12 October 2020

ARU-50/A ADI

SOLUTION

Version: V2.0 October 2020

History

04-2016 : New manual, based on the manuals “ADI Support” and “ADI Solution”. The latter two manuals are obsolete. Several corrections are contained in this manual, so do not use the old two manuals for any reference.

05-2016 : Update. Added text to prevent errors (such as wrong polarity, 115VAC 50/60Hz). Added which resistors are in series with the flag and glide slope indicator outputs, so that it is easy to identify which resistor may need another (lower) value.

06-2016 : Update. Correction of the wiring diagrams! ROLL and PITCH diagram connections were swapped. Added the jumper on X2 in all diagrams, clearly indicate which board is ROLL and which board is PITCH.

09-2020 : Update. During development of the HSI interface I discovered that the generated sine wave signal is far from a pure sine wave. Further, building an ADI interface I used a new approach. The two SDI boards and the ADI Support board are mounted on an experimenter (called “carrier”) board, and the connections of the 3 boards go only to the carrier board (as described in chapter 4). The ugly and cumbersome adjustment procedures using PuTTY are removed. Instead, the developed user-friendly Python application is used. Several no longer needed chapters are removed as well.

10-2020 : New version (V2) of the ADI Support board.

With the version v2 of the ADI Support board, the external amplifiers are no longer needed. They are included on the PCB, thus making the wiring easier. With the “carrier board” setup, you only have to do the interconnection wiring on that carrier board. All references to “external amplifiers” are removed. The parts list is updated according to the ADI-Sup-v2 board.

Contents

1. Introduction

All functions of the ARU-50/A Attitude Direction Indicator (ADI) as used in the F-16 can be controlled without opening and modifying the instrument. There is one exception, the little slip ball in the “bottom”. The ADI has 2 synchros (roll and pitch), 3 analog indicators, Glide Slope horizontal, Glide Slope vertical (Localizer), and Rate of Turn, and 3 flags (GS, LOC, and AUX on/off signals). The 4^{th} flag (OFF) is controlled by the presence of the required power supply voltages (115VAC 400 Hz and +28VDC). It is tested that +24VDC is OK instead of +28VDC.

The following parts are needed to control all functionality of the ADI.

- Two SDI (Synchro Drive Interface) boards
  The primary function of the SDI board is the generation of the signals for a synchro. However, the SDI board has extra outputs that can be used to control all other functionality of the ADI. All signals of the SDI board are not capable of driving any actuator directly. The synchro signal outputs are OpAmp outputs and require amplification before they can be used. The other outputs of the SDI board are capable of 20 mA (maximum) at 5V DC. Further, the SDI board has one analog output (PWM-based) that can have an output voltage swing of 0 ... –2V or –1V … +1V (jumper selectable).
- ROLL firmware and PITCH firmware for the two SDI boards (function-specific firmware).
- ADI Support board
  The ADI Support board changes the level of the signals from the SDI to the levels needed to drive the ADI. The PWM outputs of the SDI boards are converted to a DC voltage, have gain and offset adjustments and are buffered to increase the output swing to levels to drive the Glide Slope and Rate of Turn indicators. Further, the ADI Support board has DC/DC converters to generate several internal voltages required for proper operation of the hardware.
- 115VAC 400 Hz power supply

Summing all these functions shows that, besides the two SDI boards, several trim potentiometers to set the correct controlling levels are needed. Also, wiring is needed from each SDI board and ultimately of course a connection cable to the ADI is needed. To make a complete design (to control the ADI) relatively easy to build, the “ADI Support” board is developed.

The ADI Support board has the following features.

- Small PCB (3.1” x 3.9”), easy to build, no SMD components
- On-board activation control for roll and pitch of the ADI
- On-board activation control for the Glide Slope, Rate of Turn and flag indicators
- Amplitude adjustment for the roll and pitch synchro stator signals S1, S2, S3
- Glide Slope and Rate of Turn precise “zero” and full swing adjustment
- On-board power supplies, only 115VAC (for reference) and +24VDC needed

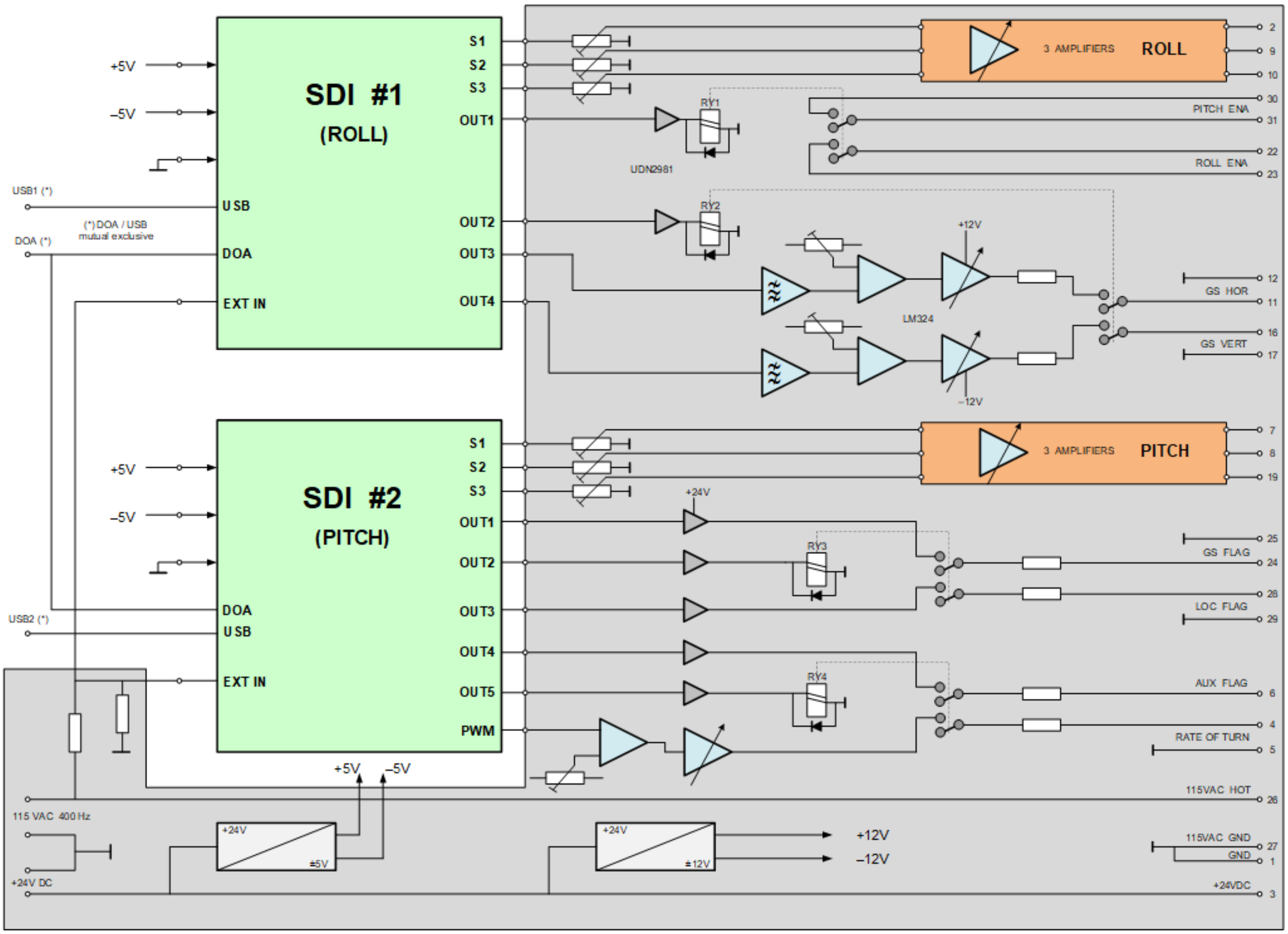
I spent quite some time developing and testing the hardware. Therefore, I put some “copy-right” on my work. You are allowed to build and use the ADI Support design for your own purpose, but you are not allowed to make commercial profit building and/or selling the work. This manual gives detailed descriptions, because I feel that this information is useful when another ADI is used. However, it is not the intention to enable easy copying of my work and try to make some money. The ADI Support board is developed for hobbyists who want to ‘bring to life’ a real instrument without modifications to the delicate mechanisms inside the instrument.

Disclaimer

All uses of the ADI Support board and all mentioned hardware are solely *your* responsibility. Any damage to the ADI Support board, other hardware or connected instrument(s) is ***not*** my responsibility. I have tried to remove any typo or error, but you cannot hold me responsible for errors if any error causes a defect.

2.1 Block diagram

The block diagram shows the complete F-16 ADI solution. The diagram also shows the position of the ADI Support board (the grey area) in the solution.



The “blue” triangular parts are OpAmps. The PWM signals from the SDI are converted to a DC voltage level, the appropriate level shift is applied to set the “zero position”, and the signal is amplified/buffered and adjustable to the desired output swing.

The “grey” triangular parts are digital drivers. The digital outputs of the SDI (ON/OFF, +5V) are directly connected to the PIC. These outputs can source/sink at maximum 20 mA. To protect the PIC the digital outputs are buffered. The power supply of the drivers is connected to +24V so that the flags of the ADI can be directly connected. A series-resistor to limit the current is optional.

2.2 Power supplies

The SDI requires +5V and –5V for proper operation. The OpAmps on the ADI Support circuit board require +12V and –12V power supply voltages. Further, the ADI itself requires +28V (+24V is also OK) and 115 VAC 400 Hz for proper operation. The SDI also needs a low-voltage signal derived from the 115 VAC. That is a lot of different power supplies …

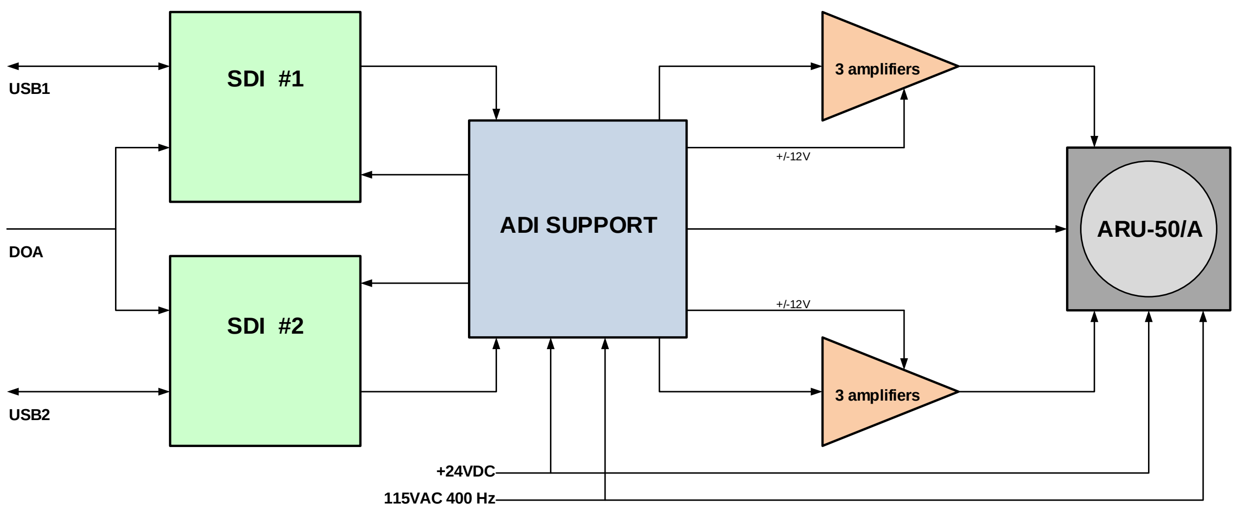
To make the power supply requirements as easy as possible, the ADI Support circuit board has on-board DC/DC converters. The input voltage for these modules is +24VDC (with a large input range) and generate well-regulated +5V and –5V for the SDI modules and +12V and –12V for the circuits on the ADI Support circuit board. The DC/DC converters are also short circuit proof.

➔ **The only power supplies needed for the F-16 ADI are +24VDC and 115VAC 400 Hz.**

2.3 Precautionary measures

The ADI is a delicate (and expensive) instrument. For that reason the ADI Support circuit board includes relays to disconnect the Glide Slope and Rate of Turn analog indicators and the GS, LOC and AUX flags. The ARU-50/A ADI has inputs that enable/disable the internal roll and pitch synchro circuits. These ENABLE inputs are also controlled via the ADI Support circuit board. As the SDI has several spare digital (ON/OFF) outputs the relays are controlled by the SDI modules. The default state after power up are of course disengaged relays.

2.4 Complete block diagram for ADI control



Interface connection is either DOA (PHCC) or USB1/USB2, mutually exclusive.
The "3 amplifiers" in the orange triangles are shown to explain the interface. The amplifiers are actually on the ADI Support v2 board integrated.

3. Connections of the ADI Support board

The ADI Support board has 11 connectors. Pin #1 is indicated on the PCB.

3.1 POWER connector

The POWER connector connects a +24 Volt DC and 115 Volt AC 400 Hz power supply to the ADI Support board. Make sure that you connect the power supply correctly.

