Grounding ADCs & DACs

ONLINE SYMPOSIUM *for* ELECTRONICS ENGINEERS

Grounding ADCs & DACs

Lecture

Grounding Analog-Digital Converters

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DESCRIPTION

Most ADCs have separate analog ground (AGnd) and digital ground (DGnd) pins, but too many engineers, and, unfortunately, too many data sheet writers as well, are uncertain how they should be connected.
The lecture considers the nature of the currents flowing in these pins, the vulnerabilities of precision data converters to internal and external noise, and the effects of various grounding and decoupling configurations, and suggests, and justifies, a grounding scheme which gives the best possible converter performance in the vast majority of cases

http://www.**techonline**.com/community/ed_resource/course/13479

Data Converters (ADCs and DACs)

are accurate and sensitive analog devices whose analog ports are vulnerable to unwanted noise (most advice in this lecture applies to both ADCs & DACs)

Mixed Signal Systems

(systems with both analog and digital processing)

often have separate analog and digital ground planes in order to isolate their sensitive analog signals from the noise which is often present on the digital ground

Data converters – that is to say Analog to digital converters (A-to-Ds or ADCs) and digital to analog converters (DACs) - are sensitive of accurate devices which are vulnerable to noise. Unless otherwise stated all the advice in this lecture applies to both types - A-to-Ds and DACs. A common problem in systems using data converters is how to ground them for best possible analog performance.

Mixed signal systems, which contain both analog and digital signal processing, frequently have separate ground planes for the analog and digital parts of the system in order to prevent logic noise from the digital system from corrupting their sensitive analog signals. These grounds meet at a single common point, sometimes called a star point, which is usually adjacent to the power supplies

ADCs & DACs

frequently have separate analog and digital ground pins (labelled, respectively, **AGND** and **DGND**)

These should be connected together and to the analog ground plane of the system, even if the data sheet suggests otherwise

A-to-Ds and DACs generally have separate analog and digital ground pins, labelled respectively AGND (or analog ground) and DGND (or digital ground), and their data sheets frequently recommend that these two pins be connected together at the device package. This creates a problem - how then to connect them to the system analog and digital grounds without creating a ground loop.

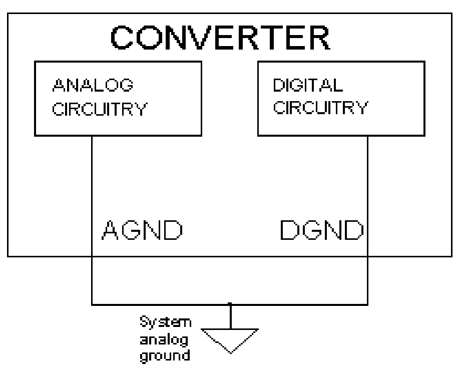
The solution is simple – don't! They should both be connected to the system analog ground.

Even if the data sheet suggests that they be connected separately to the system analog and digital grounds it is usually better to ignore this advice and connect them together and to the system analog ground.

A PHILOSOPHICAL PROBLEM!

AGND and **DGND** should both be connected to the analog ground plane of the system

The pin description **DGND** does **NOT** imply that this pin should go to the system digital ground



This, of course, raises the question of why a pin designated "Digital Ground" should be connected to the analog ground of the system.

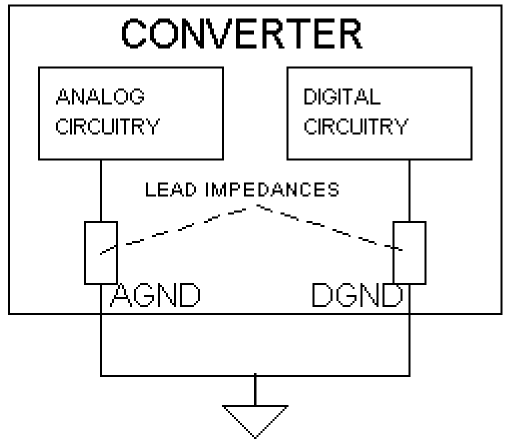
It is what philosophers refer to as a "category mistake". Put simply, we make a category mistake when we assume that the same words mean the same thing in different contexts. The pin is not called digital ground because it is to be connected to the system digital ground, it is called digital ground because it is the connection through which the ground currents of the digital circuitry of the converter will flow.

In retrospect converter manufacturers should probably have used a different name for this pin to avoid confusion, but it is too late by several decades to change it now

WHY NOT USE ONE PIN?

