Integration of an isolation amplifier into an Aerotech Servo motor controller
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SUMMARY

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The reason to make an isolation amplifier is to eliminate "ground loop" noise in the analog rpm and current data, which is being derived from the motor controller system and recorded on the Data Collection System. By utilizing an Isolation Amplifier to interrupt the ground path, which occurs by connecting the Motor Controller analog output data directly to the Data Acquisition System ground loop, noise is eliminated. The isolation amplifier makes use of the AD210, a wide bandwidth 3 – port isolation amplifier. This chip uses transformer coupling to separate grounds. Therefore the data you receive is actually your true signal.

When modifying the isolation amplifier it helps to use the accompanying diagrams, schematics, and tables. In fact it is impossible to understand the circuit without them. When modifications are completed you can start the testing which is straightforward with the instructions. These tests just verify if the isolation amp is wired properly and acting the way it should. The next set of tests verifies that the motor controller system is operating correctly. The pictures and diagrams should be an aid to anyone setting up another data acquisition system as well.

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During this work-term I modified and fixed an existing isolation amplifier. As well I integrated it into an Aerotech motor controller package by rewiring the back panel. Then I proceeded to make a duplicate isolation amplifier so that it could be interchangeable with the first. Once complete I tested the system under a variety of conditions in different places to compare it to a second (unmodified) Aerotech motor controller package. In doing so I found many flaws with the testing setup and how it should be configured, which is included in the report.

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According to the results, the system that I modified is almost as good as the original unmodified motor controller with an external isolation amplifier box attached. The difference in noise is in the $5 - 10$ mV range, which is irrelevant when you are looking at a scale of $0 - 10$ Volts. The little bit of extra noise seems to be coming from the switching that is going on inside the motor controller package. So this project was a complete success in the fact that it frees up space in the testing environment. It also saves some time when trying to find equipment because you don't have to go looking for another isolation amplifier to use with the system.

The integration of the isolation amplifier did not solve the noise problem with the system because the major noise is not coming from airborne radio frequencies. It is a combination of the motor dynamometer, signal conditioner, AC power, transformer, and radio frequencies. These problems are minimized when you separate the system into two different groups, clean and dirty. Clean being the data acquisition side and dirty being the motor controller side. You can follow my instructions and pictures and see how this is accomplished.

Acknowledgements

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Figure

1.0 Introduction

1.1 Background

The reason for this whole project is to improve an already existing Aerotech triple axis servo motor controller (I will refer to it as the motor controller). Previously the motor controller utilized an external eight-channel isolation amplifier, which was a mess. Refer to Figure 1.1.

Figure 1.1 External Isolations Amplifier   **Figure 1.2 Internal Isolation Amplifier**

The idea was to integrate the isolation amplifier into the existing motor controller box as in Figure 1.2. This should have the following advantages:

- More portable

- Less wires hanging around to pick up noise and get in the way

- More user friendly

- Protected from noise in the air by being inside of the motor controller

1.2 Problems and Methodology

A previous student created the aluminum boxes for the isolation amplifiers, populated the boards and wired it up. It was completed but did not operate correctly. Here are the problems and how they were fixed:

Problem 1:

When the motor controller was turned on it would go right to the rail meaning that it would reach top speed immediately. We tried many things to fix this, one of which was to put a 10 MΩ resistor across pins 18 and 19 on the command inputs at the AD210 amplifier. This should have caused no signal to go into the chips when no command is given, but didn't work. When I was rewiring the chips I noticed that the output for each of the tachometer channels was on the wrong pin, pin 1 instead of 19. Tachometer is the signal from the motor telling the controller what speed it is going. Essentially the signal was reversed and told the motor to go faster when it was supposed to be idle.

Problem 2:

The original isolation amplifier box design had all of the incoming signal grounds tied together, which in turn defeated the isolation of the isolation amplifiers. So in order to fix this I brought in a separate wire for each of the incoming signals. To do this I had to replace the 10 pin bendix connector with a 19 pin to accommodate the extra wires. Then I had to rewire the rear panel of the motor controller. Figure 1.3 show the box before modification and Figure 1.4 shows it after.

Figure 1.3 Unmodified isolation amplified   **Figure 1.4 Modified isolation amplifier**

Problem 3:

The grounds were still not isolated after each signal had its own ground. So in order to truly isolate the signals we have to implement a triple pole double throw switch. The

switch controls the command mode between command input BNC and remote hand held control potentiometer input. The hand held control potentiometer derives its excitation from a +/- 15 volt power supply within the motor controller which means the command isolation would be defeated if this signal were connected to the command isolation amplifier. The switch bypasses the isolation amplifier when switched to the hand held control potentiometer position. It allows only command input or remote input to work at once.

Problem 4:

There were some wiring problems that I found as I was testing and modifying the isolation amplifier circuitry. First to note is that the signal common and the power common were not connected properly across the chips. Also there were some wires crossing under chip sockets and a few other minor problems. Stripping all of the wires off the boards and rewiring everything fixed all of these problems. Figure 1.5 shows how the boards looked before and Figure 1.6 shows how it looks now.
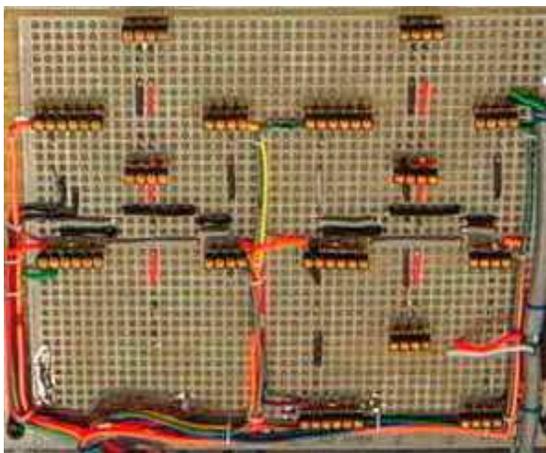
Figure 1.5 Proto board before rewiring   **Figure 1.6 Proto board after rewiring**
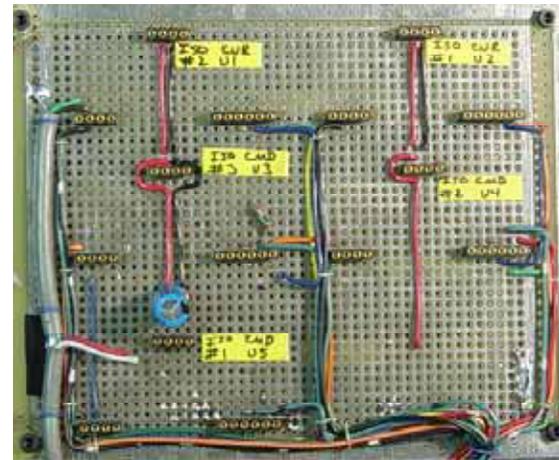
1.2 Scope

This report discusses improvements and modifications to an existing triple axis motor

controller with an internal isolation amplifier. Once created the system will have to be

tested and compared to the unmodified version, which has an external isolation amplifier.

After this the second motor controller will be modified to be the same as the first. This

report will not cover the fabrication, and building of the isolation amplifier boxes or

ordering of parts. Nathan Adams covered those topics in a previous report, <u>Reducing</u>

<u>Noise And Eliminating Ground loops in Triple Axis Servo Motor Controllers</u>.

2.0 Noise and Analog Signals

2.1 Definition of Noise

Noise is any unwanted corruption to the normal signal. According to Omega Engineering "Noise can be categorized into two broad categories based on the source-internal noise and external noise. While internal noise is generated by components associated with the signal itself, external noise results when natural or man-made electrical or magnetic phenomena influence the signal as it is being transmitted." Noise becomes a problem when you are trying to get an accurate reading of signal feedback.

2.2 Effects of Noise on Data Signals

When noise is present on a data signal there is no way to get an accurate reading of what the original signal was. Noise could be caused by sources such as fluorescent lights, radio frequencies, and air conditioning systems. Figure 2.1 shows the effects of noise on a data signal.
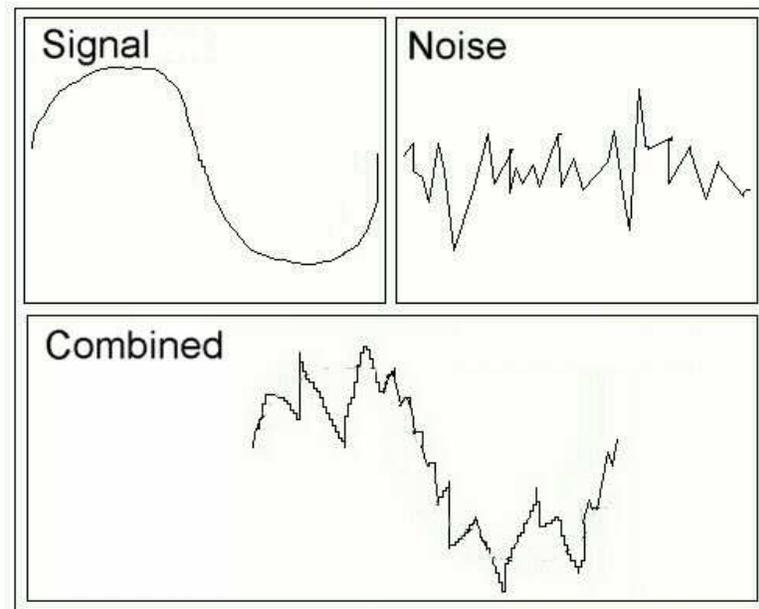
Figure 2.1 Effect of Noise on a Signal

2.3 How to Decrease Noise in a Motor Controller

There are two ways of reducing noise on a data signal, one being to get rid of the device

that is creating the external noise that is induced on your signal, the other is to use an

isolation amplifier to clean up the signal before you read it. For our purposes we did both.

The incorporation of the isolation amplifier into the motor controller will clean up the

signals before they come out of the box. This is accomplished by using the AD210 chip,

which is a 3-port isolation amplifier. In our case the isolation amplifier breaks the direct

electrical connection between the motor controller signal ground and the data collection

system signal ground and thus eliminates the potential for ground loop noise. The feature

that provides this chip with such good isolation is transformer coupling. This occurs

when two transformers are placed closely together so that the signal is passed from one

transformer to the next. In order for a transformer to work there must be an AC waveform

going into it. In figure 2.2 you can clearly see that at the output of the first op-amp there

is a modulator that converts DC signals to AC signals.
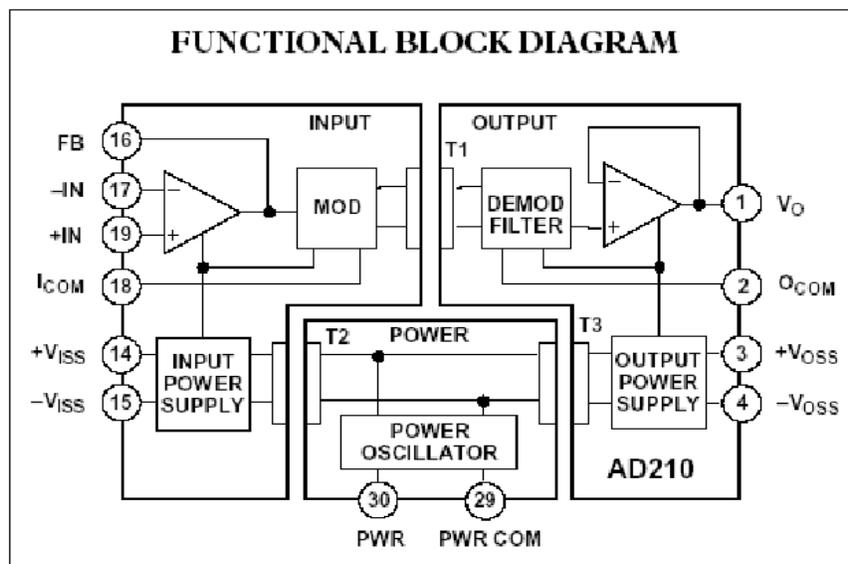
Figure 2.2 AD210 Block Diagram

This eliminates the DC noise in the signal. At the output of the second transformer there is a demodulator, which converts the signals back to DC. Figure 2.3 shows the signal before isolation and Figure 2.4 shows the signal after isolation.
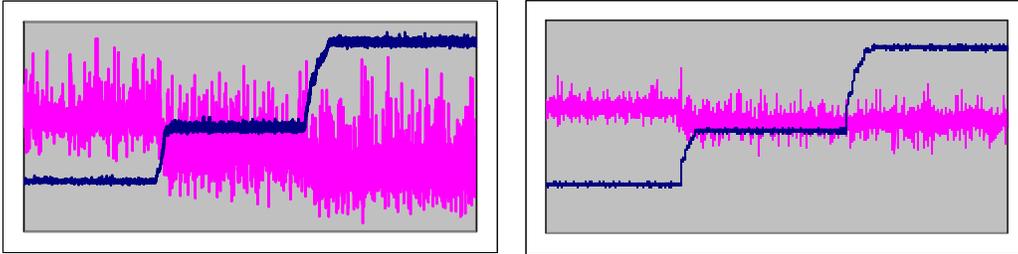
Figure 2.3 Velocity Signal Without Isolation   **Figure 2.4 Velocity Signal After Isolation**

After that you have to worry about external noise. We tried to move the motor controller testing setup around to achieve a less noisy setup in the prep shop; this is shown in Picture 1 in Appendix C. But there were air conditioners flowing and heavy machinery running which made it an overall noisy environment. In the end we found that we had to move the whole setup to the office area to reduce noise, see Pictures 2 and 3 in Appendix C. Section 5.2 outlines how to set up the isolation amplifier for noise reduction.

3.0 Building or Modifying the System

This section will explain the process to go about when building or modifying an isolation amplifier for use the Aerotech triple axis motor controller. You will need to utilize the motor controller schematic, isolation amplifier wiring tables, and AD210 layout, pin designation, and block diagram in Appendix B in order to understand how everything is interconnected. For information specific to the AD210 and how it works, refer to the data sheets in Appendix A.

3.1 Making the Cables

When making the cables for the internal connections for the isolation amplifier make sure to reference the tables and diagrams of Appendix B. Use the color coding which is used in the wiring table for each connector. This ensures uniformity among components and reduces the risk of error when soldering. The first thing to do is solder the wires to their pins on the appropriate bendix connector. The Pana Vise can be used to make this job easier by clamping it on the connector head. Make sure that you put the full assembly (strain relief clamp, bushing, and rubber insulator) on the cable before you begin soldering. When you have the cables made then you can begin to make connections to the Isolation Amplifier.

