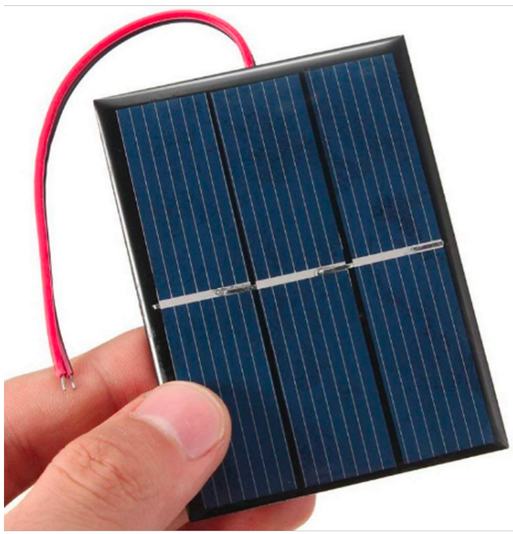
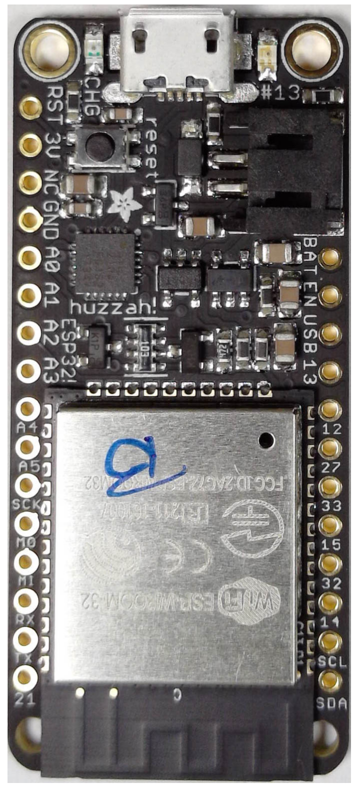
EE 49
Electronics for IoT

Microcontroller

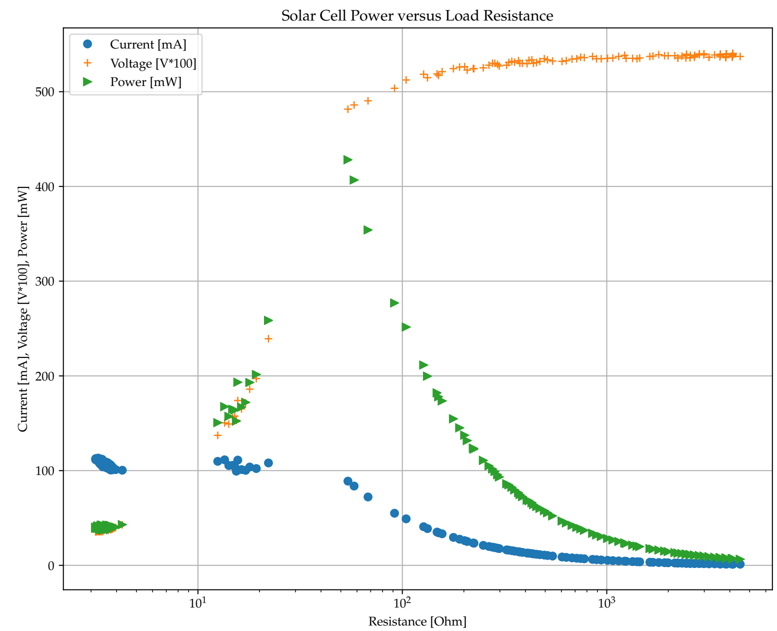
1st Project: characterize solar cell

Goal





huzzah
ESP32

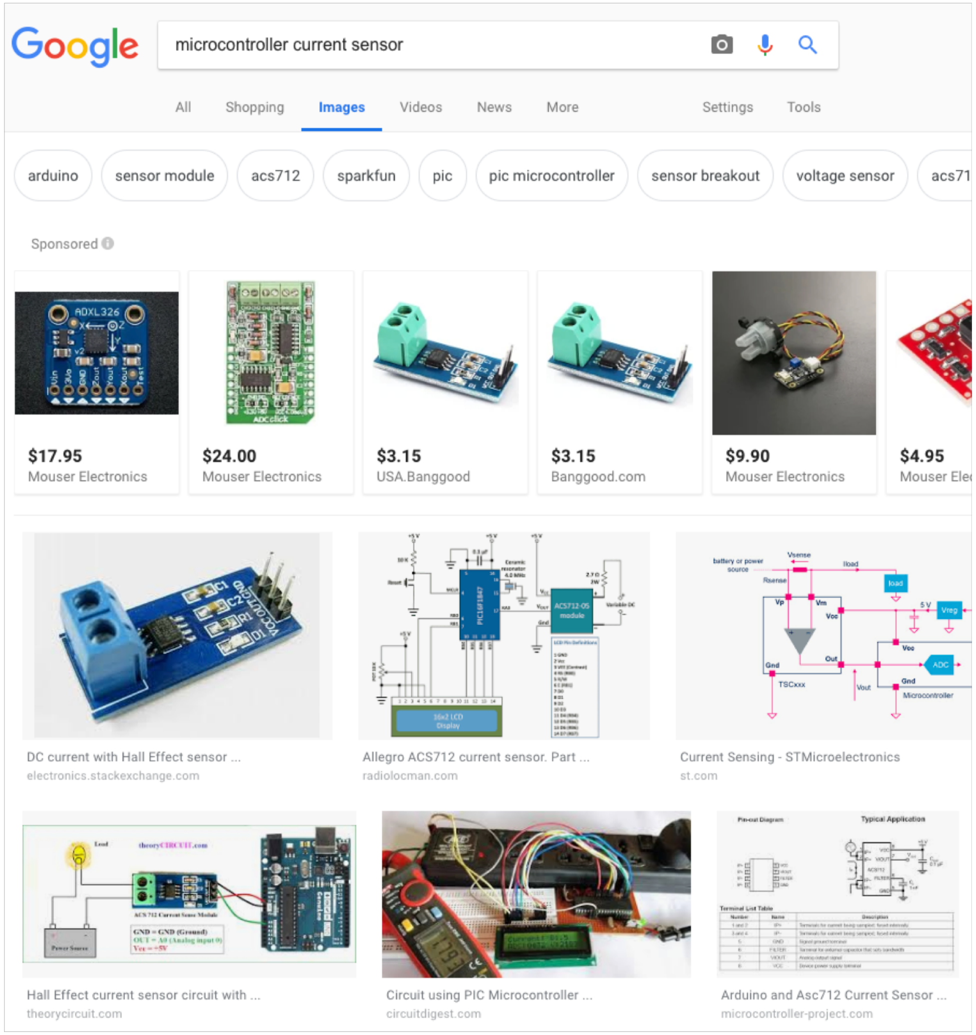


Solar Cell Power versus Load Resistance
Current [mA]
Voltage [V*100]
Power [mW]
Current [mA], Voltage [V*100], Power [mW]
Resistance [Ohm]

