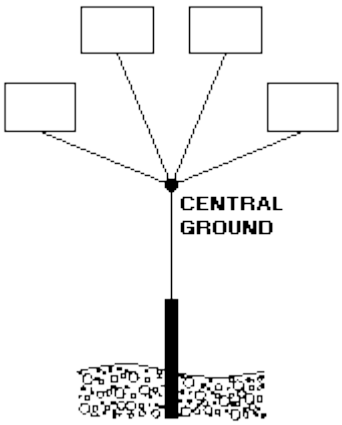
“Star Ground”



"The technique of a ground 'mecca' (a common point in the circuit to which all ground connections are tied) is often seen, but it's a crutch; with a little understanding of the problem you can handle most situations intelligently."

Horowitz and Hill, The Art of Electronics

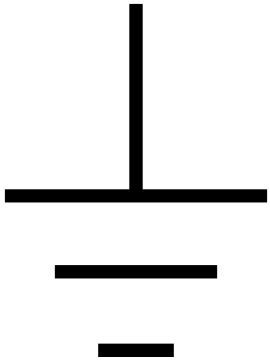
This pretty much sums up the use of a “star ground” in audio electronics. It is still the default approach for most analog audio designs including, surprisingly, class-D amplifiers. To say this approach is unsuitable for any sort of switching design is an understatement.

One reason this approach may have become prevalent in audio is when the circuitry was wired point-to-point, or when the PCBs were single-sided and drawn by hand. This does not allow for the inclusion of a solid ground plane, so point-to-point grounds were the best available choice.

“It worked just fine then, so what's wrong with it now?” Nothing is wrong with using a star ground if it is used in circuits similar to those used back in the day: simple audio frequency electronics (i.e. 20Hz to 20kHz). There is a big difference however between a good approach and an approach you can get away with in certain applications.

A solid ground plane, coupled with intelligent partitions that minimize interaction of dissimilar return currents (e.g. analog and digital), will outperform a star ground every time.

The Ground Symbol



When you see or use a ground symbol in a schematic it is important to be aware of two built-in assumptions:

- Assumption #1 – ground is ground is ground
  - This is a bad assumption. Ground always varies based on where you measure it.
- Assumption #2 – return currents are not critical
  - This is a bad assumption. The return current is every bit as important as the current going out in the first place! Remember: it is called a "circuit" for a reason.

Rejection of Electromagnetic Fields

A magnetic field will induce a current in a circuit proportional to the strength of the magnetic field and the area of the loop it is incident upon. This means circuits that make use of a ground plane will minimize interference from magnetic fields, since the area of every loop is minimized via the conformal return path in the ground plane.

An electric field will induce a voltage, and resultant current based on the circuit impedance. The current generated will find its way to earth ground. Again the ground plane circuit will offer superior rejection, as the impedance of the ground path is minimized via a continuous plane, rather than the point-to-point paths used in a star ground approach.

Single Ground Point Versus Multiple Ground Points

There is also some debate regarding the use of a single earth grounding point or multiple earth grounding points. For a system within a given chassis with only one external ground reference entering the system, multiple earth ground points are superior. The reason why is that there are now multiple paths for interference to find its way, via the ground plane, to the local earth ground.

This is especially true for the secondary side ground of a switching power supply. It is ideal to have a earth ground as near this point as possible, but it is also ideal to <u>not</u> share this ground point with sensitive low-power analog circuitry. This means at least two earth ground points should be used in this type of system. Now add a high-power analog section and yet another ground point may be needed.

Layout Advice

- Never underestimate the importance of layout.
  - Small compromises early on in the layout lead to big problems later, as there tends to be a "cascade effect" with subsequent layout.
  - The greater the dv/dt and di/dt the smaller the effective area/loop area must be to avoid problems with EMI.
  - Always remember: $v = L\frac{di}{dt}$ and $i = C\frac{dv}{dt}$
  - E.g. In a class-D amplifier 10A is switched in 20nS with 20nH of parasitic inductance. What is the resulting overshoot?
    - $v = (20\text{nH})(\frac{10\text{A}}{20\text{nS}}) = 10\text{V}$
  - E.g. A class-D amplifier transitions through 100V in 20nS. What is the current induced in an adjacent circuit if the parasitic capacitance is 20pF?
    - $i = (20\text{pF})(\frac{100\text{V}}{20\text{nS}}) = 0.1\text{A}$
  - A good design must take into account the resulting layout. This requires an iterative design process.
- Try to make the ground plane as solid as possible.
  - If there are only two layers to work with, then make it is as solid as possible in the "critical regions".
- Avoid ground planes that are intentionally split; instead segregate the circuitry as needed.
- Always use differential feedback.
  - This is the case even if the output is ground referenced.
  - A Kelvin feedback connection is used for the "+" output and for the "-" output.
    - These two lines should be kept short and close together.
  - Even though the ground plane is designed to be equipotential, it never is with switching designs.
- Always keep Maxwell's equations in mind, even if you never use them for computation.
  - $div\ \vec{E} = \frac{\rho}{\varepsilon_0}$ Electric charge density produces a diverging electric field.
  - $div\ \vec{B} = 0$ Given no magnetic monopoles, there is no diverging magnetic field.
  - $curl\ \vec{E} = -\frac{\partial \vec{B}}{\partial t}$ Time-varying magnetic field produces an opposing curling electric field.
  - $curl\ \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$ Current or time-varying electric field produces a curling magnetic field.