3.2 Isolation Amplifier Circuit Boards

Referring to the wiring table, AD210 diagrams, and schematic in Appendix B, the isolation amplifier circuit boards can be wired. It looks to be a hard task at first, but it is quite simple after some examination of tables and diagrams. If you refer to figure 3.1 you can see the layout of the top board.
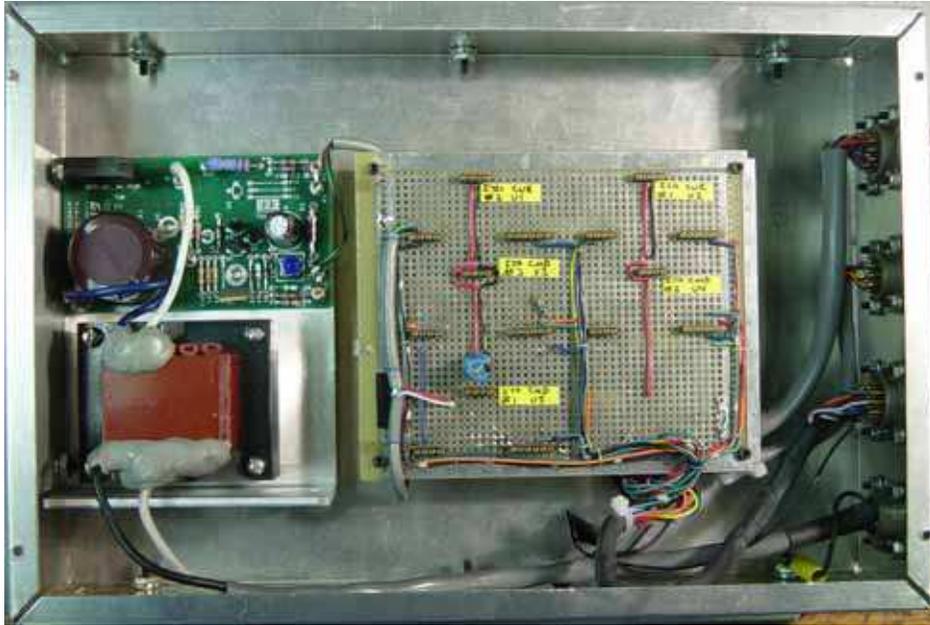
Figure 3.1 Isolation Amplifier Top View

Do not attach the cables to the box yet because you need room to work. Place the circuit

boards and power supply in the box before hand to ensure proper length for the wires.

Snip the wires when you have the correct length. Solder them into their correct places and

when all of the wires are connected, use small wires to act as tie wraps to hold the

interconnect wiring to the circuit board.

3.3 The Motor Controller Package Rear Panel

The rear panel is where everything goes in and out of the motor controller. So there are

many wires running from the rear panel to the isolation amplifier and motor controller.

This can be seen in Figure 3.2.

Figure 3.2 Rear Panel Layout

The wiring of the rear panel can be done in the same way as the isolation amplifier. You can use the schematic and the wiring tables to complete the job. Once everything is wired up and you are confident it works, then it is time to begin testing.

4.0 Testing of Isolation Amplifier

4.1 Materials

- Isolation Amplifier

- Oscilloscope

- Universal Source or Function Generator

- Digital Multimeter

- 3 BNC to BNC connectors

- Testing Cables

Figure 4.1 Modified Testing Cables

     - Modified power cable (2 pin to plugin)

     - 37 pin female connector to stripped wires

4.2 Pin Out Test

The function of this test is to ensure that connections are made correctly to specific points on each board and to the correct places on the rear panel. For this test you should use the isolation amplifier wiring diagram and schematic, which are located in appendix B. You will use the ohm's function on the DMM (digital multi-meter) to put one lead on the pin of the external connector and another lead on its appropriate point on the board. Afterwards make sure that there is no continuity between the power pins and any other pin. Then verify that the signal common is actually common between all of the chips.

4.3 Power Test

This test is just to see if power is flowing where it should or shouldn't be. Remove all AD210 chips from the circuit. (Make sure not to bend pins on the chips, they are very fragile. Plug the modified power cable into the power input of the isolation amplifier, like

in Figure 4.2. Use a multimeter to verify with the DC voltage function that there is 15 Vdc between pins 29 and 30 on each chip circuit. Then make sure there is no voltage between 29 and any other pin, and 30 and any other pin.

Figure 4.2 Modified Power Cable connected

4.4 Functional Test of Unity Gain

The following test is to check the unity gain of each of the AD210's (what goes in should come out). To perform this test all of the AD210's have to be placed in their corresponding positions. Put the cover back on the Isolation amp and then put it into the motor controller case. You are going to use the rear panel of the motor controller to perform the following test. Follow these steps:

1) Connect the modified power cable, the isolated rear panel cable, and the Motor controller cable to the Iso Amp.

2) Connect the 37 pin female end of the testing cable to the male end of the motor controller cable.

3) Connect a BNC T connector to the output of the universal source.

4) Then connect a BNC cable from the T connector to the oscilloscope and another one from the T connector to the command input on the rear panel.

5) Then connect a BNC cable to the oscilloscope and some alligator clips to the opposite end.

6) Connect the alligator clips to the motor controller output cable. Black to the black wire, red to the wire you are testing, in this case purple or CMD1.

7) Now on the oscilloscope line up channel 1 on the 2nd line from the top, and channel 2 on the 2nd line from the bottom, making sure that their amplitudes are the same. For our purposes 2 V/div should be sufficient.

8) Place the command input mode switch (triple pole double throw) in the "command BNC" position.

9) Now turn on the source let it warm up for approximately 10 minutes and set it for 5 V(peak) at 10 Hz. The waveforms on the oscilloscope should be exactly the same, see Figure 4.3.
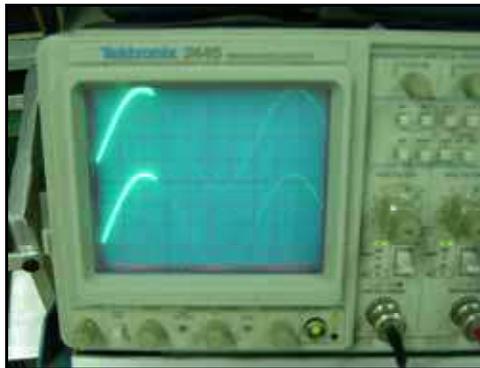
Figure 4.3 Unity gain input and output signals

Do the same for the other 2 command inputs. Inputting the signal through command and receiving it on the motor controller cable. For the Tach and Current you have to do exactly the opposite. Just switch around the cable on the BNC T connector and oscilloscope so that you have input going in through the motor controller and output coming out on the rear panel. These signals should also be exactly the same as well.

5.0 Testing of Motor Controller

5.1 Materials

- Signal conditioner with output signal buffer installed, signal conditioner power supply, and appropriate power supply output cable

- Signal conditioner analog output cable to daqboard /2000

- DASPC (#14 preferably), monitor, keyboard, mouse, Daqboard /2000 ribbon cable and DBK 201 interconnect board

- Marine UPS

- Dual output DC power supply for command signal derivation

- 2 digital multimeter

- Motor Controller Package

- Power transformer

- Motor Dynamometer

- Emergency stop for enable

- Hand held optical Tachometer

- 2 BNC – 10 pin bendix cables for connection of motor controller isolated output signals to Signal Conditioner

- 2 of 1Khz passive Low Pass filters to reduce RF rectification level shift effects on the isolated data

- 4 to 8 BNC cables, BNC to banana clips, T connectors, etc.

5.2 Setup

The first thing to do when starting the testing process is to set up each component in the correct position to achieve maximum noise reduction. Pictures 2 and 3 in Appendix C

show how I achieved this. Of the many configurations that were tested this proved to be the best scenario. . The setup block diagram in Appendix B shows where each device interconnects.

5.3 Steps to reduce noise

1 - The first thing to take note of is where you have the separate devices plugged in. Make sure that the power transformer is on a separate power grid from the meters, and UPS.

2 - The transformer should also be located as far away from the testing setup as possible so that the Switching RF noise is not radiated onto the monitoring cables.

3 - The next thing to do is make sure there are no major noise producers running in the vicinity, and especially not on the same power grid. In the case of the Model Prep Shop test area this could include the PMM, or any other motor.
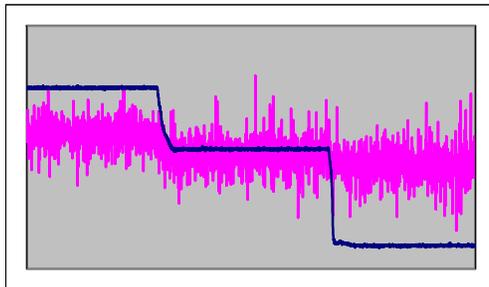
Figure 5.1 Normal operating conditions   **Figure 5.2 Noise after PMM operating**
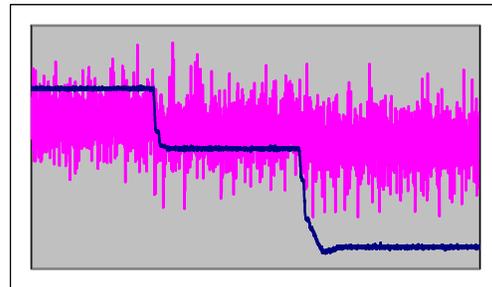
4 - After that the computer, monitor, and the signal conditioner should be plugged into the UPS.

5 - Next plug 4 grounding plugs into the signal conditioner on the 4 adjacent connections from the active measuring channels, CH 00 and 02, on the signal conditioner input. These are 01, 03, 14, and 15. This reduces cross talk produced by the signal conditioner / Daqboard /2000 data acquisition system.

6 – Finally, inline 1 Khz passive low pass filters have to be placed at the CH 00 and 02 inputs to the signal conditioner. The purpose of these filters is to reduce the effect of data level shift which is produced by RF rectification within each Signal Conditioner instrumentation amplifier channel. The designs for the 1Khz RF filters can be located in Appendix B.

Once everything is connected according to the diagram then you can begin collecting data. Prior to starting you should make sure that the motors are spinning in the right directions. Enable the driving motor and apply a command voltage from the left channel of the Dual power supply noting which direction it is going. To determine direction you look into the motor from the shaft. If it is spinning clockwise then it is considered positive. Then disable the driving motor and turn up the command voltage (right channel of the Dual Power Supply) for the current control motor (brake motor) and note the direction of rotation. This motor should be spinning in opposite direction because you are using the current motor as a brake for the driving motor.

5.4 Steps to set up the Signal Conditioner

When you get a signal conditioner, there are many things to take into consideration before using it. Ask someone in the lab to help you get an Un-buffered signal conditioner. Separate the used channels with grounding plugs and place one before and after to eliminate cross talk in the signal conditioner, refer to Figure 5.3.
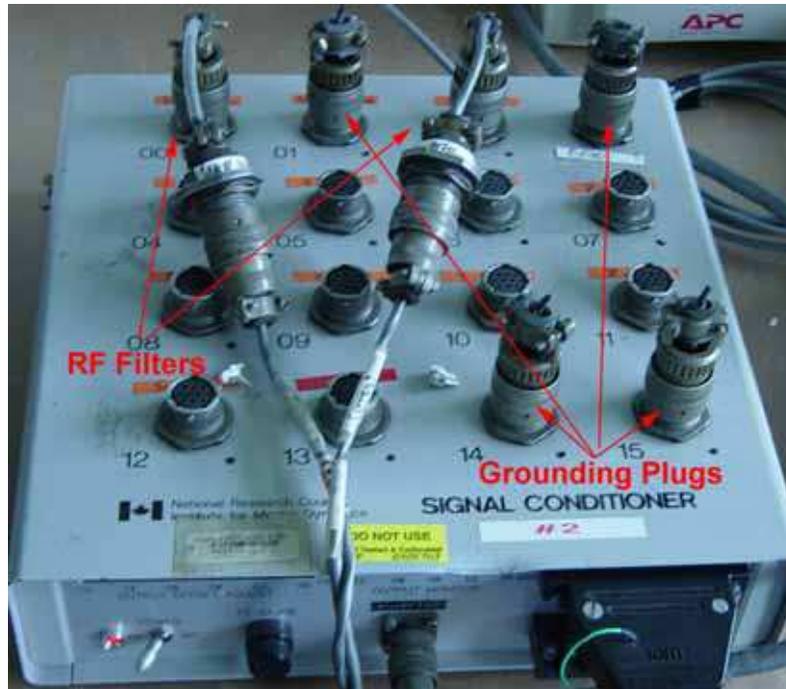
Figure 5.3 Signals Conditioner Connected

Take the back off the signal conditioner and configure it to the following settings for the inputs used:

- Set the gain of the isolated tach feedback channel (CH 00) to 2 and the gain of the isolated current feedback channel (CH 02) to 4.

- Set the filters to 10 Hz.

- Make sure both channels are configured for 10V "local" excitation mode.

- Attenuation Jumper set to "No Atten" for both channels.

When configured, place a grounding plug into the used inputs and then adjust the offset potentiometer on the front of the signal conditioner to obtain zero volts output on the corresponding channel. This removes the inherent offset on the active data channels.

5.5 Steps for Data Collection

1 - Load up daqview and load the configuration called Chad's test.DAQ from the CD, which has all of my motor controller testing on it. If you can't find the file then you

can configure the settings yourself. The sampling rate is 50 Hz, set the start and stop

triggers to manual, set the data collection to ASCII and Binary.

2 - Label the collection file to something recognizable. I used the following

format: mod_1_cmd_300_amp2. Which translates into: modified controller, motor 1,

command input, 300 RPM, isolation amplifier #2.

3 - Place the clock and daqview up on the screen as in Picture 4.

4 - Set the velocity command voltage to its corresponding RPM value according

to the calibration tables located in Appendix B. You can verify the RPM value with the

handheld tachometer.

5 – For 300 RPM motor speed, set the current command voltage until a reading of

plus or minus 0.5V (depending on direction) on the DMM is reached. This corresponds to

approx. 2.5 amps of current being drawn by the driving motor. Note that for the 1200 and

1500 RPM test speeds the DMM voltage will already be more than 0.5V due to the

current required to produce the commanded speed and overcome the torque load

produced by the brake motor at a 0 volt current command signal.

6 - Unplug the UPS from the wall. This gives clean power to the DASPC.

7 - Press the acquire data button (has coins on it). Then press the manual trigger

button when the clock arm is on a dot on the clock. Time it for 30 seconds, then change

the current command to produce a 1.0V level on the DMM. This corresponds to 5 amps

of current being drawn by the driving motor. After 30 seconds change current input to

1.8V that corresponds to 9 amps of current being drawn by the driving motor. Wait

another 30 seconds and then stop the data collection.

8 - Plug the UPS back into the wall and turn the current command back to 0.

9 - Start again from step 2 and acquire data for 1200 and 1500 RPM speeds.

10. Switch the drive motor and command and feedback connections to controller 2 and repeat steps 2 through 8.

When you get to the third motor controller, you have to switch the personality chips on the front panel of the motor controller. Motor three is working in current mode and we need to have it working in normal mode in order to test it. So just take out motor controller 1 and 3 as in Figure 5.4 being careful not to interchange.

Figure 5.4 Motor Controller Boards

Then remove the personality modules, see Figure 5.5. Swap them around and then put the motor controllers back where they were before. If you don't remember what order they were in, motor 1 is on the left.

Figure 5.5 Personality Modules

Once done the testing with command BNC inputs, it is time to start using the hand held remote control boxes to control the motors. The steps above can be followed, just make changes where you need to.

5.6 Steps to using Excel

1 – When you first open excel there are 3 tabs at the bottom of the page for different spreadsheets. You should use them to put different tests on different tabs. In this

way it makes it easy to compare from test to test. Go to the Data, Get External Data, Import text file and select the ASCII text file for the test you want. The ASCII files will be wherever you chose to save them.

2 – Right click on the data you have just imported and go to the number tab, then select general.

3 – Press the Chart Wizard button then the custom types tab and then select lines on 2 axis.

4 – Pick a size to drag your chart and use the gridlines to make them the same Amplitude scaling each time for easy comparison.

5 – Double click on each line type and turn the markers to none.

6 – Change the markers on the x-axis to none so that no marks are visible.

7 – Change the Y-axis scales so that each test has the same scale and is therefore comparable.

8 – Right click on the data and click on edit text import, copy the name of the file and then paste the name into the tab for the spreadsheet.

6.0 Results and Comparisons

This is what all of the work comes down to, seeing which motor controller produces the least amount of noise. For each of these tables the data was imported into excel for easy comparisons using the process discussed in section 5.6. RPM are in purple and use the left axis and Current is in blue and uses the right axis.

