

AD24

User's Manual

Oceanographic Embedded Systems

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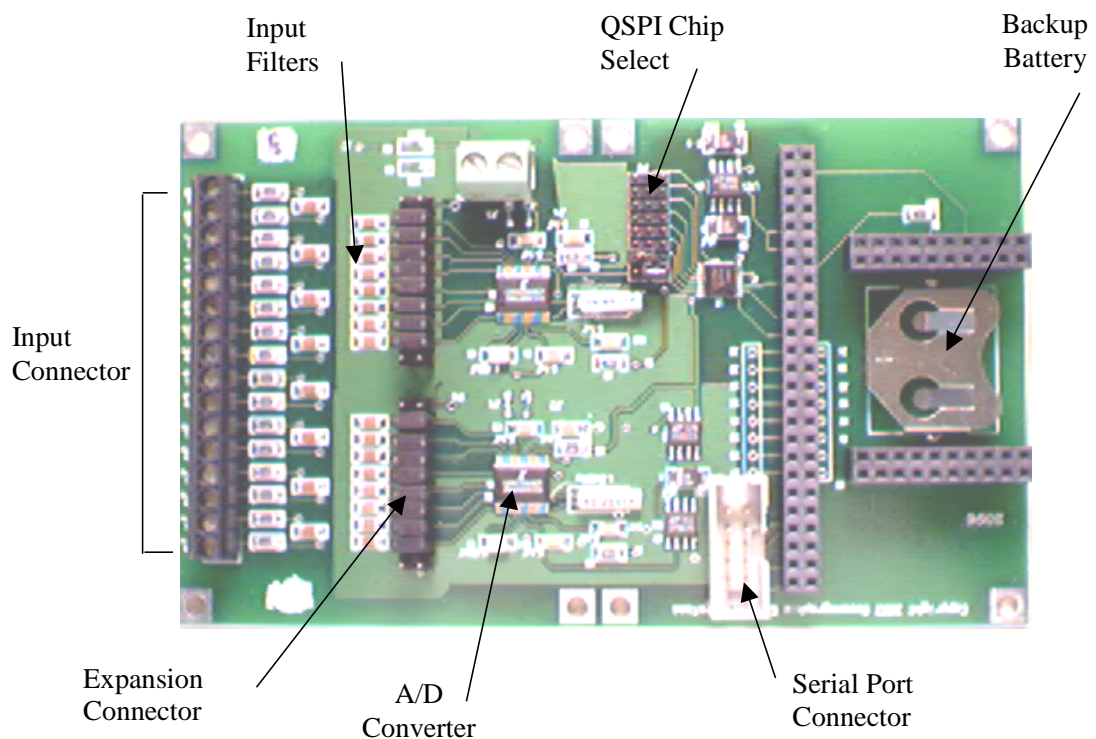
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Introduction

The AD24 is a Recipe Card® peripheral circuit board compatible with the Persistor CF-1 and CF-2 miniature data loggers. It provides the capability to digitize analog input signals with better than one part per million (20-bit) precision. The AD24 provides 8 input channels with fully differential inputs and has built-in input filtering and expansion connectors to which you can connect specialized input filters or signal-processing circuits. The card also provides a battery backup capability, power and serial port connections for the CF-1 or CF-2.

Hardware

The AD24 is built on a 3x5" printed circuit board laid out as shown in the following illustration:



Power Supply

The AD24 generates its own regulated 3.3V digital and analog power supply using an LT1521 linear voltage regulator. The AD24 provides its own regulator to minimize noise pickup from the CF-1 power supply. This LT1521 is automatically shut down when the CF-1 goes into suspend mode. An LT1044 switched-capacitor inverter

provides a -3V supply for the AD24. This supply is derived from the 3.3V VCC supply of the CF-1. This design has two benefits:

- 1) When the CF-1 VCC is shut down in suspend mode, the -3V supply is automatically shut down also.
- 2) Switching noise from the LT1044 is imposed on the VCC of the CF-1 and not on the 3.3V analog power supply.

