

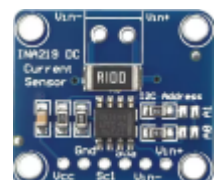
# lamaPLC: INA modules with Arduino libraries

Several INA series ICs have excellent Arduino support, with libraries provided by Adafruit and the community. The following table summarizes the most popular models and their technical specifications

IC Model	ADC Res.	Max Bus Voltage	Shunt Voltage Range	PGA	Alert Pin	Communication	Arduino Library	Key Functionality
<a href="#">INA219</a>	12-bit	26V	$\pm 40, \pm 80, \pm 160, \pm 320$ mV	Yes (1, 2, 4, 8)	No	I <sup>2</sup> C/SMBus	<a href="#">Adafruit_INA219</a>	Basic current, voltage, and power monitoring.
<a href="#">INA226</a>	16-bit	36V	$\pm 81.92$ mV	No	Yes	I <sup>2</sup> C/SMBus	<a href="#">INA226 (Rob Tillaart)</a>	High precision; monitors current, voltage, and power.
<a href="#">INA228</a>	20-bit	85V	$\pm 163.84.92$ mV	No	Yes	I <sup>2</sup> C/SMBus	<a href="#">INA228 (Rob Tillaart)</a>	Ultra-high precision; includes energy and charge accumulation.
<a href="#">INA237</a>	16-bit	85V	$\pm 163.84.92$ mV	No	Yes	I <sup>2</sup> C/SMBus	<a href="#">Adafruit_INA237</a>	High voltage support (up to 85V) for current and power.
<a href="#">INA238</a>	16-bit	85V	$\pm 163.84.92$ mV	No	Yes	I <sup>2</sup> C/SMBus	-	High voltage support (up to 85V) for current and power.
<a href="#">INA260</a>	16-bit	36V	Integrated Shunt	No	Yes	I <sup>2</sup> C/SMBus	<a href="#">Adafruit_INA260</a>	Built-in 2m shunt; supports up to 15A continuous.
<a href="#">INA3221</a>	13-bit	26V	$\pm 163.84.92$ mV	No	Yes	I <sup>2</sup> C/SMBus	<a href="#">Adafruit_INA3221</a>	3-Channel monitoring of voltage and current.

## INA219: digital current, voltage, and power monitor with I<sup>2</sup>C communication

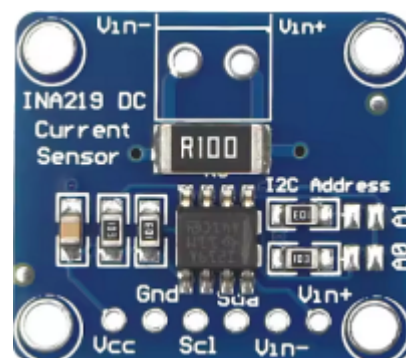
The INA219 (GY-219) is a digital current, voltage, and power monitor with an I<sup>2</sup>C- or SMBUS-compatible interface. It is primarily used for high-side current sensing but can also be configured for low-side sensing.



## INA219: Key Specifications

- **Bus Voltage Range:** Senses from 0V to 26V.
- **Supply Voltage:** Operates on a single 3V to 5.5V supply.
- **Current Draw:** Maximum of 1 mA.
- **Accuracy:** Up to 0.5% maximum over temperature (for the B-grade version).
- **Interface:** I<sup>2</sup>C/SMBUS with 16 programmable addresses via A0 and A1 pins.
- **ADC Resolution:** Integrated 12-bit ADC.
- **Temperature Range:** Operates from -40°C to 125°C.

## INA219: Pin Description



Pin	Name	Type	Description
1	VCC	Power	Supply Voltage: Powers the chip (3.0V to 5.5V).
2	GND	Power	Ground: Common ground for the sensor and logic.
3	SCL	Digital I/O	I <sup>2</sup> C Clock: Serial clock line for communication.
4	SDA	Digital I/O	I <sup>2</sup> C Data: Serial data line for communication.
5	V+ (IN+)	Analog Input	Positive Shunt: Connect to the power source side.
6	V- (IN-)	Analog Input	Negative Shunt: Connect to the load side.
7	A0	Digital Input	Address 0: Connect to GND, VS, SDA, or SCL to set I <sup>2</sup> C address.
8	A1	Digital Input	Address 1: Connect to GND, VS, SDA, or SCL to set I <sup>2</sup> C address.

## Important Considerations

- **Maximum Limits:** Do not exceed 26V or 3.2A, or the shunt resistor might be damaged.
- **I<sup>2</sup>C Address:** The default address is 0x40. You can bridge solder pads on the board to change it to 0x41, 0x44, or 0x45 to use multiple sensors.
- **Negative Current Readings:** If current reads negative, you have swapped the Vin+ and Vin- connections.
- **Precision:** If measuring very low currents, increase sensitivity by changing the Gain using `ina219.setCalibration_16V_400mA()`.

## Standard Breakout Board Address Table

The INA219 current sensor has a base I<sup>2</sup>C address of 0x40. Most breakout boards, like those from Adafruit, feature two address jumpers (A0 and A1) that allow you to set up to four unique addresses by bridging them with solder.

Address	A1 Jumper	A0 Jumper	Description
0x40	Open	Open	Default address
0x41	Open	Closed	Bridge A0
0x44	Closed	Open	Bridge A1
0x45	Closed	Closed	Bridge A0 and A1

### INA219 Arduino example code

```
#include <Wire.h>
#include <Adafruit_INA219.h>

Adafruit_INA219 ina219;

void setup(void) {
  Serial.begin(115200);
  if (!ina219.begin()) {
    Serial.println("Failed to find INA219 chip");
    while (1);
  }
  // Optional: Set calibration for higher precision (e.g., 32V 1A)
  // ina219.setCalibration_32V_1A();
}

void loop(void) {
  float shuntvoltage = 0;
  float busvoltage = 0;
  float current_mA = 0;
  float loadvoltage = 0;
  float power_mW = 0;

  shuntvoltage = ina219.getShuntVoltage_mV();
  busvoltage = ina219.getBusVoltage_V();
  current_mA = ina219.getCurrent_mA();
  power_mW = ina219.getPower_mW();
  loadvoltage = busvoltage + (shuntvoltage / 1000);

  Serial.print("Load Voltage: "); Serial.print(loadvoltage);
  Serial.println(" V");
  Serial.print("Current: "); Serial.print(current_mA);
  Serial.println(" mA");
  Serial.print("Power: "); Serial.print(power_mW); Serial.println("
mW");
  Serial.println("");
  delay(1000);
}
```

## INA226: current/voltage/power monitor with I<sup>2</sup>C communication

### 36V, 16-bit, ultra-precise i<sup>2</sup>c output current/voltage/power monitor w/alert



The INA226 is a current shunt and power monitor with an I<sup>2</sup>C or SMBUS-compatible interface. It monitors both a shunt-voltage drop and the bus supply voltage. Programmable calibration values, conversion times, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts.