→ ***The ADI Support board has no provisions against wrong power supply connections !***

pin number	Signal	Usage
1	115	115V AC 400 Hz sync signal for the ADI Support
2	GND	Ground (0V)
3	+24	+24V DC power supply for the ADI Support

3.2 SYNR connector

The SYNR connector connects to the ROLL synchro stator outputs of the (first) SDI board.

pin number	Signal	Usage
1	GND	Ground (0V)
2	S3	Roll synchro stator S3 from SDI
3	S2	Roll synchro stator S2 from SDI
4	S1	Roll synchro stator S1 from SDI

3.3 SYNP connector

The SYNP connector to the PITCH synchro stator outputs of the (second) SDI board.

pin number	Signal	Usage
1	GND	Ground (0V)
2	S3	Pitch synchro stator S3 from SDI
3	S2	Pitch synchro stator S2 from SDI
4	S1	Pitch synchro stator S1 from SDI

3.4 SV1 connector

The SV1 connector pins are inputs for the two PWM signals used to drive the Glide Slope analog indicator needle pointers, the power ON/OFF signal for the Glide Slope indicators and the ENABLE connection for the roll and pitch synchro.

pin number	Signal	Usage
1	GS POWER	ON/OFF power for Glide Slope indicators
2	ENABLE synchro	Enable roll and pitch synchro of the ADI
3	PWM GS vertical	Analog signal vertical Glide Slope indicator
4	PWM GS horizontal	Analog signal horizontal Glide Slope indicator

3.5 SV2 connector

The SV2 connector pins are inputs for the analog Rate of Turn (RT) signal, the power ON/OFF signal for the Rate of Turn indicator and the GS, LOC and AUX flags.

pin number	Signal	Usage
1	AUX	AUX flag
2	LOC	LOC flag
3	GS	GS flag
4	RT and flags POWER	ON/OFF power for RT and GS, LOC, AUX flags
5	Analog Rate of Turn	Analog voltage for the Rate of Turn indicator

3.6 SV3 connector

The SV3 connector are outputs for the +5V and –5V power supply for the SDI board(s).

pin number	Signal	Usage
1	+5V	+5V power supply for SDI board(s)
2	GND	Ground (0V)
3	–5V	–5V power supply for SDI board(s)

3.7 AC connector

The AC connector provides a reference signal based on the 115VAC 400 Hz power supply.

pin number	Signal	Usage
1	GND	Ground (0V)
2	AC	~1.5V AC 400 Hz reference signal for the SDI boards

3.8 ROLL connector

The ROLL connector are the outputs to the ARU-50/A ADI ROLL synchro stator signals.

pin number	Signal	Usage
1	S1	Roll synchro stator signal S1
2	S2	Roll synchro stator signal S2
3	S3	Roll synchro stator signal S3
4	GND	Ground (0V)

3.9 PTCH connector

The PTCH connector are the outputs to the ARU-50/A ADI PITCH synchro stator signals.

pin number	Signal	Usage
1	S1	Pitch synchro stator signal S1
2	S2	Pitch synchro stator signal S2
3	S3	Pitch synchro stator signal S3
4	GND	Ground (0V)

3.10 ADI1 connector

The ADI1 connector pins are outputs to the ARU-50/A ADI.

pin number	Signal	ARU-50/A pin#	Usage
1	RoT +	4	Rate of Turn indicator
2	RoT –	5	
3	GS flag +	24	GS flag
4	GS flag –	25	
5	LOC flag +	28	LOC flag
6	LOC flag –	29	
7	AUX flag +	6	AUX flag

3.11 ADI2 connector

The ADI2 connector pins are outputs to the ARU-50/A ADI.

pin number	Signal	ARU-50/A pin#	Usage
1	ROLL ENA1	22	Enable ROLL synchro
2	ROLL ENA2	23	
3	PITCH ENA1	30	Enable PITCH synchro
4	PITCH ENA2	31	
5	GS HOR +	11	Glide Slope horizontal indicator
6	GS HOR –	12	
7	GS VERT +	16	Glide Slope vertical indicator
8	GS VERT –	17	

4. Detailed connection diagrams

4.1 Introduction

This chapter describes the interconnections per identified functionality. The order presented enables testing and adjusting sub functionality “on the go”. If you follow this approach you can limit the “big bang” (all or nothing) test at the end. If you feel that another approach works better for you, do so! Use the diagrams as a reference for all required interconnections.

➔ **Always consider safety as the most important aspect with everything you do.**

To do most of the initial setup, you do not need the ADI (or whatever instrument you want to connect). You only need one SDI board, because it will generate all needed signals for initial testing. The SDI board must be connected to the PC using the USB connection, or the SDI board must be connected to the PHCC Motherboard using the DOA connection. Start the ADI Test application on the PC.
Some tests use specific pins of the SDI board, because the needed functionality is only available on those pins. Other tests use pins just for the test, but in your application you can use any other (output) pin of the SDI board. This is clearly indicated. Further, you need a few wires with miniature test hooks or female header connections to make the required connections.

⇨ *Always double-check the connections before you switch on the 24V power supply! If you know of yourself that you might inadvertently get the polarity wrong, add a diode in series with the +24V external power supply connection and the (optional) fuse to protect the hardware against wrong polarity.*

All outputs to the ADI have a series resistor (R29 – R34) to limit the current. In “Chapter 6 – Parts list” you can see the values which are appropriate for the ARU-50/A. If you use a different model ADI, you may have to experiment with the resistor value(s). Start with a high value, and see if the output can control the flag or move the indicator to full scale. If not, decrease the resistor value to the next lower value.

If you added a diode in series with the +24V connection, this wrong-polarity protection will cause a small voltage drop. For the electronics, that voltage drop is not a problem, but the +24V is also directly used to operate the GS, LOC, and AUX flags. It is possible that the flags move “sluggish” because of the voltage drop. In this case, you also may have to lower the series resistors R29 – R34.

4.2 Power supply input wiring

The power supply wiring for the "ADI solution" is simple, just +24V DC. The +24V DC is wired to the ADI and the ADI Support board, and the 115 VAC 400 Hz power supply. On the ADI Support board are DC/DC converters installed that generate the other required voltages (+/–5V and +/–12V).

> *If you use the ADI interface for another instrument than the ARU-50/A, and that instrument has no internal output stages to drive the coils of synchro(s), you need external amplifiers that can drive the synchro coils. The coils cannot be driven by simple OpAmps. A solution is the use of audio amplifiers. Note that the power supply for these audio amplifiers should be symmetrical (that is, the amplifiers need a positive and negative DC power supply voltage). Further, that power supply probably includes a transformer and is connected to the mains power.* ***Always observe all (mains power) safety aspects when working with these potentially lethal voltages.***

The +24V DC, 115V AC 400 Hz and GND wires are connected to the carrier board. On the carrier board these power connections are wired to the ADI output connector (the ADI itself needs +24V DC and 115V AC 400 Hz).

The operating voltages for the SDI boards are generated on the ADI Support board. Connect SV3 of the ADI Support board to the POWER connector on both SDI boards.

➔ Make sure that you do not swap the +5V, GND and –5V connections !!!

The 115V AC 400 Hz connection wire from the ADI connector connects to the ADI Support board, POWER connector, pin #1. The low-voltage output of the 115V AC (approximately 1,5V AC) on the connector AC, pin #PH on the ADI Support board, connects to the ROLL SDI board, connector X1, pin #1. On this ROLL SDI board you must install a jumper on X2, pins #3 – #4. This ROLL SDI board 'conditions' the AC signal for the stator signal generation. The conditioned signal is also fed to the PITCH SDI board. Connect a wire from the ROLL SDI board connector X1, pin #4, to the PITCH SDI board connector X1, pin #4. **No jumper** is installed on X2 on the PITCH SDI board.

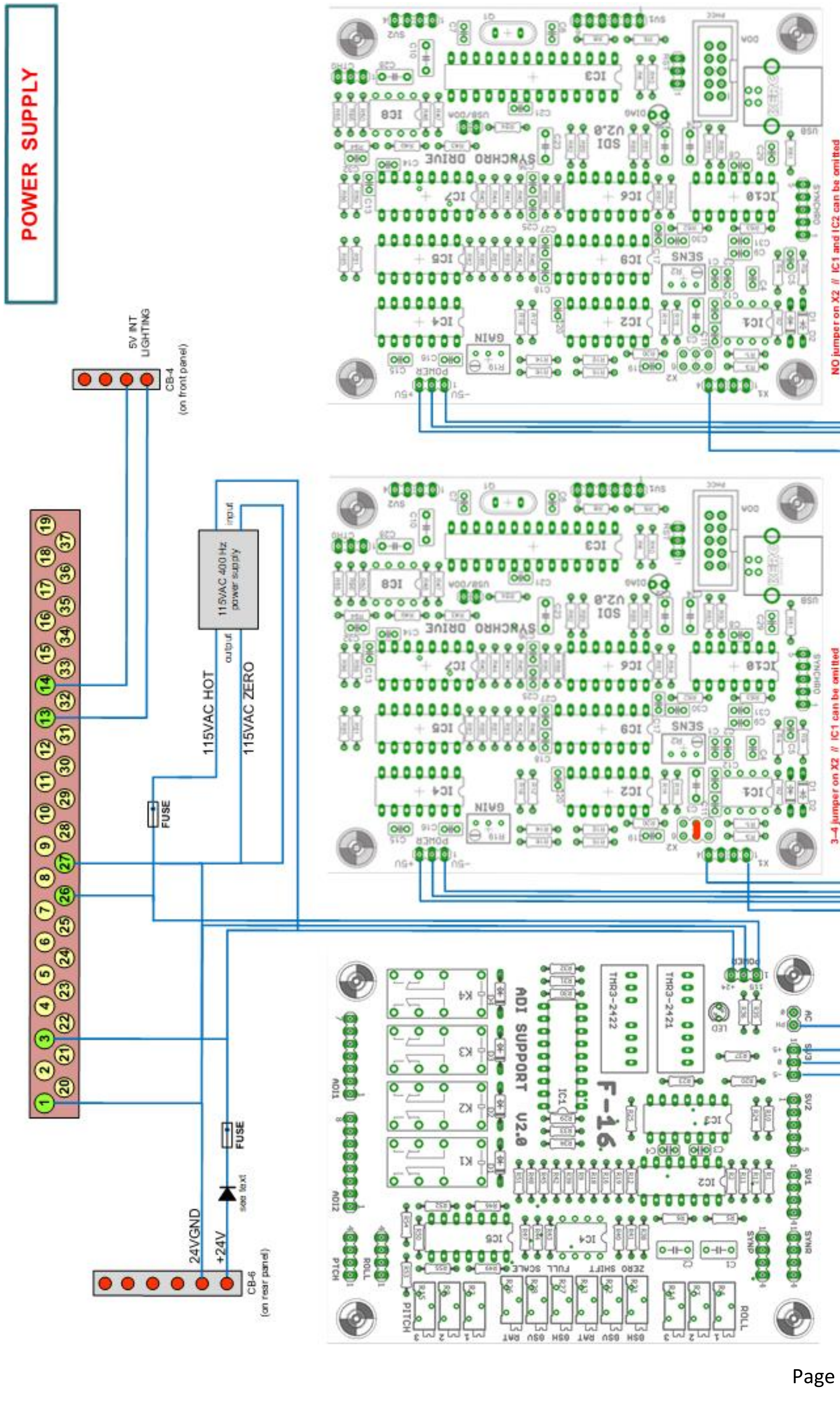
Optionally, you can remove IC1 and IC2 from both SDI boards, they are not needed.

Power connections

The table shows the power supply connections that must be made.
For each connection read the table as follows.
For ***connection*** "X" run a wire ***from*** point-1 ***to*** point-2. Optionally, if indicated, run a wire ***from*** point-3 ***to*** point-4. Etc.

Connection	from	To
115VAC [400 Hz] HOT	115VAC input terminal	to fuse holder (optional)
	from fuse holder (optional)	ADI connector #26
	ADI connector #26	ADI Support POWER #1
115VAC ZERO	115V GND input terminal	ADI connector #27
+24VGND	24V GND input terminal	ADI connector #27 and #1
	ADI connector #27	ADI Support POWER #2
+24VDC	24VDC input terminal	to fuse holder (optional)
	from fuse holder (optional)	ADI connector #3
	ADI connector #3	ADI Support POWER #3
+5V	ADI Support SV3 **#1**	ROLL SDI board POWER **#3**
	ROLL SDI board POWER #3	PITCH SDI board POWER #3
GND	ADI connector #27	ADI Support SV3 #2
	ADI Support SV3 #2	ROLL SDI board POWER #2
	ROLL SDI board POWER #2	PITCH SDI board POWER #2
–5V	ADI Support POWER **#3**	ROLL SDI board POWER **#1**
	ROLL SDI board POWER #1	PITCH SDI board POWER #1
115VAC SYNC	ADI Support AC #PH	ROLL SDI board X1 #1
	ROLL SDI board X1 #4	PITCH SDI board X1 #4
ADI INT LIGHTING	input terminal	ADI connector #13
	input terminal	ADI connector #14

NOTE: the 115V AC is not the 50/60Hz from your household mains power! The 115V AC must be 400 Hz.


POWER SUPPLY
5V INT LIGHTING
CB-4
(on front panel)
115VAC 400 Hz power supply
input
output
115VAC HOT
115VAC ZERO
FUSE
24VGND
+24V
see text
FUSE
CB-6
(on rear panel)
SYNCHRO DRIVE
SDI V2.0
NO jumper on X2 // IC1 and IC2 can be omitted
3–4 jumper on X2 // IC1 can be omitted
ADI SUPPORT V2.0
F-16

4.3 Interface wiring

The interface wiring is the wiring that connects the ADI control to the pit control PC.

If you use the PHCC design you must connect the DOA clock, DOA data, GND, and optionally the RESET pin (not standard PHCC, see the SDI manual for details) from both SDI boards to the PHCC DOA bus. The ADI hardware does not use the +5V from the DOA bus.

If you use the USB connection, you must have two USB connectors. Each SDI board has its own Type-B USB connection to a PC. Set the DOA/USB jumper on both SDI boards correctly!

As you now have realized the power supply connections and the interface connections you can already do some testing. *However, before you connect any power supply* ***check all connections*** *one more time! An error is this wiring will most likely damage your hardware!*

Interface connections

Connection	from	to
DOA bus	PITCH SDI board DOA header	ROLL SDI board DOA header
(* mutual exclusive)	ROLL SDI board DOA header	PHCC Motherboard DOA header
USB	PITCH SDI board USB socket	PC
(* mutual exclusive)	ROLL SDI board USB socket	PC

Test execution power connections

1. Connect the +24V DC and GND connections. Note that the ADI is **not yet** connected. Observe correct polarity! If you *"know yourself"*, and may goof up in the future (I do …), put a "big diode" (for example 1N5004) directly on the pin of the power socket and run the +24VDC wire from the other side of the diode to the front. The anode of the diode connects to the socket. Note that this diode also protects the (expensive) ADI itself!
2. One more time, check the power supply wiring!
3. Turn on the 24V DC power supply.

Observe that the LED on ADI Support is ON and the LED on both SDI boards starts blinking. If an LED does not what is described, turn off the 24VDC immediately. Check the wiring. I hope you did not make an error … ☹

You need a program on the PC to send commands to the ADI interface. The special-developed ADI Test application can be used with the PHCC and with the USB connection.

