

Model DA2002

High Resolution Digital to Analog Converter



Operations Manual

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Introduction

The DA2002 converts incoming 24 bit digital inputs to analog audio signals. The combination of excellent linearity, small quantization steps, fast and accurate response and low noise performance enables reproduction of the finest details. The DA2002 accommodates the original standard sample rates (44.1 & 48kHz) and the higher rates of the new standards (88.2 & 96kHz).

The DA2002 provides many enhancements to the classical resistor weighting architecture. A **triple segmented design** improves the accuracy of the 10 most significant bits. Short-term accuracy is maintained by keeping the critical components at constant temperature in a **linearly controlled oven**. Long term accuracy is achieved by extensive use of continuous **automatic self-calibration**.

A large number of **extra codes** enable the addition of digital DC offset to the signal path without signal clipping. The DC offset provides superior low level detail by keeping low level signals away from the most significant bit transitions. A **quad switch deglitcher circuit** removes the unwanted transition glitch energy.

In both PLL Mode and CrystalLock™ Mode, the DA2002 **eliminates jitter** in the incoming data stream by use of a pullable crystal oscillator.

Additional features:

- **96kHz, 88.2kHz, 48kHz and 44.1kHz conversion frequencies**
- **Multi-bit architecture with 24 bits, non Sigma-Delta**
- **Very low Total Harmonic Distortion + Noise**
- **Automatic calibration**
- **Increased low level accuracy**
- **CrystalLock™ Digital Jitter removal at 44.1 and 48 kHz**
- **Professional and consumer inputs and outputs**

PART I: Operating Instructions

Operation of the **Model DA2002 Digital to Analog Converter** requires the use of two push button switches located on the front panel:

POLARITY inverts the absolute polarity of the signal.

INPUT SELECT controls selection of digital inputs to the DAC.

Input Signal Selection

Selecting the Digital Input-The INPUT SELECT lamps indicate which input signal is selected. Pressing the INPUT SELECT push button selects the next input position.

Search Mode/ Manual Mode- Holding the INPUT SELECT button for more than one second toggles the INPUT SELECT between Search Mode and Manual Mode. The mode selected is retained when power is removed.

- In **Search Mode**, each time the INPUT SELECT button is pressed, the DA2002 will “scan” the inputs for the next input with a valid signal present. It will skip the inactive input connectors (where no signal is present). The default setting is Search Mode enabled.
- In **Manual Mode**, each press of the INPUT SELECT button moves the selection to the next position. It will not skip inactive inputs.

Input Signal Connection

The unit can be connected to one, two, or three digital input connectors located on the rear panel:

- AES/EBU input to the XLR connector designated as **AES INPUT 1**
- AES/EBU input to the XLR connector designated as **AES INPUT 2**
- SPDIF (consumer format) input to the connector designated as **IEC INPUT**

Analog Outputs

The **LEFT OUTPUT** and **RIGHT OUTPUT** XLR signals are factory set to provide Balanced analog signals (signal between pin 2 and pin 3 of the XLR connectors).

Operation in unbalanced mode (signal at pin 2 and ground at pin 3) is possible by changing the internal jumpers J8 and J10 located behind the XLR analog output connectors inside the case.

The factory default setting is for Balanced outputs-- the jumpers are positioned parallel to the front panel.

For Unbalanced mode position, the jumpers are set to 90 degrees with respect to the front panel.

Pin 1 of the XLR connectors is connected to ground potential for proper cable shield connection.

The **LEFT OUTPUT** and **RIGHT OUTPUT** IEC signals are always unbalanced and are not affected by J8 and J10 jumper settings.

Analog Output Levels

The analog output level at the IEC connectors for a full-scale digital input signal is 2V R.M.S. into 100KOhm

For Balanced XLR connection: The analog output level for a full-scale signal is 4.5V R.M.S. into 100KOhm load, 4.2V R.M.S. into 600Ohms.

For Un-balanced XLR connection: The analog output level for a full-scale signal is 2.2V R.M.S. into 100KOhm load, 2V R.M.S. into 600Ohms.

Turn-On Sequence

When applying AC power to the unit, the following sequence of events takes place:

1. The unit goes into mute mode.
2. Warm-up: An internal oven heats up the temperature-sensitive devices to a set temperature. The warm-up time depends on the initial temperature and may take up to 5 minutes for a cold unit. During warm-up, the unit blinks the two upper sample frequency lamps (44.1 and 48 LED's).
3. When set temperature is reached, the unit goes into self-calibration mode. The calibration time may take a few minutes. During calibration, the unit blinks the two lower sample frequency lamps (88.2 and 96 LED's).
4. The unit finds the first active input and converts digital audio to analog sound (if the INPUT SELECT Search Mode is enabled. Please see the Input Signal Selection section).