Plan

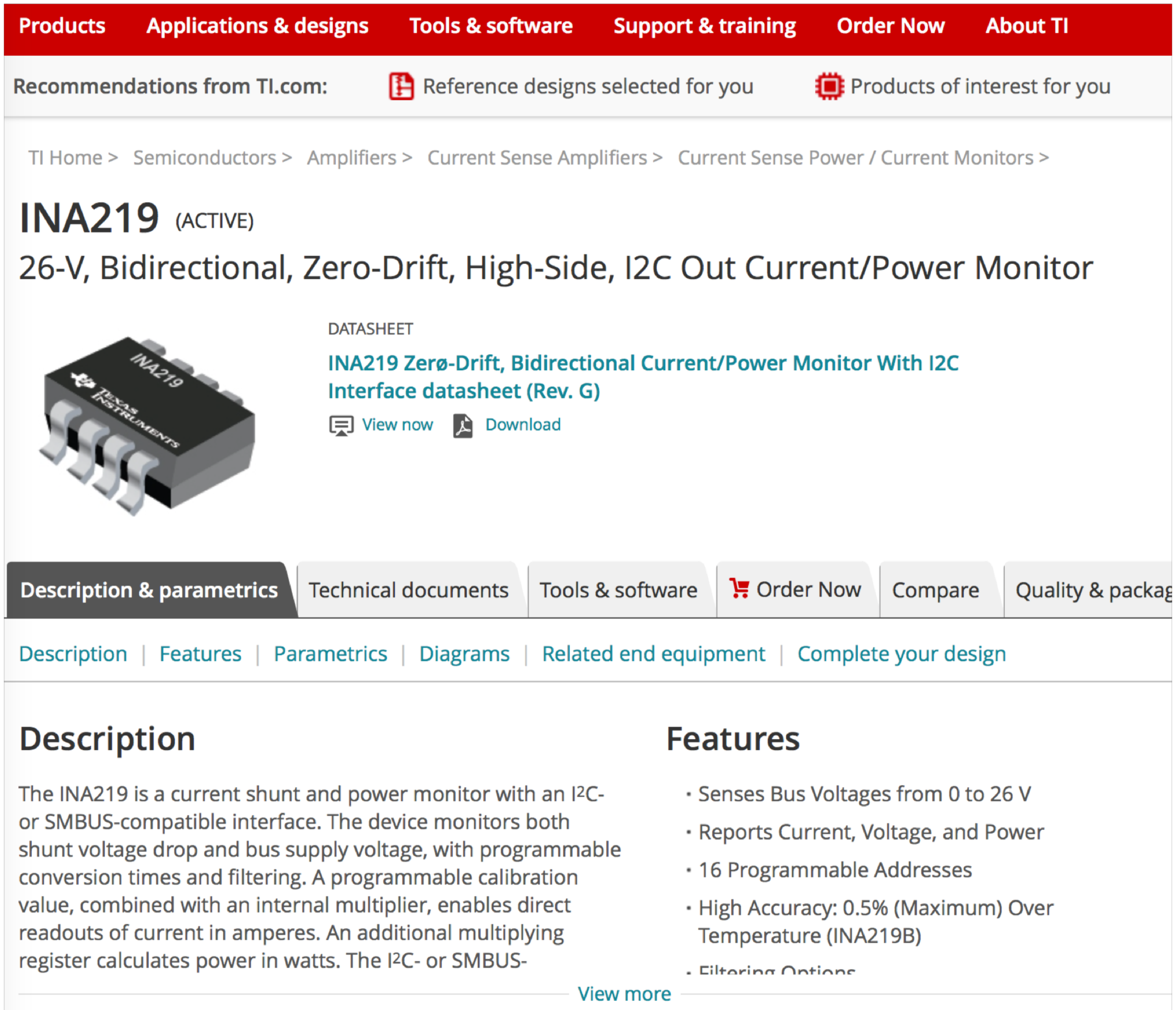
Measure Solar I, V with MCU

Web Search



Google
microcontroller current sensor
All
Shopping
Images
Videos
News
More
Settings
Tools
arduino
sensor module
acs712
sparkfun
pic
pic microcontroller
sensor breakout
voltage sensor
acs71
Sponsored
$17.95
Mouser Electronics
$24.00
Mouser Electronics
$3.15
USA.Banggood
$3.15
Banggood.com
$9.90
Mouser Electronics
$4.95
Mouser Ele
DC current with Hall Effect sensor ...
electronics.stackexchange.com
Allegro ACS712 current sensor. Part ...
radiolocman.com
Current Sensing - STMicroelectronics
st.com
Hall Effect current sensor circuit with ...
theorycircuit.com
Circuit using PIC Microcontroller ...
circuitdigest.com
Arduino and Asc712 Current Sensor ...
microcontroller-project.com

INA 219 Manufacturer Website



INA219 Datasheet

TEXAS INSTRUMENTS

INA219

SBOS448G – AUGUST 2008 – REVISED DECEMBER 2015

INA219 Zerø-Drift, Bidirectional Current/Power Monitor With I^2C Interface

1 Features

- Senses Bus Voltages from 0 to 26 V
- Reports Current, Voltage, and Power
- 16 Programmable Addresses
- High Accuracy: 0.5% (Maximum) Over Temperature (INA219B)
- Filtering Options
- Calibration Registers
- SOT23-8 and SOIC-8 Packages

2 Applications

- Servers
- Telecom Equipment
- Notebook Computers
- Power Management
- Battery Chargers
- Welding Equipment
- Power Supplies
- Test Equipment

3 Description

The INA219 is a current shunt and power monitor with an I^2C- or SMBUS-compatible interface. The device monitors both shunt voltage drop and bus supply voltage, with programmable conversion times and filtering. A programmable calibration value, combined with an internal multiplier, enables direct readouts of current in amperes. An additional multiplying register calculates power in watts. The I^2C- or SMBUS-compatible interface features 16 programmable addresses.

The INA219 is available in two grades: A and B. The B grade version has higher accuracy and higher precision specifications.

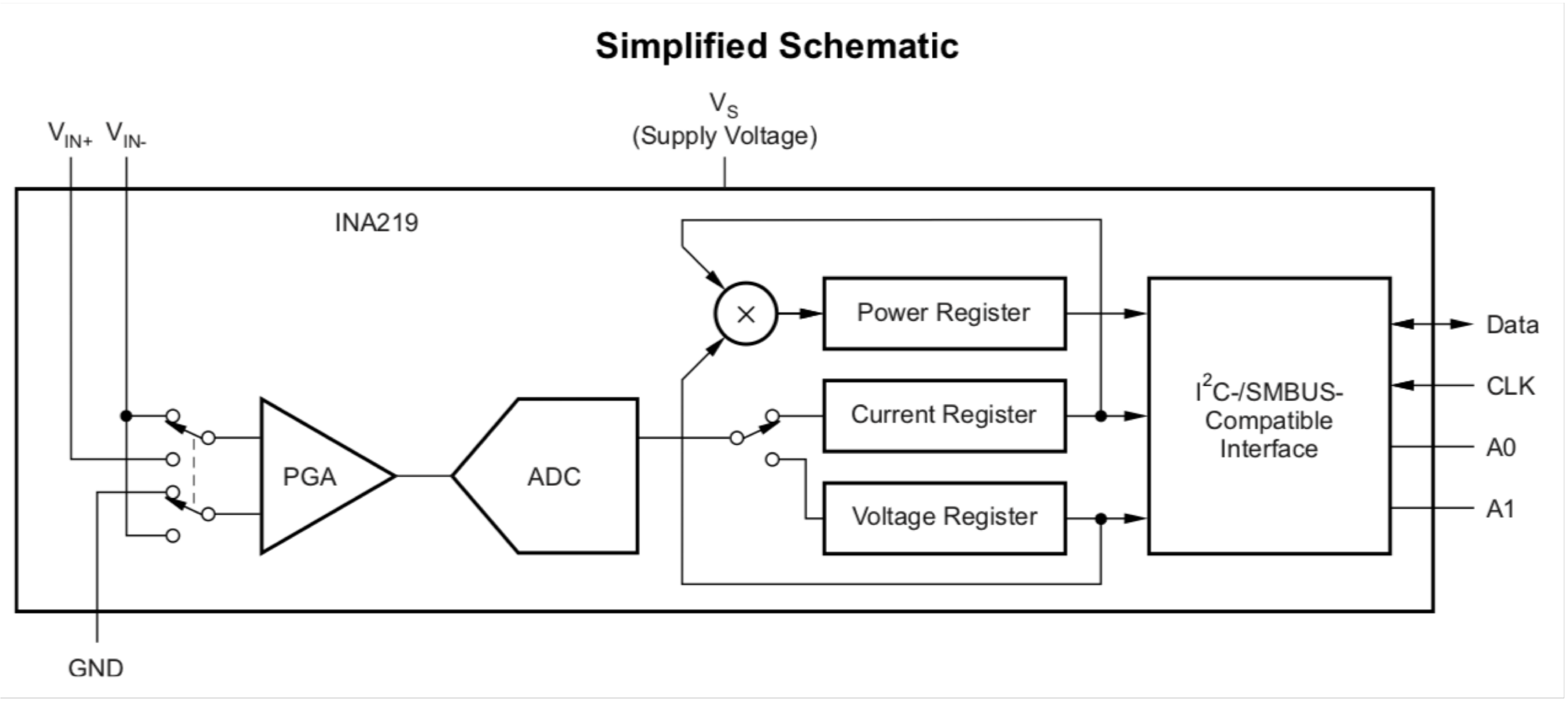
The INA219 senses across shunts on buses that can vary from 0 to 26 V. The device uses a single 3- to 5.5-V supply, drawing a maximum of 1 mA of supply current. The INA219 operates from –40°C to 125°C.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
INA219	SOIC (8)	3.91 mm × 4.90 mm
	SOT-23 (8)	1.63 mm × 2.90 mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

