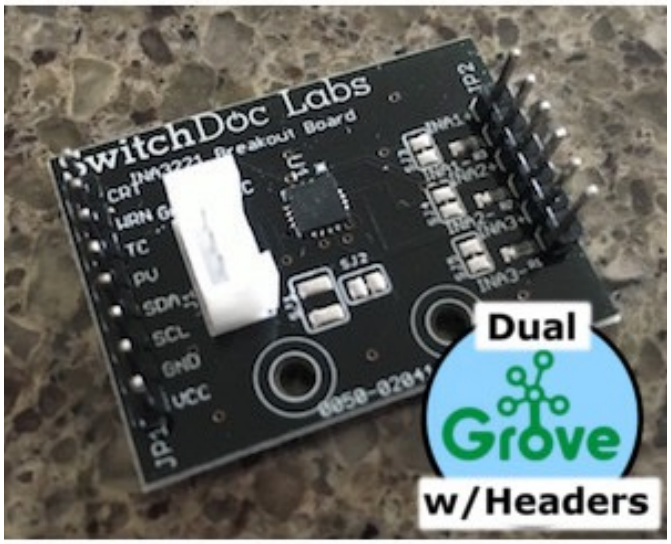
Product Specification

SwitchDoc Labs

Dual Grove/Pin INA3221 Breakout Board

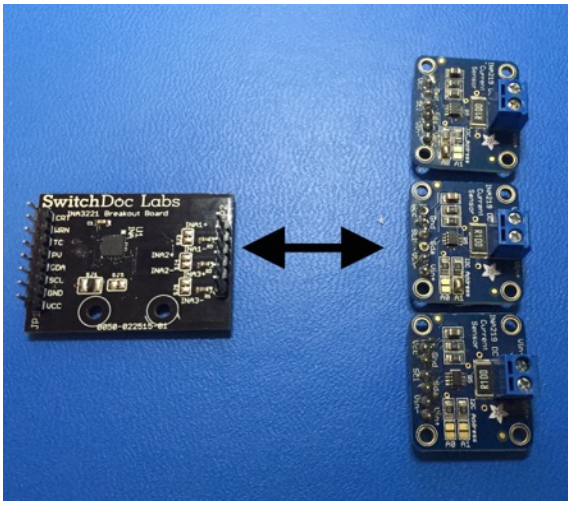


The **Dual Grove/Pin INA3221 Breakout Board** is an easy to use 3 Channel Current / Voltage I2C Monitor.

The Dual Grove/Pin INA3221 Breakout Board monitors both shunt voltage drops and bus supply voltages in addition to having programmable conversion times and averaging modes for these signals. The INA3221 also offers both critical and warning alerts to detect multiple programmable out-of-range conditions for each channel.

Features and Benefits:

- Works with Pin Headers and Grove Connectors
- 3 Channel AD converter for current/voltage
- Works with Arduino and Raspberry Pi
- 3.3V / 5.0V I2C Bus
- Senses 0V to +26V
- Offset Voltage: +/-80 uV (Max)
- Gain Error: 0.25% (Max)
- Four Programmable Addresses
- Programmable Conversion Times
- 0.1 Ohm Shunt Resistors (Can be replaced)
- Compare to using 3 INA219 single channel devices
- Software Drivers for Arduino and Raspberry Pi Included!
- Low Cost
- Quantity Discounts Available
- Immediate Availability



Introduction

The Dual Grove/Pin INA3221 Breakout Board is a three-channel, high-side current and bus voltage monitor with an I2C interface.

Sometimes, you want to measure lots of things in your system. A great example is when you have a solar powered system. To figure out what is going on in your solar system dynamically, you need to measure the current and voltage for the Solar Cells, Batteries and the Load (computer) all at the same time. The conventional way to do this is to use three $10 INA219 (same function, but only one channel) for a cost of $30 and much more wiring / space. This Dual Grove/Pin

INA3221 Breakout Board will do the same job as three INA219's **but for about half the cost** and about 40% of the space.

What is the Grove Connector System?

Grove is a modular, standardized connecter prototyping system. Grove takes a building block approach to assembling electronics. Compared to the jumper or solder based system, it is easier to connect, experiment and build and simplifies the learning system, but not to the point where it becomes dumbed down. Some of the other prototype systems out there takes the level down to building blocks. Good stuff to be learned that way, but the Grove system allows you to build real systems. It requires some learning and expertise to hook things up.