The DA2002 determines the incoming sample rate for the selected input and displays the incoming frequency (44.1, 48, 88.2 or 96KHz). When all inputs are inactive, the unit steps through the input ports continuously as indicated by the input select lamps (if in Search Mode).

Most DAC's contains relays for the purpose of muting the output during turn on (allowing the DAC to settle to proper operating conditions). The DA2002 contains no relays, in order to avoid signal degradation associated with relay contacts. The unit minimizes "turn-on spikes" by incorporating very slow tracking power supplies for its output stage, thus disabling the drive capability during turn on. The DA2002 turn-on spike may be higher then that found in other DAC's but the sound is not compromised. The spike due to power off is comparable to that found in other DAC's.

Polarity Inversion

The normal polarity is set to pin 2 "+" or "non-inverted." To invert, press the **POLARITY** switch. Signal inversion is indicated by a steadily illuminated INVERT lamp.

- Inverting while in balanced operation exchanges the polarity of the signals on pin 2 and pin 3 of the XLR connector.
- Inverting while in unbalanced operation impacts signal polarity on pin 2 of the XLR connector.
- Inverting while in unbalanced operation impacts signal polarity on the IEC center conductor.

PLL Mode and CrystalLock™ Mode

The DA2002 features a very low jitter **PLL Mode** that prevents jitter in the input digital audio signal from degrading DA conversion quality. The PLL mode is recommended for operation of the DA2002 with inputs of 88.2 or 96 kHz. The default setting is PLL mode and is indicated by the Sample Frequency indicator slowly blinking.

For additional jitter reduction with inputs of 44.1 or 48 kHz, select the **CrystalLock™ Mode**. The CrystalLock™ mode is indicated by the Sample Frequency indicator staying constantly illuminated.

To enable CrystalLock™ mode, press and hold the **POLARITY** button for 1.5 seconds. The Sample Rate indicator will become steadily illuminated. To return to PLL mode, press and hold the **POLARITY** button again. This mode setting is retained when power is removed.

Power and Fusing

The DA2002 operates at 50 or 60 Hz, and has two line voltage selections, 115 volts and 230 volts. Voltage selection is made in the power input module on the rear panel. Always disconnect the AC power cord before checking the fuses or changing the voltage setting.

The fuse holder is red in color, and the voltage setting indication printed on it is in white lettering. This setting is visible through a small “window” in the hinged cover located next to the AC power switch and input connector. To change or check the fuses or change the operating voltage, carefully open the cover by lifting the right edge and pull the red fuse holder straight out of the power input module. The voltage is set by turning the red fuse holder so the desired operating voltage is visible when the fuse holder’s cover is closed. Please Note: To avoid cracking the fuse holder, if a screwdriver is used to gently pry the red fuse holder out of the input module, please do not pry on the top or bottom of the fuse holder- only the right side (as viewed from the rear of the DA2002).

115 volts operation requires two 1/2 ampere 250 volt fast blow fuses; 230 volt operation requires two 1/4 ampere 250 volt fast blow fuses. Both American and European size fuses can be accommodated. Operation up to 240 volts is possible with no change in performance using the 230 volt setting. Optimal operation requires 115 volts AC.

Maintenance

The Model DA2002 is an auto-calibrating converter requiring no periodic adjustments. The unit's reliance on linear power supplies and discrete class A analog circuitry generates a significant amount of heat (25 watts maximum). The temperature rise is no cause for concern, but allowing for some airflow both above and below the unit is recommended.

The front panel is gold plated (24 karat gold). Use a soft cloth (and plain water, if necessary) to clean fingerprints.

Part II: Theory of Operation

The simplified block diagram (figure 1) shows the basic building blocks.

Oven Control

The PCM DAC is constructed of custom made laser trimmed thin film resistor networks; yet any resistor is subject to short term drift due to temperature variations and long term drift due to component aging. The resistor networks are kept at a constant temperature by a linearly controlled heating element. (A bang-bang controller, such as a home thermostat is undesirable because it produces turn on and turn off surges-- thus audible kicks.)

Keeping the resistors at constant temperature overcomes resistor dependency on environmental temperature variations.