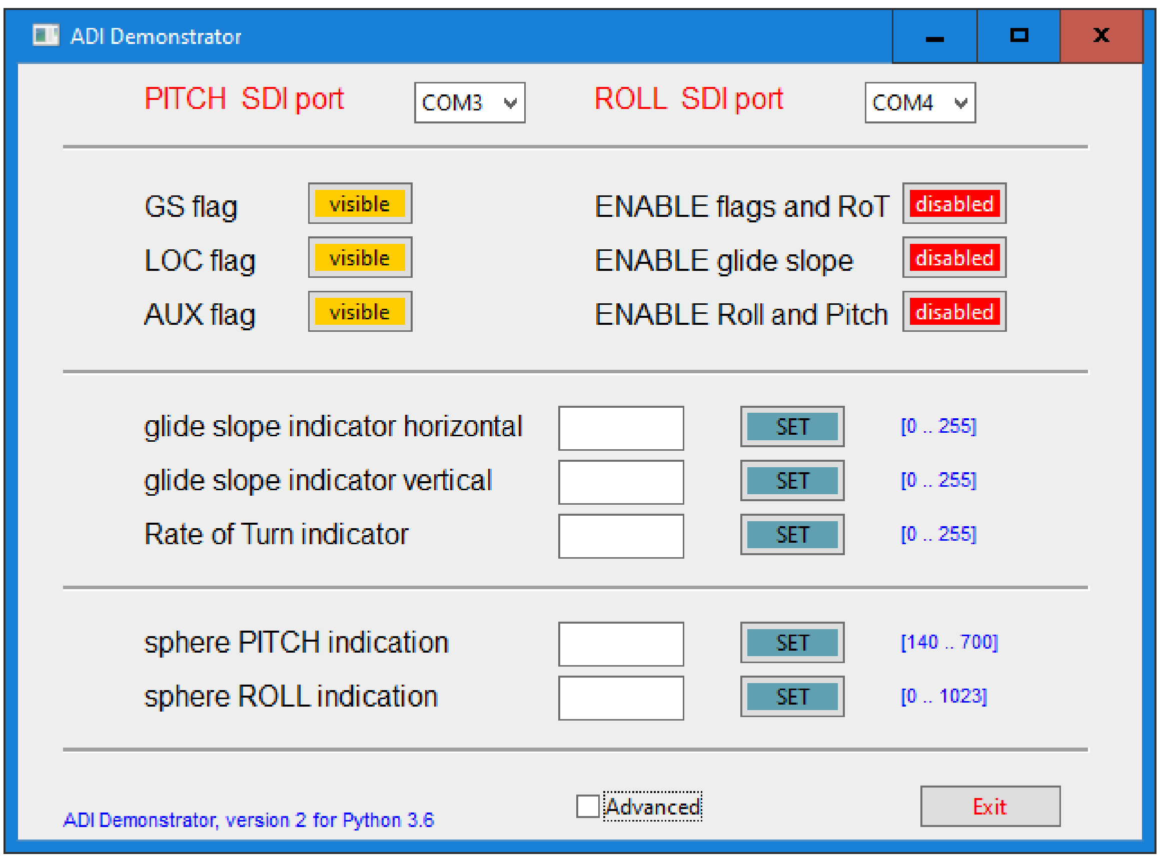
Using the ADI Test application, you can check that the communication channels are operating correctly. The test for the communication is simple. The SDI board has a "diagnostic" LED which can be controlled via the communication. After power-up, default this LED blinks ON/OFF.

If you use the PHCC connection, you must know the device address of both SDI boards. I always try to come up with a device address that makes some sense. The first SDI board is used for the generation of the pitch synchro signals. The second SDI board is used for the generation of the roll synchro signals. The letter “S” (of “SDI”) has hex code 5**3** in the ASCII table, the letter “P” (of “Pitch”) has hex code 5**0**, and the letter “R” (of “Roll”) has hex code 5**2**. So, the device address for the first SDI board is hex **30**, decimal 48 (SDI/Pitch), and the device address for the second SDI board is **32**, decimal 50 (SDI/Roll) ☺. You can choose other device addresses (programmed in the PIC processor), as long as they are unique on the DOA bus.

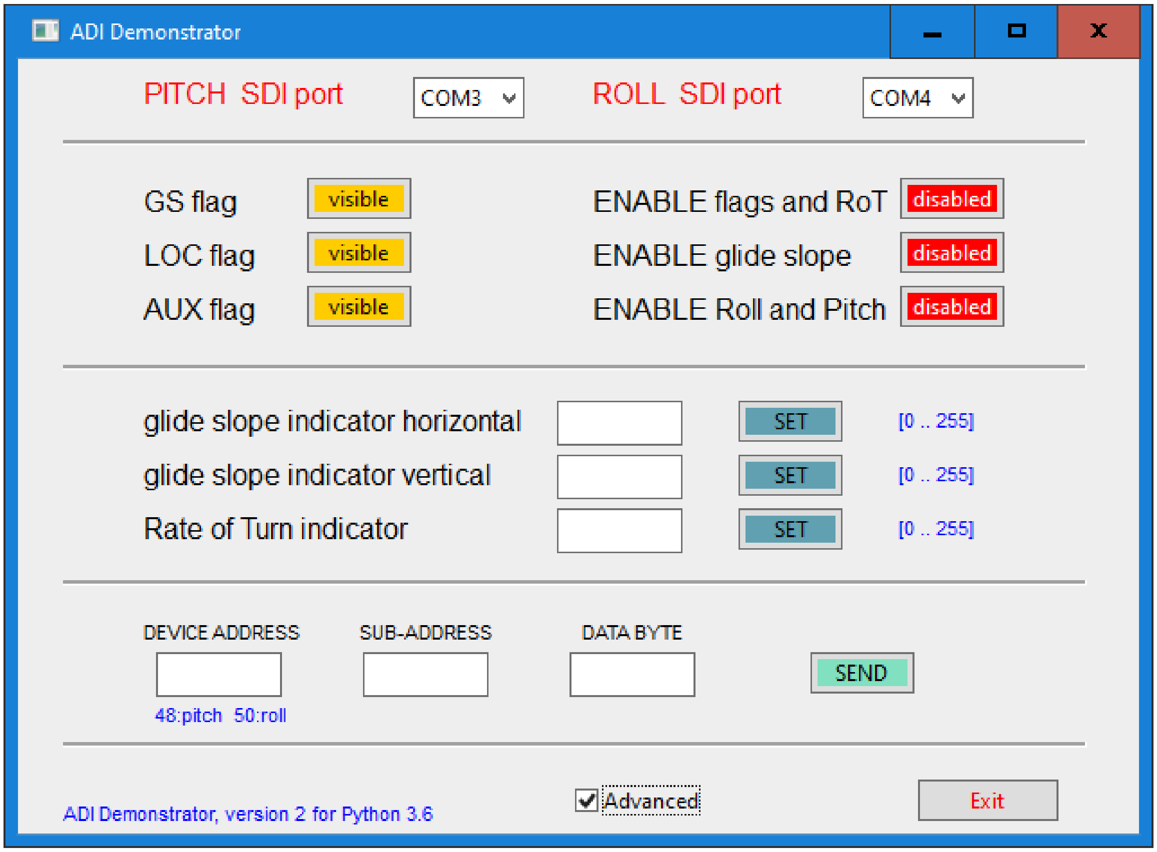
If you use the USB connection, you can test each SDI board and USB cable connection separately. Just connect one SDI board with one USB cable to the PC. After the test with the first SDI board, disconnect the USB cable to it and connect the USB cable to the other SDI board. Repeat the test. If the USB cable is not connected, the LED on that SDI board blinks at a high(er) frequency. When the USB cable is connected to the PC, the LED blinks in a one second rhythm.

Test execution communication channels

1. Connect the +24V DC and GND connections. Note that the ADI is **not yet** connected.
2. Start the ADI Test application.
3. Select the COM port for the SDI board you want to check.



4. Click the checkbox “Advanced” at the bottom.

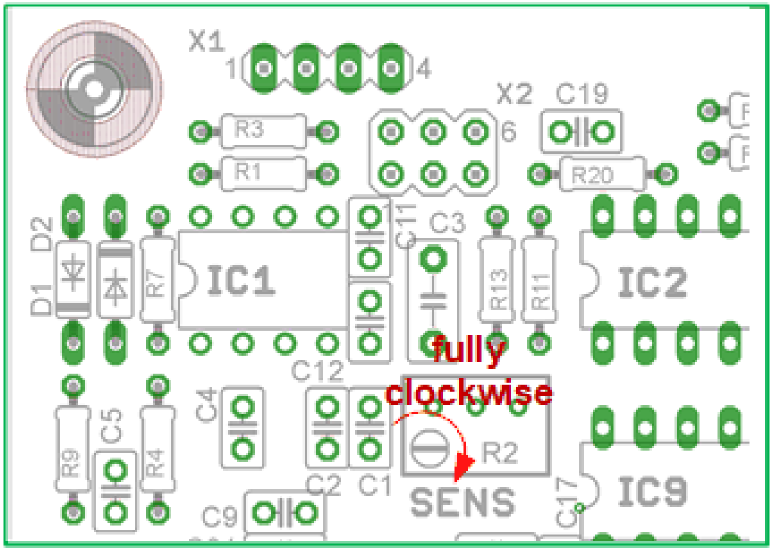


5. Enter in the “DEVICE ADDRESS” field the number 48 or 50 for the PITCH SDI or ROLL SDI board respectively.
6. Enter in the “SUB-ADDRESS” field the number 24.
7. Enter in the “DATA BYTE” field the LED control value, then click the “SEND” button.
   - Control value 0 : turn LED off
   - Control value 1 : turn LED on
   - Control value 2 : blinking LED

If all went OK, turn off the 24VDC. Wait until the LEDs are OFF before you continue.

4.4 SDI boards adjustments

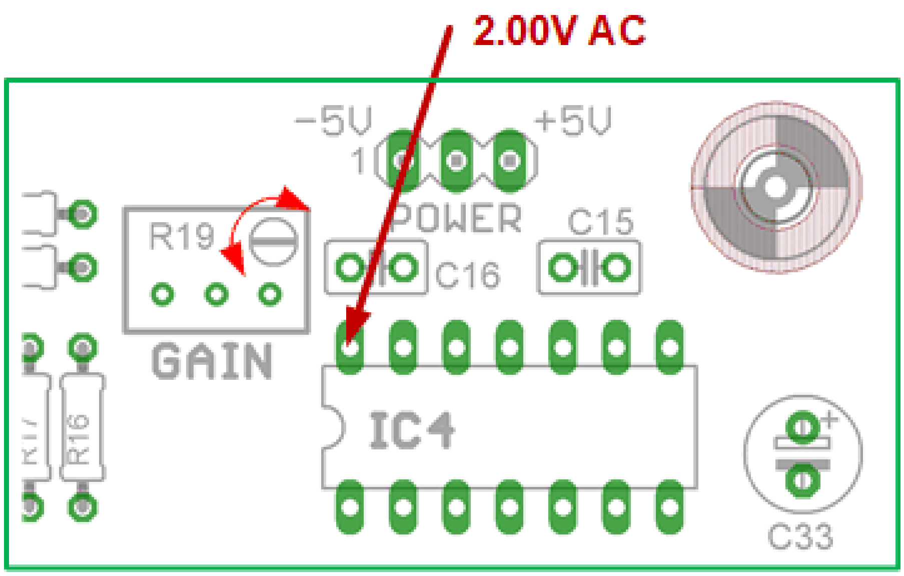
The SDI boards have two adjustment trim potentiometers, SENS and GAIN.
The first trim potentiometer (SENS) R2 on both SDI boards must be set fully clockwise, because no attenuation of the reference input signal (coming from the ADI Support board) is needed.



Adjustment steps for the SDI synchro signal generation

The other trim potentiometer (GAIN) R19 sets the amplitude of the input signal for the S1, S2, and S3 synchro stator voltage generation.

1. Set the multi-meter to **AC** Volts range.
   The + lead connects to **#14 of IC4** (using a tiny hook) and the – lead connects to **GND**.
2. Connect the +24V DC, 115V AC 400 Hz and GND connections.
   Note that the ADI is **not yet** connected.
3. Adjust R19 until the multimeter reads 2.00V AC.



4.5 Glide slope indicator wiring

The ADI has two glide slope indicators, horizontal slope and vertical slope (”localizer”). Both indicators can be set to any position respectively above/ below or left/ right of its center position. This position is controlled by an analog signal. The analog signals are realized using two digital outputs of the first SDI board. Via software the digital outputs are configured as PWM signal outputs. The digital outputs from the SDI board are connected to inputs on the ADI Support board. On the ADI Support board are amplifiers to guarantee “full swing” of each indicator. Two trim potentiometers set the center position and two trim potentiometers set the maximum position of both indicators. All 4 trim potentiometers are on the ADI Support board.

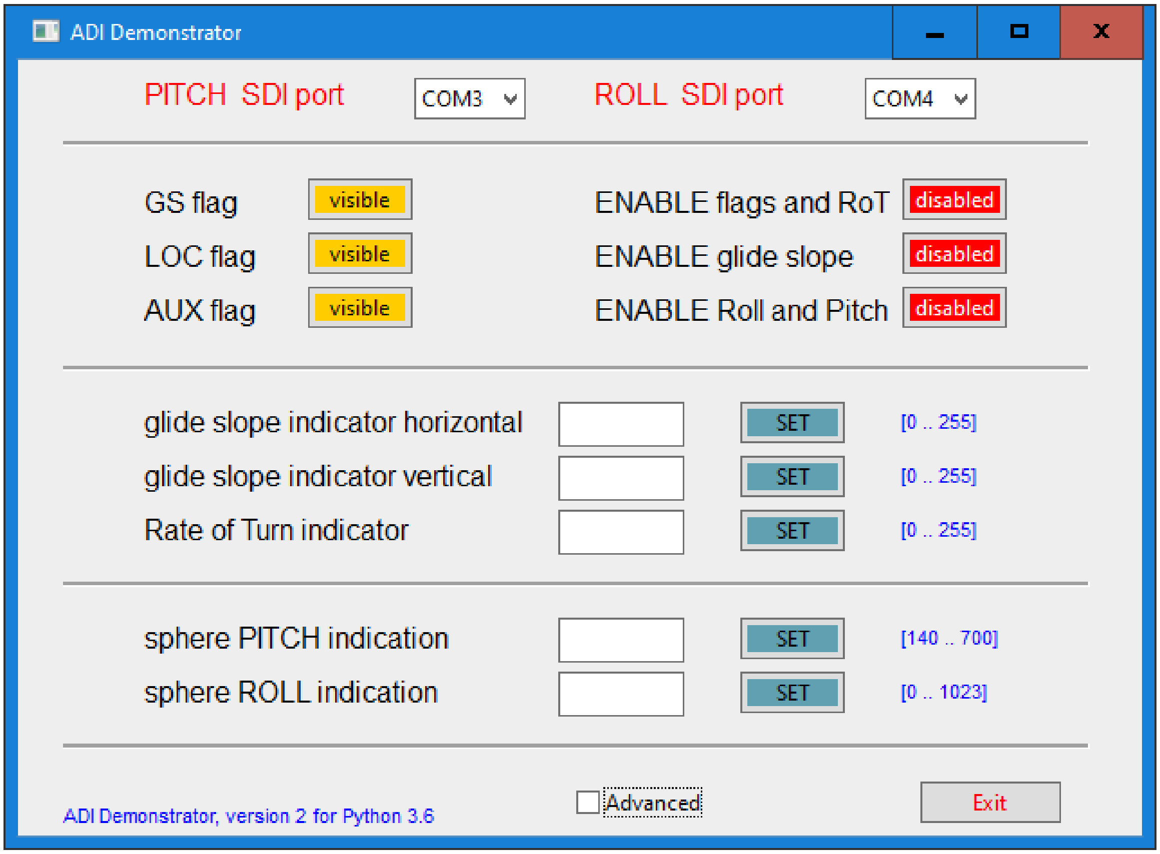
One additional digital output is used to implement a protection feature for the ADI. The horizontal and vertical glide slope indicator can be disconnected from the ADI Support board via relay contacts. Thus, to operate the glide slope indicators, you must first activate that relay. One digital output from the first SDI board connects to the ADI Support board to control that relay.