The Grove system consists of a base unit (stem) and various modules (twigs) with **standardized connectors.** The people originating the Grove system (Seeedstudio) have tried to use “stems” and “twigs” as part of the Grove lexicon. After a short period of consideration, I’m dropping those names. They just aren’t needed and just confuse the issue.

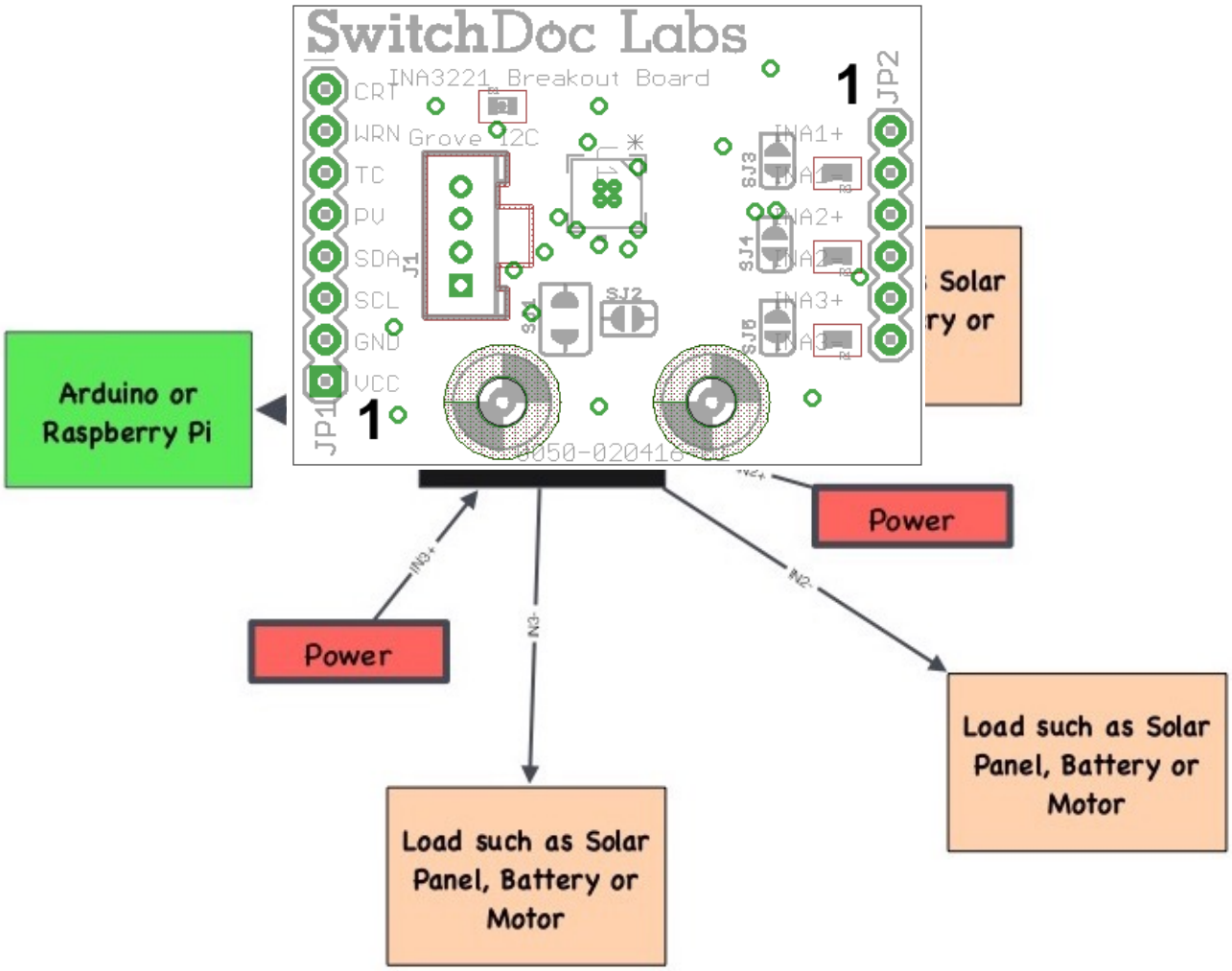
The Base unit, generally a microprocessor, allows for easy connection of any input or output from the Grove modules. and every Grove module typically addresses a single function, such as a simple button or a more complex heart rate sensor.