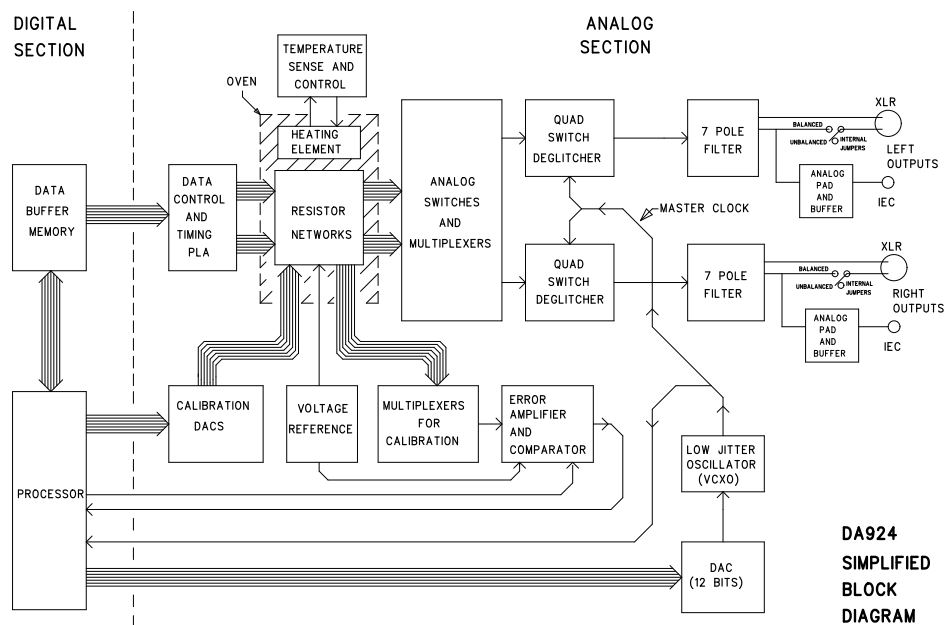


Figure 1

Calibration

A sequence where each resistor is tapped (one at a time) for voltage comparison against a reference level tells the processor the required adjustments. The voltage difference between any given network node and the reference is greatly amplified and then fed to a strobing comparator (see multiplexers for calibration and error amplifier and comparator gain blocks in the simplified diagram). The processor strobes the comparator and reads its output. The strobing is repeated 4000 times for the sake of averaging out any error due to amplifier noise. At the end of a comparator strobing cycle, the processor decides whether to increase or decrease the specific voltage of the measured node. This is done via the calibration 14 bit DACs (see diagram). Each calibration DAC is used as a 13 bit device to ensure monotonic performance. Each DAC is fed to its corresponding node through a large value resistor, thus a full 10V swing on the calibration DAC can only pull a given node by $\pm 4\text{mV}$, providing an effective adjustment of a part in 5 million per calibration DAC step.

The calibration process takes a long time because the node adjustment is interactive (adjusting a node causes some miss-adjustment at all the other nodes). A single calibration cycle consists of reading and adjusting of all the nodes. The processor repeats the calibration cycle numerous times until all the nodes are set properly. Though nodes interaction exists during the adjustment process, the overall network is guaranteed to converge on a solution by design. Calibrating a DA2002 for the first time (at the factory) often exceeds 25 minutes. Once calibrated, the settings are stored in non volatile ram for future startup point of reference, thus all future adjustments are initialized to the last settings. Therefore the initial tolerance of the components is pre calibrated already, and each new calibration needs to deal only with component drift under the same given temperature conditions (ovenized components). The remaining calibration at each subsequent power on takes less then 2 minutes typically.

Timing and Deglitcher

The conversion from a digital sample value to an analog voltage consists of translating a digital code to a corresponding setting of analog switches and multiplexers to tap the appropriate voltage from the analog nodes. Such switching causes unwanted glitch energy to come into play. The glitch energy is code and signal dependent and can not be removed by filtering. The purpose of the deglitcher circuit (see diagram) is to block the signal from feeding to the output for long enough time after each transition, thus allowing the glitches enough time to disappear, and for each new analog sample to accurately settle to its final value.

The deglitcher circuit is in off state about half a sample time, and on for the rest of the time. The on time is the critical time and no digital activity takes place anywhere near the analog circuits. The settled signals are fed to the output filter with minimum disturbance. The deglitcher off time settling requires the circuit to block as much of the transitions from feeding forwards to the output filter.