Glide slope indicator connections

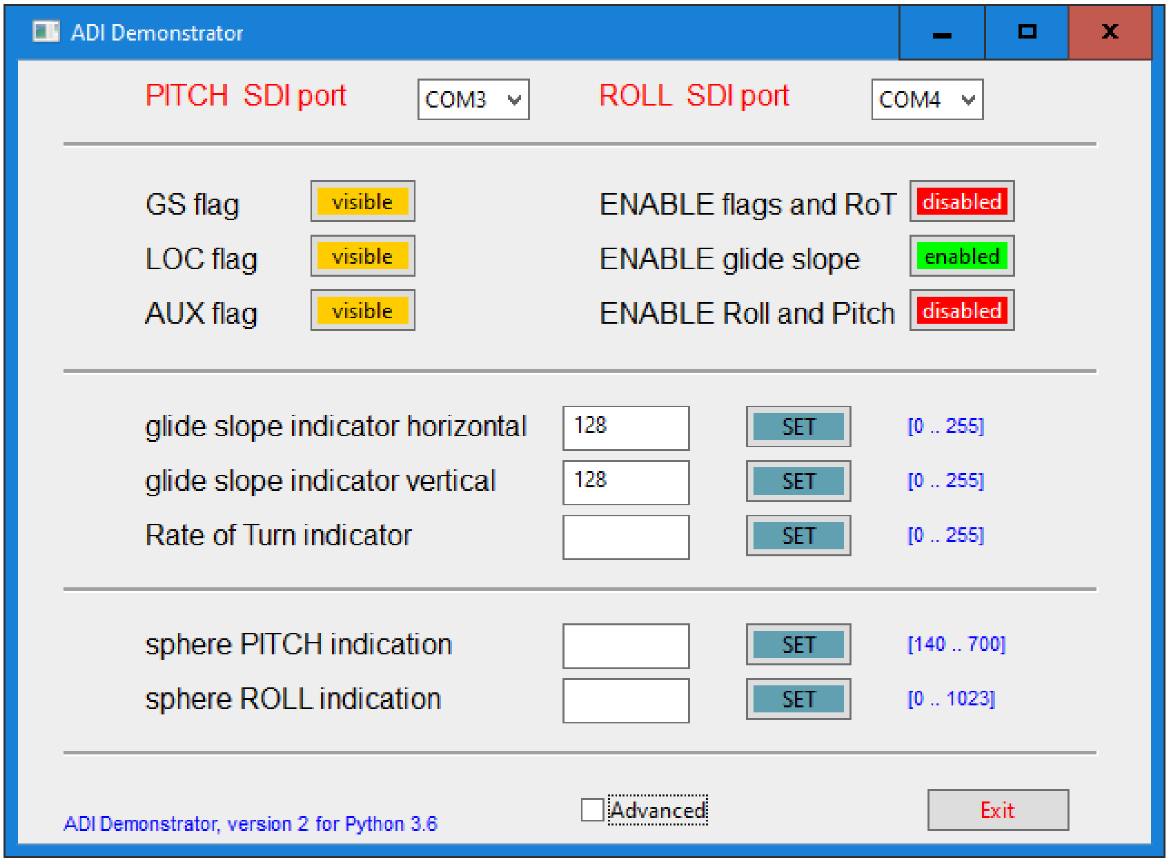
Connection	from	to
Glide slope power	SDI board #1 SV1 #2	ADI Support SV1 #1
Glide slope HOR analog	SDI board #1 SV1 #3	ADI Support SV1 #4
Glide slope VERT analog	SDI board #1 SV1 #4	ADI Support SV1 #3
Glide slope HOR SIG	ADI Support ADI2 #5	ADI connector #11
Glide slope HOR GND	ADI Support ADI2 #6	ADI connector #12
Glide slope VERT SIG	ADI Support ADI2 #7	ADI connector #16
Glide slope VERT GND	ADI Support ADI2 #8	ADI connector #17

Test execution Glide Slope indicators

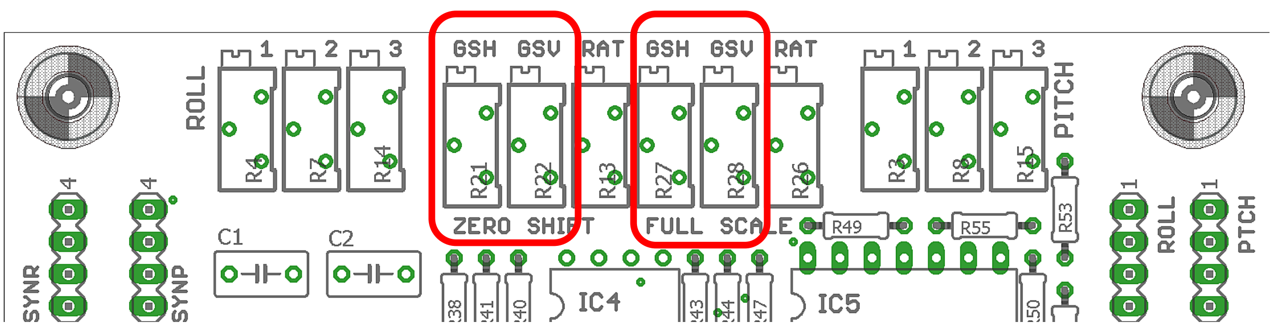
1. Connect the +24V DC and GND connections. Note that the ADI is **not yet** connected.
2. Start the ADI Test application.
3. Select the COM ports for **both** SDI boards.



4. Click the button "ENABLE glide slope". The red colored button with the text "disabled" will change to a green colored button with the text "enabled". This will activate the relay.
5. Enter the value 128 in the "glide slope indicator horizontal" field, and click the "SET" button at the right of the field.
6. Enter the value 128 in the "glide slope indicator vertical" field, and click the "SET" button at the right of the field.



After sending these commands you can adjust the "ZERO SHIFT" and "FULL SCALE" trim potentiometers GSH and GSV, Glide Slope Horizontal and Glide Slope Vertical indicator output.



Adjustment steps for the horizontal glide slope indicator

4. Connect a multi-meter set to **DC** Volts range to ADI connector.
   The + lead connects to **#11** and the – lead connects to **#12**.
5. Adjust the ZERO SHIFT GSH trim potentiometer until the voltmeter reads 0V.
6. Enter the value 0 in the "glide slope indicator horizontal" field, and click the "SET" button at the right of the field value.
7. Trim the FULL SCALE GSH potentiometer until the voltmeter reads –8.5V.

Adjustment steps for the vertical glide slope indicator

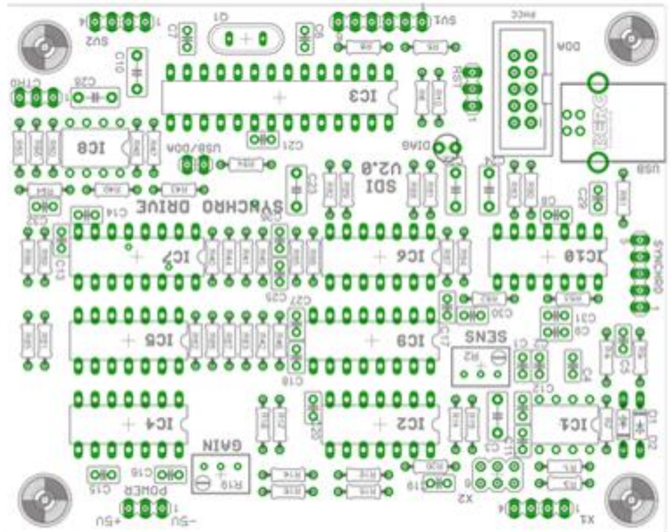
1. Connect a multi-meter set to **DC** Volts range to ADI connector.
2. The + lead connects to **#16** and the – lead connects to **#17**.
3. Adjust the ZERO SHIFT GSV trim potentiometer until the voltmeter reads 0V.
4. Enter the value 0 in the "glide slope indicator vertical" field, and click the "SET" button at the right of the field.
5. Trim the FULL SCALE GSV potentiometer until the voltmeter reads –8.5V.

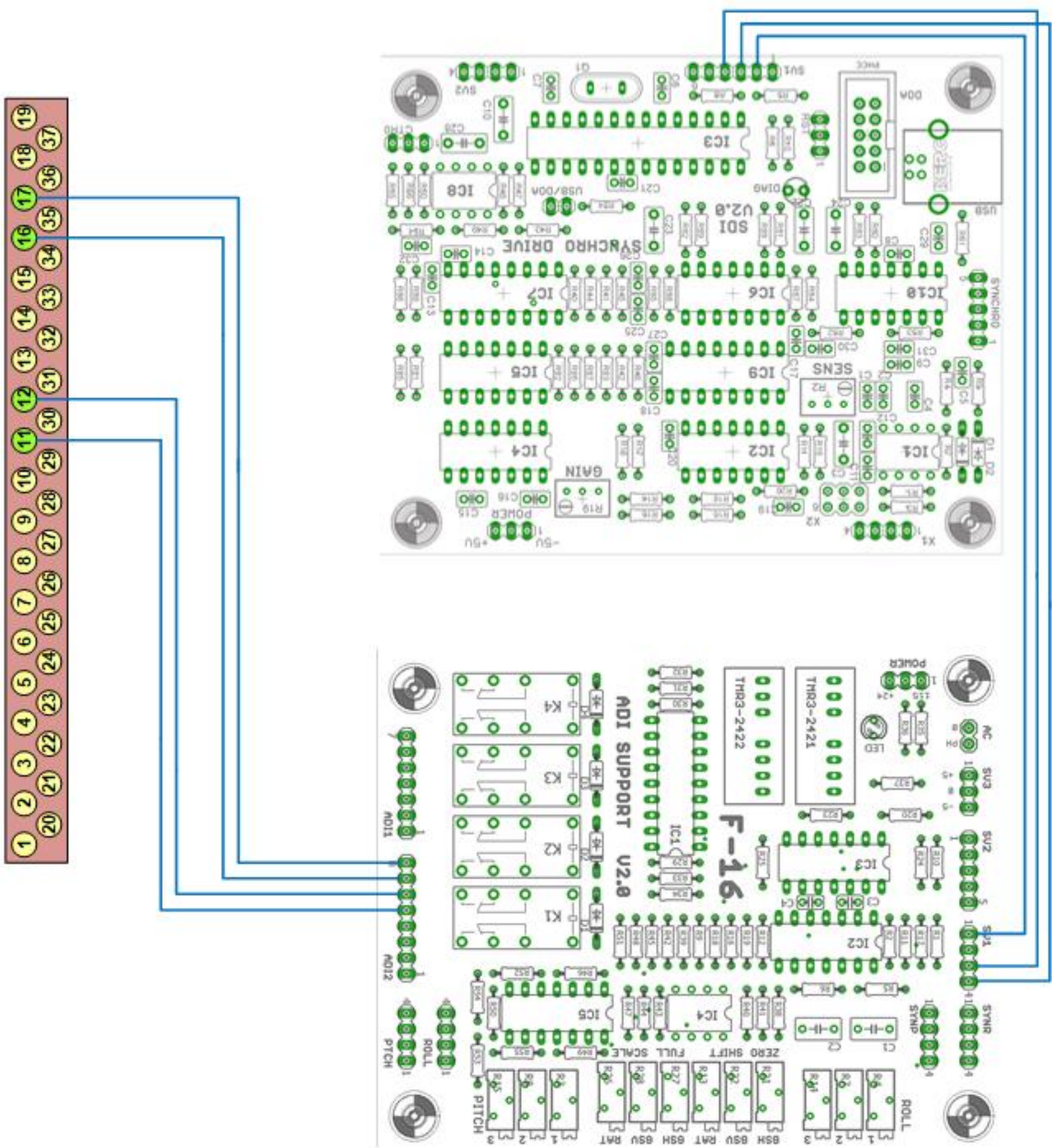
The adjustment is a bit "tricky", because the ZERO SHIFT and FULL SCALE are not completely independent. If FULL SCALE is set such that the OpAmp amplifies a lot, you will never get the output at 0V when the PWM value is set to 128. What you can do is lower the FULL SCALE setting or clip a wire on IC2 pin #1 / pin #7 on the ADI Support board, see ADI Support schematic diagram. To be safe, hook the wire while the power supply is off. Now trim ZERO SHIFT so that the voltage is 0V (while the value is set to 128). Switch power is off, then connect the wire to IC3 pin #14 / pin #8. Set the value to 0. Trim FULL SCALE so that the voltage is –8.5V.

For later, when the ADI is connected (not now!)

Optionally, you can do the adjustment again if (for example) the glide slope center position is a bit "off center". If you cannot get the glide slope indicator to the "full scale" position, you may lower the current-limiting resistor which is in series with the output. The current-limiting resistor for the horizontal glide slope indicator is **R33**. The current-limiting resistor for the vertical glide slope indicator is **R34**. I learned that the "full scale" position of both glide slope indicators is in fact *outside* the view field of the ADI.

GLIDE SLOPE





4.6 Flags and Rate of Turn indicator wiring

The ADI has four flags and in the bottom part of the ADI is the Rate of Turn indicator. One flag (OFF) is controlled by the ADI itself and will only disappear if the 24V DC **and** 115V AC power supplies are present and the signals for the roll and pitch synchro are valid. The other 3 flags (GS, LOC, and AUX) are controlled with digital outputs of the second SDI board. The outputs from the second SDI board are connected to inputs on the ADI Support board. On the ADI Support board are drivers that can actuate the flags.

The Rate of Turn indicator can be set to any position left or right of its center position. This position is controlled by an analog signal. The analog signal is realized using the dedicated PWM output of the second SDI board. On this SDI board resistor R56 must be a wire (or 0 Ω), and the header CRT0 must have a jumper on pins 2 – 3. The PWM output from the second SDI board is connected to an input on the ADI Support board. On the ADI Support board are amplifiers to guarantee "full swing" of the Rate of Turn indicator. One trim potentiometer sets the center position and one trim potentiometer sets the maximum position of the Rate of Turn indicator. Both trim potentiometers are on the ADI Support board.

