# IV Guide For the Troubled

It must be confessed that one of the hoped-for byproducts of this book is a more interesting life for Sales Engineers, because the technical inquiries they receive should become more challenging. This should be in addition to a saving of time and telephone expense for both customers and manufacturers.

It is accomplished by making broadly available as much as possible of the information that most commonly passes during conversations with customers; this we have sought to do in the preceding pages of this book.

To be useful, such information must also be accessible. In this Part, access is aided by relating material in the book to the typical inquiries that are received, and by listing specific, recurring points. Telephone conversations typically involve one of the following:

Requests for information
Requests for assistance when things don't seem to work right
Requests for advice
Urgent pleas for rescue

Listed below are a few of the most-frequently-occurring topics of conversation, with comments and sources of information likely to resolve the problem.

*FREQUENTLY-ASKED QUESTIONS*

Q. What do the codes mean? What is complementary BCD? How does offset-binary relate to 2's complement?
*A. See Part II, Chapter 1*

Q. How do converters work?
A. *See Part II, Chapter 1*

Q. How do I choose the right converter?
A. *See Part II, Chapter 4*

Q. What are the differences between voltage- and current-switching DAC's?
A. *See Part II, Chapter 1*

Q. What's a "glitch?" How is it caused? How eliminate it?
A. *See Part I, Chapters 3, 5; Part II, Chapters 1, 2, 3, 4*

Q. How does input noise affect A/D conversion? How combat it?
A. *See Part I, Chapter 2; Part II, Chapters 2, 3, 4, 5*

Q. Where can I find out about sampled-data systems?
A. *See Bibliography*

Q. What are the contributions of various components to errors?
A. *See Part II, Chapters 2, 4, 5; Part III, Chapters 1, 2, 3, 4, Product Guide*

Q. What are the timing constraints on D/A converters with registers?
A. *See individual data sheets and Product Guide*

Q. What factors affect timing of systems with sample-holds and multiplexers?
A. *See Part I, Chapters 2, 3; Part II, Chapters 4, 5; Part III, Chapters 3 & 4*

Q. What are the requirements on power supplies?
A. *See Part II Chapters 4, 5; data sheets, Product Guide*

Q. When is it desirable to use registers with DAC's?
A. *See Part I, Chapter 3*

Q. How do I connect a 10-volt device for a 10.24V full-scale range?
A. *Scale-factor adjustment will usually have insufficient range, especially in high-resolution devices. Add series feedback resistance with DAC's (the loop is usually closed externally), or use attenuation ahead of the ADC input buffer (sometimes*

*series input resistance can be used with current-summing comparators). Information on 10.24V full-scale range will be found in Part II, Chapter 1: see Table 3.*

Q. How is the bipolar offset circuitry connected and adjusted? How does it affect the specifications?

A. *See Part II, Chapters 1, 2, 3, 4*

Q. What are the suggested grounding techniques?

A. *See Part II, Chapters 1, 5*

Q. What are the issues in low-level multiplexing vs. instrumentation-amplifier-per-channel? How do instrumentation and isolation amplifiers differ?

A. *See Part I, Chapter 2; Part III, Chapters 2, 3*

Q. What is "Differential Nonlinearity?"

A. *See Part II, Chapters 1, 3, 4*

Q. Can I use the analog power supply as a source of constant voltage?

A. *Yes – if it is sufficiently quiet and well-regulated to provide the desired degree of stability and accuracy. Otherwise, derive a reference voltage using a Zener diode and, if necessary, an op amp (See Fig. 21a, Part II, Chapter 1.)*

## *FREQUENTLY-ENCOUNTERED PROBLEMS*

### *Gross Malfunctions*

Wrong digital code ("Positive true" vs. complementary)
Wrong analog polarity relationship
Grounds not interconnected
Power supply not connected, wrongly connected, or zapped
Missing or improper connections (Study the connection diagram)
Wipeouts due to applying power to devices in the wrong order (In general, power downstream units first; avoid or protect multiplexers that short in the power-off condition)
Control-logic improper (polarity, duration, timing, levels) Check logic and timing diagrams on data sheets
Uncontrolled overflow in counter configurations
Wrong diode polarity

*Poor Functioning*

Common-mode problems in "single-ended" system (use proper grounding or difference amplifier)

Grounding problems: no ground connection, fortuitous ground connection, wrong ground connection (common analog and logic return), shields returned to wrong ground or grounded at both ends.

Pickup due to proximity of digital ground plane to analog circuits, or proximity of analog and digital wiring, in general, or poor lead dress: Keep stray capacitance low.

Excessive load capacitance on outputs of voltage DAC's or other analog devices can in some cases cause slow response, poor settling, ringing, or oscillation ("noise")

Improper connection of built-in references (unused bipolar offset references may require grounding in unipolar applications; external use of internal Zener voltage reference generally requires buffering)

Op amp voltage offset adjustment used for zeroing anything but op amp *voltage* offsets, e.g., system offsets, can result in increased thermal drift

Logic overloading (logic outputs may also be used for internal purposes; check actual specified loading on data sheet)

Too much attenuation because "current-output" DAC's output impedance neglected

Nonlinearity because current-output DAC's specified maximum output voltage range exceeded

Noisy A/D conversion, increased differential nonlinearity, and missing codes caused by widening of quantization band due to noise on input signal, or picked up in wiring

Bent pin that didn't go into the socket (or perhaps even broke off)

Unanticipated "glitches" due to lack of filtering, inappropriate converter choice, marginal logic timing, limited logic slewing rates due to excessive capacitive load, stray capacitive coupling to analog circuitry

Gain and offset adjustments performed in wrong order in bipolar DAC's and ADC's (See Part II, Chapter 3, Figure 5)