At high current or high frequency the impedance of the converter leads prevents the use of a single ground pin

Low current/low frequency converters often do have just one



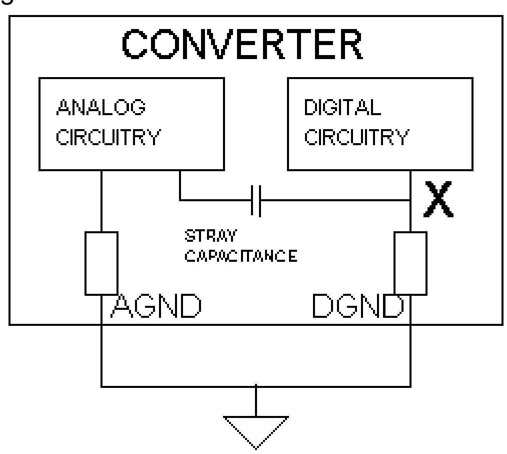
If there were a single ground pin for the whole converter there would be no problem, but the impedances of the bond-wire and package lead are sufficiently large that voltages due to digital currents flowing in the impedance of a common ground lead are, in many cases, sufficient to degrade the converter's analog performance. In fact in some high frequency converters several analog ground pins and several digital ground pins, connected in parallel, are necessary to minimise the effects of lead impedance.

But a number of low-power A-to-Ds and DACs, where digital ground currents are acceptably low, do indeed have just one common ground lead

SO WHY MUST THEY BE JOINED AT THE PACKAGE?

Ground noise at X can affect the analog circuitry of the converter via stray capacitances

This noise can be minimised by minimising the impedance between DGND, AGND and the system analog ground



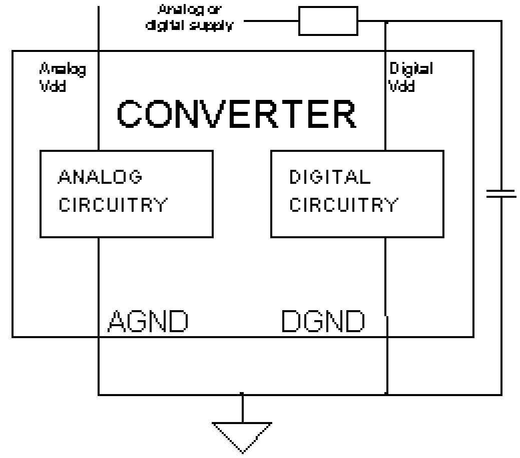
Noise in its digital circuitry can couple to the analog part of the converter by stray capacitance. Ground noise coupling is minimised if the noise voltage at node X in the diagram is as small as possible.

This is accomplished by connecting DGND directly to the analog system ground. If DGND were to be connected to the system digital ground, or to system analog ground via a resistance or inductance, the noise voltage at X relative to the converter's analog circuitry would increase - and so would the interference

SUPPLY DECOUPLING

The supply to the digital part of the converter must be decoupled to the DGND pin with a low inductance capacitor having minimum possible lead and PC track impedance

Digital VDD may be fed from the system analog or digital supplies, but should be isolated by a small impedance in either case

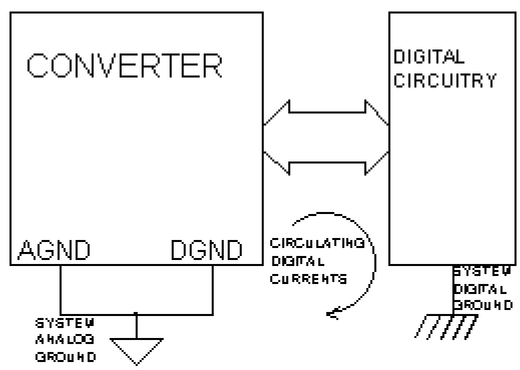


To minimise digital currents in the analog system ground the digital supply pin of the converter must be decoupled with a low inductance capacitor to the DGND pin. This capacitor must be as close as possible to the two pins in order to minimise lead and PC track inductance. This really is important – the AD9040 A-to-D works well only if its supply decoupling capacitor is within 2.5 mm of the device pins, otherwise it may have missing codes. Many other high frequency converters behave in a similar way.