QSPI Address Decoding

The AD24 decodes all four QSPI chip selects provided by the CF-1. The decoding scheme allows the A/D converters to appear in any of the possible address slots from 8 through 15. The AD24 is normally shipped with the converters set to appear in slots 9 and 10. Each A/D converter must appear at a separate slot--the hardware jumpers cannot be set to have both appear at the same slot address. You should always set the second converter to appear at the next consecutive address after the first. Figure 2 shows the position of the jumpers in their default configuration.

NOTE: The numbers '0' and '7' on the board were placed in error and do not refer to QSPI slot addresses.

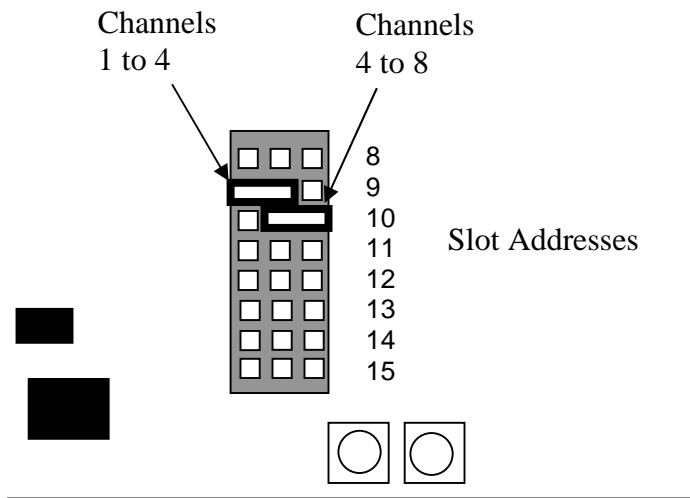


Figure 2. QSPI Slot Address Selection

A/D Converters

The AD24 uses two CS5534 four-channel Analog-to-Digital converters from Crystal Semiconductor. These converters are very versatile delta-sigma converters that produce 24-bit results. Depending on the conversion speed, you may get results with 14 to 20 bits of resolution. The PDF data sheet for the converter is included with the AD24 documentation. You should consult this data sheet for a detailed explanation of the operation and capabilities of the CS5534.

The CS5534 is a very capable and complex converter. It communicates with the CF-1 over the QSPI serial port. The setup and operation of the converter requires a series of

commands and data transfers. The AD24 library provides you with a manageable set of routines to setup the converters and collect data while allowing you to avoid many of the complexities of the CS5534.

The delta-sigma converters in the AD24 are quite different in architecture from the successive-approximation converters in the AD16 and AD16S. The following list summarizes the characteristics of the CS5534:

- Variable conversion rates for each channel—from 7.5Hz to 3940Hz.
- Separate internal offset and gain calibration for each channel.
- Internal programmable-gain instrumentation amplifier with gains from 1 to 64. Each channel may have its own gain setting.
- Internal 60Hz noise rejection filter.
- Low power consumption---approximately 7mA per converter.

Expansion Connectors

Each converter has an associated 20-pin expansion header. As delivered, jumpers are used to connect the input connections and filters to the A/D converter. However, if you need special input processing, you can remove the jumpers and design a daughter board to fit the header. The daughter board may contain whatever signal processing circuitry you require. Each expansion connector also has pins for ground, battery input power and an uncommitted test point. The test point can be connected to any other signal or power supply voltage on the board with a jumper wire. The pinouts of the expansion connectors are shown in the schematic diagram at the end of this document.

Input Connections and Filters

Connections to the A/D input channels are made through the 16 screw terminals at the edge of the board. The terminals are marked to indicate the positive and negative inputs of each channel. There is also a ground test point in front of each '-' input. You may use this point to connect the negative input to ground for single-ended signals. Each A/D input passes through an RC low-pass filter before arriving at the expansion connector. The RC filter attenuates signals above 20KHz—which is only a factor at the highest conversion rates. At lower conversion rates, the internal digital filter of the CS5534 strongly attenuates signals any at frequencies above the conversion rate. The filter has a deep notch in its response at multiples of the conversion rate. Thus, 60Hz signals are strongly attenuated by the internal filter when the conversion rate is 60Hz or slower. Consult the CS5534 data sheet for the details of the operation of the internal digital filter.