You don’t need a Base unit to connect up to Grove modules. You an use a cable (jumper wires to Grove connector) to run from the pins on the Raspberry Pi or Arduino to the Grove connectors. That is what I do in the SunRover project and in the examples below.

How To Use

The INA3221 is a three-channel, high-side current and bus voltage monitor with an I2C interface. The INA3221 monitors both shunt voltage drops and bus supply voltages in addition to having programmable conversion times and averaging modes for these signals. The INA3221 also offers both critical and warning alerts to detect multiple programmable out-of-range conditions for each channel. There are three 0.1 Ohm shunts already on the board that can be removed by cutting a trace on the board if you want some other value.

To use the INA3221, you connect the I2C bus up to an Arduino or Raspberry Pi and then connect the loads that you want to measure as shown below:



Dual Grove/Pin INA3221 V2 Breakout Board Pinout

Wiring Lists

Raspberry Pi (A/B/A+/B+/Pi 2)

Signal Name	Raspberry Pi A/B/A+/B+/Pi 2	Dual Grove/Pin INA3221 Breakout Board
Power	3.3V (GPIO/1)	VCC (JP1/1)
GND	GND (GPIO/6)	GND (JP1/2)
SCL	I2C1_SCL (GPIO/5)	SCL (JP1/3)
SDA	I2C1_SDA (GPIO/3)	SDA (JP1/4)

Arduino Uno

Signal Name	Arduino Uno	Dual Grove/Pin INA3221 Breakout Board
Power	5.0V (POWER/5V)	VCC (JP1/1)
GND	GND (POWER/GND)	GND (JP1/2)
SCL	ADC5/SCL (ANALOG IN/A5)	SCL (JP1/3)
SDA	ADC4/SDA (ANALOG IN/A4)	SDA (JP1/4)

Ardunio Mega 2560

Signal Name	Arduino Mega 2560	Dual Grove/Pin INA3221 Breakout Board
Power	5.0V (POWER/5V)	VCC (JP1/1)
GND	GND (POWER/GND)	GND (JP1/2)
SCL	SCL (COMMUNICATIONS 21)	SCL (JP1/3)
SDA	SDA (COMMUNICATIONS 20)	SDA (JP1/4)

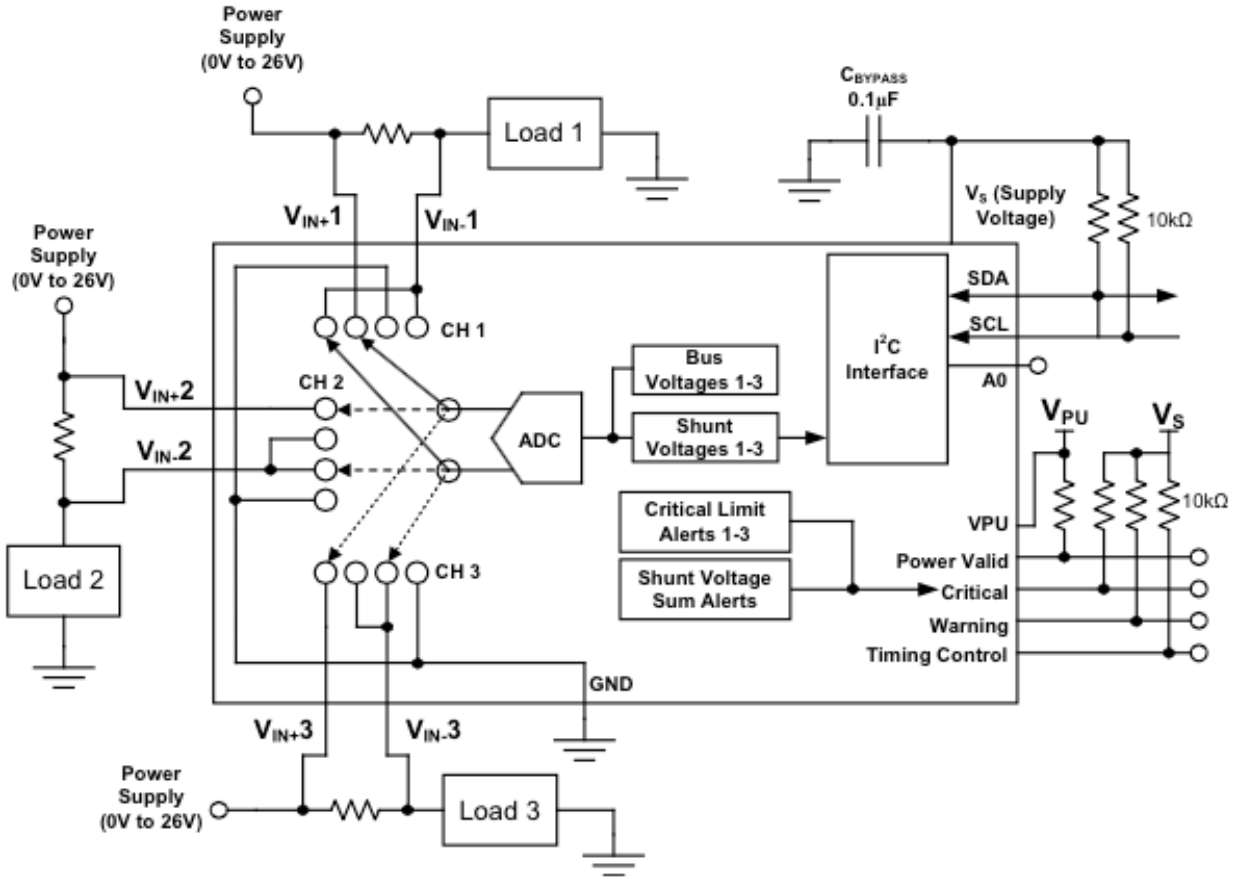
Note: As with all SwitchDoc Labs Breakout Boards, the Dual Grove/Pin INA3221 Breakout Board does not contain any Pullup resistors for the I2C Bus SCL/SDA. You must supply those somewhere on your bus (10K resistors generally work well). We do not put pull-ups on boards because if you put multiple devices on the same I2C bus you will end up having too many pull-ups.

