COMPUTER AUDIO DESIGN


# Exploring
# Ground Control

## Computer Audio Design (CAD)

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## CAD & Scott Berry: a brief introduction

Computer Audio Design (CAD) was launched in 2011 to create high-end audio components that seek to deliver the best possible sound in computer-based audio.

The past decade has seen a revolution in the way we listen to music, with computer audio becoming one of the most important growth areas. While initially driven by convenience and cost, the market has rapidly evolved to focus also on quality and authenticity in sound.

I'm Scott Berry, CAD's founder and chief designer, an American now living in the UK (CAD is a UK company). I gained a degree in electrical engineering and enjoyed a career with Tektronix and Xerox in the US before combining my digital design know-how with a life-long passion for music and hi-fi to develop CAD's first product, the 1543 DAC.

Following critical acclaim, CAD developed a MKII upgraded edition, as well as a dedicated, all in one "audio transport" unit – the CAD Audio Transport (CAT) – designed to be the best digital source available for playback of locally stored audio files or for streaming online music sources.


Further innovations followed, including award winning USB cables, all with one common goal: to enable computer-based audio to achieve a quality of sound that is tangibly closer to the original musical performance. The latest development is the CAD Ground Control, a passive device to absorb high-frequency energy.

## The Ground Control: computer audio and beyond

Throughout high quality audio engineering, a key design concern is reducing unnecessary and unwanted electrical 'noise' in hi-fi components, since it is widely accepted that noise in the audible frequency range is a key limiting factor in sonic and musical performance. But what if there were another type of noise, in a different frequency range and in different areas of audio circuitry that was also performance-limiting?

Launched in 2016 and singled out as a 'Hot Product' at the 2016 Munich High End Show, CAD's Ground Control tackles high frequency noise reduction at the level of the signal ground plane, with remarkable results. Initially designed for computer audio applications, the Ground Control has since proved astonishingly effective in enhancing the performance of all hi-fi components, across both digital and analogue systems.

## Not all ‘noise’ is the same: the CAD difference

It is widely accepted among audio designers and engineers that electrical noise in the audible frequency range (20Hz -> 20kHz) constrains sonic performance and hence needs to be properly managed. But at CAD we also concern ourselves with a much higher and broader frequency range in the scale of 500kHz to GHz. We also home in on an area of audio circuitry that tends to get surprisingly little attention: ground.

These two key areas constitute signature elements of CAD’s design focus:

- high frequency (HF) noise, far above the audible range
- signal ground *and* mains earth (symbols shown right).

FIGURE 1: Signal ground symbol.

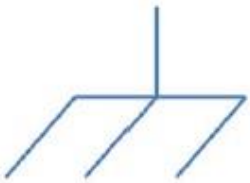

FIGURE 2: Earth ground symbol.

I believe that if an audio system is to achieve its full potential in terms of natural, authentic sound quality, then reducing noise at this higher frequency range is essential, and crucially on the signal ground and mains earth (if separate – more on this later).

I should state that what follows here are my theories, based on my experience as an electrical engineer in the high-tech digital industry, and also based on extensive empirical listening – the latter being, of course, subjective. That said, my experience has clearly shown that in reducing HF noise in audio circuitry, in both the signal or supply voltage itself and in signal ground, sound quality quite clearly improves.

## Voltage, signal ground and earth ground: a quick primer

As much as I love science myself, I’m going to assume that you have no background in electronics or circuit design.

Electrical voltage is key to our understanding here, so let’s define it. Voltage is the difference in electrical potential *between two points*.

The image (right) shows of one of the simplest voltage measurements we can make - measuring the DC voltage of a battery.

There are *always two points* in any voltage measurement: a reference point and another point in the system.

In audio components, some or all of the following voltages exist:

- Positive DC voltage
- Negative DC voltage
- Mains AC voltage
- AC analogue (music) signals
- Digital signals.

All of the above voltages are referenced to either signal ground or to earth (the latter being the mains power earth connection - the third pin on your mains power plug). So both signal ground and earth are reference points in audio design. Typically, in most audio components, signal ground and earth are not directly connected, but they can be in some designs.

My impression is that relatively few audio engineers devote attention to signal ground, perhaps because it's assumed that signal ground does not have noise or because it's believed not to be an issue, particularly above the audible spectrum. While this may be acceptable for many electronic designs, in my opinion it's worth questioning and exploring in audio design.

Unfortunately there is no standardized measurement technique for noise levels present in signal ground or earth. But measurement can be done, and if you're interested, the techniques outlined in *Measuring Ground Noise* by James M. Bryant (2001)[1] are a good place to start.