When set up for bipolar mode, the A/D will accept input voltages between -VREF and +VREF. In unipolar mode the input may range from 0 to +VREF. Since the + and - inputs of the A/D are the differential inputs to the internal instrumentation amplifier, the input channels can measure signals with significant common-mode voltage. This can be helpful when you connect to sensors with significant IR drops in their ground

circuits. If you have use a separate signal- lead connected to the proper point on the sensor, you can eliminate problems due to IR drops in the cable. However, you should ensure that the common mode voltage is low enough that no input signal exceeds V_{A+} .

Initialization and Configuration

Before you can collect data with the AD24, you must properly initialize the QSPI serial port to communicate with the CS5534 converters, then send a series of commands to the converters to bring them out of their power-up reset condition. The AD24 library contains routines to carry out these actions for you.

Data Format Conversion

The AD24 library routines return a signed 32-bit long integer. In order to convert that value to a voltage in floating point format, you must know whether the converter is in unipolar or bipolar mode and the gain setting of the internal amplifier for the channel. You must also know the exact value of the reference voltage provided to the CS5534. An example calculation is shown in the source code for the sample application.

Calibration

The CS5534 can be internally self-calibrated so that an input equal to the reference voltage results in a full-scale output value. This internal calibration can be done at any time, but should always be carried out before using the data from the converter. Some versions of the CS5534 may have an output error of up to 8% if they are not calibrated. This calibration is carried out by internally connecting the inputs to the VREF at a gain of 1.

The CS5534 can also be calibrated so that an arbitrary externally applied voltage will provide a full-scale output value. This capability is not supported in the current library. Please contact OES if you require this feature.

The internal offset of the CS5534 input circuitry can also be corrected by a call to a library function. This offset correction is performed by internally connecting the + and – inputs of a channel, after disconnecting them from the input pins. However, a functional error in some versions of the CS5534 may result in several millivolts of uncorrected offset. If you can temporarily provide a zero-volt input by shorting the inputs of a channel, you may use the system offset correction call to fully remove any offsets.

AD24 Library

The AD24 library contains the following routines to assist you in the use of the AD24 in data collection operations:

void AD24Init(ushort slot1,ushort slot2);

Parameters: Slot1 and slot2 must be the input slots selected by the address jumpers on the PC board. The default values are 9 and 10.

Usage: This is the general initialization routine for the AD24. It calls AD24SerialReset and AD24SetupQSM to initialize the hardware, then programs all the channels with startup values.

void AD24SerialReset(void);

Parameters: None

Usage: This routine resets the internal serial interface of the CS5534 converters. It must be called as part of the setup software. This routine is called from AD24Init, and will not normally be called from user software.

void AD24SetupQSM(ushort slot1, ushort slot2);

Parameters: Slot1 and slot2 must be the input slots selected by the address jumpers on the PC board. The default values are 9 and 10.

Usage: The input parameters are used to set up the Queued Serial Module of the CF2 so that it can communicate with the CS5534 converters. This routine must be called before any communication with the converters can take place. This routine is called from AD24Init, and will not normally be called from user software.

void AD24RestoreSetup(void);

Parameters: None.

Usage: This routine restores the internal setup registers of the CS5534 converters to the state contained in the setup data variables maintained on the CF2 by the software library. The setup variables control the PGA gain, bipolar/unipolar mode and conversion speed.

void SetAllSpeeds(short sdx);

Parameters: sdx is an index into the speed configuration array.

Usage: All eight channels of the AD24 are set to the same speed. The speed index is used to set the proper bits in a configuration word, then that word is transmitted to the CS5534 converters. Speed index 0 selects 7.5 conversions per second. The conversion rates range from 7.5 to 3840 conversions per second.

void SetSpeed(short chan, short sdx);

Parameters: Chan specifies an input channel (from 1 to 8). Sdx is the speed index as described under SetAllSpeeds.

Usage: This routine allows you to set the conversion speed for a specific input channel.

void SetBipolar(short chan, bool bipolar);

Parameters: Chan specifies and input channel (from 1 to 8). Bipolar is a boolean variable which selects whether the input will be bipolar or unipolar.

Usage: In bipolar mode a channel will have a range from $-V_{ref}$ to $+V_{ref}$. In unipolar mode the range is from 0 to V_{ref} .

void ShowSetup(void);

Parameters: None.