INA219 “Simplified Schematic”



INA219 Configured

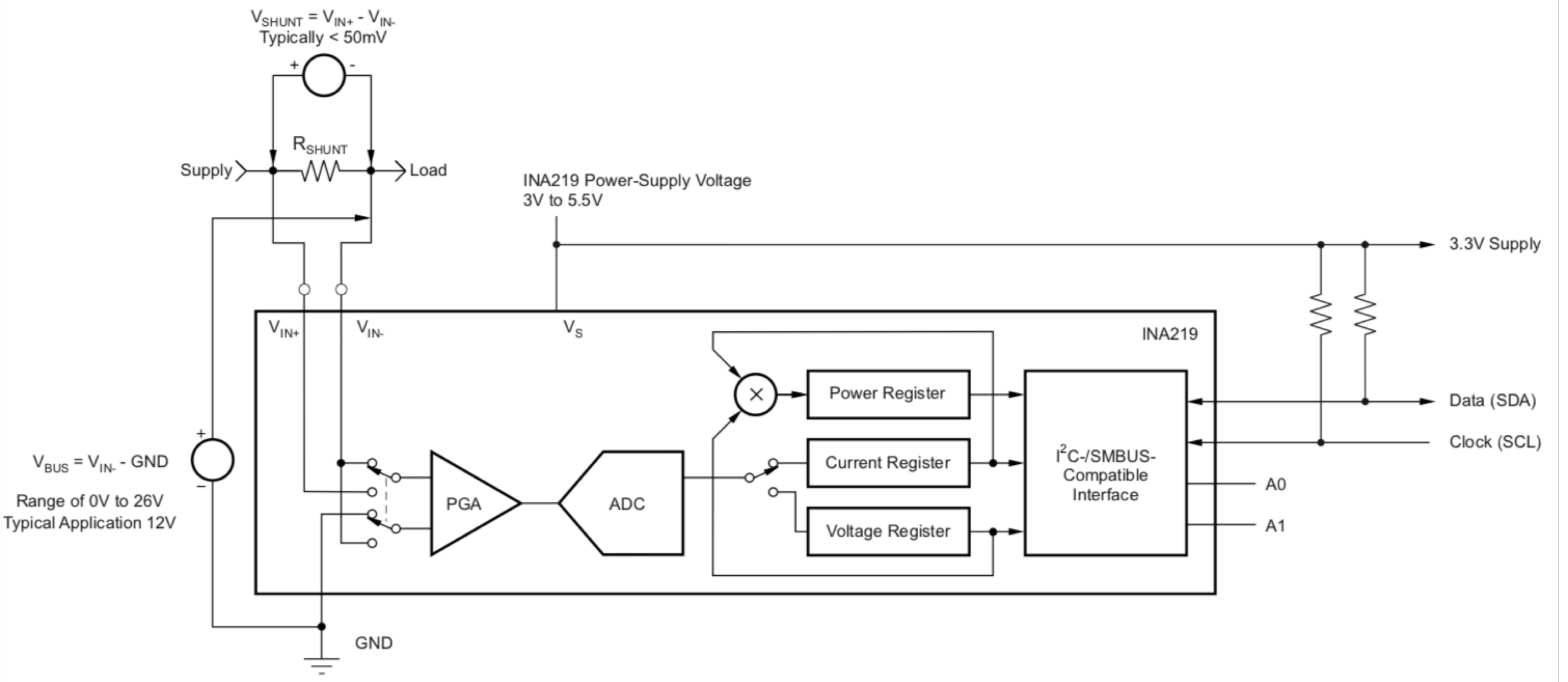


Figure 13. INA219 Configured for Shunt and Bus Voltage Measurement

Let’s Redraw this a little …

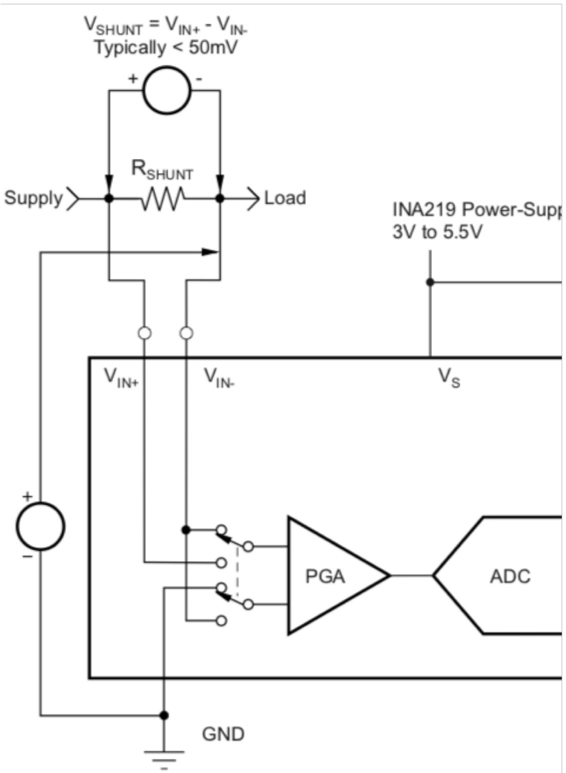
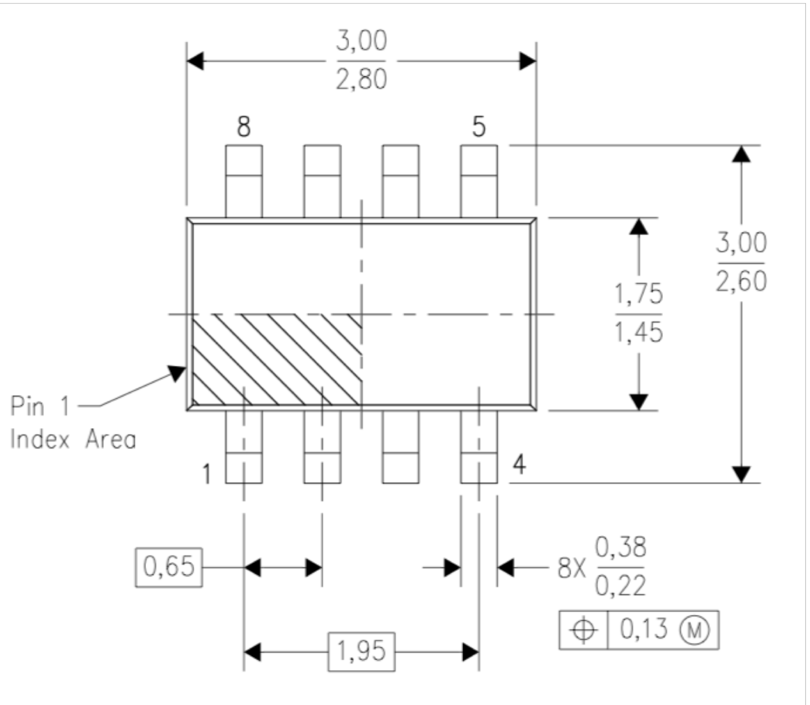
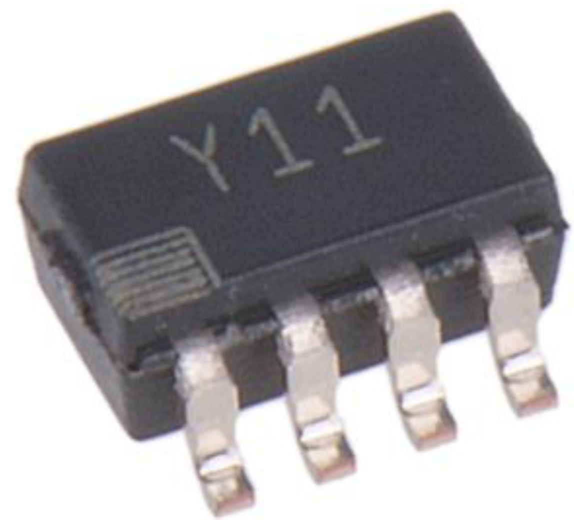