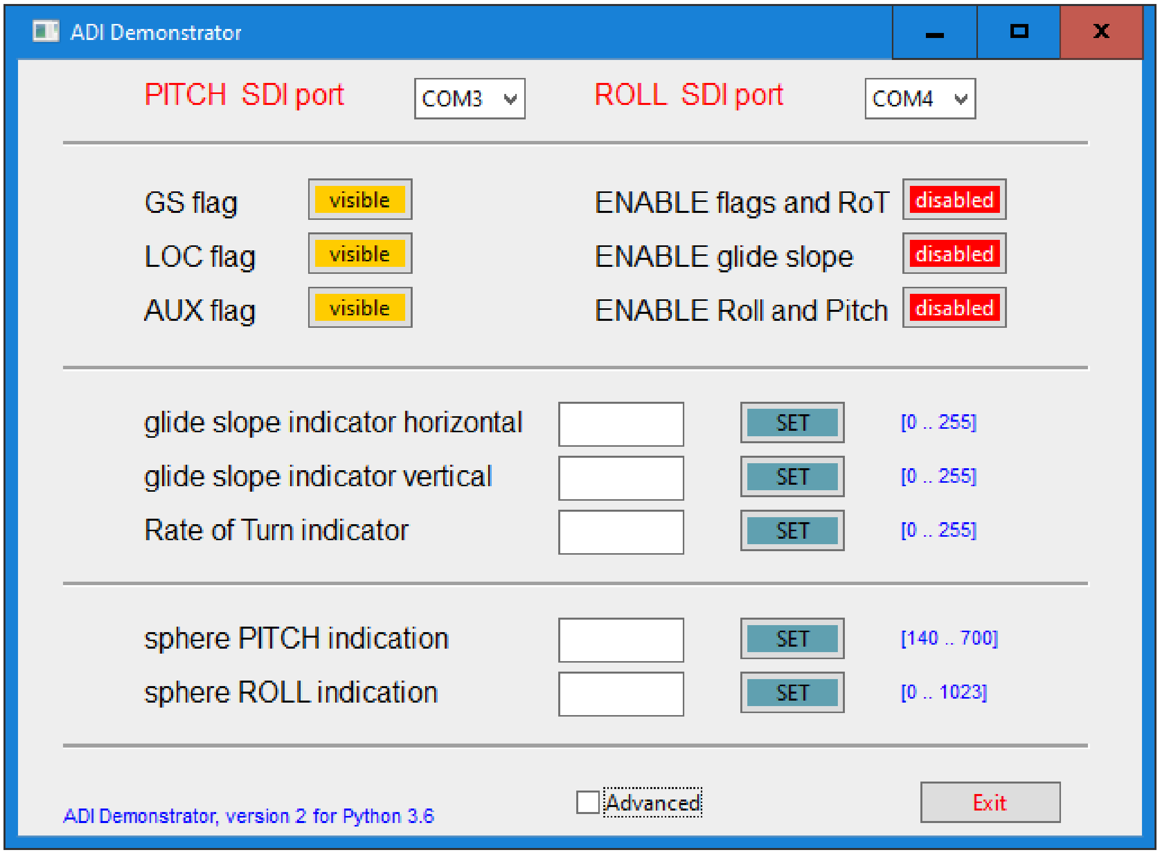
One additional digital output is used to implement a protection feature for the ADI. The GS, LOC and AUX flag and the Rate of Turn indicator can be disconnected from the ADI Support board via relay contacts. Thus, to operate the flags and Rate of Turn indicator, you must first activate that relay. One digital output from the second SDI board connects to the ADI Support board to control that relay.

Flags and Rate of Turn indicator connections

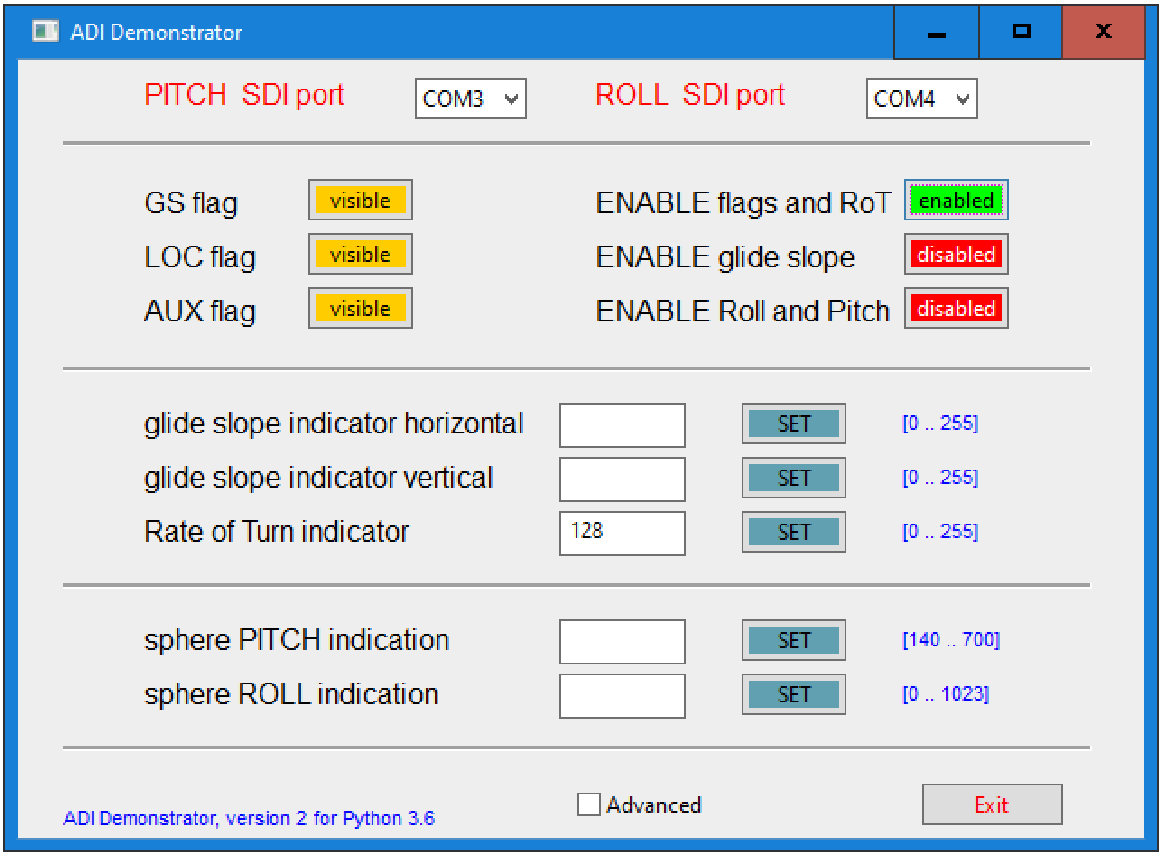
Connection	from	to
GS flag	SDI board #2 SV1 #1	ADI Support SV2 #3
LOC flag	SDI board #2 SV1 #3	ADI Support SV2 #2
AUX flag	SDI board #2 SV1 #4	ADI Support SV2 #1
Rate of Turn analog	SDI board #2 SV2 #4	ADI Support SV2 #5
Flags & Rate of Turn power	SDI board #2 SV1 #2	ADI Support SV2 #4
Rate of Turn SIG	ADI Support ADI1 #1	ADI connector #4
Rate of Turn GND	ADI Support ADI1 #2	ADI connector #5
GS flag SIG	ADI Support ADI1 #3	ADI connector #24
GS flag GND	ADI Support ADI1 #4	ADI connector #25
LOC flag SIG	ADI Support ADI1 #5	ADI connector #28
LOC flag GND	ADI Support ADI1 #6	ADI connector #29
AUX flag SIG	ADI Support ADI1 #7	ADI connector #6

Test execution Flags and Rate of Turn indicator

1. Connect the +24V DC and GND connections. Note that the ADI is **not yet** connected.
2. Start the ADI Test application.
3. Select the COM ports for **both** SDI boards.



4. Click the button "ENABLE flags and RoT". The red colored button with the text "disabled" will change to a green colored button with the text "enabled". This will activate the relay.
5. Enter the value 128 in the "Rate of Turn indicator" field, and click the "SET" button at the right of the field.



After sending these commands you can adjust the "ZERO SHIFT" and "FULL SCALE" trim potentiometers RAT, Rate of Turn, and check correct operation of the GS, LOC and AUX flags.

Check GS flag output

1. Connect a multi-meter set to **DC** Volts range to ADI connector.
   The + lead connects to **#24** and the – lead connects to **#25**.
2. Check that the multi-meter reads approximately 23V.
3. Click the button "GS flag". The yellow-orange colored button with the text "visible" will change to a grey colored button with the text "hidden".
4. Check that the multi-meter reads approximately 4V.

Check LOC flag output

1. Connect a multi-meter set to **DC** Volts range to ADI connector.
   The + lead connects to **#28** and the – lead connects to **#29**.
2. Check that the multi-meter reads approximately 23V.
3. Click the button "LOC flag". The yellow-orange colored button with the text "visible" will change to a grey colored button with the text "hidden".
4. Check that the multi-meter reads approximately 4V.

Check AUX flag output

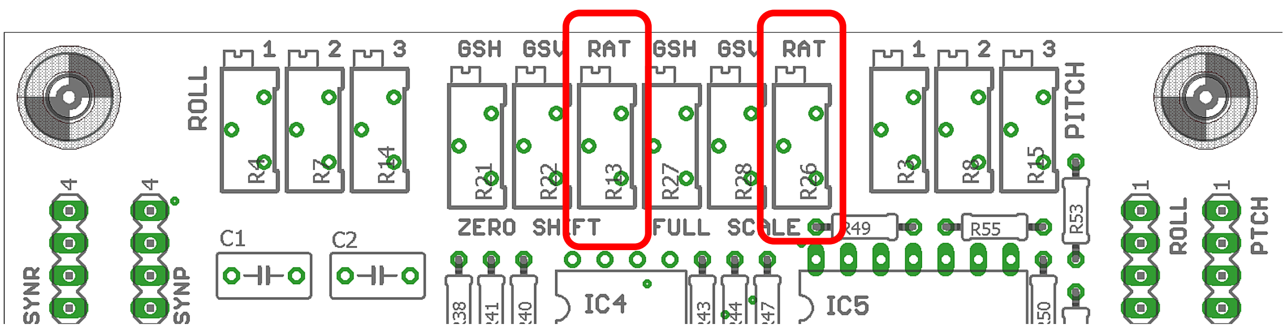
1. Connect a multi-meter set to **DC** Volts range to ADI connector.
   The + lead connects to **#6** and the – lead connects to **#29**.
2. Check that the multi-meter reads approximately 23V.
3. Click the button “AUX flag”. The yellow-orange colored button with the text “visible” will change to a grey colored button with the text “hidden”.
4. Check that the multi-meter reads approximately 4V.

For later, when the ADI is connected (not now!)

If you cannot get a flag completely “invisible”, or just partly, or the flag has a “sluggish” movement, you may lower the current-limiting resistor which is in series with each flag output. The current-limiting resistor for the GS flag is **R30**. The current-limiting resistor for the LOC flag is **R31**. The current-limiting resistor for the AUX flag is **R32**.

Adjustment steps for the Rate of Turn indicator

1. Connect a multi-meter set to **DC** Volts range to ADI connector.
   The + lead connects to **#4** and the – lead connects to **#5**.
2. Adjust the ZERO SHIFT RAT trim potentiometer until the voltmeter reads 0V.
3. Enter the value 0 in the “Rate of Turn indicator” field, and click the “SET” button at the right of the field value.
4. Trim the FULL SCALE RAT potentiometer until the voltmeter reads –8.5V.



The adjustment is a bit “tricky”, because the ZERO SHIFT and FULL SCALE are not completely independent. If FULL SCALE is set such that the OpAmp amplifies a lot, you will never get the output at 0V when the PWM value is set to 128. What you can do is lower the FULL SCALE setting or clip a wire on IC3 pin #1 on the ADI Support board, see ADI Support schematic diagram. To be safe, hook the wire on pin #1 while the power supply is off. Now trim ZERO SHIFT so that the voltage on pin #1 is 0V (while the PWM value is set to 128). Switch power is off, then connect the wire to IC3 pin #7. Set the PWM value to 0. Trim FULL SCALE so that the voltage on pin #7 is –8.5V.

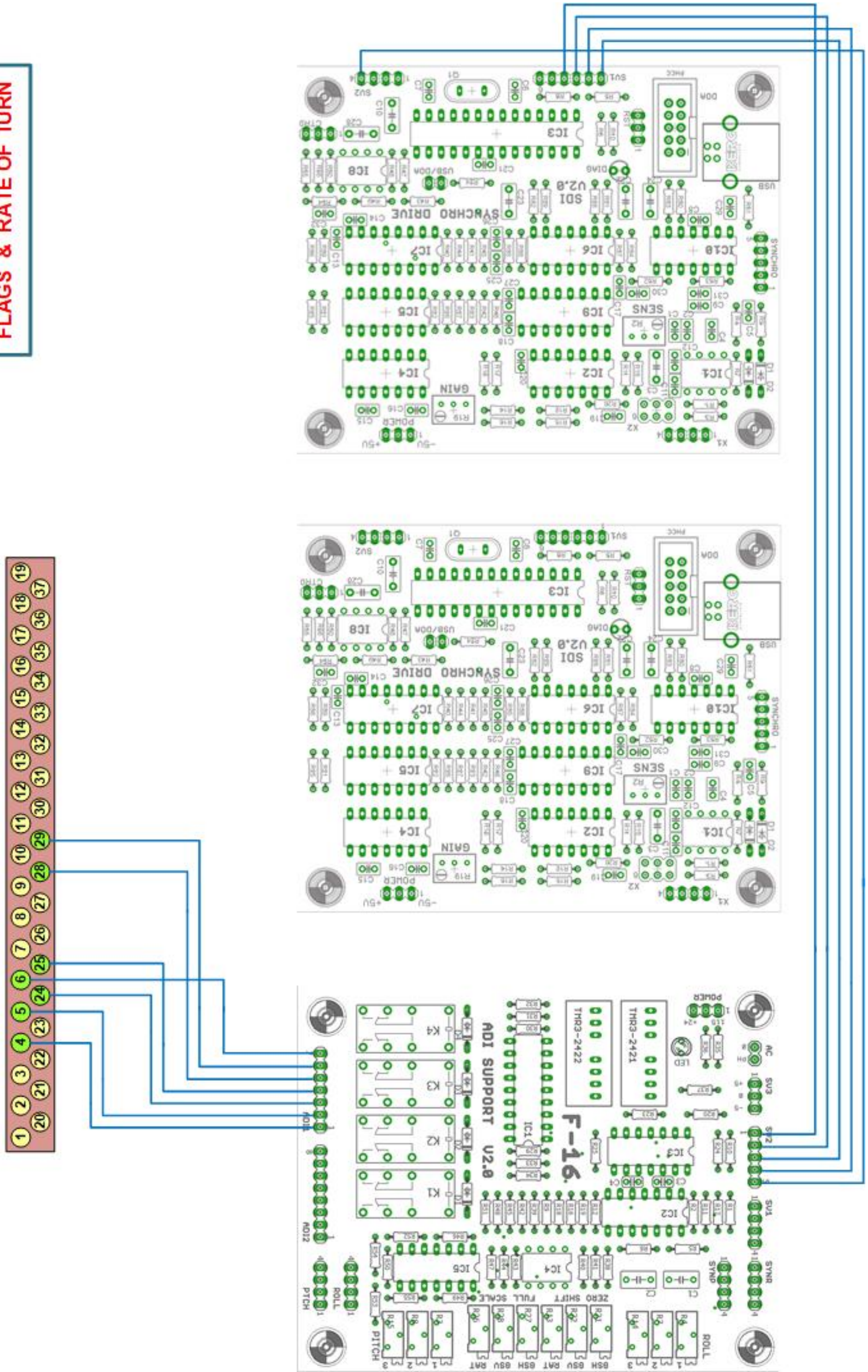
For later, when the ADI is connected (not now!)