Usage: Show setup will display the internal values of the setup registers which control the conversions in the A/D. The values are read back from the CS5534 ADCs.

long AD24GetValue(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: This function returns a 32-bit long integer which is the digitized input of a particular A/D channel. Depending on the conversion speed, this routine may take several hundred milliseconds to complete. A conversion that requires the CS5534 to switch to a different input channel from the last conversion will take 3 times the normal conversion time while the internal digital filters settle to the new value.

void AD24RequestData(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: This function starts the ADC conversion on the selected channel. The CF2 may then work on other tasks until the conversion is complete.

bool AD24DataAvailable(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: : This function returns the conversion status for a channel started with AD24Request Data. When the function returns **true** the conversion is complete and the data may be read with AD24Result.

long AD24Result(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: This function returns the conversion result when a conversion has been started with AD24RequestData.

void AD24ToArray(short chan, void *arptr, long numvals);

Parameters: Chan specifies the input channel (1 to 8). Arptr is a pointer to an array of long integer values that will receive the conversion results. Numvals sets the number of conversion to conduct.

Usage: This function is used to carry out a specified number of conversions on an input channel, storing the date in sequential locations in a user-specified array. The

conversions will take place at the data rate specified for the conversion speed of the selected channel. Since the timing of the conversions is controlled by the CS5534 clock, there will be no jitter in the timing due to interrupt routines on the CF2. This routine is therefore suitable for collecting precisely timed data for applications such as spectral analysis using a FFT. While this routine is running, you will not be able to collect data from any other channels.

void SetGain(short chan, ushort gainval);

Parameters: Chan specifies the input channel (1 to 8). Gainval specifies the gain applied by the internal programmable gain amplifier for that channel

Usage: The CS5534 will accept values of 1,2,4,8,16,32, and 64 as gain values. If you enter a number which is not in that set, the next lower power of 2 will be used. Before you increase the gain on a channel, you should be sure that no internal voltage will exceed the common-mode voltage limitations of the CS5534.

long OffsetCal(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: The offset value of the selected channel is determined and stored. This offset will value will be used to correct subsequent conversions on that channel

long SysOffset(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: The offset value of the selected channel is determined and stored. In this case, the converter does not internally ground the channel inputs, but rather assumes that the external zero level voltage is present at the input pins. This offset will value will be used to correct subsequent conversions on that channel

void AD24SetPower(short level);

Parameters: Level determines the internal power level of the AD24. One is normal power, zero specifies low power.

Usage: The AD24 power consumption can be reduced significantly by using this command to put the CS5534 converters into low-power mode. While in low-power mode, you cannot perform conversions or calibration.

void AD24SetGainCal(short chan, ulong gaincal);

Parameters: Chan specifies the input channel (1 to 8).

Usage: You may use this function to restore a previously saved gain calibration value for a particular channel.

void AD24SetOffCal(short chan, ulong offcal);

Parameters: Chan specifies the input channel (1 to 8).

Usage: You may use this function to restore a previously saved offset calibration value for a particular channel.

ulong AD24GetOffCal(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: This routine will return the internal offset calibration register for the selected channel. This value may be saved by the user software to allow the channel to be set to the same gain value at a later time.

ulong AD24GetGainCal(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: This routine will return the gaininternal offset calibration register for the selected channel. This value may be saved by the user software to allow the channel to be set to the same gainoffset value at a later time.

long GainCal(short chan);

Parameters: Chan specifies the input channel (1 to 8).

Usage: The selected channel is calibrated using the internal reference voltage. The value in the CS5534 gain register is returned as a 32-bit long integer. User software may store this value so that the same calibration factor may be used at a later time.

void ShortInputs(void);

Parameters: None.

Usage: The inputs of all eight channels have their plus and minus input internally connected. This normally results in an output value near zero if the offset calibration has been carried out. This process can be undone only by re-initializing all the AD24 channel setup registers using AD24Init(). It is intended primarily for software and hardware testing.

void ShowQSPI(void);

Parameters: None.

