The DIO-449 boards are 48-channel, high performance AC and DC digital input boards. The DIO-449 is part of UEI's Guardian series, which consists of I/O boards equipped with on-board diagnostic circuitry.

This application note details the the DIO-449 self-test functionality and provides an overview of how to configure, perform, and interpret a self-test.

DIO-449 self-test description

The DIO-449 can monitor switches or contacts without external circuitry using an on-board D/A converter (see Guardian DAC in block diagram below).

Since the input hardware for each channel includes an A/D converter in the chain, the actual raw analog voltage at each input can be monitored. This capability, combined with the board's ability to switch a programmable DAC into each channel, allows a complete and reliable self-test of the board. The capability of measuring raw analog voltages also provides quick and accurate detection of short and open circuits, as well as detection of marginal or failing drive circuitry.

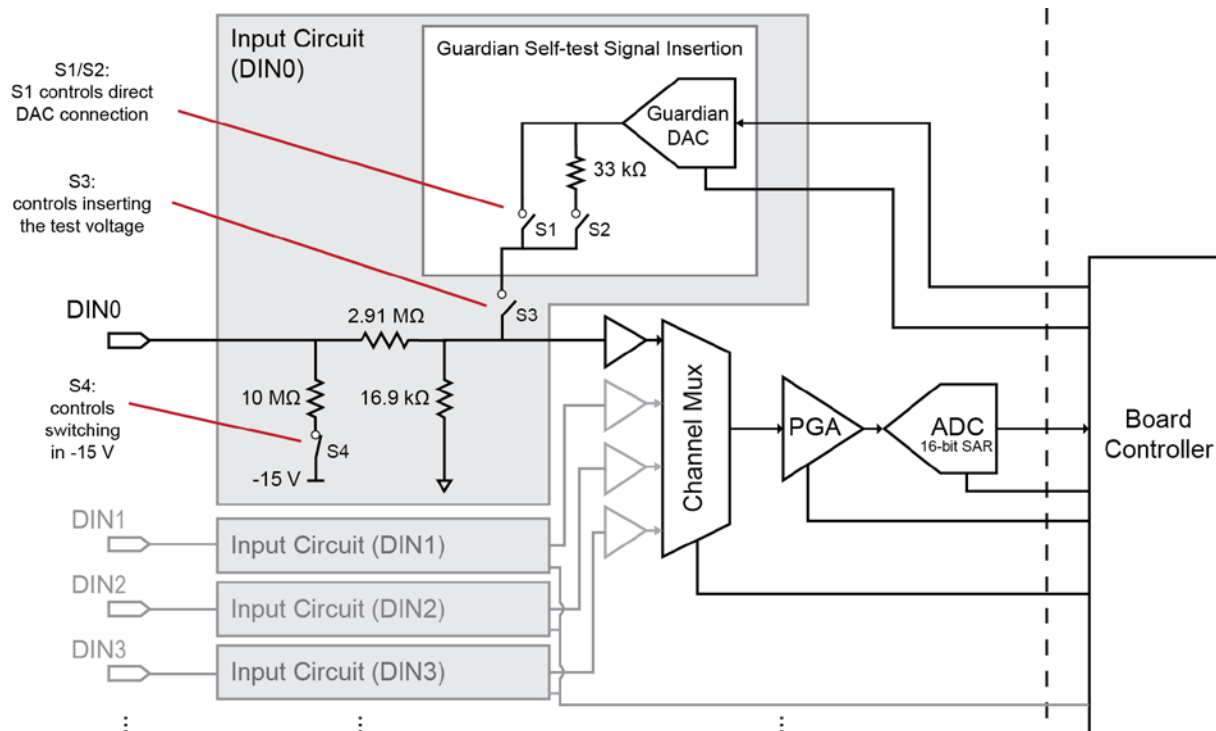## DIO-449 self-test circuitry block diagram

Figure 1 Block Diagram of Input Circuitry for DIO-449 Channel 0

DIO-449 self-test configuration and interpretation

This section provides an overview of configuring the self-test feature and interpreting results.

Software configuration

The software configuration steps for implementing the DIO-449 self-test are listed below (the low-level API that is used in each step is provided in the parenthesis):

1. Configure the anticipated voltage range (gain) (`DqAdv449SetLevels()`)
2. Configure mux states to switch in test circuitry (`DqAdv449SetGMux()`)
3. Set reference voltage level for the Guardian DAC (`DqAdv449SetGDacs()`)
4. Acquire / monitor the actual voltage reading using the ADC (`DqAdv449ReadAdc()`)

Hardware configuration

The DIO-449 self-test feature allows users to test their system with field wiring in place, without the need for any additional external circuitry.

On-board hardware configuration is accomplished via the software configuration steps listed above, where test switches are set in software to insert the user-programmed reference voltage in-circuit. A tutorial of an example configuration is provided as the last section of this document.

Result interpretation

If the field wiring is left connected, please note that an input signal on the DIO-449 digital input pin will affect the overall self-test voltage readings according to this formula:

`*reportedVoltage = (0.22 * inputVoltage) + nominalSelf-TestVoltage`

where

`reportedVoltage` is the voltage read by your application using UEI API

`inputVoltage` is the voltage at the input pin

`nominalSelf-TestVoltage` is the voltage injected by the Guardian DAC

*Note that this is an ideal equation. Source impedance at the input will affect the `reportedVoltage`. Additionally, variances in per channel impedance in the test path will also affect the `reportedVoltage`.