Figure 13. INA219 Configure

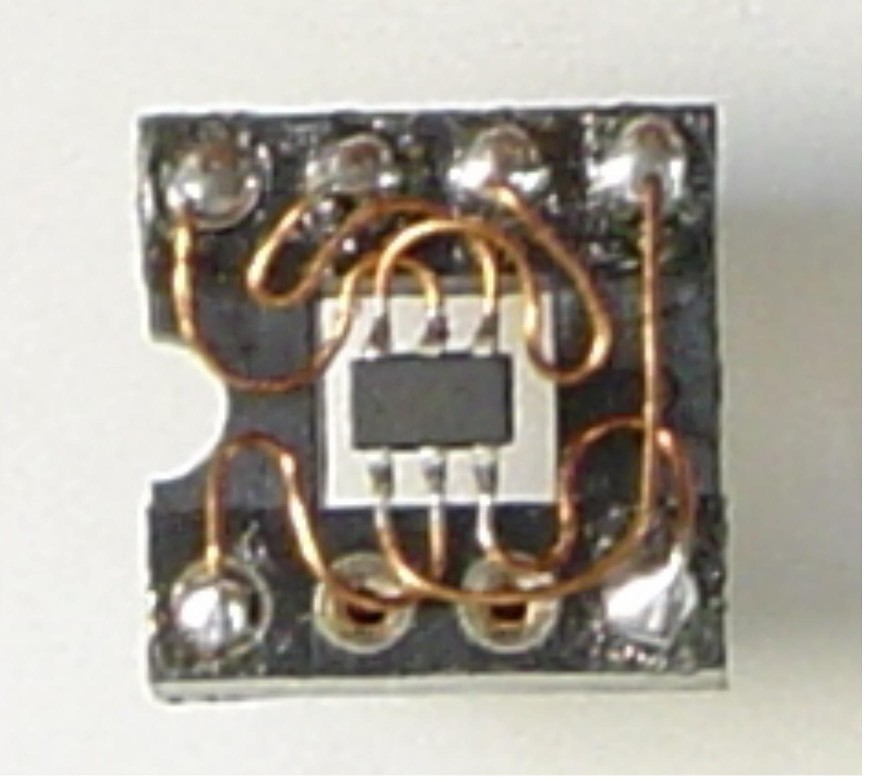
Real INA219



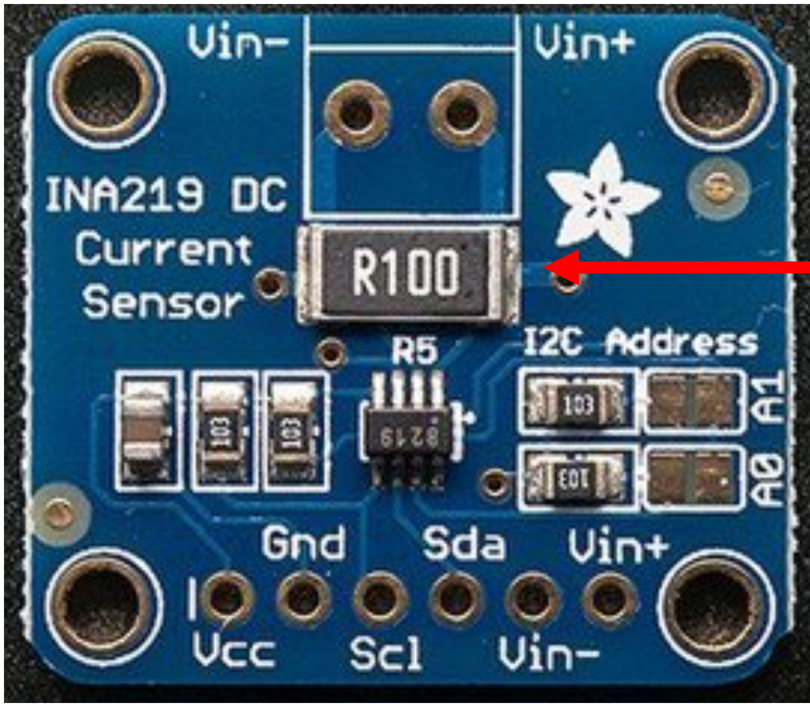
- This thing is tiny
- “big” pepper corn