6.1 Motor Controller 1 at 1500 RPM
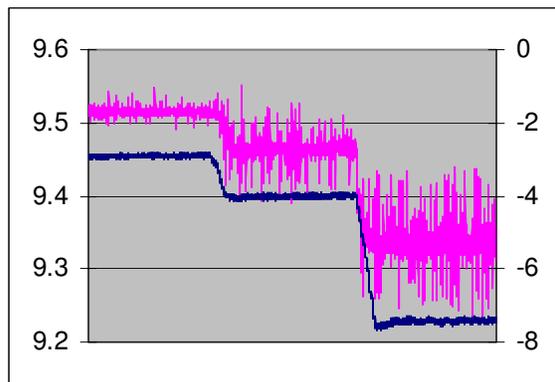
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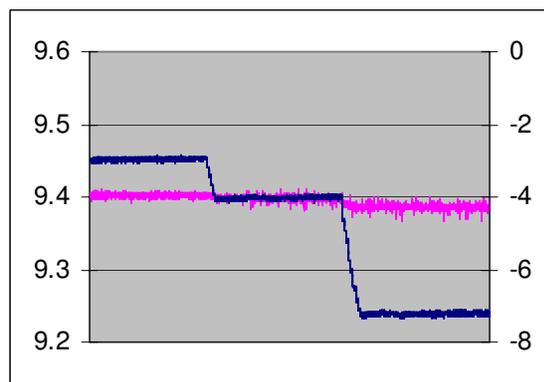
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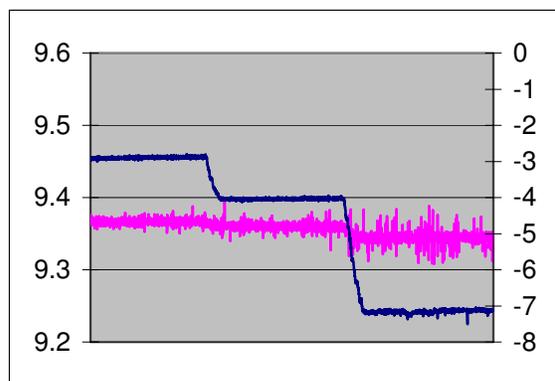
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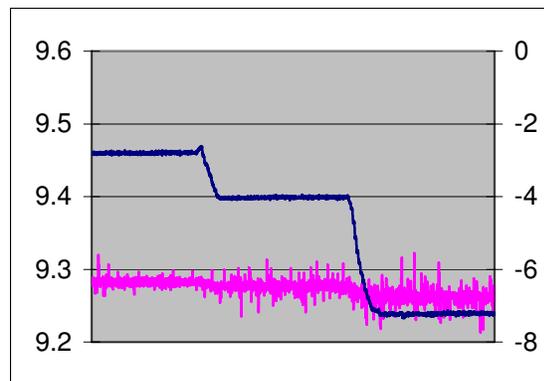
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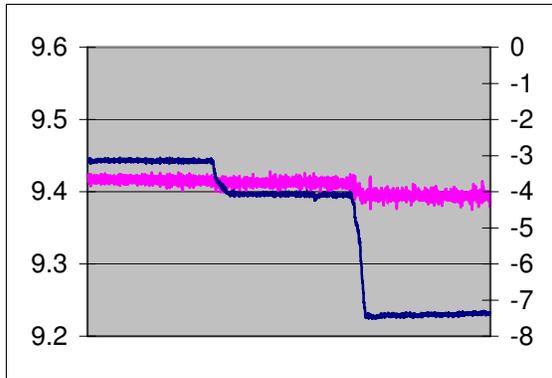
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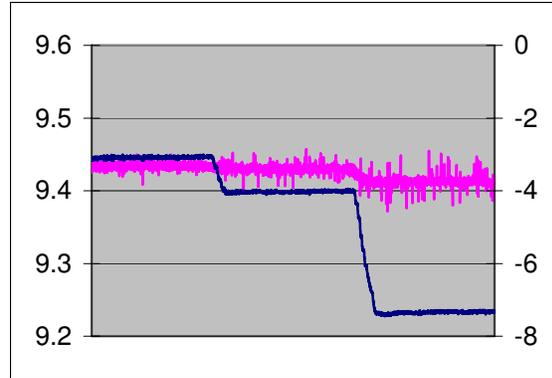
Modified, Remote, Isolation Amplifier 2

6.2 Motor Controller 2 at 1500 RPM
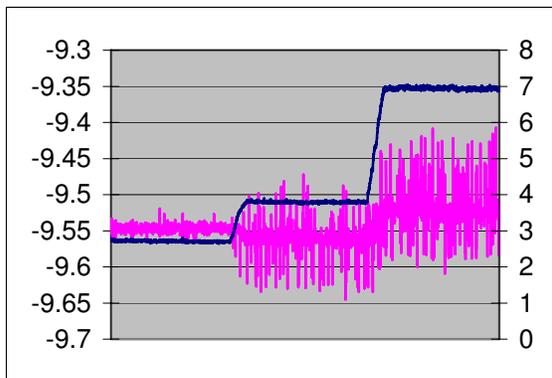
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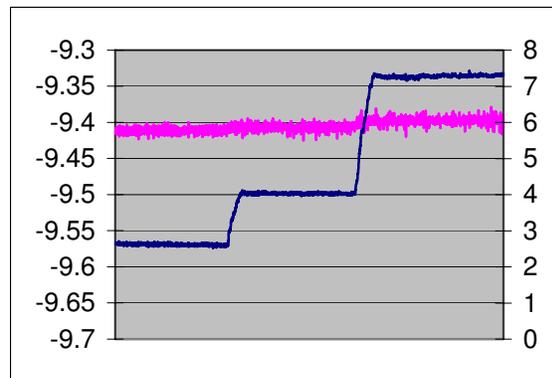
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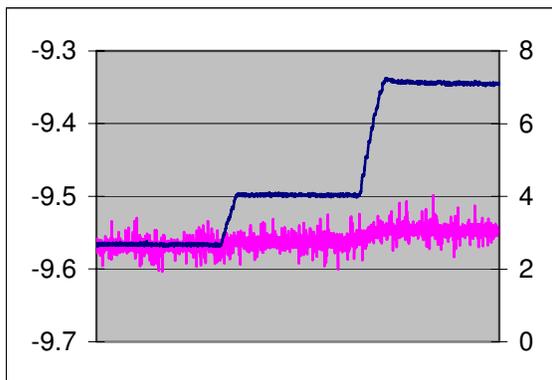
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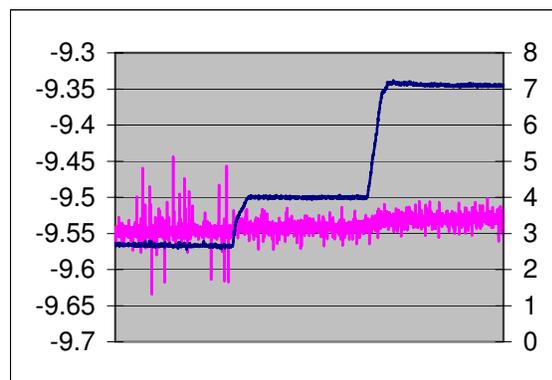
Modified, Remote, Isolation Amplifier 1
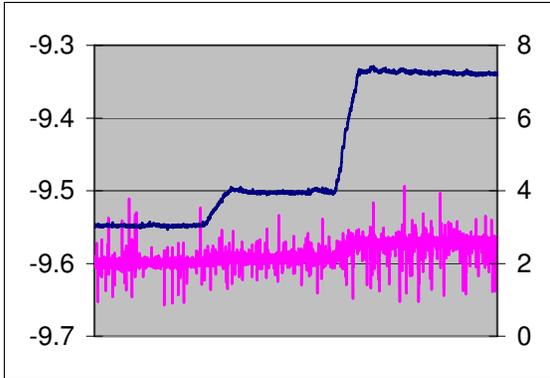
Modified, Command, Isolation Amplifier 2
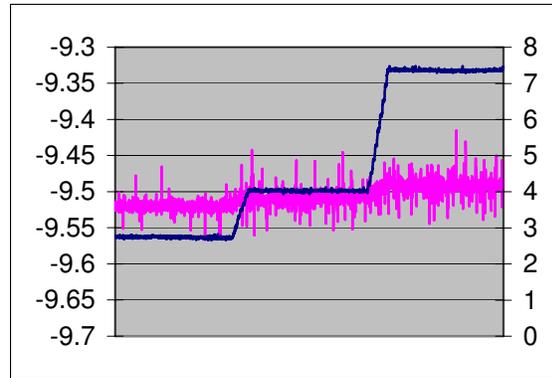
Modified, Remote, Isolation Amplifier 2

6.3 Motor Controller 3 at 1500 RPM
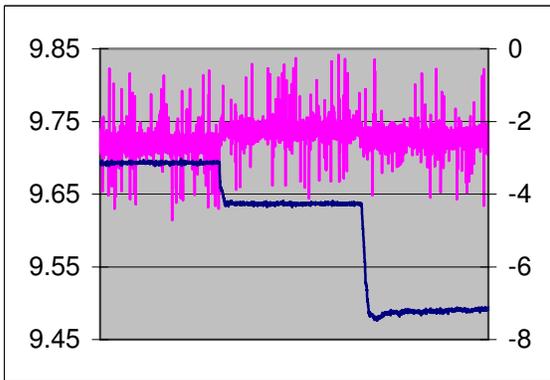
Unmodified, Unisolated
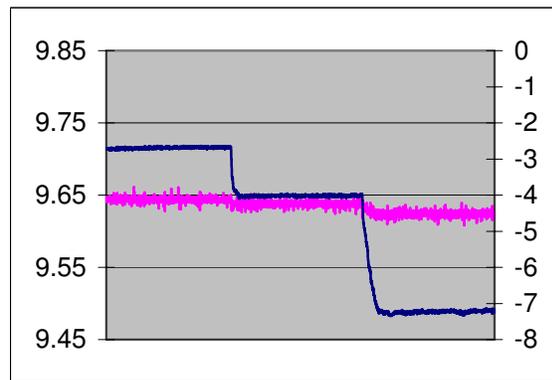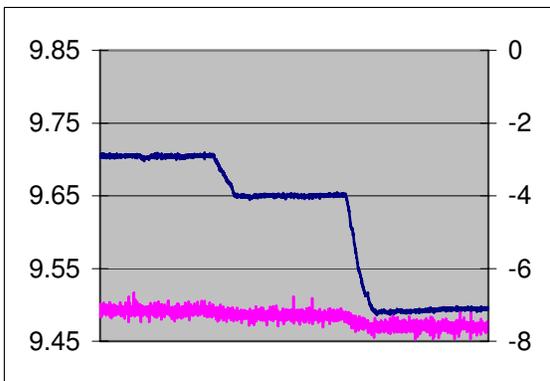
**Unmodified, External Isolation**

Modified, Command, Isolation Amplifier 1
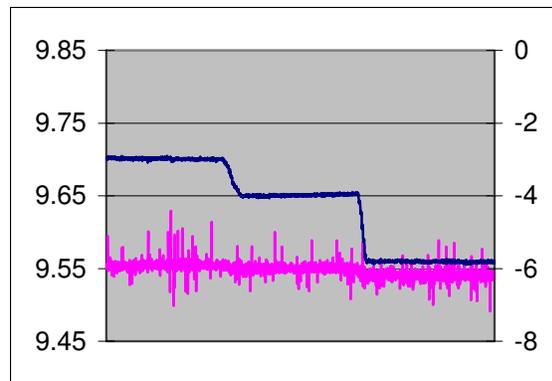
Modified, Command, Isolation Amplifier 1
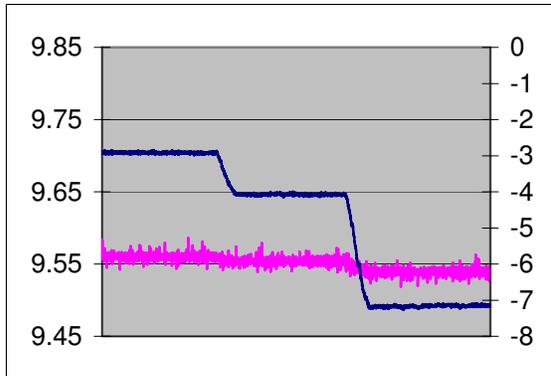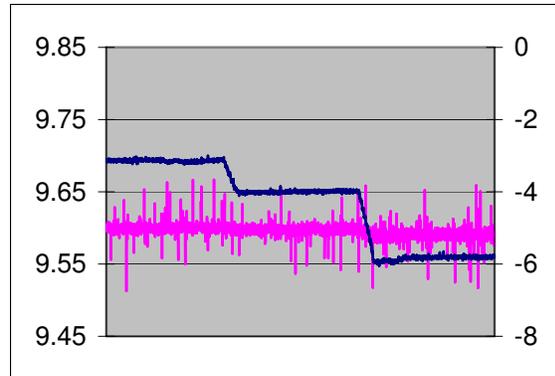
Modified, Command, Isolation Amplifier 2   **Modified, Command, Isolation Amplifier 2**

6.4 Comparisons

I tested the motor controllers under a variety of conditions. Unmodified, internally isolated, and externally isolated at +/- 300, 1200, and 1500 RPM. As well remote controlled, and with the two different isolation amplifiers that I made. I chose to only show the 1500 RPM results because each set shows the same results. From the results above it can be seen that the un-isolated motor controller has much more noise riding on the signals. This is true for each case. You can also see that the externally isolated motor controller has less noise that the internal one. But this noise difference is minimal because the scale of the reading is so small. You can also see that isolation amplifiers 1 and 2 are identical in their readings, and they should be. Except on motor 3 where you can clearly see that there are larger spikes of noise on isolation amplifier 2. This could be due to some noise in the testing area at the time of testing.

7.0 Conclusion

According to the results the system that I modified is almost as good as the original with external isolation. The difference in noise is in the $5 - 10$ mV range, which is irrelevant when you are looking at a scale of $0 - 10$ Volts. The little bit of extra noise seems to be coming from the switching that is going on inside the motor controller. Both the internal and externally isolated motor controllers out-perform the un-isolated version. The separate setups react differently in unlike environments. Because being inside the box protects it from airborne noise, the internally isolated motor controller works better in more noisy environments. You can also see from the results that as you increase load on the motor the noise also increases. This is because the motor has to work harder. From these findings the integration of the isolation amplifier into the Aerotech triple axis servo motor controller was a success.

I have put a lot of time and energy into modifying, testing and documenting the motor controller. I feel confident that this document is sufficient enough for a technologist to use if they were to modify or build an isolation amplifier. This project has helped build confidence in my field of study and has given me experience to carry into my future career.

8.0 Recommendations

The integration of the isolation amplifier did not solve the noise problem with the system because the major noise is not coming from airborne radio frequencies. It is a combination of the motor dynamometer, signal conditioner, AC power, transformer, and radio frequencies. All of this noise happens when the signals exit the motor controller box. If you were to really get rid of the noise there are larger problems to tackle. One such problem being the signal conditioners, they are a prevalent source of noise, cross talk, and other problems. Another problem is the proximity of the motor controller to the power transformer and it being on the same power grid. Also if the motor dynamometer is off balance, it will create noise. These problems are simplified when you separate the system into two different groups, clean and dirty. Clean being the data acquisition side and dirty being the motor controller side. You can follow my instructions and pictures you can see how this is accomplished. I hope that my outline for testing the motor controller solves a few problems in the future when setting up the data collection systems.

There is the issue of the remaining isolation amplifier box that I have made. It works perfect but due to time constraints I will not have time to integrate it into the other motor controller. If the next IOT student/employee wants to integrate it then the instructions I have made should work fine. It was mentioned to me that the chips inside could be used in a more cost efficient way by making a couple more external four-channel isolation amplifiers. As each AD210 costs approximately $200 then this would make a lot of sense. Whatever the case this document will be of help in doing the task.