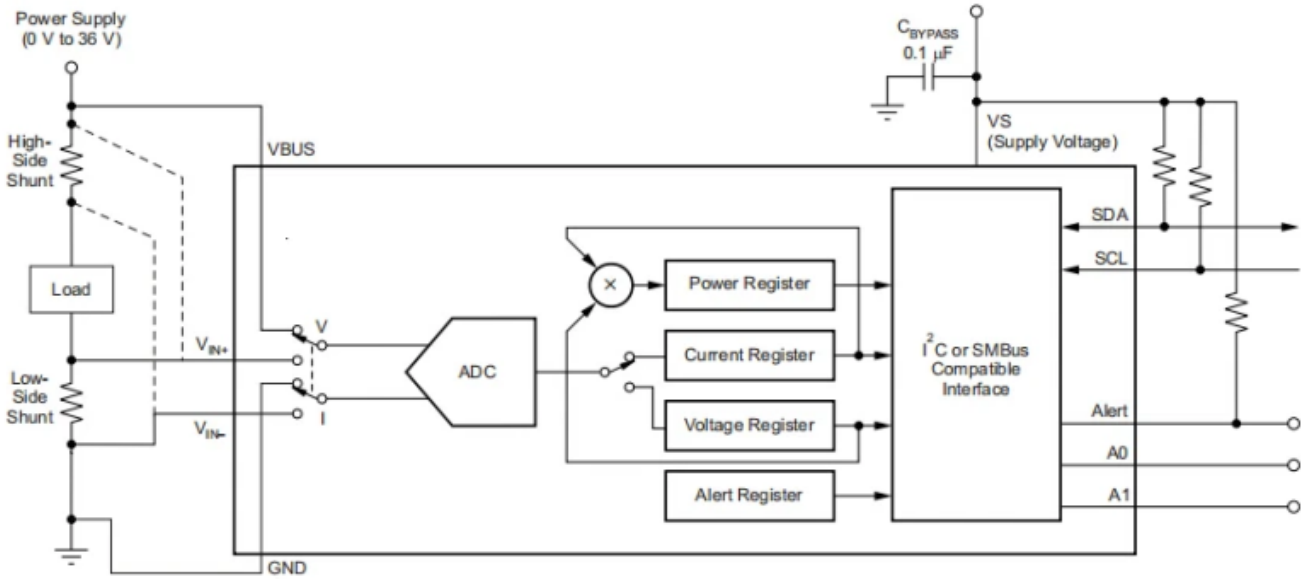
The INA226 is a current shunt and power monitor with an I<sup>2</sup>C or SMBUS-compatible interface. The device monitors both a shunt voltage drop and bus supply voltage. Programmable calibration value, conversion times, and averaging, combined with an internal multiplier, enable direct readouts of current in amperes and power in watts. The INA226 senses current on the common-mode bus, which can range from **0V to 36V**, independent of the supply voltage. The device operates from a 2.7V to 5.5V supply, drawing a typical supply current of 330  $\mu$ A. The device is specified for an operating temperature range of  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  and features up to 16 programmable addresses via an I<sup>2</sup>C-compatible interface.

The INA226 supports the fast mode (1 kHz to 400 kHz) and high-speed mode (1 kHz to 2.94 MHz) transmission protocols. All data bytes are transmitted in most significant byte-first order.

### INA226: Features

- **Senses Bus Voltages:** 0 V .. 36 V
- **Shunt Voltage Maximum:** 81.9 V
- **Current Maximum:** 20 A
- High-Side or Low-Side Sensing
- Reports Current, Voltage, and Power
- **High Accuracy:**
  - 0.1% Gain Error (Max)
  - 10  $\mu$ V Offset (Max)
- Configurable Averaging Options
- 16 Programmable Addresses
- Operates from 2.7V to 5.5V Power Supply
- 10-Pin, DGS (VSSOP) Package

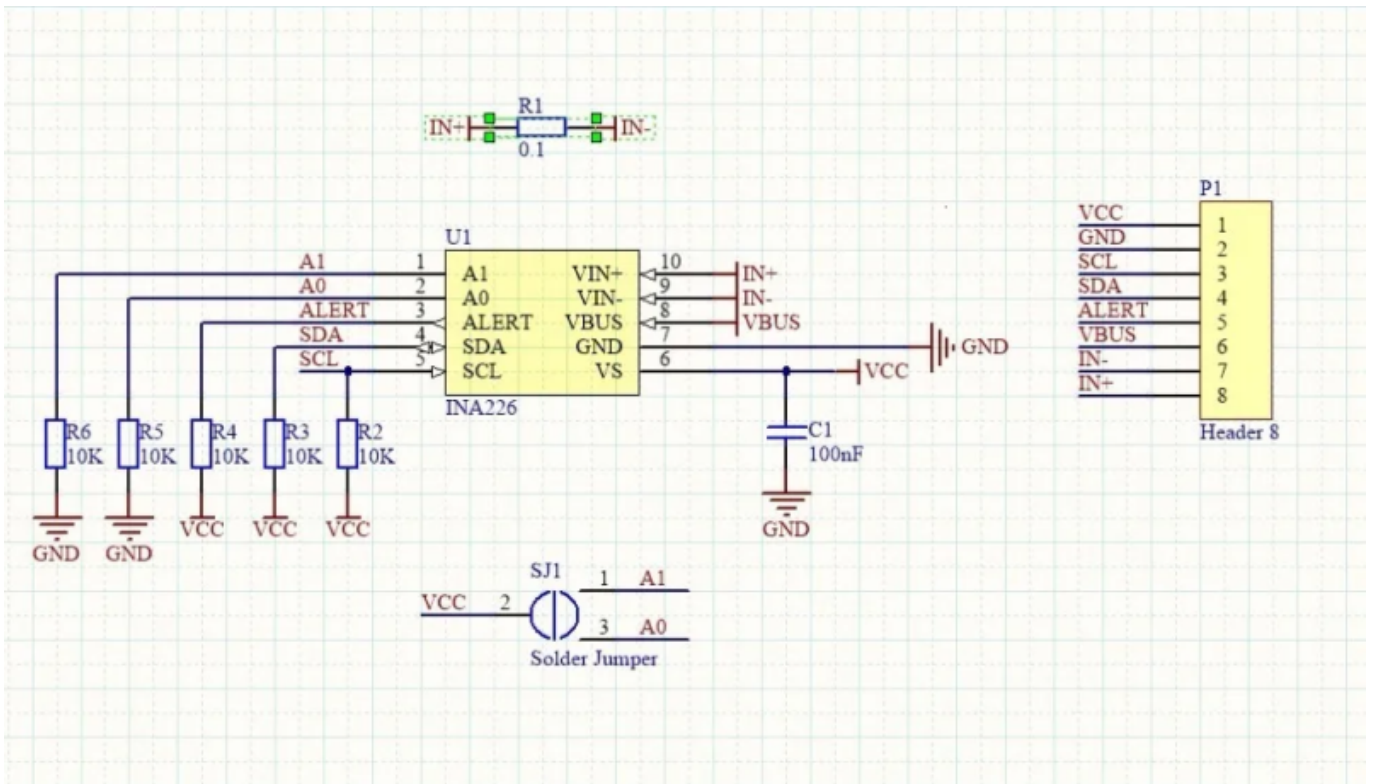
### High-Side or Low-Side Sensing Application