In my experience, signal ground needs to exhibit extremely low impedance. I've found that even a slight increase in signal ground impedance can have detrimental effects on sound quality, notably in terms of appearing to dilute pace, rhythm and timing. Clearly this limits many of the common solutions to noise (filters etc), and so I sought to develop something new.

## HF noise: if we can't hear it, why is it significant?

At this point you may be thinking that since the upper limit of human hearing is (at best) 20kHz, then why would noise in a much higher frequency range be such a big deal in terms of an audio system's sound?

It is our belief that this HF noise affects the performance of the electrical devices used in your audio components, degrading overall sound quality. In particular, we believe that devices such as operational amplifiers, transistors and DAC chips used in modern audio

circuits are all sensitive to HF noise. In our experience, reducing unnecessary high frequency noise in the system gives clearly perceptible sonic benefits.

## Where does high frequency (HF) noise come from?

High frequency noise in an audio system comes from two sources:

- mains power supply and earth connections;
- audio components themselves.

### *Mains power and earth noise pollution*

Earth is a noisy place. Dirty electricity, muddy power or electrical pollution – call it what you will - but the problem remains the same: high frequency noise in the mains power supply and mains earth.

Why? Because in modern life we all use a proliferation of electrical devices, most with switch-mode power supplies, all of which create noise over a large spectrum of frequencies - from audible up to well into the high GHz range.

From kitchen appliances - washing machines, microwave ovens - through dimmer light switches, cordless telephones, televisions, through to battery chargers, computers, routers, Wi-Fi – across the whole frequency spectrum, every one of them is dumping noise into mains power supply and mains earth.

For safety reasons, any electrical device in a conductive (metal) casing must legally have an earth connection. Most audio components have metal housings that must be earthed - the exact same earth connection as those noisy domestic devices are connected to. So your audio components are encased in a box that's conducting this very noise. This is one of the reasons why we use a non-conductive acrylic case for our CAD 1543 DAC.

### *Audio components as noise-generators*

In addition to this noise on the mains power supply and the earth connection, audio products themselves create HF noise. The worst offenders are devices like audio servers, routers, Wi-Fi and NAS (storage devices), and of course many people use laptops as an

audio component. But all digital audio components such as DACs and CD players also contain electronic devices like high-speed oscillators that produce significant HF noise.

Therefore, now, in the digital age, we often have no other option but to connect devices that produce large amounts of HF noise in the high kHz to GHz frequency range to our audio system – even if we're die-hard analogue fans at heart. The whole system is potentially affected.

## Reducing component noise – common approaches

There are many approaches to reducing audio component-generated noise. My guess is that if you had five audio engineers talking over a beer, you'd get at least five recommendations!
In my opinion a good design that doesn't create noise in the first place is the best place to start, but the fact is that even the very best designs typically can use some additional help.

*"My guess is, that if you had five audio engineers talking over a beer, you'd get at least five recommendations…"*

A common technique is filtering. All CAD products use filtering. Another approach is to use physical and electronic segregation of digital and analogue circuitry to keep the 'noisy' digital out of the 'quieter' analogue parts of the circuitry. Again, we use this approach in CAD's 1543 DAC. We also have a patent on the USB cable filter we use in our USB cables.

Tackling high frequency noise on the signal ground plane, however, is (to date) a decidedly uncommon approach. Yet CAD has, from the very beginning, held the belief that HF noise on signal ground and mains earth is one of the major limiting factors in digital audio reproduction. Which is why we have consistently developed techniques and materials to block or extract HF noise in all of our products. However, in order to meet space and cost considerations, we were somewhat limited in terms of what we could include *inside* our products. So we began to experiment with developing an independent, passive, external device. This is how the Ground Control began its journey.

## 'Clean power' solutions: the missing connection

Remember the 'dirty power' problem we mentioned above? You were no doubt thinking, 'but there are already manufacturers offering products designed to clean impure mains power'. The value of these products is the subject of some debate (check out any hi-fi online chatroom); my personal view is that while their results vary quite widely, some of them can indeed improve sound quality quite significantly and are therefore often worth investing in. But many of them are cleaning only the 'live' and 'neutral' mains power

connections, and doing nothing or very little with the earth connection. Which, for me, is an important omission.

What's more, there's legally only so much you can do to clean up the mains earth connection using standard filtering methods. The whole basis of mains earth is to offer a 'safety escape', a low impedance pathway for potentially dangerous electrical current to travel down into the earth – rather than electrocuting somebody. For example, say something goes wrong with an audio component and the mains power 'live' wire becomes disconnected and touches the metal case, making the case itself live. One of the laws of electronics is that electrical current (like water) will always take the easiest path down into the earth. In the absence of a mains earth connection, if you were to touch the live case then that 'easiest path' would be through you. But with a mains earth connection, since that connection is purposefully designed to have a much lower impedance to earth than your body, that's where the dangerous current will go. It's therefore crucial that the impedance of the mains earth connection remains as low as possible. And since typical techniques for 'cleaning up' noise would raise that impedance, this limits how much cleaning can actually be done without compromising both legality and safety.