References

Adams, Nathanael (2002). Reducing Noise And Eliminating Ground loops in Triple Axis Servo Motor Controllers. St. John's: Institute for Ocean Technology at the National Research Council.

[Anonymous] Analog Devices AD210 Data Sheets (2004); Available from: http://www.analog.com/UploadedFiles/Data_Sheets/713828300ad210.pdf via the Internet. Accessed June 12, 2004.

Areotech, INC. (1990). Operator's Manual for the DS16030 Series Servo Amplifiers and DSR/DSRF Mounting Racks. Kitchener: Optikon Corporation Ltd.

Omega Engineering, INC. Analog Signal Transmission: Noise and Grounding (2004); Avaliable from: http://www.omega.com/literature/transactions/volume2/ analogsignal2.html via the Internet. Accessed June 19, 2004.

Appendix A:
Data Sheets

ANALOG DEVICES

Precision, Wide Bandwidth 3-Port Isolation Amplifier

AD210*

FEATURES
High CMV Isolation: 2500 V rms Continuous
                                ±3500 V Peak Continuous
Small Size: 1.00" × 2.10" × 0.350"
Three-Port Isolation: Input, Output, and Power
Low Nonlinearity: ±0.012% max
Wide Bandwidth: 20 kHz Full-Power (–3 dB)
Low Gain Drift: ±25 ppm/°C max
High CMR: 120 dB (G = 100 V/V)
Isolated Power: ±15 V @ ±5 mA
Uncommitted Input Amplifier

APPLICATIONS
Multichannel Data Acquisition
High Voltage Instrumentation Amplifier
Current Shunt Measurements
Process Signal Isolation

FUNCTIONAL BLOCK DIAGRAM

GENERAL DESCRIPTION
The AD210 is the latest member of a new generation of low cost, high performance isolation amplifiers. This three-port, wide bandwidth isolation amplifier is manufactured with sur-face-mounted components in an automated assembly process. The AD210 combines design expertise with state-of-the-art manufacturing technology to produce an extremely compact and economical isolator whose performance and abundant user features far exceed those offered in more expensive devices.

The AD210 provides a complete isolation function with both signal and power isolation supplied via transformer coupling in-ternal to the module. The AD210's functionally complete de-sign, powered by a single +15 V supply, eliminates the need for an external DC/DC converter, unlike optically coupled isolation devices. The true three-port design structure permits the AD210 to be applied as an input or output isolator, in single or multichannel applications. The AD210 will maintain its high performance under sustained common-mode stress.

Providing high accuracy and complete galvanic isolation, the AD210 interrupts ground loops and leakage paths, and rejects common-mode voltage and noise that may other vise degrade measurement accuracy. In addition, the AD210 provides pro-tection from fault conditions that may cause damage to other sections of a measurement system.

PRODUCT HIGHLIGHTS
The AD210 is a full-featured isolator providing numerous user benefits including:

High Common-Mode Performance: The AD210 provides 2500 V rms (Continuous) and ± 3500 V peak (Continuous) common-

mode voltage isolation between any two ports. Low input capacitance of 5 pF results in a 120 dB CMR at a gain of 100, and a low leakage current (2 µA rms max @ 240 V rms, 60 Hz).

High Accuracy: With maximum nonlinearity of ±0.012% (B Grade), gain drift of ±25 ppm/°C max and input offset drift of (±10 ±30/G) µV/°C, the AD210 assures signal integrity while providing high level isolation.

Wide Bandwidth: The AD210's full-power bandwidth of 20 kHz makes it useful for wideband signals. It is also effective in applications like control loops, where limited bandwidth could result in instability.

Small Size: The AD210 provides a complete isolation function in a small DIP package just 1.00" × 2.10" × 0.350". The low profile DIP package allows application in 0.5" card racks and assemblies. The pinout is optimized to facilitate board layout while maintaining isolation spacing between ports.

Three-Port Design: The AD210's three-port design structure allows each port (Input, Output, and Power) to remain inde-pendent. This three-port design permits the AD210 to be used as an input or output isolator. It also provides additional system protection should a fault occur in the power source.

Isolated Power: ±15 V @ 5 mA is available at the input and output sections of the isolator. This feature permits the AD210 to excite floating signal conditioners, front-end amplifiers and remote transducers at the input as well as other circuitry at the output.

Flexible Input: An uncommitted operational amplifier is pro-vided at the input. This amplifier provides buffering and gain as required and facilitates many alternative input functions as required by the user.

*Covered by U.S. Patent No. 4,703,283.

REV. A

AD210–SPECIFICATIONS (typical @ +25°C, and V_S = +15 V unless otherwise noted)

Model	AD210AN	AD210BN	AD210JN
GAIN			
Range	1 V/V – 100 V/V	*	*
Error	±2% max	±1% max	*
vs. Temperature(0°C to +70°C)	+25 ppm/°C max	*	*
(–25°C to +85°C)	±50 ppm/°C max	*	*
vs. Supply Voltage	±0.002%/V	*	*
Nonlinearity[1]	±0.025% max	±0.012% max	*
INPUT VOLTAGE RATINGS			
Linear Differential Range	±10 V	*	*
Maximum Safe Differential Input	±15 V	*	*
Max. CMV Input-to-Output	*		
ac, 60 Hz, Continuous	2500 V rms	*	1500 V rms
dc, Continuous	±3500 V peak	*	±2000 V peak
Common-Mode Rejection	*		
60 Hz, G = 100 V/V	*		
$R_S \le 500\ \Omega$ Impedance Imbalance	120 dB	*	*
Leakage Current Input-to-Output	*		
@ 240 V rms, 60 Hz	2 µA rms max	*	*
INPUT IMPEDANCE			
Differential	$10^{12}\ \Omega$	*	*
Common Mode	5 GΩ‖5 pF	*	*
INPUT BIAS CURRENT			
Initial, @ +25°C	30 pA typ (400 pA max)	*	*
vs. Temperature (0°C to +70°C)	10 nA max	*	*
(–25°C to +85°C)	30 nA max	*	*
INPUT DIFFERENCE CURRENT			
Initial, @ +25°C	5 pA typ (200 pA max)	*	*
vs. Temperature(0°C to + 70°C)	2 nA max	*	*
(–25°C to +85°C)	10 nA max	*	*
INPUT NOISE			
Voltage (1 kHz)	18 nV/√Hz	*	*
(10 Hz to 10 kHz)	4 µV rms	*	*
Current (1 kHz)	0.01 pA/√Hz	*	*
FREQUENCY RESPONSE			
Bandwidth (–3 dB)	*		
G = 1 V/V	20 kHz	*	*
G = 100 V/V	15 kHz	*	*
Settling Time (±10 mV, 20 V Step)	*		
G = 1 V/V	150 µs	*	*
G = 100 V/V	500 µs	*	*
Slew Rate (G = 1 V/V)	1 V/µs	*	*
OFFSET VOLTAGE (RTI)[2]			
Initial, @ +25°C	±15 ±45/G) mV max	(±5 ±15/G) mV max	*
vs. Temperature (0°C to +70°C)	(±10 ±30/G) µV/°C		*
(–25°C to +85°C)	(±10 ±50/G) µV/°C		*
RATED OUTPUT[3]			
Voltage, 2 kΩ Load	±10 V min	*	*
Impedance	1 Ω max	*	*
Ripple (Bandwidth = 100 kHz)	10 mV p-p max	*	*
ISOLATED POWER OUTPUTS[4]			
Voltage, No Load	±15 V	*	*
Accuracy	±10%	*	*
Current	±5 mA	*	*
Regulation, No Load to Full Load	See Text	*	*
Ripple	See Text	*	*
POWER SUPPLY			
Voltage, Rated Performance	+15 V dc ± 5%	*	*
Voltage, Operating	+15 V dc ± 10%	*	*
Current, Quiescent	50 mA	*	*
Current, Full Load – Full Signal	80 mA	*	*
TEMPERATURE RANGE			
Rated Performance	–25°C to +85°C	*	*
Operating	–40°C to +85°C	*	*
Storage	–40°C to +85°C	*	*
PACKAGE DIMENSIONS			
Inches	1.00 × 2.10 × 0.350	*	*
Millimeters	25.4 × 53.3 × 8.9	*	*

NOTES
*Specifications same as AD210AN.
[1]Nonlinearity is specified as a % deviation from a best straight line..
[2]RTI – Referred to Input.
[3]A reduced signal swing is recommended when both $\pm V_{ISS}$ and $\pm V_{OSS}$ supplies are fully loaded, due to supply voltage reduction.
[4]See text for detailed information.
Specifications subject to change without notice.

OUTLINE DIMENSIONS
Dimensions shown in inches and (mm).
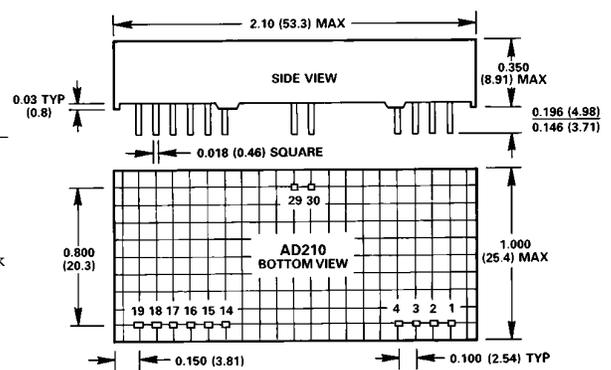
AC1059 MATING SOCKET

AD210 PIN DESIGNATIONS

Pin	Designation	Function
1	V_O	Output
2	O_{COM}	Output Common
3	$+V_{OSS}$	+Isolated Power @ Output
4	$-V_{OSS}$	–Isolated Power @ Output
14	$+V_{ISS}$	+Isolated Power @ Input
15	$-V_{ISS}$	–Isolated Power @ Input
16	FB	Input Feedback
17	–IN	–Input
18	I_{COM}	Input Common
19	+IN	+Input
29	Pwr Com	Power Common
30	Pwr	Power Input

WARNING!
ESD SENSITIVE DEVICE

CAUTION
ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although the AD210 features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

REV. A

INSIDE THE AD210

The AD210 basic block diagram is illustrated in Figure 1. A +15 V supply is connected to the power port, and ±15 V isolated power is supplied to both the input and output ports via a 50 kHz carrier frequency. The uncommitted input amplifier can be used to supply gain or buffering of input signals to the AD210. The fullwave modulator translates the signal to the carrier frequency for application to transformer T1. The synchronous demodulator in the output port reconstructs the input signal. A 20 kHz, three-pole filter is employed to minimize output noise and ripple. Finally, an output buffer provides a low impedance output capable of driving a 2 kΩ load.
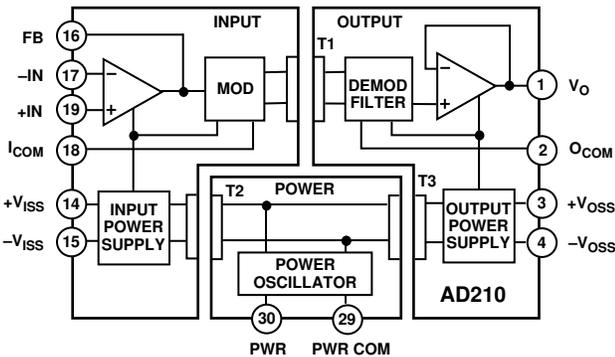

Figure 1. AD210 Block Diagram

USING THE AD210

The AD210 is very simple to apply in a wide range of applications. Powered by a single +15 V power supply, the AD210 will provide outstanding performance when used as an input or output isolator, in single and multichannel configurations.

Input Configurations: The basic unity gain configuration for signals up to ±10 V is shown in Figure 2. Additional input amplifier variations are shown in the following figures. For smaller signal levels Figure 3 shows how to obtain gain while maintaining a very high input impedance.
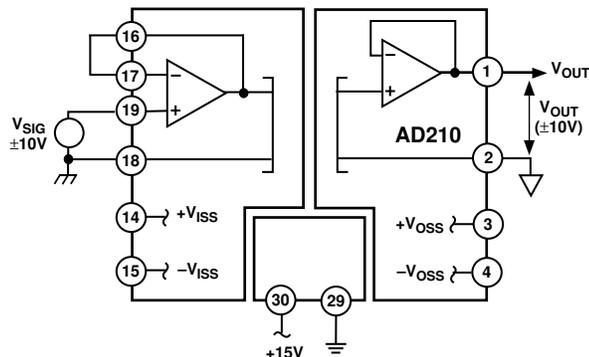

Figure 2. Basic Unity Gain Configuration

The high input impedance of the circuits in Figures 2 and 3 can be maintained in an inverting application. Since the AD210 is a three-port isolator, either the input leads or the output leads may be interchanged to create the signal inversion.
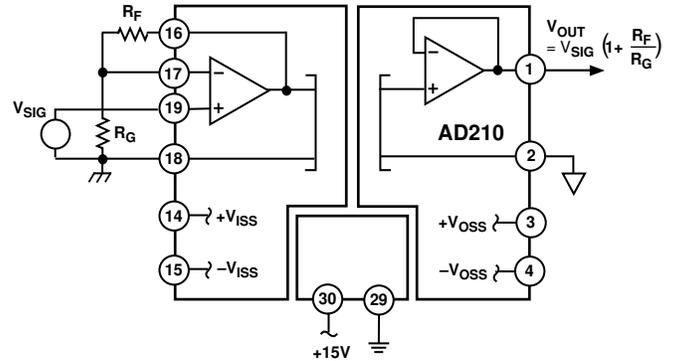

Figure 3. Input Configuration for G > 1

Figure 4 shows how to accommodate current inputs or sum currents or voltages. This circuit configuration can also be used for signals greater than ±10 V. For example, a ±100 V input span can be handled with R_F = 20 kΩ and R_{S1} = 200 kΩ.

$$V_{OUT} = -R_F \left(\frac{V_{S1}}{R_{S1}} + \frac{V_{S2}}{R_{S2}} + I_S + ... \right)$$
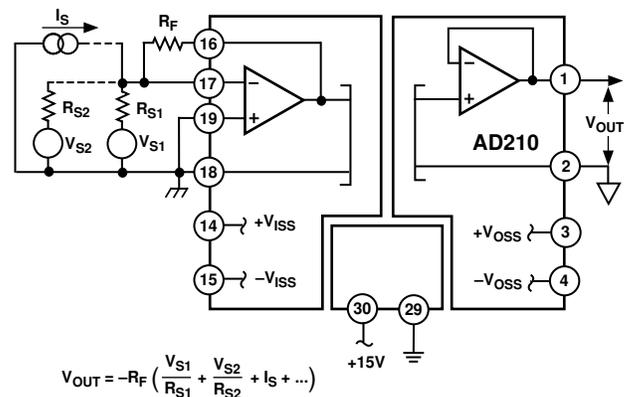
Figure 4. Summing or Current Input Configuration

Adjustments

When gain and offset adjustments are required, the actual circuit adjustment components will depend on the choice of input configuration and whether the adjustments are to be made at the isolator's input or output. Adjustments on the output side might be used when potentiometers on the input side would represent a hazard due to the presence of high common-mode voltage during adjustment. Offset adjustments are best done at the input side, as it is better to null the offset ahead of the gain.