Hone your soldering skills …



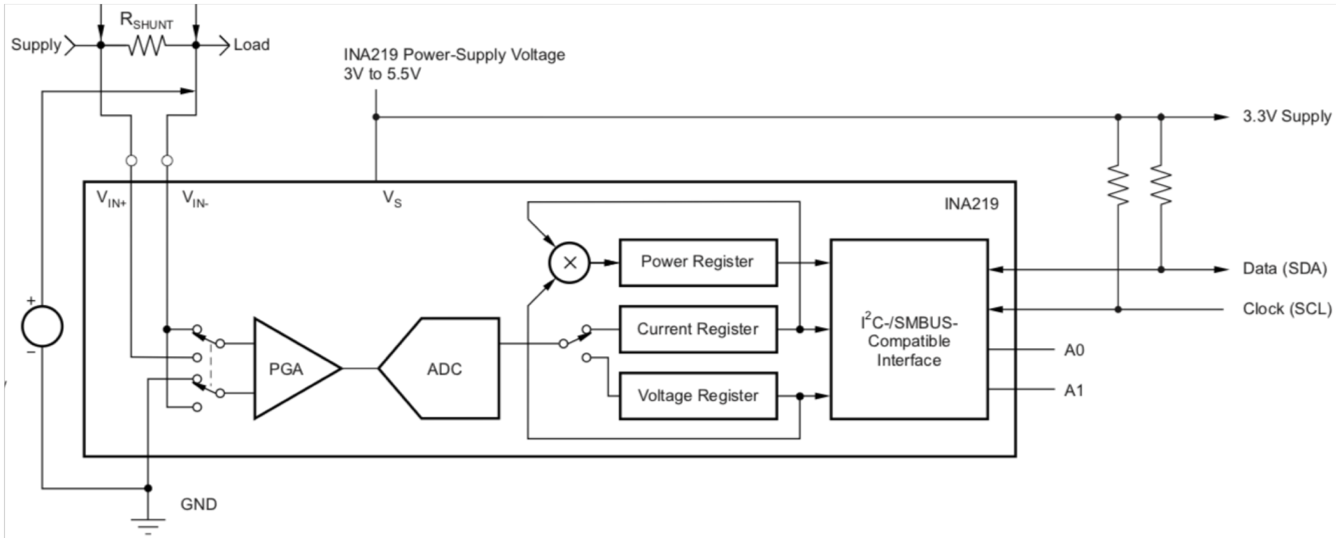
Or get a breakout board …



$R_{SHUNT} = 0.1\Omega$

- https://www.adafruit.com/product/904
- In your “goodies” bag …

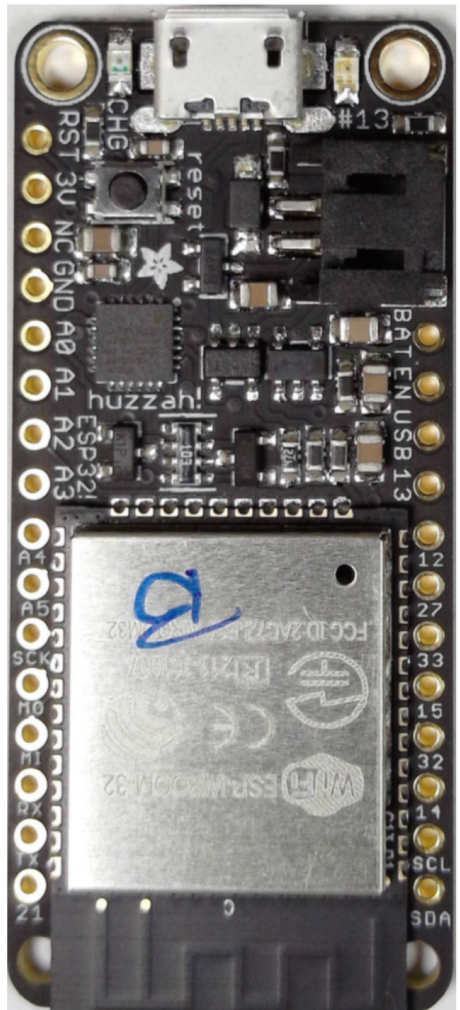
Connect to MCU



- I^2C: just 4 wires:
  - Data (SDA)
  - Clock (SCL)
  - 3.3V supply (Huzzah32 generates this)
  - GND

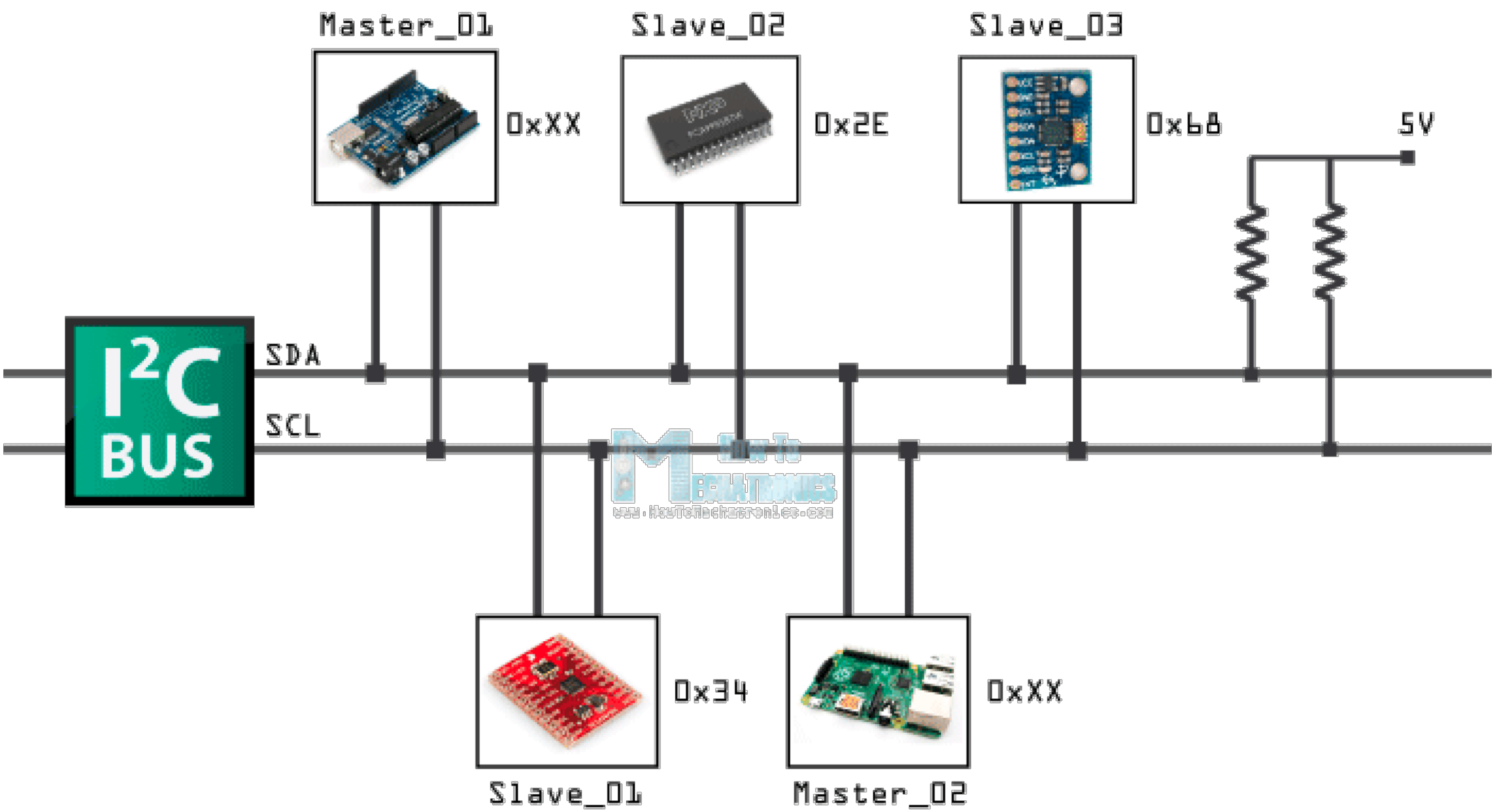
Huzzah32

GPIO	ALT	µPy	Pin
RESET			1
3.3V			2
			3
GND			4
26	DAC2	A0	5
25	DAC1	A1	6
34	ADC6	A2	7
39	ADC3	A3	8
36	ADC0	A4	9
4		A5	10
5	SCK	A16	11
18	MOSI	A17	12
19	MISO	A18	13
16		A19	14
17		A20	15
21		A21	16