When interpreting self-test results, the criteria indicating a pass should be a range of voltages instead of an exact value.

Being within 5% of the voltage indicated by the `reportedVoltage` formula demonstrates a valid self-test.

Injected Guardian DAC signal characteristics

The test voltage to be injected by the Guardian DAC is user programmable (from 0 V to 168 V). Additionally, users can program a gain value to optimize the dynamic range of the ADC based on the maximum anticipated voltage (`reportedVoltage`).

The following table lists the programmed DAC setting vs actual voltage for each of the available gain settings.

DAC setting	Gain index (Gain setting)	DC Voltage reading
0 – 127	0 (1)	0 – 168 V
0 – 63	1 (2)	0 – 83 V
0 – 23	2 (5)	0 – 31 V
0 – 11	3 (10)	0 – 15 V

Note that there is a skew from the voltage that is programmed versus the actual voltage that is injected. Also note that these values are not calibrated, so the readings are approximate.

DIO-449 self-test tutorial

This tutorial provides an overview for implementing the DIO-449 self-test using the low-level API.

Please note that only the specific steps for implementing the self-test are provided. Opening communication with the RACK or Cube, handling error codes, and other tasks not specific to self-test are omitted (examples of these tasks can be found in the DIO-449 sample code).

Test conditions

- Channels DIO-0..DIO-3 are configured and monitored
- Input voltage on channels DIO-0..DIO-2 is 24 volts
- Channel DIO-3 is floating
- Guardian DAC for each of the channels is injecting a reference voltage of 50 V
- Gain is programmed to 1 (giving the ADC a dynamic range of 0 – 168 V)

Tutorial

1. Define constants; declare variables

```
#define CLSIZE (4)   // max = 48, number of channels to use,
                     //          channel(0) to channel(CLSIZE-1)

// Variables for mux states that switch in/out self-test circuitry
uint32 muxval[2];     // for driving DAC output directly (controls S1 & S2)
uint16 gme;           // for switching in self-test circuitry (controls S3 & S4)
```

2. Configure the anticipated voltage range (gain)
The channel list sets up a list of channels to configure.

- Set up the channel list array for channel 0..3.
- Note that the channel identifier includes the channel number plus an offset (`DQL_CHAN449_ADCCHAN_START`) that specifies reading ADC data instead of digital binary representation.
- Use `DQ_LNCL_GAIN` macro to OR in programming a gain of 1 (range of 0..168 V) and DC mode:

```
// set up gains and levels for all lines
for (i = 0; i < CLSIZE; i++) {
    cl[i] = i+DQL_CHAN449_ADCCHAN_START   | // load channel numbers
            DQ_LNCL_GAIN(DQ_DIO449_GAIN1  | // gain =1
            DQ_DIO449_MODE_DC);             // expect DC voltages
}
DqAdv449SetLevels(hd, DEVN, CLSIZE, cl, (float)LEVEL_LOW, (float)LEVEL_HIGH);
```

3. Configure mux states to switch in test circuitry
The Guardian Mux Enable switches (`S3`, see Figure 1) for putting the DAC in-circuit are programmed in groupings of 4 (`gme=1` for ch0..3; `gme=2` for ch4..7; `gme=4` for ch8..11; etc.).

```
// muxval[0] configures S1/S2 self-test mux for chan 0..23;
// muxval[1] configures S1/S2 self-test mux for chan 24..47
muxval[0] = 0xf; // 0xf: S1 connects self-test DAC directly to S3
                 //      for ch0..3
muxval[1] = 0x0;
gme = 0x1;       // S3 switch connects test DAC to input channel (for ch0..3)

DqAdv449SetGMux(hd, DEVN,gme,muxval);
```

4. **Set reference voltage level for the Guardian DAC**

    Use `DQ_DIO449_LNCL_G_DAC` macro to program a reference voltage of 50 V (scale according to table on page 3).

```
// gain = 1: 38 V * approximate scale of 168/127 = ~50 V read from DAC
for (i = 0; i < CLSIZE; i++) {
     dl[i] = i  | DQ_DIO449_LNCL_G_DAC(38);
}

DqAdv449SetGDacs(hd, DEVN, CLSIZE, dl);
```

5. **Acquire / monitor the actual voltage reading using the ADC**

```
DqAdv449ReadAdc(hd, DEVN, CLSize, cl, bData, fData);

for (i = 0; i < CLSIZE; i++) {
    printf("channel %2d: %6x  %f V%s \n",
              DQ_LNCL_GETCHAN(cl[i])-DQL_CHAN449_ADCCHAN_START,
              bData[i] ,
              fData[i],
              (bData[i] & DQDIO449_BDATA_DC_FLAG )? "DC":"AC" );
}
```

Channel 0, 1 and 2 are driven with an input voltage of ~24 V, and channel 3 is floating.

On a test system, the looped output from the print above reads:

Using *`reportedVoltage = (0.22 * inputVoltage) + nominalSelf-TestVoltage`, channel 0..2 should read approximately (0.22*24 + 50 = 55.28) and channel 3 should read ~50.

Important note: The actual voltage read for a passing self-test can be within 5% of your expected `reportedVoltage,` depending on your hardware and connections. In this example, readings between 52.51 and 58.59 for channels 0 through 2 would be within the range expected.

For more information:

Please contact UEI support at support@ueidaq.com or call 508.921.4600 with any questions.