Figure 5 shows the input adjustment circuit for use when the input amplifier is configured in the noninverting mode. This offset adjustment circuit injects a small voltage in series with the
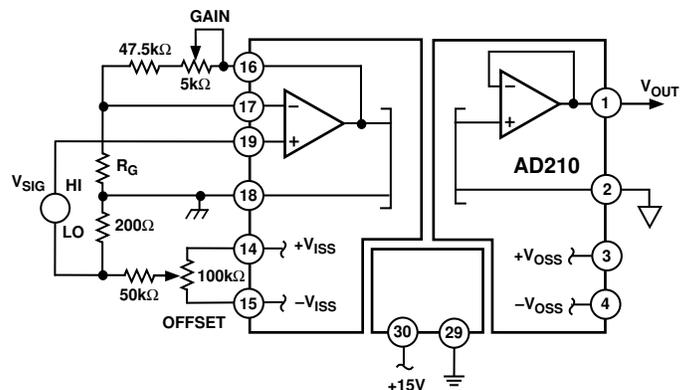
Figure 5. Adjustments for Noninverting Input

AD210

low side of the signal source. This will not work if the source has another current path to input common or if current flows in the signal source LO lead. To minimize CMR degradation, keep the resistor in series with the input LO below a few hundred ohms.

Figure 5 also shows the preferred gain adjustment circuit. The circuit shows R_F of 50 kΩ, and will work for gains of ten or greater. The adjustment becomes less effective at lower gains (its effect is halved at G = 2) so that the pot will have to be a larger fraction of the total R_F at low gain. At G = 1 (follower) the gain cannot be adjusted downward without compromising input impedance; it is better to adjust gain at the signal source or after the output.

Figure 6 shows the input adjustment circuit for use when the input amplifier is configured in the inverting mode. The offset adjustment nulls the voltage at the summing node. This is preferable to current injection because it is less affected by subsequent gain adjustment. Gain adjustment is made in the feedback and will work for gains from 1 V/V to 100 V/V.
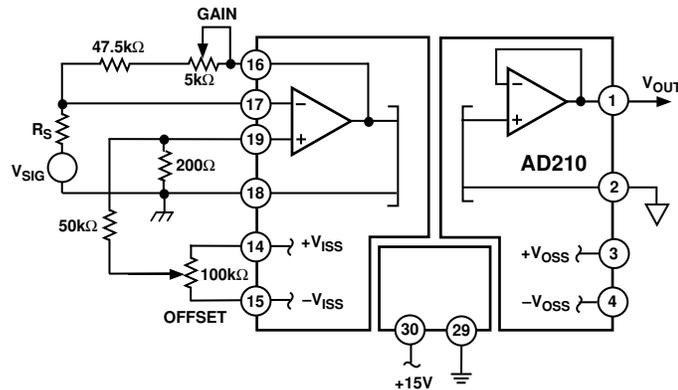

Figure 6. Adjustments for Inverting Input

Figure 7 shows how offset adjustments can be made at the output, by offsetting the floating output port. In this circuit, ±15 V would be supplied by a separate source. The AD210's output amplifier is fixed at unity, therefore, output gain must be made in a subsequent stage.
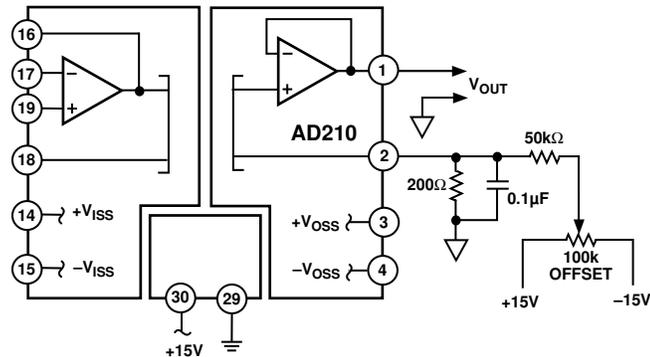

Figure 7. Output-Side Offset Adjustment

PCB Layout for Multichannel Applications: The unique pinout positioning minimizes board space constraints for multichannel applications. Figure 8 shows the recommended printed circuit board layout for a noninverting input configuration with gain.
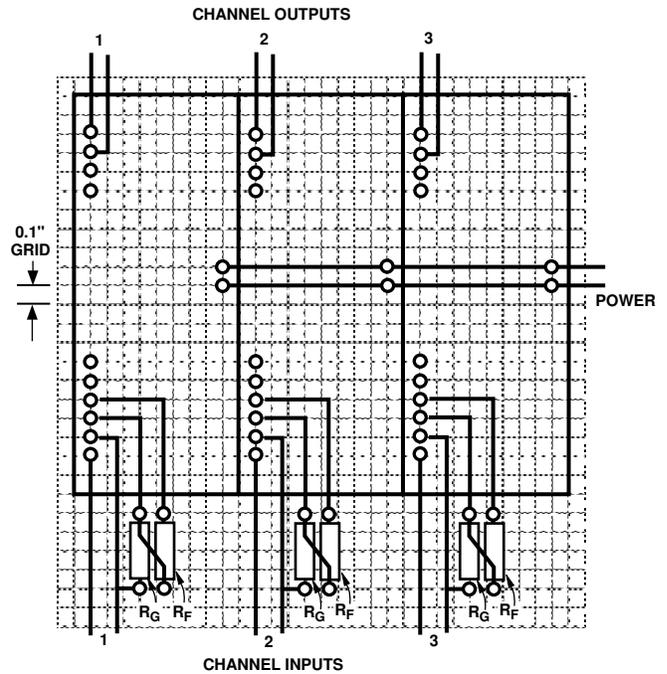
Figure 8. PCB Layout for Multichannel Applications with Gain

Synchronization: The AD210 is insensitive to the clock of an adjacent unit, eliminating the need to synchronize the clocks. However, in rare instances channel to channel pick-up may occur if input signal wires are bundled together. If this happens, shielded input cables are recommended.

PERFORMANCE CHARACTERISTICS
Common-Mode Rejection: Figure 9 shows the common-mode rejection of the AD210 versus frequency, gain and input source resistance. For maximum common-mode rejection of unwanted signals, keep the input source resistance low and carefully lay out the input, avoiding excessive stray capacitance at the input terminals.
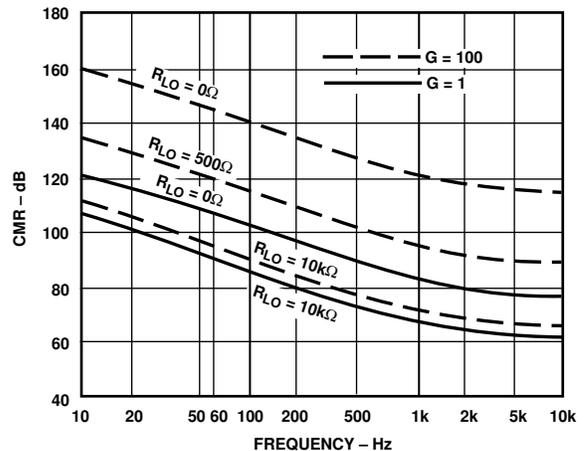
Figure 9. Common-Mode Rejection vs. Frequency

Phase Shift: Figure 10 illustrates the AD210's low phase shift and gain versus frequency. The AD210's phase shift and wide bandwidth performance make it well suited for applications like power monitors and controls systems.
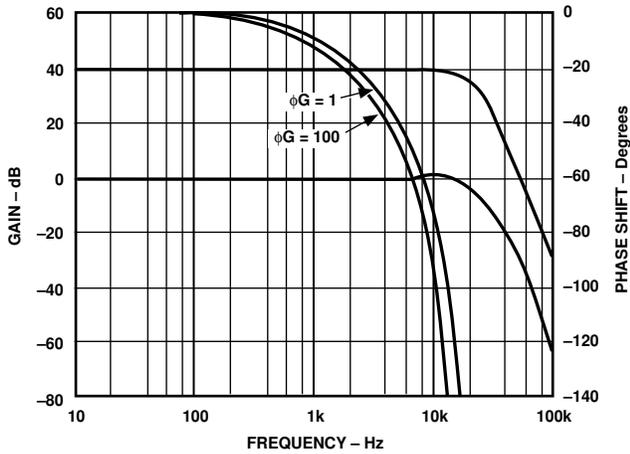
Figure 10. Phase Shift and Gain vs. Frequency

Input Noise vs. Frequency: Voltage noise referred to the input is dependent on gain and signal bandwidth. Figure 11 illustrates the typical input noise in nV/√Hz of the AD210 for a frequency range from 10 to 10 kHz.
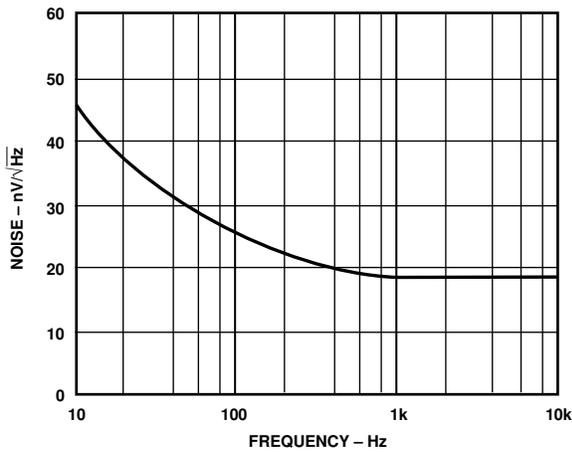
Figure 11. Input Noise vs. Frequency

Gain Nonlinearity vs. Output: Gain nonlinearity is defined as the deviation of the output voltage from the best straight line, and is specified as % peak-to-peak of output span. The AD210B provides guaranteed maximum nonlinearity of ±0.012% with an output span of ±10 V. The AD210's nonlinearity performance is shown in Figure 12.

Gain Nonlinearity vs. Output Swing: The gain nonlinearity of the AD210 varies as a function of total signal swing. When the output swing is less than 20 volts, the gain nonlinearity as a fraction of signal swing improves. The shape of the nonlinearity remains constant. Figure 13 shows the gain nonlinearity of the AD210 as a function of total signal swing.
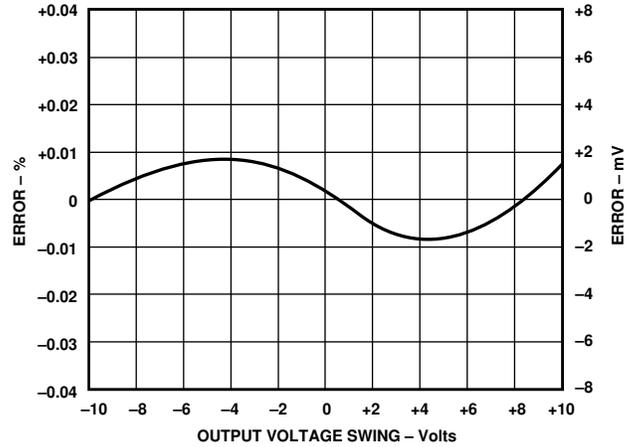
Figure 12. Gain Nonlinearity Error vs. Output
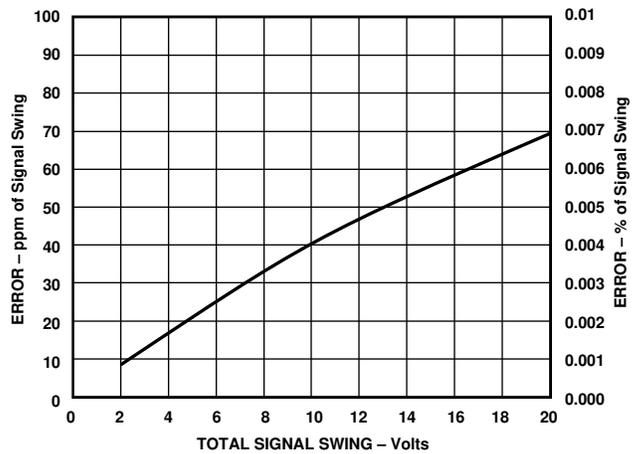
Figure 13. Gain Nonlinearity vs. Output Swing

Gain vs. Temperature: Figure 14 illustrates the AD210's gain vs. temperature performance. The gain versus temperature performance illustrated is for an AD210 configured as a unity gain amplifier.
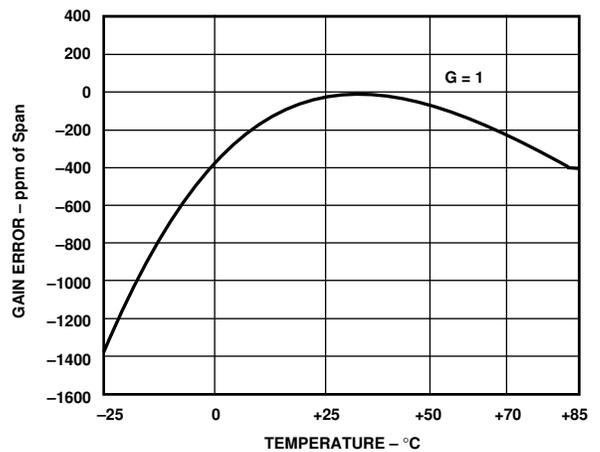
Figure 14. Gain vs. Temperature

AD210

Isolated Power: The AD210 provides isolated power at the input and output ports. This power is useful for various signal conditioning tasks. Both ports are rated at a nominal ±15 V at 5 mA.

The load characteristics of the isolated power supplies are shown in Figure 15. For example, when measuring the load rejection of the input isolated supplies V_{ISS}, the load is placed between $+V_{ISS}$ and $-V_{ISS}$. The curves labeled V_{ISS} and V_{OSS} are the individual load rejection characteristics of the input and the output supplies, respectively.

There is also some effect on either isolated supply when loading the other supply. The curve labeled CROSSLOAD indicates the sensitivity of either the input or output supplies as a function of the load on the opposite supply.
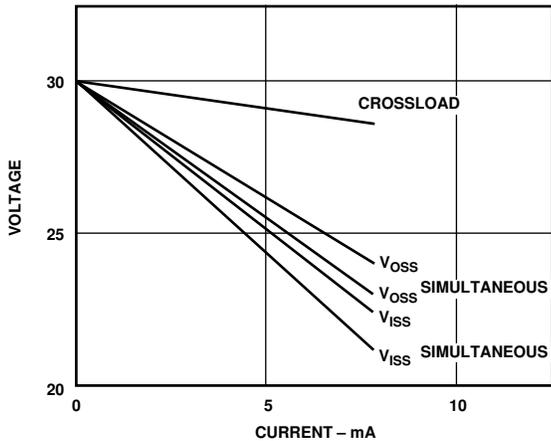

Figure 15. Isolated Power Supplies vs. Load

Lastly, the curves labeled V_{OSS} simultaneous and V_{ISS} simultaneous indicate the load characteristics of the isolated power supplies when an equal load is placed on both supplies.

The AD210 provides short circuit protection for its isolated power supplies. When either the input supplies or the output supplies are shorted to input common or output common, respectively, no damage will be incurred, even under continuous application of the short. However, the AD210 may be damaged if the input and output supplies are shorted simultaneously.
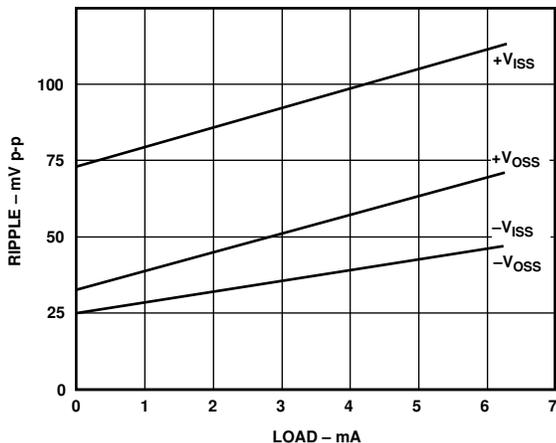

Figure 16a. Isolated Supply Ripple vs. Load (External 4.7 μF Bypass)

Under any circumstances, care should be taken to ensure that the power supplies do not accidentally become shorted.