The blocking requirement is very demanding because a transition of many volts between two adjacent sample values should feed forward less than a microvolt. A single switch can not yield such blocking performance. The deglitcher utilizes four switches: the first switch shunt (shorts) the signal to ground. The remaining signal is connected to the second switch that is in open state. Whatever comes through is shunted to ground by the third switch. The remaining tiny energy is further blocked by the fourth opened series switch.

During the deglitcher on state, the shunt switches (switch one and three) are opened and the series switches (switch two and four) are shorted to allow the signal path to the output. The deglitched circuit utilizes DMOS technology thus providing extremely low resistance during the “on” state. The remaining problems due to “on” state resistance variations are neutralized by use of the strong feedback of the deglitcher amplifier.

The main reason for using DMOS transistors is their sub nanosecond switching capabilities. The jitter critical timing point is all at the deglitcher circuit. Each sample value must exist over the same time period thus precise deglitcher turn on and turn off are critical for good results. In fact switching during deglitcher blocking time can be somewhat sloppy, as long as the signals are well settled prior to turn on. Fighting the jitter wars means feeding the deglitcher circuit a precise jitter free on / off drive signal.

Jitter Removal

Ordinary phase lock loops circuits (PLL's) do a reasonable job at removing high frequency jitter from the incoming clock. The same circuits perform very poorly in the removal of low frequency jitter from the clock signal.

The need to keep enough bandwidth for locking to and tracking the incoming data translates to zero rejection of low frequency jitter content (typically hundreds of Hz of zero rejection bandwidth). While some of the jitter content is random, much is due to coupling of the data itself into the receiver circuitry.

The DA2002 uses a two stage PLL circuit; the first one is based on a tuned circuit approach, and the second utilizes a narrow lock-range. The combination of the two provides enhanced jitter removal.

In addition, for 44.1 and 48 kHz inputs the CrystalLock™ circuit provides a non-standard approach for removing jitter. The deglitcher circuit is clocked by a pullable crystal oscillator but the control signal for the crystal is freed from having to track down incoming clock variations. The clock oscillator is controlled by a processor driven DAC, and oscillator frequency is changed by tiny amounts (.1ppm) and not very often (15 seconds or more) in a manner allowing it to track only very long term average drift. Using such an approach with ordinary PLL will cause loss of lock because the slight variations in incoming data rate cause loss of correspondence between the input and the too steady of a clock circuit. The DA2002 CrystalLock™ approach, stores enough data in a dedicated memory to guarantee that each clock cycle can find its data. Moving the clock slowly to track the long-term average drift is done just fast enough to make sure that the buffer memory does not overflow or becomes empty.

Output Filter and Drivers

The DA2002 operates in low oversampling to allow for maximum settling time of the DAC circuits and to further reduce sensitivity to jitter. The upsampling filter is calculated by the DSP. The tradeoff in favor of low oversampling operation poses an increased requirement for analog anti imaging filtering. The DA2002 incorporates a seven pole analog filter.

The transistor based output drivers are short circuit protected and are capable of driving balanced 300 Ohm loads. As always, for best results it is recommended to use high quality cables. When running a cable through an electrically noisy environment, a termination impedance of 600 Ohms (at the destination, not at the DA2002 side) may prove useful.

Part III: Specifications

Noise	-110dBFS rms, -130dBFS peak spurious response
Distortion	1kHz tone at -1dBFS: .0009%FS peak harmonic amplitude 1kHz tone at -60dBFS: .00009%FS peak harmonic amplitude 10kHz tone at -1dBFS: .0009%FS peak harmonic amplitude 10kHz tone at -60dBFS: .00009%FS peak harmonic amplitude
Sample rate range	96kHz, 88.1kHz, 48kHz, 44.1kHz at +/- 150ppm lock 40-50kHz wide lock mode (varispeed)
Crystal lock™ tracking	1ppm / 15 seconds
Channel separation	-100dBFS at 1KHz
Flatness response	+/- .05dB (10Hz -20KHz)
Phase linearity	2 degrees (10Hz - 20KHz)
Digital inputs	Two AES/EBU, 110 Ohm, transformer isolated One Consumer, 75 Ohm, transformer isolated
Analog outputs	AES/EBU balanced 4.2V R.M.S. into 600 ohms AES/EBU balanced 4.5V R.M.S. into 100Kohms AES/EBU unbalanced 2V R.M.S into 600 ohms AES/EBU unbalanced 2.2V R.M.S into 100Kohms Consumer outputs 2V R.M.S. into 100k ohms
Warm-up and initial calibration	10 minutes maximum, 3 minutes typical
Input Voltage	115V 60Hz or 220V 50Hz, 20 Watts