Optionally, you can do the adjustment again if (for example) the Rate of Turn center position is a bit "off center". If you cannot get the Rate of Turn indicator to the "full scale" position, you may lower the current-limiting resistor which is in series with the output. The current-limiting resistor for the Rate of Turn indicator is **R29**.

NOTE:

The GS flag and the LOC flag of the ADI will only operate when both +24VDC ***and*** *115 VAC 400 Hz* supply voltage is connected to the ADI.

FLAGS & RATE OF TURN



4.7 Sphere Pitch movement wiring

The pitch movement of the sphere is controlled by a synchro. The first SDI board generates the three stator signals for this synchro. These signals do not have the correct amplitude to drive the ADI directly. Therefore, these signals are connected to the ADI Support board. The ADI Support board has amplifiers and amplitude adjustment trim potentiometers. The outputs of the amplifiers are wired to the ADI connector.

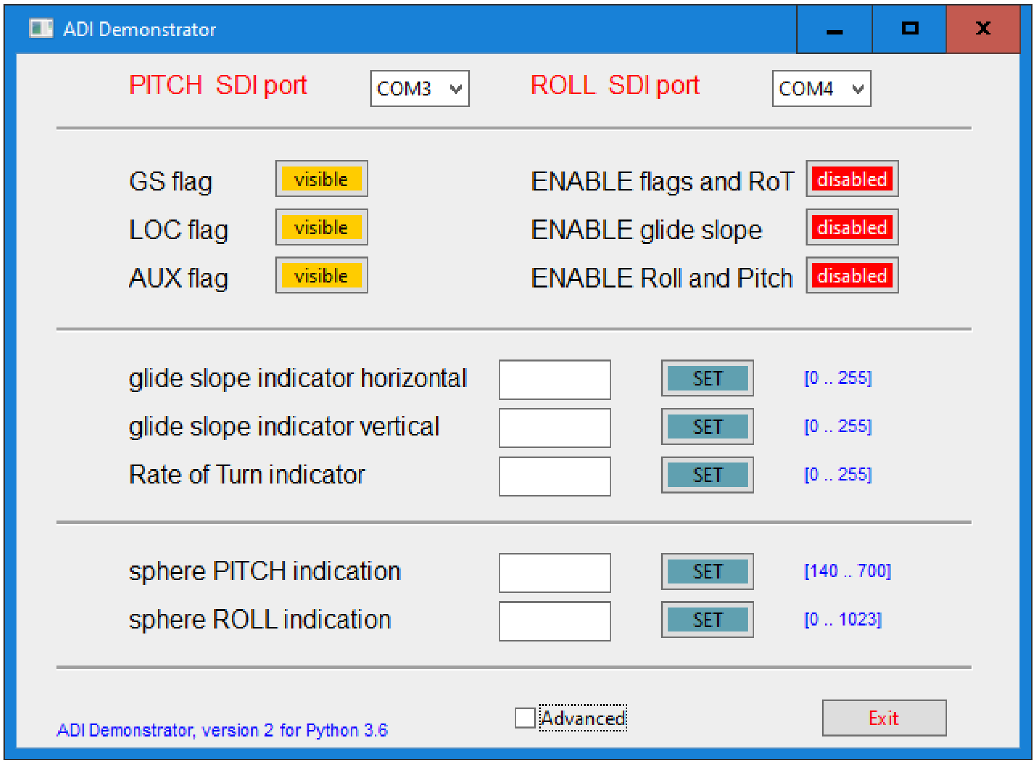
One additional digital output is used to enable/disable the Pitch and Roll servos inside the ADI. If the servos inside the ADI are disabled, the sphere will not move. This is controlled via relay contacts. Thus, to operate the sphere movement, you must first activate that relay. One digital output from the first SDI board connects to the ADI Support board to control that relay.

Sphere Pitch movement connections

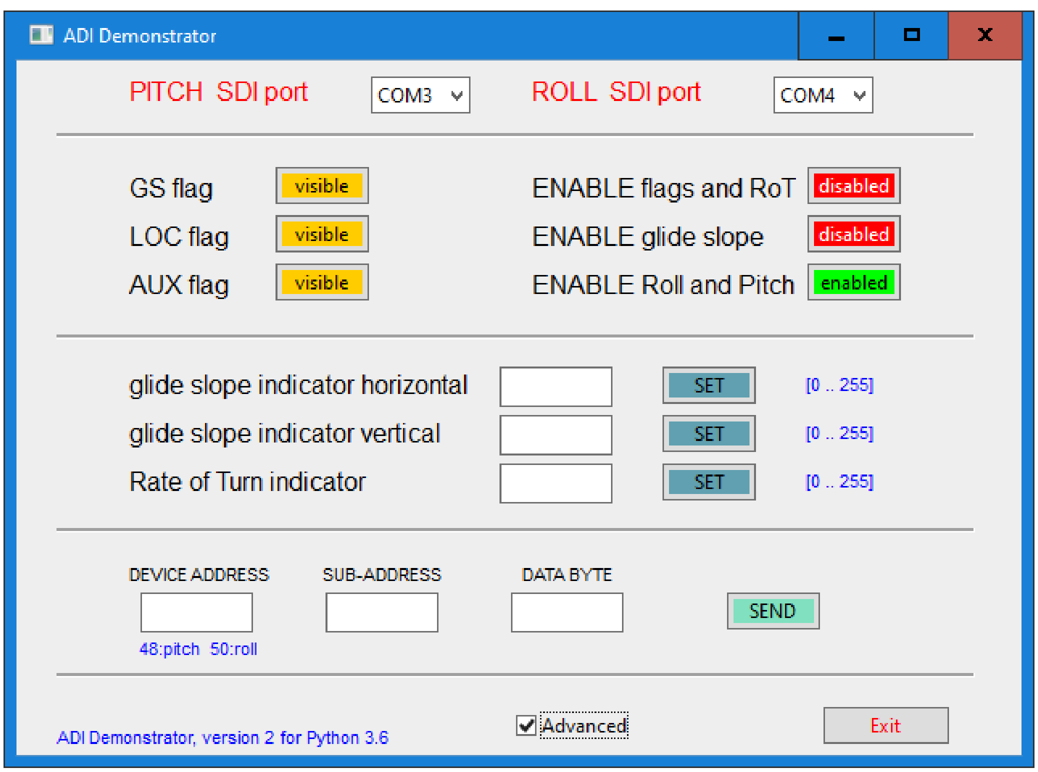
Connection	from	to
pitch synchro S1	SDI board #1 SYNCHRO #5	ADI Support SYNP #4
pitch synchro S2	SDI board #1 SYNCHRO #4	ADI Support SYNP #3
pitch synchro S3	SDI board #1 SYNCHRO #3	ADI Support SYNP #2
pitch & roll servo enable	SDI board #1 SV1 #1	ADI Support SV1 #2
pitch S1	ADI Support PTCH #1	external amplifier #1 input
pitch S2	ADI Support PTCH #2	external amplifier #2 input
pitch S3	ADI Support PTCH #3	external amplifier #3 input
pitch S1SIG	external amplifier #1 output	ADI connector #7
pitch S2SIG	external amplifier #2 output	ADI connector #8
pitch S3SIG	external amplifier #3 output	ADI connector #19
pitch ENABLE	ADI Support ADI2 #3	ADI connector #30
	ADI Support ADI2 #4	ADI connector #31

Test execution Pitch indicator

1. Connect the +24V DC, 115V AC 400 Hz and GND connections.
   Note that the ADI is **not yet** connected.
2. Start the ADI Test application.
3. Select the COM ports for **both** SDI boards.

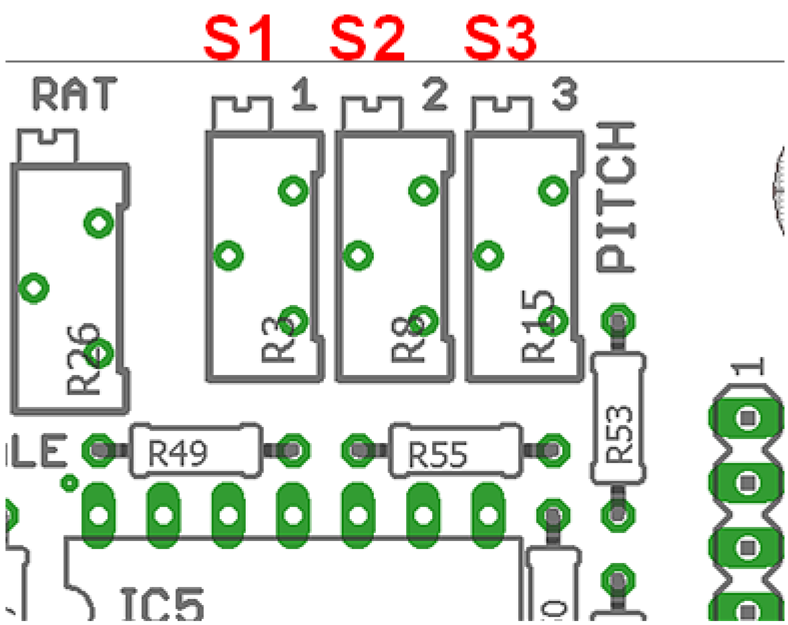


4. Click the button "ENABLE Roll and Pitch". The red colored button with the text "disabled" will change to a green colored button with the text "enabled". This will activate the relay.
5. Click the checkbox "Advanced" at the bottom.



6. Enter in the “DEVICE ADDRESS” field the number 48 for the PITCH SDI board.
7. Enter in the “SUB-ADDRESS” field the number 34 (output stator S1).
8. Enter in the “DATA BYTE” field the number 255.
9. Click the button “SEND”.
10. Enter in the “SUB-ADDRESS” field the number 35 (output stator S2).
11. Click the button “SEND”.
12. Enter in the “SUB-ADDRESS” field the number 36 (output stator S3).
13. Click the button “SEND”.

After these commands you can adjust the amplitude level of the Pitch stator amplifiers.



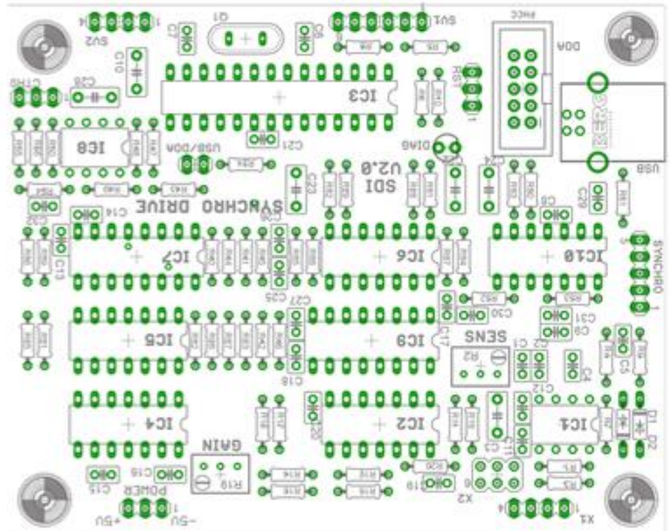
Adjustment steps for the Pitch stator coils

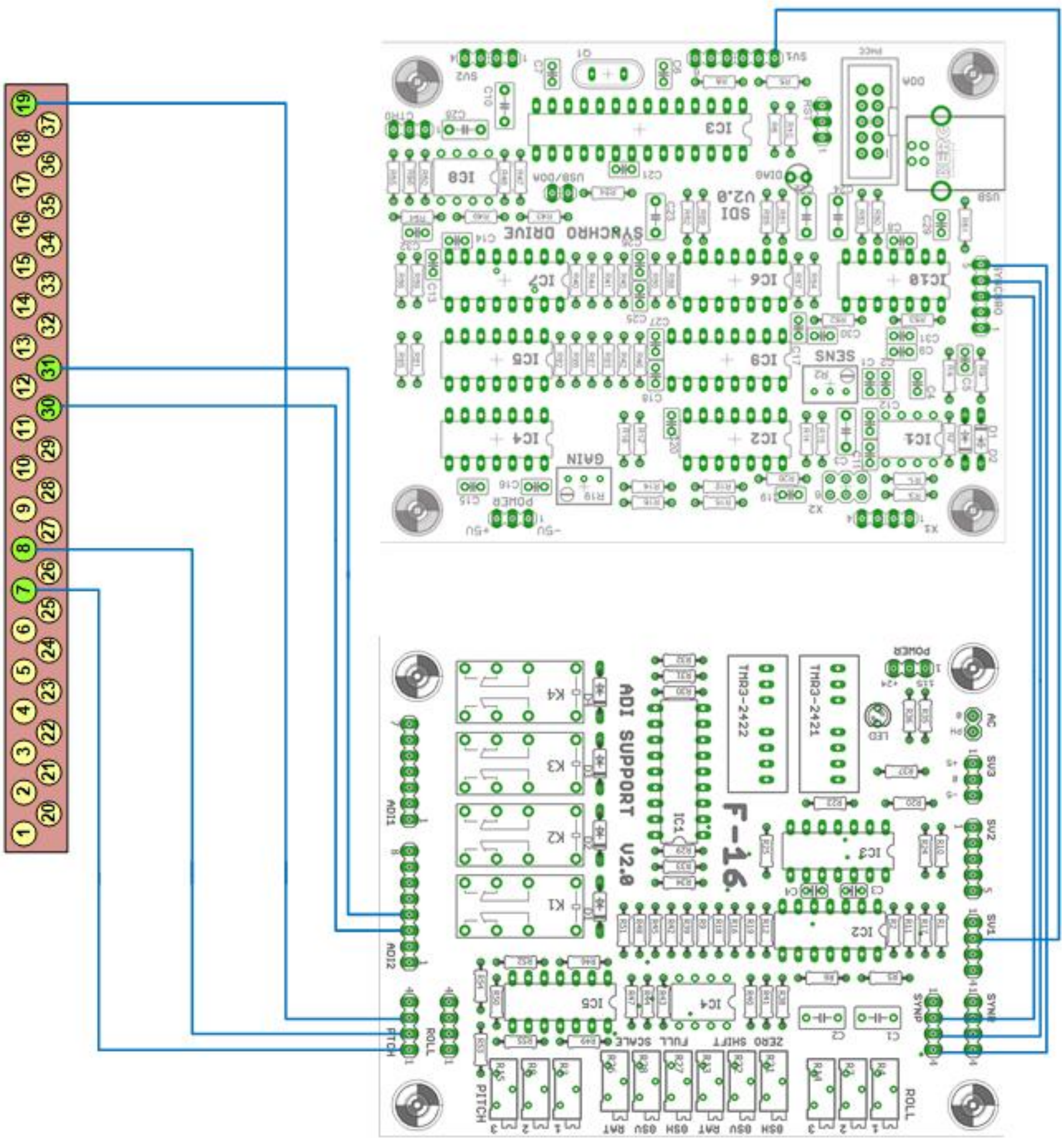
1. Connect a multi-meter set to **AC** Volts range to ADI connector.
2. The + lead connects to **#7** and the – lead connects to **#27**.
3. Adjust the PITCH S1 trim potentiometer (R3) until the voltmeter reads 7.00V.
4. The + lead connects to **#8** and the – lead connects to **#27**.
5. Adjust the PITCH S2 trim potentiometer (R8) until the voltmeter reads 7.00V.
6. The + lead connects to **#19** and the – lead connects to **#27**.
7. Adjust the PITCH S3 trim potentiometer (R15) until the voltmeter reads 7.00V.