The digital circuitry of the converter, if it has a separate supply pin, may be powered from the digital or the analog system supply, so long as this does not lead to power sequencing problems. In either case it is sensible to isolate it with a small impedance (a ferrite bead or a low resistance). If the analog system supply is used this helps to minimize noise from the converter in the supply and if the digital system supply is used it keeps supply noise out of the decoupling capacitor

GROUND RETURN CURRENT

The only current which flows between Analog and digital system grounds is the return current of the digital interfaces

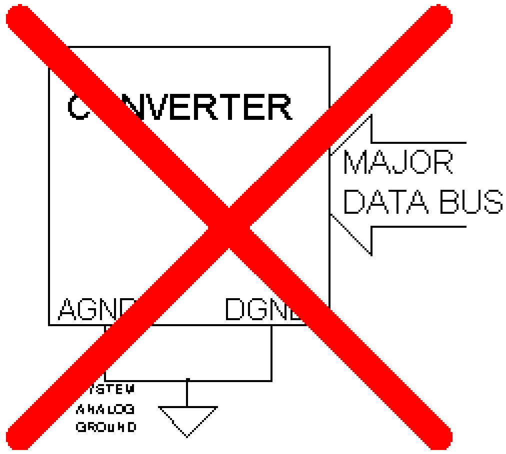


With proper decoupling the only digital currents to flow between the system analog and digital grounds are the return currents of the converter's logic interfaces. These should be kept as low as possible.

The only signal degradation to occur with this arrangement is reduction of noise immunity due to common-mode noise between the analog and digital system grounds. Since logic has noise immunity of hundreds or even thousands of millivolts this loss of noise immunity is unlikely to affect system performance

BEWARE OF THE BUS!

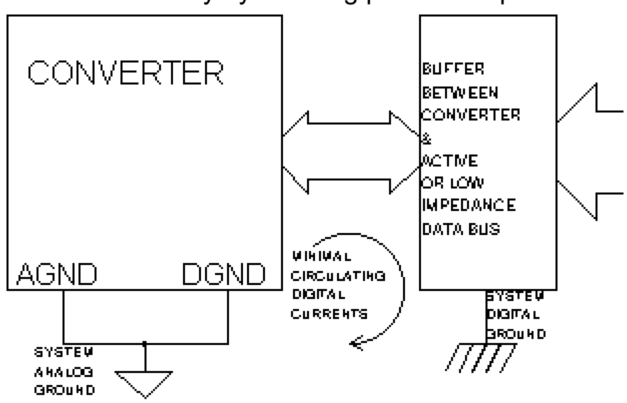
NEVER connect a major data bus directly to an ADC or DAC
It is a source of noise and most ADCs cannot drive the load



It is important never to drive a data bus directly from an A-to-Ds parallel port - the digital currents are likely to be too large. In addition to the ground return current problem we have mentioned, large output currents from a converter increase its dissipation – which may affect its accuracy due to thermal effects.
DACs also suffer from this type of connection – bus noise corrupts their analog output

BUFFER IT

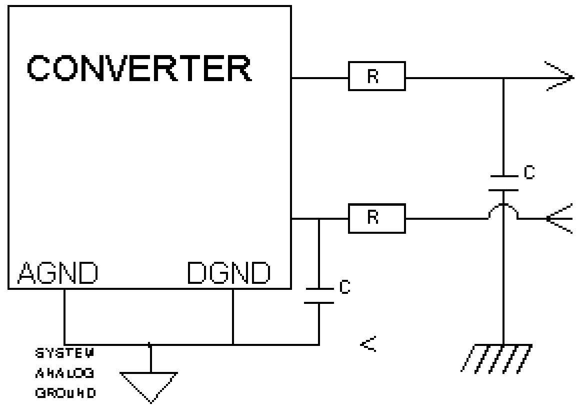
Put a buffer between a data bus and a converter
Even if the converter has an internal buffer
It minimises noise feed through
And may improve ADC accuracy by lowering power dissipation



There should almost always be a buffer between a converter and a data bus. This buffer should be mounted on the system digital ground. Buffers within the converter have insufficient fan-out and signal isolation to provide the isolation required – so even if the converter is internally buffered a separate external buffer should usually be used as well.
An exception to this rule is where the data bus only carries the converter signals during normal system operation. This is the case with most serial interfaces and some parallel ones. During power-up, when the converters are not yet active, such a bus may also be used to download code from ROMs or for other similar tasks provided that the loading due to other devices on the bus does not require the converter to drive too large an output current during normal operation

SLOW DOWN!
(If you can)