Excessive thermal drifts due to: improper converter adjustment procedure; bias current flowing through resistances (MUX $R_{on}$, for example); use of op amp voltage offset adjustment to counteract bias-current or system offsets

Loss of monotonicity over small temperature ranges: possible if a converter is specified at ±1 LSB differential nonlinearity at room temperature. A conservative specification of ½LSB allows variation of an additional ½LSB with temperature

RFI or fast pulses causing rectification that produces offsets

"Long-tailed" responses due to thermal transients (some op amp or comparator circuits), or inappropriate capacitor choice (precision capacitors should always have low dielectric absorption – polystyrene, teflon, polycarbonate are among recommended materials)

Excessive drift in low-level circuitry due to differential "thermocouple" effects in input leads (e.g., copper-to-Kovar at IC inputs) Differential-input leads should always be close together and their junctions should be as-nearly-as-possible isothermal.

When all other possibilities have been eliminated, one should not discount the possibility that the device is malfunctioning or out of specification, either innately, as a result of some recent trauma, or as a result of some "early failure" mechanism. Many manufacturers subject certain of their products to "burn-in" to eliminate innate and "early failure" problems.

By no means all problems are chargeable to the user. Manufacturers of devices and components (including Analog Devices) have been known to have made available – inadvertently, and despite considerable effort –

Data sheets with errors or insufficient data

Devices that have failed, for no apparent reason, when first plugged in.

Though rare, these possibilities should not be discounted. The user of conversion devices – especially in quantity – should be prepared to perform at least simple tests on devices to verify their performance; Chapter 3, Part II, may be found useful in this respect. If a user finds information on a data sheet that raises questions in his mind, he will find most manufacturers quite willing to discuss them and clarify the point in question, especially as it pertains to his application.

## *FREQUENTLY-GIVEN ADVICE*

### *Preventive*

Nothing beats good initial analysis of the basic problem and conservative initial design, with double-checking to make sure that the best-available data has been used, the tolerances on resolution, accuracy, and timing are adequate, and the connection scheme is proper, and follows the manufacturer's suggestions – where appropriate. Perhaps breadboarding should be used to verify sticky points. The design should include features that facilitate testing and trouble-shooting.

Be sure that common-mode, normal-mode, and induced noise problems have been considered and dealt with adequately. (Differential amplifiers, filtering, lead locations and directions.)

Be sure that grounding is proper: no ground "loops" (i.e., ground current is allowed only one path); digital and analog grounds separated; high-power and low-level signal grounds separated; One main "mecca" point where all grounds meet, if feasible; heavy ground conductors, to avoid voltage drops in signal return leads.

Be sure that interconnections of devices do not produce surprises as a result of (e.g.) currents and impedance levels, transient overloads during MPX switching, etc.

After assembly, the system should be thoroughly inspected and "buzzed-out", to be sure that all connections have been made, the right elements have been plugged into the right spots, and there are no bent or broken pins.

Check the system out in small pieces and functional groupings before putting it all together. "Going for broke" often results in just that.

*Measuring Devices*

For monitoring performance and troubleshooting, the devices that perform dc measurements should have at least twice the resolution and accuracy of the devices they are checking; the devices that perform high-speed measurements should have faster response than the devices they are checking. An oscilloscope should always be used to avoid "flying blind." A simple multimeter may be a trap (it can't see dynamic signals or oscillations; its dc resolution may be inadequate for useful measurements on the kind of high-resolution devices usually found in data systems; and its load impedance may affect the accuracy (if not the actual character) of measurements.

*Measuring and Trouble-Shooting*

*First,* check supply and ground voltages at terminals of pluggable devices, with the devices removed.

A useful procedure is to then perform dc, manual, and low-speed checks before performing measurements at speed. This ensures that the system is at least working properly under *some* conditions.

Try to isolate the problem.

If more than one unit of a given type is in use, an apparent failure at its location can be checked by substituting another unit. If similar units of the same kind exhibit the same problem, it is likely a design or system problem. (If it's a sufficiently serious problem, involving a fault condition, the original unit and its substitute may no longer be in fit condition for further use.)

Check grounding with a simple continuity test. Use an orderly procedure. Have you localized the problem? Is it static or dynamic? Gross or subtle? Catastrophic or slightly "off?" Reproducible or intermittent? Affected by mechanical manipulation (kicking the cabinet)?

*IF ALL ELSE FAILS. . .*

We want to help you solve the problem, whether it involves simple advice or the return of a unit. If the problem seems to be related to one of our conversion components (either definitely or suspected),

1. Prepare a summary of the problem, and outline it to your local Analog Devices, Inc., sales office or representative, over the telephone. He may suggest some useful diagnostic procedures or that the unit be returned.

2. If the unit is to be returned within the United States,* send it to our Norwood location, marked to the attention of "Returns Department". If you are outside the United States, our local sales office or representative will give you appropriate instructions. (We maintain a complete repair depot at our Karlsruhe office, and limited repair facilities in England and Japan.)

3. Be sure to include with any returned units

A. The name(s) and telephone number(s) of the person(s) with whom we can discuss technical (and business) aspects of the problem.

B. Complete information on the (suspected) malfunction, and the application in which it occurred.

4. If you are in a critical "bind," wire or phone the nearest sales office or our Internal Sales Department at the factory directly. Our factory address is

Analog Devices, Inc.
Route 1 Industrial Park
Norwood, Mass. USA 02062

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| Telephone: | (617)-329-4700† |
| Telex: | 924491 |
| TWX | (710)-394-6577 |
| Cable | ANALOG NORWOODMASS |

*See *the Analog Devices, Inc. Product Guide* for complete information on returns and warranty service.

†Note in the margin the phone number of your nearest sales representative, or office.