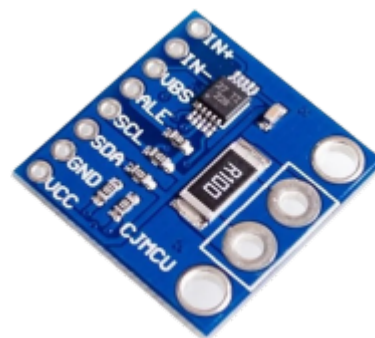
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## INA226 Pin Description



Pin Name	Description
<b>V+ / VS</b>	<b>Power Supply:</b> 2.7V to 5.5V for the chip's own logic
<b>GND</b>	<b>Ground:</b> Reference point for power and I <sup>2</sup> C
<b>SCL</b>	<b>I<sup>2</sup>C Clock:</b> Connect to the microcontroller's SCL pin
<b>SDA</b>	<b>I<sup>2</sup>C Data:</b> Connect to the microcontroller's SDA pin
<b>VBUS</b>	<b>Bus Voltage Input:</b> Connect this to the high-side or load-side to measure the actual bus voltage (up to 36V)
<b>IN+</b>	<b>Shunt Positive:</b> Connect to the supply side of the external shunt resistor
<b>IN-</b>	<b>Shunt Negative:</b> Connect to the load side of the external shunt resistor
<b>A0 &amp; A1</b>	<b>Address Pins:</b> Used to set the I <sup>2</sup> C address by tying them to GND, VS, SDA, or SCL
<b>ALERT</b>	<b>Programmable Alert:</b> Open-drain output that can trigger on over/under voltage or current thresholds

### Typical Wiring (High-Side Sensing)

- **V+ and GND:** Connect to your microcontroller's 3.3V or 5V power and ground.
- **SDA and SCL:** Connect to your microcontroller's I<sup>2</sup>C pins.
- **IN+ and IN-:** Place the shunt resistor in series with your load's positive line. Connect IN+ before the resistor and IN- after it.
- **VBUS:** Connect this pin to IN- (load side) for standard high-side power monitoring.

### INA226 I2C Address Table

The Texas Instruments INA226 supports up to 16 unique I<sup>2</sup>C addresses. The address is set by connecting the two address pins (A0 and A1) to one of four possible points: GND, VS (power supply), SDA, or SCL.

The default address is **0x40** (when both pins are connected to GND).

A1 Pin	A0 Pin	Hex Address
<b>GND</b>	GND	<b>0x40</b>
<b>GND</b>	VS	0x41
<b>GND</b>	SDA	0x42
<b>GND</b>	SCL	0x43
<b>VS</b>	GND	0x44
<b>VS</b>	VS	0x45

A1 Pin	A0 Pin	Hex Address
VS	SDA	0x46
VS	SCL	0x47
SDA	GND	0x48
SDA	VS	0x49
SDA	SDA	0x4A
SDA	SCL	0x4B
SCL	GND	0x4C
SCL	VS	0x4D
SCL	SDA	0x4E
SCL	SCL	0x4F

## INA226 Arduino wiring

- VCC/VSS → Arduino 5V (or 3.3V)
- GND → Arduino GND
- SDA → Arduino SDA (A4 on Uno)
- SCL → Arduino SCL (A5 on Uno)

## INA226 Arduino example code

In the Arduino IDE, go to *Tools > Manage Libraries*, search for “**INA226\_WE**”, and install the version by *Wollewald*.

This sketch initializes the sensor at the default address (**0x40**) and prints current, voltage, and power to the Serial Monitor.

```
#include <Wire.h>
#include <INA226_WE.h>

#define I2C_ADDRESS 0x40

INA226_WE ina226 = INA226_WE(I2C_ADDRESS);

void setup() {
  Serial.begin(9600);
  Wire.begin();

  // Initialize INA226
  if (!ina226.init()) {
    Serial.println("Failed to find INA226 chip. Check wiring!");
    while (1);
  }

  /*
   Optional: Calibrate for your shunt.
   The default is usually 0.1 Ohm.
   Parameters: (Shunt value in Ohms, Max expected current in Amps)
  */
}
```

```
*/
ina226.waitUntilConversionCompleted();
Serial.println("INA226 Ready!");
}

void loop() {
  float shuntVoltage_mV = 0.0;
  float loadVoltage_V = 0.0;
  float busVoltage_V = 0.0;
  float current_mA = 0.0;
  float power_mW = 0.0;

  // Read values
  ina226.readAndClearFlags();
  shuntVoltage_mV = ina226.getShuntVoltage_mV();
  busVoltage_V = ina226.getBusVoltage_V();
  current_mA = ina226.getCurrent_mA();
  power_mW = ina226.getBusPower_mW();
  loadVoltage_V = busVoltage_V + (shuntVoltage_mV / 1000);

  // Print results
  Serial.print("Bus Voltage:  "); Serial.print(busVoltage_V);
  Serial.println(" V");
  Serial.print("Current:      "); Serial.print(current_mA);
  Serial.println(" mA");
  Serial.print("Power:          "); Serial.print(power_mW); Serial.println("
mW");
  Serial.println("-----");

  delay(2000);
}
```