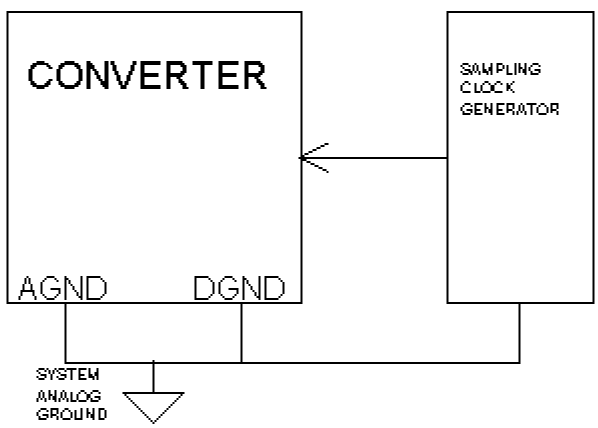
Fast logic edges at a converter's digital ports are a source of noise
Slowing them down with RC networks can reduce this noise
But system timing may not allow it – take care



Noise feedthrough can sometime be reduced by slowing the edges of digital signals going to and from a converter. This may be done with an RC network.
But this also increases propagation delay and may disrupt system timing. It is a useful technique but must be used with caution and possible ill effects carefully analysed.

SAMPLING CLOCKS

In order to minimise phase noise (jitter), which can devastate the performance of a sampled data system, the sampling clock oscillator should be built on the system analog ground



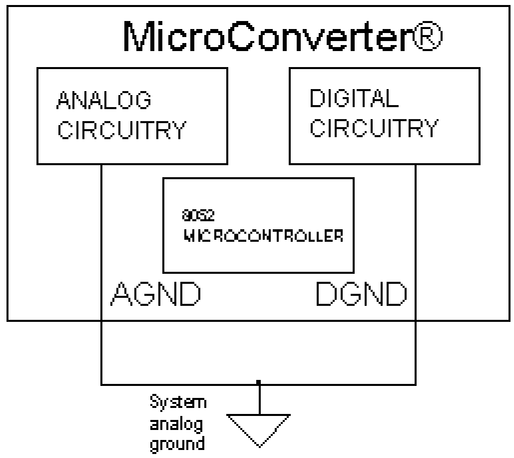
Phase noise in sampling and reconstruction clocks can devastate the performance of a sampled data system. This is, in fact, the subject of a separate lecture in this series.
One way to minimise phase jitter is to ground the sampling clock generator to the system analog ground, so that the converter and the clock share the same ground, and common-mode noise between grounds does not phase modulate the clock signal

THIS GROUNDING SCHEME IS ALMOST UNIVERSAL

If a converter contains no computation, or draws less than 30mA supply current it should use this scheme

If the data sheet suggests otherwise the data sheet is probably incorrect

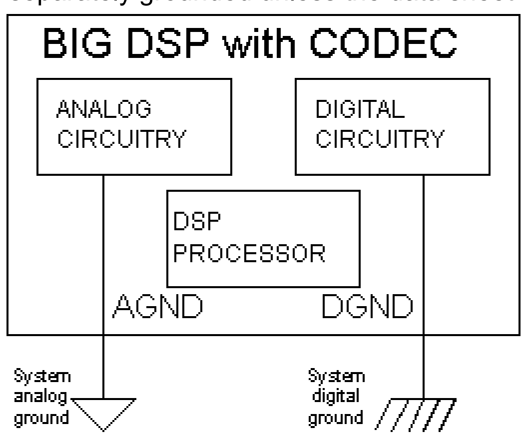
Even the MicroConverter® should be grounded this way



This grounding scheme really is the best way to ground most converters.
The Analog Devices MicroConverter® consists of one or more A-to-Ds, plus a DAC and an 8052 micrcontroller to control the converter operation. Even though it contains a complete microcontroller this device draws only a few mA and its AGND and DGND are best grounded to its system analog ground

BIG DSP DEVICES WITH CODECS ARE AN EXCEPTION

These devices have high (>100 mA) transient current on DGND and are usually designed to have good noise isolation between DGND and the analog circuitry – they should have DGND and AGND separately grounded unless the data sheet says otherwise



The only **exception** which the Applications Department at Analog Devices has yet discovered is big DSP processors which happen to contain codecs. These devices draw hundreds of mA of transient current in their DGND pin, and are also designed so that noise on this pin does not feed to their analog/converter circuitry. They are best used with their AGND pin to analog system ground and their DGND pin to digital, unless their designer suggests otherwise.
DSP processors with phase-locked loops (PLLs) sometimes have an AGND pin too. These pins, which are for the power supply decoupling of the clock-multiplying PLL, should go to the system digital ground

IN CONCLUSION

If in doubt – join **AGND** & **DGND** and connect them to system analog ground

But the general rule for data converters is that AGND and DGND pins should be connected together and to the system analog ground.