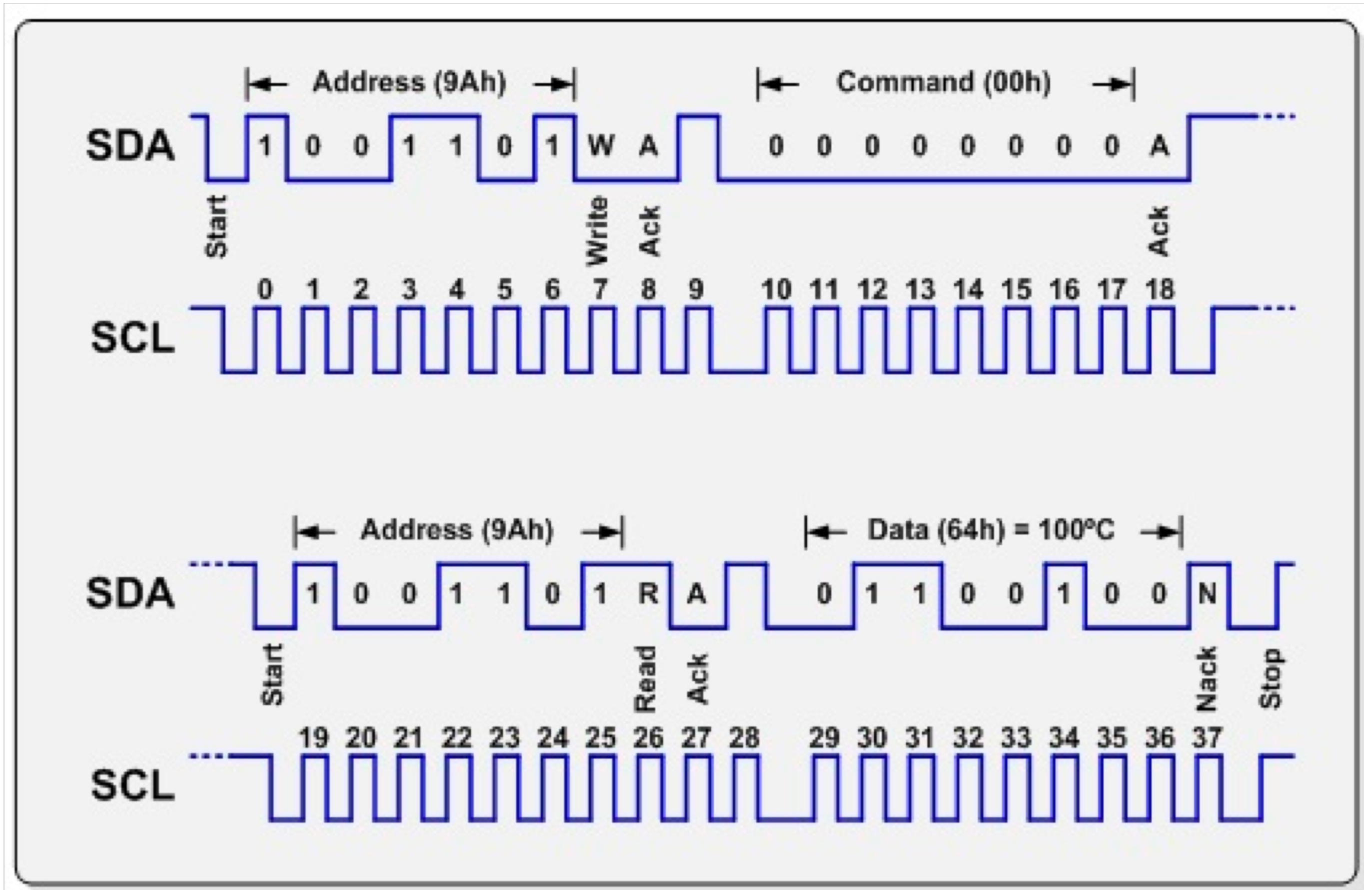


Pin	µPy	ALT	GPIO
28	VBAT		
27	EN 3.3V		
26	VUSB		
25	A12	LED	13
24	A11	BOOT	12
23	A10		27
22	A9	ADC5	33
21	A8		15
20	A7	ADC4	32
19	A6		14
18	A15	SCL	22
17	A14	SDA	23

I^2C


Master_01
0xXX
Slave_02
0x2E
Slave_03
0x68
5V
I2C BUS
SDA
SCL
Slave_01
0x34
Master_02
0xXX
www.HowToMechatronics.com

I2C Communication



INA219 I^2C Commands

4. Complement the binary result : 000 0010 1111 1111
5. Add 1 to the Complement to create the Two's Complement formatted result → 000 0011 0000 0000
6. Extend the sign and create the 16-bit word: 1000 0011 0000 0000 = 8300h (Remember to extend the sign to all sign-bits, as necessary based on the PGA setting.)

At PGA = /8, full-scale range = ±320 mV (decimal = 32000). For V_{SHUNT} = +320 mV, Value = 7D00h; For V_{SHUNT} = –320 mV, Value = 8300h; and LSB = 10μV.

Figure 20. Shunt Voltage Register at PGA = /8

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIGN	SD14_8	SD13_8	SD12_8	SD11_8	SD10_8	SD9_8	SD8_8	SD7_8	SD6_8	SD5_8	SD4_8	SD3_8	SD2_8	SD1_8	SD0_8

At PGA = /4, full-scale range = ±160 mV (decimal = 16000). For V_{SHUNT} = +160 mV, Value = 3E80h; For V_{SHUNT} = –160 mV, Value = C180h; and LSB = 10μV.

Figure 21. Shunt Voltage Register at PGA = /4

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SIGN	SIGN	SD13_4	SD12_4	SD11_4	SD10_4	SD9_4	SD8_4	SD7_4	SD6_4	SD5_4	SD4_4	SD3_4	SD2_4	SD1_4	SD0_4

At PGA = /2, full-scale range = ±80 mV (decimal = 8000). For V_{SHUNT} = +80 mV, Value = 1F40h; For V_{SHUNT} = –80 mV; Value = E0C0h; and LSB = 10μV.

Someone has already done the work!

Google

micropython ina219

All Maps Shopping Videos Images More Settings Tools

About 12,100 results (0.54 seconds)

Micropython library for the TI INA219 voltage/current sensor ...

https://forum.micropython.org › ... › Drivers for External Components

May 16, 2017 - https://github.com/chrisb2/pyb_ina219. I have written this library based on one I wrote for the Raspberry Pi. It supports the **INA219** voltage, current and power monitor sensor from Texas Instruments. The intent of the library is to make it easy to use the quite complex functionality of this sensor. Its currently ...

MicroPython on ESP32 with SPIRAM support - Page 25	Jan 10, 2018
Lolin32 Battery State	Aug 14, 2017
boot.py not executed	Aug 2, 2017
Micropython driver for TI **INA219**?	Dec 7, 2016