## INA228: ultra-precise, high-resolution digital power, energy, and charge monitor with an I<sup>2</sup>C interface



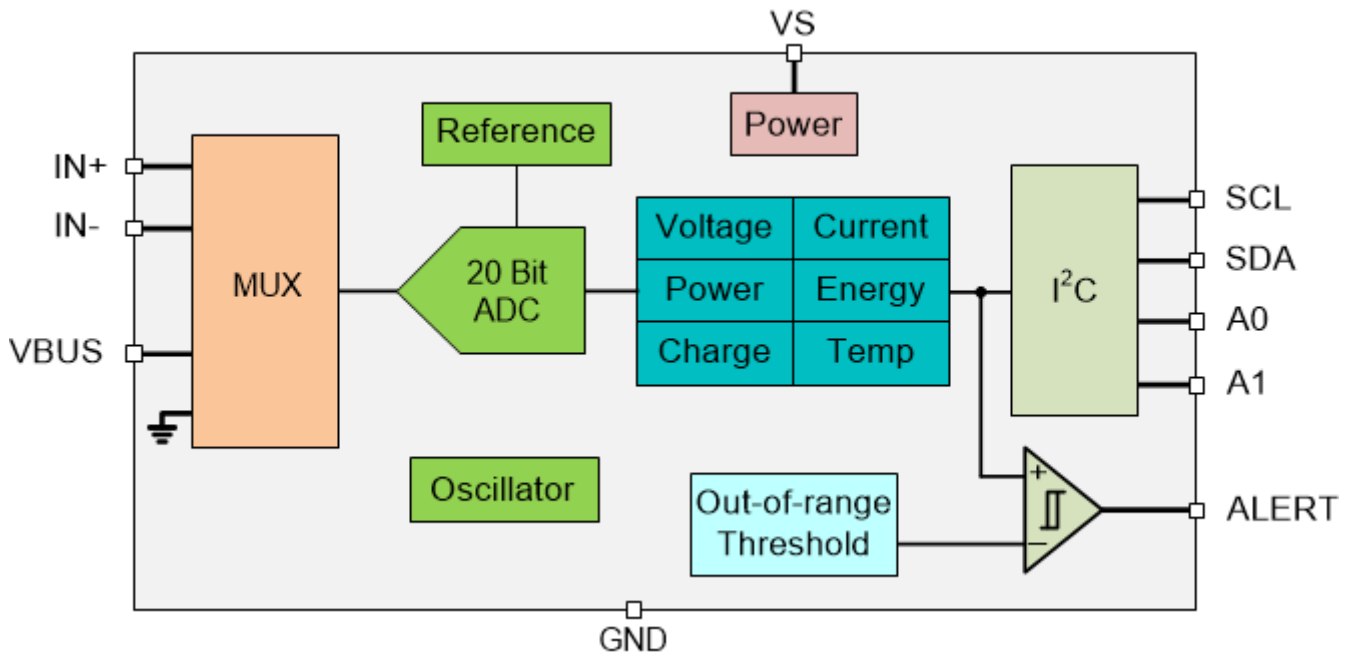
The INA228 is an ultra-precise, high-resolution digital power, energy, and charge monitor with an I<sup>2</sup>C interface. It is significantly more advanced than the INA219 or INA226, featuring a 20-bit ADC and a common-mode voltage range of -0.3V to +85V.

### Key Specifications

- **ADC Resolution:** 20-bit delta-sigma ADC for high-precision measurements.
- **Bus Voltage:** Supports 0V to 85V (more than double the INA226's 36V limit).
- **Measured Data:** Reports current, bus voltage, temperature, power, energy, and charge

accumulation.

- **Temperature Sensor:** Integrated sensor with  $\pm 1^\circ\text{C}$  accuracy for die temperature monitoring.
- **Precision:** Very low offset voltage ( $\pm 1\ \mu\text{V}$  max) and low gain drift allow for micro-amp to kilo-amp sensing.
- **Interface:** High-speed I<sup>2</sup>C (up to 2.94 MHz) with 16 programmable addresses via A0 and A1 pins.



### INA228 Pin Description

Pin No.	Name	Type	Description
1	A1	Digital Input	Address Pin: Connect to GND, VS, SDA, or SCL to set the I <sup>2</sup> C address.
2	A0	Digital Input	Address Pin: Works with A1 to configure one of 16 possible addresses.
3	Alert	Digital Output	Open-drain Alert: Triggers on over/under voltage, current, or power limits.
4	SDA	Digital I/O	Serial Data: Bidirectional I <sup>2</sup> C/SMBUS data line.
5	SCL	Digital I/O	Serial Clock: I <sup>2</sup> C/SMBUS clock input.
6	VS	Power	Supply Voltage: 2.7V to 5.5V to power the device.
7	GND	Analog	Ground: Common ground for the device.
8	VBUS	Analog Input	Bus Voltage Input: Monitors the 0V to 85V bus voltage.
9	IN-	Analog Input	Negative Shunt Input: Connect to the load side of the shunt resistor.
10	IN+	Analog Input	Positive Shunt Input: Connect to the supply side of the shunt resistor.

### INA228 Arduino example code

This sketch initializes the sensor and prints real-time power data to the Serial Monitor at 115200 baud.

```
#include <Adafruit_INA228.h>
// Initialize with default I2C address 0x40
```

```

Adafruit_INA228 ina228 = Adafruit_INA228();

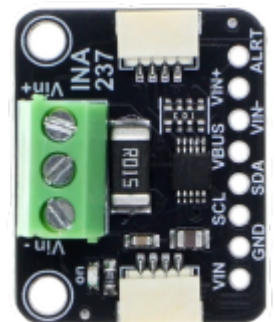
void setup() {
  Serial.begin(115200);
  if (!ina228.begin()) {
    Serial.println("Failed to find INA228 chip");
    while (1) delay(10);
  }
  // Configure: Shunt Resistance = 0.015 Ohms, Max Expected Current = 10A
  ina228.setShunt(0.015, 10.0);
}

void loop() {
  Serial.print("Bus Voltage: "); Serial.print(ina228.getBusVoltage_V());
  Serial.println(" V");
  Serial.print("Current: "); Serial.print(ina228.getCurrent_mA());
  Serial.println(" mA");
  delay(1000);
}

```

## INA237: is an ultra-precise, 16-bit digital power monitor with I<sup>2</sup>C communication

The INA237 is an ultra-precise, 16-bit digital power monitor designed for high-side or low-side current sensing in systems up to 85V. It is part of a modern family of sensors from Texas Instruments that includes the INA228 and INA238.