Check the PITCH ENABLE output

1. Connect a multi-meter set to **Ohm** range to ADI connector.
   The + lead connects to **#30** and the – lead connects to **#31**.
2. Click the button “ENABLE Roll and Pitch”.
3. Check that the multi-meter reads 0 Ω when the button is green, and the reading is ∞ “infinity” when the button is red.

PITCH





4.8 Sphere Roll movement wiring

The roll movement of the sphere is controlled by a synchro. The second SDI board generates the three stator signals for this synchro. These signals do not have the correct amplitude to drive the ADI directly. Therefore, these signals are connected to the ADI Support board. The ADI Support board has amplifiers and amplitude adjustment trim potentiometers. The outputs of the amplifiers are wired to the ADI connector.

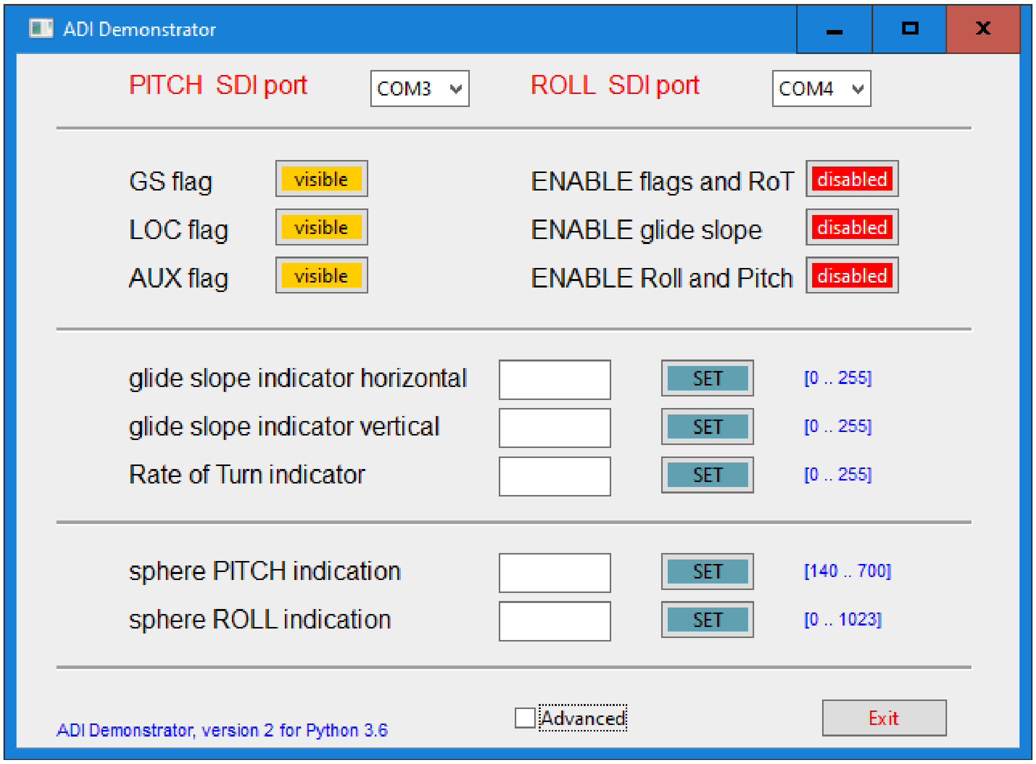
One additional digital output is used to enable/disable the Pitch and Roll servos inside the ADI. If the servos inside the ADI are disabled, the sphere will not move. This is controlled via relay contacts. Thus, to operate the sphere movement, you must first activate that relay. One digital output from the first SDI board connects to the ADI Support board to control that relay.

Sphere Roll movement connections

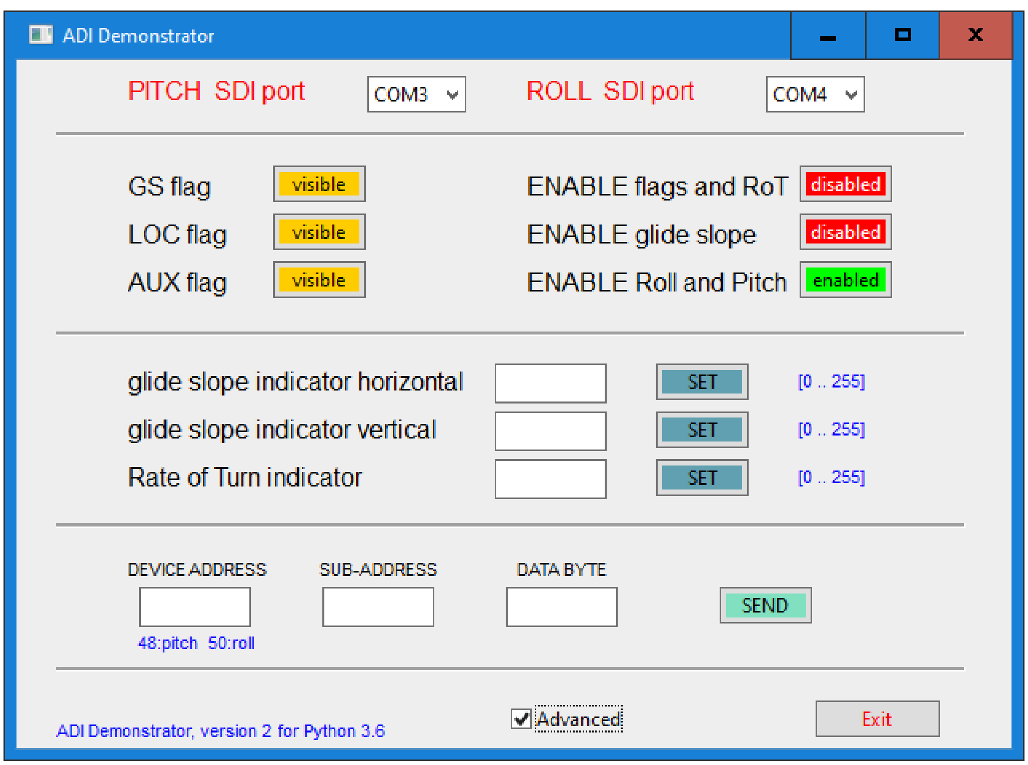
Connection	from	to
roll synchro S1	SDI board #2 SYNCHRO #5	ADI Support SYNR #4
roll synchro S2	SDI board #2 SYNCHRO #4	ADI Support SYNR #3
roll synchro S3	SDI board #2 SYNCHRO #3	ADI Support SYNR #2
pitch & roll servo enable	*SDI board #1 SV1 #1*	*ADI Support SV1 #1*
roll S1	ADI Support ROLL #1	external amplifier #4 input
roll S2	ADI Support ROLL #2	external amplifier #5 input
roll S3	ADI Support ROLL #3	external amplifier #6 input
roll S1SIG	external amplifier #4 output	ADI connector #2
roll S2SIG	external amplifier #5 output	ADI connector #9
roll S3SIG	external amplifier #6 output	ADI connector #10
roll ENABLE	ADI Support ADI2 #1	ADI connector #22
	ADI Support ADI2 #2	ADI connector #23

Test execution Pitch indicator

1. Connect the +24V DC, 115V AC 400 Hz and GND connections.
   Note that the ADI is **not yet** connected.
2. Start the ADI Test application.
3. Select the COM ports for **both** SDI boards.

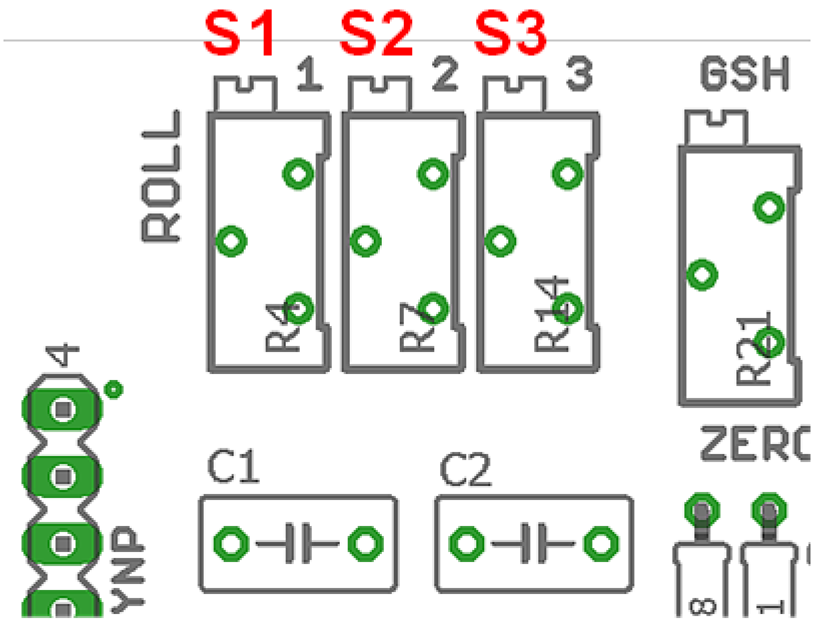


4. Click the button "ENABLE Roll and Pitch". The red colored button with the text "disabled" will change to a green colored button with the text "enabled". This will activate the relay.
5. Click the checkbox "Advanced" at the bottom.



6. Enter in the “DEVICE ADDRESS” field the number 50 for the ROLL SDI board.
7. Enter in the “SUB-ADDRESS” field the number 34 (output stator S1).
8. Enter in the “DATA BYTE” field the number 255.
9. Click the button “SEND”.
10. Enter in the “SUB-ADDRESS” field the number 35 (output stator S2).
11. Click the button “SEND”.
12. Enter in the “SUB-ADDRESS” field the number 36 (output stator S3).
13. Click the button “SEND”.

After these commands you can adjust the amplitude level of the Roll stator amplifiers.

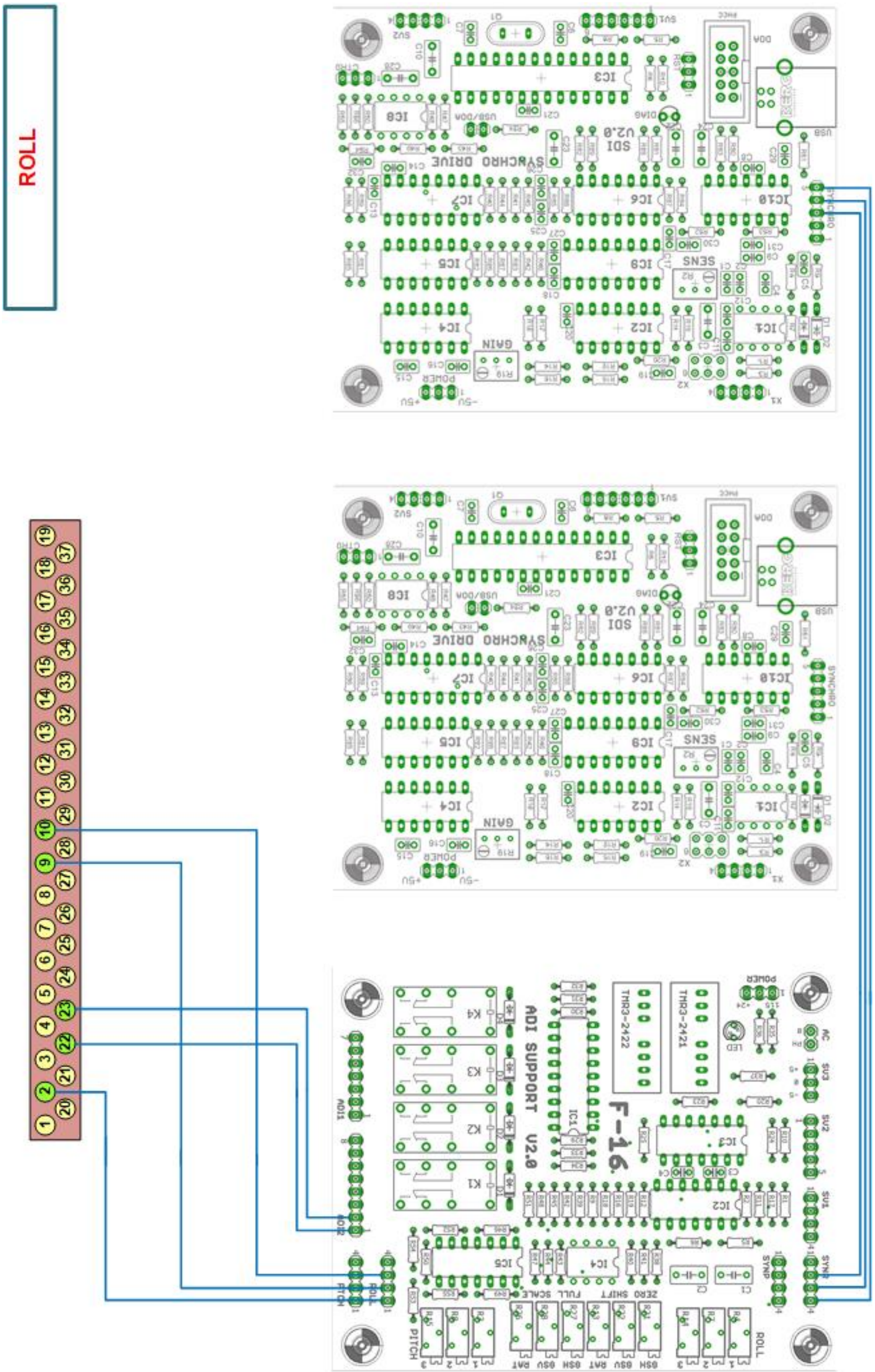


Adjustment steps for the Roll stator coils

1. Connect a multi-meter set to **AC** Volts range to ADI connector.
2. The + lead connects to **#2** and the – lead connects to **#27**.
3. Adjust the ROLL S1 trim potentiometer (R4) until the voltmeter reads 7.00V.
4. The + lead connects to **#9** and the – lead connects to **#27**.
5. Adjust the ROLL S2 trim potentiometer (R7) until the voltmeter reads 7.00V.
6. The + lead connects to **#10** and the – lead connects to **#27**.
7. Adjust the ROLL S3 trim potentiometer (R14) until the voltmeter reads 7.00V.