More results from forum.micropython.org

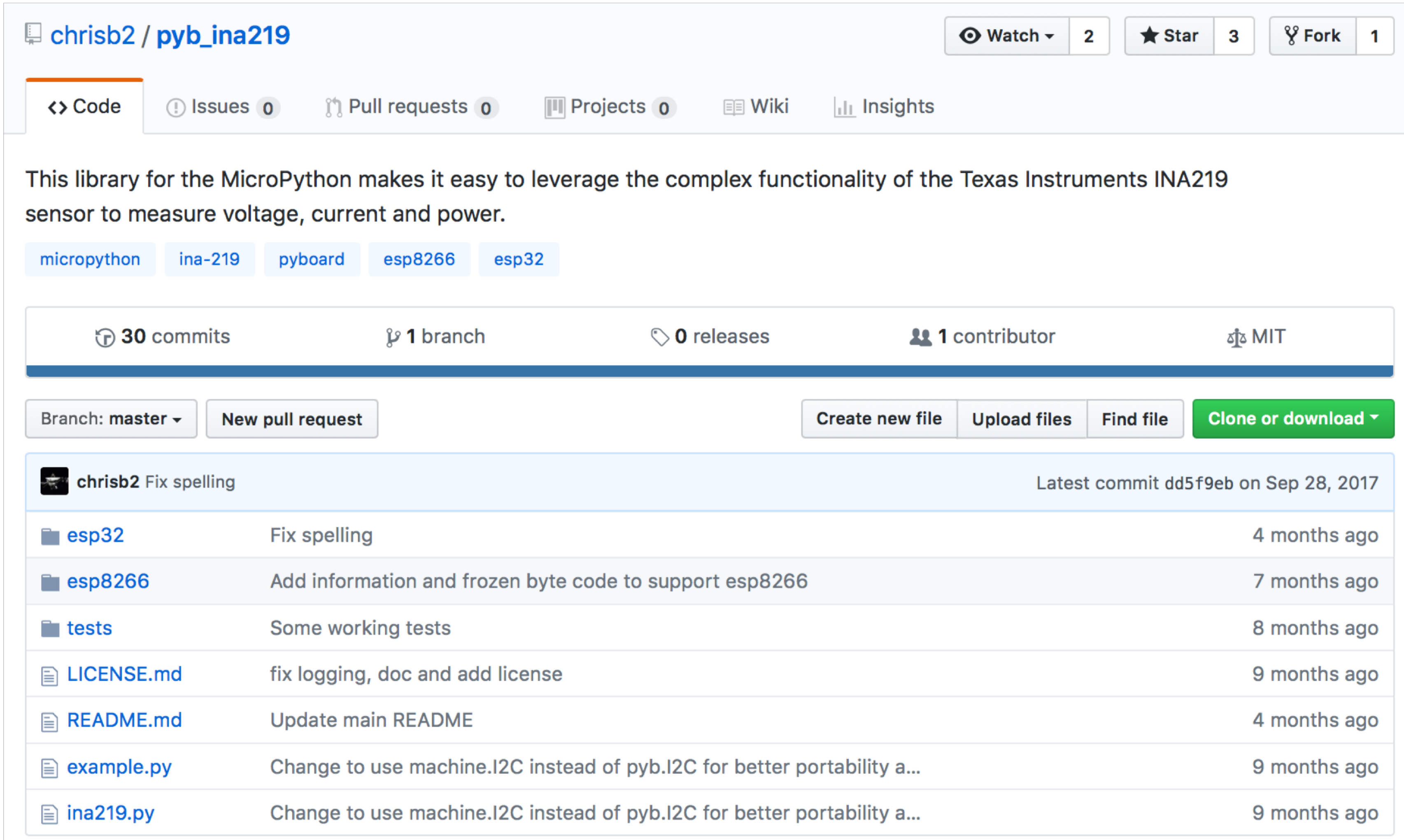
GitHub - chrisb2/pyb_ina219: This library for the MicroPython makes it ...

https://github.com/chrisb2/pyb_ina219

pyb_ina219 - This library for the **MicroPython** makes it easy to leverage the complex functionality of the Texas Instruments **INA219** sensor to measure voltage , current and power.

You've visited this page 4 times. Last visit: 1/12/18

INA219 on Github



INA219 Driver Usage Instructions

Usage

If you want to give it a try then copy *ina219.py* onto the flash drive of your pyboard, connect the sensor to the I2C(1) or I2C(2) interfaces on the pyboard, then from a REPL prompt execute:

```
from ina219 import INA219
from machine import I2C

I2C_INTERFACE_NO = 2
SHUNT_OHMS = 0.1

ina = INA219(SHUNT_OHMS, I2C(I2C_INTERFACE_NO))
ina.configure()
print("Bus Voltage: %.3f V" % ina.voltage())
print("Current: %.3f mA" % ina.current())
print("Power: %.3f mW" % ina.power())
```

← Depends on MicroPython port
See next page

https://github.com/chrisb2/pyb_ina219

INA219 Example

```
from ina219 import INA219
from machine import I2C, Pin
from board import SDA, SCL
import time

i2c = I2C(id=0, scl=Pin(SCL), sda=Pin(SDA), freq=100000)

# optional: detect all devices connected to I2C bus
print("scanning I2C bus ...")
print("I2C:", i2c.scan())

# initialize INA219
SHUNT_RESISTOR_OHMS = 0.1
ina = INA219(SHUNT_RESISTOR_OHMS, i2c)
ina.configure()

# read measurements
while True:
    v = ina.voltage()
    i = ina.current()
    p = ina.power()
    print("V = {:6.2f},  I = {:6.2f},  P = {:6.2f}".format(v, i, p))
    time.sleep(0.5)
```

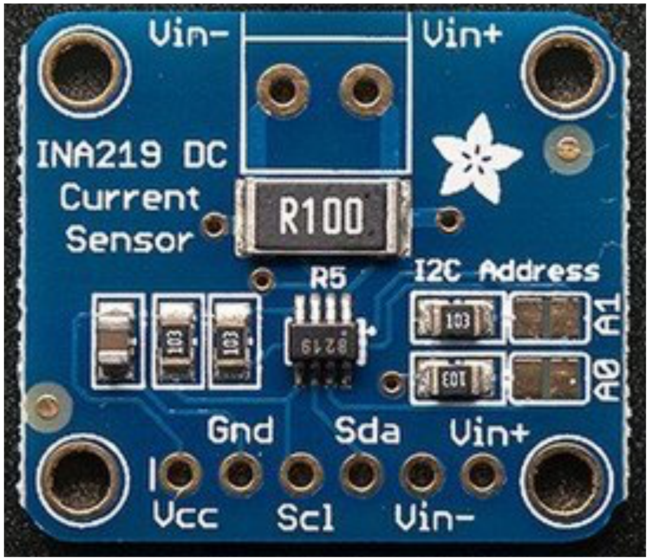
Circuit

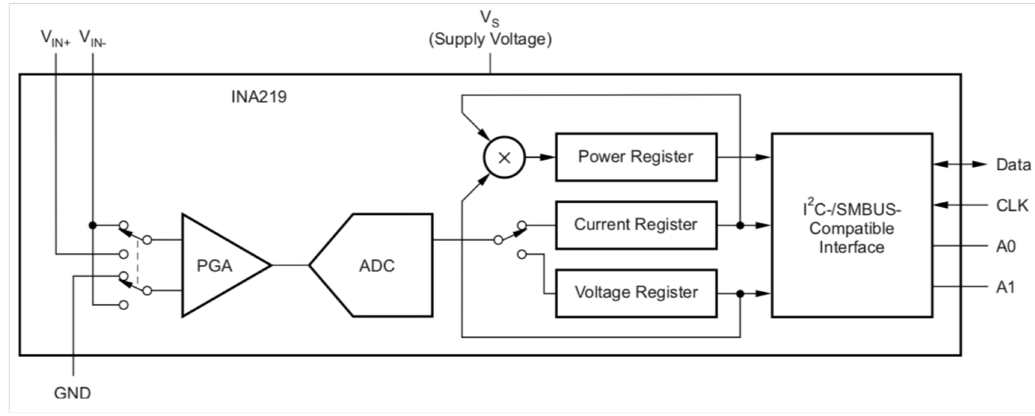
- Solar cell characterization
- Components:
  1.
  2.
  3.
  4.