### Key Specifications

- **Resolution:** 16-bit precision delta-sigma ADC.
- **Bus Voltage Range:** Monitors from 0V to 85V.
- **Common-Mode Range:** Operates from -0.3V to +85V.
- **Interface:** 2.94-MHz high-speed I2C with 16 programmable addresses.
- **Integrated Temperature Sensor:** Provides die temperature readings with  $\pm 1^\circ\text{C}$  accuracy.
- **Alert Feature:** Features a fast 75  $\mu\text{s}$  alert response for over/under limit detection.

### INA237 Pin Description

The INA237 uses the same pinout as the INA228 and INA238, making them hardware-equivalent in many designs.

Pin No.	Name	Type	Description
1	A1	Digital Input	Address Pin: Sets the I2C address (connect to GND, VS, SDA, or SCL).
2	A0	Digital Input	Address Pin: Used with A1 to select 1 of 16 addresses.
3	Alert	Digital Output	Alert Output: Open-drain pin for diagnostic reports or conversion-ready signals.
4	SDA	Digital I/O	Serial Data: Bidirectional data line for I2C communication.
5	SCL	Digital I/O	Serial Clock: Clock input for I2C communication.
6	VS	Power	Supply Voltage: Powers the device (2.7V to 5.5V).
7	GND	Power	Ground: Common ground for both power and logic.
8	VBUS	Analog Input	Bus Voltage: Sense input for monitoring the 0V to 85V bus voltage.
9	IN-	Analog Input	Negative Shunt Input: Connect to the load side of the shunt resistor.
10	IN+	Analog Input	Positive Shunt Input: Connect to the supply side of the shunt resistor.

### INA237 Arduino example code

This code initializes the sensor and prints the Bus Voltage, Current, and Power to the Serial Monitor.

```
#include <Adafruit_INA237.h>

// Initialize sensor (Default address is 0x40)
Adafruit_INA237 ina237 = Adafruit_INA237();

void setup() {
  Serial.begin(115200);
  while (!Serial) delay(10); // Wait for Serial Monitor

  Serial.println("Adafruit INA237 Test");

  if (!ina237.begin()) {
    Serial.println("Failed to find INA237 chip. Check wiring!");
    while (1) delay(10);
  }

  // --- CALIBRATION ---
  // setShunt(Shunt Resistance in Ohms, Max Expected Current in Amps)
  // Example: 0.1 Ohm resistor, 2 Amp max current
  ina237.setShunt(0.1, 2.0);

  Serial.println("INA237 Initialized.");
}

void loop() {
  // Read values from the sensor
  float voltage_V = ina237.getBusVoltage_V();
  float current_mA = ina237.getCurrent_mA();
  float power_mW = ina237.getPower_mW();
  float temp_C = ina237.getDieTemperature_C();
```

```

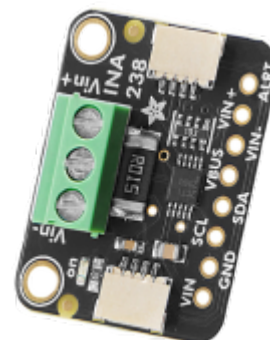
// Print results
Serial.print("Bus Voltage: "); Serial.print(voltage_V); Serial.println("
V");
Serial.print("Current:      "); Serial.print(current_mA); Serial.println("
mA");
Serial.print("Power:        "); Serial.print(power_mW); Serial.println("
mW");
Serial.print("Temperature: "); Serial.print(temp_C); Serial.println("
C");
Serial.println("-----");

delay(2000); // Wait 2 seconds between readings
}

```

## INA238: Ultra-precise digital power monitor 16-bit delta-sigma ADC with I<sup>2</sup>C communication

The INA238 is an ultra-precise digital power monitor featuring a 16-bit delta-sigma ADC designed for high-side or low-side current sensing in high-voltage systems up to 85V.



### Key Specifications

- **Common-Mode Range:** Operates from -0.3V to +85V.
- **Precision:** Features a maximum offset voltage of ±5 μV and a maximum gain error of ±0.1%.
- **Integrated Temperature Sensor:** Integrated die temperature sensing with ±1°C accuracy.
- **ADC Settings:** Selectable conversion times (50 μs to 4.12 ms) and sample averaging (1x to 1024x) to reduce noise.
- **High-Speed Interface:** 2.94-MHz I<sup>2</sup>C interface supporting 16 programmable addresses via two pins (A0, A1).
- **Fast Response:** Provides a 75 μs alert response for rapid limit detection.

### INA238 Pin Description

Pin No.	Name	Type	Description
1	A1	Digital Input	Address Pin 1: Sets the I <sup>2</sup> C address by connecting to GND, VS, SDA, or SCL.
2	A0	Digital Input	Address Pin 0: Used with A1 to select 1 of 16 possible I2C addresses.
3	Alert	Digital Output	Alert Output: Open-drain pin for over/under limit notifications or conversion-ready status.
4	SDA	Digital I/O	Serial Data: Bidirectional I <sup>2</sup> C/SMBUS data line.

Pin No.	Name	Type	Description
5	SCL	Digital I/O	Serial Clock: I <sup>2</sup> C/SMBUS clock input.
6	VS	Power	Supply Voltage: 2.7V to 5.5V input to power the device.
7	GND	Power	Ground: Common ground for the device.
8	VBUS	Analog Input	Bus Voltage: Monitors the 0V to 85V bus voltage.
9	IN-	Analog Input	Negative Shunt Input: Connect to the load side of the shunt resistor.
10	IN+	Analog Input	Positive Shunt Input: Connect to the supply side of the shunt resistor.

### INA238 Arduino example code

The INA238 uses the same 16-bit register structure as the INA237, so the code is nearly identical. You can use the Adafruit INA238 library for a quick setup.

```
#include <Adafruit_INA238.h>

// Create the sensor object (Default I2C address is 0x40)
Adafruit_INA238 ina238 = Adafruit_INA238();

void setup() {
  Serial.begin(115200);
  while (!Serial) delay(10); // Wait for Serial Monitor

  Serial.println("INA238 Precision Power Monitor Test");

  // Try to initialize the chip
  if (!ina238.begin()) {
    Serial.println("Failed to find INA238 chip. Check wiring!");
    while (1) delay(10);
  }

  // --- CALIBRATION ---
  // setShunt(Shunt Resistance in Ohms, Max Expected Current in Amps)
  // Example: 0.1 Ohm resistor, 1.0 Amp max current
  ina238.setShunt(0.1, 1.0);

  Serial.println("INA238 Initialized successfully.");
}

void loop() {
  // Read sensor data
  float bus_v = ina238.getBusVoltage_V();
  float current_ma = ina238.getCurrent_mA();
  float power_mw = ina238.getPower_mW();
  float die_temp = ina238.getDieTemperature_C();

  // Print results to Serial Monitor
  Serial.print("Bus Voltage: "); Serial.print(bus_v);      Serial.println("
V");
```

```

Serial.print("Current:    "); Serial.print(current_ma); Serial.println("
mA");
Serial.print("Power:      "); Serial.print(power_mw);   Serial.println("
mW");
Serial.print("Die Temp:    "); Serial.print(die_temp);   Serial.println("
C");
Serial.println("-----");

delay(1000); // 1-second update rate
}

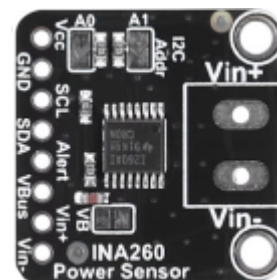
```