Theory of Operation

INA3221 IC

For more information, see the full INA3221 Specification at: http://www.ti.com/lit/ds/symlink/ina3221.pdf

The INA3221 senses current on buses that can vary from 0 V to +26 V. The device is powered from a single +2.7-V to +5.5-V supply and draws 350 µA (typ) of supply current. The INA3221 is specified over the operating temperature range of –40°C to +125°C. The I2C interface features four programmable addresses.



The INA3221 is a current-shunt and bus voltage monitor that communicates over an I2C- and SMBus-compatible interface. The device provides digital shunt and bus voltage readings necessary for accurate decision making in precisely-controlled systems and also monitors multiple rails to ensure compliance voltages are maintained. Programmable registers offer flexible configuration for measurement precision and continuous versus single-shot operation.

The INA3221 performs two measurements on up to three power supplies of interest. The voltage developed from the load current passing through a shunt resistor creates a shunt voltage that is measured between the IN+ and IN– pins. The device also internally measures the power-supply bus voltage at the IN– pin for each channel. The differential shunt voltage is measured with respect to the VIN– pin while the bus voltage is measured, with respect to ground.

As noted, the INA3221 takes two measurements for each channel. Each measurement can be independently or sequentially measured, based on the mode setting (bits[2:0] in the Configuration Register). When the INA3221 is in normal operating mode (that is, the MODE bits of the Configuration Register are set to '111'), the device continuously converts a shunt voltage reading followed by a bus voltage reading. This procedure converts one channel and then continues to the shunt voltage reading of the next enabled channel, followed by the channel bus voltage reading for that channel, and so on, until all enabled channels have been measured. The programmed Configuration Register mode setting applies to all channels. Any channels not enabled are bypassed in the measurement sequence, regardless of mode setting.

The INA3221 has two operating modes (continuous and single-shot) that determine the internal ADC operation after these conversions complete. When the INA3221 is set to continuous mode, based on the MODE bit settings, the device continues to cycle through all enabled channels until a new configuration setting is programmed.

ALERT MONITORING

Because the INA3221 allows programmable thresholds that ensure the intended application operates within the desired operating conditions, multiple monitoring functions are available via four Alert pins: Critical Alert, Warning Alert, Power Valid Alert, and Timing Control Alert. These Alert pins are open-drain connections.