Check the ROLL ENABLE output

1. Connect a multi-meter set to **Ohm** range to ADI connector.
   The + lead connects to **#22** and the – lead connects to **#23**.
2. Click the button “ENABLE Roll and Pitch”.
3. Check that the multi-meter reads 0 Ω when the button is green, and the reading is ∞ “infinity” when the button is red.


ROLL

5. Assembly of the ADI Support board

Needed tools, besides a fine low-wattage soldering iron are a multi-meter, and a small screwdriver. Read through the steps below to have an idea of the work you are about to do.

Take your time to solder the components on the PCB. Better spend a few more minutes working accurately now, than searching for that little solder excess that causes a short circuit.
Soldering the components in order from smallest height to higher has the advantage that the board lays stable on your desk while soldering and keeps the component against the PCB. Therefore the following soldering order is proposed. All components are placed on the component side of the PCB. The component side has the white text painted on the PCB (the so-called silkscreen). See the “Appendix A – Component locator” for reference.

Observe ESD safety measures to prevent static discharge damage.
(This applies to diodes, the LED and ICs)

1. Solder the four diodes. The cathode of the diode is the ‘bar’ in the symbol. The ‘bar’ shows the orientation where the ‘ring’ of the diode must be.
2. Solder all resistors, except R29, R30, R31, R32, R33, R34 and the 12 trim potentiometers. Make sure that the resistors with the different values are in their correct position. Check chapter 6 and Appendix A for reference. If you are not sure that you read the color code correctly, use an Ohm meter. Resistors R29, R30, R31, R32, R33, and R34 depend on what type of instrument you connect to the board. See chapter 4.
3. Solder the five IC sockets, if you want to use sockets. I always use sockets, not to protect the ICs, but the PCB! If an IC is defective, it can easily be swapped. A soldered IC is difficult to remove and you likely damage the PCB traces or the through-hole plating. The PCB is much more valuable than any of the ICs. Make sure that the notch, which indicates pin #1 location, is at the correct side. The silkscreen shows the notch.
4. Solder the LED. The longer wire of the LED (the anode) is “towards” header POWER, the shorter wire of the LED (cathode) is “towards” resistor R37.
5. Solder all headers.
6. Solder the two capacitors.
7. Solder the twelve trim potentiometers. The 100k trim potentiometers are the row of six, the 20k trim potentiometers are two groups of three near the “upper” corners.
8. Solder the two DC/DC converters. Make sure that they are not swapped! The TMR3-2422 is next to IC1 and the TMR3-2421 is next to the LED.
9. Solder the four relays.
10. Install all 5 ICs in their socket. See chapter 6 and Appendix A for reference. ***Observe the correct orientation; pin #1 is at the notch side.***
    → ICs with wrong orientation on the PCB will be damaged when power is applied!

Before you proceed, do a visual inspection of the board with a bright light and magnifying glass.
- ✓ Are the four diodes installed in the correct orientation?
- ✓ Are all soldering joints clean and shiny? A dull soldering joint may be a bad soldered joint.
- ✓ No small droplets of solder near the soldering joints?

TIP *You can use an old tooth brush to brush off solder residue and tiny solder droplets.*

© Functionality check.

1. Connect the +24 Volt power supply to the header POWER.
   Observe correct polarity!
   → All ICs on the PCB will be damaged if the polarity is wrong!
2. Observe that the LED turns ON.
3. Set the multimeter to measuring **DC** voltages.
   Connect the –lead to GND (0V of the power supply).
   a. Put the +lead tip on pin 4 of IC3. The meter should show +12V.
   b. Put the +lead on pin 11 of IC3. The meter should show –12V.
   c. Put the +lead tip on pin 1 of header SV3. The meter should show +5V.
   d. Put the +lead on pin 3 of header SV3. The meter should show –5V.
4. Switch OFF the power supply (and multimeter ☺). Wait until the LED is OFF before you proceed.

If steps 3a and 3b show 5 Volts and step 3c and 3d show 12 Volts, you swapped the DC/DC converters ☹ … If everything checked out fine, the electrical checks are done and you can proceed to “Setup and Adjustments”.

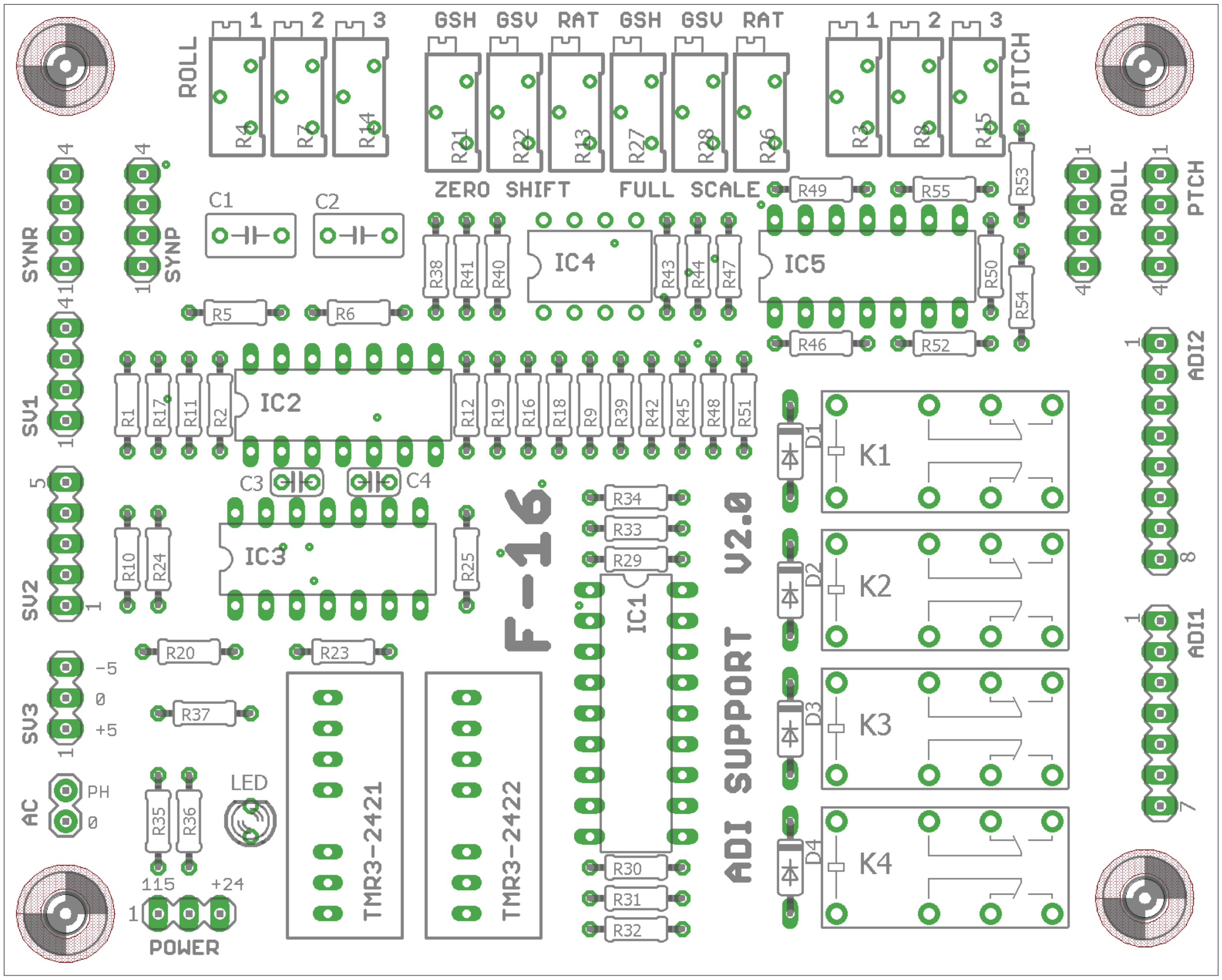
6. Parts list ADI Support board

Quantity	Component	description
1	IC1	UDN2981A
3	IC2, IC3, IC5	LM324
1	IC4	LM358
1	IC socket DIL, 8-pin	high-quality machined pin socket
3	IC socket DIL, 14-pin	high-quality machined pin socket
1	IC socket DIL, 18-pin	high-quality machined pin socket
4	D1, D2, D3, D4	1N4148
1	LED	3 mm, any color
4	K1, K2, K3, K4	relay M4 24H
1	TMR3-2421	Traco dual DC/DC converter +/–5V 3W
1	TMR3-2422	Traco dual DC/DC converter +/–12V 3W
2	C1, C2	680nF
2	C3, C4	100nF
2	C5, C6	10 µF polarized
2	R1, R2	470k
6	R3, R4, R7, R8, R14, R15	20k trim potentiometer TRIMM64Z
2	R5, R6	120k
21	R9, R10, R11, R12, R16, R18, R23, R24, R25,R38, R39, R41, R42, R44, R45, R47, R48, R50, R51, R53, R54	10k
6	R13, R21, R22, R26, R27, R28	100k trim potentiometer TRIMM64Z
3	R17, R19, R20	15k
1	R29	10k (*)
2	R30, R31	8k2 (*)
1	R32	470 Ω (*)
2	R33, R34	3k3 (*)
1	R36	1k
1	R35	100k
1	R37	1k5
6	R40, R43, R46, R49, R52, R55	56k
1	AC	2-pin male header
2	POWER, SV3	3-pin male header
5	PTCH, ROLL, SV1, SYNP, SYNR	4-pin male header
1	SV2	5-pin male header
1	ADI1	7-pin male header
1	ADI2	8-pin male header
1	PCB	ADI SUPPORT V2.0

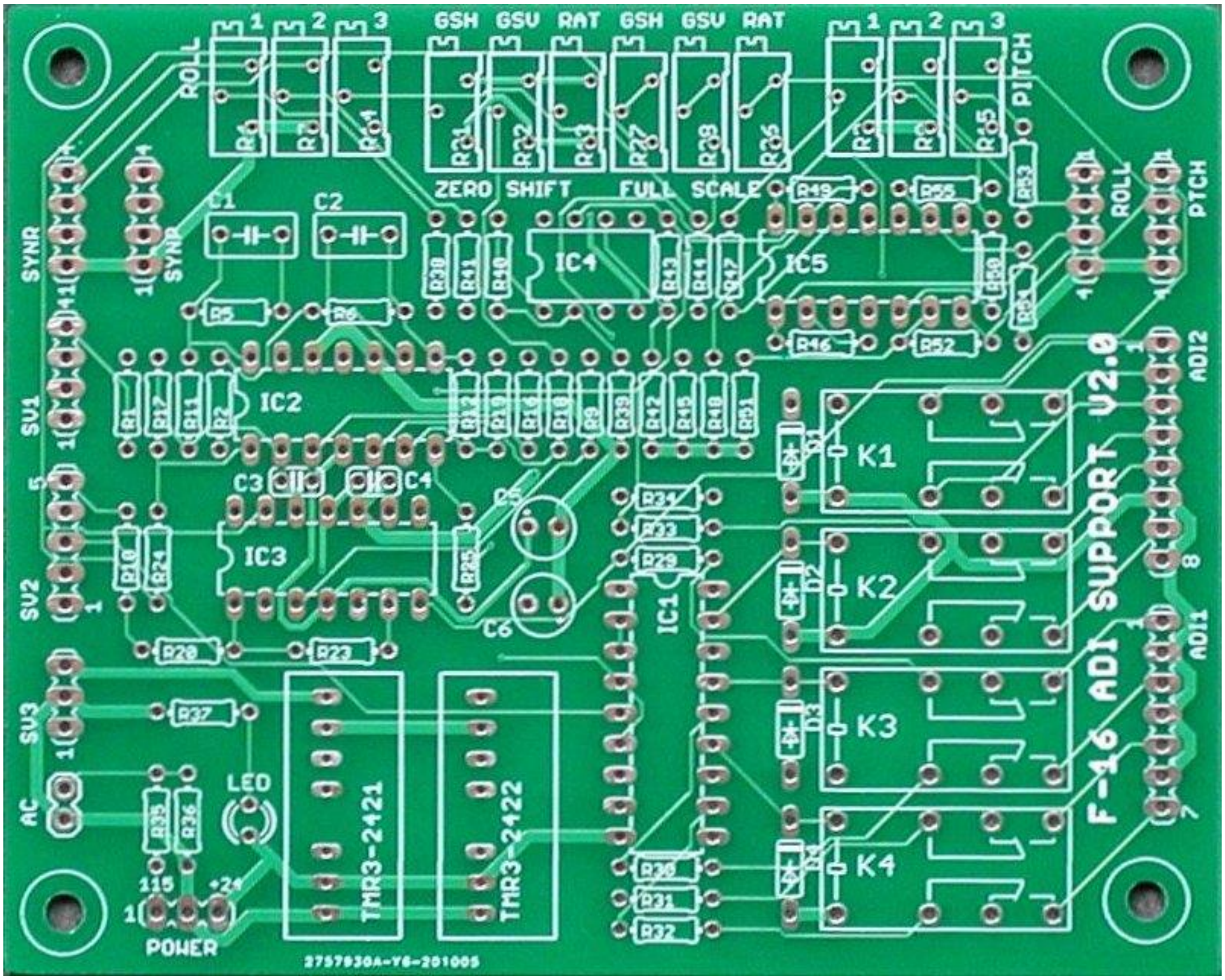
- All capacitors are non-polarized.
- Component values may change without notice.
- **(*) Value may be different depending on usage, see chapter 4.**

Appendix A. Component locator ADI Support board

This image is retrieved from the actual Eagle .BRD file. For clarity all PCB traces are removed.



Appendix B – PCB component side ADI Support board



Appendix C – Connection of the ARU-50/A

I used a 37-pin sub-D connector on the ADI box, and wired the ADI Support interface to the pins of this connector matching the pin numbers for the ARU-50/A ADI. That way the connection cable from the 37-pin sub-D connector to the connector on the ADI instrument can be “1:1”, that is, pin 1 to pin 1, pin 2 to pin 2, etc.

Pins 32 to 37 on the 37-pin sub-D are not used as the ADI connector only has 31 pins.

pin #	function
1	frame GND
2	Roll stator S1
3	+24VDC
4	Rate of Turn +
5	Rate of Turn –
6	AUX flag
7	Pitch stator S1
8	Pitch stator S2
9	Roll stator S2
10	Roll stator S3
11	Glide Slope HOR +
12	Glide slope HOR –
13	Internal lighting +
14	Internal lighting –
15	Spare
16	Glide slope VERT +

pin #	function
17	Glide slope VERT –
18	Spare
19	Pitch stator S3
20	Pitch null test
21	Roll null test
22	Roll ENABLE
23	Roll ENABLE
24	Glide slope flag +
25	Glide slope flag –
26	115VAC HOT
27	115VAC / 24VDC GND
28	LOC flag +
29	LOC flag –
30	Pitch ENABLE
31	Pitch ENABLE

Appendix D – ADI interface on a carrier board