## Tips for the INA238

- **Precision:** Because the INA238 has a very low offset ( $\pm 5 \mu\text{V}$ ), it is excellent for measuring very small currents. Ensure your shunt resistor value is entered accurately in the `setShunt()` function for the best results.
- **I<sup>2</sup>C Address:** If you have changed the A0/A1 jumpers, pass the address to the begin function: `ina238.begin(0x41)`.
- **Alert Pin:** You can use the library to set high/low thresholds that trigger the physical Alert pin on the chip for over-current protection.

## INA260: high-precision digital power monitor with I<sup>2</sup>C communication

The INA260 is a high-precision digital power monitor that stands out for its integrated precision shunt resistor. This makes it a “one-stop” solution for measuring current, voltage, and power without an external sense resistor.



## Key Specifications

- **Integrated Shunt:** Features a 2 mΩ resistor with 0.1% tolerance.
- **Current Range:** Can handle up to  $\pm 15\text{A}$  continuous current.
- **Bus Voltage:** Senses from 0V to 36V, independent of its own supply voltage.
- **Supply Voltage:** Operates on 2.7V to 5.5V.
- **Accuracy:** Offers a maximum system gain error of 0.15% and a 16-bit ADC for high-resolution data.
- **Interface:** I<sup>2</sup>C/SMBus compatible with 16 programmable addresses via A0 and A1 pins.

## INA260 Pin Description

Although the chip features 16 pins, many breakout boards simplify this layout. The original chip pinout includes several high-current pins, which help ensure low resistance and better heat dissipation.

Pin No.	Name	Type	Description
<b>1, 2, 3</b>	IN+	Analog Input	Positive Current Path: Connect to the supply for high-side sensing.
<b>4</b>	A1	Digital Input	Address Pin: Connect to GND, VS, SDA, or SCL to set the I <sup>2</sup> C address.
<b>5</b>	A0	Digital Input	Address Pin: Used with A1 to configure 1 of 16 addresses.
<b>6, 11</b>	GND	Power	Ground: Common ground for analog and digital circuits.
<b>7</b>	ALERT	Digital Output	Alert Pin: Open-drain output for over-limit or conversion-ready signals.
<b>8</b>	SDA	Digital I/O	Serial Data: Bidirectional I <sup>2</sup> C data line.
<b>9</b>	SCL	Digital I/O	Serial Clock: I <sup>2</sup> C clock input.
<b>10</b>	VS	Power	Supply Voltage: 2.7V to 5.5V to power the sensor logic.
<b>12</b>	VBUS	Analog Input	Bus Voltage Sense: Measures the actual voltage of the line (0V to 36V).
<b>14, 15, 16</b>	IN-	Analog Input	Negative Current Path: Connect to the load for high-side sensing.

### INA260 Arduino example code

This sketch initializes the sensor and prints Voltage, Current, and Power to the Serial Monitor at 115200 baud

```
#include <Adafruit_INA260.h>

// Create the sensor object
Adafruit_INA260 ina260 = Adafruit_INA260();

void setup() {
  Serial.begin(115200);
  while (!Serial) delay(10); // Wait for Serial Monitor to open

  Serial.println("Adafruit INA260 Test");

  // Default I2C address is 0x40
  if (!ina260.begin()) {
    Serial.println("Couldn't find INA260 chip. Check wiring!");
    while (1);
  }

  Serial.println("Found INA260!");
}

void loop() {
  // Read and print Voltage (mV)
  Serial.print("Voltage: ");
  Serial.print(ina260.readBusVoltage());
  Serial.println(" mV");

  // Read and print Current (mA)
  Serial.print("Current: ");
  Serial.print(ina260.readCurrent());
```

```

Serial.println(" mA");

// Read and print Power (mW)
Serial.print("Power: ");
Serial.print(ina260.readPower());
Serial.println(" mW");

Serial.println("");
delay(1000);
}

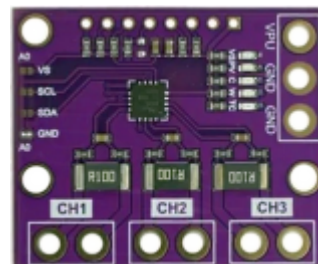
```

## Pro Tips for INA260

- **No Calibration Needed:** Unlike the INA219 or INA226, you do not need to call a `setShunt` function because the resistor is built-in and factory-calibrated.
- **Averaging:** If your readings are “jumpy,” you can add `ina260.setAveragingCount(INA260_AVG_16);` in `setup()` to smooth out the data.
- **High Current:** Since the INA260 handles up to 15A, ensure your wiring (the wires going to IN+ and IN-) is thick enough to handle the load without overheating.

## INA3221: current and bus voltage monitor with 3 channels I<sup>2</sup>C communication

The INA3221 is a high-side current and bus voltage monitor with three independent channels and an I<sup>2</sup>C-compatible interface. It is essentially a triple-channel version of the popular INA219, allowing you to monitor three separate power rails with a single chip.

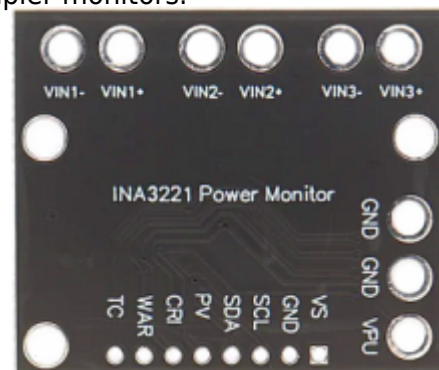


## Key Specifications

- **Channels:** 3 independent monitoring channels.
- **Bus Voltage Range:** Senses from 0V to 26V.
- **Supply Voltage:** Operates on a single 2.7V to 5.5V supply.
- **Resolution:** Integrated 13-bit ADC.
- **Current Sensing:** Measures current by detecting the voltage drop across an external shunt resistor (up to  $\pm 163.8$  mV).
- **Power Consumption:** Low typical supply current of 350  $\mu$ A.
- **Interface:** I<sup>2</sup>C/SMBUS with 4 programmable addresses (0x40 to 0x43) via the A0 pin.