Critical Alert

The Critical Alert monitors functions based on individual conversions of each shunt voltage channel. The Critical Alert Limit feature compares the shunt voltage conversion for each channel to the corresponding value programmed into the corresponding limit register to determine if the measured value exceeds the intended limit. Exceeding the programmed limit indicates that the current through the shunt resistor is too high. The default Critical Alert Limit value for each channel is set to a

positive full-scale value to effectively disable this alert at power-up. The corresponding limit registers can be programmed at any time to begin monitoring for out-of-range conditions. The Critical Alert pin is asserted and pulled low if any channel measurements exceed the limit present in the corresponding channel Critical Alert Limit. When the Critical Alert pin is asserted, the Mask/Enable Register can be read to determine which channel caused the Critical Flag Bit to assert.

The INA3221 also allows the Critical Alert pin to be controlled by the Summation Control function. The Summation Control function compares the sum of the single conversions of the desired channels based on the Summation Channel Control bits set in the Mask/Enable Register to determine if the combined sum has exceeded the programmed limit. In order for this summation limit to have a meaningful value, all included channels must use the same shunt resistor value. The individual conversion values cannot be added directly together in the Shunt Voltage Sum register to report the total current unless equal shunt resistor values are used for each channel. The Summation Channel Control bits either disable the Summation Control function or allow the Summation Control function to switch between including two or three channels in the Shunt Voltage Sum register. The Shunt Voltage Sum Limit register contains the programmed value used to compare the Shunt Voltage Sum register to determine if the total summed limit has been exceeded. If the Shunt Voltage Sum Limit value is exceeded, the Critical Alert pin is asserted low. Either the Summation Flag bit or the individual Critical Alert Limit bits in the Mask/Enable Register can determine the source of the alert when the Critical Alert pin asserts.

Warning Alert

The Warning Alert monitors the averaged value of each shunt voltage channel. The averaged value of each shunt voltage channel is based on the number of averages set with the Average Mode bits in the Configuration Register. The average value is updated in the shunt voltage output register each time there is a conversion on the corresponding channel. The averaged value is compared to the value programmed in the corresponding channel Warning Alert Limit register to determine if the averaged value has been exceeded, which indicates if the average current is too high. The default Warning Alert Limit value for each channel is set to a positive full-scale value to effectively disable this alert at power-up. The corresponding limit registers can be programmed at any time to begin monitoring for out-of-range conditions. The Warning Alert pin is asserted and pulled low if any channel measurements exceed the limit present in the corresponding channel Warning Alert Limit. When the Warning Alert pin is asserted, the Mask/Enable Register can be read to determine which channel Warning Flag Bit is asserted.

Power Valid Alert

The Power Valid Alert verifies if all power rails are above the required levels. This feature allows the INA3221 to ensure power sequencing is properly managed and that the reported measurements are valid based on system configuration. The Power Valid mode starts at power-up to detect when all channels exceed a 10-V threshold. This 10-V level is the default value programmed into the

Power Valid Upper Limit register. This value can be reprogrammed when the INA3221 is powered up to a valid supply voltage level of at least 2.7 V. When all three bus voltage measurements reach the programmed value loaded to the Power Valid Upper Limit register, the Power Valid Alert pin is pulled high. The Power Valid Alert powers up in a low state and is not pulled high until the Power Valid conditions are met, indicating all bus voltage rails are above the Power Valid Upper Limit value.

Timing Control Alert

The INA3221 has a Timing Control Alert function helps verify proper power-supply sequencing. On power-up, the default INA3221 setting is Continuous Shunt and Bus Voltage conversion mode. While in this mode at power-up, the INA3221 internally begins comparing the channel 1 bus voltage to determine when a 1.2-V level is reached.

Operating Values

			Min	Normal	Max	Unit
VCC	Supply Voltage		2.7		5.5	V
Analog Inputs	IN+, IN-	Differential (VIN+) - (VIN-)	-26		26	V
		Common-mode	0		26	V
Analog Inputs Current	IN+, IN-		0		2	A

Pin Locations

Physical dimensions of board: 38 mm x 28mm x 12mm(max).

I/O Key:

I - Digital Input
O - Digital Output
A - Analog

Grove Connector

The Grove Connector on the board is a Standard Grove I2C connector.

The Grove I2C connector has the standard Grove layout. Pin 1 is the SCL signal and Pin 2 is the SDA signal. Power and Ground are the same as the other connectors.