The isolated power supplies exhibit some ripple which varies as a function of load. Figure 16a shows this relationship. The AD210 has internal bypass capacitance to reduce the ripple to a point where performance is not affected, even under full load. Since the internal circuitry is more sensitive to noise on the negative supplies, these supplies have been filtered more heavily. Should a specific application require more bypassing on the isolated power supplies, there is no problem with adding external capacitors. Figure 16b depicts supply ripple as a function of external bypass capacitance under full load.
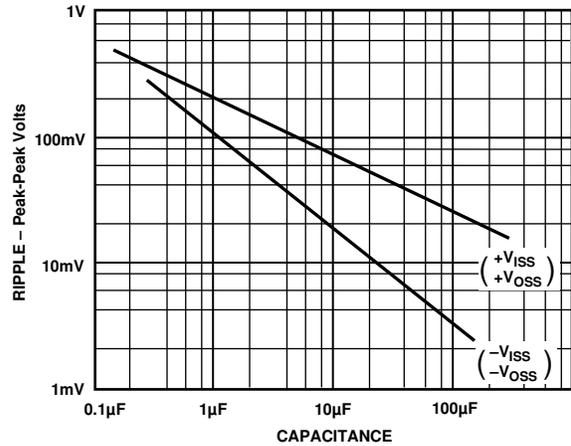
Figure 16b. Isolated Power Supply Ripple vs. Bypass Capacitance (Volts p-p, 1 MHz Bandwidth, 5 mA Load)

APPLICATIONS EXAMPLES

Noise Reduction in Data Acquisition Systems: Transformer coupled isolation amplifiers must have a carrier to pass both ac and dc signals through their signal transformers. Therefore, some carrier ripple is inevitably passed through to the isolator output. As the bandwidth of the isolator is increased more of the carrier signal will be present at the output. In most cases, the ripple at the AD210's output will be insignificant when compared to the measured signal. However, in some applications, particularly when a fast analog-to-digital converter is used following the isolator, it may be desirable to add filtering; otherwise ripple may cause inaccurate measurements. Figure 17 shows a circuit that will limit the isolator's bandwidth, thereby reducing the carrier ripple.
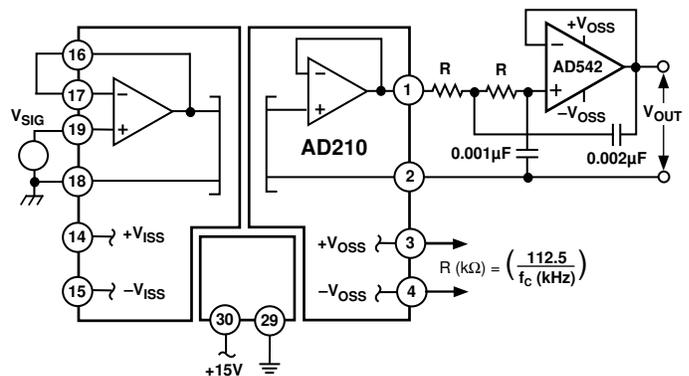
Figure 17. 2-Pole, Output Filter

Self-Powered Current Source

The output circuit shown in Figure 18 can be used to create a self-powered output current source using the AD210. The 2 kΩ resistor converts the voltage output of the AD210 to an equiva-

lent current $V_{OUT}/2$ kΩ. This resistor directly affects the output gain temperature coefficient, and must be of suitable stability for the application. The external low power op amp, powered by $+V_{OSS}$ and $-V_{OSS}$, maintains its summing junction at output common. All the current flowing through the 2 kΩ resistor flows through the output Darlington pass devices. A Darlington configuration is used to minimize loss of output current to the base.
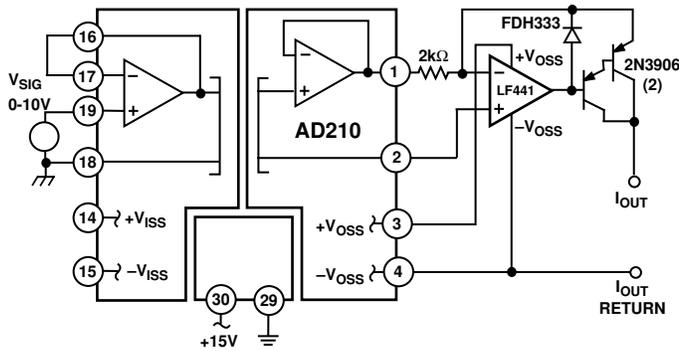

Figure 18. Self-Powered Isolated Current Source

The low leakage diode is used to protect the base-emitter junction against reverse bias voltages. Using $-V_{OSS}$ as a current return allows more than 10 V of compliance. Offset and gain control may be done at the input of the AD210 or by varying the 2 kΩ resistor and summing a small correction current directly into the summing node. A nominal range of 1 mA–5 mA is recommended since the current output cannot reach zero due to reverse bias and leakage currents. If the AD210 is powered from the input potential, this circuit provides a fully isolated, wide bandwidth current output. This configuration is limited to 5 mA output current.

Isolated V-to-I Converter
Illustrated in Figure 19, the AD210 is used to convert a 0 V to +10 V input signal to an isolated 4–20 mA output current. The AD210 isolates the 0 V to +10 V input signal and provides a proportional voltage at the isolator's output. The output circuit converts the input voltage to a 4–20 mA output current, which in turn is applied to the loop load R_{LOAD}.
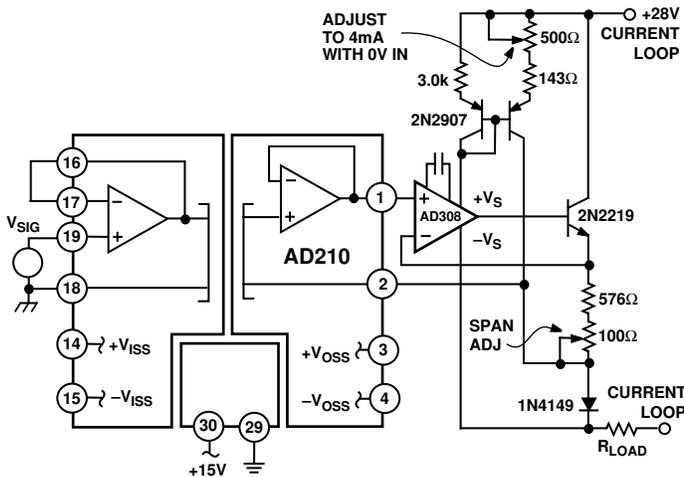

Figure 19. Isolated Voltage-to-Current Loop Converter

Isolated Thermocouple Amplifier
The AD210 application shown in Figure 20 provides amplification, isolation and cold-junction compensation for a standard J type thermocouple. The AD590 temperature sensor accurately

monitors the input terminal (cold-junction). Ambient temperature changes from 0°C to +40°C sensed by the AD590, are cancelled out at the cold junction. Total circuit gain equals 183; 100 and 1.83, from A1 and the AD210 respectively. Calibration is performed by replacing the thermocouple junction with plain thermocouple wire and a millivolt source set at 0.0000 V (0°C) and adjusting R_O for E_{OUT} equal to 0.000 V. Set the millivolt source to +0.02185 V (400°C) and adjust R_G for V_{OUT} equal to +4.000 V. This application circuit will produce a nonlinearized output of about +10 mV/°C for a 0°C to +400°C range.
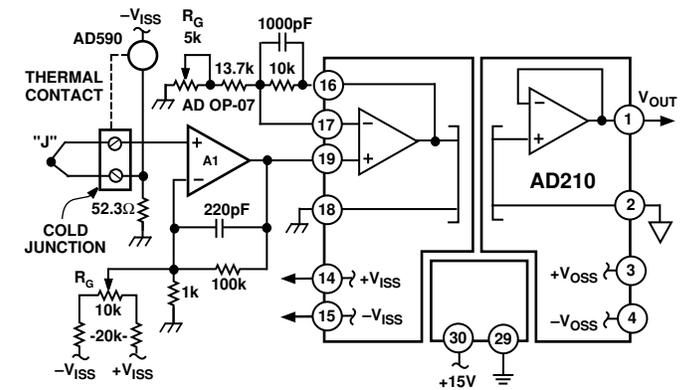
Figure 20. Isolated Thermocouple Amplifier

Precision Floating Programmable Reference
The AD210, when combined with a digital-to-analog converter, can be used to create a fully floating voltage output. Figure 21 shows one possible implementation.

The digital inputs of the AD7541 are TTL or CMOS compatible. Both the AD7541 and AD581 voltage reference are powered by the isolated power supply + V_{ISS}. I_{COM} should be tied to input digital common to provide a digital ground reference for the inputs.

The AD7541 is a current output DAC and, as such, requires an external output amplifier. The uncommitted input amplifier internal to the AD210 may be used for this purpose. For best results, its input offset voltage must be trimmed as shown.

The output voltage of the AD210 will go from 0 V to –10 V for digital inputs of 0 and full scale, respectively. However, since the output port is truly isolated, V_{OUT} and O_{COM} may be freely interchanged to get 0 V to +10 V.

This circuit provides a precision 0 V–10 V programmable reference with a ±3500 V common-mode range.
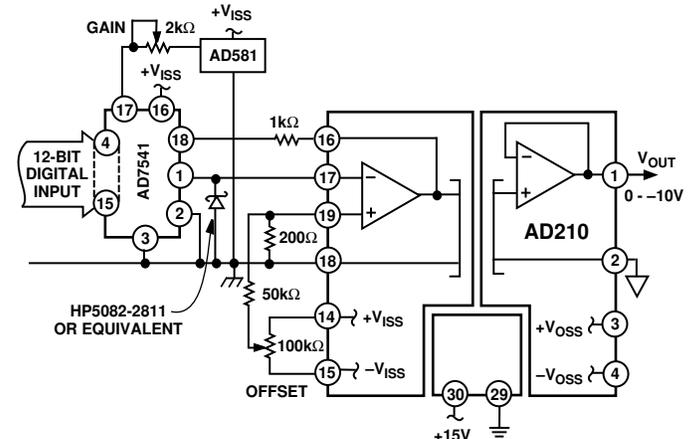
Figure 21. Precision Floating Programmable Reference

AD210
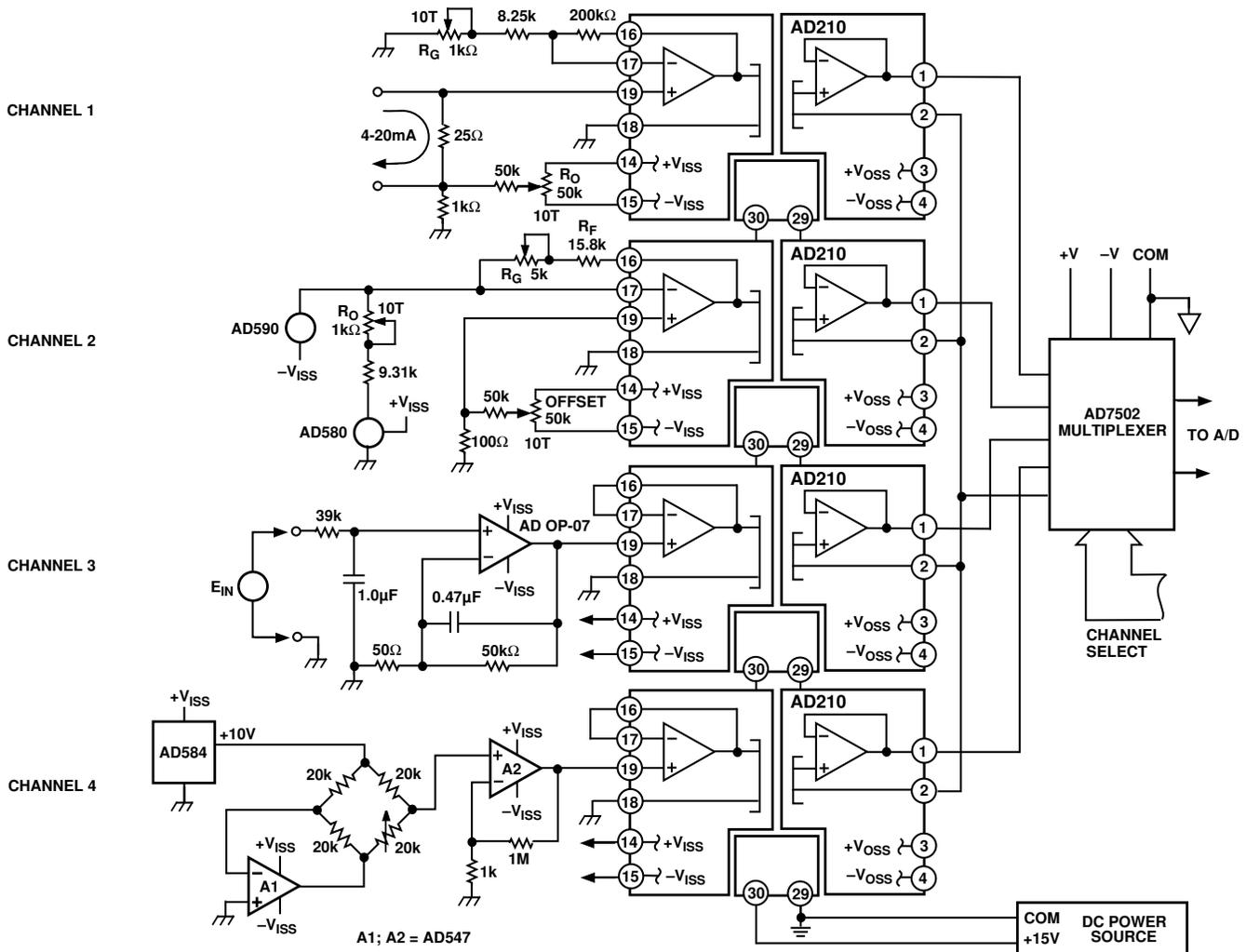
Figure 22. Multichannel Data Acquisition Front-End

MULTICHANNEL DATA ACQUISITION FRONT-END

Illustrated in Figure 22 is a four-channel data acquisition front-end used to condition and isolate several common input signals found in various process applications. In this application, each AD210 will provide complete isolation from input to output as well as channel to channel. By using an isolator per channel, maximum protection and rejection of unwanted signals is obtained. The three-port design allows the AD210 to be configured as an input or output isolator. In this application the isolators are configured as input devices with the power port providing additional protection from possible power source faults.

Channel 1: The AD210 is used to convert a 4–20 mA current loop input signal into a 0 V–10 V input. The 25 Ω shunt resistor converts the 4-20 mA current into a +100 mV to +500 mV signal. The signal is offset by –100 mV via R_O to produce a 0 mV to +400 mV input. This signal is amplified by a gain of 25 to produce the desired 0 V to +10 V output. With an open circuit, the AD210 will show –2.5 V at the output.

Channel 2: In this channel, the AD210 is used to condition and isolate a current output temperature transducer, Model AD590. At +25°C, the AD590 produces a nominal current of 298.2 μA. This level of current will change at a rate of 1 μA/°C. At –17.8°C (0°F), the AD590 current will be reduced by 42.8 μA to +255.4 μA. The

AD580 reference circuit provides an equal but opposite current, resulting in a zero net current flow, producing a 0 V output from the AD210. At +100°C (+212°F), the AD590 current output will be 373.2 μA minus the 255.4 μA offsetting current from the AD580 circuit to yield a +117.8 μA input current. This current is converted to a voltage via R_F and R_G to produce an output of +2.12 V. Channel 2 will produce an output of +10 mV/°F over a 0°F to +212°F span.

Channel 3: Channel 3 is a low level input channel configured with a high gain amplifier used to condition millivolt signals. With the AD210's input set to unity and the input amplifier set for a gain of 1000, a ±10 mV input will produce a ±10 V at the AD210's output.