## INA3221 Pin Description

The INA3221 features several specialized alert pins not found on simpler monitors.



Pin Name	Type	Description
<b>IN+ [1, 2, 3]</b>	Analog Input	Positive Shunt Input: Connect to the supply side of the shunt resistor for each channel.
<b>IN- [1, 2, 3]</b>	Analog Input	Negative Shunt Input: Connect to the load side. Bus voltage is also measured here.
<b>VS</b>	Power	Supply Voltage: 2.7V to 5.5V.
<b>GND</b>	Power	Ground: All loads and the supply must share this common ground.
<b>SCL/SDA</b>	Digital I/O	I <sup>2</sup> C Interface: Clock and data lines for communication.
<b>A0</b>	Digital Input	Address Select: Tie to GND, VS, SDA, or SCL to set the I <sup>2</sup> C address.
<b>Critical</b>	Digital Output	Critical Alert: Triggers immediately when a programmed current limit is exceeded.
<b>Warning</b>	Digital Output	Warning Alert: Triggers based on an averaged current value to avoid false alarms.
<b>PV (Power Valid)</b>	Digital Output	Goes high once all enabled channels reach a predefined voltage (default 10V).
<b>TC (Timing Control)</b>	Digital Output	Monitors power-supply sequencing at power-up.

### Important Usage Notes

- **Common Ground:** All monitored loads and the INA3221 must share the same ground reference.
- **High-Side Sensing:** Intended for high-side sensing (resistor between supply and load), though low-side sensing is possible but less typical for this chip.
- **Standard Breakout Performance:** Most modules feature 0.1Ω shunts, enabling measurements of up to approximately 1.6A per channel with a resolution of 40μV.

### INA3221 I2C Address Map

A0 Pin Connection	Hex Address	Decimal
<b>GND (Ground)</b>	0x40	64
<b>VS (VCC)</b>	0x41	65
<b>SDA</b>	0x42	66
<b>SCL</b>	0x43	67

### Wiring Reminder

The INA3221 is primarily for high-side sensing. Connect your power source to IN+ and your load to IN- for each channel you wish to monitor.

## INA3221 Arduino example code

To use the INA3221 with an Arduino, the Adafruit INA3221 Library is highly recommended for its ease of use and support for all three channels.

This sketch initializes the sensor and prints the voltage and current for all three channels to the Serial Monitor at 115200 baud.

```
#include <Adafruit_INA3221.h>

// Initialize sensor (Default address 0x40)
Adafruit_INA3221 ina3221;

void setup() {
  Serial.begin(115200);
  while (!Serial) delay(10); // Wait for Serial Monitor

  Serial.println("Adafruit INA3221 Test");

  if (!ina3221.begin()) {
    Serial.println("Failed to find INA3221 chip. Check wiring!");
    while (1) delay(10);
  }

  // Set shunt resistance for all channels (Standard modules use 0.1 or 0.05
  Ohms)
  // For 0.1 Ohm shunts:
  for (uint8_t i = 0; i < 3; i++) {
    ina3221.setShuntResistance(i, 0.1);
  }

  Serial.println("INA3221 Initialized.");
}

void loop() {
  for (uint8_t i = 0; i < 3; i++) {
    float voltage = ina3221.getBusVoltage(i);
    float current_mA = ina3221.getCurrentAmps(i) * 1000.0; // Convert to mA

    Serial.print("Channel "); Serial.print(i + 1);
    Serial.print(": "); Serial.print(voltage, 2); Serial.print(" V, ");
    Serial.print(current_mA, 2); Serial.println(" mA");
  }
  Serial.println("-----");
  delay(2000); // Update every 2 seconds
}
```

## Key Functions

- **setShuntResistance(channel, ohms):** Configures the library with your actual shunt resistor value (default is often 0.1Ω or 0.05Ω).
- **getBusVoltage(channel):** Returns the measured voltage on the specified channel (0, 1, or 2).
- **getCurrentAmps(channel):** Returns the calculated current in Amperes based on the shunt resistance.
- **setAveragingMode(mode):** Can be used to reduce noise by averaging multiple samples (e.g., `INA3221_AVG_16_SAMPLES`).

## I<sup>2</sup>C topics on lamaPLC

Page	Date	Tags
• <a href="#">lamaPLC Communication: 1-Wire</a>	2026/04/23 21:51	1-wire, communication, bus, microlan, i2c, uart, usart, ds18b20
• <a href="#">lamaPLC Communication: I<sup>2</sup>C</a>	2025/09/23 21:25	i2c, i c, smbus, philips, bus, communication, arduino
• <a href="#">LamaPLC: AHT10 Modul</a>	2026/03/22 03:14	communication, i2c, temperature, humidity, sensor, aht, aht 10, modul
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• <a href="#">LamaPLC: APDS - Avago ALS and proximity detection sensors with I<sup>2</sup>C communication</a>	2026/04/23 21:52	avago, apds-9900, apds-9930, apds-9960, als, proximity, detection, gesture recognition, gesture, i2c, communication, sensor, arduino, code
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• <a href="#">lamaPLC: CJMCU-811 CCS811 Gas Sensor (VOCs TVOC CO2)</a>	2026/03/22 00:08	cjmcu-811, ccs811, gas, sensor, vocs, tvoc, eco2, co2, arduino, air quality metal oxide, mox, i2c
• <a href="#">LamaPLC: D6T Omron Non-Contact Thermal Sensors with I<sup>2</sup>C communication</a>	2026/04/23 21:52	d6t, d6t-32l, d6t-44l, d6t-8l, d6t-1a, omron, non-contact, thermal, sensor, i2c, arduino, code
• <a href="#">LamaPLC: DPS Infineon Temperature/Pressure sensors with I<sup>2</sup>C communication</a>	2026/04/23 21:52	dps310, infineon, temperature, pressure, sensor, arduino, i2c, communication, code
• <a href="#">lamaPLC: Energy, power, current, and voltage</a>	2025/05/31 23:32	i2c, i c, communication, arduino, energy, power, current, sensor, ina226

- [LamaPLC: ENS ScioSense Multi-gas sensors with I<sup>2</sup>C communication](#) 2026/04/23 21:52