Grove I2C		
Pin 1	SCL	I2C Clock
Pin 2	SDA	I2C Data
Pin 3	VCC	Power for Grove Module (5V or 3.3V)
Pin 4	GND	Ground

Pin Functions

JP1 - Computer Side Pins

Input / Output Control Lines for INA3221 Breakout Board

NAME	PIN	I/O	DESCRIPTION
VCC	JP1 / 1	A	Power for the INA3221 Breakout Board. Use 3.3V with Raspberry Pi and 5.0V with Arduino
GND	JP1 / 2	A	GND
SCL	JP1 / 3	I	Serial bus clock line; open-drain input.
SDA	JP1 / 4	I/O	Serial bus data line; open-drain input/output.
PV	JP1 / 5	O	Power Valid Output; open-drain output.
TC	JP1 / 6	O	Timing Control Alert Output; open-drain output.
WRN	JP1 / 7	O	Warning Alert Output; open-drain output.
CRT	JP1 / 8	O	Critical Alert Output; open-drain output.

JP2 - Measurement Input Pins

Used for connecting loads and power supply that are to be measured.

NAME	PIN	I/O	DESCRIPTION
INA1+	JP2 / 1	A	Connect to load side of the channel 1 shunt resistor. Bus voltage is the measurement from this pin to ground. Shunt resistor of 0.1 Ohm on board. May be replaced by cutting trace.
INA1-	JP2 / 2	A	Connect to supply side of the channel 1 shunt resistor.
INA2+	JP2 / 3	A	Connect to load side of the channel 2 shunt resistor. Bus voltage is the measurement from this pin to ground. Shunt resistor of 0.1 Ohm on board. May be replaced by cutting trace.
INA2-	JP2 / 4	A	Connect to supply side of the channel 2 shunt resistor.
INA3+	JP2 / 5	A	Connect to load side of the channel 3 shunt resistor. Bus voltage is the measurement from this pin to ground. Shunt resistor of 0.1 Ohm on board. May be replaced by cutting trace.
INA3-	JP2 / 6	A	Connect to supply side of the channel 3 shunt resistor.

SJ1 / SJ2 - I2C Address Jumpers

SJ2 is connected to GND and SJ1 is connected to VCC.

SJ2 is by default connected on the board, giving an an I2C Address of 0x40. Cutting SJ2 and soldering SJ1 will give an address of 0x41.

SJ3, SJ4, SJ5 - 0.1 Ohm Shunt Resistor Bypass Jumpers

SJ3, SJ4 and SJ5 are by default connected on the board, running the measured current through the default 0.1 Ohm Shunt resistors on the INA3221 Breakout Board. Cutting these jumpers allows the user to supply their own shunt resistors.

Software for Arduino and Raspberry Pi

SwitchDoc Labs developed this pure Python INA3221 Raspberry Pi library as part of the SunAirPlus product development and for this INA3221 Breakout Board

It is similar to using three INA219 High Side Current Monitors, but not quite. There are significant differences in the chip itself and especially in the software needed. In SunAirPlus, we want to measure the current and voltage for all three major subsystems: The LiPo Battery, Solar Panels and the Computer.

The software is located on the SwitchDoc Labs github under https://github.com/switchdoclabs/SDL_Pi_INA3221.

Arduino drivers are also located on github under https://github.com/switchdoclabs/SDL_Arduino_INA3221.

The first test on the Raspberry Pi should always be “i2cdetect -y 1” which should show you the INA3221 at the default address of 0x40. A similar test can be run on the Arduino.

Running the test results from the INA3221 Breakout board are below:

```
Test SDL_Pi_INA3221 Version 1.0 - SwitchDoc Labs


Sample uses 0x40 and SunAirPlus board INA3221
Will work with the INA3221 SwitchDoc Labs Breakout Board



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LIPO_Battery Bus Voltage: 4.15 V
LIPO_Battery Shunt Voltage: -9.12 mV
LIPO_Battery Load Voltage:  4.14 V
```

```
LIPO_Battery Current 1:  91.20 mA

Solar Cell Bus Voltage 2:  5.19 V
Solar Cell Shunt Voltage 2: -73.52 mV
Solar Cell Load Voltage 2:  5.12 V
Solar Cell Current 2:  735.20 mA

Output Bus Voltage 3:  4.88 V
Output Shunt Voltage 3: 48.68 mV
Output Load Voltage 3:  4.93 V
Output Current 3:  486.80 mA
```