The techniques that the CAD Ground Control uses have no effect on earth impedance and therefore offer an effective solution for reducing HF noise on mains earth while maintaining safety.

## Ground Control construction and use

CAD's Ground Controls are designed to tackle high frequency noise at the level of the signal ground and mains earth, aiming to improve the sonic performance of audio components. It reduces noise in the frequency range of about 700kHz to well over 10GHz.


The Ground Control is manufactured by fabricating a compressed 'sandwich' of various specialist materials which, in combination, effectively convert HF energy over a broad frequency range into heat. These materials are normally used in the aeronautical and electronics industries.

The Ground Control does not connect to any power source - it is a *passive* device. It attaches in parallel to the audio device, thus it does not affect, change or limit the attached device in any way other than to lower the HF noise in the device.

This is why the Ground Control can be so effective with mains earth noise. There is no increase in impedance and hence no impact on safety, yet there is a reduction in HF noise. Similarly, as noted earlier, signal ground also needs to exhibit extremely low impedance, since even a slight increase in signal ground impedance can have detrimental effects on sound quality (e.g. diluting pace, rhythm and timing). Again, the Ground Control reduces HF noise in signal ground with no increase in impedance.

The Ground Control comes in two models: the smaller GC1 and larger GC3.
Using our specialised grounding cables, the Ground Control can be connected to any unused connector on any device. The cables are available with a wide choice of different terminations - USB, RCA, XLR, spade, BNC - or anything required (to order). Our GC cables use only the ground connection in each of these terminations, giving a connection directly to signal ground in the device.

So, for example, you can connect an unused USB socket on a laptop to a Ground Control, or an unused RCA output on a DAC or CD player. Whether you're using an audio product or a computer / router / NAS, there will typically be an unused connection that can be connected to the Ground Control.

The Ground Control can be connected to signal ground or to mains earth. Some mains power outlet strips have earth connections and many audio components offer a connection to the chassis/case or earth point. Alternatively, if your power outlet strip or audio component has a metal conductive case, you can sometimes loosen a screw and use a Ground Control cable with a spade connector to connect to the case. Be sure to have your dealer help you with this.

We generally don't recommend connecting both signal ground of an audio component ***and*** mains earth together using the same Ground Control device. In this case, you would be directly connecting signal ground *to* earth which could make noise problems worse. In most higher-end audio components, signal ground is not connected directly, or at all, to mains earth. In the case of some DACs, for example, there may be 'galvanic isolation' stopping the current from a USB input from reaching the DAC chips. This is the case with the CAD 1543 DAC. Connecting earth to signal ground would override the galvanic isolation and possibly introduce noise from the mains earth into the DAC - noise which the designer put a lot of effort into eliminating!

I therefore recommend connecting a Ground Control to *either* signal ground *or* earth. Better still, if you have two Ground Controls, connect one to each.

In our experience, the greatest impact on sound quality is achieved by attaching a Ground Control to the 'most noisy' device in any system – which would typically be a computer, audio server, DAC or CD player. However, every system is different, and we recommend experimenting and comparing the effect, working through from source onwards to see at what point Ground Control has the biggest impact.

Try connecting to the output sockets of a source component or the input sockets of a pre-amplifier, for example. If you are fortunate enough to have two or three Ground Controls, try grouping comparable equipment types e.g. one for digital devices, one for analogue, one for mains power, etc.

Having experimented widely with multiple configurations, our findings suggest that the best sonic result is achieved by connecting each audio component to one Ground Control. Obviously this has budget implications, so we do include two sockets on every GC1 and six per GC3, offering the flexibility to connect multiple devices. It also enables one Ground Control to be 'daisy chained' to another, offering a way of adding HF noise reduction capacity without rendering the first Ground Control obsolete.

I'd love to hear about your experiences. When you've had a chance to experiment, do get in touch and let me know what you found. As an engineer I'm always keen to share and evaluate the findings of experimentation. And as a music lover and audiophile, I'm keen to discover how your system and your music are performing.

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Notes

1. *Measuring Ground Noise* by James M. Bryant, Head of European Applications, Analog Devices Inc (2001), is available to download at http://www.analog.com/media/en/analog-dialogue/raqs/groundNoiseMeasurement.pdf


Less noise. More music.
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