Channel 4: Channel 4 illustrates one possible configuration for conditioning a bridge circuit. The AD584 produces a +10 V excitation voltage, while A1 inverts the voltage, producing negative excitation. A2 provides a gain of 1000 V/V to amplify the low level bridge signal. Additional gain can be obtained by reconfiguration of the AD210's input amplifier. ±V_{ISS} provides the complete power for this circuit, eliminating the need for a separate isolated excitation source.

Each channel is individually addressed by the multiplexer's channel select. Additional filtering or signal conditioning should follow the multiplexer, prior to an analog-to-digital conversion stage.

Appendix B:
Tables, Drawings, and Schematics

Isolation Amplifier Wiring Tables

Isolated Input/Output					
Signal	*Pin*	*Color (2464)*	*Color (pre modified)*	*Iso Amp*	*Rear Panel*
CMD 1	A	Orange w/Red	Violet	U5 / 19	Remote 1 pin C & CMD 1 BNC pin 1
CMD 1 GND	B	Green w/Black		U5 / 18	Switch center 1
CMD 2	C	Orange w/Green	Red	U4 / 19	Remote 2 pin C & CMD 2 BNC pin 1
CMD 2 GND	D	Green w/White		U4 / 18	Switch center 2
CMD 3	E	Orange	Orange	U3 / 19	Remote 3 pin C & CMD 3 BNC pin 1
CMD 3 GND	F	Green		U3 / 18	Switch center 3
CURR 1	G	White	Yellow	U2 / 1	CURR 1 BNC pin 1
CURR 1 GND	H	Black		U2 / 2	CURR 1 BNC pin 2
CURR 2	J	White w/Black	Green	U1 / 1	CURR 2 BNC pin 1
CURR 2 GND	K	Black w/White		U1 / 2	CURR 2 BNC pin 2
CURR 3	L	White w/Red	Blue	U9 / 1	CURR 3 BNC pin 1
CURR 3 GND	M	Black w/Red		U9 / 2	CURR 3 BNC pin 2
TACH 1	N	Blue	Brown	U8 / 1	TACH 1 BNC pin 1
TACH 1 GND	P	Red		U8 / 2	TACH 1 BNC pin 2
TACH 2	R	Blue w/Red	Grey	U7 / 1	TACH 2 BNC pin 1
TACH 2 GND	S	Red w/Black		U7 / 2	TACH 2 BNC pin 2
TACH 3	T	Blue w/White	White	U6 / 1	TACH 3 BNC pin 1
TACH 3 GND	U	Red w/Green		U6 / 2	TACH 3 BNC pin 2
SHIELD	V	Brown (in iso amp)	Silver		Remote 3 Screw

Unisolated Input/Output					
Signal	*Pin*	*Color (9540)*	*Iso Amp*	*Rear Panel*	*Motor Controller*
Sig Common	A	Green	U1, U2, U6 – U9 pin 18 & U3 – U5 pin 2	Remote 1–3 pin H, BNC 10–12 pin 2, Tach 1&3 pin C&D, Tach 2 pin A&C, Switch Top side	Pin E / 7 and F / 9
Sig Common	B	Violet			
Enable #1	C	Blue		Remote #1 pin G & Enable #1 BNC pin 1	Pin C / 4
Enable #2	D	Orange		Remote #2 pin G & Enable #2 BNC pin 1	Pin G / 10
Enable #3	E	Yellow		Remote #3 pin G & Enable #3 BNC pin 1	Pin K / 16
-12 VDC	F	Black		Remote 1-3 pin F	Pin D / 5
+12 VDC	G	Red		Remote 1-3 pin E	Pin H / 11
Tach #1	H	Brown	U8 pin 19	Motor Tach #1 pin A	Pin L / 21
Tach #2	J	Grey	U7 pin 19	Motor Tach #2 pin D	Pin P / 27
Tach #3	K	White	U6 pin 19	Motor Tach #3 pin A	Pin T / 33
Shield		Silver		Remote 3 screw	

Isolation Amplifier Wiring Tables (Continued)

Motor Controller				
Signal	*Pins*	*Color*	*Iso Amp*	*Unisolated Input*
Motor 1 Shutdown	C / 4	Blue w/ Black		Pin C
-12Vdc (External)	D / 5	Black		Pin F
Signal Common	E / 7	Green	U1, U2, U6 - U9 pin 18	Pins A & B
Signal Common	F / 9	Red w/ Black & White	& U3 – U5 pin 2	
Motor 2 Shutdown	G / 10	Black w/ Red & White		Pin D
+12Vdc (External)	H / 11	Red		Pin G
Motor 3 Shutdown	K / 16	Orange w/ Green		Pin E
Motor 1 TACH	L / 21	Black w/ White	U8 pin 19	Pin H
Motor 1 CMD	M / 22	Blue w/ Red	U5 pin 1	
Motor 1 CURR	N / 23	Orange w/ Red	U2 pin 19	
Motor 2 TACH	P / 27	Black w/ Red	U7 pin 19	Pin J
Motor 2 CMD	R / 28	Red w/ White	U4 pin 1	
Motor 2 CURR	S / 29	Green w/ Black	U1 pin 19	
Motor 3 TACH	T / 33	White w/ Black & Red	U6 Pin 19	Pin K
Motor 3 CMD	U / 34	Orange	U3 pin 1	
Motor 3 CURR	V / 35	Blue	U9 pin 19	

Power Input (3 pin Amphenol)				
Signal	*Pin*	*Color*	*Connector J2*	*Power Supply*
115 VAC Line	A	Black	AC HI (Fuse)	Pins 1 & 2
115 VAC Neutral	B	White	AC LOW	Pins 3 & 4
Earth Ground	C	Green	Earth Ground	

From power supply to circuit				
Signal	*Pin*	*Color (pre modification)*	*Color (post modification)*	*Iso Amp*
15 Vdc	S+ & V+	Red & White	2 Red twisted	U1-U9 pin 30
DC Common	S- & V-	Black & Green	2 Black Twisted	U1–U9 pin 29
Shield		Silver	silver	

| Switch (triple pole double throw)			
Position	*1*	*2*	*3*
Top	Un-isolated Sig Common	Un-isolated Sig Common	Un-isolated Sig Common
Center	Isolated CMD #1 GND	Isolated CMD #2 GND	Isolated CMD #3 GND
Bottom	CMD #1 BNC pin 2	CMD #2 BNC pin 2	CMD #3 BNC pin 3

AD210 layout, pin designation, and block diagram

Bottom View

4112-4 Minng Side
Vector Electronics & Technology, Inc.

Top View

4112-4 Components Side
Vector Electronics & Technology, Inc.

AD210 PIN DESIGNATIONS

| Pin	Designation	Function
1	V_O	Output
2	O_{COM}	Output Common
3	$+V_{OSS}$	+Isolated Power @ Output
4	$-V_{OSS}$	–Isolated Power @ Output
14	$+V_{ISS}$	+Isolated Power @ Input
15	$-V_{ISS}$	–Isolated Power @ Input
16	FB	Input Feedback
17	–IN	–Input
18	I_{COM}	Input Common
19	+IN	+Input
29	Pwr Com	Power Common
30	Pwr	Power Input

FUNCTIONAL BLOCK DIAGRAM

Calibration Tables

The values in these tables are dependant on the gain control of the motor controllers at the time of testing and are only to be used as guidelines to find the right settings.

	Modified Controller								
	Velocity CMD (V)								
RPM	*Controller 1 - Velocity Controller 3 - Current*			*Controller 2 - Velocity Controller 3 - Current*			*Controller 3 - Velocity Controller 1 - Current*		
	Command	*Remote*	*Tach*	*Command*	*Remote*	*Tach*	*Command*	*Remote*	*Tach*
300	-0.949	4.62	0.95	0.440	5.20	-0.95	-0.285	4.89	0.96
1200	-3.820	3.41	3.76	1.710	5.73	-3.78	-1.127	4.53	3.80
1500	-4.790	3.01	4.64	2.140	5.91	-4.80	-1.390	4.42	4.77
-300	0.970	5.41	-0.93	-0.410	4.83	0.96	0.280	5.12	-0.96
-1200	3.840	6.62	-3.78	-1.695	4.30	3.84	1.135	5.48	-3.88
-1500	4.820	7.02	-4.69	-2.130	4.11	4.83	1.400	5.60	-4.86

	Un-modified Controller without Isolation		
	Velocity CMD (V)		
RPM	*Controller 1 - Velocity Controller 3 - Current*	*Controller 2 - Velocity Controller 3 - Current*	*Controller 3 - Velocity Controller 1 - Current*
300	-0.73	0.76	-0.745
1200	-2.97	3.08	-3.080
1500	-3.73	3.86	-3.790
-300	0.77	-0.79	0.786
-1200	3.04	-3.13	3.070
-1500	3.80	-3.91	3.830

	Un-modified Controller with Isolation		
	Velocity CMD (V)		
RPM	*Controller 1 - Velocity Controller 3 - Current*	*Controller 2 - Velocity Controller 3 - Current*	*Controller 3 - Velocity Controller 1 - Current*
300	-0.73	0.764	-0.730
1200	-2.97	3.080	-2.990
1500	-3.73	3.860	-3.740
-300	0.77	-0.790	0.790
-1200	3.04	-3.150	3.075
-1500	3.80	-3.916	3.830

Block Diagram of Motor Controller Testing Setup

UPS Transformer (Power)

DC Power Supply

Velocity Current

115 Wall 70

Sig Con.
Power

Enable

70 115

Sig Con.

Motor Controller

DMMs

Tach Current

Note: Current
Driven, therefore NO
TACH.