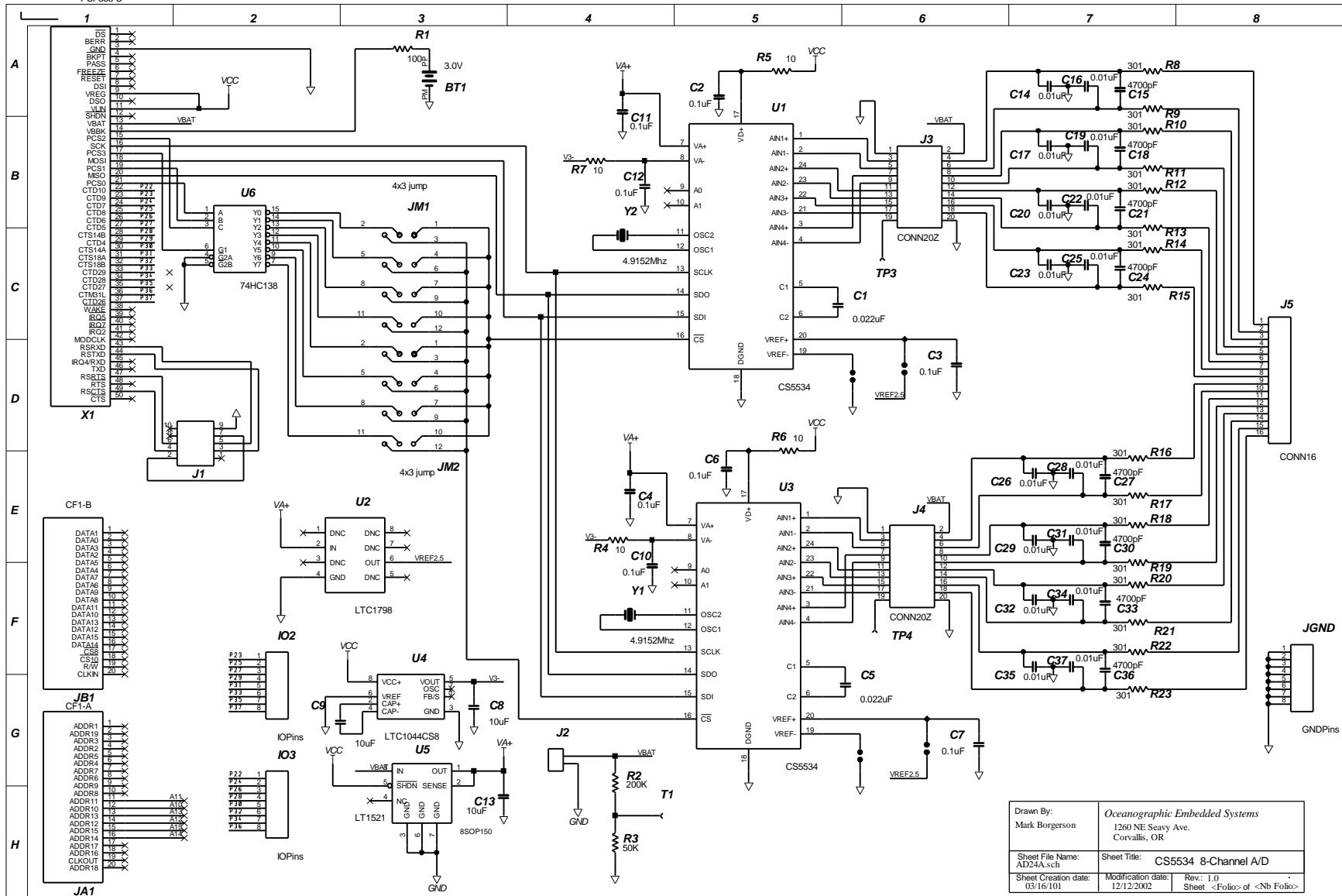
Usage: This routine displays internal values used in debugging the setup of the QSPI on the CF2.

Sample Application

The AD24 disk includes a sample application that will allow you to test the capabilities of the AD24. The application source code also provides examples of the proper usage of the library functions. The sample application on the disk is a project

set up for the CF-2 and the CodeWarrior PalmOS development system. If you are using CWPro, you should be able to use the library and the source code to generate a working application on that development system

Pressing the '?' key in the sample application will present a list of the single-character command accepted by the program.



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