Approach

- Symbols
- Circuit diagram
- Optional: wiring diagram

INA219 Breakout Board





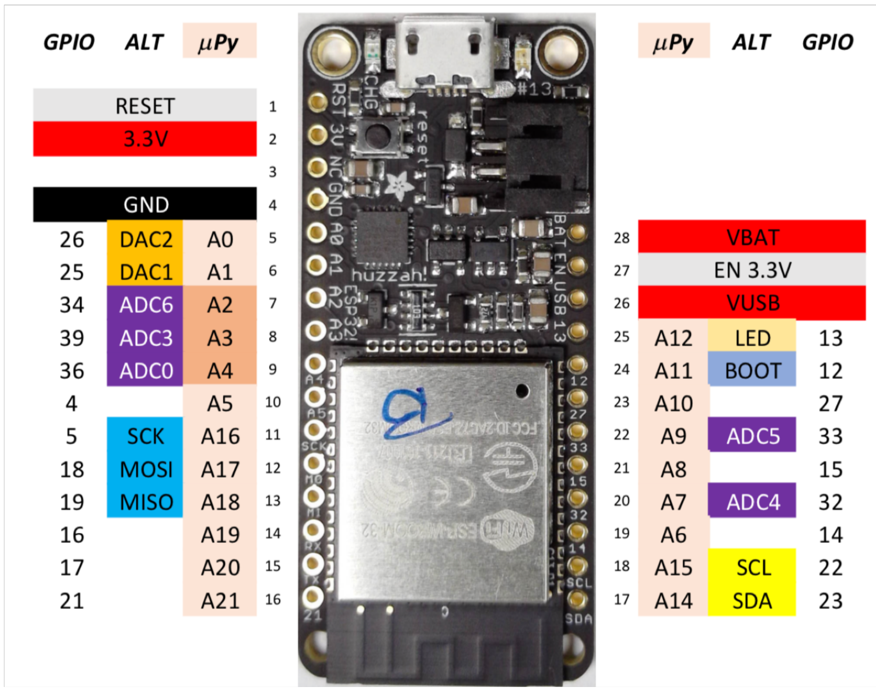
Huzzah32

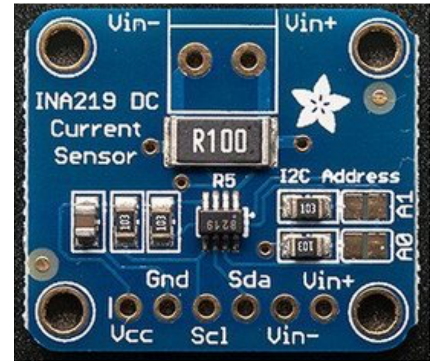
GPIO	ALT	µPy	Pin
RESET			1
3.3V			2
			3
GND			4
26	DAC2	A0	5
25	DAC1	A1	6
34	ADC6	A2	7
39	ADC3	A3	8
36	ADC0	A4	9
4		A5	10
5	SCK	A16	11
18	MOSI	A17	12
19	MISO	A18	13
16		A19	14
17		A20	15
21		A21	16

Pin	µPy	ALT	GPIO
28	VBAT		
27	EN 3.3V		
26	VUSB		
25	A12	LED	13
24	A11	BOOT	12
23	A10		27
22	A9	ADC5	33
21	A8		15
20	A7	ADC4	32
19	A6		14
18	A15	SCL	22
17	A14	SDA	23

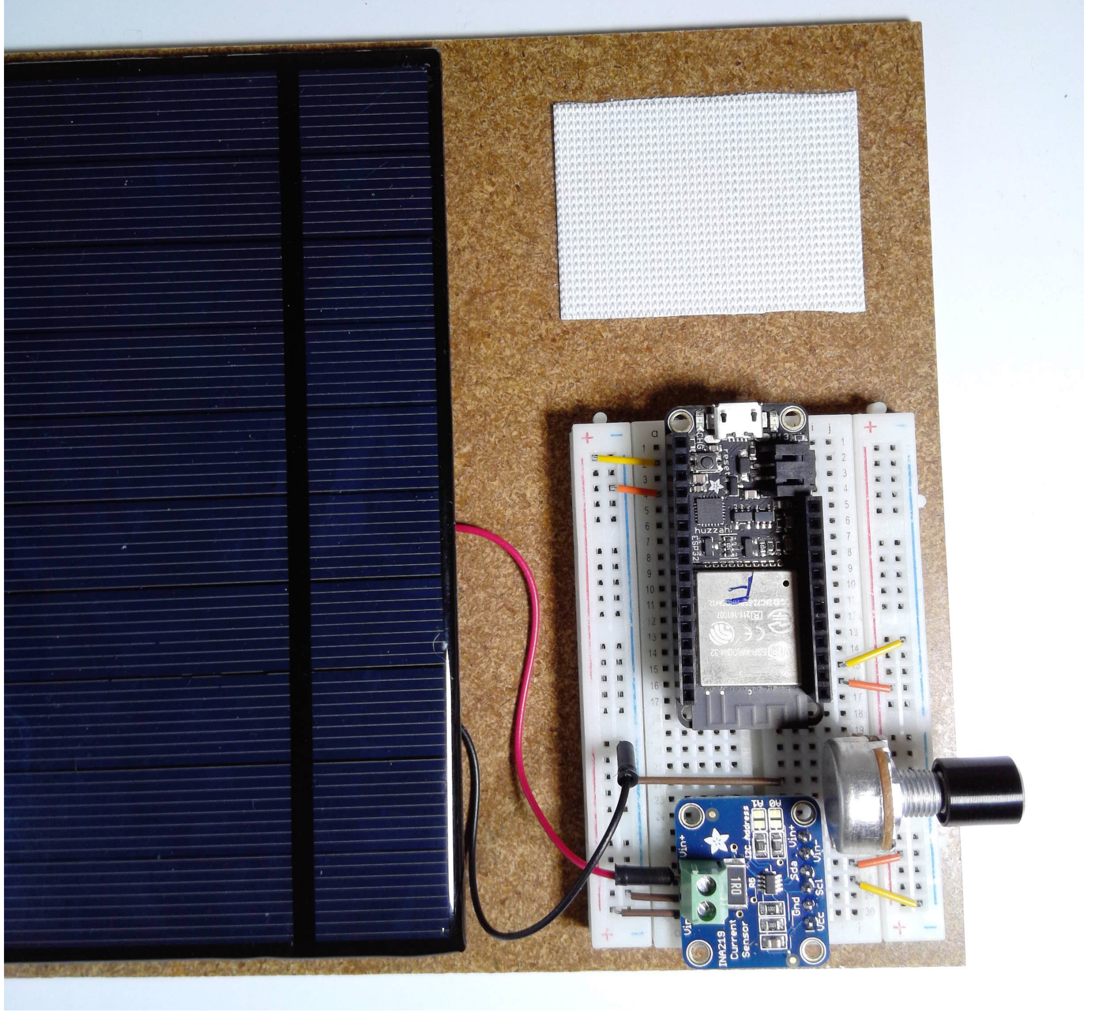
Circuit Diagram

Wiring Diagram





Complete Circuit



Testing

```
V =   5.13V,   I =    1.97mA,   P =     10mW,   R = 2606.3Ohm
V =   5.16V,   I =    2.10mA,   P =     11mW,   R = 2461.9Ohm
V =   5.18V,   I =    2.60mA,   P =     13mW,   R = 1989.5Ohm
V =   5.14V,   I =    3.54mA,   P =     17mW,   R = 1454.5Ohm
V =   5.11V,   I =    5.16mA,   P =     26mW,   R =  990.1Ohm
V =   5.12V,   I =    9.43mA,   P =     49mW,   R =  542.8Ohm
V =   5.13V,   I =   13.40mA,   P =     69mW,   R =  382.7Ohm
V =   5.13V,   I =   16.16mA,   P =     82mW,   R =  317.5Ohm
V =   5.08V,   I =   19.63mA,   P =     98mW,   R =  258.7Ohm
V =   5.05V,   I =   24.76mA,   P =    126mW,   R =  204.0Ohm
V =   5.07V,   I =   31.23mA,   P =    160mW,   R =  162.2Ohm
V =   5.04V,   I =   42.50mA,   P =    216mW,   R =  118.6Ohm
V =   4.38V,   I =  110.48mA,   P =    446mW,   R =   39.6Ohm
V =   0.16V,   I =  135.02mA,   P =     19mW,   R =    1.2Ohm
V =   0.23V,   I =  140.01mA,   P =     26mW,   R =    1.6Ohm
V =   0.13V,   I =  144.61mA,   P =     15mW,   R =    0.9Ohm
V =   0.12V,   I =  149.01mA,   P =     18mW,   R =    0.8Ohm
```

How can we plot the result?

- Connect plotter to ESP32?
  - And run Matlab or Excel?
- Better solution
  - Do the plotting on a computer that’s made for this (e.g. laptop)
  - How do we get the data there?

Summary

- IoT Application
  - Circuits
  - Python
  - Internet …
- Sensors
  - INA219
  - I2C
  - Driver
- Prototyping
  - Wiring
  - Electrical and software testing