Driving
Motor

Load
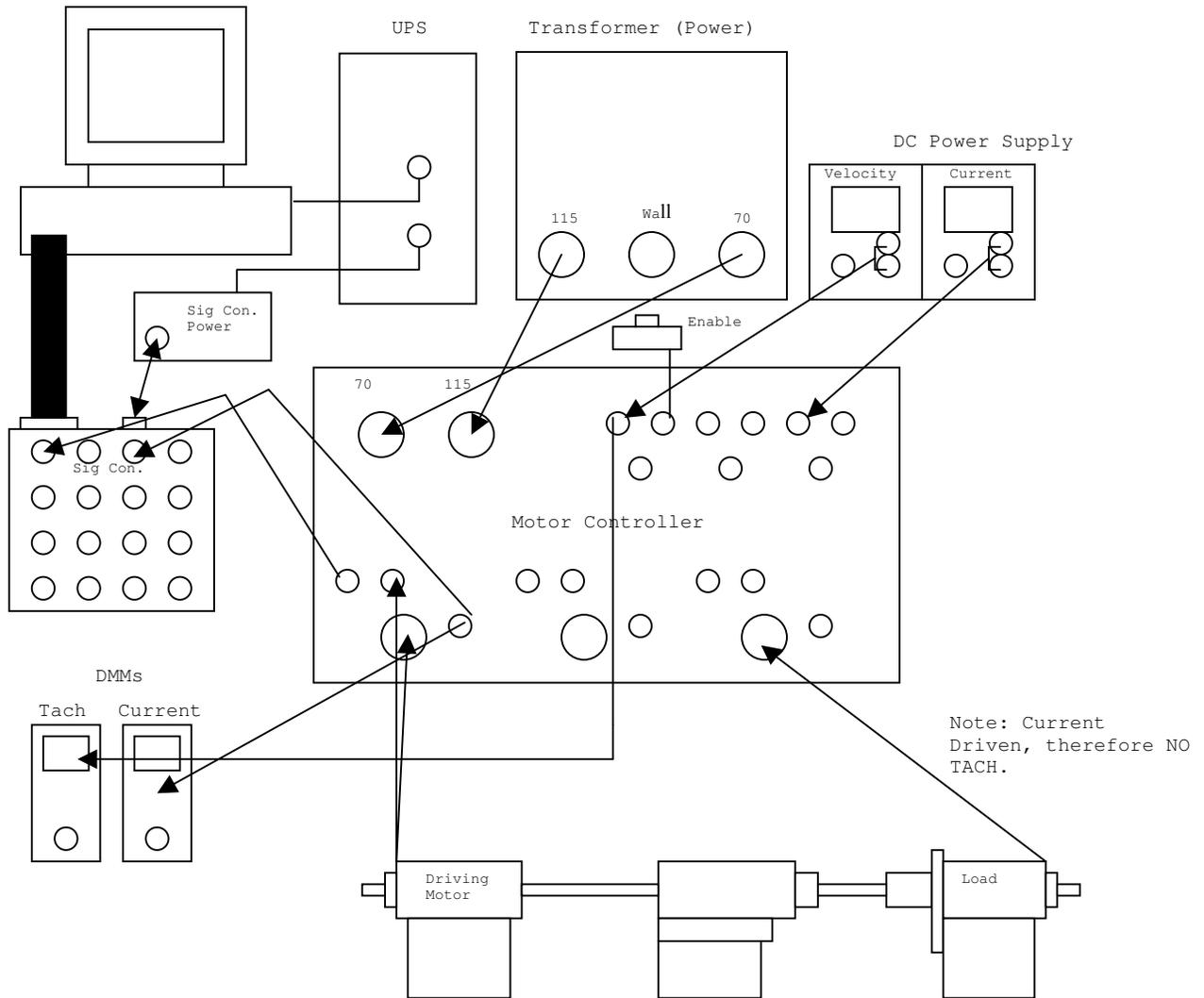
RF Filter Diagram

10 pin female
flange connector

10 pin male
cable connector

H   +OUT (White)   K

15.8 KΩ Resistor

H

0.01 uF Capacitor

G   -OUT (Green)   G

J   Shield (Silver)   J

D   EXC COM (Black)   D

E   EXC (Red)   E
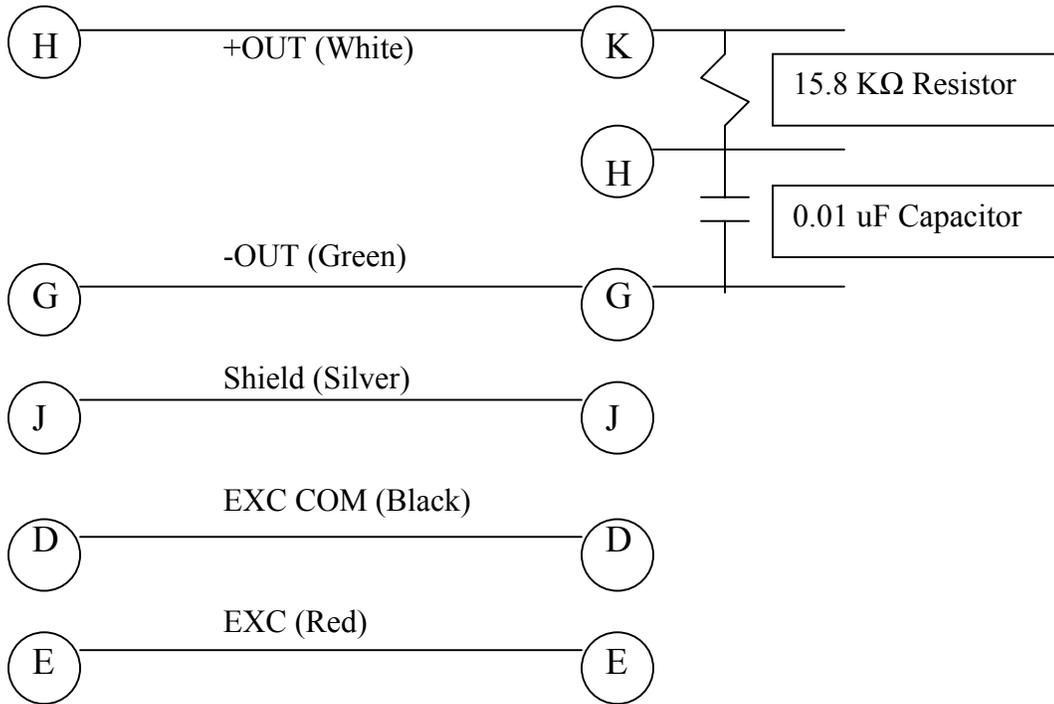
Appendix C:
Photos

**Picture 1: Testing Setup In the Preparation Shop**
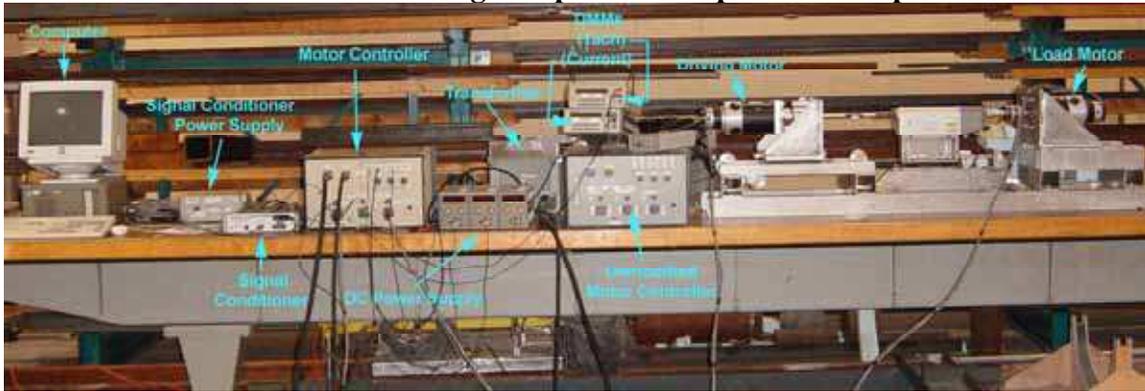
Picture 2: Testing Setup, Bench 1
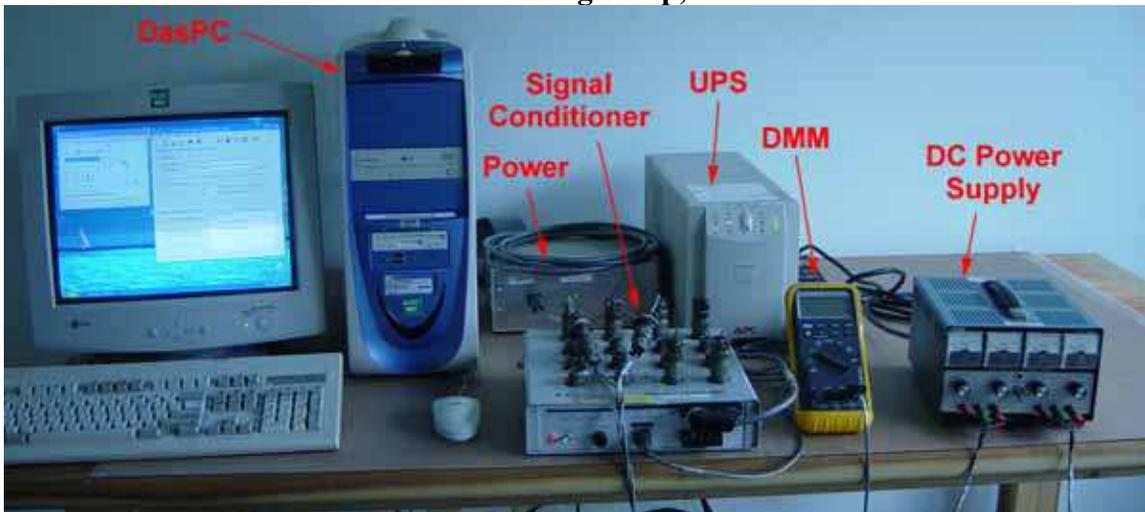
Picture 3: Testing Setup, Bench 2
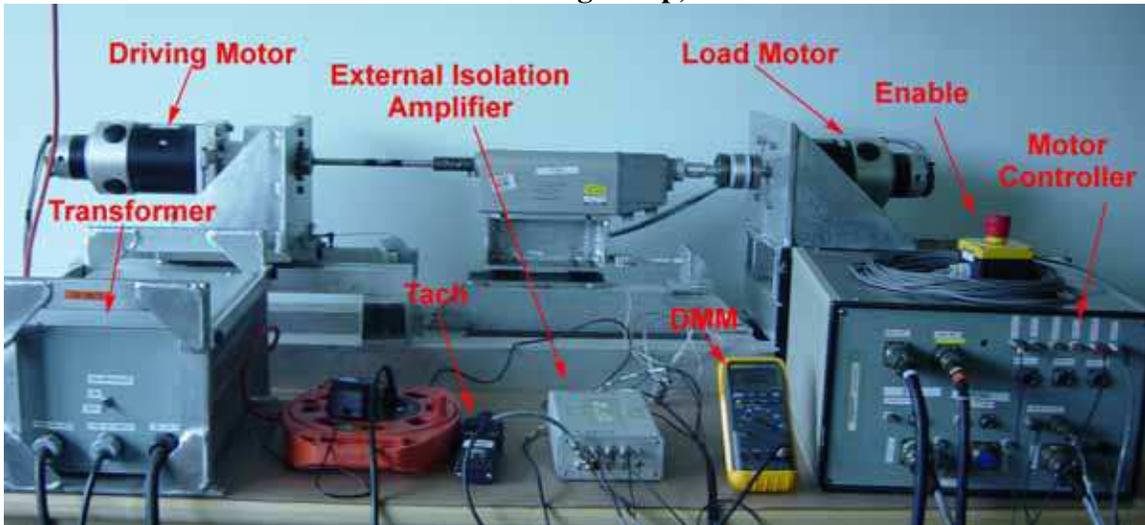
**Picture 4: Data collection with DaqView**
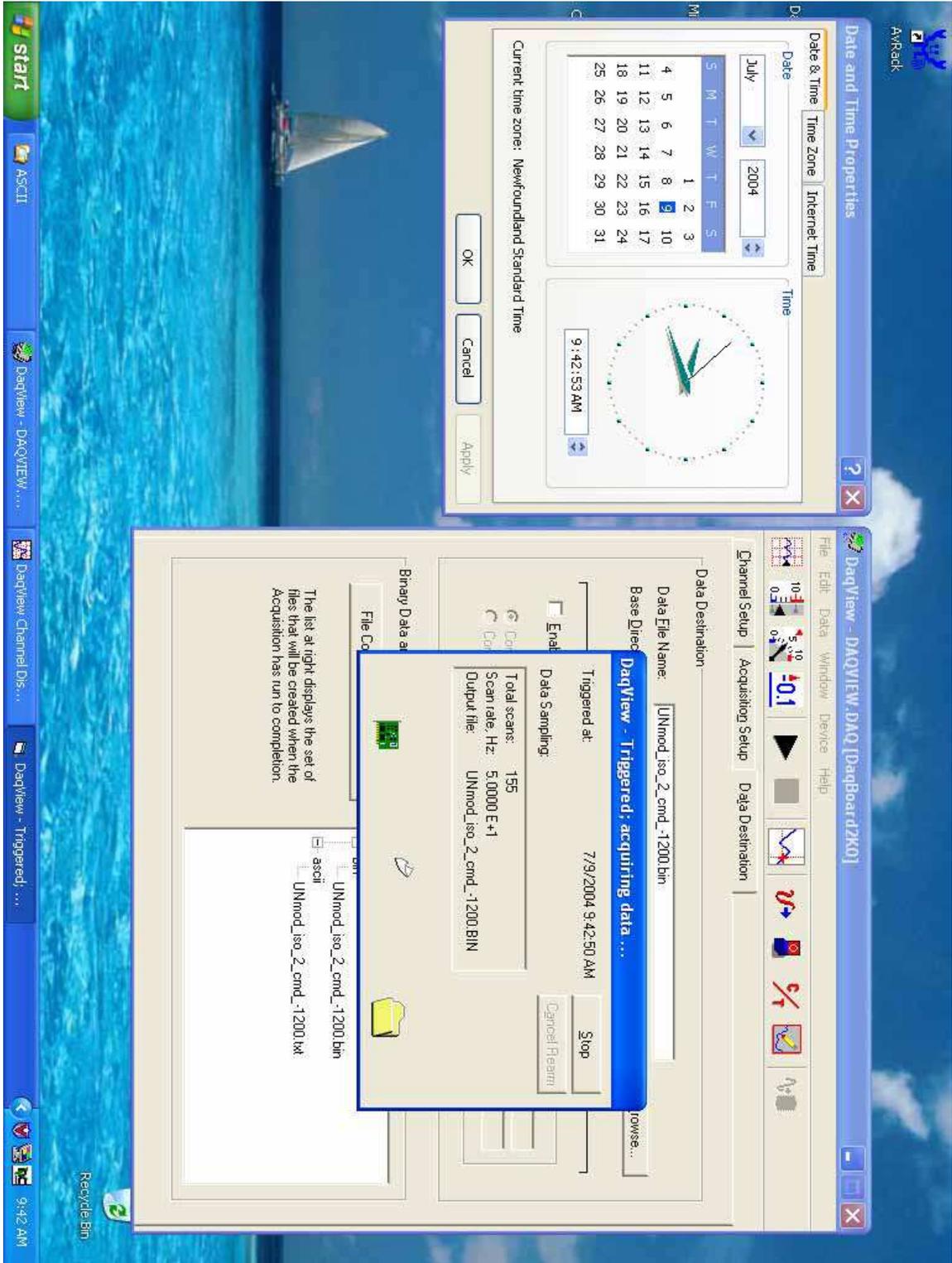
Modified Motor Controller Package

Unmodified Rear Panel
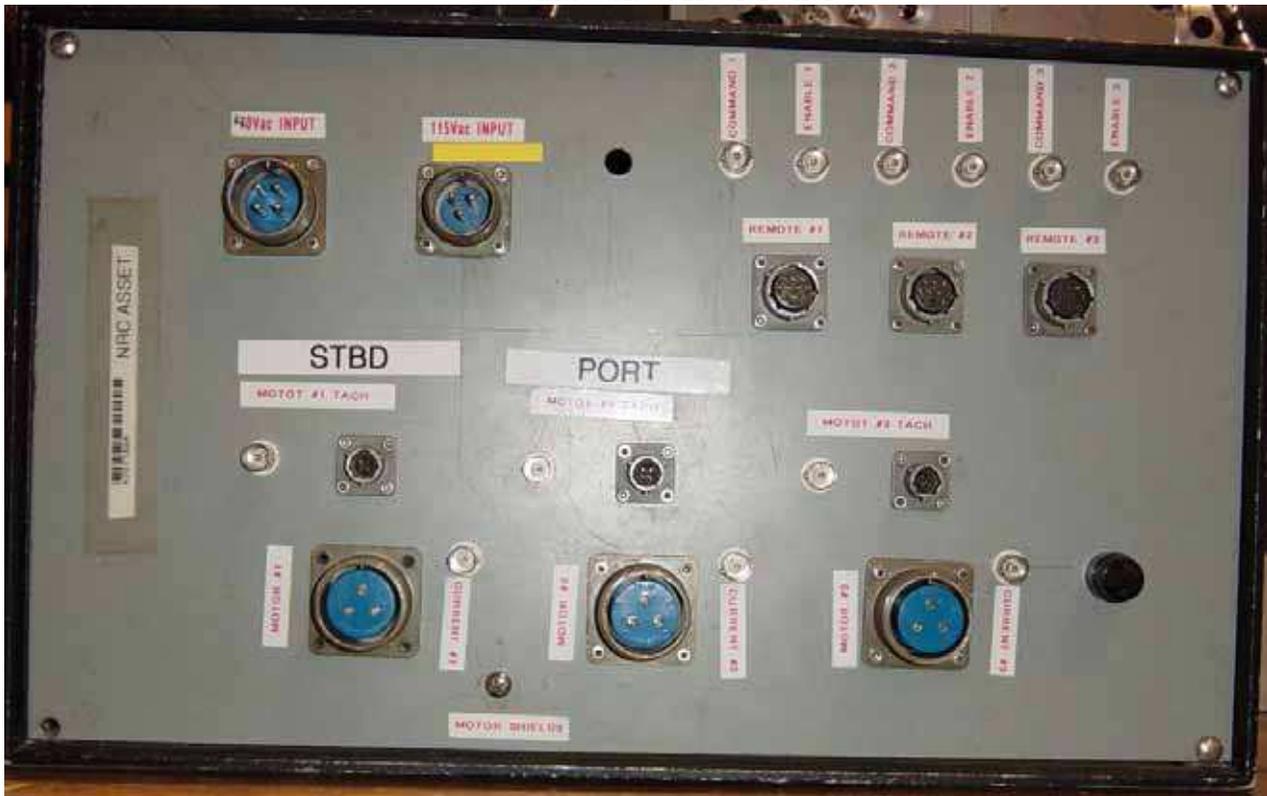
Modified Rear Panel

Isolation Amplifier
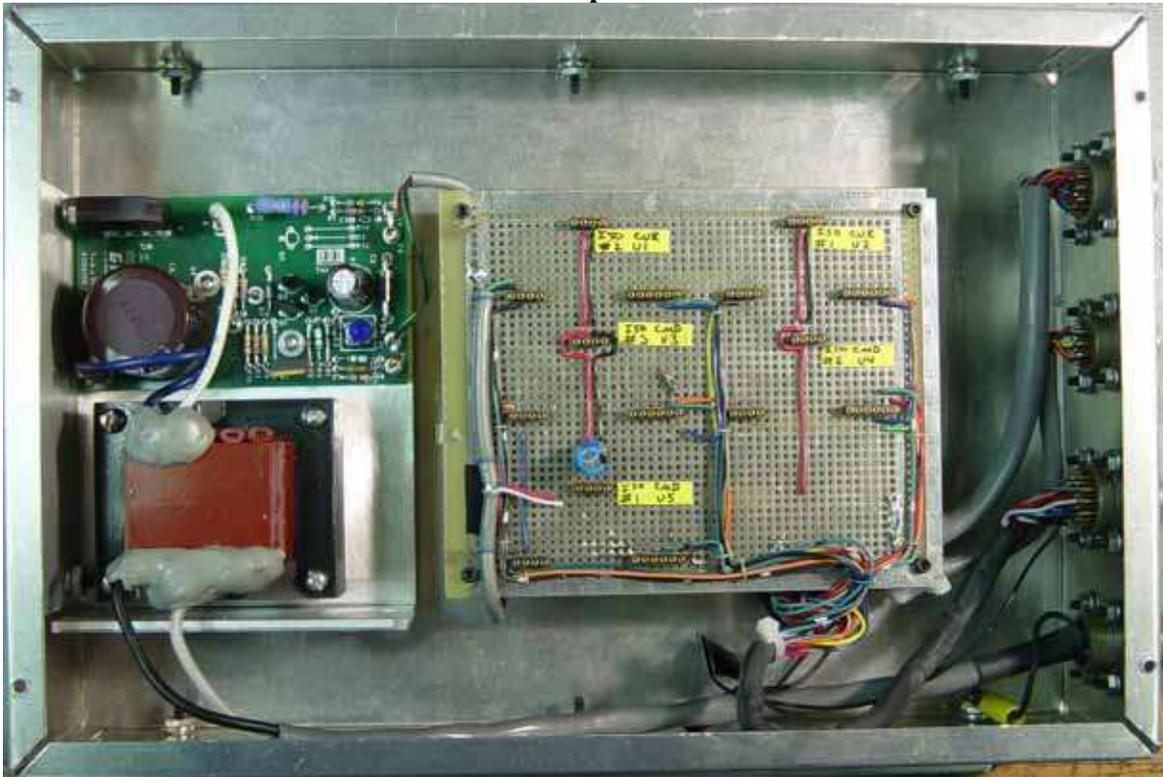
Isolation Amplifier with Chips

Power Transformer