[ens160](#), [sciosense](#), [gas-quality](#), [i2c](#), [communication](#), [sensor](#), [arduino](#), [code](#), [eco2](#), [tvoc](#), [aqi](#), [indoor air quality](#), [iaq](#), [co2](#), [voc](#)
- [lamaPLC: ESP32 / ESP8266](#) 2025/11/22 00:07

[esp8266](#), [esp32](#), [esp32-c2](#), [esp32-c3](#), [esp32-c5](#), [esp32-c6](#), [esp32-c61](#), [esp32-h2](#), [esp32-s2](#), [esp32-s3](#), [esp32-p4](#), [espressif systems](#), [communication](#), [ethernet](#), [ip](#), [wi-fi](#), [thread](#), [zigbee](#), [matter](#), [homekit](#), [bluetooth](#), [mqtt](#), [adc](#), [spi](#), [uart](#), [i2c](#), [i2s](#), [rmt](#), [pwm](#), [usb](#), [usb otg](#), [twai](#)

[gas](#), [sensor](#), [i2c](#), [onewire](#), [communication](#), [mq-3](#), [mq-4](#), [mq-5](#), [mq-6](#), [mq-7](#), [mq-8](#), [mq-9](#), [mq-135](#), [gm-102b](#), [gm-302b](#), [gm-502b](#), [gm-702b](#), [alcohol](#), [ch4](#), [natural gas](#), [smoke](#), [lng](#), [co](#), [co2](#), [lpg](#), [h2](#), [iso-butane](#), [nox](#), [nh3](#), [benzene](#), [town gas](#), [formaldehyde](#), [propane](#), [humidity](#), [temperature](#), [voc](#), [grv gas sens v2](#)
- [LamaPLC: Gas sensors](#) 2023/07/01 17:29

[stmicroelectronics](#), [lsm303dlhc](#), [i2c](#), [lsm303](#), [sensor](#), [gy-511](#), [6dof](#), [pololu](#), [module](#), [arduino](#)
- [lamaPLC: GY-511 6DOF sensor module](#) 2026/03/22 01:44

[ak8963](#), [gy-9250](#), [mpu-9250](#), [9-axis](#), [motion detection](#), [magnetometer](#), [communication](#), [i c](#), [i2c](#), [spi](#)
- [LamaPLC: GY-9250 MPU-9250/6500 9-axis Attitude Sensor Board](#) 2026/04/23 21:52

[sht21](#), [htu21](#), [si7021](#), [gy-21](#), [gy-213v](#), [hdc1080](#), [gy-213v-hdc1080](#), [cjmcu](#), [cjmcu-1080](#), [texas instruments](#), [temperature](#), [humidity](#), [sensor](#), [i2c](#), [communication](#), [arduino](#), [code](#)
- [LamaPLC: HDC Texas Instruments Temperature/humidity sensors with I<sup>2</sup>C communication](#) 2026/04/23 21:52

[i2c](#), [7-segment display](#), [display](#), [ht16k33](#), [arduino](#)
- [lamaPLC: HT16K33 display controller](#) 2026/04/23 21:51

[htu](#), [htu31d](#), [htu21d](#), [htu20d](#), [sht20](#), [htu20](#), [sht21](#), [htu21](#), [si7021](#), [gy-21](#), [gy-213v](#), [hdc1080](#), [si702](#), [gy-20](#), [sht31](#), [htu31](#), [si7031](#), [gy-31](#), [te connectivity](#), [temperature](#), [humidity](#), [i2c](#), [communication](#), [sensor](#), [arduino](#), [code](#)
- [LamaPLC: HTU TE Connectivity temperature/humidity sensors with I<sup>2</sup>C communication](#) 2026/04/23 21:52

[i2c](#), [i c](#), [communication](#), [arduino](#), [energy](#), [power](#), [current](#), [monitor](#), [sensor](#), [ina219](#), [gy-219](#), [ina226](#), [gy-216](#), [ina228](#), [gy-228](#), [ina237](#), [ina238](#), [ina260](#), [ina3221](#), [ina](#)
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[i2c](#), [i c](#), [communication](#), [arduino](#), [energy](#), [power](#), [current](#), [monitor](#), [sensor](#), [ina226](#), [ina219](#), [ina](#)
- [lamaPLC: INA226 - current/voltage/power monitor with I<sup>2</sup>C communication](#) 2026/04/23 21:52

[communication](#), [i2c](#), [display](#), [lcd](#), [1602](#), [2004](#), [hd44780](#), [pcf8574](#), [pcf8574t](#), [pcf8574at](#), [arduino](#)
- [lamaPLC: LCD 1602/2004 with I<sup>2</sup>C communication](#) 2026/02/14 18:27

- [LamaPLC: MAX30100/MAX30102 Heart Rate Click Sensor Module](#) 2026/04/23 21:52 [max30102](#), [max30100](#), [heart rate click](#), [sensor](#), [communication](#), [i2c](#), [arduino](#), [code](#)
- [lamaPLC: MCP23017 / MCP23S17 16-Bit I/O Expander with Serial Interface I<sup>2</sup>C / SPI](#) 2026/04/23 21:52 [communication](#), [i2c](#), [mcp23017](#), [mcp23s17](#), [spi](#), [i o expander](#), [serial](#), [cjmcu-2317](#), [cjmcu](#)
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- [LamaPLC: SGP Sensirion TVOC/VOC sensors with I<sup>2</sup>C communication](#) 2026/04/15 19:41 [sgp30](#), [sgp40](#), [sgp41](#), [sensirion](#), [gas-sensor](#), [i2c](#), [communication](#), [sensor](#), [arduino](#), [code](#), [eco2](#), [voc](#), [tvoc](#), [indoor air quality](#), [iaq](#), [nox](#), [hydrogen](#)
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- [LamaPLC: VL6180X STMicroelectronics Time-of-Flight \(ToF\) sensor with I<sup>2</sup>C communication](#) 2026/04/23 21:52 [vl6180x](#), [stmicroelectronics](#), [time-of-flight](#), [tof](#), [i2c](#), [communication](#), [sensor](#), [arduino](#), [code](#)
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[I2c](#), [I<sup>2</sup>C](#), [communication](#), [Arduino](#), [energy](#), [power](#), [current](#), [monitor](#), [sensor](#), [INA219](#), [GY-219](#), [INA226](#), [GY-216](#), [INA228](#), [GY-228](#), [INA237](#), [INA238](#), [INA260](#), [INA3221](#), [INA](#)

This page has been accessed for: Today: 2, Until now: 4

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Last update: **2026/04/21 20:47**

